Final Feasibility Study Report for KV Line

DOHWA Engineering Co. Ltd in JV with
Oriental Consultants Global,
BARSYL in association with
PCKK, RDC, CEA and CESL

April 11, 2019

EXECUTIVE SUMMARY

KV line is passing populated urban area with serious traffic congestion which brings huge indirect social cost such as VOC (Vehicle Operation Cost), VOT (Vehicle Operation Time), Accident, and Emission. It is anticipated that the economic loss will be increased significantly in 2025.

The improvement of railway can ease the traffic congestion, increase transport capacity, enhance the passenger convenience, better serve population distribution, gain commercial market share, and finally assist uniform economic development.

The following table shows summary of the passenger demand forecast for 2025 and 2035 on the basis of the Alternate Modelling Scenario 3 which is Medium Growth Megapolis Development Scenario.

Indicator	2025	2035
PPHPD	18,405	20,973
Max Section	Kirillapone-Nugegoda	Kirillapone-Nugegoda
Max. Daily Sectional Passenger Trips	176,969	201,662
Total Daily Passengers Trips	273,566	365,731

The horizontal alignment will follow the existing KV line to minimize the additional land acquisition which brings huge cost and delay of project. However, the increase of track from 1 to 2 resulted in a minimum land acquisition of 81,000 m^2 to be procured.

The vertical alignment is elevated railway between Maradana and Malapalla because the train Operation frequency is only 7 min that the existing level crossings (56 Nos.) cannot be maintained with that short frequency.

The other section from Malapalla to Avissawella will be at-grade railway with minimized level crossings (58 Nos.) maintained with protection because the frequency of 14 min (Malapalla – Padukka) and 30 min (Padukka – Avissawella) is enough to operate level crossings.

While double tracks will be planned between Maradana and Padukka, single track will be planned between Padukka and Avissawella.

The Operation Plan is as follows:

Section	Type of Train	Frequency	Travel Time	Length	Remarks
		Peak Time (min)	All Stop (min)	(Km)	
Maradana~ Makumbura North	20 EMU Train Sets	7	41	21.9	2025 5+5 2035 6+6
Makumbura North ~ Padukka		14	23	13.02	2025 5+5 2035 6+6
Padukka~ Avissawella	4 DMU Train Sets	30	55	23.48	

- The above 20 EMU includes 3 EMU to prepare for maintenance and emergency.
- The above 4 DMU includes 1 DMU to prepare for maintenance and emergency.

Since side tracks are placed along the main line, express operation can be available.

The existing stations (33 Nos.) will be maintained and 2 new stations (Dambahena, Makumbura North) are to be installed newly considering future development and smooth train operation. The main stations with large grade will be 6 stations (Maradana, Cotta Road, Nugegoda, Makumbura North, Padukka, Avissawella).

Regarding light maintenance, this Consultant has deemed the Dematagoda as the optimized location and will develop the depot layout through discussions with all of the concerned stakeholders.

However, if final decision on the Dematagoda during the detailed design stage, this Consultant will come up with other alternatives.

Regarding heavy maintenance, the location of heavy maintenance depot will be determined later because it is necessary in 2028 and requires high cost for heavy maintenance facilities. Therefore, EMU heavy maintenance depot for the total 4 suburban railways will be prudently reviewed through discussions with all the concerned stakeholders including PMU and SLR.

Signalling and Train Control System as ERTMS Level 2 with GSM-R radio system was basically recommended considering optimization of technical and financial strategy. Detailed sectional plan will be established during Detailed Design stage.

Telecommunication system includes Optical Fiber, as M-R and LTE System. LTE System is recommended basically considering world-wide trend towards LTE, but further investigation will be taken to finalize the system considering cost and local condition.

Power Supply and Electrification will be 25 kV AC transformed from 132k kV power supplied by the CEB. The main source is Pannipitiya GSS near the railway alignment and the Colombo 1 GSS will be the back-up source. As the first phase, the railway from Maradana to Padukka will be electrified.

ICT system considered Automatic Fare Collection (AFC), Passenger Information System (PIS), Asset Management System (AMS), Enterprise Resource Planning (ERP) to facilitate smoothly the train operation and maintenance.

Environmental Study was performed according to Sri Lanka Act and Regulation, and ADB requirements. The major items are Climate Change, Air, Noise, Dust, Water quality, Habitats, Fauna and Flora, Socio-economic, Drainage and Slope stability.

The survey results before construction, Anticipated Environmental Impacts, and Mitigation Plan during construction was included in this report.

Social Impact Assessment was performed according to NIPP (2001) and ADB SPS (2009) and the total No. of houses to be resettled is about 2200 houses (No. of residents is about 8500). The total estimated cost for resettlement is to be 15.7 Bil. LKR.

Financial analysis of the KV line shows that project cash flows are not sufficient to fully recover the investment cost of USD 1.42 billion as evident by negative Financial Net Present Value (FNPV) of USD -981.92 million and negative Financial Internal Rate of Return (FIRR) of -3.84%. Even though the Project cash flows are not sufficient to fully recover the total investment and associated cost of funding, it could recover approximately 21.26% of the investment cost and related cost of funding under 30-year analysis and it can go up to 27.41% with 50-year financial evaluation. Recovering the rest of the investment costs and paying the related cost of funding could not be made with project cash flows generated thus the government needs budgetary allocation from common public funds for the same which is the usual case with public sector railway projects in many countries. But O&M costs and replacement costs can easily be recovered with railway tickets and other income of the KV line.

In many railways around the world, which focuses on passenger transport alone cannot recover half of the O&M costs. However, KV line is in a commendable position in recovering O&M and replacement costs through ticket and other incomes.

Economic analysis of the KV line shows that under the 9% discount rate, NPV is US $ million 1967.00, EIRR is 15.78% and the benefit-cost ratio is 2.73. The sensitivity analysis is carried out to determine the robustness of the project under the individual and combined eight scenarios of demand, costs, benefits and construction delays which re-confirmed the robustness of the project under various extreme situations. In this context, this KV line can be developed as a state-of-art model railway line to attract lost passengers back to the railway and, it is better to explore the possibility of extension of this line to link it to the main line via the Ratnapura, Balangoda, and Ambilipitiya to Kataragama cities. Furthermore, there is a possibility to attract high value-added small freight transportation and other commercial development such as hotels, housing schemes, trade, and distribution center's along the line to generate more income to recover overall costs in the long run.

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Abbreviations

A/C	Air Conditioning
AC	Alternative Current
ACS	Access Control System
ADB	Asian Development Bank
ADM	Add-Drop Multiplexer
AFC	Automated Fare Collection
AGP	Angampitiya
AHB	Automatic Half-Barriers (Type of Level Crossing)
AHH	Affected Head of Household
AMS	Asset Management System
ANSI	American National Standards Institute
AO	Administrative Officer
AOLC	Automatic Open Level Crossing
AP	Access Points
APC	Automatic Power Control
Aps	Affected Parties
APs	Affected Persons
ARS	Automatic Route Setting
ARTC	Australian Rail Track Corporation
ARV	Automatic Train Reversal
ARW	Arukwathpura
ASP	Audio Selection Panel
ATACS	Advanced Train Administration and Control System
ATC	Automatic Train Control
ATD	Automatic Tensioning Device
ATMS	Advanced Train Management System
ATO	Automatic Train Operation
ATP	Automatic Train Protection
AVS	Avissawella Railway Station
AVS	Avissawella
BCC	Backbone Control Center
BIQ	Basic Information Questionnaire
BOR	Black-Out Relief
BS	British Standards
BS	Base Station
BSC	Base Station Controller
BSL	Baseline Road
BTM	Balise Transmission Module
BTN	Backbone Transmission Network
BTS	Base Trans-ceiver Station

CAPEX	Capital Expenditure
CB	Circuit Breaker
CBTC	Communications Based Train Control
CCTV	Closed-Circuit Television
CDRS	Centralized Digital Call Recording System
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CEO	Chief Executive Officer
CMC	Colombo Municipal Council
CMR	Colombo Metropolitan Region
CMRN	Colombo Metropolitan Railway Network
CMS	Crew Management System
CO	Carbon Monoxide
COAM	Centralized Operation Administration & Maintenance
CRD	Cotta Road
CSR	Colombo Suburban Railway
CSRP	Colombo Suburban Railway Project
CSTE	Chief Signal & Telecommunications Engineer
CT	Current Transformer
CTC	Centralized Traffic Control
CTCC	Colombo Train Control Centre
CTCS	Chinese Train Control System
CVRS	Central Voice Recording System
CVT	Capacitive Voltage Transformer
CWR	Continuous Welded Rail
D	Draughtsman (Note: includes both male and female staff)
DB	Database
dB	Decibel
dB[A]	A-weighted Decibels – Perceived level of sound
DC	Direct Current
DCC	Depot Control Centre
DCPT	Dynamic Cone Penetration Test
DCS	Data Communication System
DD	Detail Design
DEMU	Diesel Electric Multiple Unit
DFL	Depot Feeder Line
DIR (COM)	District Inspector (Signal & Telecommunications) (Communications)
DIR (E)	District Inspector (Signal & Telecommunications) (Electrical Workshop)
DIR (GLE)	District Inspector (Signal & Telecommunications) (Galle)
DIR (HQ)	District Inspector (Signal & Telecommunications) (Head Quarters)

DIR (M)	District Inspector (Signal & Telecommunications) (Mechanical Workshop)
DIR (S) (MDA)	District Inspector (Signal & Telecommunications) (South) (Maradana)
DIR	District Inspector (Signal & Telecommunications)
DLT	Digital Direct Line Telephone
DMI	Driver-Machine Interface
DMU	Diesel Multiple Unit (also known in Sri Lanka as reversible trains)
DN	Down
DOA	Drawing Office Assistant
DOO	Driver Only Operation
DOR	Department of Railways
DPs	Displaced Persons
DPS	Depot Protection System
DRC	Depreciated Recovery Cost
DS	Divisional Secretary
DS	Divisional Secretariat
DSD	Divisional Secretariat Division
DSDs	Divisional Secretariat Divisions
DSS	Depot Signalling System
DSTE (O&M)	Deputy Chief Signal & Telecommunications Engineer (Operation & Maintenance)
DSTE (P&D)	Deputy Chief Signal & Telecommunications Engineer (Planning & Development)
DTO	Driverless Train Operation
DTS	Data Transmission System
DVAS	Digital Announcement System
DWLC	Department of Wildlife Conservation
E&B	Earthing & Bonding
EA	Executive Agency
EHPS	Emergency Help Phone System
EI	E: Elastic Modulus, I: Moment of Inertia
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EIRENE	European Integrated Railway Radio Enhanced Network
EM	Earth Mast
EMC	Electro-Magnetic Compatibility
EMG	Electro-Magnetic Generation
EMI	Electro-Magnetic Interference
EMP	Environmental Management Plan
EMU	Electric Multiple Unit (also known in Sri Lanka as reversible trains)
EN	European Standard

EN	European Norms
EOA	End of [Movement] Authority
EPL	Environmental Protection License
ERP	Enterprise Resource Planning
ERTMS	European Railways Traffic Management System
E-S	Earting Switch
ETCS	European Train Control System
F	Follow
FGD	Focus Group Discussions
FMS	Fleet Management System
FOS	Freight Operations System
FOT	Colombo Fort Railway Station
FS	Feeder Station
FS	Feasibility Study
FT	Fibre [Optic] Transmission [Network]
GCS	Ground Controller System
GGA	Godagama
GGSN	Gateway GPRS Support Node
GHz	Giga-Hertz
GIS	Geographic Information System
GMA	Gammana
GN	Grama Niladhari
GND	Grama Niladhari Division
GoSL	Government of Sri Lanka
GPRS	General Packet Radio Services
GPS	Global Positioning System
GRC	Grievance Redress Committee
GRM	Grievance Redress Mechanism
GSM	Global System for Mobile Communications
GSMB	Geological Survey and Mines Bureau
GSM-R	Global System for Mobile Communications - Railways
GSS	Grid Sub Station
GWh	Giga Watt hours
HD	High Definition
HHR	Homagama Hospital
HLR	Home Location Register
HMA	Homagama
HMD	Heavy Maintenance Depot
HQ	Head Quarter
HR	Human Resources

HV	High Voltage
Hz	Hertz
IA	Implementing Agency
ICT	Information and Communications Technology
ICTA	Information and Communication Technology Agency of Sri Lanka
ID	Identity
IDF	Intensity Duration Frequency
IEC	International Electrotechnical Commission
IEE	Initial Environmental Examination
IEEE	Institute of Electrical and Electronic Engineering
IEER	Initial Environmental Examination Report
IP	Internet Protocol
IP	Institute of Petroleum
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IR	Infra-Red
I-RBC	Infill Radio Block Centre
IRSE	The Institution of Railway Signal Engineers
IS	Isolation Mode
ISA	Independent Safety Assessor
ISO	International Standards Organization
ISO	Isolator
IT	Information Technology
ITCS	Incremental Train Control System
ITU	International Telecommunication Union
IXL	Interlocking
JRU	Juridical Recorder Unit
JV	Joint Venture
k	Kilo- (Thousand)
KDG	Kadugoda
kHz	Kilo-Hertz
km	Kilometre
kN	Kilo Newton
KOT	Kottawa
KPE	Kirillapone
kph	Kilometres per hour
KSG	Kosgama Railway Station
KV	Kelani Valley
kV	kilo Volt
L	Length

LA	Lightning Arrester
LAA	Land Acquisition Act 1950
LAN	Local Area Network
lb	Libra(Pound)
LC	Level Crossing
LCD	Liquid Crystal Display
LCN	Loco Junction
LED	Light Emitting Diode
LEU	Line-side Electronic Unit
LEW	Lightning Earth Wire
LMA	Limit of Movement Authority
Loco	Locomotive
LOHB	Locally-Operated [by Community] Half Barriers (Type of Level Crossing)
LTE	Long Term Evolution
LTE-R	Long Term Evolution – Railways
LX	Level Crossing
m	Metre
MAG	Maharagama
MC	Municipal Council
MCS	Master Clock System
MDA	Maradana Railway Station
MFB	Manually-Operated Full Barriers (Type of Level Crossing)
MFF	Multi-tranche Financing Facility
MGD	Meegoda
MGW	Media Gateway
MHB	Manually-Operated Half Barriers (Type of Level Crossing)
MHz	Mega-Hertz
MIS	Management Information System
MLLD	Ministry of Land and Land Development
MMI	Man-Machine Interface
MOTCA	Ministry of Transport and Civil Aviation
MPL	Malapalla
MPT	Mackintosh Probe Test
MPTSL	Mid-Point Track Sectioning Location
MRK	Morakele
MSC-CS	Mobile Service Switching Center
MT	Motor Car
MTTR	Mean Time to Repair
MU	Multiple Unit [Train]
MVA	Mega Voltage Ampere

MVar	Mega Var
MW	Mega Watt
NBRO	National Building Research Organization
NEA	National Environmental Act
NGO	Non-Governmental Organisation
NHP	Narahenpita
NIRP	National Involuntary Resettlement Policy
NMS	Network Management System
NO.	Number
NO2	Nitrogen Dioxide
NPS	Negative Phase Sequence
nr	Number
NS	Non-skilled Staff
NTC	National Train Control [System]
NTP	Network time Protocol
NUG	Nugegoda
NWN	Nawinna
O	Oppose
O&M	Operations and Maintenance
OCC	Operations Control Centre
OCS	Overhead Catenary System
OCS	Overhead Contact System
OEM	Original Equipment Manufacturer
OFC	Optical-Fibre Cable
OFCS	Optical Fibre Communication System
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
OPEX	Operational Expenditure
OPH	Operational Hand portable Radio
OPS	Operational Shunting Hand portable
P&L	Profit and Loss
PA	Public Address
PAN	Pannipitiya
PAPs	Project-Affected Persons
PABX	Private Automatic Branch Exchange
PAS	Public Address System
PC	Personal Computer
PC	Pre stressed Concrete
PCC	Point of Common Coupling
PCR	Physical and Cultural Resources

PCT	Pre stressed Concrete tie
PCU-R	Pulse Code Unit for Railways
PD	Project Director
PDK	Padukka
PICO	Post-Installation Check-Out
PID	Passenger Information Display
PIDS	Passenger Information Display System
PIS	Passenger Information System
PIU	Project Implementing Unit
PM	Particulate Matter
PMU	Project Management Unit
PNG	Panagoda
PNW	Pinnawala
PPEs	Personal Protective Equipments
PPHPD	Passengers Per Hour Per Direction
ppm	Parts per million
PPTA	Project Preparatory Technical Assistance
PQRS	Plasser Quick Rel- Peak Passenger Hour Per Direction
PRW	Pengiriwatta
PS	Pradeshiya Sabha
PSC	Pre-Stressed Concrete
PTC	Positive Train Control
PTP	Point-to-Point
PSTN	Public Switched Telephone Network
PUCSL	Public Utilities Commission Sri Lanka
PWP	Puwakpitiya
QPSK	Quadrature Phase Shift Keying
R.C.	Reinforced Concrete
R.L.	Rail Level
RAMS	Reliability, Availability, Maintainability and Safety
RBC	Radio Block Centre
RBS	Radio Base Station
RBTMS	Radio Block Train Management System
RCS	Radio Communication System
RDA	Road Development Authority
RDW	Radio Dispatcher Workstation
REC	Railway Emergency Call
R-EOB-OD	Radio – Electrically Operated Barrier – Obstruction Detector (Type of Level Crossing)
RETB	Radio Electronic Token-less Block

REW	Return Earth Wire
RIP	Resettlement Implementation Plan
ROW	Right of Way
RoW	Right of Way
RREI	Road-Rail Exposure Index
RTU	Remote Terminal Unit
S	Skilled Staff
S&D	Service and Diagnostic
S&DS	Service and Diagnostic System
S&T	Signal & Telecommunication
SCADA	Supervisory Control And Data Acquisition
SCP	Service Control Point
SE (C)	Signal Engineer (Central)
SE (N)	Signal Engineer (North)
SE (P&C)	Signal Engineer (Planning & Construction)
SE (R)	Signal Engineer (Radio)
SE (U)	Signal Engineer (Upper)
SE (W/S)	Signal Engineer (Workshop)
SEC	Shunting Emergency Call
SER	Signalling Equipment Room
SFC	Static Frequency Converter
SGSN	Service GPRS Support Node
SIA	Social Impact Assessment
SIL	Safety Integrity Level
simbids	Simplified Bi-Directional Signalling
SK CS	Storekeeper – Colour Light Signalling Stores
SK RTS	Storekeeper – Railway Telegraph Stores
SK SSW	Storekeeper – Signal Stores (Workshop)
SK Tools	Storekeeper – Storekeeper (Tools)
SK	Store keepers
SLD	Single Line Diagram
SLR	Department of Sri Lanka Railways
SLR	Sri Lankan Railways
SM	Station Master
SMS	Short Message Service
SMSC	Short Message Service Center
SO2	Sulphur Dioxide
SPAD	Signal Passed at Danger (Driver Error)
SPAR	Signal Passed at Red (System Failure or Operational Reason)
SPL	Sound Pressure Levels

SPM	Suspended Particulate Matter
SPP	Small Power Producer
SPT	Standard Penetration Test
SPV	Special Purpose Vehicle
SQM	Per Square Meter
SQT	Smalls Quick Transit
SR	Staff Responsible Mode
SRC	Single Regulated Contact
SSP	Service-Switching Point
sta.	Station
STB	Steel Box
STI (EWS)	Signal & Telecommunications Inspector (Electrical Workshop)
STI (F)	Signal & Telecommunications Inspector (Faults)
STI (FOT)	Signal & Telecommunications Inspector (Fort), Office at Colombo Fort
STI (MLV)	Signal & Telecommunications Inspector (Mount Lavinia)
STI (MRT)	Signal & Telecommunications Inspector (Moratuwa)
STI (MWS)	Signal & Telecommunications Inspector (Mechanical Workshop)
STI (PAN)	Signal & Telecommunications Inspector (Pannipitiya)
STI (Phones)	Signal & Telecommunications Inspector (Phones), Office at Maradana
STI (PND)	Signal & Telecommunications Inspector (Panadura)
STI (TKS)	Signal & Telecommunications Inspector (Tracks), Office at Maradana
STI	Signal & Telecommunications Inspector
STM	Specific Transmission Module
SVC	Static Var Compensator
TC	Trailing Car
TCBL	Tie Circuit Breaker Location
TCO	Total Cost of Ownership
TCP	Transfer Control Protocol
TCS	Train Control System
TCU	Trans Coder Unit
TD	Train Describer
TDMA	Time Division Multiple Access
TDRS	Train Data Radio System
TEC	Technical Evaluation Committee
TER	Telecommunications Equipment Room
TESS	Train Existence Supervision System
TETRA	Terrestrial Trunked Radio
TIA	Telecommunications Industry Association
TIS	Train Control Information Management System
TMS	Train Monitoring System

TNIS	Train Number Indication System
TO	Train Operator
TOR	Terms of Reference
TPWS	Train Protection and Warning System
TSR	Temporary Speed Restriction
TV	Television
TVM	Ticket Vending Machine
UC	Urban Council
UGL	Uggala
UHM	Udahamulla
UIC	International Union of Railways (Union Internationale des Chemins de fer)
UK	United Kingdom [of Great Britain and Northern Ireland]
UN-H	United Nations Habitat
UPS	Uninterruptible Power Supply
USA	United States of America
USD	United States Dollar
UTX	Under Track Crossings
V	Volts
VBS	Voice Broadcast Services
V&V	Verification and Validation
VDU	Visual Display Unit
VGCS	Voice Group Call Services
VLR	Visitor Location Register
VMS	Voice Mail System
VOB	Vehicle On-Board [systems]
VWDS	Video Wall Display System
W	Watt
WAK	Watareke
WAN	Wide Area Network
WGG	Waga

CHAPTER

1

Introduction

Chapter 1 Introduction

1.1 General

An agreement was signed on 13th of December, 2017 between the Government of Sri Lanka, Ministry of Transport and Civil Aviation (Client) and DOHWA Engineering Co. Ltd.(KOR) in joint venture with Oriental Consultants Global Co., Ltd.(JPN) and Balaji Railroad Systems Private Limited (IND), and in association with sub-consultants, namely Pacific Consultants Co., Ltd.(JPN), Central Engineering Services(Private) Limited(SRL), Resources Development Consultants Ltd.(SRL), and Consulting Engineers & Architects Associated(Private) Ltd.(SRL) for the execution of Feasibility Study and Detailed Design of Colombo Suburban Railway.

1.2 Background and Objective

1.2.1 Background

The Sri Lankan Government has plans to improve the railway system in the Western Province, including the Colombo Metropolitan Region (CMR), which has a population of 5.8 million. The population growth of CMR is expected to be 1.5% per annum by 2035, so CMR faces increasingly more traffic congestion. Currently, the railway system carries about 13% of passenger transport within the CMR. The Government plans to significantly increase the share of the railway in total passenger and freight traffic.

The Kelani Valley (KV) Line extending from Maradana to Avissawella is 60 km with daily passenger volume of 14,600. The average speed of train being operated on the KV Line is approximately 26 km/h. Long delays occur due to failures in the signal system, and frequent failures also in older telecommunication systems. The poor condition of the track also affects the long delay.

1.2.2 Objective

The main objective is to prepare the railway project(s) ready for investment and implementation by completing feasibility studies, detailed engineering, safeguards planning documents, and bidding documents. All designs prepared under this project shall enable future electric operation of the railway network with overhead catenary system (OCS), although the OCS may not be installed in the individual projects at an initial stage. The prepared projects and/or components shall be designed in a modular way with a clear prioritization of components to schedule implementation in accordance with financial resources. All improvements on existing lines shall be designed in such a way that the disruption of ongoing operation will be minimized to a level acceptable to SLR. The Consultant's services include the following:

- Complete feasibility study, detailed design, safe guard planning documents and bid documents to thoroughly conduct preparation works of the project investment and implementation.
- Collect information/data necessary for railway design from related agencies and reflect review result.
- Coordinate and consult with stakeholders and provide improved services through knowledge transfer.

- Prepare technical documents for procurement of civil engineering and equipment, and assist the Client to apply for and obtain ADB loans.
- Provide improved services for the suburban area by minimizing construction cost and environmental impact and ensuring safety.

The project will modernize and upgrade the track, signal and telecommunications infrastructure, and apply electric railways to improve railway network capacity and operation speed of KV Line. As a result, by increasing the utilization rate of the railway system, passengers will be attracted into railway transportation, thereby increasing market share and reducing road congestion.

1.3 Scope of Work and Expected Benefits

1.3.1 Scope of Work

This Project is aimed to provide consulting services for eight tasks for 36 months and the scope of work is described as follows.

Task 1	Technical Feasibility
Task 2	Economic and Financial Assessment
Task 3	Poverty and Social Assessment
Task 4	Land Acquisition and Resettlement Planning and Indigenous
Task 5	Environmental and Climate Change Risk Assessment
Task 6	Detailed Engineering Design
Task 7	Cost Estimates and Bidding Documents
Task 8	Procurement Assistance

(1) Collect and review all available relevant studies, reports, materials, documents, and information including findings from the PPTA.

(2) Collect all necessary information of existing, ongoing and future planned development works of Government and private sector in and around the project site and consult all relevant agencies/stakeholders. Take all findings into consideration in the study. Support the client in carrying out continuous coordination and consultations with all relevant stakeholders.

(3) Examine all existing infrastructure, operational facilities, rolling stock maintenance facilities, ICT Infrastructure, line capacity and business opportunities and make specific recommendations for their improvement.

(4) Finalize detailed scope of work, technical aspects & design parameter of all components/projects in consultation with SLR and develop new design standard, e.g., based on new rolling stock and operational procedures for suburban trains, future railway electrification, etc. Develop design standards for all relevant track components, bridges, stations, signaling and telecom (Including Train Control Center), rolling stock and workshops that will enable future railway electrification with OCS. In addition, develop maintenance standards by considering existing maintenance practices of SLR and by considering the needs of the new systems.

(5) Calculate the power demand for the electric trains based on traffic forecast and proposed operation program considering also degraded operation and emergency operation and power demand in case of partial failures of the power supply system; define feeding points and capacity of the substations; develop a layout of feeding lines from the national grid that minimizes the risk of total power failure in case of planned blockage, e.g., due to scheduled maintenance or failure of individual supply lines in the national grid.

(6) Consider effects of electromagnetic compatibility between the future railway electrification and signaling and telecom system, as well as external systems such as power lines, pipes, pipelines or communications networks and define minimum safety distances to avoid interference.

(7) Define requirements on the track structure to support return current to the traction power substations and requirements on linkage of tracks and bonding, installation of CWR and insulated rail joints, etc.

(8) Assess the need and justification of the proposed components/projects for railway improvement in CMR as outlined under the ongoing PPTA. Assess probable effects upon project implementation including direct and indirect effects. Assess benefits of the proposed project, not only in terms of financial or economical, but also in terms of safety, environmental impacts, transportation and travel costs, poverty reduction, enhancement of trade and commercial activities likely to be created as an outcome of all the components.

(9) Identify the various technical solutions and various options for implementing all the components involving construction of tracks and bridges including signaling, telecom. and operational facilities such as stations yards, maintenance sheds, etc. with a view to identify the most suitable solution. Carry-out survey and necessary investigations covering surrounding areas of each option for option analysis and to finalize the most suitable solution.

(10) Seriously consider the safety issue in operating trains with different operating specifications, higher speeds, and increased frequency.

(11) Carry-out detailed topographical survey. The topographic works have to be performed in relation to the required accuracy using satellite base survey equipment (DGPS, data logger & total station) that can be used for detailed design and construction.

(12) Prepare topographic maps at suitable scale following international standards which would give a good definition of all the necessary details for good approximation concerning earthwork quantities to avoid further problems during construction.

(13) Collect data on planned and existing utilities in the project area and incorporate the information in the topographical maps.

(14) Finalize alignment and layouts duly considering the topography, land formation, commercial aspects, economical and safeguard considerations, existing infrastructures of the area, ongoing and future development plan and schemes of both the Government and private sectors in the area. Drafts are to be consulted and presented to SLR before finalization. Finalize 'Construction Right of Way' (CROW) in the final alignment including land required temporary for railway construction and access to the site, camp-sites or quarries etc. Scale of alignment design drawings shall be or more detailed as appropriate at selected critical locations.

(15) Carry-out detailed traffic, social, environmental, hydrological and other engineering survey and detailed soil, hydrological & morphological, environmental investigations on the finalized alignment and layouts. Identify the need for additional survey/investigations for detailed design.

(16) Analyze the existing traffic of various modes of transports. Assess the effects of the project over other modes of transportation. Assess detailed traffic forecasts of national and local freight and passenger traffic for all the components/projects with due consideration of other modes of transport, other ongoing and future development plans for other modes of transport such as Light Rail and Monorail, etc., bus service improvements and private sectors investments.

(17) Conduct traffic census on existing roads crossing on railway line (both authorized and unauthorized) and re-categorize the types and location of level crossing gates as required based on traffic forecast. Recommend upgradation and closure of existing level crossing gates, authorization of level crossing gates, new level crossing gates to improve safety at level crossings and measures to prevent illegal track trespassing. Coordinate with other concerned authorities such as the Road Development Authority (RDA) and Urban Development Authority (UDA) on the design of level crossings and under-/overpasses.

(18) Review the design of existing stations, redesign if necessary, and recommend improvements to accommodate increased traffic, based on the traffic forecast.

(19) Design facilities for multimodal connectivity of the railway with other public and individual modes of transport, suggest location for bus terminals, taxi stands, parking lots for cars, motorbikes and bikes, etc. Coordinate the design with concerned stakeholders including local Governments, UDA, RDA, etc.

(20) Recommend areas for commercial development in the stations such as advertising and for supporting establishments such as coffee shops, kiosks, food stores, restaurants, bookshops, convenience stores etc. depending on the size and category of stations and the commercial functions available in the station environment.

(21) Review the access from the road level to the platforms, calculate the number and dimension of stairs, ramps, elevators and/or escalators required for operation of the railway service, for

degraded operation and for emergency evacuation. Ensure access to all stations including supporting functions such as ticket offices, waiting rooms, toilets, etc. for elderly-children-women and disabled persons.

(22) Identify the locations of level crossing gates required, grade separation between railway and road by either overpass or underpass based on traffic forecast.

(23) Review the location and status of existing bridges over the railway, evaluate bridge condition and remaining economic lifespan, recommend design options on how to operate the railway with the existing bridges, considering future railway and rolling stock design, railway electrification, etc.

(24) Examine existing signaling and interlocking system and telecommunication system. Identify the scope of work to establish computer-based signaling and Interlocking system and optical fiber based telecommunication system with radio communication to Train Crew, Operation, Maintenance and Security Personnel and centralized train control (CTC) system in all the components/projects. Interconnection and interoperability with Electric Control Center also need to be considered. The CTC shall also include facilities for passenger information system, public address system and safety and security monitoring.

(25) Safety issues and interoperability with Signaling System needs to be considered when designing rolling stock

(26) Finalize the phasing of construction considering work plan, interfacing, railway operation and signaling issues. Consultant shall make specific recommendation to resolve interfacing issues.

(27) Regular train operation must not be interrupted during the project construction period and accordingly, phasing of construction, construction methodology and safety measures are to be considered based on the latest technology.

(28) Develop an operation concept plan during and after construction of all the proposed projects. Prioritizing the urban railway time schedule while parallely considering the long distance time schedule needs to be done.

(29) Finalize procurement packages and frame suitable investment projects covering all the components mentioned. Consultant may suggest inclusion of additional component which might be essential to achieve the full benefit of all the components.

(30) Conduct mathematical hydrodynamic modeling study for major bridges having waterway 100m and above to establish hydrological parameters for fixation of the location of bridge, formation level of the railway track identifying the highest flood level, catchments area at bridge openings, identify scour & erosion in the vicinity of major bridges and river banks and design river training works and protection works.

(31) Conduct an in-depth study covering the surrounding area for fixation of formation level of the proposed structures, recommend proper drainage system identifying the out fall of the drainage system.

(32) Examine existing rolling stock day to day maintenance facilities and assess scope of works to establish modern, improved rolling stock maintenance preferably for modern diesel-electric

multiple units and future electrical multiple units. Identify new rolling stock maintenance facilities requirements for all new construction lines including stabling yards, scheduled maintenance facilities and workshops for overhaul of the rolling stock.

(33) Examine the age profile of existing rolling stock fleet and assess demand of rolling stock considering replacement of old ones. Estimate additional new rolling stock requirements with types based on traffic forecast for all the components.

(34) Study different types of rolling stock, such as loco-driven trains, push-pull trains and diesel-electric or electric multiple units and recommend suitable rolling stock procurement program; study best way to accommodate changes in demand based on traffic forecast by splitting and joining trains and recommend locations for stabling facilities for surplus trains during daytime off-peak hours.

(35) Prepare Rolling stock demand analysis report on rolling stock requirement for replacement of old-aged rolling stocks and new demand to be created due to the projects.

(36) Assess operation and maintenance (O&M) personnel and other resources/facilities requirements for operation and maintenance works for all components. Prepare capacity building plan, propose training facilities and the maintenance tools and equipment.

(37) The study should also include conceptual engineering design and layout plan for all necessary railway tracks, stations and yards, signaling and telecom, bridges, culverts, over pass/fly over/underpass, level crossing gates, other structure, residential and functional buildings, cuts and other facilities. Prepare cost estimates for proposed project, showing foreign and local currencies, and tax and duty elements, etc.

(38) Prepare Feasibility study report which will contain main report with detailed scope of work, all technical aspects, drawings/layouts, cost estimate and Resettlement Plan (RP), Land Acquisition Plan (LAP), Environment Management Plan (EMP), Operational plan, Hydrological & Morphological report and other required documents.

(39) Review manuals and rulebooks of SLR and recommend updates and additional documentation required due to modern technologies or new technologies introduced in SLR such as CWR, electric train operation, modern signaling system, etc.

(40) Review exiting operating, time scheduling, crew management and train controlling practices and make recommendations for improvements by considering the train operating scenario that will be developed with the project implementation.

(41) Prepare maintenance standards and practices by considering the technologies that will be utilized in the project and by considering the allowable tolerances.

(42) Review existing practices of occupational safety and standards and prepare safety code for SLR.

(43) Evaluate existing ICT infrastructure and organization’s capacity and design an ICT Development plan for SLR.

The scope of this consultancy services would be to prepare feasibility study, detailed engineering design, safeguard planning documents, and bidding documents for four priority railway projects.

1) Maradana to Padukka (Kelani Valley Line)

The Kelani Velley line extending from Maradana to Avissawella is 60 km with daily passenger volume of 14,600. This single track railway line was originally narrow gauge and was converted to broad gauge along the same trace at a later stage. It has been identified that Padukka which is 35 km from Maradana is the best location to attract passengers from Horana Corridor. Therefore by considering the present and future demands, the intension is to upgrade the railway line to double track up to Padukka and to rehabilitate the existing single track in the balance section up to Avissawella.

2) Colombo to Rambukkana (Main Line)

Rambukkana is 83 km away from Maradana and is the end station of the double line section in the 291 km long Main Line. The section from Maradana to Ragama is having three tracks and the rest of the section upto Rambukkana is double track. The daily ridership is approximately 100.000 with majority of the suburban trains, serving morning peak period, start from Rambukkana. Focusing at passenger volume by 2035, it is intended to construct forth line in Maradana – Ragama section and third track in Ragama- Veyangoda section and rehabilitate the double track up to Rambukkana.

3) Colombo to Kaluthara South (Coastal Line)

Coastal Line of the Sri Lanka is 159 km long and Kaluthara South is 43.0 km away from Maradana. The section from Maradana to Colombo Fort is having four lines and the rest upto Kaluthara South is having two lines. The daily passenger volume in the section upto Kaluthara is approximately 80.000 and the intention is to construct third line upto Panadura and to rehabilitate the existing double line up to Kaluthara South to cater the passenger volume generated by 2035.

4) Ragama to Negombo (Puttalam Line)

Puttalam Line deviates from Main Line at Ragama runs upto Puttalam and the line length is 133 km from Maradana with double track upto Seeduwa and single track beyond. Sri Lanka Railway has commenced double tracking upto Negombo and has almost completed upto Katunayake, at present. Negombo is 37 km from Maradana with daily passenger volume of 20,000.

1.3.2 Expected Benefits

1) Political and Economic Ripple effects

The Western Area is promoted as a city with international competitiveness by 2030 which is the top priority of the current Government.

: Promote economic growth through modernization of railway and punctuality in accordance with the Government policy.

2) Creation of New Industry and Job

Economic infrastructure environment in Sri Lanka is centered around the Western and urban areas causing severe economic imbalance.

: Generate employment by establishing mass transit system between cities and suburban areas, and vitalize tourism industry through development of leisure industry.

3) Reinforcement of Manpower Capacity

Insufficient high value-added industries and professionals are regarded as obstacles to the economic growth of Sri Lanka.

: Acquire railway construction, operation and maintenance technologies through advanced overseas railway know-hows.

1.4 Experts Involved

1.4.1 International Experts

Team Leader	Jong Seok Han
Transport Economist	Klaus-Dieter Schneider
Rail Operation Specialist	Yogendra Sharma R. N. Das
Railway Alignment and Survey Engineer	Young Ju Shin Jong-up Park
Railway Track Engineer	Chul-kee Hong
Railway Bridge Engineer	Seon-taek Lim Ick-soo Mun Choong-soo Lee
Station Architect	Hyouk- jung Kwon
Power Supply Engineer	Ben Jacobs
Railway Electrification Engineer	John Alan Forsyth
Signal Engineer	John A. Hewitt
Rolling Stock and Workshop Engineer	Soo-dong Jeong Harng Rhee
ICT Specialist	Luis Fillipe Peixoto Faria

1.4.2 National Experts

Transport Economist	Sarath W. S. B. Dasanayaka R. K. L. P. Caldera
Financial Analyst	Dimantha De Silva
Geotechnical Engineer	Mohamed Azim Thawfeek Chandima Atapattu Susiri Kumara Jayawardana
Environmental Specialist	Nilanthi J. G. J. Bandara P. M. C. Bandara Digana
Social Resettlement/Gender Specialist	M. H. S. Dayaratne P. B. Piyarathna de Silva
Alignment and Survey Engineer	Asanka Ovitipana Gimhani A. Dissanayake
Railway Track Engineer	G. J. C. Gunathilake

Bridge Engineer	A. A. D. I. Rasikamal
Signal Engineer	D. G. Hemachandra
Embankment Engineer	K. D. Y. E. Siriwardana
Electrical Engineer	G. R. M. E. Kumara H. Jayalath Warnakulasuriya
Procurement Specialist	M. D. P. Devasiri
Quantity Surveyor	M. A. D. I. Namal Amarasinghe A. N. R Alahakoon M. B. S. Nisansala
Structural Engineer	J. W. M. Lloyd C. Seimon
Building/Landscape Architect	C.K. Nikapitiya
Drainage Engineer	D. A. J. Ranwala
Junior Engineer	K.D.C.R. Dissanayake W.D.S.H. Jayaranga B. M. K. Indunil Basnayake Thotagamuwage Sajani U. K. Chamil Kumara D.J.S.I. Siriwardana / S. Lavanyan
Draughtsman	A. K. I. Kanthi Gunathilaka H. C. J. Samarasekara B. N. Francis / W. T. N. Kumara

CHAPTER

2

Traffic Studies and Ridership for Demand Forecast

Chapter 2 Traffic Studies and Ridership for Demand Forecast

Chapter Summary

This describes the demand estimation methodology and the analysis. Further the results of the traffic surveys at railway crossing are also included.

The demand analysis for the KV line is based on JICA STRADA software and uses a traditional four step methodology that is widely used in the world. The model was developed by JICA as part of the CoMTrans Master Plan study in 2014.The model has been used widely in many modelling exercise in the recent past including the development of the Megapolis Transport Masterplan, JICA LRT Feasibility Study and Colombo Suburban Railway Project – Panadura – Veyangoda Initial Feasibility. The base year of the model is year 2013 where the model has been calibrated.

3 Alternate modelling scenarios was considered for modeling with two scenarios having a socio economic assumptions of a medium and high future growth of population and employment based on the Megapolis Structure plan spatial distribution. In addition one scenario was considered with less public transport supply making 12 scenario runs to evaluate the demand for the KV line based on different combination of project and future year scenarios. The project scenario for the study for other sections was selected as the Alternate Modelling Scenario 3 with a medium growth Megapolis development scenario.

The design flow in terms of passenger per hour per direction (PPHPD) is calculated from the maximum daily sectional volume per direction considering a peak hour factor of 13% and peak direction ratio of 80%. The PPHPD increases from 18,405 from operational year 2025 to 20,973 for the operational year 2035.

The total number of daily passenger trips using the KV line is estimated as 273,566 in the year 2025 and increasing to 365,731 by the year 2035.

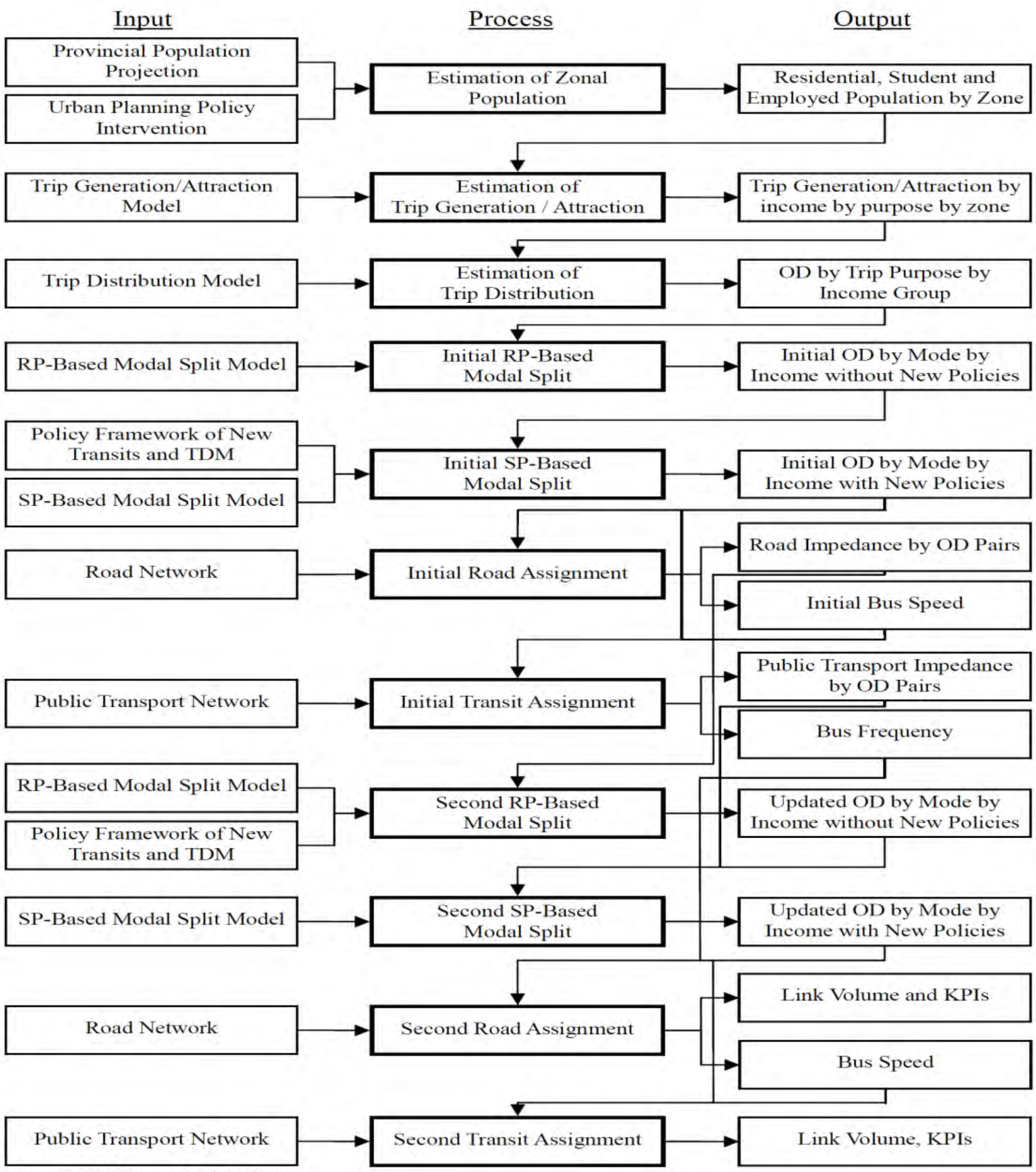
Table 2-0 Daily Passenger Volume Summary for Project Scenario

Indicator	2025	2035
PPHPD	18,405	20,973
Max Section	Kirillapone-Nugegoda	Kirillapone-Nugegoda
Max. Daily Sectional Passenger Trips	176,969	201,662
Total Daily Passengers Trips	273,566	365,731

2.1 Transport Demand Forecast

2.1.1 Introduction

The demand analysis for the KV line is based on JICA STRADA software. STRADA (The system for traffic demand analysis) developed by the Japan International Cooperation Agency (JICA) is one of the widely-used software in the Asian region for demand projections. The software is a window based package where the development started in 1993 by JICA under the leadership of Prof. Hideo Nakamura at Tokyo University with other experts in relevant fields. The software consists of 17 individual modules.



Source: CoMTrans Project Team

Figure 2- 1 Flow of Transport Demand Forecast

The transport demand analysis in this study uses a traditional four step methodology that is widely used in the world. The model was developed by JICA as part of the CoMTrans Master Plan study in 2014.

The model has been used widely in many modelling exercise in the recent past including the development of the Megapolis Transport Masterplan, JICA LRT Feasibility Study and Colombo Suburban Railway Project – Panadura – Veyangoda Initial Feasibility. The base year of the model is year 2013 where the model has been calibrated. The Figure 2-1 shows the flow of the modelling process where the Modal split, road assignment and transit assignment is taken through a minimum of two iterations. The detailed methodology including the model parameter estimations, calibrations and validations are found in the Technical report No 5 Transport Demand Forecast in the CoMTrans Final Report.

2.1.2 Methodology

The demand for the KV line depends on a) the Socio economic assumptions for future years b) Operational assumptions and c) the Other Transport Projects assumed to be completed as illustrated in Figure 2-2. Each of these key attributes is discussed below. The alternatives considered for modelling includes two scenarios for socio economic growth and two scenarios for other transport projects out of which a project scenario has been derived which is described

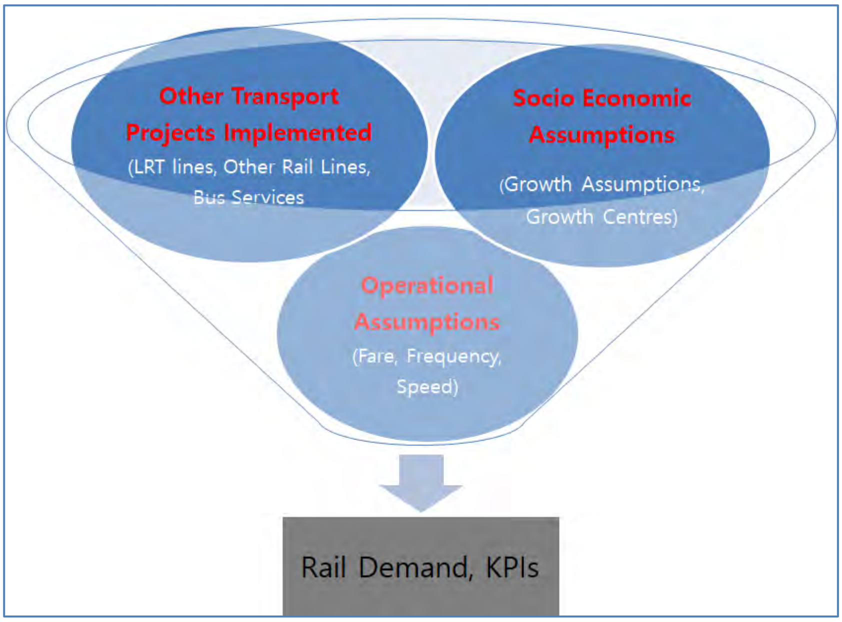


Figure 2-2 Dependencies of the Transport Demand

2.1.2.1 Socio Economic Indicators

Population of the country was enumerated to be 20.4 million in the 2012 census and recorded an annual average growth of 0.7 percent in the preceding decade. Based on this trend, the current population is estimated to be 24.3 million. The average population density in the country is currently 338 persons per sq.km which is similar to many other South Asian countries. Since 1950, the average annual growth of population has steadily declined from 2.8% to 0.7% in 2012. In 1971, agriculture sector contributed to about 33 % of GDP and employed nearly 50 % of the work force while industry and services accounted for the remaining. Currently, agriculture contributes to 8 % of the GDP and employs 26% of the work force while industry and services account for the remaining. The economy has transitioned from agriculture based to manufacturing and services as is typical of developing economies. Sri Lanka's economy grew at 8 to 9% in the first few years of this decade but in the last few years, the growth has slowed down to between 3 and 5% per annum. With the progressive increase in GDP, the per capita GDP has also grown from USD 2744 in 2001 to USD 4073 in 2017. Sri Lanka is now the only country in South Asia which is in middle income group.

With over 93 % adult literacy level, Sri Lanka stands out as one of the most literate populations in the South Asian region. Though the labor participation rate is about 54%, the unemployment rate has been restricted to around 4 % of the workforce and is one of the lowest among the South-Asian countries. Economic growth has also translated into shared prosperity with the national poverty headcount ratio declining from 15.3 percent in 2006/07 to 4.1 percent in 2016. Sri Lanka has made significant progress in its socio-economic and human development indicators. Prosperity index and Human Development Index rank among the highest in South Asia and compare favorably with those in middle-income countries. The country has comfortably surpassed most of the MDG targets set for 2015.

The Western Province - identified as the project influence area for this study- comprises of the districts of Colombo, Gampaha and Kaluthara. This province is considered to be the engine of economic growth in Sri Lanka. Apart from being the administrative, business and financial center of Sri Lanka, the WP stands out as the trend setter for other region in the country. Though the WP constitutes only 5.6% of the country's area, it has 28% of the country's population, 24% of the registered vehicles in the country and contributes to 39% of the national GDP. Per capita incomes in the WP is 32% higher than the national average.

Colombo district accommodates 40% of the population in the WP while Gampaha and Kalutara districts account for 39% and 21% respectively. Matching the national trend, there has been a decline in the average annual growth of population during the period 2001 to 2012 in Colombo and Gampaha districts while Kalutara maintained an average annual growth of 1.3% over the same period.

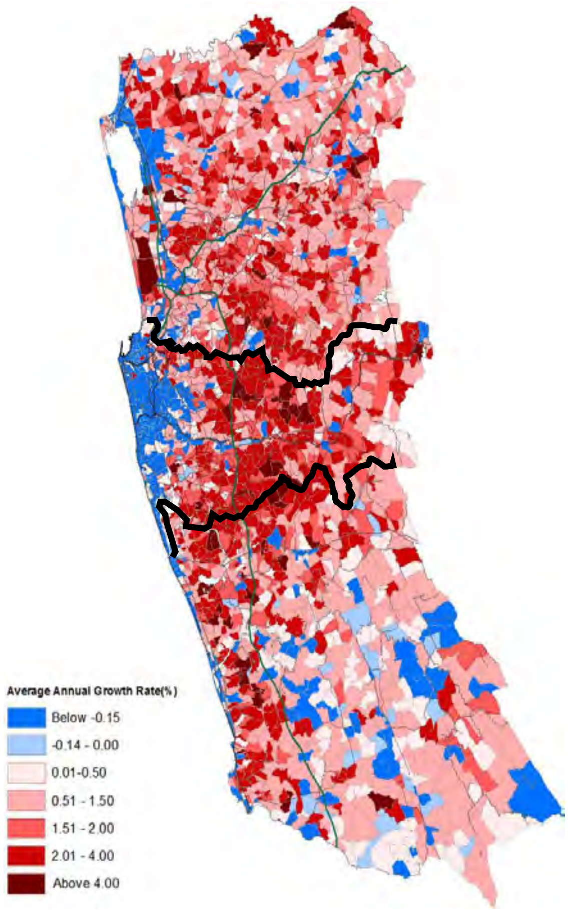


Figure 2-3 Changes in Population 2001-2012

Figure 2-3 shows the change in population growth in the GNDs between 2001 and 2012. There has been a steady decline in population in the Colombo Municipal Council (CMC) whereas areas outside the CMC especially towards Gampaha in the north-east, Malabe in the east and Kaluthara in the south there has been a higher than average growth in population. These are the emerging areas where significant traffic and travel demand can be expected to be generated in the WP.

Spatial development pattern in the WP has been an outward extension from the Colombo Fort area generally in the form of infilling and ribbon development along important transport corridors as can be seen from Figure 2-4 which show the population settlement density in 2001 and 2012. With most of the land in the city center having been fully utilized, new developments are progressively spreading outwards from the core. The city center is gradually transforming itself into a work center to accommodate the increasing employment that is being generated in the services sector. Meanwhile new residential areas are developing further away from the work centers resulting in longer commuting distances and travel time.

Major axes of development have been along the Kandy Road corridor towards the north east, Malabe road corridor towards the east, Kottawa road corridor towards the south east and the Galle Road corridor towards the south.

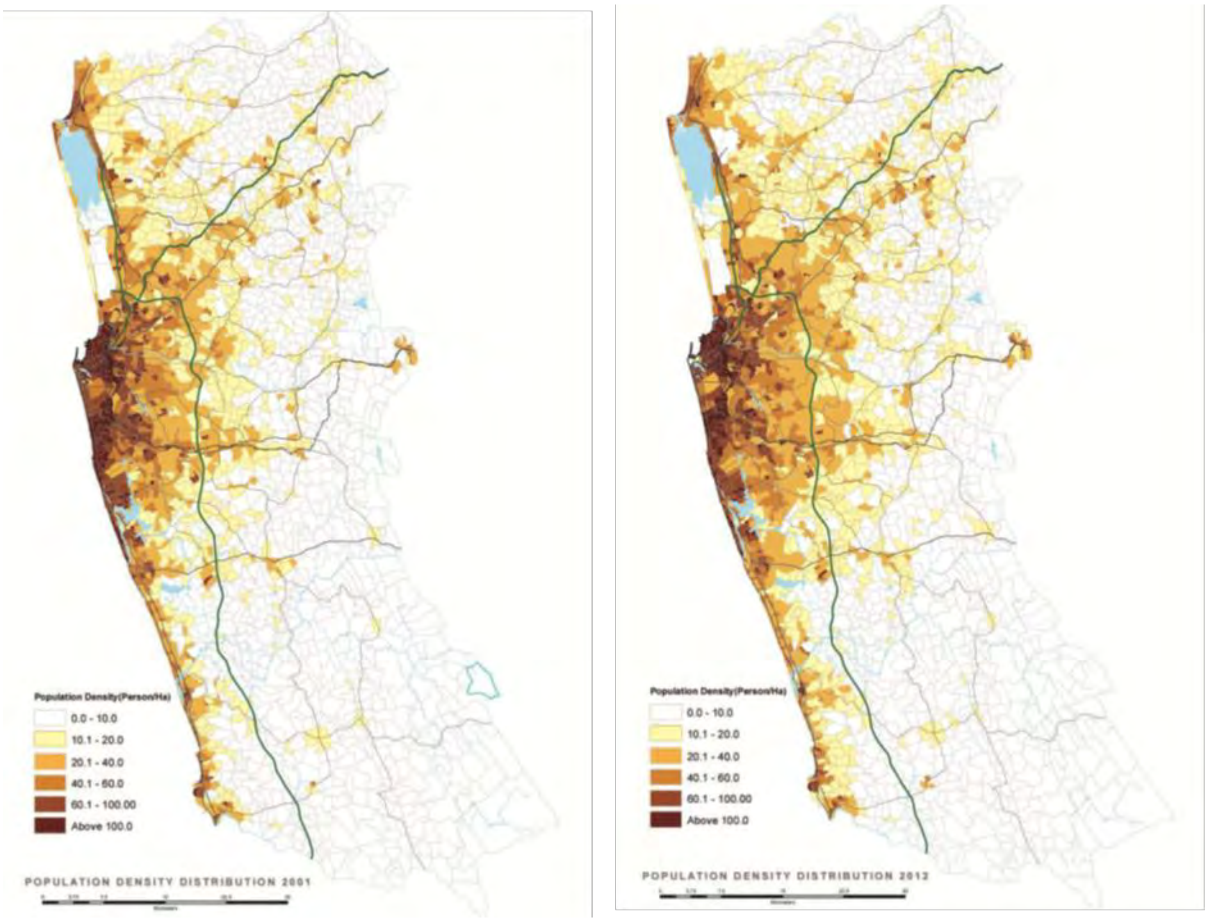


Figure 2-4 Changes in Population Density 2001-2012

In 2015, there were 1.54 million motor vehicles in WP. 50% of it was in Colombo District, 35% in Gampaha and 15% in Kalutara districts respectively. Figure 2-5 shows the growth trend in number of vehicles between 2005 and 2015. WP recorded about 9.6% growth per annum. The corresponding rates for Colombo district was lesser at 7.3% while Gampaha and Kalutara districts registered higher growth rates of 11% and 17% respectively.

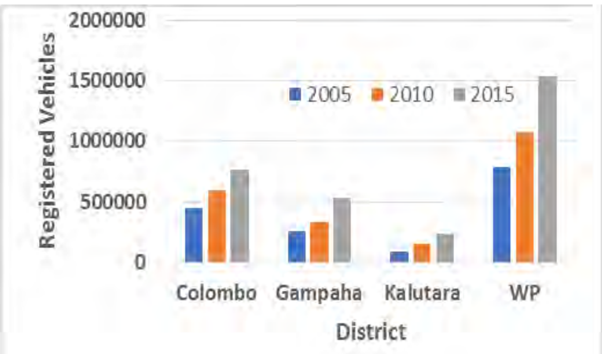


Figure 2-6 Growth of vehicles in WP

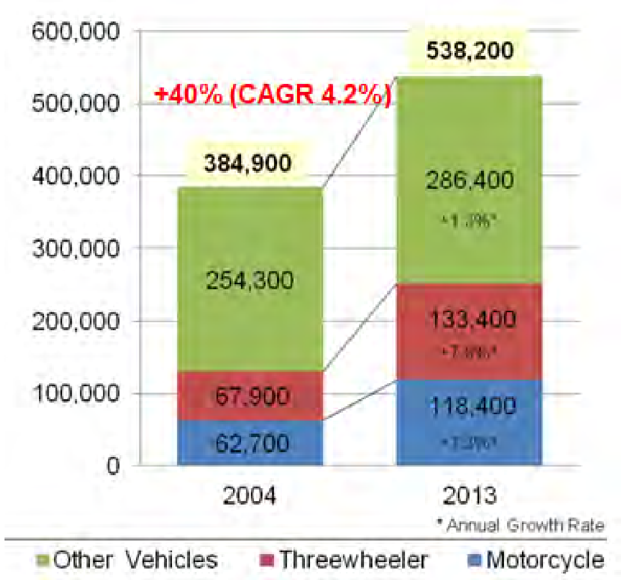


Figure 2-6 Traffic Growth at CMC Boundary 2004-2013

There have been 384,900 vehicles entering each day at CMC Boundary in 2004 which has grown to 538,200 vehicles having a compound annual growth rate of 4.2%. However the data from RDA shows that the growth on A & B class roads have been much higher with around 6-8% growth per year.

District	East-West orientation	North-South orientation
Colombo	8.2%	7.5%
Gampaha	7.9%	6.2%
Kalutara	8.1%	8.0%

Figure 2-7 Annual Traffic Growth in A& B class Roads

The ComTrans Study in 2013 has identified that there are close to 2.0 million passenger trips entering CMC limit daily having a 2.5% annual growth rate from 2004 to 2013 as shown in Figure 2-8. The data shows that 174,000 passenger trips enter from the high level road corridor which is the influence area for the study.

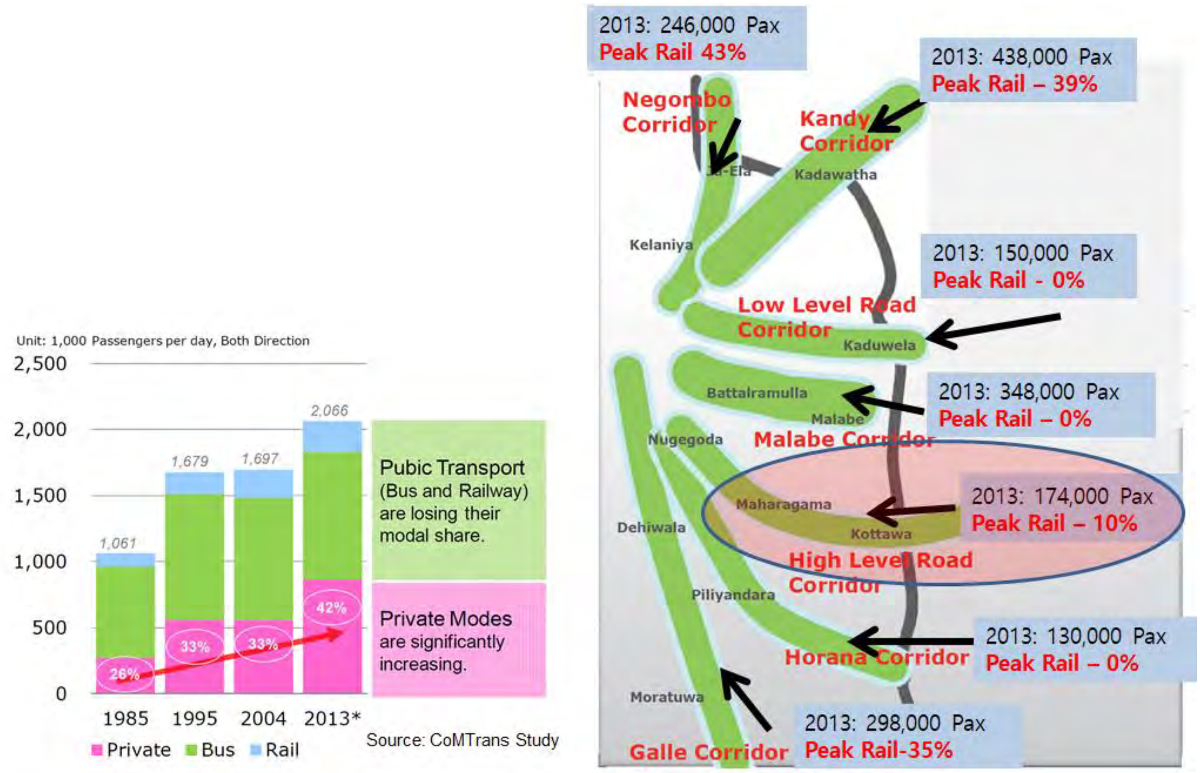


Figure 2-8 Passenger Trips Entering CMC limit

The latest government developed document which depicts the future development plan is based on the Megapolis Structure plan that considers that the 5.8 million in year 2013 will grow to 9.1 million by the year 2035. This is planned high growth scenario with an annual growth of 2.1%.

Spatial distribution of economic activity within the WP has been based on the principle of functional zoning of specialized activities depending upon the strengths and opportunities offered by various zones of the WP.

Key development zones identified by the WPMMP are:

- Aero City Zone - Katunayake
- Logistics Corridor - linking Airport and Harbor
- Eco Zone - Muthurajawela
- Industrial Townships - Mirigama
- Core Area Zone - centered in Colombo Port and surrounding suburbs
- Science & Technology City - Malabe
- Industrial Townships - Horana
- Coastal Tourism Belt
- Plantation City - Avissawella
- Forest & Plantation City - Baduraliya
- Tourism & Luxury Housing Zone – Dedduwa Lake & surrounding, Bolgoda Lake & Surrounding
- Marine Development Zone – Exclusive Economic Zone bounded from Kochchikade to Aluthgama

The expected populations by the functional zones are presented in Figure 2-9.

Planning Area		Extent of Planning Area (ha)	Population ('000)		
			2020	2025	2030
1	Central Business district (CBD)	16,465	1,290	1,362	1,443
2	Colombo Fringe	43,713	1,158	1,263	1,383
3	Aero City	31,170	630	748	893
4	Meerigama Industrial City	17,403	185	221	264
5	Horana Industrial City	16,771	247	305	381
6	Forest City	73,215	383	418	459
7	Gampaha Residential Zone	64,139	954	1,060	1,185
8	Knowledge City	15,639	383	440	508
9	Logistics Corriodor	20,263	459	526	617
10	Muthurajawela Tourism Zone	11,048	359	425	508
11	Plantation City	16,690	282	338	407
12	Southern Tourism Corridor	46,390	588	655	737
Western Province		372,906	6,919	7,762	8,786

Source: Western Region Megapolis Planning Project

Figure 2-9 Population by Planning Area Division in Megapolis Master Plan

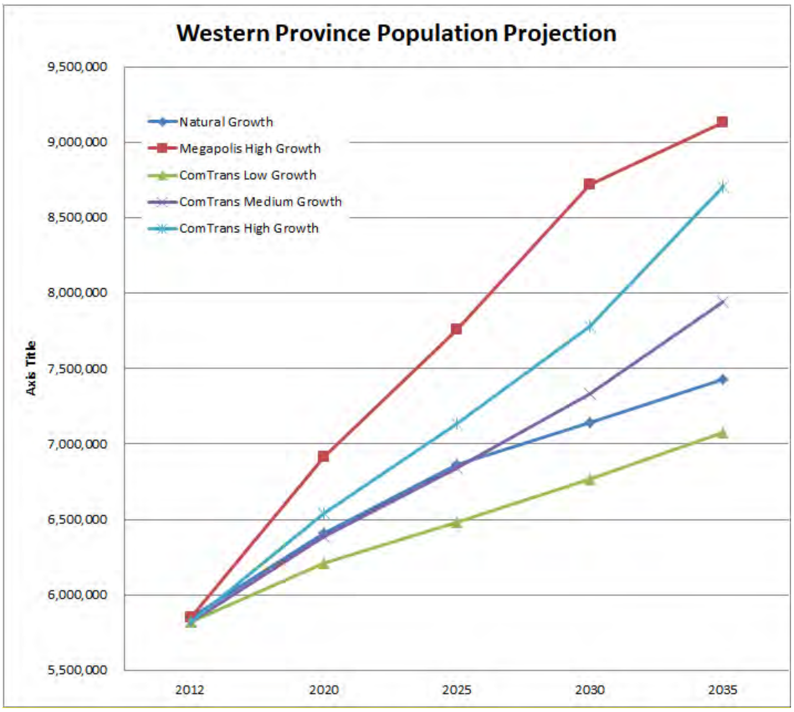


Figure 2-10 Population Growth Projections for the Western Province.

The population projections for the western province has been estimated contrastingly under different studies. The ComTrans Study has considered a more conservative approach of using a Medium growth scenario that is more inline with the natural growth of the western province. The detail estimates by each districts are shown in Table 2-1. Both the Comtrans medium growth scenario and the Megapolis High growth scenario will be considered in the Alternate modelling scenarios.

Table 2-1 Population Projections by District based on Megapolis and ComTrans

	Districts	2012	2015	2020	2025	2030	2035
Megapolis High Growth	Colombo	2,324,349	2,426,810	2,641,122	2,878,870	3,138,020	3,278,399
	Gampaha	2,304,340	2,433,902	2,813,494	3,228,223	3,704,086	3,884,364
	Kalutara	1,221,948	1,279,107	1,461,012	1,654,695	1,874,055	1,967,640
	Grand Total	5,850,637	6,139,820	6,915,627	7,761,788	8,716,162	9,130,403
	Districts	2012	2015	2020	2025	2030	2035
ComTrans Medium Growth	Colombo	2,309,809	2,359,400	2,476,100	2,624,400	2,624,400	2,979,700
	Gampaha	2,294,641	2,377,900	2,536,700	2,725,700	2,725,700	3,178,500
	Kalutara	1,217,260	1,270,200	1,373,200	1,492,100	1,492,100	1,782,000
	Grand Total	5,821,710	6,007,500	6,386,000	6,842,200	6,842,200	7,940,200

The trip rates in the Western province have been estimated at a gross rate of 1.87 and net rate of 2.9 as shown in Figure 2-11.

Region	Out-going Ratio	Gross Trip Rate	Net Trip Rate
CMA	65.2%	1.92	2.95
Non-CMA	63.3%	1.77	2.80
Western Province	64.5%	1.87	2.90

Source: CoMTrans Home Visit Survey, 2013

Figure 2-11 Passenger Trips Entering CMC limit

The transport model considers the trip generation by Home base Work (HBW), Home based School (HBW), Home base other (HBO) and Non home based (NHB) trips . Accordingly it is estimated that the 7.9 million motorized trips in year 2012 will increase up to 15.7 million under a medium growth and up to 18.2 million under a high growth scenario. This is a CAGR of 3.0 and 3.7 respectively which is slightly higher than the current passenger growth in the region. But this is expected with the economic growth expected in the region. The region wide improvement of public transport is expected to increase the current public transport ridership from 51% to 59%.

The corridor based analysis show that the current passenger trips of 174,000 per day would increase to 354,000 and 420,000 under the medium and high growth scenarios at a CAGR of 3.1% and 3.9% respectively. This is well within the vehicle growth of 6% that has been experienced in the same corridor. The improvement to the KV line is expected to increase the current corridor based rail passenger tips from 10% to 50%.

Year		2012	2035	2035
Scenario		Surveyed	High Growth	Med Growth
Total Trips (WP)		7,928,986	18,228,732	15,700,517
	Pub Trip	4,025,905 (51%)	10,715,358 (59%)	9,292,178 (59%)
	PV trip	3,903,081 (49%)	7,513,374 (41%)	6,408,340 (41%)
KV Corridor **Daily** Passenger Trips (Kirulapone - Nugegoda Section)	PV	42,636	46,600	41,900
	Bus	114,079	132,200	110,300
	Railway	17,285	240,800	201,600
	Total	174,000	419,600	353,800
KV Corridor **Peak** Passenger Trips (Kirulapone - Nugegoda Section)	PV	3,700 (24.5%)	6,149 (20%)	5,454 (21%)
	Bus	9,900 (65.6%)	8,593 (28%)	7,170 (28%)
	Railway	1,500 (9.9%)	25,043 (52%)	20,966 (51%)
	Total	15,100 (100%)	39,785 (100%)	33,589 (100%)

Figure 2-12 Passenger rip Estimations for WP and Study Corridor

2.1.2.2 KV line Operational Assumptions

The model parameters for operational speeds and fares were considered similar to the model specification outlined in the Technical report No 5 Transport Demand Forecast in the CoMTrans Final Report apart from following.

The operational speeds for the KV line was considered as 35km/h as per the operational speeds determined as per the analysis shown later in the report.

The Rail fares for the base year of 2013 were considered with a base fare cost of Rs 10 for base fare distance of 10km and an excess fare of Rs 1 per km. This is consistent with the current fare rates employed by the Sri Lanka Railways. The fare was considered to be 1.5 times the fare of 2013 for the years 2025 and 2035 similar to the assumptions made in the ComTrans Study.

2.1.2.3 Alternate Scenarios for Modelling

The modelling was considered for 3 alternate modelling scenarios having 12 run scenarios described below.

- Alternate Modelling Scenario 1: Socio economic growth based on Megapolis Structure plan with a high growth scenario with planned other transport development projects as shown in Figure 2- 13. (referred as High Growth Megapolis Development Scenario)
- Alternate Modelling Scenario 2: Socio economic growth based on Megapolis Structure plan with a high growth scenario with only committed public transport projects been considered

as shown in Figure 2- 13, where the LRT lines proposed other than the JICA LRT is not considered. Also the railway modernization is only limited to mainline, coast line and KV line. The objective of this scenario is to evaluate the impact on the KV line if other public transport is not developed or rather an evaluation of whether such high growth of socio economic would materialized. (referred as High Growth Less PT Development Scenario)

- Alternate Modelling Scenario 3: Socio economic growth based on Megapolis Structure plan, but with a medium growth scenario with planned other transport development projects as shown in Figure 2- 13 (referred as Medium growth Megapolis Development Scenario)

The following 12 scenarios were considered for the Demand modelling.

- Scenario 1 (AMS1_2025_BC) – Base Case scenario without KV line upgrade for year 2025 with expected Projects as per Megapolis Transport Masterplan (Figure 2- 13) and High Socio economic Growth.
- Scenario 2 (AMS1_2025_SC1) – Project scenario with KV line upgrade for year 2025 with expected Projects as per Megapolis Transport Masterplan (Figure 2- 13) and High Socio economic Growth.
- Scenario 3 (AMS1_2035_BC) – Base Case scenario without KV line upgrade for year 2035 with expected Projects as per Megapolis Transport Masterplan (Figure 2- 13) and High Socio economic Growth.
- Scenario 4 (AMS1_2035_SC1) – Project scenario with KV line upgrade for year 2035 with expected Projects as per Megapolis Transport Masterplan (Figure 2- 13) and High Socio economic Growth.
- Scenario 5 (AMS2_2025_BC) – Base Case scenario without KV line upgrade for year 2025 with Less PT Development Scenario (Figure 2- 13)
- Scenario 6 (AMS2_2025_SC2) – Project scenario with KV line upgrade for year 2025 with Less PT Development Scenario (Figure 2- 13)
- Scenario 7 (AMS2_2035_BC) – Base Case scenario without KV line upgrade for year 2035 with Less PT Development Scenario (Figure 2- 13)
- Scenario 8 (AMS2_2035_SC2) – Project scenario with KV line upgrade for year 2035 with Less PT Development Scenario (Figure 2- 13)
- Scenario 9 (AMS3_2025_BC) – Base Case scenario without KV line upgrade for year 2025 with Medium growth Megapolis Development Scenario (Figure 2- 13)
- Scenario 10 (AMS3_2025_SC3) – Project scenario with KV line upgrade for year 2025 with Medium growth Megapolis Development Scenario (Figure 2- 13)
- Scenario 11 (AMS3_2035_BC) – Base Case scenario without KV line upgrade for year 2035 with Medium growth Megapolis Development Scenario (Figure 2- 13)
- Scenario 12 (AMS3_2035_SC3) – Project scenario with KV line upgrade for year 2035 with Medium growth Megapolis Development Scenario (Figure 2- 13)

Projects	Alternate Modelling Scenario 1 (High Growth Megapolis Development Scenario)				Alternate Modelling Scenario 2 (High Growth Less Public Transport Scenario)				Alternate Modelling Scenario 3 (Medium Growth Megapolis Development Scenario)			
	2025		2035		2025		2035		2025		2035	
	AMS1_2025_BC	AMS1_2025_SC1	AMS1_2035_BC	AMS1_2035_SC1	AMS2_2025_BC	AMS2_2025_SC2	AMS2_2035_BC	AMS2_2035_SC2	AMS3_2025_BC	AMS3_2025_SC3	AMS3_2035_BC	AMS3_2035_SC3
Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
Socio Economic Growth	High Growth	High Growth	High Growth	High Growth	High Growth	High Growth	High Growth	High Growth	Med. Growth	Med. Growth	Med. Growth	Med. Growth
RTS												
RTS 1 - Green Line (JICA)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RTS 1 - Green Line (Remaining)	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
RTS 2 - Yellow Line	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
RTS 3 - Red Line	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
RTS 4 - Borella Malabe	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RTS 5 - Malabe - Kottawa	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
RTS 6 - Malabe Kaduwela	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓
RTS 7 - Kelaniya to Kadawatha	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Railway Electrification and Modernization												
Kalutara - Panadura	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Panadura Fort	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fort - Veyangoda	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Veyangoda - Rambukkana	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Kelani Valley Line up to Padukka	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Kelani Valley Line up to Padukka- to Avissawella	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Negambo Line with Airport Access	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Kottawa - Horana Line	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Kelaniya - Kosgama Line	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Roads												
Marine drive extension to Dehiwela	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Marine drive extension to Galleface	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Duplication road extension	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Baseline extention	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RDA on going projects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RDA Proposed	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OCH III	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Inland water transport												
Wellawatta - Battaramulla (W1)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fort - Union Place (W2)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mattakkuliya - Hanwella (W3)	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Expressway												
Central Expressway	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ruwanpura Expressway	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
New Kealni Bridge to Port	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Elevated Kelaniya - Rajagiriya - Pore	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Modernization of Public Bus Transport System in Western Region	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 2- 13 Project Combinations Considered for Demand Modelling

2.1.3 Demand Estimation Results for Alternate Modeling Scenario 1

2.1.3.1 Summary of Passenger Volumes for Alternate Modelling Scenario 1

Table 2-2 shows the summary of the demand forecast for the years 2025 and 2035 for the Alternate Modelling Scenario 1. This scenario is based on the High Growth Megapolis Development Scenario. The scenario was not selected as the project scenario for the study.

The design flow in terms of passenger per hour per direction (PPHPD) is calculated from the maximum daily sectional volume per direction considering a peak hour factor of 13% and peak direction ratio of 80%. The PPHPD increases from 19,543 from operational year 2025 to 25,039 for the operational year 2035.

The total number of daily passenger trips using the KV line is estimated as 295,538 in the year 2025 and increasing to 425,919 by the year 2035.

Table 2-2 Daily Passenger Volume Summary for Alternate Modelling Scenario 1

Indicator	2025	2035
PPHPD	19,543	25,039
Max Section	Kirillapone-Nugegoda	Kirillapone-Nugegoda
Max. Daily Sectional Passenger Trips	187,917	240,759
Total Daily Passengers Trips	295,538	425,919

2.1.3.2 Sectional Daily Volumes for Project Scenario

The daily sectional volumes of the KV line between the stations for the years 2025 and 2035 are shown in Figure 2-14. The figure also shows the PPHPD between the stations calculated based on the assumption described above. The Figure 2-15 and Figure 2-16 illustrate the daily passenger flows on the KV line and the other rail lines in the vicinity for the year 2025 and 2035.

Station Name	Station Name	Daily Passenger Volumes (High Growth Megapolis Development)		Peak Hour Passenger Volume per Direction (PPHPD)	
		Year 2025 (AMS1_2025_SC1)	Year 2035 (AMS1_2035_SC1)	Year 2025 (AMS1_2025_SC1)	Year 2035 (AMS1_2035_SC1)
Maradana	Baseline	145,854	206,150	15,169	21,440
Baseline	Kotta Road	145,071	197,287	15,087	20,518
Kotta Road	Narahenpita	155,896	205,471	16,213	21,369
Narahenpita	Kirillapone	181,193	233,710	18,844	24,306
Kirillapone	Nugegoda	187,917	240,759	19,543	25,039
Nugegoda	Pangiriwatta	186,824	232,906	19,430	24,222
Pangiriwatta	Udahamulla	169,479	212,618	17,626	22,112
Udahamulla	Navinna	155,955	198,286	16,219	20,622
Navinna	Maharagama	145,788	191,130	15,162	19,878
Maharagama	New1_Dambaher	113,965	161,884	11,852	16,836
New1_Dambahen	Pannipitiya	111,848	163,588	11,632	17,013
Pannipitiya	Kottawa	111,848	163,588	11,632	17,013
Kottawa	Malapalla	100,786	152,983	10,482	15,910
Malapalla	Makumbura	96,858	115,487	10,073	12,011
Makumbura	Homagama Hosp	86,465	103,108	8,992	10,723
Homagama Hospi	Homagama	75,187	87,389	7,819	9,088
Homagama	Panagoda	62,550	67,901	6,505	7,062
Panagoda	Godagama	60,931	66,468	6,337	6,913
Godagama	Meegoda	55,697	59,650	5,792	6,204
Meegoda	Watareka	42,743	45,713	4,445	4,754
Watareka	Padukka	40,766	43,160	4,240	4,489
Padukka	Arukwathupura	34,985	36,765	3,638	3,824
Arukwathupura	Angampitiya	34,443	36,519	3,582	3,798
Angampitiya	Uggalla	34,373	37,931	3,575	3,945
Uggalla	Pinnawala	36,145	40,668	3,759	4,229
Pinnawala	Gammana	37,909	43,440	3,943	4,518
Gammana	Morakele	31,783	37,999	3,305	3,952
Morakele	Waga	32,148	38,417	3,343	3,995
Waga	Kadugoda	28,900	37,959	3,006	3,948
Kadugoda	Kosgama	28,039	40,522	2,916	4,214
Kosgama	Hingurala	23,570	50,037	2,451	5,204
Hingurala	Puwakpitiya	31,241	60,044	3,249	6,245
Puwakpitiya	Avissawella	30,318	60,145	3,153	6,255

Figure 2 -14 Summary of Daily Sectional Volumes between Stations for Alternate Modeling Scenario1

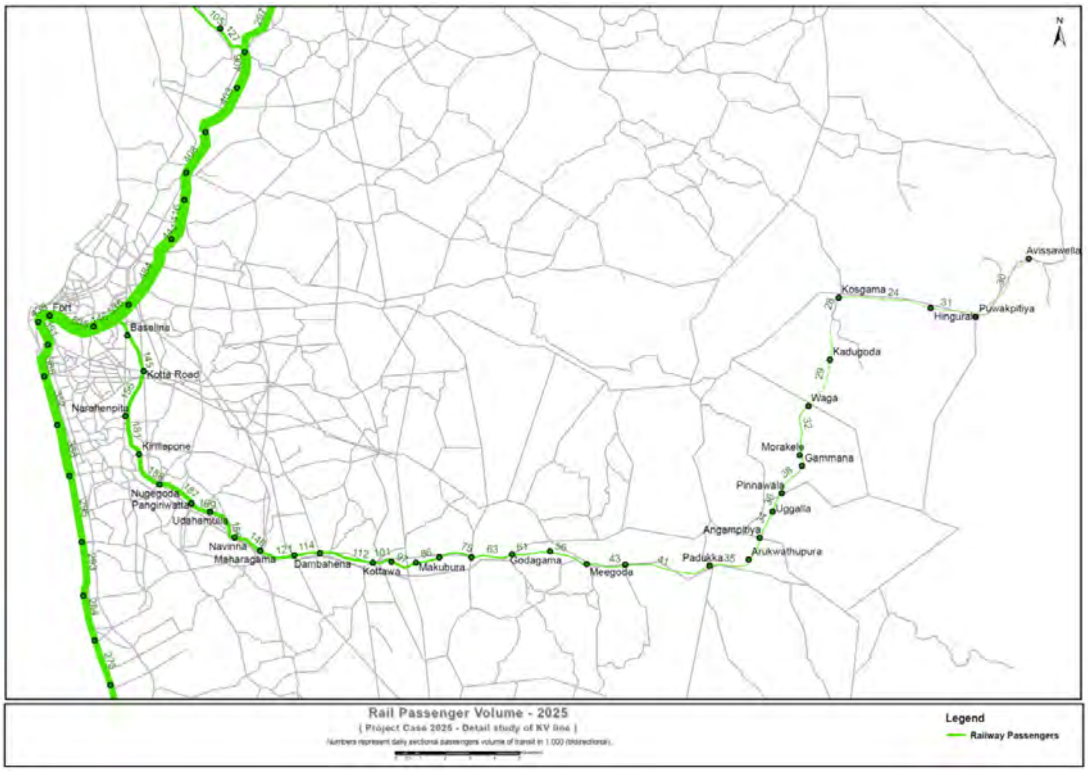


Figure 2- 15 Daily Sectional Volumes on KV line in Year 2025 for Alternate Modeling Scenario1

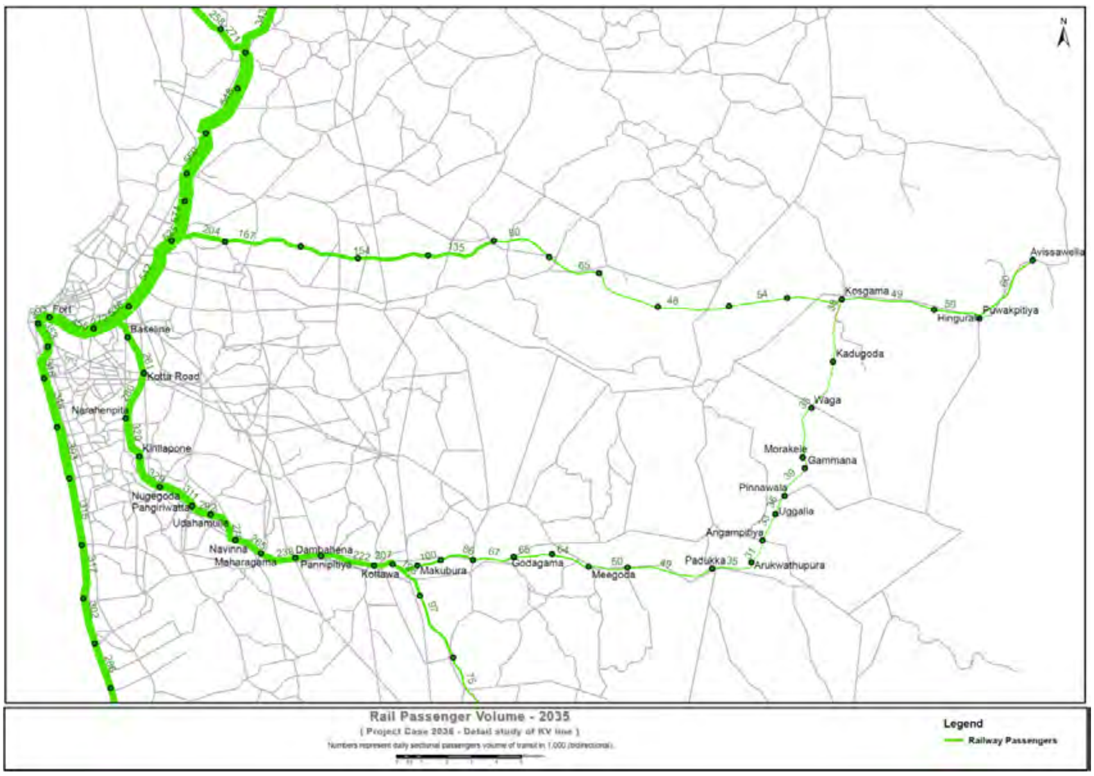


Figure 2 -16 Daily Sectional Volumes on KV line in Year 2035 for Alternate Modeling Scenario1

2.1.3.3 Boarding/Alighting Passenger Volumes for Alternate Modelling Scenario 1

The Figure 2-17, Figure 2-18, shows the boarding and alighting volumes by stations for the year 2025 and year 2035.

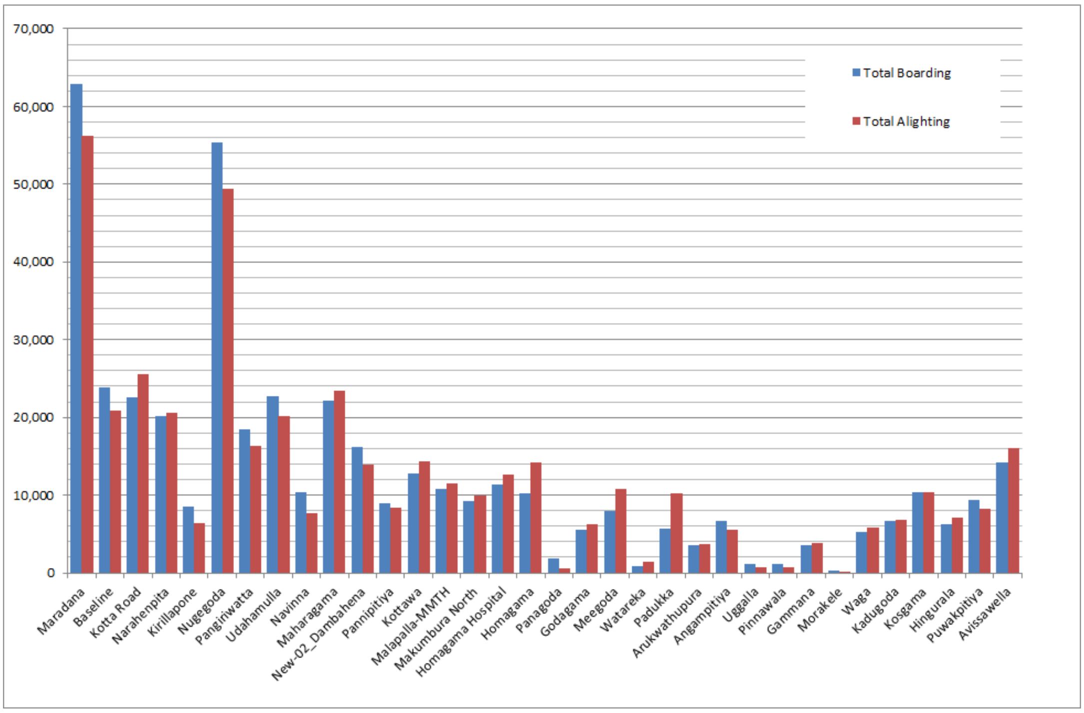


Figure 2- 17 Daily Boarding and Alighting by Station in 2025 for Alternate Modelling Scenario 1

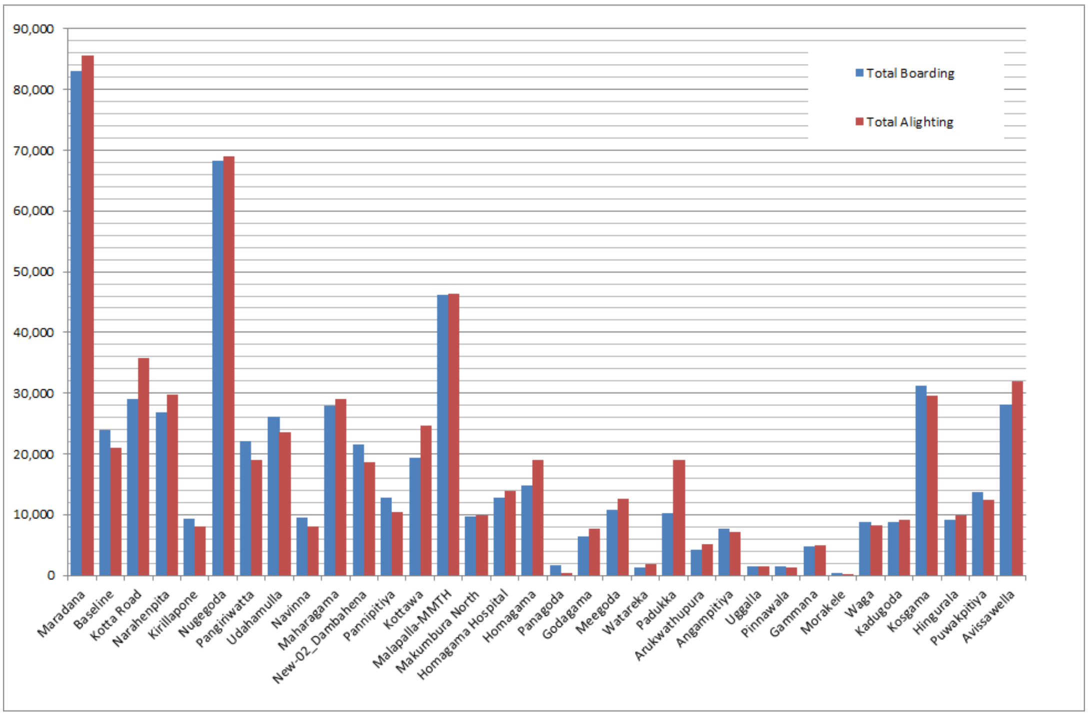


Figure 2- 18 Daily Boarding and Alighting by Station in 2035 for Alternate Modelling Scenario 1

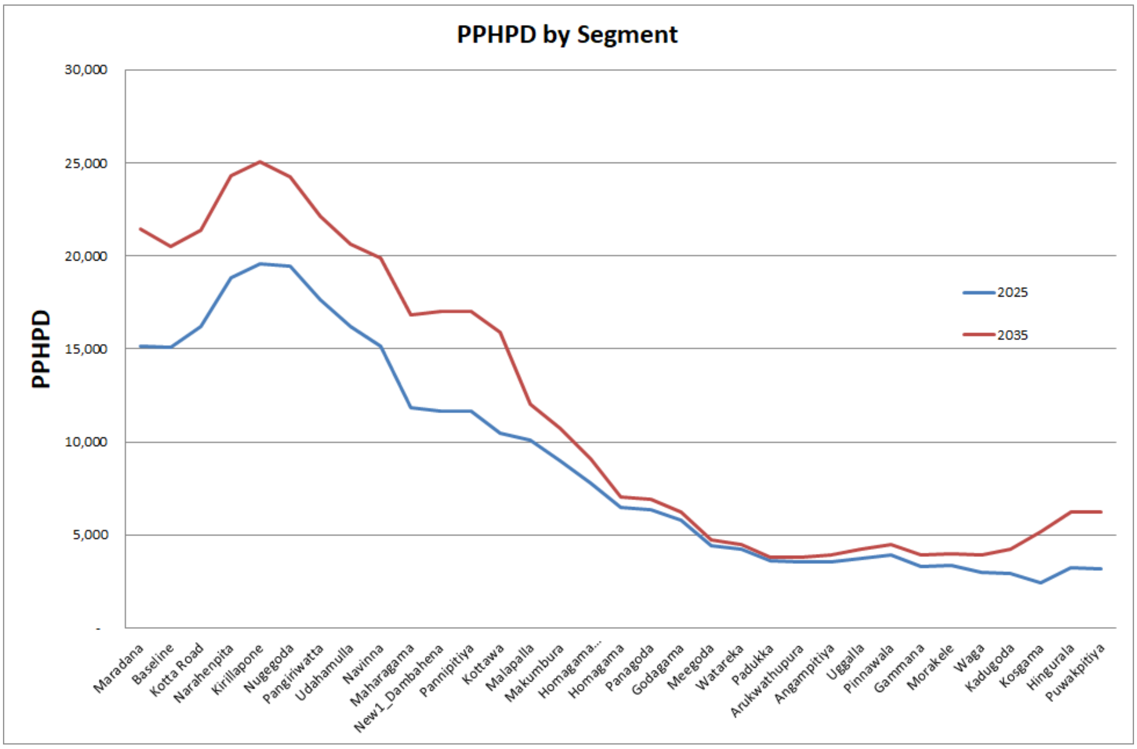


Figure 2- 19 Passengers per Direction per hour by Segment for Alternate Modelling Scenario 1

2.1.3.4 Key Performance Indicators for Alternate Modelling Scenario 1

The summary of the STRADA modelling outputs for each of the scenarios outlined above is provided in term of following parameters for measurement of KPI in Figure 2-20.

- Scenario – Described in above
- Total trips per day – total estimated trips by each mode for each year in the CMR
- Total Public transport trips
- Total Car trips
- Total motor cycle (MC) trips
- Total three wheeler (3W) trips
- Total Truck Trips
- Vehicle km per day - Total daily vehicle kms estimated to be made by each mode in the CMR considering average operational times for bus and rail as 14hrs, LRT and BRT as 18 hrs and water transport as 12 hrs.
- Passenger km per day – Total number of passenger km estimated to be made per day in the CMR.
- Trip length – the average trip length in km
- Passenger hrs per day – the total number of passenger hours spent in transport per day in CMR.
- Average speed- the Average speed by mode within the CMR.

	2025		2035	
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Motorized Trips per Day (millions)	15.5	15.5	18.2	18.2
Public	8,113,265	9,084,214	9,796,040	10,635,614
Cars	1,872,254	1,629,539	2,082,819	1,899,532
MC	2,806,571	2,446,955	3,073,991	2,791,367
3W	2,519,489	2,149,763	2,960,065	2,584,814
Truck	234,264	234,264	309,155	309,155
Public Transport Share (trips)	52%	58%	54%	58%
Vehicle Km Travelled				
Bus	3,014,270	2,938,796	2,877,434	2,818,858
Rail	33,824	38,738	35,560	35,574
RTS	18,558	18,756	38,034	39,024
Water	2,388	2,520	7,440	6,900
Car	17,022,058	15,787,698	18,753,714	18,206,679
MC	18,578,243	17,531,753	20,664,645	20,396,698
3W	7,344,479	7,412,554	8,622,894	8,999,549
Trucks	6,258,570	6,197,163	8,488,420	8,481,823
Total Motorized	52,272,389	49,927,977	59,488,141	58,985,104
Passenger Km Travelled				
Bus	72,227,266	70,063,142	69,630,958	67,667,236
Rail	23,175,942	28,171,203	35,062,150	39,052,992
RTS	6,760,020	6,953,271	16,223,379	16,044,890
Water	88,394	78,082	270,398	217,530
Car	29,277,940	27,154,841	32,256,388	31,315,488
MC	22,665,456	21,388,738	25,210,867	24,883,971
3W	10,429,160	10,525,826	12,244,509	12,779,359
Trucks	6,258,570	6,197,163	8,488,420	8,481,823
Total Motorized	170,882,747	170,532,266	199,387,069	200,443,289
Average Trip Distance (km)				
Pub	5.99	6.03	5.89	5.95
Private (Car,MC)	5.26	5.59	5.62	6.62
3W	2.33	2.76	2.78	2.78
Trucks	26.72	26.45	27.44	27.44
Of all Motorized Vehicles	10.08	10.21	10.43	10.70
Passenger Hours Travelled (hrs)				
Bus	3,581,876	3,463,955	3,499,940	3,382,093
Rail	569,019	685,876	751,077	813,502
RTS	288,190	292,510	713,477	699,323
Water	6,127	5,412	18,754	15,081
Car	705,300	632,981	842,948	803,015
MC	685,445	625,897	837,698	817,787
3W	331,630	323,030	437,367	455,587
Trucks	182,746	175,915	272,658	270,149
Total Motorized	8,093,866	6,205,576	7,256,538	7,256,538
Average Travel Speed (km/h)				
Ave Pub	23.00	23.67	24.32	25.05
Ave PV	36.02	37.13	32.71	33.01
Ave Motorized	21.11	27.48	27.48	27.62

Figure 2- 20 KPIs for the KV Line for Alternate Modelling Scenario 1

2.1.4 Demand Estimation Results for Alternate Modeling Scenario 2

2.1.4.1 Summary of Passenger Volumes for Alternate Modelling Scenario 2

Table 2-3 shows the summary of the demand forecast for the years 2025 and 2035 for the less public transport development scenario. This scenario is based on the High Growth Megapolis Development Scenario but with less public transport development considered as the Less Public Transport Scenario. The scenario was not selected as the project scenario for the study.

The design flow in terms of passenger per hour per direction (PPHPD) is calculated from the maximum daily sectional volume per direction considering a peak hour factor of 13% and peak direction ratio of 80%. The PPHPD increases from 25,094 from operational year 2025 to 32,995 for the operational year 2035.

Table 2-3 Daily Passenger Volume Summary for Alternate Modelling Scenario 2

Indicator	2025	2035
PPHPD	25,094	32,995
Max Section	Narahenpita - Kirillapone	Narahenpita - Kirillapone
Max. Daily Sectional Passenger Trips	241,289	317,263
Total Daily Passenger Trips	579,488	732,924

In this case the passenger volumes are much higher than the Alternate Modelling Scenario 1, with maximum sectional volume estimated as high as 317,000 and total passenger trips of 732,924. This is indication that many trips from other corridors have been attracted to the KV line, mainly due to sudden drop of average road speed as illustrated in Figure 2- 21 and due to non-availability of necessary other public transport infrastructure such as other rail and LRT lines.

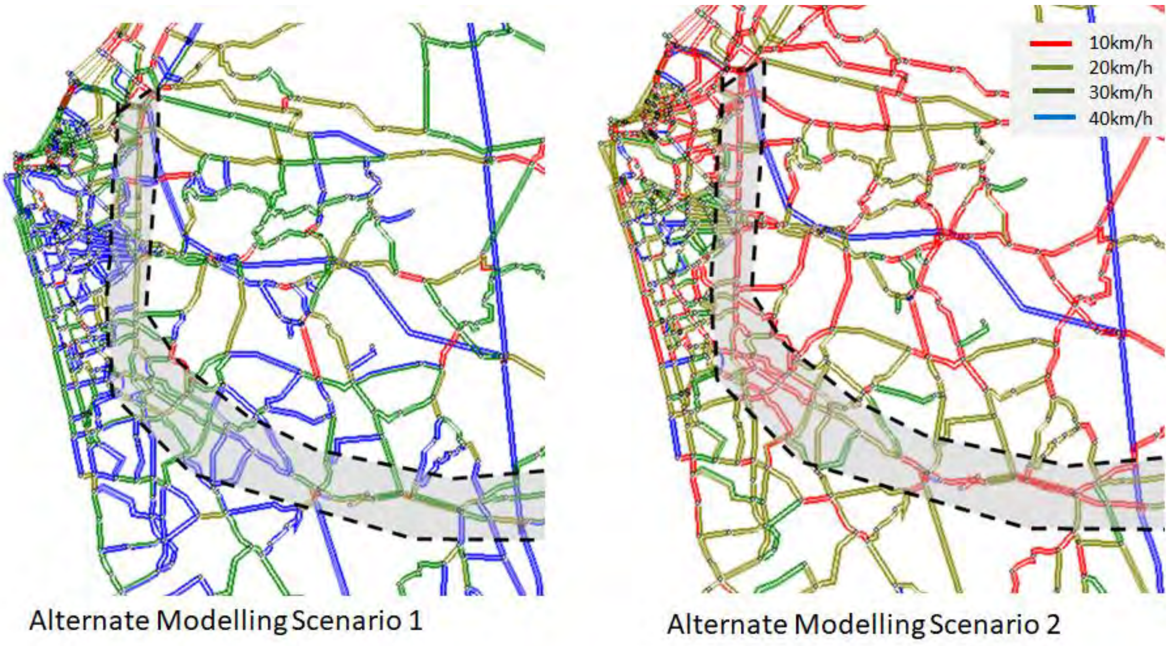


Figure 2- 21 Average Road Speeds between Alternate Modelling Scenario 1& 2

The model estimates a high demand to the KV line due to the constraints of the transport supply. Considering that the socio economic growth is fixed in the modelling, this is an indication that the high growth assumed in the Megapolis will not materialize since the Colombo or the Western province will not be an attractive place to locate. Therefore care should be taken to consider the above scenario not as a positive to the KV line but an scenario that will not materialize.

2.1.4.2 Sectional Daily Volumes for Alternate Modelling Scenario 2

The daily sectional volumes of the KV line between the stations for the years 2025 and 2035 are shown in Figure 2-22. The figure also shows the PPHPD between the stations calculated based on the assumption described above for academic purpose only.

Station Name	Station Name	Daily Passenger Volumes		Peak Hour Passenger Volume per Direction (PPHPD)	
		Year 2025 Low Project Sc (HG_2025_SC2)	**Year 2035 Low Project Sc (HG_2035_SC2)**	**Year 2025 Low Project Sc (HG_2025_SC2)**	**Year 2035 Low Project Sc (HG_2035_SC2)**
Maradana	Baseline	217,548	281,072	22,625	29,231
Baseline	Kotta Road	215,867	280,872	22,450	29,211
Kotta Road	Narahenpita	234,620	310,749	24,400	32,318
Narahenpita	Kirillapone	241,289	317,263	25,094	32,995
Kirillapone	Nugegoda	220,781	293,072	22,961	30,479
Nugegoda	Pangiriwatta	208,007	263,598	21,633	27,414
Pangiriwatta	Udahamulla	190,736	243,762	19,837	25,351
Udahamulla	Navinna	173,046	223,978	17,997	23,294
Navinna	Maharagama	160,103	209,623	16,651	21,801
Maharagama	New1_Dambahena	125,102	157,117	13,011	16,340
New1_Dambahena	Pannipitiya	120,589	152,337	12,541	15,843
Pannipitiya	Kottawa	120,589	152,337	12,541	15,843
Kottawa	Malapalla	108,935	131,974	11,329	13,725
Malapalla	Makumbura	94,949	114,596	9,875	11,918
Makumbura	Homagama Hospital	84,975	103,153	8,837	10,728
Homagama Hospita	Homagama	76,039	93,850	7,908	9,760
Homagama	Panagoda	66,778	80,377	6,945	8,359
Panagoda	Godagama	62,956	78,047	6,547	8,117
Godagama	Meegoda	56,983	71,598	5,926	7,446
Meegoda	Watareka	43,443	56,540	4,518	5,880
Watareka	Padukka	41,294	53,310	4,295	5,544
Padukka	Arukwathupura	35,333	45,985	3,675	4,782
Arukwathupura	Angampitiya	34,432	44,418	3,581	4,619
Angampitiya	Uggalla	34,394	44,491	3,577	4,627
Uggalla	Pinnawala	36,169	46,825	3,762	4,870
Pinnawala	Gammana	37,932	49,123	3,945	5,109
Gammana	Morakele	31,651	41,418	3,292	4,307
Morakele	Waga	32,000	41,844	3,328	4,352
Waga	Kadugoda	28,849	37,540	3,000	3,904
Kadugoda	Kosgama	28,020	37,119	2,914	3,860
Kosgama	Hingurala	23,710	30,727	2,466	3,196
Hingurala	Puwakpitiya	31,442	41,780	3,270	4,345
Puwakpitiya	Avissawella	30,721	43,787	3,195	4,554

Figure 2- 22 Summary of Daily Sectional Volumes between Stations for Alternate Modelling Scenario 2

2.1.5 Demand Estimation Results for Alternate Modeling Scenario 3

2.1.5.1 Summary of Passenger Volumes for Alternate Modelling Scenario 3

Table 2-4 shows the summary of the demand forecast for the years 2025 and 2035 for the Alternate Modelling Scenario 3. This scenario is based on the Medium Growth Megapolis Development Scenario. **The scenario was selected as the project scenario for the study**.

The design flow in terms of passenger per hour per direction (PPHPD) is calculated from the maximum daily sectional volume per direction considering a peak hour factor of 13% and peak direction ratio of 80%. The PPHPD increases from 18,405 from operational year 2025 to 20,973 for the operational year 2035.

The total number of daily passenger trips using the KV line is estimated as 273,566 in the year 2025 and increasing to 365,731 by the year 2035.

Table 2-4 Daily Passenger Volume Summary for Alternate Modelling Scenario 3

Indicator	2025	2035
PPHPD	18,405	20,973
Max Section	Kirillapone-Nugegoda	Kirillapone-Nugegoda
Max. Daily Sectional Passenger Trips	176,969	201,662
Total Daily Passengers Trips	273,566	365,731

2.1.5.2 Sectional Daily Volumes for Alternate Modelling Scenario 3

The daily sectional volumes of the KV line between the stations for the years 2025 and 2035 are shown in Figure 2-23. The figure also shows the PPHPD between the stations calculated based on the assumption described above. The Figure 2-24 and Figure 2-25 illustrate the daily passenger flows on the KV line and the other rail lines in the vicinity for the year 2025 and 2035. The volumes in the medium growth scenario in contrast to the high growth scenario considered in Alternate modelling Scenario 1 is between 15- 22% less.

Station Name	Station Name	Daily Passenger Volumes (Medium Growth Megapolis Development)		Peak Hour Passenger Volume per Direction (PPHPD)	
		Year 2025 (AMS3_2025_SC3)	**Year 2035 (AMS3_2035_SC3)**	**Year 2025 (AMS3_2025_SC3)**	**Year 2035 (AMS3_2035_SC3)**
Maradana	Baseline	133,771	168,893	13,912	17,565
Baseline	Kotta Road	132,807	160,817	13,812	16,725
Kotta Road	Narahenpita	144,468	170,352	15,025	17,717
Narahenpita	Kirillapone	169,559	194,403	17,634	20,218
Kirillapone	Nugegoda	176,969	201,662	18,405	20,973
Nugegoda	Pangiriwatta	173,328	197,899	18,026	20,581
Pangiriwatta	Udahamulla	156,471	180,373	16,273	18,759
Udahamulla	Navinna	140,155	166,655	14,576	17,332
Navinna	Maharagama	131,353	160,494	13,661	16,691
Maharagama	New1_Dambaher	102,406	133,684	10,650	13,903
New1_Dambahen	Pannipitiya	100,224	134,653	10,423	14,004
Pannipitiya	Kottawa	100,224	134,653	10,423	14,004
Kottawa	Malapalla	88,547	127,291	9,209	13,238
Malapalla	Makumbura	85,306	96,574	8,872	10,044
Makumbura	Homagama Hosp	77,267	85,359	8,036	8,877
Homagama Hospi	Homagama	68,704	72,049	7,145	7,493
Homagama	Panagoda	54,888	55,077	5,708	5,728
Panagoda	Godagama	53,683	53,965	5,583	5,612
Godagama	Meegoda	48,727	48,378	5,068	5,031
Meegoda	Watareka	37,529	36,477	3,903	3,794
Watareka	Padukka	35,781	34,564	3,721	3,595
Padukka	Arukwathupura	31,122	30,014	3,237	3,121
Arukwathupura	Angampitiya	29,750	29,617	3,094	3,080
Angampitiya	Uggalla	29,036	30,596	3,020	3,182
Uggalla	Pinnawala	30,444	32,690	3,166	3,400
Pinnawala	Gammana	31,868	34,925	3,314	3,632
Gammana	Morakele	26,509	30,289	2,757	3,150
Morakele	Waga	26,823	30,644	2,790	3,187
Waga	Kadugoda	24,235	30,695	2,520	3,192
Kadugoda	Kosgama	23,728	32,402	2,468	3,370
Kosgama	Hingurala	19,906	38,900	2,070	4,046
Hingurala	Puwakpitiya	25,744	46,401	2,677	4,826
Puwakpitiya	Avissawella	25,132	43,787	2,614	4,554

Figure 2- 23 Summary of Daily Sectional Volumes between Stations for Alternate Modeling Scenario 3

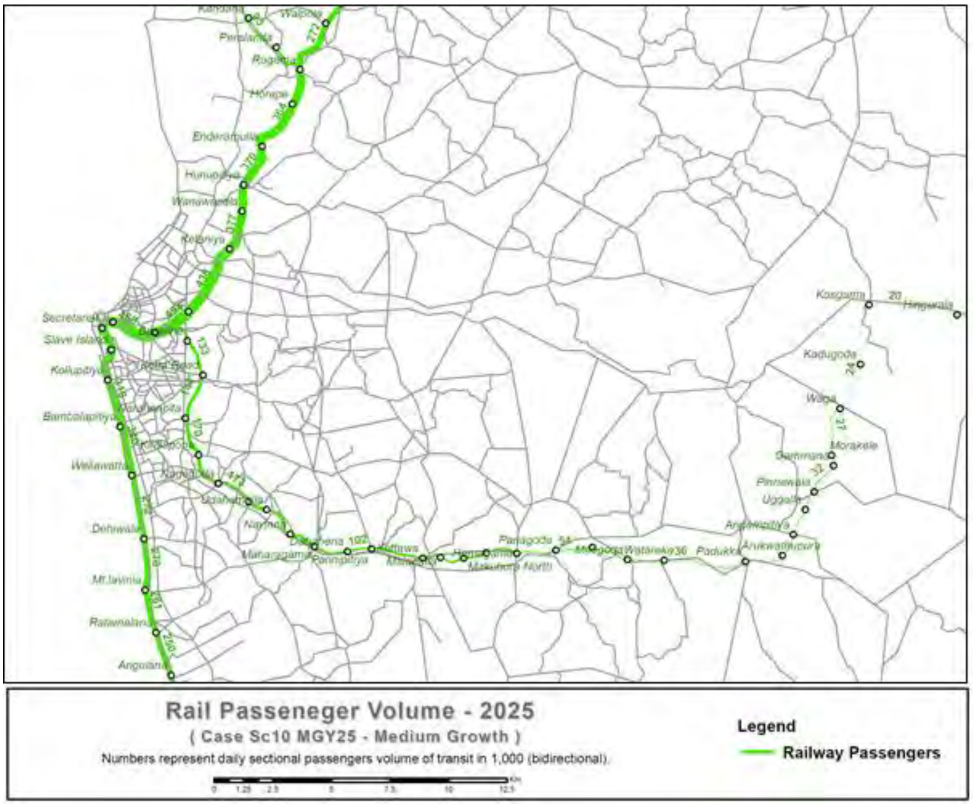


Figure 2- 24 Daily Sectional Volumes on KV line in Year 2025 for Alternate Modeling Scenario 3

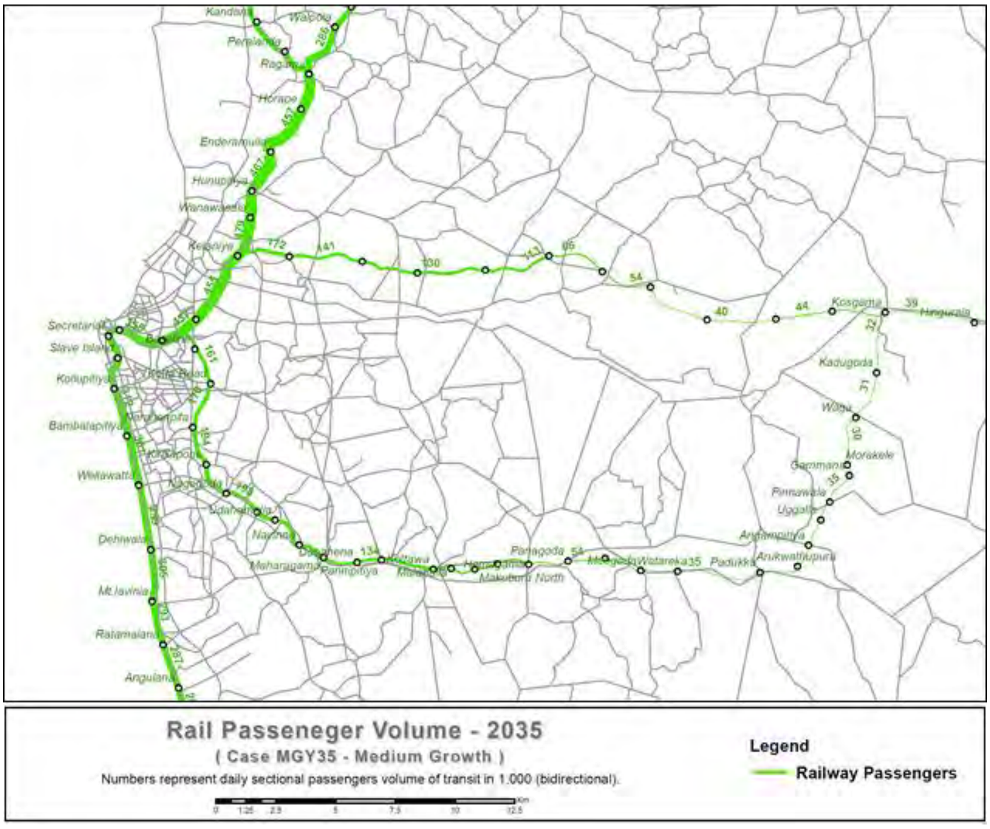


Figure 2- 25 Daily Sectional Volumes on KV line in Year 2035 for Alternate Modeling Scenario 3

2.1.5.3 Boarding/Alighting Passenger Volumes for Alternate Modelling Scenario 3

The Figure 2-26, Figure 2-27, shows the boarding and alighting volumes by stations for the year 2025 and year 2035.

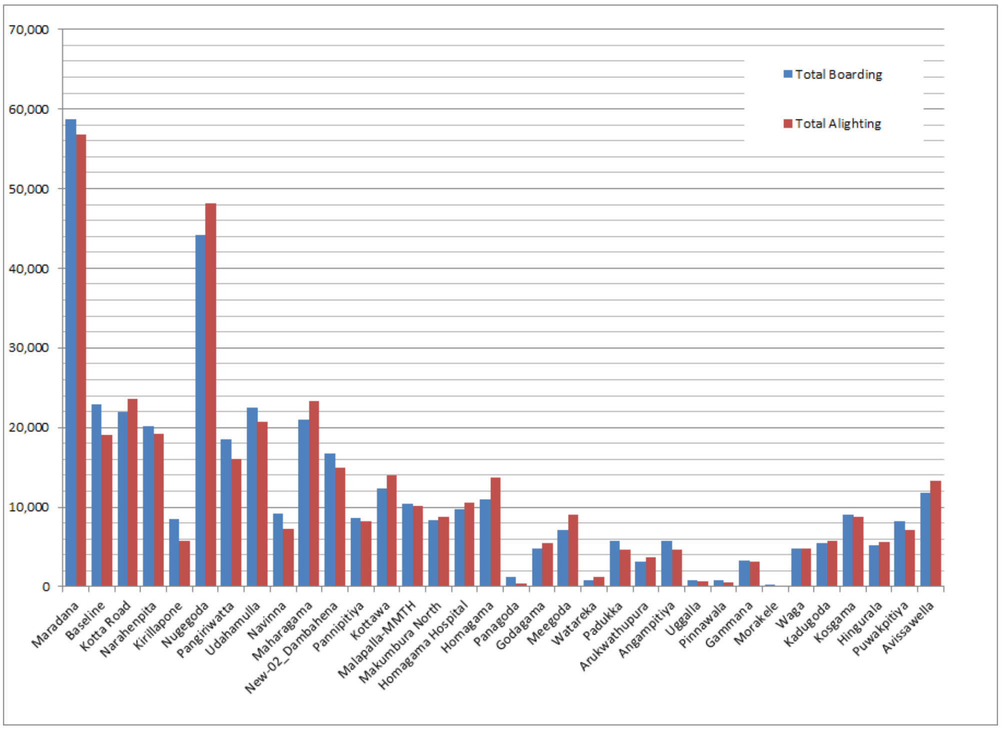


Figure 2-26 Daily Boarding and Alighting by Station in 2025 for Alternate Modelling Scenario 3

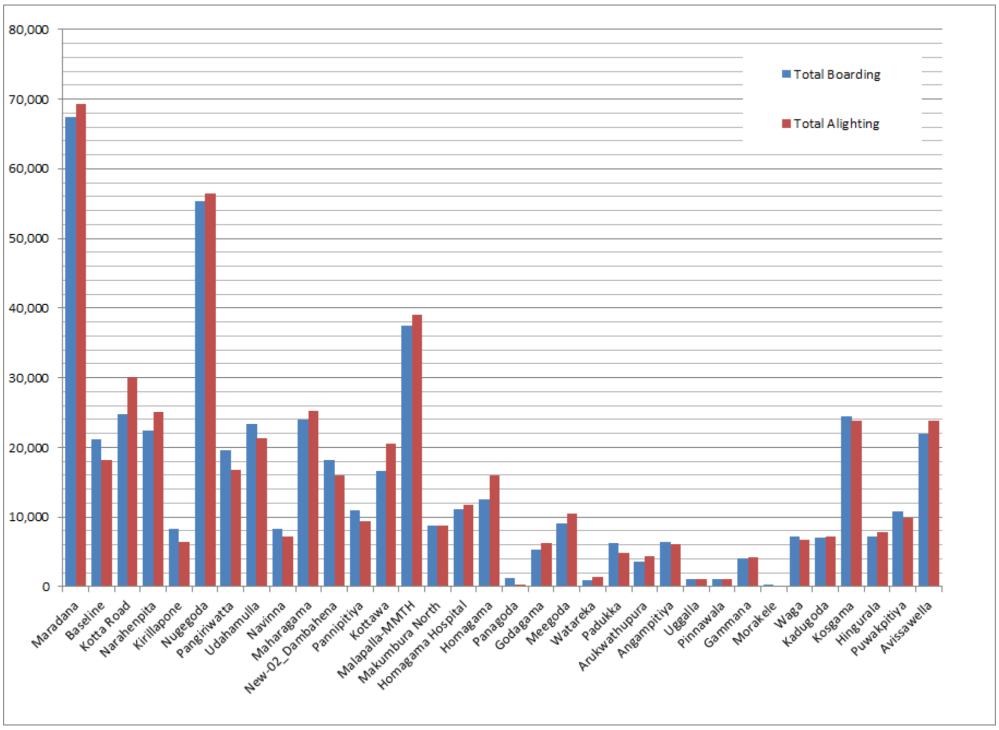


Figure 2- 27 Daily Boarding and Alighting by Station in 2035 for Alternate Modelling Scenario 3

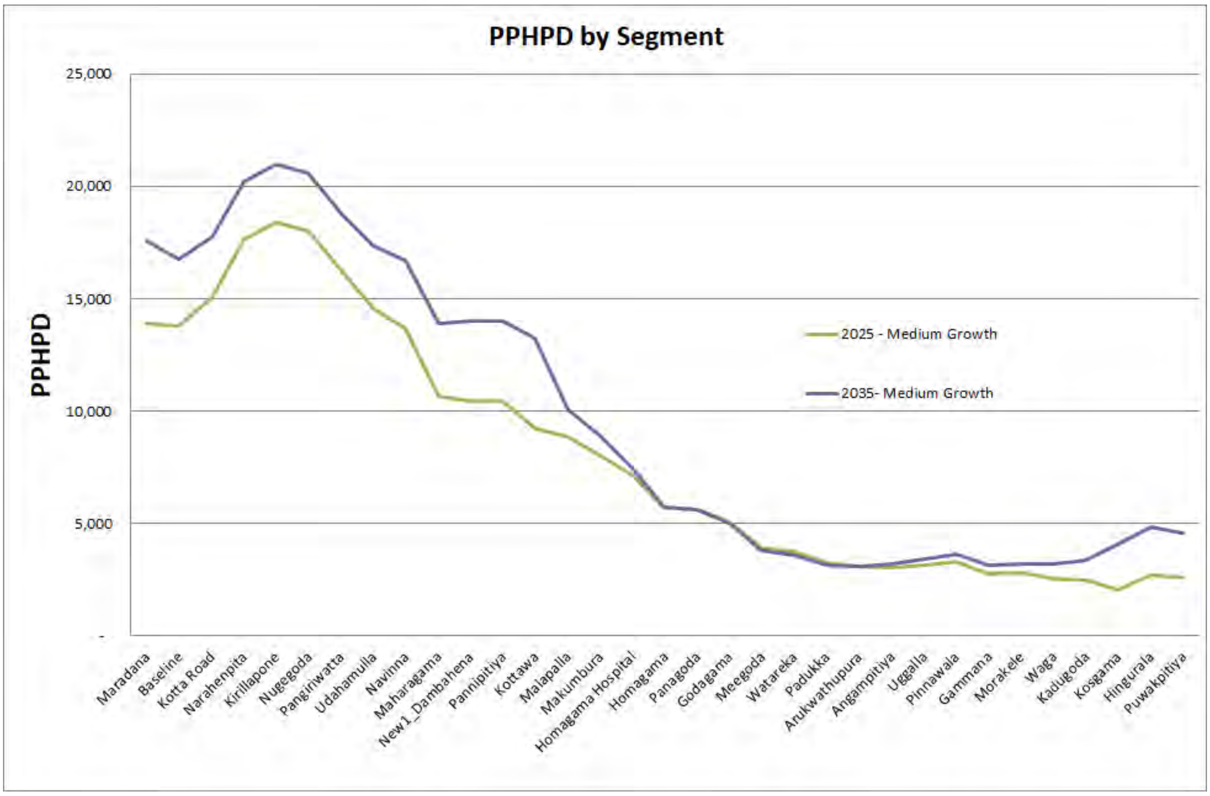


Figure 2-28 Passengers per Direction per hour by Segment for Alternate Modelling Scenario 3

2.1.5.4 Key Performance Indicators for Alternate Modelling Scenario 3

The summary of the STRADA modelling outputs for each of the scenarios outlined above is provided in term of following parameters for measurement of KPI in Figure 2-29.

- Scenario – Described in above
- Total trips per day – total estimated trips by each mode for each year in the CMR
- Total Public transport trips
- Total Car trips
- Total motor cycle (MC) trips
- Total three wheeler (3W) trips
- Total Truck Trips
- Vehicle km per day - Total daily vehicle kms estimated to be made by each mode in the CMR considering average operational times for bus and rail as 14hrs, LRT and BRT as 18 hrs and water transport as 12 hrs.
- Passenger km per day – Total number of passenger km estimated to be made per day in the CMR.
- Trip length – the average trip length in km
- Passenger hrs per day – the total number of passenger hours spent in transport per day in CMR.
- Average speed- the Average speed by mode within the CMR.

	2025		2035	
	Scenario 9	Scenario 10	Scenario 11	Scenario 12
Motorized Trips per Day (millions)	13.4	13.4	15.7	15.7
Public	6,972,255	8,191,903	8,394,811	9,828,107
Cars	1,589,652	1,262,904	1,784,595	2,040,152
MC	2,448,888	1,992,255	2,701,456	3,056,522
3W	2,180,706	1,760,211	2,512,276	3,002,375
Truck	234,264	234,264	309,155	309,155
Public Transport Share (trips)	52%	61%	53%	58%
Vehicle Km Travelled				
Bus	2,384,424	2,441,824	2,475,270	2,346,834
Rail	31,402	36,092	28,840	31,570
RTS	16,326	17,892	36,018	36,576
Water	2,388	2,520	6,780	6,648
Car	14,385,588	12,357,395	16,183,694	15,794,215
MC	15,362,610	13,069,075	17,579,028	17,415,855
3W	6,111,788	5,730,774	7,172,498	7,505,254
Trucks	6,658,870	6,071,852	8,326,395	8,319,684
Total Motorized	44,953,396	39,727,424	51,808,522	51,456,636
Passenger Km Travelled				
Bus	57,116,985	57,943,373	58,824,965	55,308,183
Rail	19,992,463	25,500,873	29,354,898	34,005,570
RTS	6,085,917	6,694,112	13,934,680	13,870,760
Water	79,635	74,303	194,568	180,068
Car	24,743,211	21,254,719	27,835,954	27,166,050
MC	18,742,384	15,944,272	21,446,414	21,247,343
3W	8,678,738	8,137,699	10,184,946	10,657,460
Trucks	6,658,870	6,071,852	8,326,395	8,319,684
Total Motorized	142,098,204	141,621,203	170,102,820	170,755,118
Average Trip Distance (km)				
Pub	6.11	6.16	5.96	6.03
Private (Car,MC)	5.17	5.22	5.14	5.21
3W	2.30	2.30	2.29	2.30
Trucks	26.63	26.53	27.52	27.41
Of all Motorized Vehicles	10.05	10.05	10.23	10.24
Passenger Hours Travelled (hrs)				
Bus	2,811,751	2,847,370	2,912,937	2,738,799
Rail	487,983	617,696	626,675	727,351
RTS	260,162	283,184	613,716	606,113
Water	5,521	5,151	13,488	12,478
Car	567,139	467,327	673,561	648,787
MC	535,190	433,713	655,695	645,691
3W	256,759	228,545	327,709	343,212
Trucks	184,852	160,888	248,919	247,981
Total Motorized	5,109,357	5,043,875	6,072,700	5,970,413
Average Travel Speed (km/h)				
Ave Pub	23.36	24.03	24.55	25.31
Ave PV	38.10	39.84	35.57	35.74
Ave Motorized	27.81	28.08	28.01	28.60

Figure 2- 29 KPIs for the KV Line for Alternate Modelling Scenario 3

2.2 Traffic Surveys at Railway Crossings

Traffic surveys were conducted at the following locations along the Kelani Valley Railway Line crossings from Homagama to Padukka. The traffic counts consist of one weekday 12 hour manual classified counts at the main railway crossings and peak hours (4 hours in the morning or afternoon) counts at 3 minor road intersections, as shown below.

Table 2-5 Survey Location and Type

Location ID	Road	Chainage	Survey location		Type of survey
			Latitude	Longitude	
58	Wimana Rd Level Crossing	25+010	80.008282	6.846289	A
59	Panagoda Station Rd Level Crossing	26+330	80.019212	6.846829	A
60	Godagamagewatta Rd Level Crossing	27+360	80.027344	6.848278	C
61	Godagama Station Rd, level Crossing	28+050	80.033062	6.847918	A
62	Level Crossing C3	28+530	80.037348	6.847189	D
63	Samadhi Mw	28+720	80.039035	6.846856	D
64	Palpolawatta Rd Level Crossing	28+790	80.039607	6.846565	A
65	Asiri Uyana Rd	28+980	80.041099	6.845794	D
66	Puwakwatta Rd Level Crossing	29+060	80.041771	6.845449	B
67	Meegoda Station	29+600	80.045539	6.843359	B
68	Udagewatte Rd	30+300	80.051942	6.842855	A
69	Madulawa Rd	30+820	80.059865	6.843167	A
70	Opathaella Rd	31+850	80.065755	6.843263	A
71	Kurugala Rd	33+630	80.079622	6.838866	A
72	Level Crossing C4	34+440	80.085437	6.838949	No surveys
73	Polwatta Rd C1	34+660	80.087366	6.839497	No surveys
74	Polwatta Rd C2	34+750	80.088103	6.839851	B
75	Padukka Road Level Crossing	34+900	80.089248	6.840338	B

Note: Map reference for survey locations:
https://www.google.com/maps/d/edit?mid=1IIDj83sN9IaFBSqrSdimJhIfLuGv0kOy&ll=6.837585033496552%2C80.08925034692083&z=17

Table 2-6 Description of Traffic Survey Types

Survey type	Survey description	Survey duration	
A	MCC in one direction and total traffic counts in one direction	12hr	7.00 AM to 7.00 PM
B	MCC both direction	12hr	7.00 AM to 7.00 PM
C	MCC both direction (peak period)	4hr	7.00 AM to 11.00 AM or 2.00 PM to 6.00 PM
D	MCC + total (peak period only)	4hr	7.00 AM to 11.00 AM or 2.00 PM to 6.00 PM

- MCC – manual classified counts
- All surveys will be carried out during weekdays

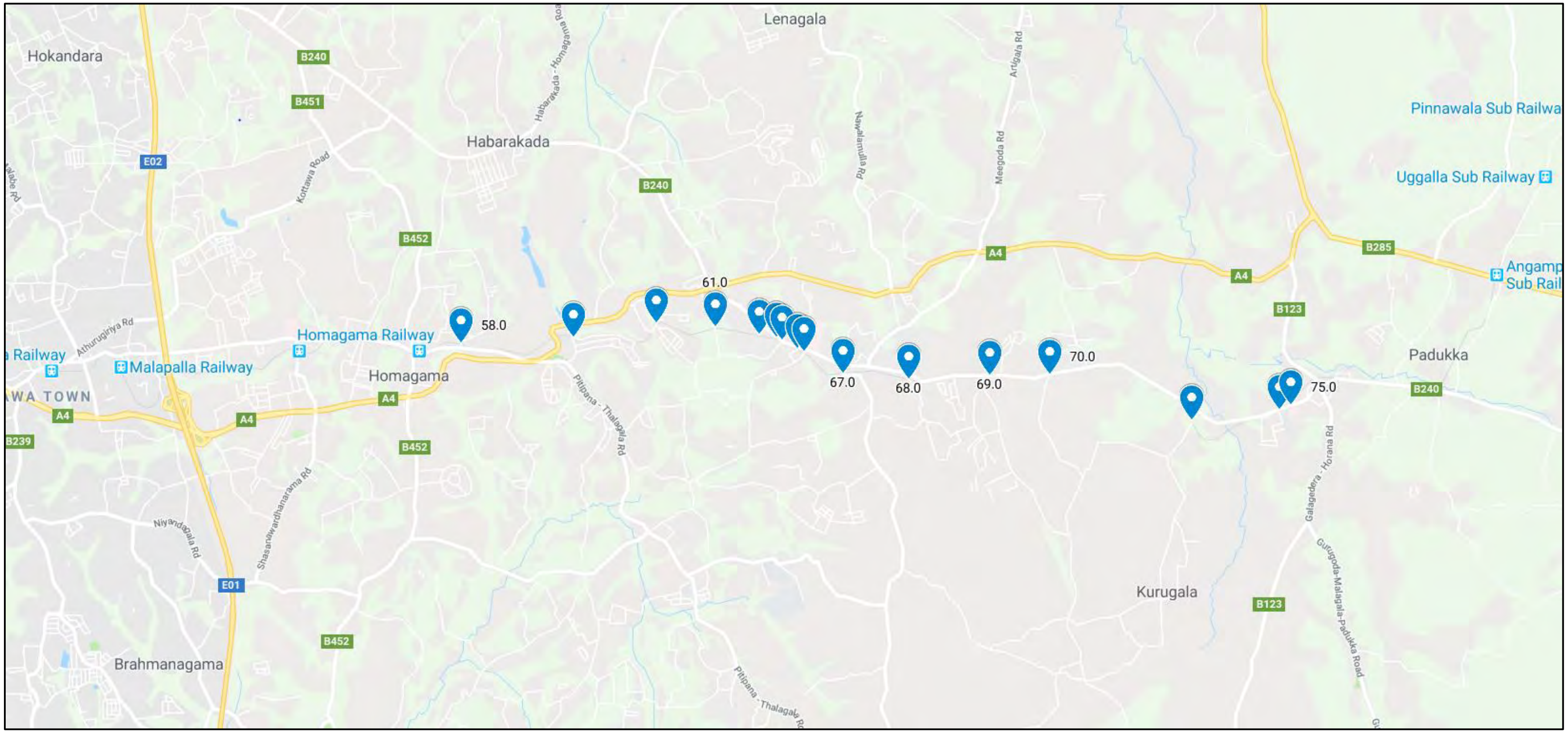


Figure 2- 30 KPIs for the KV Line for less PT Development Scenario

Figure 2- 31 Location 58: Wimana Road Level Crossing

Figure 2- 32 Location 59: Panagoda Station Road Level Crossing

Figure 2- 33 Location 60: Godagamagewatta Rd Level Crossing

Figure 2- 34 Location 61: Godagama Station Rd, level Crossing

Figure 2- 35 Location 63: Samadhi Mw

Figure 2- 36 Location 64: Palpolawatta Rd Level Crossing

Figure 2- 37 Location 65: Asiri Uyana Rd

Figure 2- 38 Location 66: Puwakwatta Rd Level Crossing

Figure 2- 39 Location 67: Meegoda Station

Figure 2- 40 Location 68: Udagewatte Rd

Figure 2- 41 Location 69: Madulawa Rd

Figure 2- 42 Location 70: Opathaella Rd

Figure 2- 43 Location 71: Kurugala Rd

Figure 2- 44 Location 74: Polwatta Rd C2

Figure 2- 45 Location 75: Padukka Road Level Crossing

2.2.1 Survey Methodology

Trained enumerators were assigned to each location in shifts to carry out the classified traffic counts. All were trained in adhering to basic safety practices in conducting road side traffic counts. Permission was sought from the relevant authorities prior to commencement of the surveys.

The survey form template used for the traffic counts is given in Figure 2-33.

Project Name:-
MANUAL CLASSIFIED COUNTS (MCC)

ROAD NAME:		DIRECTION	FROM	FORM NO:
LOCATION NO			TO	
DAY				
DATE				

Time	Motor Cycle	3wheeler	Car/saloon	Utility (Van/Jeep / Pickup)	Goods Vehicle				Mini Bus	Large Bus	Service Vehicle	Tractors	Bicycle	Cart	Total
					Light	Medium	Heavy	Multi-axle							
6.00-6.15															
6.15-6.30															
6.30-6.45															
6.45-7.00															
6.00 -7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 2- 46 Traffic survey form

2.2.2 Summary of the Results

A summary of the results of the surveys is presented in the section.

Table 2-7 Summary of Survey results

Location	Survey Duration	Total vehicle Flow	Average vehicle Flow	Peak vehicle Flow
Location 58 Wimana Rd Level Crossing	12 hrs	2939	244	621 (7.00-8.00) 287 (13.00-14.00)
Location 59 Panagoda Station Rd Level Crossing	12 hrs	3709	309	549 (7.00 - 8.00) 469 (18.00-17.00)
Location 60 Godagamagewatta Rd Level Crossing	4 hrs	538	134	207 (7.00-8.00)
Location 61 Godagama Station Rd, level Crossing	12 hrs	1336	111	233 (7.00- 8.00) 146 (17.00-18.00)
Location 62 Level Crossing C3	4 hrs	38	9	16 (7.00- 8.00)
Location 63 Samadhi Mw	16 hrs	37	2	11 (14.00-15.00)
Location 64 Palpolawatta Rd Level Crossing	12 hrs	1122	94	152 (7.00-8.00) 186 (17.00-18.00)
Location 65 Asiri Uyana Rd	4 hrs	109	27	41 (17.00-18.00)
Location 66 Puwakwatta Rd Level Crossing	12 hrs	6091	507	798 (7.00-8.00) 755 (17.00-18.00)
Location 67 Meegoda Station	12 hrs	5985	499	887 (7.00-8.00) 654 (17.00-18.00)
Location 68 Udagewatte Rd	12 hrs	1693	141	217 (7.00-8.00) 175 (17.00-18.00)
Location 69 Madulawa Rd	12 hrs	3850	321	468 (7.00-8.00) 468 (18.00-19.00)
Location 70 Opathaella Rd	4 hrs	559	139	74 (7.00-8.00) 67 (16.00-17.00)
Location 71 Kurugala Rd	12 hrs	2150	179	350 (7.00-8.00) 221 (17.00-18.00)
Location 74 Polwatta Rd C2	12 hrs	1534	128	279 (7.00-8.00) 206 (13.00-14.00)
Location 75 Padukka Road Level Crossing	12 hrs	8510	709	1270 (7.00-8.00) 870 (18.00-19.00)

2.2.3 Impact of Rail Crossing on the Road Network

The Traffic surveys at the rail crossing form the PFS study and FS study were combined and a total of 39 rail crossing locations were considered as shown in Figure 2-47

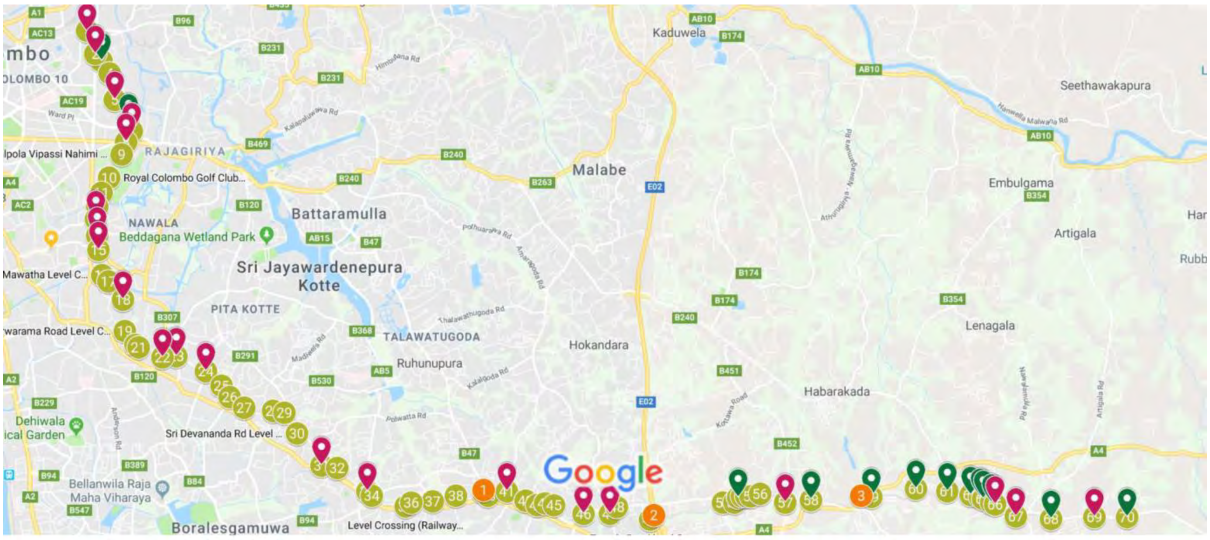


Figure 2- 47 Rail Crossing across KV line and Survey Locations

The impact at a rail crossing on the road network would be based on the frequency of the closure of the rail gate and the flow rate on the road. The gate closure will have a similar impact at a signalized intersection. The higher the frequency of the gate closure the time required to clear the queue generated will be less. Therefore if the queue generated from the previous gate closure does not clear during the green time, the accumulation of the queue will have impacts on the road network.

To analyze the impact the total ADT (PCU) was recorded from eth surveys. Although, The total ADT would be a good evaluation factor, the true impact is based on the Peak hour flow in the peak direction per lane, since some of the roads having high ADT might have more lane and the corresponding peak hour flow was estimated based on the peak hour factor of 0.1 and directional split of 65%. The peak hour flow was converted to a value of PCU per hour per Lane by considering the number of lanes at each of the road section. The Volume to Capacity ratio was calculated at each junction where a V/C ration greater than 1 showed that the junction is at capacity at the peak hour and would require grade separation. The crossing numbers 1 to 18 that are highlighted in red in the Figure 2-48 shows that from Maradana to Athurugiriya Road (near kottawa station) would require grade separation to minimize the impact on the road network.

Crossing number	Location	ADT (PCU) 2017	Peak Hour flow Peak Direction	Total Number lanes	PCU/L/p.D	Capacity per Lane	V/C	Elevated	Notes
1	Dematagoda Rd	33,834	2,199	2	2,199	1,400	1.57	✓	
2	Baseline rd	83,895	5,453	6	1,818	1,600	1.14	✓	
3	Sri Nigrodharama mw	12,544	815	2	815	1,200	0.68	✓	Expressway ramp
4	Leslie Rangala Mw	23,916	1,555	2	1,555	1,200	1.30	✓	
5	Ruhunukala Mw	8,168	531	2	531	1,200	0.44	✗	
6	Cotta Rd	45,772	2,975	4	1,488	1,200	1.24	✓	
7	Sri Jayawardenapura Mw	88,867	5,776	6	1,925	1,400	1.38	✓	
8	Muhandiram Rd	19,895	1,293	2	1,293	1,200	1.08	✓	
9	Kirimandala Mw	18,503	1,203	2	1,203	1,200	1.00	✓	
10	Narahenpita Nawala Rd	30,203	1,963	2	1,963	1,200	1.64	✓	
11	D.M. Colombage Mw	18,027	1,172	2	1,172	1,200	0.98	✓	
12	B120 at Nugegoda	49,701	3,231	4	1,615	1,200	1.35	✓	
13	Old Kespbewa	28,390	1,845	4	923	1,200	0.77	✓	320 m from B120
14	Mirihana Rd	25,004	1,625	4	813	1,200	0.68	✓	500m from Previous
15	Old Kottawa rd	26,233	1,705	2	1,705	1,200	1.42	✓	
16	Pamunuwa RD	17,378	1,130	2	1,130	1,000	1.13	✓	
17	Pannipitiya Malabe rd	14,519	944	2	944	1,000	0.94	✓	
18	Athurugiriya Rd	26,918	1,750	2	1,750	1,200	1.46	✓	
19	Kottawa Malabe Rd	8,049	523	2	523	1,200	0.44	✓	500 m from Previous
20	Galawila Rd	10,759	699	2	699	1,200	0.58	✗	
21	Athurugiriya Rd 2	20,141	1,309	2	1,309	1,200	1.09	✓	
22	Wimana Rd Level Crossing	3,468	225	2	225	800	0.28	✗	
23	Panagoda Station Rd Level Crossing	4,391	285	2	285	800	0.36	✗	
24	Godagamagewatta Rd Level Crossing	1,491	97	2	97	800	0.12	✗	
25	Godagama Station Rd, level Crossing	1,454	94	2	94	800	0.12	✗	
26	Level Crossing C3	117	8	2	8	800	0.01	✗	
27	Samadhi Mw	39	3	2	3	800	0.00	✗	
28	Palpolawatta Rd Level Crossing	1,364	89	2	89	800	0.11	✗	
29	Asiri Uyana Rd	319	21	2	21	800	0.03	✗	
30	Puwakwatta Rd Level Crossing	7,407	481	2	481	800	0.60	✗	
31	Meegoda Station	8,618	560	2	560	800	0.70	✗	
32	Udagewatte Rd	2,032	132	2	132	800	0.17	✗	
33	Madulawa Rd	5,482	356	2	356	800	0.45	✗	
34	Opathaella Rd	1,722	112	2	112	800	0.14	✗	
35	Kurugala Rd	2,546	165	2	165	800	0.21	✗	
36	Level Crossing C4	-	-	2	-	800	-	✗	
37	Polwatta Rd C1	-	-	2	-	800	-	✗	
38	Polwatta Rd C2	1,816	118	2	118	800	0.15	✗	
39	Padukka Road Level Crossing	11,165	726	2	726	1,200	0.60	✗	

Figure 2- 48 Volume to Capacity Ratio at Peak hours at the Rail Crossings

CHAPTER

3

Environmental Study

Chapter 3 Environmental Study

Chapter Summary

According to the regulations of the NEA this subproject is a “prescribed project” requiring a EIA. In terms of the ADB requirements the subproject could also be categorized as “Category A” which requires an EIA. This feasibility report was prepared to provide background environmental information, potential impacts that would arise due to project related activities, effective mitigatory measures to overcome impacts, an effective environmental management and a monitoring plan.

The existing railway line traverses through highly urban, urban and semi urban areas and runs through residential areas with man-made environments such as low income settlements, illegal housings, home gardens, paddy fields, marshy areas and tea and rubber plantations. The natural ecological resources in the project area are limited and the railroad does not run adjacent to an ecologically sensitive area. There are a considerable number of households and business entities by the roadside and there is likelihood that these would be affected by project related activities.

Construction related impacts include hydrological impacts, impact on water quality, noise and vibrations and emissions of dust and impact on considerable number of structures and employments. During the operation stage inadequate infrastructure facilities in the new settlement locations, impacts on social relations and economic activities, impacts of noise and vibration on neighboring communities are the main impacts. Several mitigation measures are proposed to be taken to minimise these issues.

The main mitigation measures during the construction stage include provision and maintenance of temporary culverts and openings, proper storage practices, proper sanitary facilities for workers and oil and grease traps, use of Tarpaulin or cover sheets, limiting operations which create high noise levels to hours that would cause least nuisance to public, minimisation of dust emissions, monitoring of noise levels during the construction phase, provision of PPEs to workers and erection of temporary barriers such as GI fences around the boundary of the construction sites. A tree planting program and settling of compensation based on a carefully designed resettlement and compensation package are also proposed. The main mitigatory measures proposed during the operational stage include proper handling and management of solid waste and wastewater from stations and depots, installation of adequate noise and vibration barriers and implementation of a proper EMP.

Inspite of the above mentioned environmental issues the overall impact of the investment program is expected to be positive. The program will serve as a tool for poverty alleviation, allowing poor people in the area to directly access the commercial capital of the country and helping them to engage in a number of social and economic activities. During the environmental examination consultations were held with stakeholders including local communities and local government agents.

The feasibility study includes a standard EMP. A contract package with specific EMPs will be prepared by the contractor. The implementation of the EMP will be the responsibility of the contractor.

It is concluded in the feasibility study that all the environmental impacts anticipated from the subproject can be mitigated with appropriate mitigatory measures and by following the proposed environmental management plan. In line with the requirements of the CEA of Sri Lanka a BIQ was submitted to the CEA which has issued the TOR for a detailed EIA to be submitted for environmental clearance. The preparation of the detailed EIA is presently underway.

3.1 Introduction

The Environmental aspects of the proposed subproject are discussed in this chapter.

3.1.1 Project Background and Justification

As a part of national transport strategy of the Government of Sri Lanka (GoSL), the Ministry of Transport and Civil Aviation (MOT&CA) intends to improve the railway system in the Western Province, including the Colombo Metropolitan Region (CMR). The existing population of the CMR is 29% of the total population of the country and growth rate is expected to be 1.5% annually until 2035 and hence, CMR is facing growing traffic congestion. Currently the railway system carries about 13% of the passenger transport within CMR and the existing connectivity is inadequate for passenger and freight traffic.

Therefore Government of Sri Lanka is undertaking extensive improvements in the railway sector. These improvements will bring significant economic, social and environment benefits to the region and the country. Since the railway is better for passenger movement on land compared to buses and more cost effective for transporting of passengers and bulk freight, railway in Sri Lanka needs to be modernized substantially and expand the share to facilitate efficient internal transport linkages. For this purpose four priority railway projects in CMR have been already identified under the ADB-funded TA for Colombo Suburban Railway Project, Maradana to Padukka (Kelani Valley Line), Colombo to Rambukkana (Main Line), Colombo to Kaluthara South (Coastal Line) and Ragama to Negombo (Puttalam Line). MOT&CA will implement the above sub projects through its Project Management Unit and through Department of Sri Lanka Railways (SLR).

Out of these priority railway projects, this feasibility report is prepared for the modernization of the Kelani Valley (KV) railway line from Maradana to Avissawella (60km). The main option for the modernization of the KV line is the upgrading of the single track as a double track parallel to the existing line from Maradana up to Padukka (35km) and to rehabilitate the existing single track 25km, from Padukka up to Avissawella. In addition it is proposed to have an elevated track from Maradana to Malapalla and the track will be at-grade from Malapalla to Avissawella.

3.1.2 Objectives of the Subproject

The existing Kelani Valley Line is single track and not very attractive to commuters due to low train speeds and frequencies. The average speed in Kelani Valley line is around 26 kmph. Long delays occur due to failures in the signaling system, and frequent failures also occur in the outdated communication system. The poor condition of the tracks also contributes to long delays. High loading level is another issue especially during peak hours. The existing single track railway line is originally of narrow gauge and was converted to broad gauge along the same trace at a later stage. Dematagoda, Nugegoda, Maharagama, Homagama, Padukka and Avissawella are the main urban and sub urban centers located along the Kelani Valley line and a large number of people travel to the Colombo metropolitan city along the existing corridor using other modes of land transport for daily activities. The Kelani Valley line extending from Maradana to Avissawella has a daily passenger volume of 14,600.

It has been identified that Padukka which is located 35 km from Maradana is the best location to attract passengers from the Horana Corridor. Hence, the proposed project is a top priority from Maradana to Padukka considering the present and future demands. Implementation of the Project will significantly benefit various sectors of the economy of Sri Lanka, and will allow the operation of additional trains. The construction of this Project will improve the level of services leading to increased services for passengers and additional capacity for freight traffic on this link.

3.1.3 Objectives of the Environmental Impact Assessment

According to the Environmental Guidelines of the Central Environmental Authority (CEA) for Road and Rail Development the proposed subproject is categorized as a prescribed project requiring environmental clearance through the Environmental Impact Assessment (EIA) process of the country. As required a Basic Information Questionnaire (BIQ) was filled and submitted to the CEA which has issued a Terms of Reference (TOR) for a detailed EIA.

The overall objective of an EIA report is the preparation of a comprehensive account of the current environmental condition of the project affected area of Kelani Valley line from Maradana to Avissawella. This study ensures that the Project is developed in an environmentally sound and sustainable manner ensuing that all adverse negative effects are mitigated to the extent possible and positive impacts are enhanced during project planning, construction and operational stages. Accordingly an EIA report will be submitted to facilitate their decision making.

The Environmental Impact Assessment Report (EIAR) is to provide: (i) information about the existing physical, biological and social environmental settings of the subproject influential area (ii)information on potential impacts during planning, construction and operational stages of the subproject, (iii)information on effective mitigation measures to minimize the subproject induced adverse impacts while enhancing the beneficial impacts and (iv)an effective environmental management and monitoring plan.

3.1.4 Extent, Scope of the Study and Personnel

The EIA study for the feasibility included field reconnaissance of the 60 km of railroad which was conducted during the months of March to August 2018 by a team of experts. The subproject is located in the Colombo district of the Western province of the country.

In the entire subproject area an environmental background study was done in an area comprising a 100 m corridor from the center line of the relevant rail road section for the existing trace with the following exceptions.

- for hydrology and drainage the extent is extended to the sub-catchment boundaries of the streams and other drainage paths crossing the road and to the downstream of the stream as far as the effects on the stream is exerted by the hydraulic structures such as bridges and culverts and the restrictions created by the road embankments in some segments;
- for air, water quality, noise and vibration the study area extends beyond the 100 m corridor depending on the intensity of the impacts;
- for biology, especially for fauna (including avifauna) which is a mobile entity the study area extends beyond 100m depending on the habitat locations and fauna migratory pattern which could be influenced by road rehabilitation activities;
- any socially sensitive entities such as schools, temples, hospitals beyond the 100 m corridor were considered based on the significance of the impact.

3.1.5 Applicable Laws, Regulations, Standards and Requirements Covering the Proposed Subproject

The applicable laws, regulations, standards and requirements covering the proposed subproject is given in Section 1.1 of the Requirement and Rule Book.

3.2 Description of the Existing Environment

The existing environment of the project is categorized as physical environment, biological environment and social environment and is described under these categories. Where possible the entire railroad stretch is grouped together and discussed, but where the environment is specific to a given section of the rail track it is discussed separately.

3.2.1 Physical Environment

3.2.1.1 Location

The Colombo district which is situated between the north latitude 6055'54.98" and east longitude 79050'52.01" is bordered in the north by the Kelaniganga, in the South by the Bolgoda ganga, Kalu ganga and the boundary of the Kalutara district, in the east by the Ratnapura and Kegalle districts and in the west by the coast line. The district administrative structure consists of the Divisional Secretariat Divisions of Colombo, Dehiwala, Ratmalana, Moratuwa, Kesbewa, Maharagama, Hanwella, Kolonnawa, Sri Jayewardenepura Kotte, Homagama, Padukka, Thimbirigasyaya, Kaduwela, 557 Grama Niladhari divisions and 808 villages.

Out of these the project area includes Colombo, Thimbirigasyaya, Maharagama, Sri Jayewardenepura Kotte, Homagama, Padukka and Sithawaka. It goes through 70 GN divisions.

3.2.1.2 Existing land use pattern along the trace

The landuses along the subproject areas are different in different subproject areas and are primarily dependent on whether the setting is urban, suburban or rural. The rail road runs through residential areas with man-made environments such as low income settlements, illegal housings, home gardens, paddy fields, marshy areas and tea and rubber plantations.

The existing railway line traverses through highly urban, urban, semi urban and rural agricultural environment from Maradana to Avissawella. The terrain of the road is flat, undulating and slightly hilly with a large number of bends as well as straight sections through variety of human-modified habitats with high, mid and low density populated areas. Based on the land use pattern 4 different areas can be identified along the stretch as Maradana to Nugegoda, Nugegoda to Homagama, Homagama to Padukka and Padukka to Avissawella.

A detailed description of the landuses for each subproject is given below.

Maradana to Nugegoda

The section from Maradana to Nugegoda is highly urbanised with built up environment. A large extent of small, medium and large scale ribbon type developed commercial and business structures, industries, housing complexes, residences, stores, service centers etc, are located just outside the railway reservation. In addition high density clusters of above structures are located in the vicinity of the entire railroad section.

High density shanties developed in a ribbon type manner with permanent and temporary structures are located within the railway reservation. Most of these shanties are constructed close to the railway line beside the road in a vulnerable way and most are temporary constructions built with wood, planks and asbestos.

Nugegoda to Homagama

The section from Nugegoda up to Kottawa can be categorized as an urban environment with all types of commercial, public and residential structures beside the railway line and reservation. A large number of low income families with densely arranged shanties are located around Pangiriwaththa and Udahamulla railway stations while some scattered and low density shanties are located in different locations from Nugegoda up to Kottawa. Some locations of the ROW are restricted to the single rail line due to heavy encroachment around Pangiriwaththa and Udahamulla. The population density of the shanties is very high. The rail line just after the Nugegoda station runs about 1km parallel to the old Kesbewa road, through the narrow excavated trench which is located below the ground level. Few shanties are also located on the left hand side (LHS) of the line with limited reservation.

In general local roads are located on one side in parallel or beside the railway reservation in most of the sections. Ribbon type developed business structures, service centers, workshops, public places and residences are located beside the local roads close to the town centers of the road as Nugegoda, Maharagama, Pannipitiya, Kottawa and Homagama. Ribbon type developed residences with small to medium size home gardens with several mixed cultivations are located in between the town centers.

Homagama to Padukka

The land use pattern besides the road includes a semi urban environment with agro ecological pattern in a number of locations. A large number of residences with small to large scale home gardens, business premises, industries, coconut, rubber and mix cultivations, large extent of paddy fields, vegetable plots and marshy areas are located beside the road as well as in the vicinity. The section after the Homagama station consists of a large extent of land belonging to the Sri Lanka Army up to Panagoda station.

Few scattered encroached shanties can be seen at different locations of the road. At some locations fences have been erected within the reservation area to expand the private lands which are located beside the rail reservation. The population density in the area is much less compared to the previous two sections.

After the Godagama station the railway line runs on the LHS and in parallel to the Godagama – Padukka road while at some locations it runs adjacent to the rail line without appropriate boundaries. Ribbon type developed residences, government and private sector buildings and business premises are located in between the road and rail road. Meepe and Padukka are medium size townships located along the rail line and at some sections the surrounding environment appears to be consisting of rural agricultural landuse. There are a number of public sensitive sites located close to the rail road.

Padukka to Avissawella

This section of the railroad runs through a rural residential and agricultural environment mainly up to Kosgama. A large extent of rubber cultivations, home gardens, coconut and mix cultivations, paddy fields, vegetable plots, pineapple cultivations as well as small scale tea estates are also located beside and in the vicinity of road.

The section of the road from Kosgama to Avissawella is primarily of rural agricultural environment and changes to semi urban and urban around Avissawella. Built up areas with considerable inhabitants are found besides the two ends of the rail road at Padukka and Avissawella. Low density residences are located beside the road with big home gardens at the mid-section of the road. The population density of the area up to Kosgama is comparatively low compared to other sections of the road as well as the end section of Avissawella.

After the Padukka railway station, the rail road runs parallel to the Ingiriya road up to some extent. The rail road also runs parallel to the Colombo- Rathnapura road from Kosgama up to Avissawella and a considerable length adjacent to LHS of the road without boundaries.

A number of irrigation and drainage paths are located across the road at numerous locations.

There are several public sensitive locations located in this stretch.

3.2.1.3 Climate

Seasonal variation of temperature in Sri Lanka is not significant as it is surrounded by the ocean situated close to the equator. The annual mean temperature varies from 150 C (in highland) to 29 0C in the low land. The mean annual temperature in the Colombo district is 27.70 C.

Sri Lanka, being a tropical island, experiences two monsoons and two intermediate periods during a year. These four seasons are characterized by the patterns of wind and rainfall. The two monsoons are Southwest and Northeast which prevail from May to September and December to February respectively. March to February being the first intermediate period is called the first inter-monsoon and October and November are the second inter-monsoon months. During the inter-monsoons the regional pressure systems are not important and hence, generally weak winds prevail.

The rain is confined to the southwestern parts during the southwest monsoon. Apart from the winds the rainfall pattern is also very much related to the topographical features significantly. The southwest monsoon winds are mostly warm and moist and hence, they bring rain to the southwestern/ western parts of the country where the subprojects are located. The heavy rainfalls during this season are normally concentrated to the windward slopes of the central hills and interior parts of Colombo district.

However, at the beginning of the season, namely in May and in the first week of June, rain producing systems, such as low pressure systems are more active over the region of Sri Lanka and produce heavy rain and the entire western province is vulnerable to floods and landslides during this period. Thus for subprojects in the western province this is a period to avoid construction activities.

As the individual convective clouds do not extend for a large horizontal length, usually, this type of flash floods is experienced in a limited area unless there is no supporting mechanism like the presence of disturbance. Yet, flash flood events are becoming more frequent due to less percolation caused by urbanization. Since the district is located on the threshold of the sea coast, both monsoon and convectional rains are experienced. Rain is received throughout the year in the Colombo district amounting to about 2500 mm. per annum. This exceeds the normal rainfall of 1905 mm. received in the wet zone. The highest rainfall is recorded in the month of May, but this occurs sometimes in October and November as a result of atmospheric depressions and cyclones. During the north east monsoon the lowest rainfall is received from December to February. Although these fluctuations occur with the occurrence or otherwise of rain, a special characteristic is the absence of a distinct seasonal change, the reason being that some volume of rain is received in the district during every month.

3.2.1.4 Air and Noise

a. Air

Ambient Air Quality of the Colombo, where the entire project is to be implemented is within the National Standards with respect to Carbon Monoxide (CO), Sulphur Dioxide (SO2), Particulate Matter (PM) and Nitrogen Dioxide (NO2) according to the sources of Environmental Atlas of Sri Lanka, Central Environment Authority (CEA). The latest ambient air quality data of the project area is not available with any of the relevant institutes or Authorities.

b. Noise

The proposed railroad traverses through urban, semi urban, rural, residential and agricultural areas. However, alongside the rail road in most parts the road network runs close to and in parallel to the rail road. In some instances the road network appears on both sides of the road while in certain others it is only on one side of the road and a considerable number of vehicles pass this road particularly during the day time particularly from Maradana to Homagama. Therefore, the noise levels are high during rush hours.

3.2.1.5 Geology, Topography and Soils

a. Topography

The project area is located in the western province of Sri Lanka and topography is generally on a flat and rolling terrain. The subproject is on a flat terrain.

b. Geology and Soils

The project area falls within the Highland Complex and Wanni complex which is characterized by thick sequences of gneisses, dominated by hard charnockitic gneisses interbeded with softer peliticpara gneisses and calc gneiss. The major rock types found within the rail line alignment are Charnockitic Gneisses, and Garnetiferrous Quartzo feldspathic Gneisses, Garnet Silimanitebiotitre Gniess and Quartzo Feldspathic Gneiss. These formations exhibit a high metamorphic gneissic foliation and local stretching foliation, which indicate the intense flattening associated with the earliest stage of deformation. These rocks are overlain by residual soils and alluvium. Lateritic soil which is derived from in-situ weathering of the base crystalline rocks is quite well developed, especially towards the south end of road alignment.

The residual soils encountered overlaying bedrock represents the complete range of weathering from the parent bedrock to completely decomposed clays and lateritic soils. Different zones in the weathering profile can be given as:

Zone A-1. Soil overburden, comprising structureless sands, silts and clays with or without gravel sizes, are classified either as lateritic soils. Residual soils, which have not been transported, termed as lateritic soils, have been derived by weathering in place and are typically red and yellowish brown in color.

Zone A-2. Completely decomposed rock (CDS) is typically encountered beneath Zone-A. CDS has the faint residual structure of the parent rock mass, with slight banding of colors from the foliation of the parent rock and darker lineations which are relics of the jointing structure.

Zone B. Highly weathered rock (HWR) is classified as the upper weathered horizon of the parent rock, comprising blocks of a very weak rock which is highly jointed.

Zone C. Moderately weathered rock consisting of core stones in a matrix of residual material where the core stones occupy 50 to 90 percent of the volume. These are rectangular and have interlocking structure.

Zone D. Slightly weathered rock where more than 90% of the material is rock. Some residual material occurs along discontinuities which are considerably discolored.

Zone E. Unweathered rock does not show signs of weathering along joints.

While the entire stretch is primarily man made ground special geological features are observed at some locations. These include:

- From Narahenpita to Nugegoda lateritic residual soils
- From Nugegoda to Pangiriwatte lateritic residual soils and rock outcrops
- From Pangiriwatta to Malapalla lateritic residual soils
- From Malapalla to Homagama Hospital flat bottom valley
- From Homagama Hospital to Homagama rock outfalls and lateritic residual soils
- From Homagama to Panagoda lateritic residual soils
- From Panagoda to Padukka flat bottom valleys and firm grounds contain Lateritic residual soils

3.2.1.6 Hydrology

<u>Drainage Aspects</u>

Types and Locations of Hydraulic Structures

Mainly four types of cross flow hydraulic structures were encountered during the walkthrough field reconnaissance. These structures are;

- Major Bridges (Bridges)
- Minor Bridges
- Culverts
- Cross Flow Paths

Drainage across the KV Rail Track takes place through hydraulic structures such as major bridges, minor bridges, culverts and cross flow paths (minor flow paths). The KV Trail track traverses along Colombo Catchment, Bolgoda basin and Kelani basin. These river basins are depicted in Figure 3-2. Overall hydraulic structure locations are given in Figures 3-1a and 3-1b. Detailed maps showing the locations of hydraulic structures and major catchment areas are given in Figure 3-3 to Figure 3-8.

Figure 3-1a Typical Drainage Structures

Typical Inlet Canal to a Culvert

A Culvert Covered with Weed

An Open Culvert

A Drain Parallel to the Railway

A Typical Stream Inlet to a Culvert

A Bridge Over an Urban Canal

Figure 3-1b Typical Drainage Structures

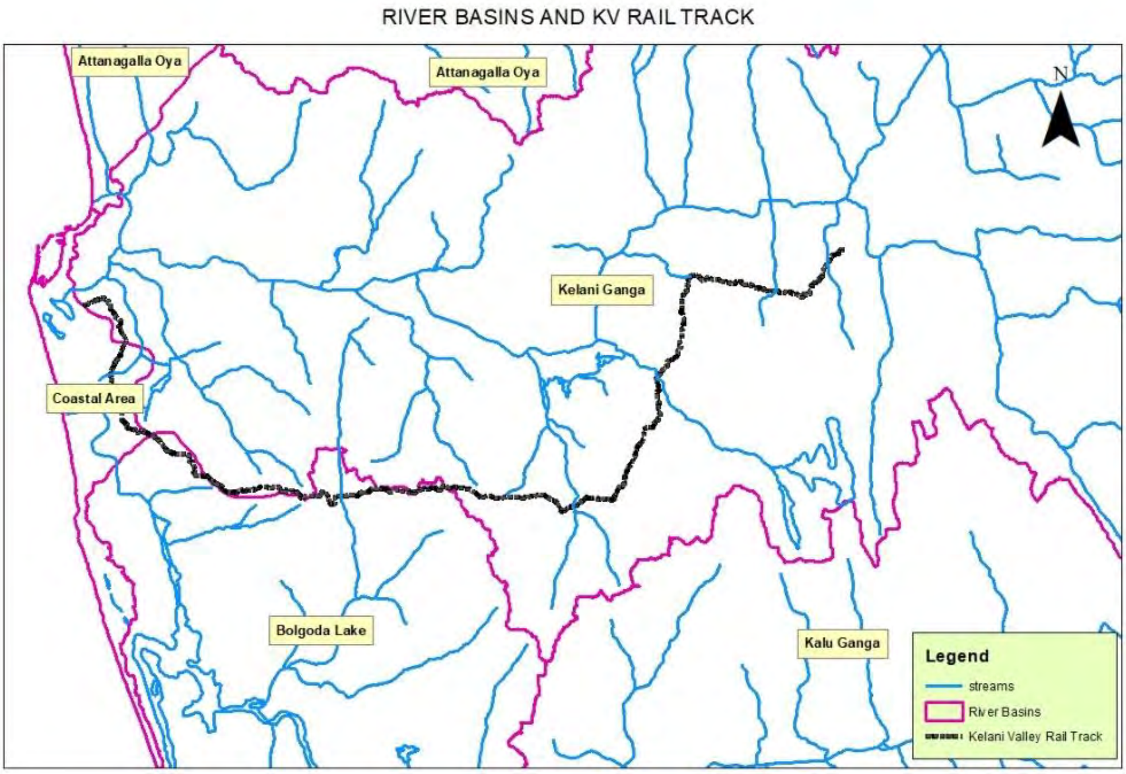


Figure 3-2 River Basins and KV Rail Track

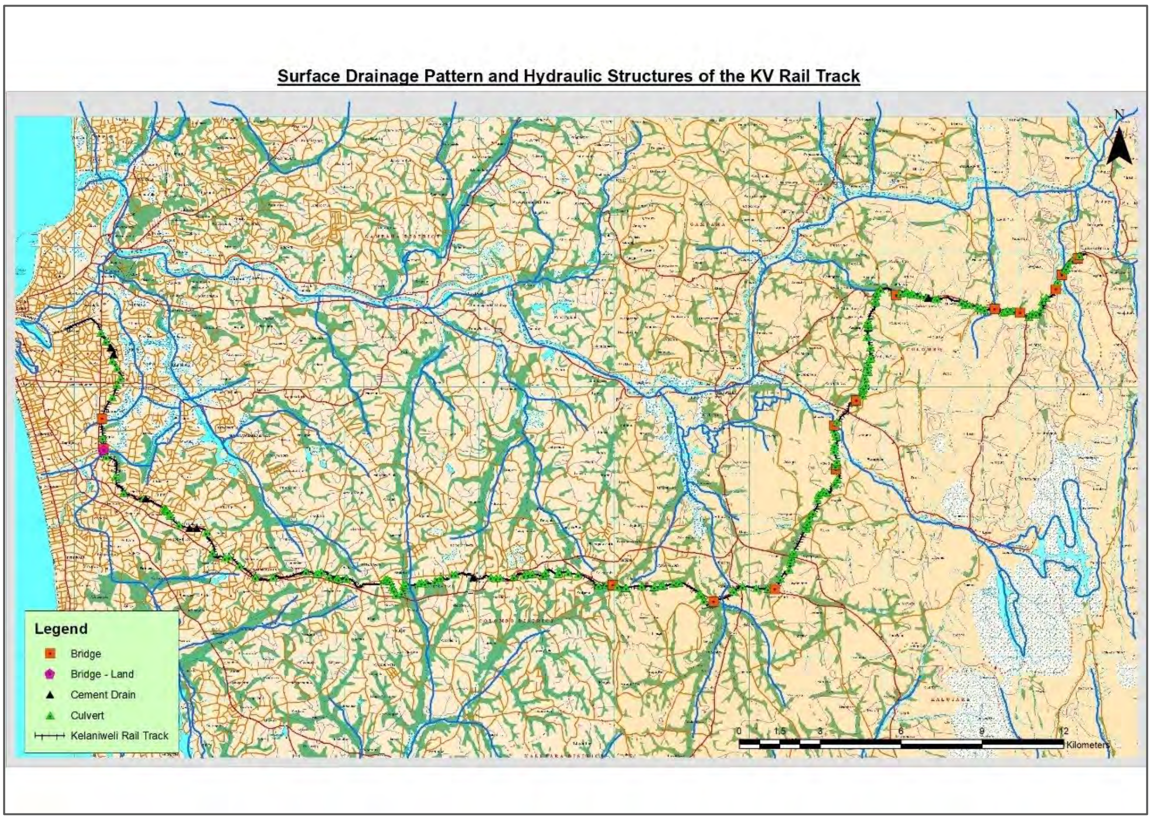


Figure 3-3 Overall Hydraulic Structure Locations -KV Rail Track

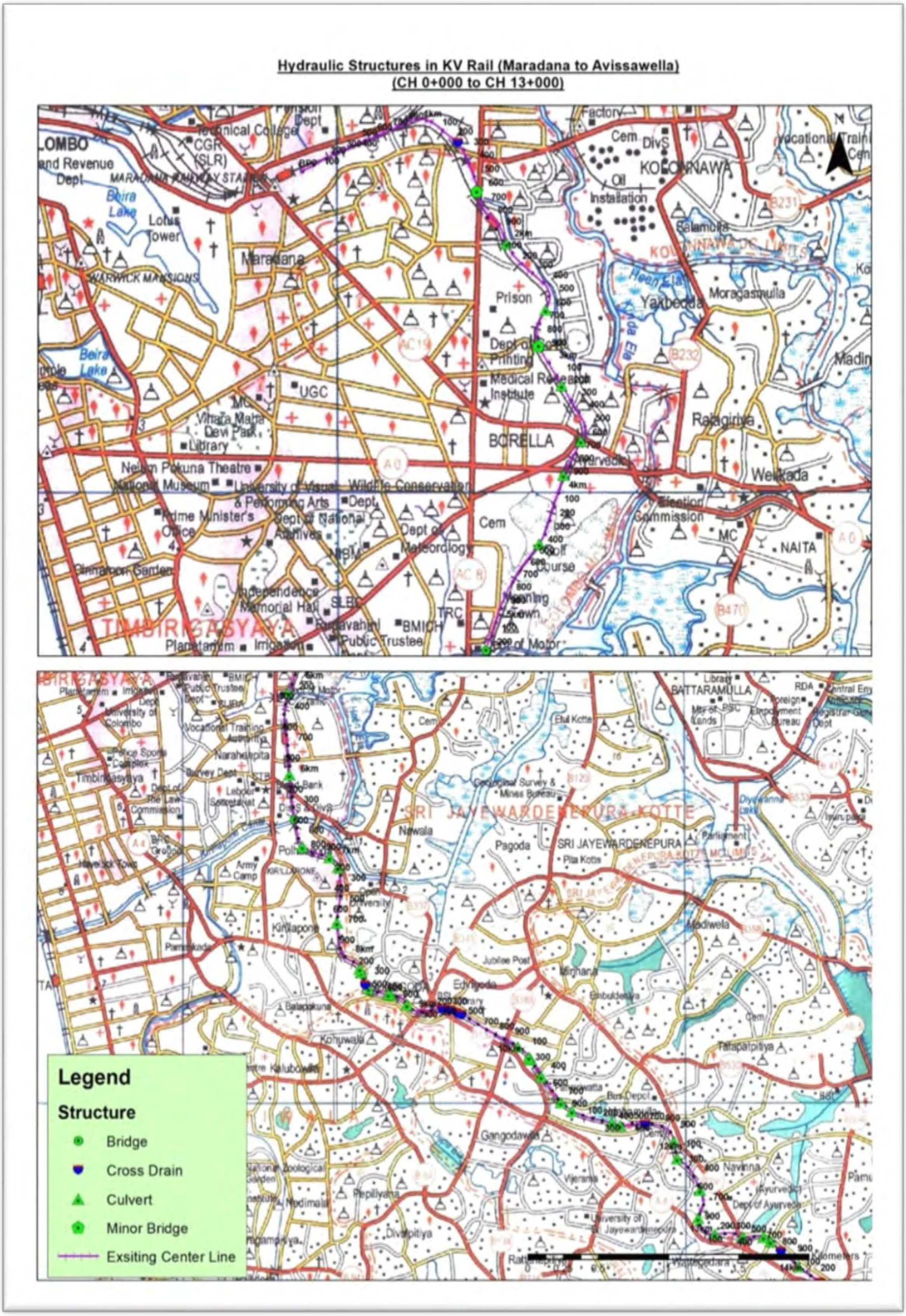


Figure 3-4 Hydraulic Structure Location Map from 0+000km to 13+000km

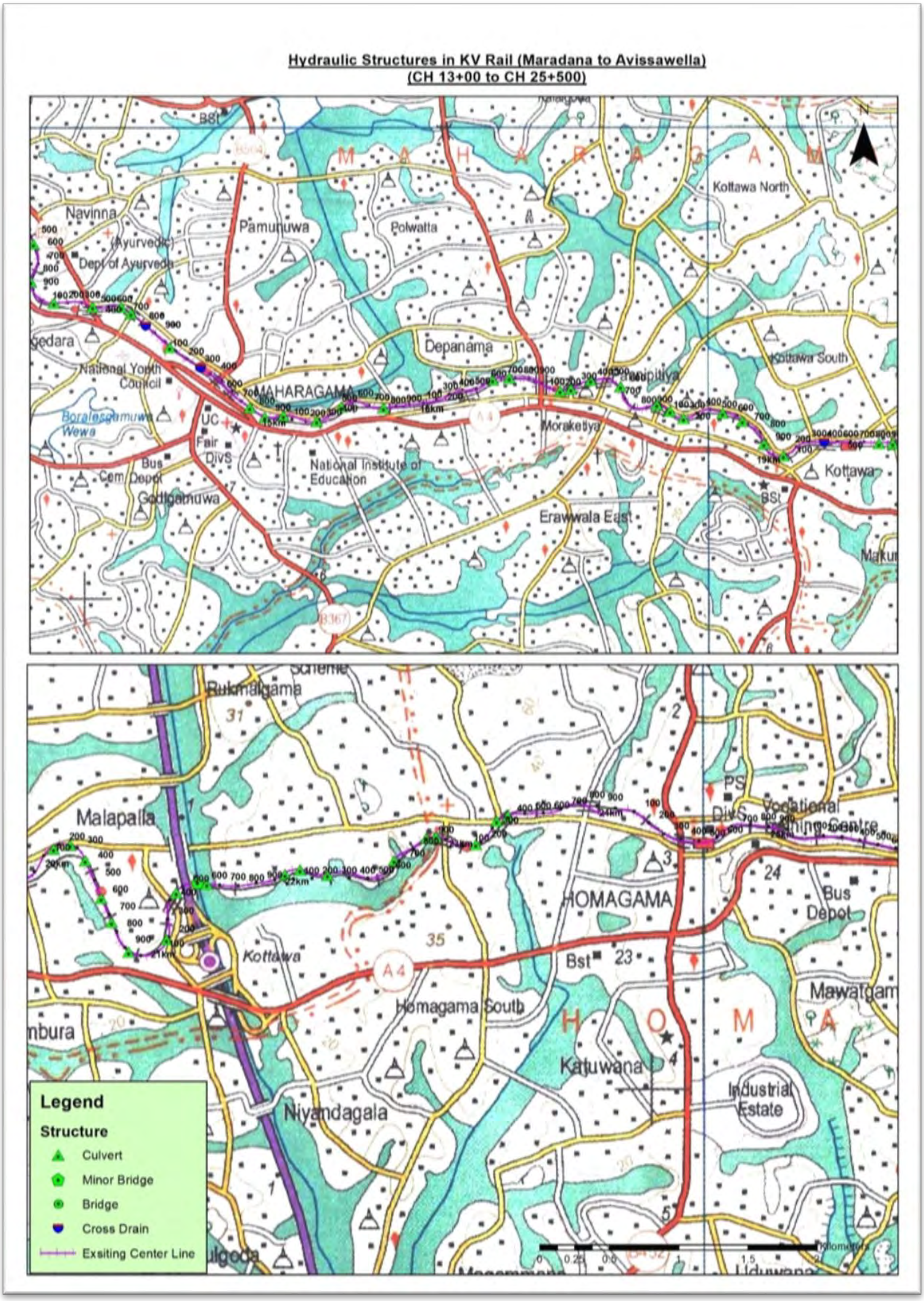


Figure 3-5 Hydraulic Structure Location Map from 13+000km to 25+500km

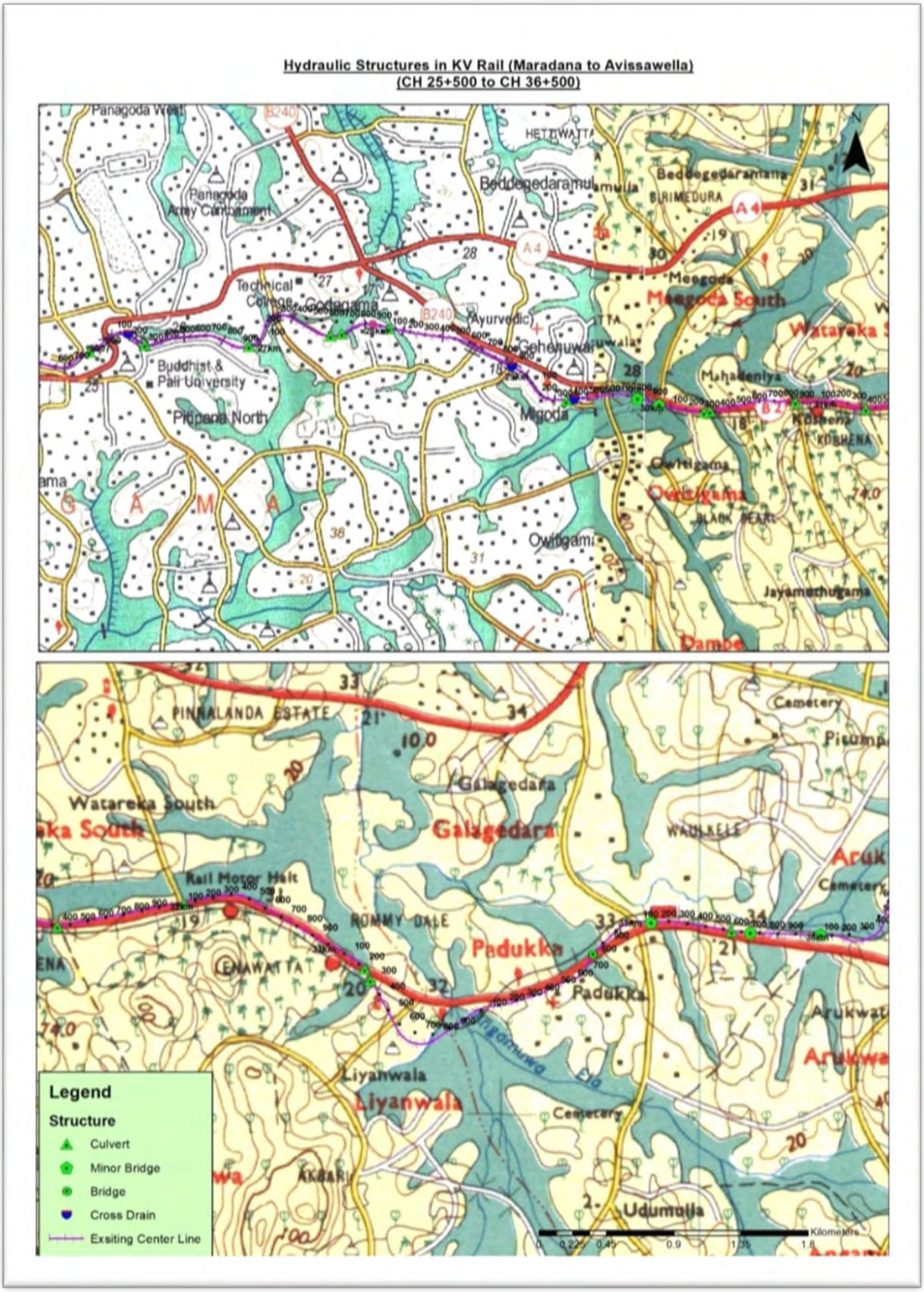


Figure 3-6 Hydraulic Structure Location Map from 25+500km to 36+500km

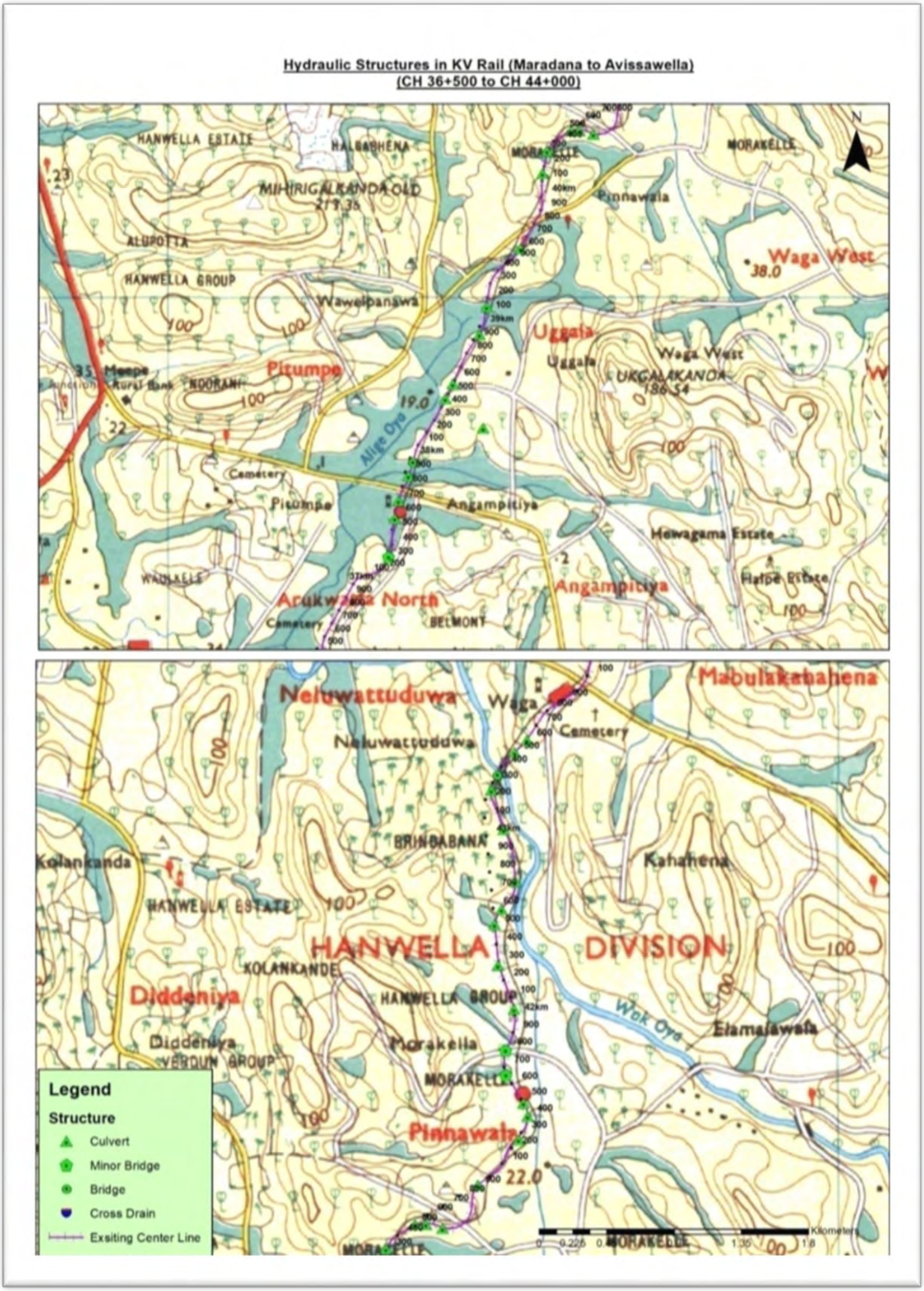


Figure 3-7 Hydraulic Structure Location Map from 36+500km to 44+000km

Hydraulic Structures in KV Rail (Maradana to Avissawella)
(CH 53+400 to CH 59+185)

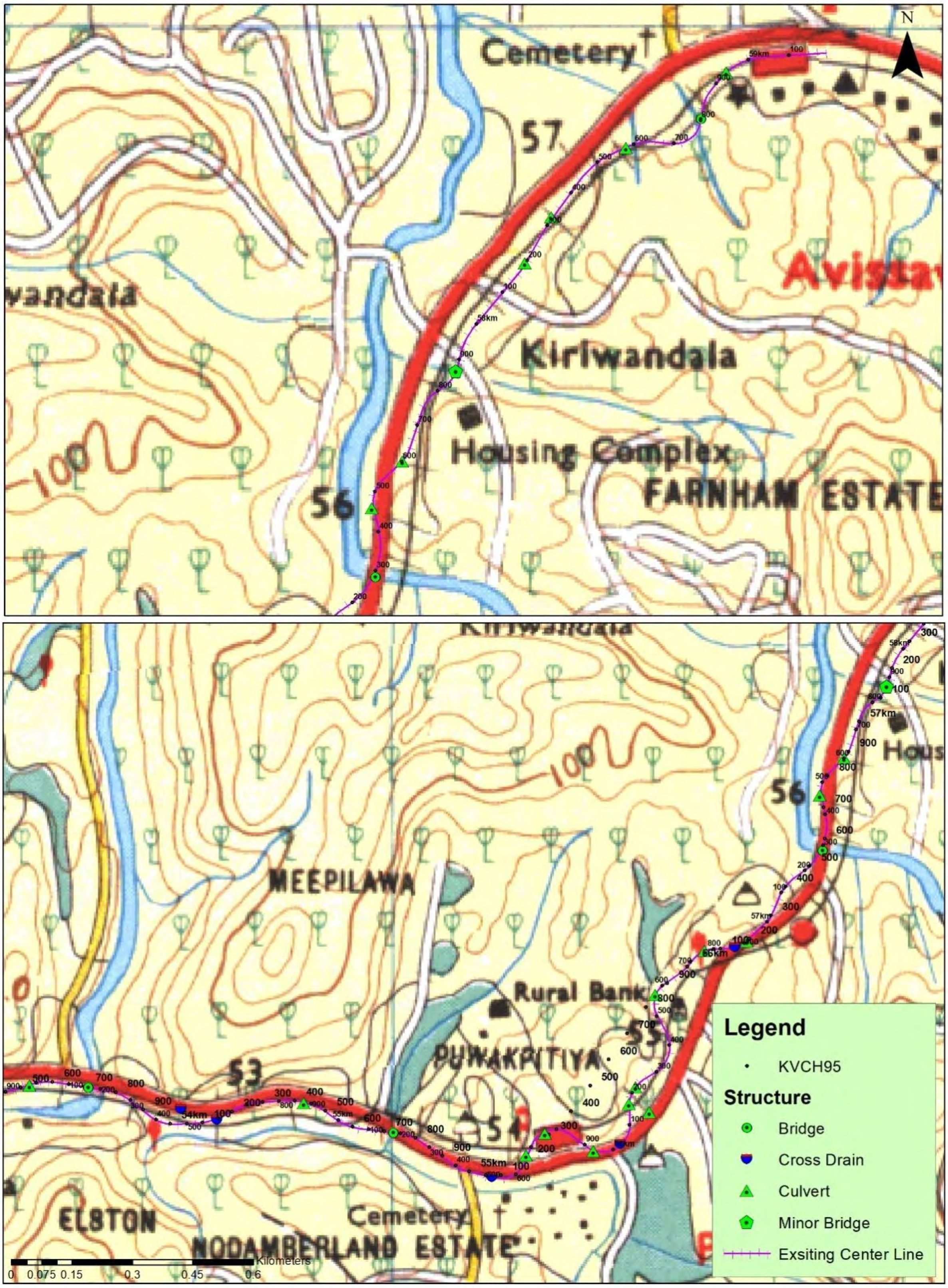


Figure 3-8 Hydraulic Structure Location Map from 44+000km to 53+400km

Major Waterways Across KV Rail Track

The Table 3-1 shows the major waterways across the KV Rail Track.

Table 3-1 Major Waterways across KV Rail Track

Name of The Waterway	Approximate Crossing Chainage	Flow Direction
Torrington Canal	5+220km	Left to Right
Kirulapona Canal	6+420km	Left to Right
Malapalla Ela	21+550km	Left to Right
Angomuwa Ela	34+200km	Right to Left
Arukwatte Oya	36+650km	Right to Left
Branch of Alige Oya	38+175km	Right to Left
Wak Oya	43+800km	Right to Left
Branch of Kelani River	54+150km	Right to Left
Branch of Kelani River	57+300km	Right to Left

KV Rail Track Urban Drainage System within Colombo

Apart from the open canals, streams and drains there are many underground drains and manholes in the Colombo Municipal Council (CMC) area. Although a detailed account of all these drains is not available, the locations of these underground drains are available with the Drainage Division of the Colombo Municipal Council. Locations of Manholes and underground drains are given in Figure 3-9 and Figure 3-10.

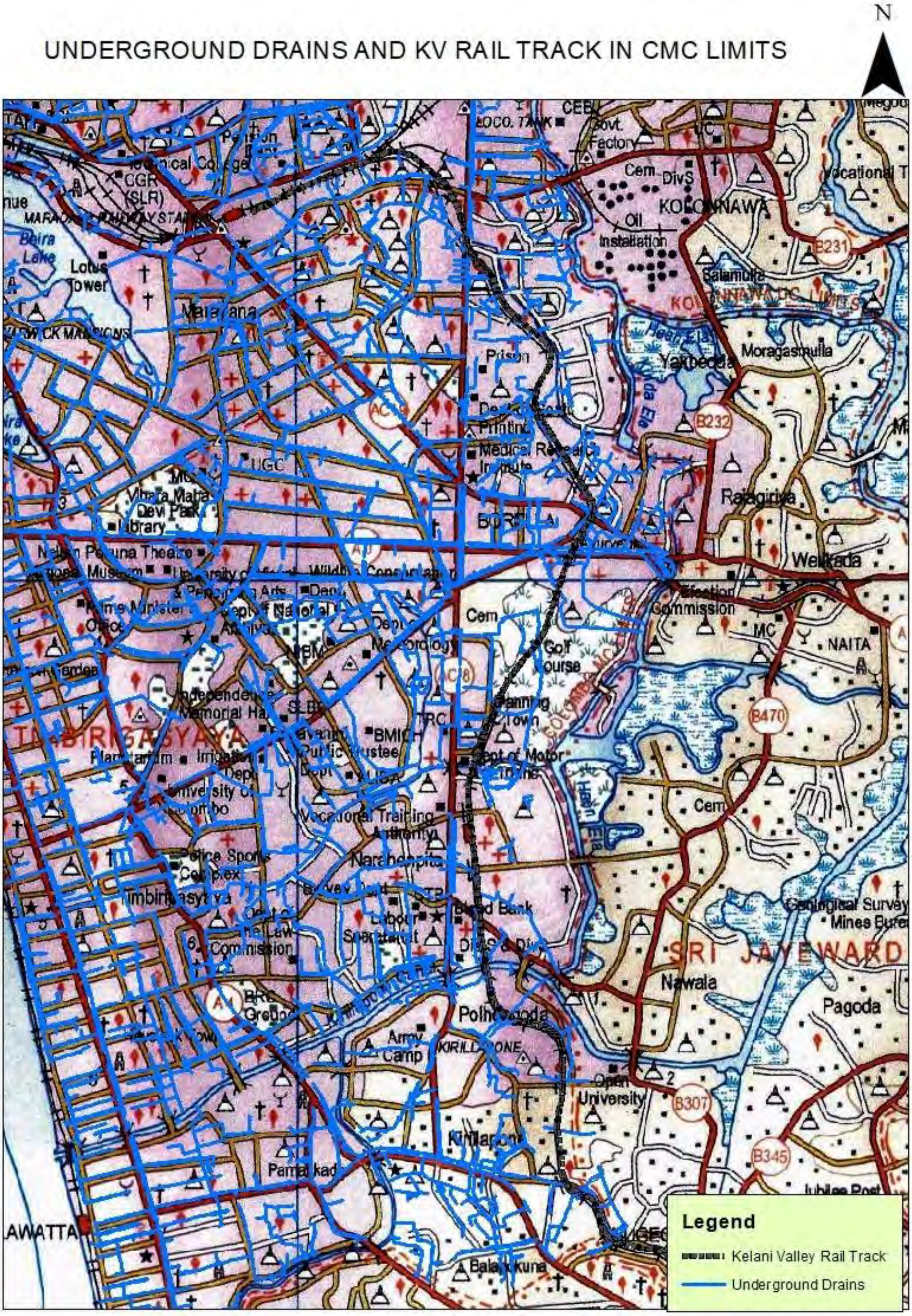


Figure 3-9 CMC Underground Drains and KV Rail Track

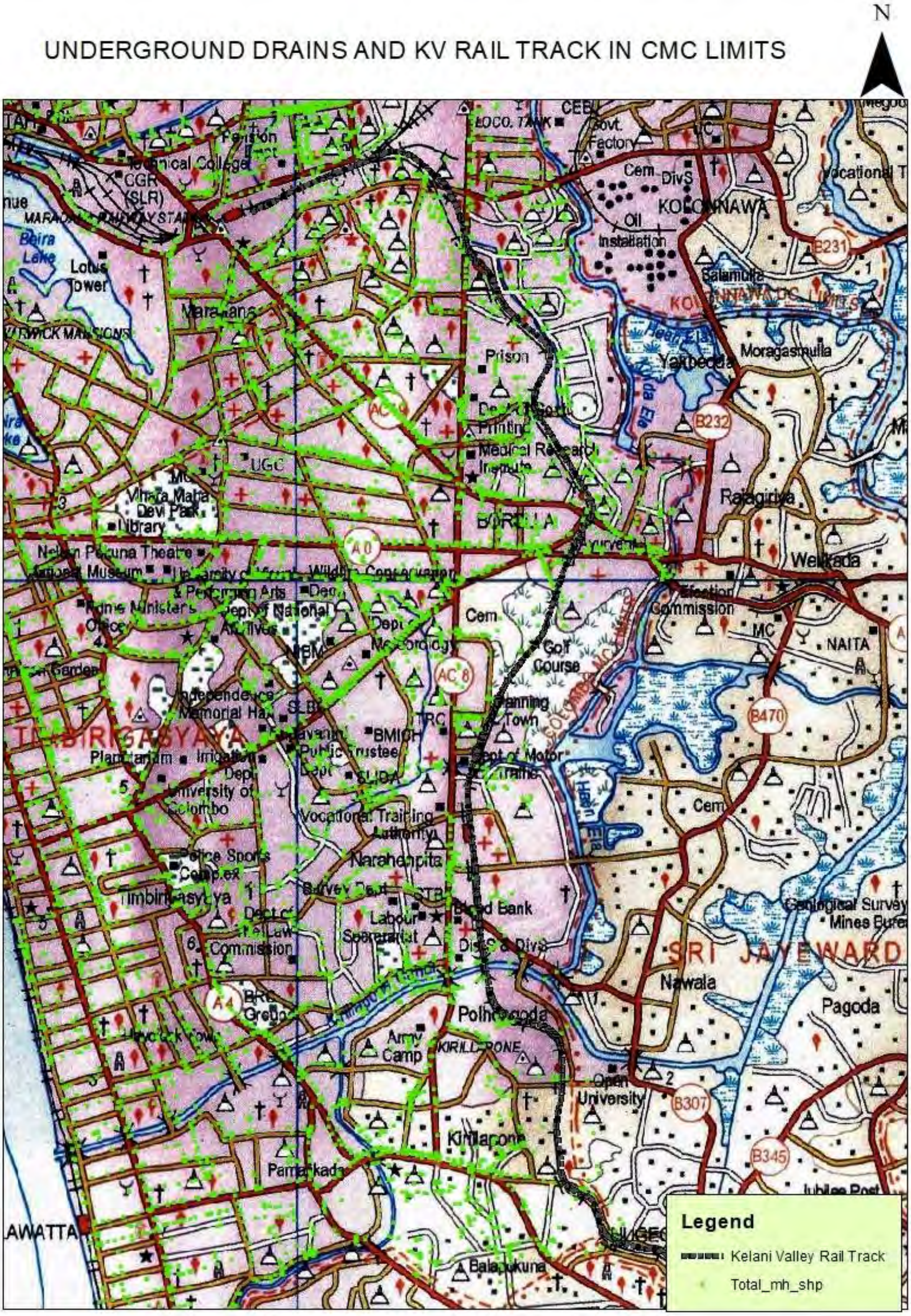


Figure 3-10 CMC Manholes and KV Rail Track

Longitudinal Drainage of the Rail Track

As the rail tract is mostly laid on an embankment need for side drains for longitudinal drainage is minimal. The drain like space created probably by taking soil to form the embankment serves as a side drain. There are also some sporadic earth side drains in cuts and flat terrain. Very limited number of concrete side drains exists in stations (e.g. Maharagama and Nugegoda).

3.2.1.7 Water Quality

A detailed investigation is underway. Baseline data is been collected on the quality of surface and ground water.

3.2.2 Biological Environment

The proposed subproject falls within the Western province of Sri Lanka. The railroad traverses through either highly urbanized semi urban or agricultural areas and hence can be considered as already disturbed areas. As a result even at present the natural ecological resources in the project area are limited. From initial investigations it can be seen that the railroad does not run adjacent to an ecologically sensitive area.

A detailed investigation of the species diversity of the Project Impact Area (species of flora and fauna in the sub project area) will be carried out to estimate of the number and types of trees directly affected by the subproject.

3.2.2.1 Existing habitats

The terrestrial and aquatic habitats beside the KV line and surrounding area from Maradana up to Kottawa are man-made and the fauna and flora comprise mainly of common species that are found in association with man modified habitats. The section from Kottawa up to Avissawella includes both manmade as well as semi natural habitats with partially disturbed rural agricultural environment with diverse species. Several water canals located in the initial section are highly polluted and aquatic species cannot survive due to contamination of water with waste materials and discharges of wastewater.

Terrestrial and aquatic habitats located along the trace and surrounding area

Seven main habitat types can be identified within the project affected area including 6 different terrestrial habitats and two aquatic habitats as follows.

- Home Gardens and Residences
- Business and Commercial areas
- Road reservations
- Marsh lands
- Paddy fields
- Cultivations
- Streams
- Canals and Drainage paths

1. Home Gardens and Residences

Different types of home gardens and residences are observed beside the road trace from built up areas upto rural agricultural areas beside the road. A large number of densely arranged shanties are located in the initial section within the existing ROW of the road without home gardens. Residences with small home gardens are located within the township while medium and considerably large home gardens are located towards the end section. All types of home gardens in the built up areas within the township and other areas are included under this sub topic. Different species of plants like fruits, vegetables, flowers and ornamental plants are intensively cultivated in home gardens. Common home garden species such as jackfruit (Artocarpushetarophyllus), coconut (Cocosnucifera), arecanut (Areca catechu), breadfruit (Artocarpusincisus), mangoes (Mangiferaindica), banana (Musa x paradisiaca) amberella (Spondisdulci), papaw (Carica papaya), guava (Psidium guava), pini-jambu (Syzygiumsamarangense), weralu (Elaeocarpusserratus), rambutan (Nepheliumlappaceum) etc., are commonly found in home garden habitats. Typical vegetation is shown in Figure 3-11.

Figure 3-11 Different types of home gardens and residences

2. Business and Commercial areas

The project affected area consists mainly of ribbon type developed business premises, small, medium and large scale industries, ware houses, container yards and other service providing places. A considerable land area beside the railway line, local road as well as at the vicinity especially in the town area is covered with business and commercial structures as well as some government buildings such as schools. In addition religious places and religious structures are also common in this area. Cultivated flora including economically important species, fruits and number of species belonging to ornamental category and shading species are found in the above habitat with some species of big trees {Ficusbenghalensis (Mahanuga), Ficusreligiosa (Bo), Terminaliacatappa (Kottamba), Mesuaferrea (Na), Swieteniamahagoni (Mahogani), Artocarpusheterophyllus (Kos), Peltophorumpterocarpum (Kahamara), Albiziaodoratissima (Suriyamara), Mangiferaindica (Amba), Filiciumdecipiens (Pehimbiya), Tabebuiarosea (Tabebuia)} belonging to different species. Typical vegetation is shown in Figure 3-12.

Figure 3-12 Business and commercial environment

3. Road Reservations

Road side trees and vegetation located beside the railway line and beside the local road network are considered as road reservations. Majority of big trees are located beside the reservation of railway line specially around main stations and beside local road network. Leucaenaleucocephala (Ipil-ipil), Peltophorumpterocarpum (Kahamara), Terminaliacatappa (Kottamba), Macarangapeltata (Kanda), Dichrostachyscinerea (Andara), Samaneasaman (Para-mara), Swieteniamahagoni (Mahogani), Artocarpusheterophyllus (Kos), Mesuaferrea (Na), Terminaliaarjuna (Kumbuk), Ficusbenghalensis (Mahanuga), Ficusracemosa (Attikka), Ficusreligiosa (Bo), Tectonagrandis (Thekka), Cassia auriculata (Ranawara), Cassia fistula (Ehala), Tabebuiarosea (Tabebuia) etc, are the main species located within the road reservation. Panicum a type of invasive grass species is commonly observed close to the railway track along the trace. Typical vegetation is shown in Figure 3-13.

Figure 3-13 Road reservations with some trees

4. Marsh Lands

Both small patches as well as considerably large marsh lands are located beside the road as well as surrounding area. Most of the marshy area is surrounded by rapidly developing urban and semi urban environments. Marshes provide an important service as flood retention areas; provide habitats for different species of aquatic and semi aquatic flora and fauna as well act as protect surrounding inhabited areas. Marshes are a significant halt for migratory birds and provide essential roosting sites for resident water birds as well as migratory birds during the migrant season. In addition numbers of invertebrate species including butterflies and dragonflies as well as different species of fish inhabit the marshes. Utricularia reticulate (Ketala), Eichhoranicrassipes (Japan-jabara), Salviniamolesta (Salvinia), Lagenandra sp., Eleocharis sp., Cyperus sp. Frimbristylis sp., Typhaangustifolia (Hampu-pan), Annonaglabra (Wel-attha), Colocasiaesculenta (Gahala), Dilleniasuffruticosa (Diya-para), Eriocaulontruncatum (Kokmota) etc, are common species inhabiting the marsh land. Typical vegetation is shown in Figure 3-14.

Figure 3-14 Marsh lands

5. Paddy fields

Large extents of cultivated, non-cultivated and abandoned paddy fields are located beside the road as well as at the vicinity of road. Most of the paddy fields are serviced with an irrigation canal network. Majority of the paddy fields around urban and sub urban sections are abandoned and in many locations paddy fields are converted to vegetable plots. Paddy fields located beside the road after Homagama are functional and a large extent of cultivated paddy fields is located from Padukka up to the end section. Paddy lands are cultivated only with Paddy (Oryza sativa). In addition big trees can be seen in some locations of the paddy fields. Further different species of weeds, herbs and shrubs are also common in Paddy lands. Typical vegetation is shown in Figure 3-15.

Figure 3-15 Paddy fields

6. Cultivations

Both monoculture cultivations as well as mix cultivations are common beside the road. Coconut, rubber and pineapple cultivations were mainly observed as monoculture cultivations and at some locations a small extent of tea cultivations are also observed. Rubber plantations are mainly observed as monoculture agriculture practices in large-scale as a cash crop. In addition mixed cultivations are also widely available beside the trace and in the vicinity. Coconut, Pineapple, Cinnamon, different species of fruits, ornamental plants and economically important as well as valued timber species are observed within the mix cultivations. Typical vegetation is shown in Figure 3-16.

Figure 3-16 Rubber, pineapple and coconut cultivations

7. Streams

Numbers of natural streams and water ways are located along the trace especially after Padukka up to Avissawella. The characteristic feature of the streams includes flowing water within the bed and banks of canals. Existing streams provide habitats for a diverse species of plants, fish, mollusks, insects and other animals. A number of endemic fish species are recorded from those streams. Streams located along the road provide water for drinking, washing and also bathing. Some of the slow moving waterways are directed to paddy fields by the people at several locations. In addition stagnant water puddles are also observed in some locations. Typical vegetation is shown in Figure 3-17.

Figure 3-17 Streams

8. Canals and drainage paths

Canals are human-made or artificial waterways used for crop irrigation, water supply or drainage. Several freshwater canals cross the initial section of the road in the project affected area at different locations and is connected to the Kelani River, Sea and Bolgoda lake at the end. Some of the big canals located in the initial section are highly polluted and birds or other faunal species cannot be observed. Invasive aquatic plants can be seen at some sections while there are no other native species. The polluted water in canals indicate the adversity of human involvement in nature and the canals are used as dumping grounds for municipal garbage, human and animal excreta and organic waste matter. Almost all the drainage paths are connected to the existing canal system which arise from residential, commercial and business area and are then connected to the canal system. Waste water from the toilets and washrooms from industries and small restaurants are also released to the canal system through drainage paths. Typical vegetation is shown in Figure 3-18.

Figure 3-18 Canals with polluted water

3.2.2.2 Fauna of the proposed project area

The terrestrial habitats in the proposed project area are predominantly man made and the fauna comprise mainly of common species that are found associated with man modified habitats. There are a variety of species including Dragon flies, Butterflies, Snails, fish, Amphibians, Reptiles, Birds and Mammals. A detailed investigation is underway for recording the details of faunal species present in the project area.

3.2.2.3 Environmentally sensitive locations

Aquatic water bodies located along and beside the railway line can be considered as highly environmentally sensitive locations. However, fresh water canals located at the initial section such as the canal under the Kalupalama of Dembatagoda, Heenela at Narahenpita, Kirulupone canal and Katuela of Pangiriwaththa are highly polluted fresh water canals located along the road. Few small water ponds with aquatic vegetation are also located within the premises of the Golf ground at Narahenpita. Medium and large water ways including Puseli Oya and Wak Oya intersect the road at different locations after the Padukka station.

For the subproject a significant number of trees need to be removed. Most of the trees to be removed are not of ecological significance. However, some trees which are endangered and near threatened status might need to be removed. This will be studied in details for the detailed investigation.

3.2.3 Socio –Economic Environment

3.2.3.1 Socio-Economic profile of the project area

The total population living in the immediate hinterland of the KV-Line as of 2011 Census is reported as 317,180 of which 160,053 are male and 157,127 are female. The detailed population data relevant to the specific GN divisions of the subproject area is given in the social impact assessment of the feasibility report.

Population density is very high in all DS divisions crossed by the rail track from Maradana up to Homagama. This group consists of 2,555 households with a total population of 8,492 persons, contributed to by 4,341 females (51.1%) and 4,151 males (48.9%). The affected households beyond

Homagama are very limited. It is negligible in the Padukka – Avissawella Section, where only a single rail-line is ear-marked for rehabilitation. Compared to the Maradana-Homagama Section, the ROW of this Section is almost devoid of squatters or encroachers.

3.2.3.2 Economic Activities

- Agriculture – According to the labour force survey in 2014 carried out for each district, 1.6%, of the total labour force is engaged in Agricultural sector in the Colombo district. Paddy and small holdings of tea, rubber and coconut are the major agricultural cultivations in the Colombo district. In Sri Lanka, Colombo district is having the least number of people engaged in agricultural activities while 30.3% and 68.2% of the labour force is engaged in Industries and Services respectively.
- Livestock - Cattle, Buffaloes, Poultry, Pigs and Goats are reared to a certain extent in the Colombo district. These activities take place in the project area also.
- Fishing – Although fisheries is a prominent economic activity in the coastal belt of the Colombo district it does not happen in the project area. Fresh water fishing is done to a certain extent.
- Industries - Labour force survey of 2014 reveals that 36.1% of the total workforce is engaged in industries and Colombo district has a labour force of 30.3%. Colombo District ranks first in industrial development.
- Transport facilities - Road transport is the dominant mode of transportation in the project area.

3.2.3.3 Social & Cultural Resources

General Socio – Economic Status

It is recorded that households in the project impact area are dependent on multiple sources of economic activities, which have given them employment in the areas of; a) industrial and service sectors comprised of public sector (national, provincial, local), b) private sector employment (trade, commerce, industry, finance), and c) business activities, passenger and goods transport (public, private, taxi including 3-wheel transport etc.). There is also self-employment, daily paid wage employment, and foreign employment. Based on the primary occupation of the head of the household the employment pattern observed are summarized as:

- Self-employment is the dominant source of employment – 44 percent,
- Followed by unskilled labor - 15 percent,
- Private sector employment 14 percent, and
- Public sector employment – 7 percent.

It is found that about 12 percent of the household heads are reported to be unemployed at the time of the Survey in 2018. The existing socioeconomic profile of the project area is described based on the socioeconomic studies carried out by UN-Habitat for the first section of KV-Line (Maradana-Homagama).

Administrative framework
The project area along the KV-Line consists of 70 GN Divisions in 7 DS Divisions and they are coming under the administration district of Colombo, which falls to the Western Province of Sri

Lanka. Local Government-wise it belongs to 6 councils as 2 Municipal Councils, 2 Urban Councils and 2 Pradeshiya Sabhas.

The total length of the existing KV Line from Maradana to Avissawella has a total of 36 Railway Stations, which include 6 main Satellite Cities in Colombo Metropolitan Region. A good majority of stations between Padukka and Avissawella serve as halting places without even basic facilities

The social profiles of the sub project areas are discussed in detail in the Social Assessment of the feasibility study report.

According to this, the railroad sections from Maradana to Nugegoda and Nugegoda to Homagama run through highly congested urban areas. In these sections there is a considerable number of households and business entities by the roadside and there is a likelihood that these would be affected by project related activities. In these sections there are a number of low income illegal shanties built on the railway ROW itself.

It can be seen that there are a considerable number of socially sensitive places such as schools and temples, cemeteries and temples located close to the railroad. Any construction related activities must take into consideration the presence of these places and potential impacts on them.

3.2.3.4 Environmental and Social Issues

Following environmental and social issues had been observed in the area.

Existing Environmental Issues:

- Inadequate water and sanitation facilities for the encroachers/ those living on the ROW.
- Continuous noise pollution due to unsafe machineries in garages, saw mills and other types of workshops.
- Environmental degradation due to improper waste disposal
- Air pollution due to burning of degradable and non-degradable waste materials
- Health issues of both encroachers and other residents surrounding the rail reservation due to mal-practices of garages such as in haphazard discharges of used paint and waste
- Pollution of drainage paths canals and streams due to discharge of kitchen, toilets and industrial waste.
- Spread of vector borne diseases due to creation of breeding grounds, flies, mosquitoes and rats etc., around shanties.
- Indoor air pollution due to firewood and kerosene stoves
- Temporary inundation due to blockage of drains and other natural water paths
- Transmission of infectious diseases due to overcrowding and poor ventilation
- Continuous air and noise pollution due to heavy traffic around some of the level crossings
- Pollution of rail reservation due to removal of household, commercial and industrial waste (solid and other toxic waste materials)
- Lack of open spaces and recreation areas
- Deterioration of the quality of the surrounding environment due to encroachments

- Illegal construction of buildings, residences and other structures in reservations of rail, national and local rods as well as irrigation reservations.
- Reclamation of low lying lands

Social Issues:

- Squatter families living along the KV-Line ROW (from Maradana-Homagama) have been occupying the corridor for decades, without any legal rights,
- Temporary houses have been the shelter for extended families with more than 2 sub-families (nuclear),
- It is reported that some of these squatter families living in the ROW between Maradana and Maharagama are involved in social abuses like alcoholism, drug-trafficking, underground deals and prostitution,
- Particularly women and children in these households are not secured socially or economically.
- Several religious places located in close proximity to KV-Line will face direct impact of the project both socially and environmentally.

3.3 Anticipated Environmental Impacts

3.3.1 Physical Environmental Impacts

The environmental impacts anticipated from the subproject are discussed under the sections of impacts on the physical environment, impacts on the biological environment and impacts on the social environment.

3.3.2 Physical Environmental Impacts

3.3.2.1 Hydrological Impacts

Baseline Hydrological Impacts

Existing Drainage Issues in the Rail Road

As the rail road is mostly in embankments drainage issues are very limited. Historically the rail track has never got inundated. Following drainage issues prevail.

- Most of the small culverts, culvert inlet channels and leader way drains are partially or totally blocked or weeded creating temporary backwater upstream.
- Capacity of culverts could be inadequate to pass a design flood (e.g. 100-year flood). As a result, there will be an extra flood lift.
- Water ingress into the rail track takes place at level crossings where water from by roads or high ground crosses the rail track. (Locations:1+750,3+520, 6+870,11+715,16+580, 22+660,24+310,31+000,35+210,36+965,40+120,40+135,42+130,48+510,50+800,51+750,52+ 130,53+200,53+580,54+300,54+700,55+520).
- At some places instead of culverts water crosses the track through cross drains or as cross flow paths through the space created by two sleepers. The adequacy of the capacity of these drains is

questionable and as a result such drains could overflow into the rail track. There could also be drainage congestion on the upstream of such drains as soggy track was observed at some such places. (Locations:0+230, 2+250, 5+500, 9+250, 9+365, 9+425, 11+630, 14+330, 19+420, 26+250, 29+070, 34+880, 56+020, 56+860).

- Water stagnation inside and outside the rail track in cut sections and the cross drains in the cut sections. (Locations: 9+200 to 9+900).

Hydrological Impacts during Construction Stage

Construction impacts will depend on the method of construction. The rail road will be on pillars from Colombo up to Malapalla and it will be on embankment from there onwards. Construction impacts will be greater on the diverted sections of the alternative routes.

Impacts from the Pilot Road

Even for elevated constructions some pilot roads will be required after trimming the existing embankment at high elevated places. Pilot roads have the potential to hinder sheet flow. Generally, the pilot road will have openings for lower return periods. During periods of heavy rain, flood water could overtop the pilot road and because of inadequate openings there could be flooding further upstream because of backwater effect.

Impacts on irrigation schemes

Irrigation schemes may be negatively impacted by placement of railway embankment through canals and structures. Such canals and structures will need to be relocated causing a hindrance to the supply of irrigation water to paddy and other agricultural lands which they feed.

Even if there are several paddy fields there are no major irrigation schemes crossed by the rail road. However, there is a small anicut close to 34+150 km. There are many minor irrigation schemes crossed by the track and these minor irrigation schemes are managed by the Department of Agrarian Development. Small anicuts are also encountered in the vicinity of the rail road.

During construction these paddy fields could get temporary disturbed by siltation, temporary blockage of drainages, water stagnation etc. The anicut at 34+150 is on the downstream of the rail track and because of the coffer dams constructed for the upstream rail bridge the flow velocity will increase in the flow towards the anicut. This is shown in Figure 3-19

	
Anicut at 34+150	Anicut in a canal parallel to the rail track

Figure 3-19 Anicut

Impacts during floods due to loss of retention/detention area

Most of the low-lying paddy areas have a certain amount of flood retention capacity. Filling of these paddy lands for the railway pilot road construction will temporarily reduce the flood retention capacity. Loss of retention capacity could cause a marginal elevation of flood water levels and an increase in the flood recession time. There will not be any extra loss of retention in the normal route of the railway as the retention has already been lost for the existing track embankment.

Impacts on drainage pattern of the project area

The following hydrological impacts could be expected during the construction stage

- Hindrance to sheet flow and regular drainage paths because of the embankment of the pilot road and the railway.
- Hindrance to irrigation water supplies to farm lots in paddy areas.
- Soil erosion and washed off sediment deposition in paddy fields, irrigation and drainage canals and lead way canals because of temporary loose soil mounds used for the pilot road embankment.
- Loss of water retention capacity in low-lying areas because of the pilot road embankment.
- Closure of minor stream paths resulting in water logging.
- Water logging on the upstream side of the railway embankment because of poor drainage.
- Temporary flood aggravation flood plain areas of Kelani River and Bolgoda Lake.
- High velocities through the hydraulic structures will cause downstream erosion.

Hydrological Impacts during the Operational Stage

During the operational stage openings of structures (including leader in and leader away canals) could get silted. Once this happen the flow through these structures will get impeded resulting in upstream backwater and delay in flood recession causing protracted water logging on the upstream of the railway embankment. As flood recession will take a considerable time during heavy floods prolong inundation of the rail embankment will suffer from soaking and even collapsing.

3.3.2.2 Water Quality Impacts

Impacts on Surface Water Quality

During Construction Phase

The proposed project activities of removal of existing rail tracks, installation of new tracks, structures for the elevated tracks, stations and related facilities, rail yards and storage-related facilities involve activities such as land clearing, cut and fill operations, excavations, blasting and drilling, soil disposal and soil stabilization, construction of access roads and landscaping which would invariably result in surface water quality deterioration mainly as a result of high turbidity and colour, especially during the rainy season.

The modified rail track from Malapalla to Avissawella will be constructed at-grade on embankments, which demands a considerable amount of soil, which will be transported to the project area. This may lead to high rates of erosion in the area where borrow pits are located and also in sections where there are significant amounts of filling (Erosion can be expected from freshly placed earth fills and burrow areas until the soil layers are stabilized). Surface runoff from such areas will carry substantial amounts of eroded soil particles, which will cause severe turbidity and colour problems in rivers and streams. Surface water quality deterioration due to surface and subsurface runoff enrichment will be significant during the heavy rainy periods.

Transportation of soil may cause emissions of dust and spills which may contribute to increased sediment loads in road-side drainage and canals, and ultimately nearby streams or low-lying areas. In addition to surface water bodies, shallow unprotected wells located close to access roads, burrow areas and project area may receive considerable loads of wind-borne dust particles. Improper storage of fill material will also be a possible source contributing to high silt loads.

Certain construction activities such as land clearing, blasting and drilling, dredging etc., could also cause substantial amounts of topsoil to be washed away with runoff. Construction and expansion of bridges, culverts, openings and canal systems will occasionally need dredging and bank stabilization, which will increase turbidity in water and also lead to colour problems. Disposal of dredged material may also cause similar impacts.

Construction vehicles conveying earth and other construction material will require washing and cleaning which will contribute substantial amounts of solids to water bodies. Oil spills, fuel and lubricant leakages from vehicles and construction machinery and equipment will contaminate both surface and groundwater. Haphazard storage of construction material and waste and debris can be a potential source of pollution of both surface and groundwater.

The railway track passes adjacent to numerous streams, irrigation tanks and low-lying areas and crosses a few. At locations where the railway line passes through paddy fields or above water bodies, the water quality would be affected. This will be a considerable impact during the construction stage. The small dam area after 34 km is vulnerable to siltation from surface runoff.

Another potential impact on water quality can be sewage and solid waste produced by the work force occupying construction campus. Unless these are disposed with proper care, inadequate waste handling will result in increased levels of BOD, nutrients and pathogens in water.

A significant quantity of concrete that is required for construction, wash-water arising during the cleaning of the machines involved in concrete plant operations or batching plants could cause color and turbidity problems in water bodies and contamination with oils or hydrocarbons (HCs) and even heavy metals such as Pb and Fe. Although these are short term impacts considering the small duration of the construction phase the effects can be significant when several machinery and equipment are washed.

In addition to above impacts, dredging operations during construction stages will affect surface water quality, particularly pH due to run off of large amounts of peat. Construction of railway yards and stations in low-lying areas will require excavation of peaty material. In addition, improper storage and disposal of soil material (for cut and fill operations) may cause short-term water quality deterioration in nearby waterways, and also could result in high turbidity and suspended matter in surface waters.

Effects on water quality will be significant if the duration of the construction phase becomes long due to unforeseen circumstances.

<u>During the Operational Phase</u>

During operational stages, increased rail transportation, storage of petroleum products, operations at railway yards and stations will give rise to spillage of oil, grease and other petroleum products which if washed away with surface water will contaminate surface waters. This will contribute hydrocarbons, oils and trace metals such as Pd and Zn into surface run-off. However, this will be less of an impact than at present when the rail line is electrified and all rolling stocks are electric.

Cleaning, servicing of engines, carriages, and other machinery and equipment, operations at storage facilities will generate substantial amounts of waste or wastewater that could potentially contaminate watercourses. Transportation and storage of hazardous and/or dangerous material can be a potential source of severe contamination of surface water if proper and consistent procedures are not observed.

Improper disposal of wastewater and solid waste from stations and related facilities can be regarded as pollution sources. Litter thrown away by rail passengers while the train is in transit will contribute to pollution of rail-side environment. Haphazard disposal of refuse clogs open drains and sewers, thereby leading to overflow of wastewater and contamination of the surrounding area. Surface water (and occasionally groundwater) can be polluted when it receives surface runoff that has been contaminated with leachate from landfill areas. Untreated sewage disposed from toilets in the trains has the potential to contaminate surface waters.

Disposal of wastewater and spoilage from maintenance depots will introduce toxic substances to both surface and groundwater. Storage of petroleum products, operations at maintenance depots, yards and railway stations will give rise to spillage of oil, grease and other petroleum products which if washed away will contaminate surface and groundwater, including low-lying areas and paddy fields. Such pollutants will contribute hydrocarbons, oils and trace metals such as Pd and Zn into surface run-off. Cleaning, servicing of engines, carriages, and other machinery and equipment, operations at storage facilities will generate substantial amounts of waste or wastewater that could potentially contaminate watercourses. Transportation and storage of hazardous and/or dangerous material can be a potential source of severe contamination of surface water if proper and consistent procedures are not observed.

Ground Water Quality

During Construction and Operational Phases

Haphazard disposal of wastewater and solid waste generated from worker camps (during construction), stations and related facilities (during operational phases) can contaminate groundwater sources and pose a risk of parasitic infections, hepatitis and various gastrointestinal diseases including cholera and typhoid.

Solid and liquid waste disposal into pits from worker camps, stations such as kitchen and other biologically degradable wastes will produce leachate that demand high amounts of oxygen or undergo anaerobic decomposition. Such wastes can temporarily contaminate shallow groundwater.

However, possibility of contamination of soil and subsequent pollution of groundwater with potential harmful substances including petroleum products, chemicals, and oils due to spillages, leaks and disposal of wastewater from storage facilities, railway yards, and maintenance shops will be considerable.

3.3.2.3 Topographical and Geotechnical Impacts

Anticipated impacts on topological and geotechnical aspects due to the proposed project are discussed under soil erosion, landform, mineral resources/construction material, slope stability and settlement of the ground.

Soil Erosion

The entire railway trace runs through the wet climatic region of the country. However, the entire rainfall is concentrated for about two months of the year. The Clearing of the land due to project activities will invariably expose surface soil to erosion. Moreover, excavation of the elevated ground and filling of the low lying areas will also contribute to soil erosion. Soil erosion and transportation of the eroded soil will cause several environmental problems such as siltation and blocking of existing waterways, reducing the yield of the agricultural crops, flooding due to blockage of drainage paths and pollution of drinking water sources.

Landform

Since the railway track is already in place, the landform of the project corridor is not expected to change much.

Mineral Resources/ Construction Material

There are no important mineral deposits located within the project corridor except the commonly found rock forming minerals. Rocks required for the railroad construction may be quarried from outside the trace and therefore, mineral deposits outside the project corridor may be used up for the construction of the proposed railroad extension. However, since these minerals are commonly found in other areas of the region there will not be a significant impact on the mineral resources due to the construction of the railroad extension.

Slope Stability

Since the rail track is on a relatively flat terrain and the slope is rather mild there will not be any impact on the stability of the slope by the proposed project activities. However, the slopes, which are stable during the dry season, might become unstable during the rainy season due to development of excess pore water pressure and the loss of shear strength of the unsaturated soil due to saturation.

Settlement of the Ground

At places, where the trace runs through valleys of the streams, the subsurface consists of organic soils or soft alluvial deposits. Within these low lying areas, significantly high embankments are needed to prevent flooding of the rail track and to maintain the gradient less than the permissible maximum. Construction of high embankments over such soft compressible deposits will invariably give rise to large primary and secondary consolidation settlements.

3.3.2.4 Air Quality Impacts

During Construction Phase

Impacts on Ambient Air Quality

Incidences of air pollution in terms of suspended particulate matter (SPM or SP10) notably dust, (which will include dry spoil material) and even cement particles would occur during activities such as the construction of access roads (which may include clearing of vegetation), excavation works and cut and fill operations. Movement of heavy vehicles such as container carriers, lorries and trucks on bare soil in the construction site could result in significant dust generation.

The presence of significant fine dust particles, cement particles along with other suspended particulate matter could affect nearby sensitive recipients such as residential areas. In this respect elderly people and small children would be at risk from asthmatic and other respiratory problems. Furthermore, significant dust would lead to asthmatic and other respiratory problems to the work force too. It is anticipated that dust from exposed earthwork will be high in areas having laterite soil and even in areas having sandy clay or clay soil (in the dried form) when vehicles are travelling at high speeds and also when the weather is too windy.

Dust emission scenarios would be high during dry weather and gusty wind conditions, though such impacts may be temporary. Generally meteorological conditions and fineness of the material are some of the triggering factors for increased dust pollution scenarios. The more fine materials may be carried away to considerable distances before being deposited either on nearby structures or vegetation or on residences in the form of a thin film depending on the weather conditions or wind patterns.

Dust emission scenarios could also occur during concrete mixing, batching plants/ ready-made concrete plants and transport of quarry material (rock/metal aggregates). Also improper handling and transferring of excavated soil material (i.e., spoil especially when dry and other debris rising due to demolition of houses and other infrastructure) in large amounts into vehicles for external or internal transport, unloading of construction material such as cement from construction vehicles (such as tractors and trucks/tippers) and improper storage or cover of construction material could lead to significant dust emissions. Blowing of dust is anticipated when transporting construction material and taking away excavated soil material and building debris to disposal locations unless the vehicles are well covered to prevent dust emissions and spillage.

Furthermore, improper storage or cover of spoil material, building debris (demolition wastes) and construction material could lead to significant dust emissions. It should be noted that dust emissions could occur from the large piles of spoil material (especially from material such as laterite soil and clay soil when in the dried forms) if such material is improperly stored in open areas, which are often subject or exposed to winds.

In addition to dust problems, air pollution in terms of unpleasant diesel smoke (rich in partly burnt or unburnt hydrocarbons) and gaseous pollutants such as NOx, SO_2 and CO could also arise from the large number of excavators/ backhoes and diesel powered construction vehicles (transporting construction material to the project site) having faulty or poorly functioning exhaust silencers. However, the impacts are temporary and not severe. Production of concrete/batching plants may cause fairly high emissions of various materials such as cement particles, gaseous pollutants and unburnt or partially burnt petroleum products (hydrocarbons) which will cause pollution of the immediate neighbouring atmosphere.

Moreover, any air borne emissions would eventually impact the soil and water bodies during rainy periods (i.e., due to wet deposition).

Impacts on Ambient Air Quality due to effects of Quarry Sites

Construction material exploration and exploitation are major activities of a project of this nature. For the proposed project it is anticipated that a substantial amount of the construction material is to be found from licensed quarry sites. For instance rock material is needed for the railways. Therefore, it seems that blasting of hard rocky material is required, which could cause considerable air pollution in terms of fine dust particles along with high noise and vibration levels. Drilling works can also cause significant dust emissions when compressed air operated hand drills are used.

Crushing plants also could cause significant dust if they are not properly located and inadequately covered with wet gunny bags. This can lead to respiratory problems such as silicosis and even cardio thoracic problems especially in children and elderly persons in the vicinity of quarry sites. Dust can also cause significant sociological issues/ problems such as increased difficulties in maintenance of houses and drying of washed clothes.

Blasting operations can produce moderate amounts of toxic gases such as CO, H_2S and NO_x such as N_2O_3 and NO_2. People can be exposed to high doses of nitroglycerine also which can cause severe headaches. Vehicles involved in transporting quarry material could lead to dust emissions when travelling on unpaved roads.

3.3.2.5 Impacts on Noise and Vibrations

Impacts due to High Noise Levels

Due to a project of this nature it is anticipated that there will be a considerable flow of construction vehicular traffic. High noise from engines and irritating noise emanating from beeping horns and vibration effects of the heavy flow of construction vehicles will cause inconvenience to nearby schools, religious places and residential areas close to the project area. This is of particular significance on the stretch from Maradana to Padukka where the rail line traverses through congested areas. The line traverses through several noise sensitive locations such as schools, courts, temples etc. Moreover traffic noise might also have a disturbing effect on the birds in sensitive ecosystems such as marshy areas.

It should be noted that the noise levels in terms of Leq dB(A) or L10 dB(A) should be maintained below the levels given in Table 3-2 depending on the land use/type in accordance to the National Environmental (noise control) regulations no 1 of 1996 issued by the CEA. Therefore, in view of these facts the impacts will be high since the heavy vehicles emit noise levels exceeding 55 dB (A). It is reported that at a distance of 50 ft trucks and tractors could emit noise levels in the range of 83-93 dB(A) and 78-95 dB(A), respectively.

* The maximum permissible noise levels at boundaries in LAeq'T are given in Table 3-2.

Table 3-2 Maximum permissible noise levels at boundaries

Area	LAeq'T	
	Day Time	Night Time
Low Noise	55	45
Medium Noise	63*	50
High Noise	70	60
Silent Zone	50	45

Source : the National Environmental (Noise Control) Regulations No. 1 of 1996.

* Provided that the noise level should not exceed 60 dB (A) inside existing houses, during day time.

- "Low noise area" - an area located within any Pradeshiya Sabha area.
- "Medium noise area" - an area located within any Municipal Council or Urban Council area.
- "High noise area" - any export processing zone established by the Board of Investment or industrial estates approved under part IV C of the National Environmental Act;
- "Silent zone" - the area covered by a distance of 100 meters from the boundary of a courthouse, hospital, public library, school, zoo, sacred areas and areas set apart for recreation or environmental purposes.

The same regulations also specifies the maximum permissible noise levels at boundaries of the land in which the source of noise is located (in LAeq,T), for construction activities as given in Table 3-3.

Table 3-3 Maximum Permissible Noise Levels

LAeq,T	
Day Time	Night Time
75	50

Construction processes connected with extraction, handling and material transportation may also cause increased noise levels. Blasting of rocks could result in producing disturbing effects to neighboring residential areas, etc. Therefore, it is highly recommended that quarry sites are not located in the vicinity of noise and vibration sensitive areas especially residential areas and even religious and archeologically important places.

Since construction works require the use of heavy machinery (apart from the use of several construction vehicles), noise levels will be very significant, though the effects may be temporary (since the construction phase is confined to a shorter time period). Table 3-4 and Table 3-5 presents noise levels of some of the machinery used in construction works.

Table 3-4 Relative Range of Noise Levels for Some Common Types of Heavy Construction Machinery

Machinery	Noise levels at distance of 50 ft
Compactors (rollers)	71-75
Front loaders	70-83
Backhoes/excavators	70-85
Tractors	78-95
Scrapers, graders	78-93
Pavers	85-88
Trucks	83-93
Concrete mixers	75-88
Concrete pumps	81-83
Jack hammers and drills	82-98

Table 3-5 Noise Levels of Construction Equipment

Equipment	Noise level at 7 m in dB(A)
Crow bar	115
Compressor	109
Pile drivers (drop hammer type)	110
Truck, scraper or grader	94
Pneumatic drill	85
Excavator	112
Loader	112
Roller vibrator	108
Poke vibrator	113
Sound reduced jack hammers and lock drills	82

Equipments involved in cut and fill operations and mechanical compaction such as compactors are known to generate high noise. When several equipments and machinery are used the total Sound Pressure Levels (SPL) will be high. Demolishing of existing structures and buildings and clearing of sites would require the use of jack hammers and JCB backhoes which would generate significant noise levels. Concrete mixing and batching plants also could cause some undue noise and vibration.

Hence, it can be said that the noise generated from the machinery involved in construction works could significantly disturb nearby communities since the noise levels generated tend to exceed the permissible day time (defined from 6 am to 9 pm) limit of 75 dB(A) stipulated in Sri Lanka for construction activities.

Construction works for power (transmission) lines consisting of the foundation works, tower erection works and wire-stringing works and hammering activities involved in connecting railway lines would contribute to noise. This could disturb nesting, breeding and feeding habits of nearby fauna (especially birds) in ecosystems such as marshy lands if emitted in high levels, though the effects may be restricted to short time periods.

Constant exposure to very high noise levels can often cause hearing deficiencies and machine operators who are directly involved in such activities are at high risk.

3.3.3 Ecological Environmental Impacts

Proposed project activities may create a number of direct and indirect ecological impacts during construction and operations stage of the project due to removal of trees and green cover vegetation, excavation and piling, filling of lowland areas, storage of construction materials, stockpiling, construction of service roads, labour camps etc.

3.3.3.1 Impacts on Natural Habitats

The existing rail line predominantly runs through man modified habitats including areas of marshlands, paddy fields, home gardens, cultivated lands etc. In addition a number of fresh water streams are located along the section after Padukka station. From the above habitats some extent of land will be affected due to establishment of pilling sites for elevated structures, filling for permanent and temporary sites for construction facilities, transportation and widening of the road for two-lane construction etc.

Since most of the construction activities are restricted to the existing ROW of the Department of the Railway, a small extent of surrounding habitats are acquired for the proposed project activities. Hence habitat degradation at significant levels is not expected throughout the project. Since at the initial section of the railroad the track is elevated, and also because this area is anyway highly urbanized, fragmentation of habitats is not expected and movement of animals will be better or more facilitated than at present. However, there are several amphibians, reptiles and small mammals living beside the existing trace and those small populations will get divided by the construction of a wider and higher embankment than at present, which will endanger their survival. Decline of the extent of habitat for some species of flora and fauna, reduction of water retention area, obstruction of direct sunlight to the ground in the elevated section resulting in the decrease of shade loving species, will be expected through the project.

However, a few abandoned paddy fields along the road trace beyond Homagama, have been colonized by aquatic plants and these are now gradually converted to marshes, which are natural habitats for water birds. Aquatic ecosystems such as marshes, rivers, streams, ponds/ tanks are habitats for important food sources and characterized by a richness of flora and fauna and high productivity. These habitats are important because of their role in regulating the flow in waterways, in filtering water, and in serving as habitats for migratory birds. These aquatic habitats will be disturbed during the construction of the new rail road. Erosion from poorly constructed and rehabilitated sites can lead to siltation of these habitats. Alterations of water levels and flood cycles can affect the productivity of the habitat and effect on the food chains and food webs.

3.3.3.2 Impacts on Flora and Fauna

Most of the impacts on flora associated with the activities of the subproject will occur during the construction phase of the project. Impacts on flora and fauna are associated with site clearance, excavation, removal of vegetation, earth moving, construction of an embankment and increased human activities. Most of the section of KV line runs through highly urban, urban and semi urban environment with built-up areas. Therefore majority of the recorded species belong to the common home garden species and fauna species are well adapted to the man modified habitats. Some species of endemic and threatened floral and faunal species are also found along the trace. However, project activities will not cause direct impacts to the fauna, since most of them are highly mobile and able to tolerate human disturbances. Although, some endemic species of trees need to be removed for the proposed project, these species are not restricted to the proposed ROW and can be found in similar habitats within the project affected area.

Nevertheless, fauna and flora living in streams and other associated water bodies will be affected during the construction and operation phases while turbidity of water bodies may be caused due to sand and silt being trapped up when constructing on bridges and culverts across streams and irrigation canals.Sludge from piling activities, accidental spilling of oil from machinery and construction materials such as cement may temporarily pollute the water and harm aquatic life. Therefore implementation of proper mitigation actions is essential to protect aquatic habitats with their flora and fauna. In addition significant impacts are not expected on flora and fauna species, since most of the proposed trace mainly runs along the existing railway reservation area along the existing line.

The impact on individuals and populations of terrestrial flora and fauna found in all the habitats along the road trace would be minimal as these comprise of common species with very low endemicity with few being regarded as threatened.

About 2% of the road trace intersects water bodies (marshes, rivers, streams, tanks etc.) and 33% is on paddy fields (cultivated and abandoned paddy fields that are converted to marshes). Therefore, species that inhabit these habitats such as freshwater fish and invertebrates as well as water birds that utilize the habitat for feeding and breeding will be affected directly during the construction phase. Habitat degradation and habitat loss would be a major impact on aquatic fauna and water birds.

3.3.3.3 Impacts on Rare/ Endangered Species

Few endangered species, two species of flora and 3 species of fauna were recorded during the field survey within the proposed ROW and surrounding habitats. Since some of these species are recorded from habitats located beside the existing railway reservation, these species will not be directly affected due to proposed construction activities. Impacts on the survival is negligible for all recorded endangered fauna species (dragonfly, fish and mammal), since they are highly mobile species. In addition all recorded species are not restricted to the reported habitats and can be found in other locations of the project affected area.

The number of rare and endangered flora and fauna encountered during the field survey and findings from the information available for this area revealed that there are very few species belonging to this category. All threatened plants and animal species recorded from the habitats within and in the surroundings of the road trace are found in other geographic locations of the country. Therefore, impacts on these species due to the activities (construction and operational phases) of the project would be marginal.

3.3.3.4 Impacts on Migratory Paths

No permanent animal movements or migration pathways had been observed along the existing trace during the field survey. However, construction of a wider and taller embankment will affect fauna in different ways since it will act as a physical barrier for the movement of animal species. It will also enhance the mortality of animal and restrict their mobility and limit basic requirements for their survival.

3.3.3.5 Impacts on Protected Areas

Environmentally Protected Areas are not located along or beside the existing trace. Therefore impacts on environmentally protected areas such as sanctuaries or protected wetlands are not expected from project activities.

3.3.3.6 Spread of Invasive Alien Species

Both invasive flora and fauna species are found along the trace. There is a possibility of introduction of other invasive flora and fauna species due to transportation of construction materials and other related construction activities from external areas to project affected area. There is also a possibility of spread of species in-between different construction areas along the stretch of railway line. Areas cleared of existing ground cover and newly filled-up areas are vulnerable for occupation of invasive species and thus there is a risk of displacement of native species. Introduction of invasive species will also have impacts on ecosystem services, natural habitats and biodiversity.

3.3.3.7 Impacts of Noise, Vibration and Dust on Ecological Aspects

Noise, vibration and dust from heavy machineries and equipment, piling activities, excavation and compaction have the potential to disturb breeding; feeding and nesting behavior of avifaunal species inhabiting marshy areas and associated aquatic habitats. Some species of migrant birds also visit the project affected area during the migration season. In addition other related construction activities and civil works will potentially impact on the behavior of common species of birds, reptiles, amphibians and mammals inhabiting cultivated lands, water bodies, home gardens and road reservations too. Impact on the aquatic fauna (including fish) due to construction activities over water bodies is also possible during the construction phase.

3.3.4 Impacts on Socio-Economic Environment

Detailed investigations on the socio-economic aspects of the project are presently underway. The survey up-to Homagama has been completed.

3.3.4.1 Impacts on Land Acquisition and Relocation

The investigation up to Homagama has estimated that a total extent of 3,062.62 perches will need to be acquired, There are people who have encroached on the reservation or the existing ROW and built houses and other structures. It has been observed that there are housing schemes built by the government on this land. Further, in some instances the SLR has leased out property to individuals and institutions. A substantial part of the public land will be repossessed. Therefore, the proposed project requires repossession of public land and acquisition of private land, resulting in involuntary resettlement impacts involving physical and economic displacement of populations.

In addition to private land a further extent of nearly 9,175.95 perches of public lands will also be required for the project. The total estimated land requirement for the project is thus 12,238.57 perches. In total, there are 2,494 land plots ranging from less than 2 perches to more than 6 perches in extent. There are 926 private landholdings and 1,568 non-titled land plots. The survey up to Homagama also has estimated that out of a total of 2,509 land plots about 2,263 or 90% of total is likely to experience major impacts due to the project. (UN-Habitat 2017)

3.3.4.2 Impact on Structures

A considerable number of structures are affected by the clearing up of ROW. It is estimated that up-to Homagama, out of the total 3,055 structures affected, the highest number of structures getting affected include 2,206 residential structures followed by 762 business structures. In addition to the private structures requiring relocation, a total of 87 structures have been listed under institutions and physical and cultural resources (PCR). These structures include public institutions, private organization, temples, public bathing and sanitary facilities and common places.

Impacts on Residential Structures

It is estimated that up-to Homagama out of the total 2,206 residential structures affected, 1,547 units are permanent structures, and the balance 454 and 158 units are semi-permanent and temporary structures. About 1,467 houses are owned by non-titleholders and 692 houses are occupied by non-titleholders. Majority of the non-title group of structures is located in Thimbirigasyaya DSD (1,060 Nos.) followed by Maharagama with 195 Nos. of residential structures affected. The affected housing units range from temporary structures, line houses, free standing single houses, twin-houses or row-houses, houses with several floors, flats, annexes etc. The common type of all, however, is free-standing individual housing units (63%), followed by double-storied houses (16%) and line houses (12%) and three-storied houses (3%). (UN-Habitat 2017)

The affected houses are of varying sizes in terms of floor area ranging from less than 100 Sq. Ft. to greater than 1000 Sq. Ft. that generally reflects the variation in socioeconomic standing of the affected households. Majority of the affected houses are concentrated in the group of houses containing a floor area of 400 sq. ft. or less.

Another significant impact that should be considered is the effect of construction activities on close-by structures which would not have to be removed but might be affected (such as wall cracks) due to construction activities. Such impacts might occur during the operational phase of the subproject also since the frequency of train operation is expected be higher once the subproject is in place than at present.

Impacts on Business Structures

The survey has also estimated that up-to Homagamaa total of 762 business structures will be affected by the subproject and that at least 549 or 97.3% of the business structures will be displaced. The displacement is most prominent in Maharagama DSD followed by Kotte DSD where 679 out of total 762 business structures affected (89%) are located.

In addition to these formal business structures, there are temporary movable structures called "Bukkies" within the project boundary. These will also be affected by the sub project.

Impacts on Institutions

Several institutions will be affected by the subproject and it is estimated that upto Homagama out of a total of 84 institutions including physical and cultural resources affected, 38 structures will incur impacts greater than 10% while 46 structures will be marginally affected.

Impacts on infrastructure facilities provided to affected structures

At present the affected structures have access to various facilities such as electricity, safe drinking water supply, telephone, internet etc. Up-to Homagama it is estimated that these structures have a total number of electricity supply connections of 2,468 and the water supply connections amounting to1,628. Most of the facilities are connected to residential structures. Some marginally affected structures may face difficulties with respect to access to facilities. At present the sanitary facilities available for the community is not adequate and due to this unhealthy conditions prevail in the project area. Resettling of these community members into sites with adequate and proper sanitary facilities will be a significant positive impact especially on the women and children.

In addition, at present the practices of handling and management of solid waste and wastewater from the shanty dwellings is haphazard and environmentally damaging. Almost all of them dispose such waste into close-by open areas without any consideration of sanitary conditions or government regulations. Thus the resettlement of these communities into housing schemes with such infrastructure facilities and proper mechanisms in-place would be both socially and environmentally advantageous.

3.3.4.3 Impacts due to Inadequate Infrastructure Facilities in Settlement Sites

The resettlement sites might not have adequate infrastructure facilities to serve those who are relocated in these sites due to the subproject. It needs to be ensured that these alternative housing facilities are provided with basic facilities such as electricity, water and telephone facilities. Some of the common resources may be either closed down or relocated. In addition when resettled the community members are cut off from their regular service providers and will find it difficult to start over again.

3.3.4.4 Impacts on Employment

Most of those whose employment is negatively affected are unskilled/ daily paid/ contract labour and self employed. It is estimated that up-to Homagama, the unskilled/ daily paid/ contract labour group consisting of 482 households will have negative impacts due to loss of their long established customer/ client relationships with people in the neighborhood. The self employed group of 741 households is affected due to displacement from their current residences since most of their economic activities are based in residences and its neighborhood. The disabled group in 11 households might face negative impacts on employment during the resettlement phase. On the other hand the un-employed category in 307 households may find new opportunities due to livelihood restoration programs that may be implemented in the newly resettled areas. (UN Habitat 2018).

3.3.4.5 Encroachment on Archeological/ Cultural Sites

As there are no known archeologically or culturally significant sites the impacts on these are minimal. The impacts on religious sites and activities are discussed under impacts on landuse.

3.3.4.6 Impacts on Social Relations

Resettlement of people would affect the existing relations between community members with community based organizations as they will be completely separated from these organizations. In addition to these, there is a considerable negative impact due to conflicts that may arise between community members and construction workers, particularly those who are staying for a considerable time in worker camps. These can lead to unpleasant and adverse situations unless precautionary measures are taken.

3.3.4.7 Impacts on Land Use Patterns

Since the rail track is on the existing ROW and the need for acquisition outside of the ROW is minimal the changes on landuse is not that promiscuous except for the removal of illegal dwellings and vegetation on either sides of the rail track in the existing ROW. The removal of illegal slumps would bring about a positive change in the landuse pattern of the area. Aesthetically also this would bring about a significant positive change to the area.

3.3.4.8 Impacts on Economic Activities

Impacts on Trees

The clearance for the subproject requires removal of a large number of trees. Up-to Homagama, it is estimated that 9,240 trees including mostly food trees (5,551 Nos.), fruit trees (2,150), trees and crops of cash value (226), trees of timber value (28) and 1,285 other trees will need to be removed for the subproject.

Impacts on Agriculture

During the construction activities agricultural activities such as paddy cultivation would be affected to a certain extent. However, these impacts are minimal during the operational phase since the rail track does not deviate much from the existing line.

Impacts on business activities and self employment

In addition to above, the impacts on business activities is considerable. Since the community members are at present employed in numerous self employed business activities such as working as house maids, cleaners, gardeners etc. which are based on serving a regular clientele, relocation to a distant place would jeopardize these income generating informal sector activities.

3.3.4.9 Impacts on Transport Network

During the construction period the normal operations of the road network will get disturbed. The disturbances will be significant in the road where high traffic volumes are reported. This is of particular significance at locations where railway crossings are present.

During the operations period the railway system will get properly established in its functions but some disturbance to the traffic of the other crossing roads can be expected in the long run.

3.4 Proposed Mitigation Measures

3.4.1 Measures to Mitigate Physical Environmental Impacts

3.4.1.1 Mitigation of Hydrological Impacts

Mitigation Measures for Baseline Impacts

Baseline hydrological impacts such as the inadequate capacity of the culverts could be mitigated through design. Large opening sizes could be provided, and the leader way canals could be improved. Hydrological /hydraulic calculations will be performed to assess the existing capacity of the culverts and bridges and larger opening sizes will be proposed to suit the catchment discharges for 100-year return period flow.

Mitigation Measures for Construction Impacts

Mitigation Measures for Impacts from the Pilot Road

- Height and width of the pilot road will be minimized to a low height to allow floods of higher (greater than 10 years) return periods to overtop the pilot road.
- Temporary culverts will be provided to all drainage paths and at places of the flood plain (where flow balancing is required) crossing the pilot road.
- Filling will be breached at strategic locations in case of a flood if there is a backwater build up.

Mitigation Measures for Loss of Retention

Loss of retention cannot be fully mitigated. However, the backwater impacts created by loss of retention will be mitigated by the provision of culvert openings of adequate capacity.

Mitigation Measures for the Impacts on the Drainage Pattern

Existing drainage pattern could be mostly preserved where the designed rail track follows the existing rail track. At the segments of track deviations in the low-lying areas the same mitigation measure could be applied. There may be instances where diversion of the existing drainage paths is required, and such drainage problems will be site specifically mitigated.

Mitigation Measures for the track Diversion Impacts

Because of the track diversion in low lying areas, loss of retention and impact from the pilot road will occur for which mitigation measures applied to those impacts could be applied.

Mitigation Measures for Erosion Impacts

During construction loose soil will not be exposed to wind or rain. Temporary soil mounds, drainage paths, silt traps will be built to mitigate the impact of erosion.

Mitigation Measures for Operational Impacts

During the operation all culvert openings and leader way canals will be maintained.

3.4.1.2 Mitigation of Impacts on Water Quality

Mitigation of Impacts on Surface Water Quality

Proposed Measures to Address Surface Water Quality Deterioration

To control sediment loads carried by the runoff, and to prevent contamination of water by oxygen demanding waste, oils, grease and any other harmful material appropriate and well designed drainage facilities shall be installed.

Prevention of Degradation of Soil Cover from Erosion, Removal, or Loss of Soil during Construction

Erosion of the cut and fill areas would be controlled by carrying out both temporary (during construction) and permanent erosion control plans as a precautionary measure to prevent contamination of surface water bodies with heavy sediment loads. This will ensure that turbidity and colour in surface water is not affected by project related activities. It will be ensured that cut and fill operations are carried out, during dry days rather than on rainy days to the extent possible. This will prevent high suspended solid loads from been carried out in the surface runoff from the project site.

Temporary Measures that will be taken to Minimize loss of Soil cover during Construction

Silt fencing

Temporary silt trap basins and interceptor drains and sedimentation tanks will be installed to divert runoff from the site and collect suspended solids contained in surface runoff before discharging into surface water.

Exposed sloping areas shall be thatched with dead or live vegetation to minimise generation of wind-blown dust. Short term seeding or mulching of exposed soil areas (particularly on slopes) will also be carried out for this purpose.

Permanent measures to minimize loss of soil cover during construction

Erosion control plans focusing on establishment of stable native vegetation species along the embankment slopes will be implemented as a permanent measure to minimize loss of soil cover.

Prevention of Water Contamination from other sources

During both the construction and operational stages of the project on-site management will be properly carried out to prevent or minimize run off of oil and grease, and other harmful material entering water bodies. Oil and grease traps will be installed to prevent runoff of oil and grease during construction. Even during operational phases, oil interceptors or traps will be placed at stations, rail yards, maintenance shops, and storage facilities.

In addition it will be ensured that good housekeeping practices aiming at reduction of wastage and prevention of spills are implemented. These practices include measures such as sorting and segregation of wastes and proper storage until properly treated before discharge.

In order to minimize runoff, other measures taken include minimizing stock piling of construction material and debris and regular monitoring of leakages from storage facilities. It will be ensured that runoff, waste streams and discharges conforms to CEA stipulated discharge standards for inland surface waters. If it is found that the standards are not met immediate measures will be taken to rectify the situation.

Another source of contamination is the worker camps during the construction period which can be a significant source of human waste matter unless proper and adequate sanitary facilities are provided. Pit latrines will be provided in areas where the ground water table is deep and if the number of workers in a camp is in the order of 100-150 persons or less. If the number of workers exceeds 150, wastewater will receive primary-equivalent treatment before it is discharged into natural watercourses.

Wastewater generated from stations (including toilets and canteens) is domestic in character and would be disposed in a septic tank. Special care would be taken in the construction of septic tanks near paddy fields or low-lying areas. Disposal of raw sewage into rivers will be avoided at any cost.

Waste in any form liquid or solid will not be disposed to a natural water body at any time. Pollutants such as petroleum based waste and wash water containing oil and grease or lubricants will be collected on-site and properly treated before being discharged.

Mitigation Measures for minimizing Impacts on Ground Water Quality

By following the remedial measures employed for preventing surface water contamination groundwater contamination from project activities would also be reduced. These measures include proper disposal of all types of wastewater and solid waste during both construction and operational phases. Agreements will be reached on with the respective local authorities for proper collection and disposal of solid waste generated in stations.

If water supply during operational phase is from groundwater sources, it has to be ensured that projected use of groundwater is within the capacity of the natural system to replenish itself.

3.4.1.3 Mitigation of Impacts on Topographical and Geotechnical Environment

Mitigation Measures during Design Stage

Earth slope, created due to project activities, shall be designed in such a way to minimize soil erosion. During the design stage mitigation measures such as turfing of the surface or paving, slope reduction, designing of proper runoff and drainage facilities, will be considered.

Mitigation Measures during Construction Stage

Area of the ground, which will be subjected to soil erosion during the construction stage, will be identified considering the factors such as: surface soil type, topography, magnitude and intensity of rainfall etc. In ground areas vulnerable for soil erosion due to soil type, topography and magnitude and intensity of rainfall, construction activities shall be planned and phased out to minimize soil erosion.

Construction activities will be carried out in a manner to minimize the exposure of unprotected sloping ground during rainy season. Artificial covering will be used if necessary. Stockpiling of construction material and debris will not be done near waterways, drinking water sources and agricultural lands so as to minimize damages through runoff.

Temporary drainage facilities will be constructed to prevent and minimize runoff from erodable areas during the construction period. Measures such as silt traps and detention facilities shall be provided to minimise excessive flow velocities and surface erosion.

Post Construction Mitigation Measures:

Landscaping of the borrow areas will be done to minimize surface erosion due to topographical changes occurring from borrowing activities.

Mitigation of Impacts on Landform

Precautions will be taken to minimize the surface area and the depth of extraction so as not to significantly alter the landform of the area selected for such activities. Construction of embankments for the rail track through low lying areas may give rise to flooding and other related issues. Such factors must be given due consideration during the design stage. Landscaping will be done to mitigate the effects of the change of the landform.

In selecting borrow areas precautions would be taken not to locate borrow areas very close to each other to prevent adverse effects on the environment. Landscaping will also be done to minimize changes to the landform due to borrowing activities.

Mitigation of Impacts on Mineral Resources

Mitigation Measures during Construction Stage

It will be ensured that the earth borrows areas and rock quarry sites from where construction material is obtained is not located close to residential areas, main roads and sources of drinking water. It will also be ensured that extraction of rock for construction activities shall be carried out only from licensed and designated sites, which are also approved by the Geological Survey and Mines Bureau (GSMB).

If blasting is necessary blasting procedure shall be designed by well-experienced persons in order to minimize the damages and inconvenience caused to near-by structures and occupants. A crack survey will be conducted of nearby structures before implementation of the actual blasting operation and residents should be assured that damages are assessed and compensated for.

Mitigation of Slope Stability

Mitigation Measures during Design Stage

The side slopes will be designed taking into consideration relevant soil strength parameters. The soil shear strength parameters of the soil-rock interface will be considered during the design stage. Moreover, if the slope is made up of compacted material, appropriate soil strength parameters will be considered in the design.

The amount of water infiltration during rainy season will be reduced by way of providing adequate and suitable drainage system. Moreover a suitable type of green cover should be designed to protect the sloping surfaces to enhance the stability of the slope. Due to the soft underlying soil deposits, both the long-term and short-term stability of the embankment slope should be checked. If the embankment slope doesn't have an adequate factor of safety, provision of additional reinforcements should be considered.

Mitigation Measures during Construction Stage

Stability of natural slopes would not be compromised during construction activities such as cut and fill operations, site clearing and removal of land cover on natural slopes. Special attention would be paid to the stability of the soil overburden above the bedrock level, if rock blasting is done to excavate the rock beneath it as the ground acceleration generated by the blast may destabilize the slope.

Post Construction Mitigation Measures

As a precautionary measure during the post construction stage of the project the critical slopes along the rail track shall be monitored periodically, especially before the rainy season. Loading at the top of the slope outside the ROW shall be carefully monitored and necessary measures shall be taken to avoid such occurrences. Proper functioning of the surface water drainage system shall also be periodically checked.

Mitigation of Settlement of the Ground

Mitigation Measures during Design Stage

Detailed investigations would be done in areas of the ground along the trace, where soft soil layers are present to obtain the special variation of the thickness and properties of the soft soil layers. If the rail track is passing through areas where surface soil is expansible, necessary design measures will be taken to minimize the movement of the track due to swelling of the surface.

Mitigation Measures during Construction Stage

It will be assured that the selection of the soil for the construction of the embankment will be done only after assessing the swelling potential of such soils to minimize the ground movement due to swelling of expansive soils.

During the construction stage before laying of the rail tracks the settlement of the embankment, especially in areas with soft soil, shall be monitored and rail line will be laid only after the rate of consolidation settlement has reached a certain minimum level. In addition it will be assured that embankment construction will be done assuring a certain uniform degree of compaction. Thus a quality control program shall be in place to ensure that a minimum compaction level is achieved, reducing post construction creep settlement.

Post Construction Mitigation Measures

Soft ground treatment areas shall be monitored for occurrence of secondary consolidation settlements and appropriate remedial measures shall be taken, if such a settlement is observed.

3.4.1.4 Mitigatory Measures for Impacts on Air Quality

Measures to Curtail Dust

Dust emissions will be minimized through measures such as frequent wetting or wet spraying of dusty surfaces and any exposed earthwork surface by using sprinklers, tankers or bowzers. In addition measures such as compaction of loosened soil, regular manual cleaning of the construction sites, covering of all exposed earthwork areas with material such as black polythene cover and gunny bags.

Tarpaulin or cover sheets will be used while transporting construction materials and debris, to avoid wind induced dust and spillage. A Speed limit of about 10 km/h will be imposed on construction vehicles to reduce dust emissions. Construction material and debris will be stockpiled carefully and will be covered properly with tarpaulin to avoid dust emissions. Temporary sheds will be established to prevent construction material from been blown away with the wind and washed away with heavy rains.

As mitigatory measures if there are any accidental spills of material on roads during transportation immediate measures will be taken to clean and clear all such material.

Measures to minimise Dust from Crushing Plants at Quarries

While it will be ensured that material is acquired from only licensed quarries it will be ensured that crushing plants are sited adequately away from sensitive receptors such as hospitals, schools, places of worship, and residential areas. It will be assured that crushing plants are located about 500 m upwind and 100 m of a sensitive receptor. It will also be assured that dust emission points of a crushing plant are covered up to the extent possible with material such as fabric bag filters or gunny bags which should be frequently wetted.

Dust emissions at quarry sites will also be minimized through spraying of the quarry sites prior to blasting activities and also right after blasting. At the same time it will be ensured that misfires will not take place from wetting. While transporting quarry material it will wetted through spraying and covered up with tarpaulin to prevent dust emissions during loading, transporting and unloading.

Mitigatory Measures to minimize air emissions from construction equipment, machinery and facilities

It will be ensured that all construction vehicles, machines and equipment are serviced and maintained regularly to avoid smoke emissions and air pollution. The construction vehicles used will be in full compliance with the national and local regulations (National Environmental Air Emissions Fuel and Vehicle Standards E.O. Gazette 1137/35 of June 2000, updates by air emissions fuel and vehicle standards (importation standards) 1268/18 December 2002 and 1295/11 June 2003).

Where cement mixing operations and plants are used they shall be located away from sensitive recipients. Precautions will be taken to avoid cement mixing activities during heavy winds. In addition to taking precautions to protect the environment from dust emissions and gas emissions it will also be ensured that all workers and employees working on site and in quarry sites use personal protection measures (PPEs) such as masks and goggles for safety reasons.

Mitigatory Measures to minimize air pollution during the Operational phase

While it is not anticipated that drastic measurements are needed during the operation phase, it will be assured that all locomotives are regularly serviced and well maintained to reduce both air pollution and noise from engines. It will be emphasized that regular monitoring will be conducted as stated in the EMP. In order to capture any dust and airborne particles a vegetation cover as a buffer zone will be maintained and trees will be replanted to the extent possible near the rail way track area. This will also reduce noise pollution.

3.4.1.5 Mitigatory Measures for Impacts on Noise and Vibrations

Mitigatory Measures for Noise from Vehicles, Plants and Equipment

Noise levels will be monitored during the construction phase as stated in the EMP. In the event ambient levels are far higher than the stipulated limit of 75 dB(A) for daytime construction works (from 6 am to 9 pm), then measures will be taken. All construction workers exposed to noise generating activities and in the vicinity of loud noise and those working with or in compaction, batching or concrete mixing operations, jack hammering, etc. will be provided with standard personal protective equipments (PPEs).

It will be ensured that all construction related machineries and equipments are regularly well maintained by measures such as proper lubrication and will be fitted with noise reduction devices such as exhaust silencers/mufflers. Vehicles used for construction will also have good quality mufflers or silencers to reduce exhaust noise.

High noise emitting machineries, equipments and operations for which it is difficult to apply noise reduction measures such as mechanical compaction, use of saws, crushing plants, excavation works using excavators, jack hammers, concrete mixing and batching, rock drills and rock breakers, will not be used during the night time (from 8 pm to 6 am the following day). It will also be assured that such works shall be done at a reasonable distance away from sensitive receptors to the extent possible.

Near sensitive receptors other measures that will be taken include erection of temporary barriers such as GI fences (about 8-10 feet in height) around the boundary of the construction sites to reduce noise and even dust emission to some extent.

In addition if high power generators are to be used during emergency power failures, it will be assured that low noise emitting generators will be used to the extent possible or to confine the generators in enclosures.

As a precaution to minimize night time disturbance on neighboring communities from noise, heavy vehicle movements will not be carried out during night time (from 8 pm to 6 am the following day).

Mitigation of Vibration due to Blasting Activities

Where blasting activities are required prior to commencement of such activities the contractor will be required to undertake dilapidation surveys to identify any archaeologically/historically important and weak structures that are likely to collapse from high ground vibration levels. A pre-crack survey will also be carried out on structures that will not be removed to monitor and assess any project related impacts from vibration. Prior to blasting activities several test blasts, will be carried out in order to determine the optimum quantity of ANFO and dynamite required per borehole.

3.4.2 Measures to Mitigate Biological Environmental Impacts

Most of the anticipated biological impacts can be mitigated up to minor significance. The residual impact regarding the biological impact should also be very low once appropriate mitigation measures are implemented.

3.4.2.1 Mitigatory Measures for Impacts from Removal of Trees

Considerable amount of trees need to be removed from the ROW and other related facilities. Therefore, a significant impact on the ecological environment is expected. To compensate for the damage, a tree planting program of at least 1:3 ratio with native species will be carried out along with project activities during the construction period. This program would be planned during the detail design stage and an allocation shall be made to implement in suitable locations wherever possible around the project affected area. Further, during construction, removal of trees on temporarily used lands for the project activities would be avoided to the extent possible. When felling trees, it will be confirmed that there are no eggs/ nestlings or roosting on trees. Any guidelines and recommendations made by the CEA or other line agencies with regard to felling of trees will be strictly followed.

3.4.2.2 Mitigatory Measures for Impacts on Fauna and Flora

Significant impacts are not expected from the terrestrial and aquatic fauna and flora during the construction and operation stage of the project and any anticipated impacts can be easily mitigated with proper actions. The clearing of vegetation shall be minimized with the objective of reducing any impacts to the flora and fauna especially including threatened and endemic species. Areas to be cleared will be clearly demarcated and vegetation shall only be cleared when and where absolutely necessary. If possible, vegetative cover shall be left in place. Installation and proper maintenance of exclusion fences for fauna will be assured to reduce mortality of animal during construction and operation period.

To protect aquatic lives, release of construction wastes into water bodies shall be avoided and sedimentation tanks shall be provided to remove the suspended solids. Construction activities which generate a large amount of wastewater shall be carried out at a distance away from water bodies to avoid contamination.

3.4.2.3 Mitigatory Measures for Impacts on Habitats

Habitat degradation from a linear infrastructure development project can be controlled by implementing appropriate mitigation measures. The best form of mitigation is avoidance through designs, so that the potential ecological damage can be stemmed at the source. Incorporation of engineering solutions would help to minimize habitat fragmentation such as tunnels and/or bridges. These structures would help to reduce population isolation by providing links between potentially fragmented habitats. It is essential to limit right of way to areas already showing noticeable signs of habitat degradation. A proper plan shall be developed concerning transportation routes and storage for equipment and material without impacting marshy areas, water bodies and agricultural lands. Soil erosion and sedimentation will also be reduced to the extent possible.

3.4.2.4 Mitigatory Measures for Impacts on Animal Movements and Migratory Paths

Fencing and construction of barrier walls in combination with crossing structures will be used as an effective measure to facilitate animal crossings and will help to prevent access to the rail line and reduce mortality. Fencing of the ROW with climbing guards will prevent both ground dwelling and climbing species from entering the road. Construction of crossing structures (culverts, bridges, small underpass) will be done to minimize mortality and to enhance safety of animals and to provide fundamental requirements.

However, it is noted that the existing rail line also acts as a physical barrier for the movement of animal species. Therefore, significant impacts compared to the current situation will not be expected through the project.

3.4.2.5 Mitigatory Measures for Impacts from Spread of Invasive alien Species

Spread of alien species due to construction activities is a great threat to the environment. Therefore care should be taken to avoid introduction of invasive species to the construction area or spread of existing invasive species within the site from one location to the other. For the purpose contractor would ensure that, construction vehicles, equipments and machineries brought to the site and construction materials obtained from outside areas are free from invasive species. When alien plants are detected in construction areas or sources of construction materials, these would be controlled and cleared using the recommended control measures.

3.4.2.6 Mitigatory Measures for Impacts from Noise, Vibration and Dust

Activities within the project with the potential to cause high noise, vibration and dust will be limited to acceptable levels. The SLR will ensure that the main contractor is experienced in the type of work contained in this project and employ well developed practices to minimize disturbances to neighboring habitats due to noise, dust and vibration.

3.4.3 Measures to Mitigate Socio-Economic Environmental Impacts

3.4.3.1 Mitigatory Measures for Impacts on Relocation

The detailed description of impacts and mitigatory measures on the social environment is given in the Social Impact Assessment section of the Feasibility Report.

For ensuring that a fair and transparent resettlement process is in place it will be carried out as a collaborative effort of a number of government institutions and the public. Relocation of the displaced houses and business establishments will be organized through engagement of these institutions and the DPs and with support from media. It will be ensured that all parties have sufficient information for their decisions and choices and compromises.

Following are some mitigatory measures that will be taken to minimize the social impacts due to relocation.

- Prior to commencement of construction all socially sensitive locations where social impacts are critical will be identified.
- A study will be conducted to verify the present conditions of the resettled communities.
- To the extent possible the affected parties (APs) will be resettled in an environment similar to the environment they had lived previously (Those who were in urban or semi urban settings will be relocated in urban or semi urban settings etc.)
- It will be ensured that the APs are resettled in suitable sites with basic infrastructure facilities. It will also be assured that these basic facilities such as access, water, sanitary facilities and electricity are in place prior to resettlement. Other considerations that would be used in site selections are; location of schools, work places of APs, places of worship etc.
- A comprehensive program will be established to provide guidance, facilitation, and also other required financial and technical support to resettled communities to establish sustainable livelihood systems so that they will be better adapted to the new environment.
- Negotiation with land owners for acquisition will be done prior to relocation.
- A special focus study will be conducted to prepare a relocation action plan.
- Compensation would be paid based on a carefully designed resettlement and compensation package.
- When acquired lands are assessed for compensation perennial crops grown in such lands shall also be taken into account.
- Monitoring and Evaluation of the implementation of the Resettlement Plan will be done to ensure that the plan is effective, there are no unanticipated issues and if necessary take immediate actions to resolve these issues.

3.4.3.2 Mitigatory Measures for Impacts on Landuse Patterns

To minimise any adverse changes on the existing landuse it will be assured that detailed layout plans and architectural designs for any buildings including stations are prepared in advance. It will also be assured that required physical infrastructure, parking facilities, well landscaped areas and other amenities are provided to each and every station. In addition as a precaution to prevent any new encroachments in to the newly cleared up ROW, special regulations and enforcement measures will be introduced.

As a positive impact on landuse secondary development activities and informal business would be encouraged and planned out in a comprehensive manner. Such activities would be accommodated in to the main layout of railway stations and its surroundings.

3.4.3.3 Mitigatory Measures for Impacts on Economics

The subproject will ensure that all parties who will face economic impacts due to loss of commercial buildings, home based industries and livelihood are compensated for even if their building structures are not affected physically by the subproject. The subproject will ensure that if a business center is demolished the owners would be compensated for them to re-establish their business/ commercial centers in an alternative place. In addition it will be assured that construction sites are properly managed to avoid disturbances to the business/ commercial centers located in the immediate vicinity of the railroad trace.

Compensation will be paid for the extent of land lost and perennial crops.

3.4.3.4 Mitigatory Measures for Impacts on Transport Networks

During the construction period users of the roads running across the proposed railway track would be given alternative access and design engineers will explore methods of providing alternate or bypass roads to the sections of the roads that are disturbed due to railroad construction activities.

During the operation phase of the subproject overhead bridges or surface rail crossings will be designed to mitigate the potential negative impacts on the road network in the area. In the design of the subproject safe crossings will be provided for important minor roads identified during detailed field verifications by way of underpasses or over passes or at-grade control systems. The rest of the minor roads would also be connected through service roads running parallel to the Railway line. Exact lengths and locations would be identified during field verifications. The decision on provision of an overpass or an underpass will depend on the formation levels of the expressway based on geographic and hydrology requirements (high flood level).

Measures will be taken to coordinate the bus services with the new railway stations. At certain locations re-planning of bus routes may be required as the use of railway is expected to increase significantly after implementation of the subproject.

3.4.3.5 Mitigatory Measures for Impacts on Aesthetic Considerations

Necessary actions will be taken to identify and inventories areas and sites of aesthetic significance. In the design of stations and other project related structures compatibility with the existing environment and structures would be ensured.

3.5 Grievance Regress Mechanism

The Grievance Regress Mechanism applicable for the subproject is discussed in detail in the Social Impact Assessment Section of the Feasibility Report.

3.6 Environmental Management Plan

A. Environmental Management Plan (EMP)

The Environmental Management Plan (EMP) forms a part of the Bid Documents and should be considered alongside the specifications. Thereby the prescriptions detailed in the EMP are mandatory in nature and also contractually binding. The EMP will also be equally applicable to sub-contractors including nominated sub-contractors if any. The main contractor will be responsible for the compliance with the requirements of the EMP by sub-contractors including nominated sub-contractors. With the assistance of the Construction Supervision Consultant the "Engineer" on behalf of the Employer the Ministry of Transport and Civil Aviation will monitor the compliance of EMP by the contractor.

This EMP identifies the geographical locations where the clauses stated in the EMP are particularly applicable. The EMP for the subproject is given in Section 1.3 of the Requirement and Rule Book.

3.7 Conclusions and Recommendations

The Environmental Assessment for the feasibility has shown that there are certain environmental impacts associated with the subproject. The main concerns are noise and vibration impacts on the adjoining communities and structures for which mitigatory measures are proposed and will be included in to the detailed design. The socio-economic impacts are significant due to the large number of resettlements required for the clearing of ROW even if they are illegal settlements. This will be mitigated through a carefully planned resettlement program.

It is concluded in the feasibility study that all the environmental impacts anticipated from the subprojects can be mitigated with appropriate mitigatory measures and by following the proposed environmental management plan. In line with the requirements of the Central Environmental Authority (CEA) of Sri Lanka a Basic Information Questionnaire (BIQ) was submitted to the CEA which has issued the TOR for a detailed Environmental Impact Assessment to be submitted for environmental clearance. The preparation of the detailed EIA is presently underway.

CHAPTER

4

Social Impact Study

Chapter 4 Social Impact Study

Chapter Summary

As per the survey on the first section of KV-Line (Maradana-Homagama) there are 3,055 structures impacted in total, of which 2,206 are residential houses. About 1,908 residential houses will incur risk of demolition due to major impacts while a further 298 houses will risk minor damages. Of these households of residential structures, 163 sub families share accommodation, sometimes more than one sub-family in the same house. The residential units consist of 692 titleholders and 1,467 non-titleholders. The most severely affected group is the people who lose their present housing due to the project. This 2,206 HHs consist of 8,492 persons, of which 4,341 are females (51.1%) and 4,151 are males (48.9%).

The affected households are very limited and quite negligible, beyond Homagama particularly in the Padukka–Avissawella Section, where only single rail-line is ear-marked for rehabilitation. Compared to the first Section, the RoW of second Section is almost devoid of squatters of encroachers. Adding to the 8,492 affected persons in the first Section of KV-Line, it is assumed that with rough estimates, there will be another 1,500 APs in the Second Section, totaling to 10,000 APs in the entirety of existing KV Line.

The people were generally enthusiastic about the project and believed that it will bring social and economic development into the region. People believed that the development of railway will improve connectivity for the local people from one place to another. Of the people, falling to the category of poor, around 244 persons receive welfare benefits from the government under Samurdhi programme. Another 135 persons receive benefits from other government welfare programmes due to their lower income and other social vulnerabilities, and there are 11 other persons below poverty line not receiving welfare as yet.

The resettlement cost estimate for this project includes eligible compensation, resettlement assistance and support cost for RP implementation. The support cost, which includes staffing requirement, monitoring and reporting, involvement of Implementing Agency in subproject implementation and other administrative expenses are part of the overall project cost. The unit cost for land and other assets in this budget has been derived through field survey, consultation with affected families, relevant local authorities and reference from old practices. Contingency provisions have also been made to take into account variations from this estimate. The total Estimated Cost (indicative) for the Social Resettlement / Land Acquisition of KV Line stands at SLR 15.793 billion or US $ 99.328 million.

The most critical factor to be considered in resettlement of squatters living in State land under SLR is their entitlements for compensation. As per ADB Safeguard Policy and the NIRP of Sri Lanka, squatters are entitled only for replacement cost, and most of the housing structures within the RoW land are extremely small dwellings for which replacement cost would be minimal, not adequate at all for the APs to resettle elsewhere.

Keeping in line with the critical and challenging nature of the project being a category A of ADB in terms of resettlement requirement, the lessons learnt from similar resettlement projects should be properly utilized by the PMU of this project for timely implementation of the project.

4.1 Project Location

The total length of the section from Maradana to Padukka is 35.24 km. As the alignment is planned within the existing ROW, it has many curve sections with small radius of curves. In this reason, speed limit for operation is inevitable; hence the commercial speed is very low. Meanwhile, this option causes less land acquisition, which leads to low cost as well as less time for land purchase. Thus, it would make use the advantage of minimizing the project duration.

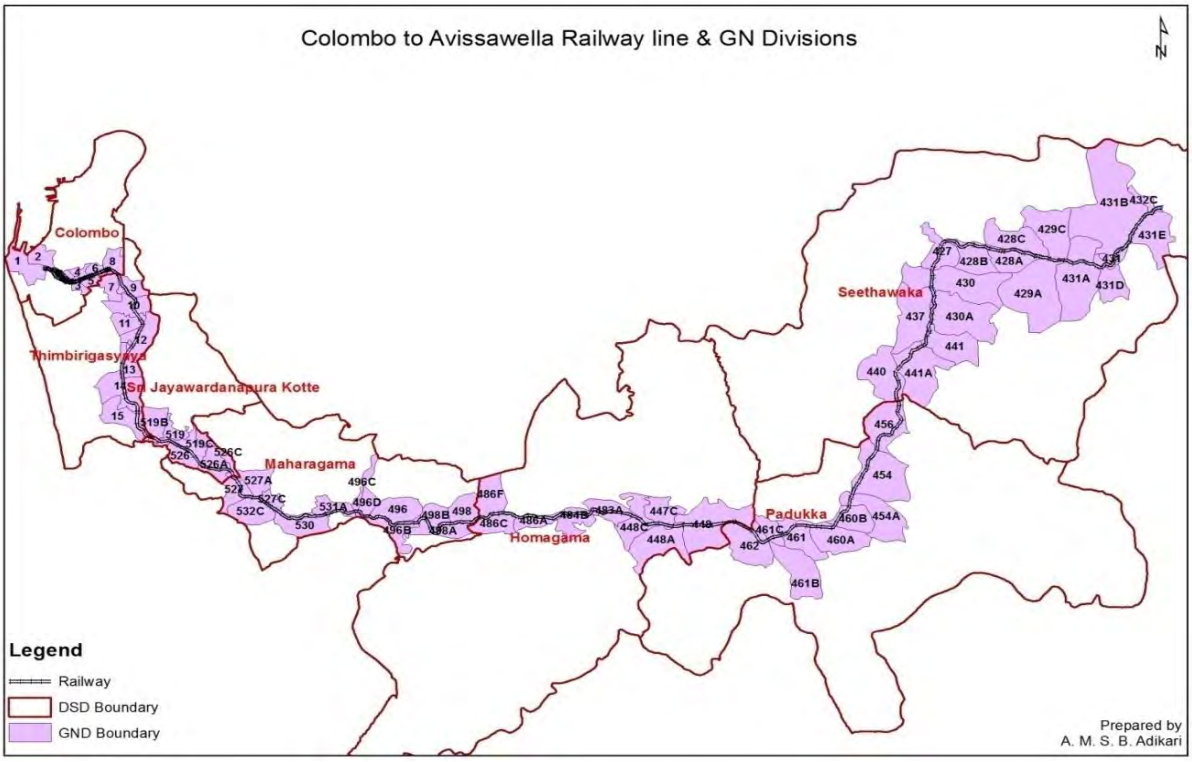


Figure 4-1 Map Showing the Project Area – KV Line by DS and GN Divisions

4.2 Socio-Economic Profile of the Affected Area

4.2.1 Demographic Characteristics

The project area along the KV-Line consists of 70 GN Divisions in 6 DS Divisions and they are coming under the administration district of Colombo, which falls to the Western Province of Sri Lanka. Local Government-wise it belongs to 6 councils distributed as 2 Municipal Councils, 2 Urban Councils and 2 Pradeshiya Sabhas.

The total length of existing KV Line from Maradana to Avissawella has a total of 36 Railway Stations, which include 6 main Satellite Cities in Colombo Metropolitan Region. A good majority of stations between Padukka and Avissawella serve as halting places without even basic facilities (Table 4-1):

Table 4-1 Towns / Main Stations Connected by KV Line

Serial No.	Name of Railway Station	Distance from Maradana Railway Station (km)railway Station (Km)	Serial No.	Name of Railway Station	Distance from Maradana Railway Station (km)
1	Baseline Road	01.88	19	Padukka *	35.24
2	Cotta Road	03.55	20	Arukwatta	37.00
3	Narahenpita*	05.62	21	Angampitiya	38.06
4	Kirulapone	07.36	22	Uggala	39.08
5	Nugegoda*	09.15	23	Pinnawala	40.10
6	Udahamulla	11.52	24	Gammana	41.34
7	Navinna	13.29	25	Morakele	42.14
8	Maharagama*	14.46	26	Waga	44.36
9	Pannipitiya	17.11	27	Kudugoda	46.66
10	Kottawa	19.41	28	Aparangama	47.84
11	Malapalla	17.60	29	Kosgama	49.33
12	Homagama Hospital Roundabout	22.40	30	Aluthambalama	50.90
13	Homagama*	24.61	31	Miriswatta	52.18
14	Panagoda	26.30	32	Higurala	53.52
15	Godagama	28.02	33	Puwakpitiya	55.40
16	Meegoda	29.60	34	Puwakpitiya Town	56.27
17	Watareka	31.20	35	Kiriwandala	57.43
18	Liyanawala	33.60	36	Avissawella*	59.14
*	*Main Stations or 'Tablet Stations' along the KV-Line*				

Source: Sri Lanka Railways

The total population living in the immediate hinterland of the KV-Line as of 2011 Census is reported as 317,180 of which 160,053 are male and 157,127 are female (Table 4-2).

The information included into this section is based mainly on: 1) Socio-economic Survey conducted by UN-Habitat on the 1st Section of KV-Line Maradana to Homagama, and 2) Desk Study and Random survey conducted by the Social, Resettlement and Gender (SR&G) Team of the project.

Table 4-2 GN Level Demographic information in the Project Area - 2011

DS Division	GN Division	LG - MC/UC/PS	Population	Male	Female
COLOMBO	Maligakanda	Colombo MC	8068	4133	3935
	Maradana	Colombo MC	4548	2419	2129
	Panchikawatta	Colombo MC	8420	4203	4217
	Pettah	Colombo MC	1749	1699	50
	Fort	Colombo MC	653	428	225
	Maligawatta West	Colombo MC	8893	4402	4491
	Maligawatta East	Colombo MC	11477	5776	5701
Sub Total	7		43,808	23,060	20,748
THIMBIRIGASYAYA	Kuppiyawatta East	Colombo MC	10544	5499	5045
	Wanathamulla	Colombo MC	17313	8536	8777
	Borella South	Colombo MC	4910	2460	2450
	Borella North	Colombo MC	21078	13472	7606
	Narahenpita	Colombo MC	11062	5519	5543
	Gothamipura	Colombo MC	6448	3200	3248
	Kirulapone	Colombo MC	17705	8767	8938
	Kirula	Colombo MC	20249	9693	10556

DS Division	GN Division	LG - MC/UC/PS	Population	Male	Female
Sub Total	8		109,309	57,146	52,163
SRI J'PURA KOTTE	Nugegoda	Sri J'puraKotte MC	3312	1690	1622
	Nugegoda West	Sri J'puraKotte MC	5585	2616	2969
	Gangodavila North	Sri J'puraKotte MC	5323	2485	2838
	Gangodavila South	Sri J'puraKotte MC	7243	3534	3709
	Gangodavila East	Sri J'puraKotte MC	3305	1639	1666
	Pagoda East	Sri J'puraKotte MC	5883	2899	2984
Sub Total	6		30,651	14,863	15,788
MAHARAGAMA	Kottawa North	Homagama PS	2284	1087	1197
	Kottawa South	Homagama PS	7147	3462	3685
	Kottawa West	Homagama PS	2752	1343	1409
	Kottawa Town	Homagama PS	5479	2775	2704
	Malapalla West	Homagama PS	2673	1297	1376
	Makumbura North	Homagama PS	3436	1652	1784
	Maharagama West	Maharagama UC	2460	1257	1203
	Pathiragoda	Maharagama UC	6536	3187	3349
	Pannipitiya South	Maharagama UC	2253	1069	1184
	Maharagama Town	Maharagama UC	5422	2682	2740
	Navinna	Maharagama UC	4892	2303	2589
	Malapalla East	Homagama PS	3602	1746	1856
	Godigamuwa North	Maharagama UC	4045	1822	2223
Sub Total	13		52,981	25,682	27,299
HOMAGAMA	Homagama Town	Homagama PS	2614	1293	1321
	Pitipana Town	Homagama PS	3060	1596	1464
	Godagama South	Homagama PS	3122	1520	1602
	Ovitigama	Homagama PS	4691	2317	2374
	Watareka South	Homagama PS	6379	3090	3289
	Kurunduwatta	Homagama PS	3850	1825	2025
	Gehenuwala	Homagama PS	2020	997	1023
	Galavilawatta North	Homagama PS	3512	1688	1824
	Homagama South	Homagama PS	3203	1649	1554
Sub Total	9		32,451	15,975	16,476
PADUKKA	Liyanwala	Homagama PS	1173	571	602
	PahalaPadukka	Seethawaka PS	1328	639	689
	Udumulla	Seethawaka PS	2326	1131	1195
	Pinnawala North	Seethawaka PS	843	406	437
	Padukka	Seethawaka PS	2958	1460	1498
	Ganegoda	Seethawaka PS	1156	547	609
	Arukwatta South	Seethawaka PS	2155	1068	1087
	Angampitiya	Seethawaka PS	2164	1057	1107
	Uggalla	Seethawaka PS	1926	948	978
Sub Total	9		16029	7827	8202
SEETHAWAKA	Kahahena	Seethawaka PS	1626	798	828
	Kadugoda North	Seethawaka PS	1447	692	755
	Kadugoda South	Seethawaka PS	1729	842	887
	Eswatta South	Seethawaka PS	1620	792	828
	Pahala Kosgama East	Seethawaka PS	1830	918	912
	Aluth Ambalama	Seethawaka PS	1834	874	960
	Miriswatta	Seethawaka PS	2092	1031	1061
	IhalaKosgama South	Seethawaka PS	1307	612	695
	Hingurala	Seethawaka PS	2088	976	1112
	Weragolla North	Seethawaka PS	1876	879	997
	Mambula	Seethawaka PS	1126	533	593
	Neluwattuduwa	Seethawaka PS	664	322	342
	Mawalgama	Seethawaka PS	2028	980	1048

DS Division	GN Division	LG - MC/UC/PS	Population	Male	Female
Sub Total	13		21,267	10,249	11,018
SEETHAWAKA	Puwakpitiya	Seethawakapura UC	1281	611	670
	Egodagama	Seethawakapura UC	1296	625	671
	Kiriwandala South	Seethawakapura UC	2128	1063	1065
	Ukwatta	Seethawakapura UC	2632	1258	1374
	Kiriwandala North	Seethawakapura UC	3347	1694	1653
Sub Total	5		10,684	5,251	5,433
GRAND TOTAL	70	6 LGs	317,180	160,053	157,127

Note:
According to the Socioeconomic Survey of UN-Habitat -2017, the total no. of affected persons, is 8,492 in the Maradana – Homagama Section of KV-Line; and it is assumed with rough estimates, there will be another 1,500 APs in the Second Section (P-A), totaling to 10,000 APs in the entirety of existing KV Line.

Source: Department of Census and Statistics 2011

Main socio-economic data, in the preceding section are mainly derive from the findings of the UN-Habitat's survey (2017), except for general information and specific estimates made on the Homagama-Avissawella Section of the KV-Line by the SR&G Team of the project.

4.2.2 Households Characteristics - Size and Distribution

Unless otherwise mentioned, the demographic analyses in the preceding sections are mainly on the Maradana-Homagama section, based on the total survey conducted by UN-Habitat. Accordingly, it is a fact that the most severely affected group of all is the people who lose their present housing due to the project. This group consists of 2,206 households with a total population of 8,492 persons, of which 4,341 are females (51.1%) and 4,151 are males (48.9%) as summarized in Table 4-3.

The affected households are very limited and quite negligible, beyond Homagama particularly in the Padukka–Avissawella Section, where only single rail-line is ear-marked for rehabilitation. Compared to the Maradana-Homagama Section, the RoW of this Section is almost devoid of squatters of encroachers.

Squatters near Udahamulla Station

A Permanent Building within the RoW in Udahamulla

Figure 4-2 Map Showing the Project Area – KV Line by DS and GN Divisions

Table 4-3 Distribution of Affected Households by DS Division and Gender

DS Division	No. of HHs	Female		Male		Total
		No	%	No	%	
Homagama	63	120	49.38	123	50.62	243
Kotte	317	603	51.19	575	48.81	1178
Maharagama	456	875	51.08	838	48.92	1713
Thimbirigasyaya	1370	2743	51.19	2615	48.81	5358
Total	2206	4341	51.12	4151	48.88	8492

Source: Socioeconomic Survey of UN-Habitat, 2017

As shown in Table 4-4, the sub-family households share the housing unit with the main family. The number of main households with one sub family sharing is 124. In 11 other cases the same premises is shared by 2 sub families, and it was also found the rare case of five households accommodating 3 to 4 sub-family households.

Table 4-4 Distribution of Sub-family Households by DS Division

DS Division	One sub family within the main house	Two sub families within the main house	Three sub families within the main house	Four sub families within the main house	Total
Homagama	01	0	0	0	01
Kotte	18	01	0	0	19
Maharagama	12	0	0	0	12
Thimbirigasyaya	93	10	3	2	108
Total	124	11	3	2	140

Source: Socioeconomic Survey of UN-Habitat, 2017

UN-H Survey has also found that nearly 51 percent of the heads of project affected households are persons in age category of 40-60 years. About 25 percent of heads of households are above 61 years, while only 2.4 percent of heads are between 17 to 25 years in age as given in Table 4-5.

Table 4-5 Distribution of Project Affected Heads of Households by Age Categories

DS Division	No Response		17 to 25 Years		26 to 40 Yrs.		41 to 60 Yrs.		Above 61 Yrs.		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	
Homagama	1	1.59	3	4.76	5	7.94	36	57.14	18	28.57	63
Kotte	2	0.63	2	0.63	65	20.50	141	44.48	107	33.75	317
Maharagama	2	0.44	6	1.32	97	21.27	221	48.46	130	28.51	456
Thimbirigasyaya	5	0.36	41	2.99	309	22.55	727	53.07	288	21.02	1370
Total	10	0.45	52	2.36	476	21.58	1125	51.00	543	24.61	2206

Source: Socioeconomic Survey of UN-Habitat, 2017

The children below 5 years accounts for 5.6 percent of the total affected population. The population within schooling age is 21.4 percent. From the total population, about 61.5% of people are within employable age. About 11.5 percent of the populations are above 61 years or above and some of them may have disabilities due to age. The information on age diversity of the project affected population in the group that would be permanently displaced is shown in Table 4-6.

Table 4-6 Distribution of Project Affected Persons (APs) by Age Category and DS Division

DS Division	5 <	%	5 - 18	%	19 - 29	%	30 - 60	%	> 61	%	Total	%
Homagama	11	4.53	51	20.99	35	14.40	110	45.27	36	14.81	243	2.86
Kotte	62	5.26	248	21.05	179	15.20	518	43.97	171	14.52	1178	13.87
Maharagama	73	4.26	376	21.95	261	15.24	740	43.20	263	15.35	1713	20.17
Thimbirigasyaya	325	6.07	1142	21.31	1031	19.24	2353	43.92	507	9.46	5358	63.09
Total	471	5.55	1817	21.4	1506	17.73	3721	43.82	977	11.5	8492	100.0

Source: Socioeconomic Survey of UN-Habitat, 2017

UN-H Survey has revealed that household size ranged from 1 to 10 persons or more, with the 4 to 5 person category constituting the predominant group with 923 or 41.8 percent of total households, followed by 37.3 percent of households consisting of 2 to 3 members, and only about 6.3 households are single member households, which is given in Table 4-7.

Table 4-7 Distribution of Household by Size

DS Division	Size of Household and Distribution as Percentage of Total										
	1	%	2 to3	%	4 to 5	%	6 to 10	%	> 10	%	Total
Homagama	8	12.7	21	33.33	22	34.92	12	19.05	0	0	63
Kotte	22	6.94	115	36.28	143	45.11	36	11.36	0	0	317
Maharagama	22	4.82	180	39.47	202	44.3	51	11.18	0	0	456
Thimbirigasyaya	87	6.35	506	36.93	556	40.58	217	15.84	4	0.29	1370
Total	139	6.3	822	37.26	923	41.84	316	14.32	4	0.18	2206

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.3 Ethnicity and Religion

With regards to ethnicity as found in SES of UN-H, some 78 percent of households identified for resettlement are Sinhala, 18 percent Tamil and 4 percent Muslim, as depicted in Table 4-8.

Table 4-8 Distribution of Population by Ethnicity

DS Division	Sinhala	%	Tamil	%	Muslim	%	Other	%	Total
Homagama	240	98.77	3	1.23	0	-	0	-	243
Kotte	1031	87.52	107	9.08	35	2.97	5	0.42	1178
Maharagama	1667	97.31	20	1.17	21	1.23	5	0.29	1713
Thimbirigasyaya	3686	68.79	1376	25.68	280	5.23	16	0.30	5358
Total	6624	78	1506	17.73	336	3.96	26	0.31	8492

Source: Socioeconomic Survey of UN-Habitat, 2017

As per the religious composition of the households indicates that 75 percent are Buddhists, 10 percent Christian, 11 percent Hindus and 4 percent Islamic, which is shown in Table 4-9;

Table 4-9 Distribution of Affected Population by DS Division and Religion

DS Division	Buddhist	%	Christian	%	Hindu	%	Muslim	%	Total
Homagama	240	98.77	1	0.41	2	0.82	0	0.00	243
Kotte	1635	95.45	49	2.86	6	0.35	23	1.34	1713
Maharagama	3540	66.07	691	12.90	856	15.98	271	5.06	5358
Thimbirigasyaya	984	83.53	128	10.87	41	3.48	25	2.12	1178
Total	6399	75.35	869	10.23	905	10.66	319	3.76	8492

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.4 Period of Residence

In terms of the period of occupancy in the present place of residence of 87 percent of all households exceeds 3 years. In most cases (70.5%), it exceeds 10 years as given in Table 4-10.

Table 4-10 Period of Occupancy in Present Place of Residence

DS Division	Less than 3 Yrs		4 to 5 Yrs		6 to - 8 Yrs		9 to 10 Yrs		More than 10 Yrs.		Not responded		Total
	No	%	No	%	No	%	No	%	No	%	No	%	No
Homagama	11	17.46	0	0	1	1.59	6	9.52	43	68.25	2	3.17	63
Kotte	28	8.83	7	2.21	17	5.36	26	8.2	230	72.56	9	2.84	317
Maharagama	68	14.91	11	2.41	24	5.26	24	5.26	317	69.52	12	2.63	456
Thimbirigasya	175	12.77	33	2.41	60	4.38	110	8.03	965	70.44	27	1.97	1370
Total	282	12.78	51	2.31	102	4.62	166	7.52	1555	70.49	50	2.27	2206

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.5 Household Amenities

It is observed that most households have access to piped water supply service from the NWSDB. About 1, 341 households have individual supply connections while 230 access common tap water points installed by the government. About 150 households draw drinking water from wells. About 276 households have access to other water sources as indicated in Table 4-11.

Table 4-11 Access to Drinking Water

Water Source	Homagama		Kotte		Maharagama		Thimbirigasyaya		Total
	No	%	No	%	No	%	No	%	No.
Common tap (Public tap stand)	1	1.59	57	17.98	9	1.97	163	11.90	230
Common well	3	4.76	4	1.26	4	0.88	2	0.15	13
Neighbours	3	4.76	22	6.94	28	6.14	75	5.47	128
Neighbours Well	8	12.70	5	1.58	19	4.17	1	0.07	33
Neighbours Tap	1	1.59	2	0.63	2	0.44	5	0.36	10
Other Water Source	5	7.94	16	5.05	44	9.65	211	15.40	276
Own tap (pipe borne)	23	36.51	194	61.20	281	61.62	873	63.72	1,341
Own well	19	30.16	7	2.21	68	14.91	10	0.73	104
Not responded	0	0.00	10	3.15	1	0.22	30	2.19	41
Total	63	100	317	100	456	100	1,370	100	2,206

Source: Socioeconomic Survey of UN-Habitat, 2017

As regards to sanitation facilities, over 54 percent of the households have toilets with squatting pan while 32 percent have toilets with commodes as shown in Table 4-12.

Table 4-12 Access to Sanitary Facilities

DS Division	Commode	%	Squatting Pan	%	Other	%	Total
Homagama	21	34.4	32	52.5	8	13.1	61
Kotte	114	36.1	147	46.5	55	17.4	316
Maharagama	194	42.2	218	47.4	48	10.4	460
Thimbirigasyaya	376	27.5	796	58.1	197	14.4	1,369
Total	705	32.0	1,193	54.1	308	14.0	2,206

Source: Socioeconomic Survey of UN-Habitat, 2017

In the area of access to energy for household purposes, except for 180 households that use kerosene lamps and 77 households that use other sources for lighting, most households have access to electricity from the national grid, as recorded in the SES Report of 2017. Most households use LP Gas for cooking purposes. Firewood is an important source for 40 percent of households in Homagama, 22 percent in Maharagama and 20 percent in Kotte. On the other hand, Kerosene is used for cooking by 19 percent of households in Thimbirigasyaya, as given in Table 4-13.

Table 4-13 Access to Energy for Cooking Purposes

Source of Cooking	Homagama		Kotte		Maharagama		Thimbirigasyaya	
	No	%	No	%	No	%	No	%
LP Gas	44	55	250	73.53	390	70.78	1085	72.19
Kerosene Oil	2	2.5	15	4.41	15	2.72	286	19.03
Electricity	2	2.5	7	2.06	24	4.36	18	1.20
Firewood	32	40	68	20.00	120	21.78	110	7.32
Other	0	0	0	0.00	2	0.36	4	0.27
Total	80	100	340	100	551	100.00	1503	100

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.6 Household Assets

As per household assets, 832 households have a car, bus, van, three-wheeler or a motor bicycle. Three-wheeled vehicles are available in 384 households, 133 households own a car or cabs, and a further 37 households possess vans or buses. While motor cycle owners and push-bicycle owners account to 278 and 220 respectively, about 69 households own water pumps (Table 4-14).

Table 4-14 Ownership of Movable Assets

No.	Item	No. of Households	Percent
1	Television	1606	72.80
2	Radio/CD player	1215	55.08
3	Sewing machine	591	26.79
4	Fan	1602	72.62
5	Refrigerator	1024	46.42
6	Air conditioner	28	1.27
7	Motor cycle	278	12.60
8	Bicycle	220	9.97
9	Three wheeler	384	17.41
10	Car/cab	96	4.35
11	Bus/van	37	1.68
12	Water pump	69	3.13
13	Washing machine	417	18.90
14	Other - Furniture	207	9.38
15	Other -Kitchen Appliances	14	0.63
16	Other-Computers	72	3.26
17	Other-Mobile Phones	107	4.85

Source: Socioeconomic Survey of UN-Habitat, 2017

Among other assets, the electrical appliances used by households are television (1,606), radio (1,215), fans (1,602), refrigerator (1,024), air-conditioners (28), washing machines (417), and computers (72). In addition, sewing machines are available in 591 households, and Mobile phones are available in 107 households.

4.2.7 Livelihoods Pattern

It is recorded that Households in the project impact area are dependent on multiple sources of livelihoods, which include; a) employments in the industrial and service sectors comprised of public sector (national, provincial, local), b) private sector employment (trade, commerce, industry, finance), and c) business activities, passenger and goods transport (public, private, taxi including 3-wheel transport etc.). There is also self-employment, daily paid wage employment, and foreign employment. Based on the primary occupation of the head of the household the employment pattern observed are summarized as:

- Self-employment is the dominant source of employment – 44 percent,
- Followed by unskilled labour - 15 percent,
- Private sector employment 14 percent, and
- Public sector employment – 7 percent.

It is found that about 12 percent of the household heads are reported to be unemployed at the time of the Survey in 2017. Table 4-15 provides the breakdown.

Table 4-15 Primary Occupation of the Head of the Household

CHH's Primary Occupation	Homagama		Kotte		Maharagama		Thimbirigasyaya		Total	
	No	%	No	%	No	%	No	%	No	%
Govt. / Semi Govt.	1	1.2	22	4.0	48	5.2	127	8.9	198	6.6
Private sector	11	14.4	59	10.7	88	9.6	259	18.0	417	14.4
Unskilled/daily paid/ contract labor	15	18.3	88	15.9	79	8.6.	279	19.4	461	15.4
Self-employed	34	41.5	276	49.9	543	59.3	468	32.6	1,321	44.3
Retired with pension	8	9.8	33	6.0	43	4.7	62	4.3	146	4.9
Foreign employment	3	3.7	14	2.5	18	2.0	43	3.0	78	2.6
Unemployed	12	12.2	61	11.0	96	10.5	197	13.7	364	12.2
Total	84	2.7	553	18.5	915	30.7	1,435	48.1	2,985	100.0

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.8 Household Income & Expenditure Pattern

According to the SES, about 408 chief householders earn a monthly income of Rs.15,000 or less. The group with an income of Rs.15,001 to Rs.50,000 per month consists of 1,268 persons while 274 chiefs earn a monthly income higher than Rs.50,000 as shown in Table 4-16.

Table 4-16 Reported Income of Heads of Households

DS Division	> 10,000	10,000 - 15,000	15,001 - 25,000	25,001-50,000	> 50,000	Not Responded	Total
Homagama	4	12	17	19	5	6	63
Kotte	16	52	81	86	40	42	317
Maharagama	37	60	82	145	87	45	456
Thimbirigasyaya	66	161	347	491	142	163	1370
Total	123	285	527	741	274	256	2206

Source: Socioeconomic Survey of UN-Habitat, 2017

Coming to household income, the category earning a monthly income of Rs. 15,000 or less is about 6.6 percent of all households, and around 52 percent households earn income of Rs. 15,001 to Rs. 50,000, while the category earning income higher than Rs, 50,000 per month is about 41 percent.

Within each DSD, the high income earning category forms the largest group, ranging from 36 percent in Homagama to 45 percent Maharagama as shown in Table 4-17.

Table 4-17 Reported Total Household Income

DS Division	Less than 10,000		10,000 to 15,000		15,001 to 25,000		25,001 to 50,000		Greater than 50,000		Total
	No	%	No	%	No	%	No	%	No	%	No
Homagama	3	5.08	4	6.78	9	15.25	22	37.29	21	35.59	59
Kotte	5	1.62	22	7.14	50	16.23	105	34.09	126	40.91	308
Maharagama	14	3.11	16	3.56	49	10.89	170	37.78	201	44.67	450
Thimbirigasyaya	21	1.55	59	4.34	166	12.22	562	41.38	550	40.5	1358
Total	43	1.98	101	4.64	274	12.6	859	39.49	898	41.29	2175
Note: Only 2175 families (out of 2206) given their Income											

Source: Socioeconomic Survey of UN-Habitat, 2017

Regarding the expenditure pattern, about 52 percent of the households spend more than Rs.35,000 a month, 9 percent of households spend Rs.15,000 or less, and 39 percent households spend Rs.15,001 to Rs.35,000 per month, as shown in Table 4-18.

Table 4-18 Pattern of Expenditure of Potentially Resettled Households

Expenditure Range	< 5,000		5,001 to 10,000		10,001 to 15,000		15,001 to 25,000		25,001 to 35,000		More than 35,000		Not given		Total
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	
Homagama	1	1.7	4	6.8	5	8.5	10	16.9	8	13.6	31	52.5	4	6.8	59
Kotte	6	2.0	4	1.3	27	8.9	60	19.7	63	20.7	144	47.4	13	4.3	304
Maharagama	6	1.4	14	3.2	17	3.8	57	12.8	84	18.9	266	59.9	12	2.7	444
Thimbirigasyaya	7	0.5	30	2.2	73	5.4	247	18.3	312	23.1	679	50.4	22	1.6	1348
Total	20	0.9	52	2.4	122	5.7	374	17.4	467	21.7	1120	52.0	51	2.4	2155

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.9 Poverty and Vulnerability

Of the people, who fall to category of poor, around 244 persons receive welfare benefits from the government under Samurdhi programme. Another 135 persons receive benefits from other government welfare programmes due to their lower income and other social vulnerabilities, and there are 11 other persons below poverty line but not receiving welfare as yet as given in Table 4-19.

Table 4-19 Poverty Status of Project Affected Families

DSD	Homagama		Kotte		Maharagama		Thimbirigasyaya		Total
	No	%	No	%	No	%	No	%	
Samurdhi Families	1	0.4	51	17.9	60	24.6	132	54.1	244
Other Welfare	0	0.0	16	11.9	26	19.3	93	68.9	135
Below Poverty Line	0	0.0	2	18.2	5	45.5	4	36.4	11
Total	**1**	**0.3**	**69**	**17.7**	**91**	**23.3**	**229**	**58.7**	**390**

Source: Socioeconomic Survey of UN-Habitat, 2017

As revealed in the SES report of UN-H, there are presences of 408 persons with disability, 54 persons with mental disorders, 155 persons with chronically ill condition, 492 persons widowed, 52 separated persons and 977 elderly persons, which are shown in Table 4-20.

Table 4-20 Distribution of Vulnerable Persons by DS Division

DS Division	Disabled Members	Mental Diseases	Chronically Ill	Widowed	Separated	Elderly
Homagama	7	1	4	17	4	36
Maharagama	122	11	48	98	10	171
Thimbirigasyaya	237	33	81	296	33	263
Kotte	42	9	22	81	5	507
Total	**408**	**54**	**155**	**492**	**52**	**977**

Source: Socioeconomic Survey of UN-Habitat, 2017

4.2.10 Role of Women and Gender Issues

According to the FGDs and KIIs-based findings of the Socioeconomic Survey Report, main the aspects that are emphasized in relation to the socioeconomic situation of women are:

- Women play a critical role in household decision making
- Women possess higher standards of education than men
- Women living in the SLR reservation have access to common water and sanitation facilities
- Women are the most vulnerable group in the reservation area

There are 4,341 females in the 2,206 households that need to be resettled. Nearly 49.3 percent of all females are married (inclusive of 0.25% unregistered marriages), 11.3 percent widows, 1.2 percent separated, and 0.6 percent divorced. Almost 24.6 percent of the total female population belongs to the age group below 18 years, as indicated in Table 4-21.

Table 4-21 Marital Status of Female Population of the Potentially Resettled Community

Marital Status	Homagama		Kotte		Maharagama		Thimbirigasyaya		Total	
	No	%	No	%	No	%	No	%	No	%
Registered Marriage	53	44.17	288	47.76	434	49.60	1353	49.33	2128	49.02
Unmarried(below18)	28	23.33	144	23.88	217	24.80	680	24.79	1069	24.63
Unmarried(above18)	18	15.00	83	13.76	110	12.57	351	12.80	562	12.95
Divorced	0	-	2	0.33	5	0.57	20	0.73	27	0.62
Widowed	17	14.17	81	13.43	98	11.20	296	10.79	492	11.33
Separated	4	3.33	5	0.83	10	1.14	33	1.20	52	1.20
Unregistered Marriage	0	-	0	-	1	0.11	10	0.36	11	0.25
Total	120	100.00	603	100.00	875	100.00	2743	100.00	4341	100.00

Source: Socioeconomic Survey of UN-Habitat, 2017

In general, women play an important role in household level decision making. These decisions include: daily expenses of the households (38%), income saving (40%) and preparation of daily meals (52%). Two of the main household decisions taken jointly by the husband and wife include, voting at elections (40%), and buying electrical items (31%). Table 4-22 gives the breakdown.

Table 4-22 Involvement in Household Decision Making

Decision	Husband		Wife		Husband and Wife		Children		As a family	
	No	%	No	%	No	%	No	%	No	%
Buying electrical items	382	17.32	294	13.33	688	31.19	174	7.89	236	10.70
Children's Education	130	5.89	480	21.76	548	24.84	71	3.22	112	5.08

Decision	Husband		Wife		Husband and Wife		Children		As a family	
	No	%	No	%	No	%	No	%	No	%
Daily expenses	392	17.77	836	37.90	513	23.25	67	3.04	151	6.84
Getting a loan	251	11.38	369	16.73	585	26.52	74	3.35	147	6.66
Obtaining membership in societies	232	10.52	427	19.36	634	28.74	75	3.40	181	8.20
Meals	136	6.17	1151	52.18	369	16.73	68	3.08	161	7.30
Savings	212	9.61	878	39.80	464	21.03	116	5.26	142	6.44
Voting at an election	225	10.20	229	10.38	873	39.57	52	2.36	420	19.04
Note: Percentages calculated against total households of 2206										

Source: Socioeconomic Survey of UN-Habitat, 2017

4.3 Social Impact Assessment

4.3.1 Impact on Structures

The SES has revealed Out of the total 3,055 structures affected, the highest number of structures getting affected includes 2,206 residential structures followed by 762 business structures (Table 4-23). In addition to the private structures requiring relocation, a total of 87 structures have been listed under institutions and Physical and Cultural Resources (PCR). These structures include public institutions, private organization, temples, public bathing and sanitary facilities and common places.

Table 4-23 Impact on Structures by Type of Structure

Type of Structure	Permanent	Semi-permanent	Temporary	Not Responded	Total
Residential	1,547	454	158	47	2206
Commercial	456	29	276	1	762
Institutions and physical and cultural resources	71	1	1	11	84
Total	2,074	484	435	59	3,052

Source: Socioeconomic Survey of UN-Habitat, 2017

4.3.2 Impact on Land

In total, the affected land spreads over nearly 24,490.31 perches, of which about 9,175.95 perches or 37.5 percent, belongs to the State, most of which would belong to SLR due to being located within the existing ROW. The affected extent of land under private ownership is approximately 15,314.36 perches (62.5%) of which 3,062.62 perches will be acquired for the proposed infrastructure development. This extent of private land acquisition corresponds to 20 percent of the total extent under private ownership. However, the public land identified above is not free from encumbrances. There are people who have encroached on the reservation or the existing ROW and built houses and other structures. In addition, there are housing schemes built by the government on this land. Further, in some instances the SLR has leased out property to individuals and institutions. A substantial part of the public land will be repossessed. Therefore, the proposed project requires repossession of public land and acquisition of private land, resulting in involuntary resettlement impacts involving physical and economic displacement of populations. Scope of land acquisition and repossession is presented in Table 4-24.

Table 4-24 Scope of Land Acquisition in the Project

DS Division	Affected Public Land (Perches)	Affected Private Land (Perches)	Affected Total Extent (Perches)	Private Land Required for Acquisition		
				Total Extent of Acquisition (Perches)	As % of Total Private Land in the DSD	Distributed as % of Total Land Acquisition of all DSD
Homagama	522.84	1,004.57	1,527.41	67.04	6.7%	2.2%
Kotte	1,902.82	1,034.66	2,937.48	382.52	37.0%	12.5%
Maharagama	2,349.90	12,598.80	14,948.70	2,145.84	17.0%	70.1%
Thimbirigasyaya	4,400.39	676.34	5,076.73	467.23	69.1%	15.3%
Total	9,175.95	15,314.36	24,490.31	3,062.62	17.0%	100%

Source: Socioeconomic Survey of UN-Habitat, 2017

Another aspects surveyed is that the ownership claim for land plots identified in the survey. It was found that there are 2,494 land plots consisting of 926 private landholdings and 1,568 non-titled land plots. Majority of private landholdings is located in Maharagama, whereas the non-titled land plots are mostly concentrated in Thimbirigasyaya, as shown in Table 4-25.

Table 4-25 Impacted Land Plots by Ownership Claims

DS Division	No. of Titleholder Land Plots	No. of Non- titleholder Land Plots	Total No. of Land Plots	Distribution of Land Plots as % of Total
Homagama	45	57	102	4%
Kotte	197	244	441	18%
Maharagama	423	294	717	29%
Thimbirigasyaya	261	974	1,234	50%
Total	926	1,568	2,494	100%

Source: Socioeconomic Survey of UN-Habitat, 2017

The surveyed land plots mentioned above consist of small and tiny holdings ranging from less than 2 perches to more than 6 perches in extent. As shown in Table 4-26, the non-title holdings of less than 5 perches correspond to about 59 percent of the total land plots, compared to 11 percent of private landholdings. On the other hand, 51 percent of the total landholdings of the private landholdings extend over 5 perches in comparison with 9 percent in non-title category (Table 4-26).

Affected Paddy Land near Watareka

Affected Private Resident within RoW in Nugegoda

Figure 4-3 Affected Land plots along the KV-Line

Table 4-26 Impacted Land Plots by Size in residential Landholding

Land Plot Size	Title	Percent	Non-Title	Percent
Less Than 2 perch	136	21.05	843	66.33
3 to 5 perch	166	25.70	285	22.42
More than 5 perch	328	50.77	109	8.58
Not responded	16	2.48	34	2.68
Total	646	100.00	1271	100.00

Source: Socioeconomic Survey of UN-Habitat, 2017

4.3.3 Severity of Impacts on Land

It was found that out of a total 1,917 residential land plots, 1,753 are anticipated to incur impacts exceeding 10 percent of the total land holding. The number of land plots likely to be affected less than 10 percent relative to the total holding amounts to 164, as given in Table 4-27.

Table 4-27 Impacted Residential Land: Severity of Impact

Affected % of Landholding	Land Plots with Title		Land Plots without Title	
	No.	Percent	No.	Percent
<6	53	8.20	5	0.39
6 - 10	94	14.55	12	0.94
11-15	78	12.07	7	0.55
16-20	73	11.30	10	0.79
21-25	33	5.11	4	0.31
25-30	32	4.95	8	0.63
31-50	72	11.15	23	1.81
>50	205	31.73	1184	93.15
No Response	6	0.93	18	1.42
Total	646	100.00	1271	100.00

Source: Socioeconomic Survey of UN-Habitat, 2017

Furthermore, out of a total 763 business land plots, 21 parcels will have minor impacts as less than 10 percent of the landholding is affected; however, the balance 742 business land plots will incur major impacts as more than 10 percent of the total land will be affected by the proposed project as worked out in Table 4-28.

Table 4-28 Impacted Business Land: Severity of Impact

Affected Percentage of Land	Title		Non-Title		Total
	Nos.	Percent	Nos.	Percent	
<6	2	1.20	3	1.76	5
6 – 10	5	2.99	0	-	5
11-15	2	1.20	2	1.18	4
16-20	2	1.20	1	0.59	3
21-25	0	-	0	-	0
25-30	2	1.20	1	0.59	3
31-50	4	2.40	0	-	4
>50	19	11.38	131	77.06	150
% not given	131	78.44	32	18.82	163
Total	167	100.00	170	100.00	337

Source: Socioeconomic Survey Report 2018 (Table 66)

With regards to land plots belonging to institutions and common resources, 35 land plots out of a total of 80 will incur loss of less than 10 percent the total landholding. The balance 55 land plots will have impacts more than 10 percent, and 7 institutions interviewed did not respond.

4.3.4 Public and Private Institutions and Common Places

The survey found 87 other structures occurring with the 20 m ROW that belong to public institutions or private organizations. The total number of employees is 44 persons. It is observed that none of these employees are affected as only marginal impacts on the ancillary structures are likely due to the project for which compensation will be paid. Whereas the owners of private structures will be paid compensation, public properties will be rehabilitated by the project. Information on type of activities of undertaken by different institutions/ organization is given in Table 4-29.

	
Affected Business Place within Nugegoda Town	Govt. School in Padukka located closer to KV-Line

Figure 4-4 Affected Institutions & Public places along the KV-Line

Table 4-29 Institutions and Public Places Affected

Type of Institution and Activity	No.	%
Bank/Microfinance/Lending	6	06.12
Business/Services	20	17.41
CGR Premises	3	03.06
Conducting Social Service Activities	5	05.10
Community Center	2	02.04
Conducting Religious Activities	16	16.33
GYM	2	02.04
Pre- School/Daycare/Education Centers	19	19.39
Providing Sanitary Facilities	11	11.22
Providing public services/GN	3	03.06
Retail store/Grocery store/Restaurant	11	11.23
Total	**98**	**100**

Source: Socioeconomic Survey of UN-Habitat, 2017

4.4 Population Identified for Involuntary Resettlement

It is of vital importance that a clear understanding on the people who are affected by land acquisition that impacts on their life as such information is crucial for planning to address the impacts on them before the construction programme commences.

4.4.1 Households Identified for Resettlement

The survey on the first section reveals that there are 3,055 structures impacted by the project, and 2,206 of these are residential houses, and about 1,908 residential houses will incur risk of demolition due to major impacts while a further 298 houses will risk minor damages. The survey has also revealed that there are 2,206 households resident in these residential structures where 163 sub families share accommodation, sometimes more than one sub-family in the same house. About 108 sub families are residents of Thimbirigasyaya DSD, while balance 32 is distributed between Homagama (1), Kotte (19) and Maharagama (12). The residential units consist of 692 titleholders and 1,467 non-titleholders.

Table 4-30 Impacted Population of the Residential Structures

DS Divisions	Total No. of Houses	Female		Male		Total	
		No	Percent	No	Percent	No.	Percent
Homagama	63	120	49.38	123	50.62	243	3
Kotte	317	603	51.19	575	48.81	1178	14
Maharagama	456	875	51.08	838	48.92	1713	20
Thimbirigasyaya	1370	2743	51.19	2615	48.81	5358	63
Total	2206	4341	51.12	4151	48.88	8492	100

Source: Socioeconomic Survey of UN-Habitat, 2017

The total impacted resident population including those of the sub families amounts to 8,492 persons, contributed to 51.1 percent females and 48.9 percent males. A good majority of the population (63%) lives at Thimbirigasyaya DS Division. About 20 percent of the total population lives at Maharagama DSD, as shown in Table 4-30.

All in all, some 2,206 households including 163 sub family households with a population of 8,492 persons resident in the affected residential structures will be displaced. This population consists of 4,341 females and 4,151 males and is distributed across four DSDs, Thimbirigasyaya (63%), Maharagama (20%), Kotte (14%) and Homagama (3%). The second section needs further surveys, which are under way.

4.4.2 Business Households Identified for Relocation or Re-establishment

It is reported that SES of UN-H has interviewed 779 businessmen operating within the project boundary whose permanent residence is elsewhere, majority from Maharagama DS Division. The total population of this group amounts to 2,820 persons, distributed more or less equally between females and males This group will incur livelihood impacts, and the business owners will either be relocated in alternative business places or provided with assistance to re-establish their livelihood, or both (Table 4-31).

Table 4-31 Impacted Population of Non-Resident Business Households

DS Division	No. of Households	Female		Male		Total
		No	%	No	%	
Homagama	19	45	57.69	33	42.31	78
Kotte	236	414	46.26	481	53.74	895
Maharagama	459	829	51.55	779	48.45	1608
Thimbirigasyaya	65	124	51.88	115	48.12	239
Total	779	1412	50.07	1408	49.93	2820

Source: Socioeconomic Survey of UN-Habitat, 2017

In summary, 779 business households with a total population of 2,820 persons consisting of 1,412 females and 1,408 males will be affected due to the impact on their source of livelihood located within the project boundary. The permanent residence of this population is outside the project boundary, the majority coming from Maharagama and Kotte DSDs.

It is also found that out of the total 926 private landholdings the owner-operators occupy 608 land plots (65%). In addition, there are 41 land plots leased, 141 rented with house, and 124 on lease purchase from National Housing Development Authority (NHDA) that will be private property in due course (Table 4-32).

Table 4-32 Tenure Status of Private Landholdings

Type of Ownership	No. of Land Plots	As % of Total Land Plots
Individual deed of transfer	608	65.73
Leased	41	4.42
On lease purchase from NHDA	124	13.36
Owned by Temple	3	0.32
Rented with house	141	15.19
Shared Ownership	9	0.97
Total	926	100.00

Source: Socioeconomic Survey of UN-Habitat, 2017

4.4.3 Public Information and Consultation

Public information and consultation were conducted as an important method of involving various stakeholders particularly, local community with reference to the proposed development initiatives. It provides a platform to participants to express their views, concerns and apprehensions that might affect them positively or negatively. Through participation and consultation stakeholders influence development initiatives, and decision making process. The effectiveness of participation and consultation is directly related to the degree of involvement by the likely project affected persons and the local community and integration of outcome of consultations wherever feasible in the proposed development initiatives. Detailed planning is required to ensure that likely project affected persons, local community, interested groups, non-governmental organizations, civil society organizations; local government, line departments, etc. are consulted regularly, frequently and purposefully during different stages of the project including project preparation.

4.5 Consultation and Participation

Public information and consultation was carried out during the project preparation stage in the form of public meeting, focus group discussion, in-depth interviews and individual consultations. The consultation process ensured that the likely project affected persons (PAPs), local community and other stakeholders were informed in advance, and allowed to participate actively and consulted. This serves to reduce the insecurity among local community and likely PAPs and thereby opposition to the project because of its transparent nature inbuilt in the consultation process.

The purpose of consultations was to inform people about the project, take note of their issues, concerns and preferences, and allow them to make meaningful choices. Consultation will be carried out during the implementation, and monitoring and evaluation of the project as well. Concerns, views and suggestions expressed by the participants during these consultations have been presented in the following sections. The outcomes of consultations have been shared with design team so as to integrate their concerns and suggestions wherever possible. Concerns expressed by the participants covered compensation for lost assets, impacts on structures, shifting of religious structures, etc. The local leaders were found actively involved in all the consultation meetings.

Consultation with PAPs is the starting point to address involuntary resettlement issues concerning land acquisition and resettlement. People affected by resettlement may be apprehensive that they will lose their livelihoods and communities. Participation in planning and managing resettlement helps to reduce their fears and gives PAPs an opportunity to participate in key decisions that affect their lives. The first step in developing plans for consultation and participation is to identify the primary and secondary stakeholders. Information sharing is the first principle of participation.

4.5.1 Objectives of the Consultation Process

The main objective of the consultation process is to maximize the benefits from the project and to minimize negative impacts of the project. The objectives of public consultation as part of this project are:

- Promote public awareness and improve understanding of the potential impacts of proposed projects;
- Identify alternative sites or designs, and mitigation measures;
- Solicit the views of affected communities / individuals on environmental and social problems;
- Improve environmental and social soundness;
- Clarify values and trade-offs associated with the different alternatives;
- Identify contentious local issues which might jeopardize the implementation of the project;
- Establish transparent procedures for carrying out proposed works;
- Create accountability and sense of local ownership during project implementation.

4.5.2 Levels of Consultations

The public consultations were carried out at the screening, feasibility and Social Impact Assessment stages of the project. The extent of likely adverse impacts was one of the major criteria for deciding the locations of public consultations. Types of consultations done with various participants using various tools including, interviews with government officials, individual consultations, key informant interviews, focus group discussion, stakeholder consultations, etc., are presented in Table 4-33.

Table 4-33 Types of Consultations

Level	Type	Key Participants
Individual	Local level Consultation	People along the project corridor
Individual	Sample Door to Door Personal Contact	People along the project corridor including those that are not impacted directly
Settlement	Focus Group Discussion	PAP, Women, truckers, weaker sections, agriculturist, School teachers
Institutional	Stake holder Discussion	Line departments

Source: Socioeconomic Survey Report 2017

4.5.3 Methodology Adopted

The following methodology has been adopted for carrying out public consultations in this project which were held at GND and DSD levels:

- Disseminating information and requesting villagers to attend the public consultation meetings
- Sharing the opinions and preferences of the PAPs
- Involving the PAPs in decision-making.

Different techniques of consultation with stakeholders were used during the preparatory stage, viz., in-depth interviews, public meetings, group discussions, Individual Consultations etc. to understand the socio-economic profile of the community and the affected families. Questionnaires were designed and information was collected from the individuals on one-to-one basis. The consultations have also been carried out with special emphasis on the vulnerable groups. The key informants during the project preparation phase included both individuals and groups namely:

- Heads and members of households likely to be affected
- Groups/clusters of PAPs
- Village Head and members
- Local voluntary organizations and NGO
- Government agencies and departments such as local revenue authority
- Other project stakeholders with special focus on PAPs belonging to the vulnerable group

4.5.4 Types of Consultations

(1) General Consultations

The dissemination process and the type of information shared with the stakeholders during consultations are described below:

- While undertaking inventory of rail-side utilities and structures, and census survey of PAHs, information dissemination focused on the proposed road improvements.
- Potential PAHs were consulted to inform them about the proposed road improvement program, resultant impacts and possible socio-cultural conflict (if any) including loss of access to and relocation of PCRs.

- People were requested to gather at common places including common places like temples, schools, Village Organization centers, etc.
- During these consultations pictorial Methods were also used to explain proposed improvement and possible social impacts in the concerned villages.

(2) Structured Consultations

Besides general consultations described above, consultations were conducted in a structured manner. For this purpose, date and venue of consultation were fixed in advance and in coordination with the PRI representatives at village level and officials from RD, PWD and NGOs.

Such structured consultations helped in highlighting issues as raised by stakeholders with regard to the proposed road improvement.

(3) Specific Consultations

In addition to the local/village level meetings, consultations were organized at specific locations; - critical stretches along the proposed corridors. At these locations, FGDs were also organized.

(4) Discussions with Divisional Level Officials

In the discussion with officials of the Divisional Secretariat and other relevant stakeholders were explained about the proposed project interventions. Some of the issues with regard to shifting of utilities, common facilities etc. were also discussed in these meetings with the respective officials.

4.5.5 Details of Consultation

Details of consultations carried out of the project preparation covering issues discussed (land acquisition, compensations for land and structures, road safety, general perception about the project) and suggestions from participants to mitigate hardships resulting from dislocation and loss of livelihood, resettlement options, perception about HIV/AIDS awareness, CPR requirement, etc., are presented in Table 4-34.

Table 4-34 Issues raised during Consultations through FDGs

Date	Place	Stakeholder Group	Resettlement Issue discussed	Suggested Mitigation measures
27.06.2017	Dematagoda	Women's Group	• Negative effects on livelihoods which are based on highly local customer relationships • Negative effects on children's education • Difficult adaptation to new lifestyle in apartment/high rise	• Relocate in vicinity in order to allow access to the same schools, markets, etc. • Support livelihood restoration programmes, including vocational training; establish new livelihood centres
25.10.2017	Wanathamulla	Women's Group	• Many households with subfamilies in the ROW with a need for their own apartments • Households want to keep their animals • Negative impacts on livelihoods which are dominated by home-based self-employment	• Provide enough apartments for households with subfamilies • Best to resettle into individual houses instead of high-rises • Otherwise: Find accommodation for households' animals • Ensure good quality of flats,

Date	Place	Stakeholder Group	Resettlement Issue discussed	Suggested Mitigation measures
			• Security concerns about life in high-rises, especially regarding girls/females	common spaces for recreation, parking spaces • Support livelihood restoration programmes; allow for home-based self-employment • Community-building and other programmes to enhance security
No date mentioned	Narahenpita Kirimandala	Residents, Others	• Negative impacts on livelihoods • Highly diverse community	• Relocate in the vicinity of current location in order to allow access to the same schools, markets etc. • Include diversity aspects in the relocation process
16.06.2017	Narahenpita	Residents, Others	• Negative impacts on livelihoods if resettled far away • Negative impacts on access to education & urban amenities	• Relocate in the vicinity of current location in order to allow access to the same schools, markets, etc. • They proposed a vacant land at Kirimandala Mawatha as an alternative housing site
27.06.2017	Dematagoda, Wanathamulla	Residents, Others	• Negative impacts on livelihoods if resettled faraway • Negative effects on children's education • Many households with subfamilies in the ROW with a need for their own apartments	• Relocate in the vicinity of current location in order to allow access to the same schools, markets, etc. • Provide enough apartments for households with subfamilies
28.10.2017	Avarihena,	Persons with access difficulties	• Unnecessary Displacement	• Participants proposed to use SLR land (with few houses) on the left side (from Maradana) to implement the project. If a flyover railway system is implemented, Averihena Road can be developed up to Nugegoda by adjoining current railway road and this road
No date mentioned	Nugegoda, Kattiya Junction	Persons with access difficulties	• Negative livelihood impacts • Negative impact on children's education • Access difficulties to their properties • Increased traffic	• Livelihood restoration programmes, include DPs into the workforce of the project • Relocate in vicinity in order to allow access to the same schools, markets etc. • Build railway flyovers
28.10.2017	Pagiriwatta, Nugegoda	Persons with access difficulties	• DPs not willing to shift to temporary shelters • If the PMU acquires part of their land plots, the remaining part will not be enough to continue their activities	• Provide reasonable compensations which allow them to buy similar properties in Nugegoda.

Date	Place	Stakeholder Group	Resettlement Issue discussed	Suggested Mitigation measures
22.07.2017	Makumbura	Persons with access difficulties	• Access to the land and houses will get affected. • Differently-able people among the DPs	• Ensure accessibility for differently-able DPs and the elderly.
26.07.2017	Mapalana	Persons with access difficulties	• Accesses to their properties will get affected. • If part of land plots is used for the proposed project, the remaining pieces of land plots will not be adequate for residential use. • Negative impact on children's education • Negative livelihood impacts • Social isolation after relocation	• Establish an alternative road along the barren land which is located nearby KV line to guarantee access. • Resettlement in the vicinity of their current location
05.06.2017	Nugegoda,	Business Community of Janatha Pola	• No land nearby to re-establish their business (Janatha Pola & Railway Road) • Many DPs have both their livelihood and their residence in ROW • Negative effects on children's education • Road traffic will increase	• Relocation in nearby places • Allocate resources for livelihood restoration for DPs, including new livelihood canters in Nugegoda area. • Avoid Station Road & Janatha Pola from project and use a different 30 ft. land plot along the railway line
10.06.2017	Nugegoda,	Business Community of Railway Road	• No land nearby to re-establish their business (Janatha Pola & Railway Road) • Road traffic will increase	• Build railway line as a flyover or Build 2nd line on the right side from Maradana where there is an available land • Establish alternative business centres close by
14.07.2017	Maharagama	Business Community Maharagama	• More than 200 business people will have to give up their business (cloth trade) in that location due to the project • Negative impact on business during construction period	• In-advance information on the construction for them to arrange the road space in order to avoid disturbances or conflicts
02.08.2017	Pamunuwa Maharagama	Businessmen who sell garment on the rail tract	• Negative livelihood effects	• Provide alternative business locations for them, include business premises in the Maharagama station
07.06.2017	Udahamulla	Residents, Others	• Negative impact on children's education • Negative livelihood impacts • Social isolation after relocation	• Relocate in the vicinity of current location to allow access to the same schools, markets etc. • Construction activities should be started after the

Date	Place	Stakeholder Group	Resettlement Issue discussed	Suggested Mitigation measures
				resettlement • Support for re-establishment of livelihoods, incl. training, credit or grant, marketing supports, etc.
28.10.2017	Nugegoda, Kattiya Junction	Residents, Others	• If the railway line is built as a flyover, sound and vibration are expected	• Minimize sound, vibration and negative effect
28.10.2017	Walauwatta Junction Homagama	Residents, Others	• None of the unauthorized • Households have been entitled for government welfare benefit (not evening the case of natural disasters. The GN of the area did not certify applications due to the status as an unauthorized residence. Certification for school admission of children is also not certified by the relevant authorities.	• Include unauthorized residents in the Relocation/compensation process and treat them fairly - as citizens–and hand them everything to which they are entitled.
25.10.2017	Wanathamulla	Students, Youth Group	• Negative effects of livelihoods • Isolation from their relatives due to resettlement • Space in flats not enough to keep their current belongings state of other housing schemes regarded as in bad condition	• Livelihood re-establishment support by PMU, incl. New livelihood centre • Relocation in the vicinity of their current location& as one community • Provide enough residential space

Source: Adopted from the Resettlement Plan of UN-Habitat- 2018

4.5.6 Consultation Outcomes

The people were generally enthusiastic about the project and believed that it will bring social and economic development into the region. There is scarcity of employment opportunities and health facilities etc. within the villages which is affecting overall social and economic development. People believed that the development of railway will improve connectivity for the local people to one place to another place.

4.6 Resettlement and Rehabilitation

The resettlement cost estimate for this project includes eligible compensation, resettlement assistance and support cost for RP implementation. The support cost, which includes staffing requirement, monitoring and reporting, involvement of Implementing Agency in subproject implementation and other administrative expenses are part of the overall project cost. The unit cost for land and other assets in this budget has been derived through field survey, consultation with affected families, relevant local authorities and reference from old practices. Contingency provisions have also been made to take into account variations from this estimate. As per the social screening indicative cost of first section from Maradana to Homagama are mentioned below:

The total Estimated Cost (indicative) for the Social Resettlement / Land Acquisition of KV Line stands at SLR 15.793 billion or US $ 99.328 million, as presented in Table 4-35 and 4-36.

Table 4-35 Indicative cost of Resettlement Plan – Section 1 (Maradana – Homagama)

Type of Entitlement	Impact Item	No.	Unit	LKR/Unit	Total (LKR)
	Colombo MC	226.14	Perch	2,000,000	452,280,000
	Sri Jaya-Kotte MC	380.35	Perch	1,550,000	589,542,500
	Maharagama UC	1309.92	Perch	1,816,667	2,379,688,437
	Homagama PS	324.44	Perch	650,000	210,886,000
Compensation for loss of structures	Alternative Houses	1,408	Number	4,000,000	5,632,000,000
	Houses - Fully Affected	423	Number	Sum	1,463,604,400
	Houses - Partially Affected	271	Number	Sum	15,803,768
	Business Structures-Partially affected	18	Number	Sum	1,683,208
	Business Structures-Fully affected	206	Number	Sum	314,966,479
	Business Structures – Non-titled	538	Number	Sum	538,000,000
	Institutions (fully affected - Private)	30	Number	Sum	374,127,608
	Institutions (Partially Affected-Private	4	Number	Sum	282,808
	PCR	50	Number	Sum	3,160,000
Compensation for loss of Income	Business Income (Temporary)	249	DP	300,000	74,700,000
	Business Income (Permanent)	670	DP	100,000	67,000,000
	Loss of Wage/Salary	3,725	PAPs	180,000	670,500,000
	Loss of income from rent/ lease	204	PAH	50,000	10,200,000
Compensation for loss of trees & crops	Trees and Crops	4,211	Number	Sum	22,020,000
Allowances	25% Statutory (Buildings)	952	Number	Sum	544,546,366
	Self-relocation (Commercial)	100	Number	500,000	50,000,000
	Income foregone	1,592	PAH	15,000	23,880,000
	Livelihood restoration	1,560	PAH	90,000	140,400,000
	Transition	2,988	PAH	10,000	29,880,000
	Transport	2,988	PAH	2,500	7,470,000
	Other Accessories	3,038	PAH	15,000	45,570,000
	Section 9 inquiry	2,988	PAH	15,000	44,820,000
	Advertising	779	Number	5,000	3,895,000
	Vulnerable families	415	PAH	15,000	6,225,000
	Loss of official accommodation	104	DP	200,000	20,800,000

Type of Entitlement	Impact Item	No.	Unit	LKR/Unit	Total (LKR)
	Loss of rental accommodation	204	DP	150,000	30,600,000
Other	External Monitoring	108	Months	800,000	86,400,000
Sub Total 1					13,854,931,574
Community Development (1% of sub Total)			Lump sum		138,549,316
Income restoration program (1% of subtotal)			Lump sum		138,549,316
Administration Cost (0.5%)			Lump sum		69,274,658
Contingency 2.5%			Lump sum		346,373,289
Total					14,547,678,152

Table 4-36 Social Resettlement / Land Acquisition Cost Estimates for KV Line

KP	Length Meters	Area (Perches) for 16m	Length Meters Location (Station to Station)	Population Density / Land Value (High/ Moderate/ Low)	Land Acquisition & Resettlement Cost		
					Unit Cost by Perch LKR	Total Cost LKR	Total Cost US$
00-24+480	24,480		Maradana - Homagama	High & Moderate	As per UN-H RP(1)	14,547,678,157.00	91,494,831.18
26+300	1,820	1164.80	Homagama - Panagoda	Moderate	200,000 X 40%	93,184,000.00	586,062.89
28+020	1,720	1100.80	Panagoda - Godagama	Moderate	200,000 X 40%	88,064,000.00	553,861.64
29+600	1580	1011.20	Godagama - Meegoda	Moderate	200,000 X 40%	80,896,000.00	508,779.87
31+200	1600	1024.00	Meegoda - Watareka	Low	100,000 X 20%	20,480,000.00	128,805.03
33+600	2400	1536.00	Watareka- Liyanawala	Low	100,000 X 20%	30,720,000.00	193,207.55
35+240	1640	1049.60	Liyanawala - Padukka	Moderate	200,000 X 40%	83,968,000.00	528,100.63
37+000	1760	1126.40	Padukka - Arukwatta	Moderate	200,000 X 40%	90,112,000.00	566,742.14
38+060	1060	678.40	Arukwatta - Angampitiya	Moderate	200,000 X 40%	54,272,000.00	341,333.33
39+080	1020	652.80	Angampitiya - Uggala	Low	100,000 X 20%	13,056,000.00	82,113.21
40+104	1024	655.36	Uggala - Pinnawala	Low	100,000 X 20%	13,107,200.00	82,435.22
41+344	1240	793.60	Pinnawala - Gammana	Low	100,000 X 20%	15,872,000.00	99,823.90
42+144	800	512.00	Gammana - Morakele	Low	100,000 X 20%	10,240,000.00	64,402.52

KP	Length Meters	Area (Perches) for 16m	Length Meters Location (Station to Station)	Population Density / Land Value (High/ Moderate/ Low)	Land Acquisition & Resettlement Cost		
					Unit Cost by Perch LKR	Total Cost LKR	Total Cost US$
44+364	2220	1420.80	Morakele - Waga	Low	100,000 X 20%	28,416,000.00	178,716.98
46+664	2300	1472.00	Waga - Kudugoda	Low	100,000 X 20%	29,440,000.00	185,157.23
47+844	1180	755.20	Kudugoda - Aparangama	Low	100,000 X 20%	15,104,000.00	94,993.71
49+334	1490	953.60	Aparangama - Kosgama	Moderate	200,000 X 40%	76,288,000.00	479,798.74
50+904	1570	1004.80	Kosgama-Aluthambalama	Moderate	200,000 X 40%	80,384,000.00	505,559.75
52+184	1280	819.20	Aluthambalama - Miriswatta	Moderate	200,000 X 40%	65,536,000.00	412,176.10
53+520	1336	855.04	Miriswatta - Higurala	Moderate	200,000 X 40%	68,403,200.00	430,208.81
55+404	1884	1205.76	Higurala - Puwakpitiya	Moderate	200,000 X 40%	96,460,800.00	606,671.70
56+274	870	556.80	Puwakpitiya - Puwakpitiya Town	Moderate	200,000 X 40%	44,544,000.00	280,150.94
57+434	1160	742.40	Puwakpitiya Town - Kiriwandala	Moderate	200,000 X 40%	59,392,000.00	373,534.59
59+144	1710	1094.40	Kiriwandala - Avissawella	Moderate	200,000 X 40%	87,552,000.00	550,641.51
Homagama - Avissawella	34,664	22,184.96				1,245,491,200.00	7,833,277.987
Grand Total (Maradana – Avissawella)	59,144					15,793,169,357.00	99,328,109.16

(1) – The indicative costs presented in the Resettlement Plan for Maradana – Homagama Section by UN-Habitat (2017), were used.
Assumptions made on the Social Costs (Acquisition / Resettlement / Livelihood Compensation from Homagama to Avissawella:
RoW width of (20 – 4 m) 16m was used for calculation of the land area,
Area with Moderate acquisition /compensation need and medium land value was worked out at Rs.200,000 / perch X 40 %
Area with low acquisition /compensation need and low land value was worked out at Rs.100,000 / perch X 20 %

4.7 Conclusions and Recommendations

The general conclusions and recommendation of the Social Impact study focused on the KV-Line are presented using all hitherto completed SES and RP of the UN-Habitat in particular and field surveys and inspection conducted by the consultants in general:

4.7.1 Conclusions

- The total KV-Line is 59 km consisting of 70 GN Divisions in 6 DS Divisions and they are coming under the administration district of Colombo, which falls to the Western Province of Sri Lanka,
- The First Phase of detailed study of UN-Habitat confined to the 25 km length of KV Line from Maradana to Homagama, which has 13 stations covering 43 GNDs in 4 DSDs; and within the 25 km length and 20 m width land belt of this section, the number of affected persons is fairly high, making it a significant project in terms of involuntary resettlement impacts.
- Within this belt, the most severely affected group that lose their present housing due to the project consists of 2,206 households with a total population of 8,492 persons, of which 51.1 percent are females and 48.9 percent are males,
- According to the categorization of Social Safeguard Policy of ADB and the national involuntary resettlement policy, this project falls under the ‘Category A’, since more than 200 families need to be resettled.
- The Affected Families, within the SLR land reservation (RoW) are in a vulnerable situation, despite their tenure is over 10 years by over 70 percent of the total APs since they do not own alternative land or houses in other locations,.
- The main livelihood activities of most of the families, specifically within the SLR land reservation are either attached to their current residences or to the neighboring environment at large; and as such they are keen to be resettled in alternative locations within a 4 km radius from the current residences so that they can continue the same livelihoods.
- Some of the business activities affected in the project implementing area are located as clusters; the business persons in these clusters are expected to be relocated as a group in order to keep the same informal institutional network, especially the marketing network continuation without disturbances (e.g. Nugegoda Janatha Fair & Maharagama Textile),
- The business activities in the Maharagama-Pamunuwa textile market are complex because there are several parties inter-dependent of the business activities such as raw material suppliers, out sourced tailors, business persons of bulk purchases, who sell materials elsewhere and other regular customers of this business location.
- The social relations among families living as a ‘community’ in the SLR reservation are strong, and are highly inter-related to each other especially in communities known as ‘Watta’, which is similar to a village hamlet,
- Although many of the laborers in the informal sector among communities draw a substantial daily income, their financial management is rather poor, resulting in that most of them do not have savings for use in an emergency; and therefore the majority of these income earners in the RoW of SLR fall into the category of vulnerable people due to lack of accepted basic norms (i.e. alternative lands, permanent jobs, education & skills, social acceptance etc.),

- The most critical factor to be considered in resettlement of squatters living in public land belonging to SLR is their entitlements for compensation; according to the ADB safeguard policy and the NIRP of Sri Lanka, squatters are entitled only for replacement cost, and most of the housing structures within the RoW land are extremely small dwellings for which replacement cost would be minimal, not adequate at all for the APs to resettle elsewhere
- The proposed alignment of the KV-Line will have a significant impact on existing access roads, and most of the negative impacts on access roads will be effective beyond the construction phase, as these access roads may permanently be blocked,
- In certain locations, acquisition of a 20 m wide land belt will be extremely critical due to possible damage to the properties; these properties include the boundary wall of two leading Girls' Colleges in Colombo 8 and Nugegoda, which call for careful consideration during design stage.
- Another critical issue to be considered includes the large number of rail crossings, canals and bridges within this 25 km long rail road, and beyond up to Padukka, which is the tract that ADB will fund as its first phase.
- Alternative locations to resettle a large number of families are presently not available; and it will not be practical for the affected families to stay in rented houses until alternative housing schemes are completed, and they affected communities are not willing to stay in rented houses; as such it is essential to resettle the affected communities in permanent locations.

4.7.2 Recommendations

- Keeping in line with the critical and challenging nature of the project being a category A of ADB in terms of resettlement requirement, the lessons learnt from similar resettlement projects should be properly utilized by the PMU of this project for timely implementation of the project
- All the residential households and residence cum business premises which are fully affected due to the project activities within the RoW land belt and the adjacent land belt should be provided with alternative housing facilities.
- In view of the difficulty to provide housing purely to facilitate businesses, an acceptable livelihood restoration programme need to be introduced; aspects like training for capacity building, facilitation for credit facilities, and introduction of new income generation opportunities are recommended,
- PMU should harness the potential to resettle communities in alternative houses constructed within the 1 km to 5 km radius of their present residences; the preferences made by APs is to be resettled within the jurisdiction of their current DS division.
- Appropriate actions should be taken to re-establish the disturbed business clusters located in areas such as Pamunuwa textile and Nugegoda Janatha Fair, including innovative options to mitigate the negative impacts on those two business clusters, on priority basis; this should consider as a serious concern of the detailed designing of the KV line; the affected business community strongly suggested to get resettled as a group avoiding physically isolation,
- An active total participation and close interactions should be established with different types of business APs during the resettlement phase of the project, as these local community members

can offer innovative and pragmatic solutions which should be carefully evaluated to decide on their feasibility and arriving in negotiated alternative solutions with the consent of the affected.

- The suggested Post-Resettlement monitoring is an essential management tool which needs to be adhered to observe the social cohesion, living standards and livelihood patterns of the APs in the provided new locations; PMU and other independent groups should carry out regular surveys using appropriate indicators to identify the changes and unforeseen issues.
- Information collected through external monitoring studies can be used in developing and implementing relevant strategies as well as in re-establishing disturbed livelihood activities; PMU together with the Sub-Project Designing team need to pay careful attention to sort out issues related to access for different facilities.
- It is also recommended that the Design Engineers should pay adequate attention to sensitive Segments of the KV line in proposing improvements, and critical locations that exist in the highly populated first half of the KV Line include unprotected Railway crossings, multi-story permanent buildings, natural streams and storm water drainage canals are some of the sensitive areas needing serious consideration.

CHAPTER

5

Alignment Selection and Route Description

Chapter 5 Alignment Selection and Route Description

Chapter Summary

Horizontal Alignment Selection

There are many sharp curves along the existing alignment of the KV line and the line has crossed through many nearby private residential areas. In order to reduce the land acquisition, the consultant plans the alignment within the existing ROW. And, in order to increase the commercial speed of the train and decrease the overall travel time, the Consultant has come up with three options for optimal alignment from Maradana to Padukka where the train frequency will be 7 min. in 2025 and there are many level crossings to be eliminated.

Option 1	The alignment is planned within the existing ROW as much as possible. This option can minimize additional land acquisition.
Option 2	The alignment is planned with the maximum speed of 70 km/h and minimum radius of curve of 300 m. This option makes the alignment laid out of the existing ROW at certain sections.
Option 3	The alignment is planned with the maximum speed of 80 km/h and minimum radius of curve of 400 m. This option makes the alignment laid out of the existing ROW at many sections.

The above 3 options were reviewed by fields and the optimal one will be selected through a comprehensive analysis of alignment engineering, social and environment impact, economic and financial effect, etc.

The alignment from Maradana to Padukka is planned to be double line and from Padukka to Avissawella it is planned to be single line.

From the analysis, Option- I which is the re-alignment within the ROW is the best choice for KV line. Higher scores on alignment, social/resettlement/gender and environment have place Option I comparatively in higher position among other options. Option 1 requires only minimum land acquisition by utilizing the existing ROW. Option 2 or Option 3 is better alignment than Option 1, but only 5.4 minutes time) saving although the land acquisition and resettlement compensation cost increase much more. Therefore, Option 1 (Alignment within the existing ROW) is recommended as the optimal alignment.

Vertical Alignment Selection

Since the KV line has many level crossings, it is necessary to plan the vertical alignment considering level crossings. From the operational point of view, frequency of train was reviewed to 7 minutes from Maradana to Makumbura North and 14 minutes from Makumbura North to Padukka.

From Maradana to Makumbura North the frequency of train is short as 7 minutes, it is difficult to solve the road traffic problems at the level crossing. So the structures such as elevated or underground is advantageous as a vertical alignment.

In this section, 4 kinds of option was studied such as Option 1 (Elevated line), Option 2 (Underground line), Option 3 (Elevated + Underground line), Option 4 (Elevated + Underground line + At grade line). As a result of option studies, the Option 1 was selected as the optimal vertical alignment.

From Malapalla to Padukka the frequency of train is rather long as 14 minutes, it is rather easy to solve the road traffic problems at the level crossing. At-grade structure is advantageous as a vertical alignment considering construction cost.

Because there are many level crossings in the KV line, the consultant decided the vertical alignment considering such characteristics and by comparing advantages and disadvantages such as frequency of train, construction cost, environmental and social aspect, etc.

Stations

From Maradana to Avissawella, there are 38 stations. Among them, 5 stations have not been used any more. In order to reduce construction cost and increase the Commercial speed and decrease travel time, the consultant decided to delete these 5 stations. The names of the stations in KV line that are to be removed are as follows:

Arapangama, Aluth Ambalama, Miriswaththa, Puwakpitiya New Town, and Kiriwandala

Regarding new stations, at the early stage of this review, the consultant considered to add 4 new stations. However considering the distance between stations, commercial speed and economic weights for the stations and construction cost, finally 2 stations (New 02 and New 04) have been selected as additional stations.

The chainage of New 02 station is 15km890. This site is located near the Maharagama Central College, more specifically, at the edge of the Maharagama town, and it has close access to the A4 and Old Kesbewa Road. It also gives access to the Maharagama Town and sub urban residential neighborhood. New Station 02 is on the straight line, a good condition to establish a new station.

The chainage of New 04 station is 21km700. Proposed new station is ideally situated closer to the country's main highways connecting hub of the 'Kottawa Intersection' making the station multi model transport connecting node.

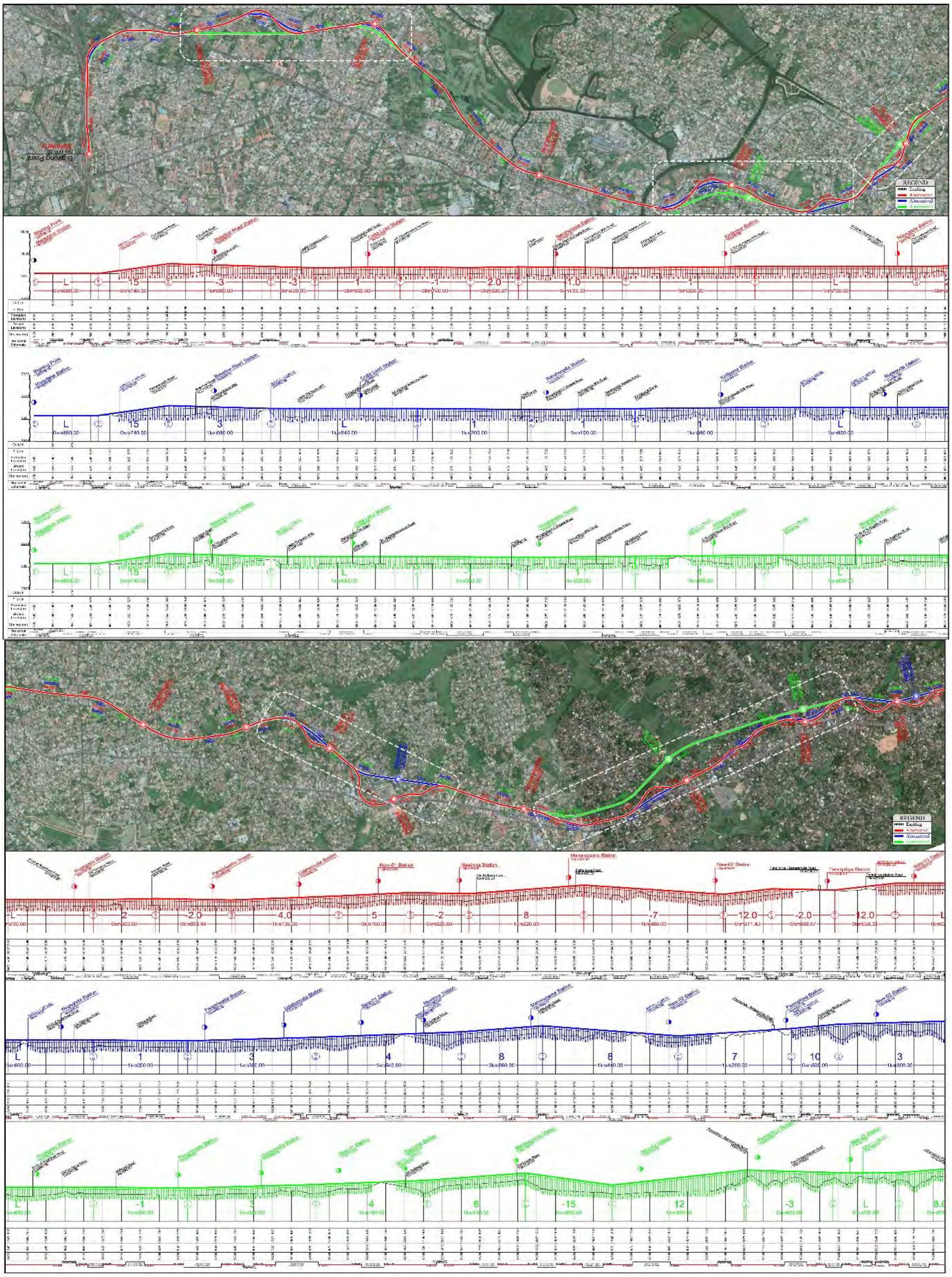
The alignment of near the New station 04 is composed of straight line and curve radius R = 300 m. The condition for turn back system is proper. This station is a very important place for operation turn back system.

Between Kosgama and Hingurala, planned to establish signal box for effective train operation.

At last from Maradana to Avissawella, there will be a total of 35 stations in the KV line.

5.1 Horizontal Alignment

5.1.1 Alignment & Profile



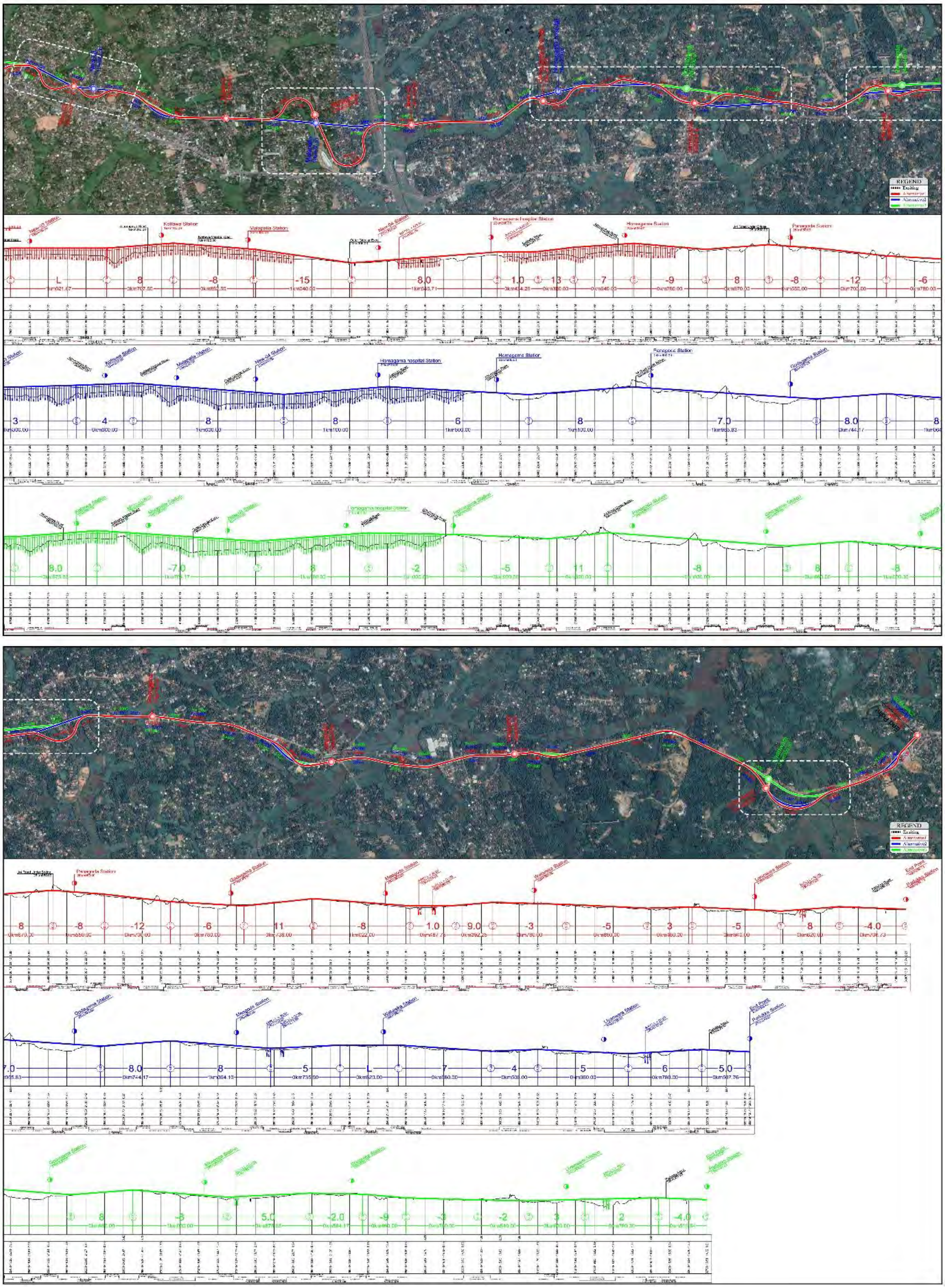


Figure 5-1 Alignment & Profile of Option 1,2,3

5.1.2 Review of Alternative Options

5.1.2.1. Horizontal Alignment Option 1

(1) General

According to this option, the total length of the section from Maradana to Padukka is 34.906 km. As the alignment is planned within the existing ROW, it has many curve sections with small radius. For this reason, speed limit for operation is inevitable; hence the commercial speed is very low. Meanwhile, this Option causes less land acquisition, which leads to low cost as well as less time for land purchase. Thus, this option takes advantage of minimizing the project duration.

(2) Curvature

The status of the curvatures on Option 1 is shown in the table below:

Table 5-1 the Length of straight and curved line on Option 1

Total length	34.906 km	100%
Straight	18.914 km	54%
Curve	15.992 km	46%

The alignment is planned to have expanded radius of curve compared to the existing line, but the curve section is quite long and small radius of curves are applied.

(3) ROW Analysis

By utilizing the existing ROW at maximum, Option 1 requires only little land acquisition. The status of temporary land lease and land acquisition for construction is seen in the table below:

Table 5-2 Land acquisition analysis for option 1

Sections	Required Area(m^2)	Current ROW in Area(m^2)	Additional Area Required(m^2)		
			Permanent	Temporary	Total
Maradana~Nugegoda	145,600	137,004	6,447	2,149	8,596
Nugegoda~Homagama	249,001	228,388	15,460	5,153	20,613
Homagama~Padukka	-	-	-	-	-
Total	394,601	365,392	21,907	7,302	29,209

As shown above, the area of required land is 394,601 m^2 in total, and available existing land is 365,392 m^2. Permanent land acquisition to be additionally purchased is 21,907 m^2.

(4) TPS (Train Performance Simulation) Analysis

From the TPS analysis, it is analyzed that the commercial speed is 36.10 km/h, and the travel time is 58 minutes from Maradana to Padukka. Table 5-3 shows the betterment of existing line which has the commercial speed of 23.5 km/h and travel time of 62 minutes from Maradana to Homagama.

Table 5-3 Comparison of option 1 with existing line

Existing Alignment Maradana to Homagama		Re- Alignment Maradana to Homagama		Increase/Decrease	
commercial Speed	Travel Time	commercial Speed	Travel Time	commercials Speed	Travel Time Save
23.5 km/h	68 mins	35.2 km/h	41.6mins	+ 11.7 km/h	-26.4mins
Maradana – Padukka travel time will be 58 minutes after improvement.					

5.1.2.2. Horizontal Alignment Option 2

(1) General

According to this option, the total length of the section from Maradana to Padukka is 33.248 km. By planning the speed limit above 70 km/h, the minimum radius of curvature is 300m. This alignment has several sections deviating from the existing ROW.

(2) Curvature

The status of the curvatures on option 2 is analyzed as below:

Table 5-4 Length of straight and curved line on Options 2

Total length	33.248 km	100%
Straight	20.226 km	61%
Curve	13.022 km	39%

(3) ROW Analysis

Land acquisition is increased when compared with Option 1 and the status of temporary land lease and land acquisition for construction is seen in the table below:

Table 5-5 Land acquisition analyses for option 2

Sections	Required Area(m^2)	Current ROW in Area(m^2)	Additional Area Required(m^2)		
			Permanent	Temporary	Total
Maradana~Nugegoda	142,400	114,303	21,073	7,024	28,097
Nugegoda~Homagama	227,198	145,273	61,444	20,481	81,925
Homagama~Padukka	-	-	-	-	-
Total	369,598	259,576	82,517	27,505	110,022

As shown above, the area of required land is 369,598 m^2 in total, and available existing ROW is 259,576 m^2. Permanent land to be additionally purchased is 82,517 m^2.

(4) TPS Analysis

From the TPS analysis, it is analyzed that the commercial speed is 37.6 km/h, and the travel time is 53 minutes. This shows the betterment of existing line which has the commercial speed of 23.5 km/h and travel time of 62 minutes from Maradana to Homagama.

Table 5-6 Comparison of option 2 with existing line

Existing alignment Maradana to Homagama		Realignment Maradana to Homagama		Increase/Decrease	
Commercial Speed	Travel Time	Commercial Speed	Travel Time	Commercial Speed	Travel Time
23.5 km/h	68 mins	37.5 km/h	36.6mins	+ 14.0 km/h	-31.4mins
Maradana – Padukka travel time will be 54.4 minutes after improvement.					

5.1.2.3. Horizontal Alignment Option 3

(1) General

According to this option, the total length of the section from Maradana to Padukka is 32.793 km. The speed is planned to be 80 km/hr and the minimum radius of curvature is 400 m. Thus, there are many sections where the alignment is laid off bounds of the existing ROW.

(2) Curvature

The following table shows the condition of curvatures on Option 3.

Table 5-7 Length of straight and curved line on Option 3

Total length	32.793 km	100%
Straight	20.126 km	61%
Curve	12.667 km	39%

(3) ROW Analysis

Land acquisition is increased when compared to Option 1 and 2, and the status of temporary land lease and land acquisition for construction is seen in the table below:

Table 5-8 Land acquisition analyses for option 3

Sections	Required Area(m^2)	Current ROW in Area(m^2)	Additional Area Required(m2)		
			Permanent	Temporary	Total
Maradana~Nugegoda	140,820	90,723	37,573	12,524	50,097
Nugegoda~Homagama	223,335	101,436	91,424	30,475	121,899
Homagama~Padukka	-	-	-	-	-
Total	364,155	192,159	128,997	42,999	171,996

As shown above, the total area of required land is 364,155 m^2, and utilizable existing land is 192,159 m^2. Permanent land to be additionally purchased is 128,997 m^2.

(4) TPS Analysis

According to the result of TPS analysis, the Commercial speed is 38.7 km/h, and the travel time is 50.9 minutes. This is a significant upgrade from the existing line which has the Commercial speed of 23.5 km/h and travel time of 62 minutes from Maradana to Homagama.

Table 5-9 Comparisons of option 3 with the existing line

Existing alignment Maradana to Homagama		Realignment Maradana to Homagama		Increase/Decrease	
Commercial Speed	Travel Time	Commercial Speed	Travel Time	Commercial Speed	Travel Time
23.5 km/h	68 mins	37.3 km/h	36.2mins	+ 13.8 km/h	-31.8mins
Maradana – Padukka travel time will be 54 minutes after improvement.					

5.1.3 Selection of Optimal Horizontal Alignment

5.1.3.1. Comparisons of Alignment Options

A comparative analysis on the options from Maradana to Homagama is presented in the following table:

About the Option 2 and Option 3, the cost of land acquisition is very high, but the time-saving effect was not so good compared to Option 1. The time saves between Option 1 and Option 3 is only 5.4 minutes although the land acquisition and resettlement compensation cost increase much more. Option 2 and Option 3 are almost identical to each other in terms of commercial speed and travel time.

Table 5-10 Comparisons of alignment options

From Maradana to Homagama					
Items			Option 1	Option 2	Option 3
Length			34.9 km	33.2 km	32.8 km
Minimum Radius of Curvature			120 m	300 m	400 m
Commercial Speed			35.2 km/h	37.5 km/h	37.3 km/h
Travel Time			41.6 min.	36.6 min.	36.2 min.
Land	Required Land		394,601 m^2	369,598 m^2	364,155 m^2
	Existing Land		365,392 m^2	259,576 m^2	192,159 m^2
	Additional Land	Permanent	21,907 m^2	82,517 m^2	128,997 m^2
		Temporary	7,302 m^2	27,506 m^2	42,999 m^2
Alignment Engineering			Due to the usage of existing land, additional land will be rarely purchased.	Additional land purchase is required, but train speed will be increased.	Additional land purchase is required, but train speed will be increased.
Social/Resettlement			Land acquisition & Resettlement is mostly required within ROW and the need for private land acquisition is minimal.	Land acquisition & Resettlement will be greater than Option 1 outside the ROW and some private land needs to be acquired.	Land acquisition & Resettlement will be greater as land use within ROW is less than the other 2 options.
Environment			lowest impact	moderate impact	highest impact

5.1.3.2. Weight Comparison for Selection of Optimal Alignment

Table 5-11 finally presents the final score on different alignment options. Overall scores on the items like Alignment, social/resettlement/gender, environment and transport economy on three options are presented.

Table 5-11 Summary of Alignment option study

Classification	Weights	Option-1	Option-2	Option-3
Alignment	40.0	28.0	20	21.6
Social/Resettlement/Gender	25.0	18.8	15.8	13.3
Environment	20.0	11.8	10.6	8.6
Transport Economy	15.0	13.3	12.8	12.4
Average Weight	100.0	71.9	59.2	55.9

5.1.3.3. General conclusion

The current ROW is provided by the client from Maradana to Homagama, therefore only this section was possible to review for relative comparison.

From the analysis presented in this table, the Consultant recommends Option- 1 which is the re-alignment within the ROW as the best choice for KV line. Higher scores on alignment, social/resettlement/gender and environment have place Option 1 comparatively in higher position among other options. While TPS analysis shows a minor improvement in train operation in Option 2 and Option 3, they have greater drawbacks in alignment, social/resettlement/gender and environment sectors.

Shown in the table below, Option 1 requires only little land acquisition by utilizing the existing ROW at maximum. Option 2 or Option 3 is a better alignment than Option 1, but only 5.4 minutes time saving although the land acquisition and resettlement compensation cost increase much more. Therefore, Option 1 (Alignment within the existing ROW) is recommended as the optimal alignment.

Table 5-12 Land acquisition and resettlement compensation additional area

Item	From Maradana to Homagama			Remarks
	Total	Existing available	Addition	
Option 1	394,601 m^2	365,392 m^2	21,907 m^2	
Option 2	369,598 m^2	259,576 m^2	82,517 m^2	
Option 3	364,155 m^2	192,159 m^2	128,997 m^2	

Table 5-13 Velocity or time difference

Item	From Maradana to Homagama		Remarks
	Commercial Speed (km/h)	Travel Time (minutes)	
Existing Alignment	23.5	68	( ) is velocity or time difference between Existing Alignment
Option 1	35.2 (+ 11.7)	41.6(-26.4)	
Option 2	37.5 (+ 14.0)	36.6(-31.4)	
Option 3	37.3 (+ 13.8)	36.2(-31.8)	

Table 5-14 In case of Option 1& 3, the commercial speed and travel time for each section are as follows.

Section	Commercial speed (km/h)	Travel time (minutes)		Difference between Travel time of Options (minutes)
		Option 1	Option 3	
Maradana ~ Homagama	35.2	41.6	36.2	5.4

5.1.4 Detailed Description of Selected Horizontal Alignment

5.1.4.1. Alignment Details

By the study of 5.1.3 Selection of Optimal Horizontal Alignment, Option 1 (designing within ROW) is selected as optimal Horizontal alignment. This means that the new line designed within ROW as much as possible is the most effective line as the KV line.

The alignment is being reviewed continuously, so that some parts of alignment may be changed.

From Maradana to Avissawella, the total length is 58.400 km. In the route, Maradana to Padukka is planned for double track (length is 34km920), and from Padukka to Avissawella is planned for single track (length is 23km480).

From Maradana to Kottawa, it has been planned to establish elevated railway; and from Kottawa to Avissawella, to establish at grade.

As mentioned, it was planned to improve the alignment within the ROW if possible. For some sections, the alignment was improved by using the agricultural land sections in order to minimize the interference of the residents and dwells. According to Option 1, the curve status by sections of the improved alignment is as follows.

Table 5-15 Number of curves in the KV line

ITEM	Maradana~ Homagama		Homagama~ Padukka		Padukka~ Avissawella		Total Maradana~ Avissawella	
R<=200	51	61%	12	38%	72	69%	135	61%
200<R<=300	10	12%	5	16%	16	15%	31	14%
300<R<=400	7	8%	7	22%	5	5%	19	9%
400<R<=500	3	4%	3	9%	7	7%	13	6%
500<R	12	14%	5	16%	5	5%	22	10%
SUM	83	100%	32	100%	105	100%	220	100%

Table 5-16 Length of curves in the KV line

ITEM	Maradana~ Homagama		Homagama~ Padukka		Padukka~ Avissawella		Total Maradana~ Avissawella	
R<=200	8km112	63%	1km741	37%	6km866	62%	16km719	58%
200<R<=300	1km333	10%	0km803	17%	1km998	18%	4km134	14%
300<R<=400	0km927	7%	1km163	25%	0km723	7%	2km813	10%
400<R<=500	0km505	4%	0km386	8%	0km768	7%	1km659	6%
500<R	2km134	16%	0km627	13%	0km652	6%	3km413	12%
SUM	13km011	100%	4km720	100%	11km007	100%	28km738	100%

Table 5-17 The portion of straight and curved line on KV line

Total length	58km461	100%
Straight	29km723	51%
Curve	28km738	49%

From Maradana to Padukka, the improvement of curves are as follows. The improved Chainage is based on the existing line:

Table 5-18 The improvement of curves

Existing chainage	Existing Radius	Improved Radius (Option 1)	Remarks
Between Maradana station and Baseline Road station, from 0km 920 to 1km 300			The existing ROW width is about 6m, so an additional 10m width land acquisition is required.
Between 1km700 and 2km100, ROW is wide and Baseline Road Station is located	R=220m, R=200m, R=350m	R=300m and R=400m	Three curves are reduced by two curves Baseline Road station can be established in a straight line section. The distance of changed station is about 80 meters.
Between 2km400 and 2km580	R=130m	R=150 m	Radius is enlarged
Between 5km400 and 5km800			the center line of railway is moved about 8 m to left in order to include the typical section of 16m ROW
Between 7km400 and 7km500	R=450 m	R=500 m	Radius is enlarged
Between 8km110 and 8km230	R=130m	R=150 m	Radius is enlarged
Between 8km320 and 8km460	R=140 m	R=160 m	Radius is enlarged
Between 8km690 and 8km820	R=150 m	R=160 m	Radius is enlarged
Between 9km260 and 9km320	R=150 m	R=250 m	Radius is enlarged
Between 11km350 and	S curve of	R=300m,	In order to install new Udahamulla

Existing chainage	Existing Radius	Improved Radius (Option 1)	Remarks
11km660	R=400m and R = 200m	straight and R = 250m	station in the straight section, it is inevitable to move about 15m
Between 14km860 and 15km400	3 places S curve of R=170m, R=150m and R=200m	R=250m straight and R=250m	Three curves can be changed to straight-line within the ROW
Between 15km540 and 15km670	R=120 m	R=130 m	Radius is enlarged
Between 16km180 and 16km310	R=320 m	R=400 m	Radius is enlarged
Between 16km350 and 16km430	R=140 m	R=200 m	Radius is enlarged
Between 16km480 and 16km580	R=130 m	R=160 m	Radius is enlarged
Between 17km510 and 17km670	R=120 m	R=125 m	Radius is enlarged
Between 18km700 and 19km330	R=120 m	R=300 m	Radius is enlarged out of ROW
Between 19km920 and 20km050	R=120 m	R=150 m	Radius is enlarged
Between 21km770 and 22km880	8 curves of the existing alignment R=300m, R=120m R=120m, R=130m, R=150m, R=120m, R=120m, R=150m	3 curves R=300m, R=1000m, R=120m	Using the farmland on the right side of minimum residence conflict
Between 23km360 and 23km500	R=130 m	R=150 m	Radius is enlarged
Between 23km790 and 23km910	R=120 m	R=130 m	Radius is enlarged
Between 23km950 and 24km210	3 places S curves of existing alignment R=120m, R=120m and R=110m	R=130m, straight, R=130m	Using the farmland on the left side of the alignment to minimize the conflict of residence
Between 24km260 and 24km680	R=400m, R=120m, R=120m	R=200m, straight, R=150m	The location of Homagama station will be established on the straight new railway line.
Between 24km740 and 24km830	R=110 m	R=120 m	Radius is enlarged
There is no ROW from Homagama to Padukka. The consultant planned the new alignment near the existing railway minimizing the interference with nearby residence.			
Between 24km970 and 25km430	R=150m, R=150m and R=350m	R=1000m, R=1000m	Using the farmland on the left side of the alignment to minimize the conflict of residence
Between 25km700 and 26km050	R=120m, R=130m and R=150m	R=150m, R=350m	
Between 26km790 and 26km870	R=120 m	R=150 m	Radius is enlarged
Between 26km960 and 27km230	R=180m, R=110m	R=150 m	Curves are replaced
Between 27km280 and 28km090	R=120m, R=200m and R=200m	R=130m, R=1000m and	Using the farmland on the left side of the alignment to minimize the conflict of residence

Existing chainage	Existing Radius	Improved Radius (Option 1)	Remarks
		R=1000m	
Between 29km100 and 29km190	R=200 m	R=400 m	Radius is enlarged
Between 29km320 and 29km540	R=120m, R=500m	R=150 m	Curves are replaced
Between 29km860 and 29km940	R = 180 m	R=400 m	Radius is enlarged
Between 30km740 and 30km880	R=1000m, R=180m	R=300 m	Curves are replaced
Between 31km000 and 31km430	R=500m, R=2000m and R=200m	R=500m, R=150m	The new railway center line is shifted 5m to right side.
Between 32km400 and 32km650	R=500m, R=170m	R=200 m	Curves are replaced
Between 33km300 and 33km430	R=230 m	R=400 m	Radius is enlarged
Between 33km600 and 34km200	R=140m	R=250m	Using the farmland on the left side of the alignment to minimize the conflict of residence
Between 34km270 and 34km520	R=230m R=230m	R=200 m	Curves are replaced
Between 34km650 and 34km780	R=200m, R=150m	R=300m, R=400m	Radius is enlarged
Between 36km200 and 36km600	R=150m, R=150m R=130m, R=200m	R=300m	The existing curve R=120m→150m→130m→200m is planned to expanded R = 300m. 3private house is in conflict with the expansion of the curve. There is no ROW.
Between 37km700 and 38km100	R=250m, R=150m R=350	R=350m	Existing alignment is composed of three small curves in successive sections where 1 private house is in conflict with the expansion of the curve. By using the farmland section, it may be possible to straighten the alignment and station. There is no ROW.
Between 38km800 and 39km100	R=500m, R=150m	R=300m	Existing alignment is composed of two small curves in successive sections. By using the farmland section, it may be possible to straighten the alignment and station.
Between 40km500 and 41km000	R=180m, R=120m R=120m	R=1,000m	Existing alignment is composed of curve R=180m→120m→ 120m curves in successive sections. 2 private house is in conflict with the expanded R = 1000m. By using the farmland section, it may be possible to straighten the alignment. There is no ROW.
Between 41km000 and 41km500	R=180m, R=120m R=150m	R=180m, R=150m	Existing alignment is composed of three small curves in successive sections. 2 private houses are in conflict with the

Existing chainage	Existing Radius	Improved Radius (Option 1)	Remarks
			expansion of the curve. By using the farmland section, it may be possible to straighten the alignment and station. There is no ROW.
Between 42km500 and 43km300	R=150m, R=150m R=300m, R=120m	R=250m	Existing alignment is composed of curve R=150m→150m→300m→120m curves in successive sections. By using the farmland section, it may be possible to straighten the alignment. There is no ROW.
Between 55km100 and 56km000	R=80m, R=80m R=85m, R=90m R=95m, R=75m R=120m, R=80m R=90m	R=120m, R=600m R=300m, R=120m R=120m	Existing alignment is composed of nine sharp curves. Existing Puwakpitiya station is not to be planned for the current location. Station location movement and straightening are inevitable
Between 56km700 and 57km140	R=80m, R=120m R=80m, R=80m	R=120m, R=120m R=120m, R=120m	Existing alignment is composed of curve R=80m→120m→80m→80m curves in successive sections. Minimum sharp curve section extends to the curve R = 120m.
Between 57km900 and 58km200	R=120m, R=65m R=100m	R=120m, R=80m R=120m	Existing alignment is composed of curve R=120m→65m→100m curves in successive sections. Minimum sharp curve section extends to the curve R = 80m

5.1.4.2. Major Section Drawing

Three curves are replaced by two curves to eliminate one.
Baseline Road station can be established in a straight-line section. The distance of the changed station is about 80 meters.

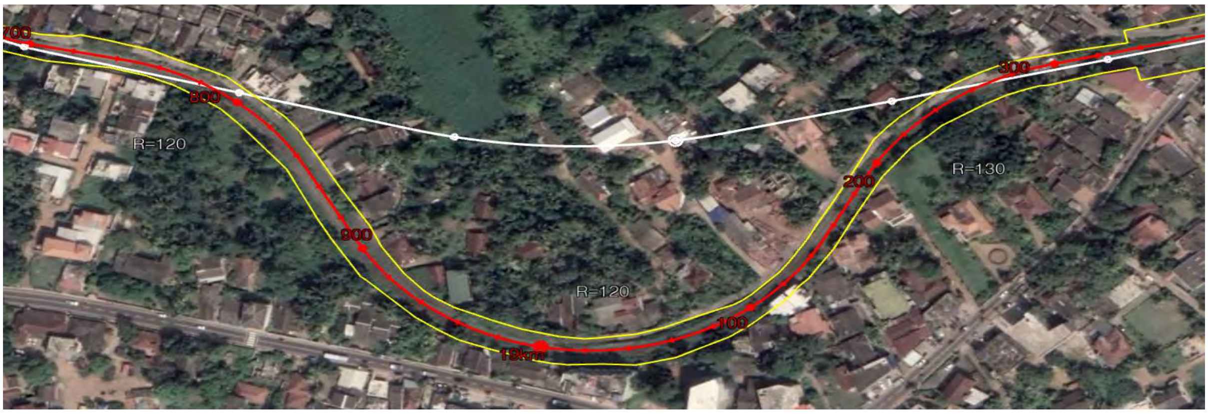
Figure 5-2 1km700 ~ 2km100 : ROW is wide and Baseline Road Station is located

In order to construct the new Udahamula station in the straight section, it is inevitable to move about 15m

Figure 5-3 11km350 ~ 11km660 : Changing alignment is possible

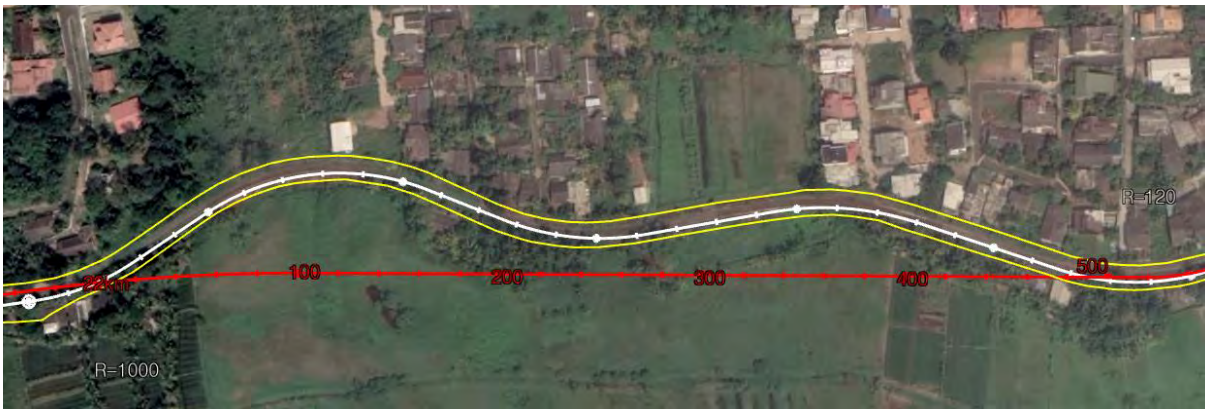
Three curves can be changed to straight-line within the ROW.

Figure 5-4 14km860 ~ 15km400 : Changing alignment is possible



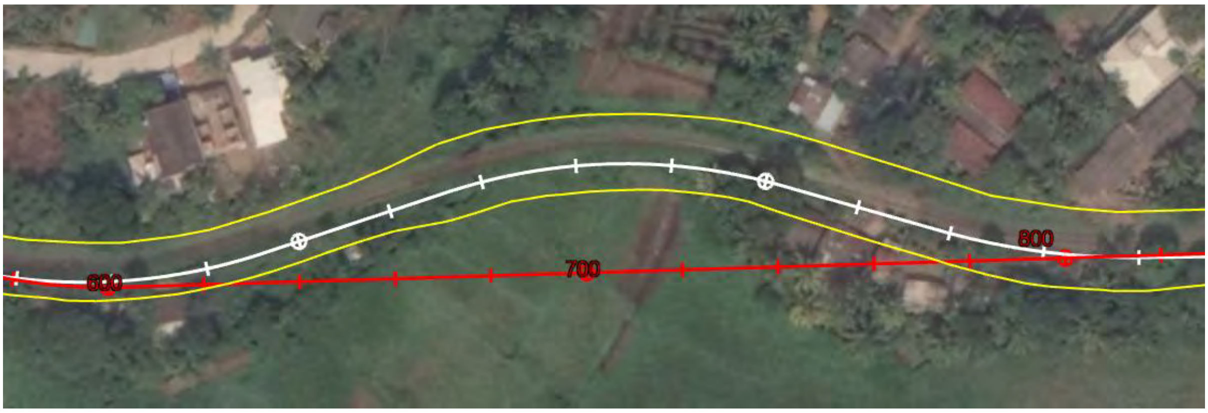
The existing line consisted of S-curve as R=120m→120m→130m
The consultant planned 1 curve to a continuous section of small curves.
However, as a result of field survey, it is expected to encounter civil complaint due to the dense population.

Figure 5-5 18km800 ~ 19km300 : Changing alignment is impossible



In this section, there are 5 small curves continuously. Field survey shows that it is possible to straighten the existing alignment. In order to exclude civilian conflicts, the farmland section is used.

Figure 5-6 22km000 ~ 22km500 : Changing alignment is possible



Existing alignment is composed of three small curves in successive sections.
By using the farmland section, it may be possible to straighten the alignment.

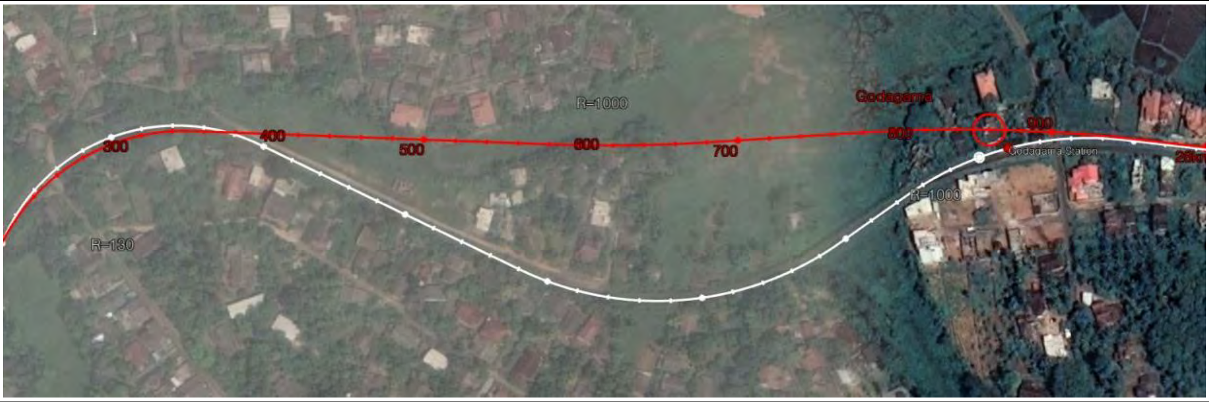
Figure 5-7 22km600 ~ 22km800 : Changing alignment is possible

Existing alignment is composed of three small curves in successive sections.
By using the farmland section, it is possible to straighten the alignment.
It may be possible to change the alignment even though there are two private houses.

Figure 5-8 23km950 ~ 24km210 : Changing alignment is possible

Existing alignment is composed of three small curves in successive sections.
2 private houses are in conflict with the expansion of the curve. There is no ROW.
By using the farmland section, it may be possible to straighten the alignment.

Figure 5-9 24km970 ~ 25km430 : Changing alignment is possible



Existing alignment is composed of three small curves in successive sections.
3 private houses are in conflict with the expansion of the curve. There is no ROW.
By using the farmland section, it may be possible to straighten the alignment.

Figure 5-10 27km280 ~ 28km090 : Changing alignment is possible

The existing curve R = 140m is planned to be expanded for R = 250 m. 1 private house is in conflict with the expansion of the curve. There is no ROW.
By using the farmland section, it may be possible to straighten the alignment.

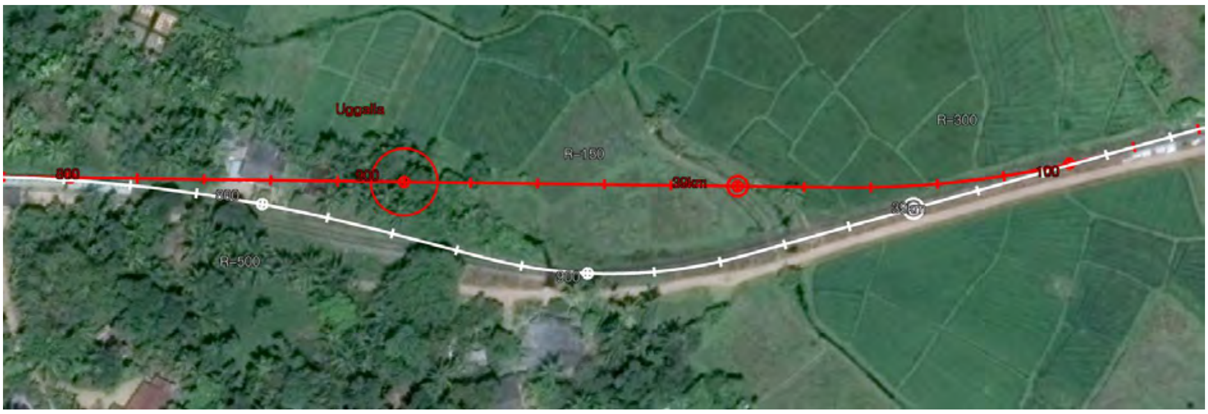
Figure 5-11 33km600 ~ 34km200 : Changing alignment is possible

The existing curve R=120m→150m→130m→200m is planned to be expanded for R = 300m. 3 private houses are in conflict with the expansion of the curve. There is no ROW.

Figure 5-12 36km200 and 36km600 : Changing alignment is possible

Existing alignment is composed of three small curves in successive sections.
2 private houses are in conflict with the expansion of the curve.
By using the farmland section, it may be possible to straighten the alignment and station.
There is no ROW.

Figure 5-13 37km700 ~ 38km100 : Changing alignment is possible



Existing alignment is composed of two small curves in successive sections.
By using the farmland section, it may be possible to straighten the alignment and station.

Figure 5-14 38km800 and 39km100 : Changing alignment is possible

Existing alignment is composed of curve R=180m→120m→ 120m curves in successive sections. 2 private houses are in conflict with the expanded R = 1000m. By using the farmland section, it may be possible to straighten the alignment. There is no ROW.

Figure 5-15 40km500 ~ 41km000 : Changing alignment is possible

Existing alignment is composed of curve R=180m→120m→ 120m curves in successive sections. 2 private houses are in conflict with the expanded R = 1000m. By using the farmland section, it may be possible to straighten the alignment. There is no ROW.

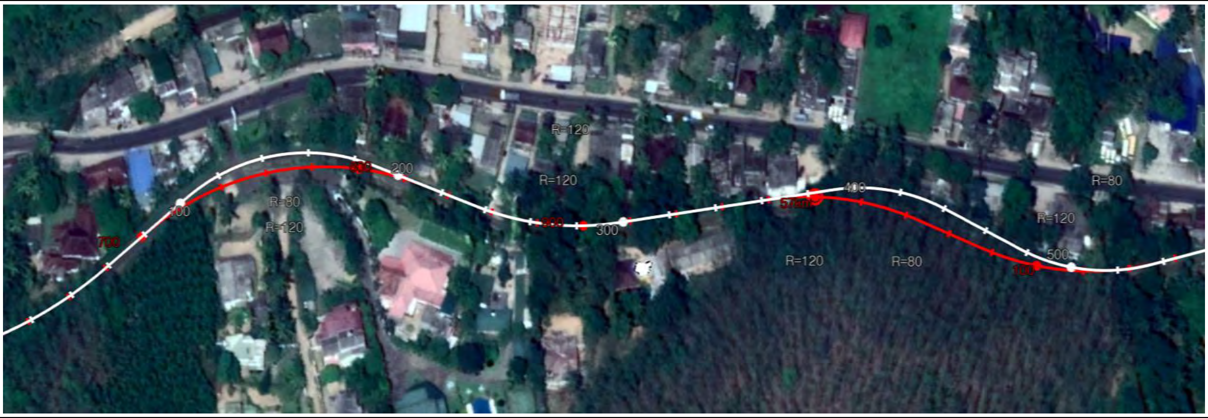
Figure 5-16 41km000 ~ 41km500 : Changing alignment is possible

Existing alignment is composed of curve R=150m→150m→300m→120m curves in successive sections. By using the farmland section, it may be possible to straighten the alignment. There is no ROW.

Figure 5-17 42km500 ~ 43km300 : Changing alignment is possible

Existing alignment is composed of nine sharp curves. Existing Puwakpitiya station is not planned for the current location. Station location movement and straightening alignment are inevitable.

Figure 5-18 55km100 ~ 56km000 : Changing alignment is possible



Existing alignment is composed of curve R=80m→120m→80m→80m curves in successive sections. Minimum sharp curve section extends to the curve R = 120m.

Figure 5-19 56km700 ~ 57km140 : Changing alignment is possible

Existing alignment is composed of curve R=120m→65m→100m curves in successive sections. Minimum sharp curve section extends to the curve R = 80m.

Figure 5-20 57km900 ~ 58km200 : Changing alignment is possible

5.2 Vertical Alignment

5.2.1. Brief Details

5.2.1.1. Section of Maradana~ Makumbura North

The review of the vertical alignment was made in section from Maradana to Malapalla. Makumbura North is the next place from Malapalla station. The distance from Maradana to Makumbura North is 21.900 km. There are 13 existing stations and New2 station, New4 station (Makumbura North). This section is a very populated urban area. Frequency of train is 7 min in this section and there are so many level crossings.

If vertical alignment is planned at grade, road traffic congestion will be extremely severe in the populated urban area. It is effective to consider an elevated railway to avoid congestion at the crossings in a population-dense area. Many number of Level crossings is a major cause of congestion in road traffic, making the huge economic loss. For the country's long future, KV line should be elevated.

When KV line is elevated in this section, there are many advantages as follows;

- Avoid separation of the city area. Freely come and go between regions.
- Relieve from road traffic congestion in the highly dense urban area.
- Also the space under the elevated viaduct can be utilized as exercise facility, resident convenience facility, parking lot, etc.

The review of the vertical alignment was made in section from Maradana to Malapalla. Makumbura North is the next station from Malapalla station.

5.2.1.2. Section of Makumbura North~ Padukka

The distance from Makumbura North to Padukka is 13.020 km. There are 8 existing stations.

From Makumbura North to Padukka, this section is a less populated suburban area. Frequency of train is 14 min in this section and there are not so many level crossings.

The traffic volume at the level crossing is significantly less than the traffic volume between Maradana and Makumbura North.

For the construction cost, it is proper to construct at grade in this section.

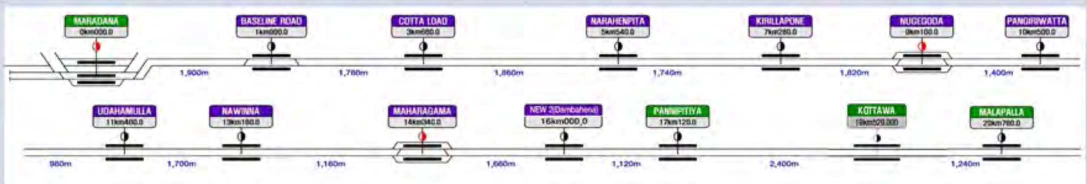
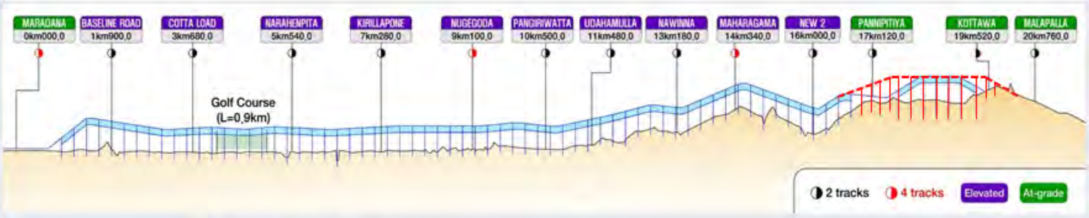
In case of at grade in this section, traffic congestion is not expected in the future. The construction cost will be low when construction is considered at grade. It is reasonable to consider reducing the construction cost by establishing flyover only where there is particularly heavy traffic place.

5.2.2. Review of Vertical Options(From Maradana to Malapalla)

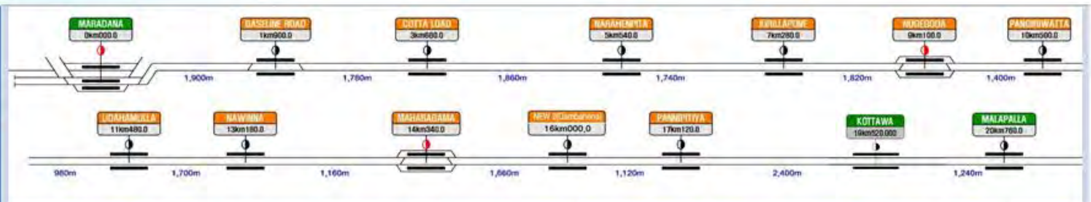
The consultant studied 4 kinds of vertical options in the section of Maradana to Malapalla and by comparing advantages and disadvantages such as frequency of train, construction cost, environmental and social aspect, etc, the most proper Vertical alignment was decided.

- Option 1 : Elevated line
- Option 2 : Underground line
- Option 3 : Elevated + Underground line
- Option 4 : Elevated + Underground line + At grade line

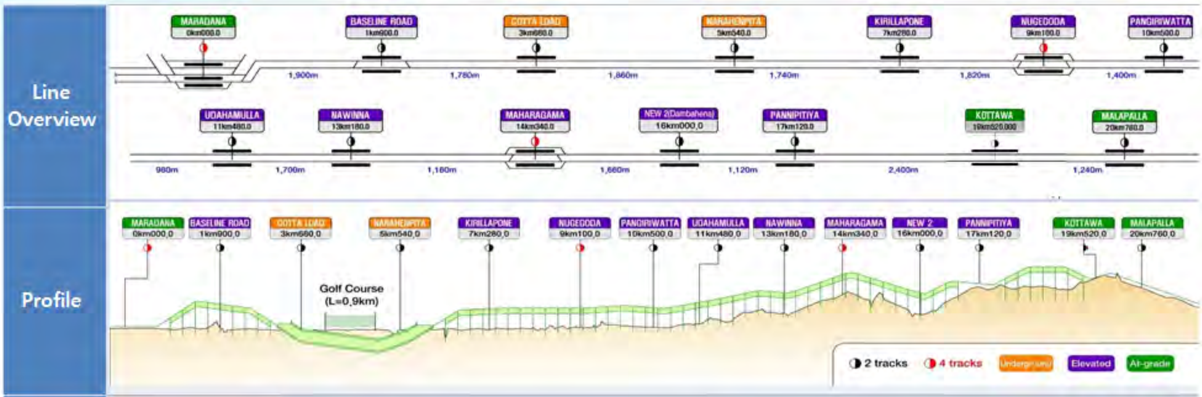
5.2.2.1. Vertical Alignment Option 1(Elevated line)

Stake-holder	• RDA & PMU (18 July, Megapolis Office) - Level crossing of Elevated (Pannipitiya station)	• Royal Colombo Golf Club (20 July, Golf club office) - Elevated railway in golf course section(Golf Club)
Line Overview		
Profile		
Total Length	L=20.76km	• Elevated : 18,9 km • Earthwork : 1,86 km • Total : 20.76 km (Include station : 3.38 km)
Structures (Station)	• Elevated station : 11nos - 2 tracks (L=200m) = 8 nos , 4 tracks(L=512m) = 3 nos • At-grade station : 3nos - 2 tracks (L=200m) = 2 nos , 4 tracks(L=512m) = 1 nos	
Comments	• Total Length 20.76km (Elevated : 18,9 km , Earthwork : 1.86 km , Station : (14 nos))	

5.2.2.2. Vertical Alignment Option 2 (Underground line)

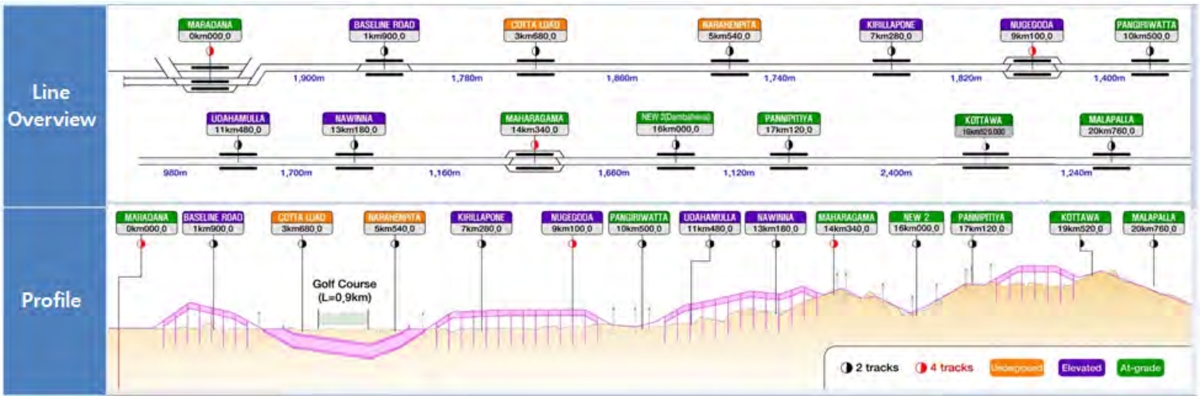
Line Overview		
Profile		
Total Length	L=20.76km	• Cut-and-Cover Tunnel : 18.17 km • Earthwork : 2.59 km • Total : 20.76 km (Include station : 3.38 km)
Structures (Station)	• Underground station : 11 nos - 2 tracks (L=200m) = 8 nos , 4 tracks(L=512m) = 3 nos • At-grade station : 3 nos - 2 tracks (L=200m) = 2 nos , 4 tracks(L=512m) = 1 nos	
Comments	• Total Length 20.76km (Cut-and-Cover Tunnel : 18,17 km , Earthwork : 2.59 km , Station : (14 nos))	

5.2.2.3. Vertical Alignment Option 3 (Elevated + Underground line)



Total Length	L=20.76km	• Elevated (13.74 km) • Earthwork (3.92 km)	• Open-Cut Tunnel : 3.1 km • Total : 20.76 km (Include station : 3.38 km)
Structures (Station)	• Elevated station : 8 nos • Underground station : 2 nos • At-grade station : 4 nos	- 2 tracks (L=200m) = 6 nos , 4 tracks(L=512m) = 3 nos - 2 tracks (L=200m) = 2 nos - 2 tracks (L=200m) = 2 nos , 4 tracks(L=512m) = 1 nos	
Comments	• Total Length 20.76km (Elevated : 13.74 km , Cut-and-Cover Tunnel : 3.1 km , Earthwork : 3.92 km , Station : (14 nos))		

5.2.2.4. Vertical Alignment Option 4 (Elevated + Underground line + At grade line)



Total Length	L=20.76km	• Elevated (9.5 km) • Earthwork (8.16 km)	• Open-Cut Tunnel : 3.1 km • Total : 20.76 km (Include station : 3.38 km)
Structures (Station)	• Elevated station : 5 nos • Underground station : 2 nos • At-grade station : 7 nos	- 2 tracks (L=200m) = 4 nos , 4 tracks(L=512m) = 2 nos - 2 tracks (L=200m) = 2 nos - 2 tracks (L=200m) = 4 nos , 4 tracks(L=512m) = 2 nos	
Comments	• Total Length 20.76km (Elevated : 9.5 km , Cut-and-Cover Tunnel : 3.1 km , Earthwork : 8.16 km , Station : (14 nos))		

5.2.2.5. Construction Cost by Option(From Maradana to Malapalla)

(UNIT : USD 1million)

Classification		Option1	Option2	Option3	Option4	Remark
Construction Cost	Station	220.6 Elevated (11) At grade (3)	169.4 Under ground (11) At grade (3)	216.2 Elevated (9) Under ground (2) At grade (3)	159.6 Elevated (6) Under ground (2) At grade (6)	
	Architecture Work	113.4	141.4	118.2	117.6	
	Main line	493	439	490	385	
	Flyover		13.6 (1nos)	54.5 (4nos)	186.1 (12nos)	
	Soil disposal (Under ground section)		46 (2.6m m³)	6 (0.4m m³)	6 (0.4m m³)	
	Ventilation		28.6	5.2	5.2	
Subtotal (A)		**827.1**	**838.3**	**890.4**	**859.5**	
System Construction Cost		56.5	62.6	57.6	62.0	
Subtotal (B)		**56.5**	**62.6**	**57.6**	**62.0**	
(A) + (B) (Average Cost per km)		**883.6 (42.5)**	**900.9 (43.4)**	**948.0 (45.7)**	**921.5 (44.4)**	
Other Cost	Land acquisition and resettlement costs	91.5 P : 307,500 m² T : 7,440 m²	89.9 P : 288,046 m² T : 83,040 m²	91.4 P : 309,764 m² T : 28,080 m²	98.2 P : 328,180 m² T : 45,040 m²	**P (Permanent) T (Temporary)**
Subtotal (C)		**91.5**	**89.9**	**91.4**	**98.2**	
Total Cost (A+B+C)		**975.1**	**990.8+α**	**1039.4**	**1019.7**	

※ **1) Maintenance cost of pumping house for underground not counted for.**
2) + α : Can be more than 100 Mn. USD (Rock excavation, Ground Improvement, Maintenance Cost)

5.2.2.6. Advantages and Disadvantages

	Option 1	Option 2	Option 3	Option 4
Options	Elevated : 18.9 km At Grade : 1.86 km Total : 20.76 km	Underground : 18.17km At Grade : 2.59 km Total : 20.76 km	Elevated : 13.74 km Underground : 3.1 km At Grade : 3.92 km Total : 20.76 km	Elevated : 9.5 km Underground : 3.1 km At Grade : 8.16 km Total : 20.76 km
Advantages	• Prevention of area Separation • Minimum social impact • No impact to utilities • No impact to traffic • Minimum operation interruption • Low construction cost • Minimum disturbance to public during construction Elevated section	• Prevention of area Separation • No vibration or noise • Surface ground to be public use • No impact to traffic • Aesthetic merit Under ground section	• Prevention of area Separation • Option 1 + Golf club rehabilitation	• Shorter construction period • Main trackbed cost low w/o Flyover At grade section

Options	Option 1	Option 2	Option 3	Option 4
Disadvantages	• Need sound protection barrier • Prospect and sunlight right limited • Violation of privacy of houses in vicinity of line	• Massive soil disposal • Unsuitable for DMU operation • Additional costs depending on the ground conditions • Effect of Vibration on above ground buildings • Ventilation and refugee system required • Disruption to traffic during construction • High disruption to existing habitats • Utilities relocation • Pumping drainage system	• Option1 + Option2 • Area separation(3km) outside golf club	• Option3 + • Difficult traffic control • High cost for Flyover • More land acquisition
Result	○			

5.2.3. General conclusion.

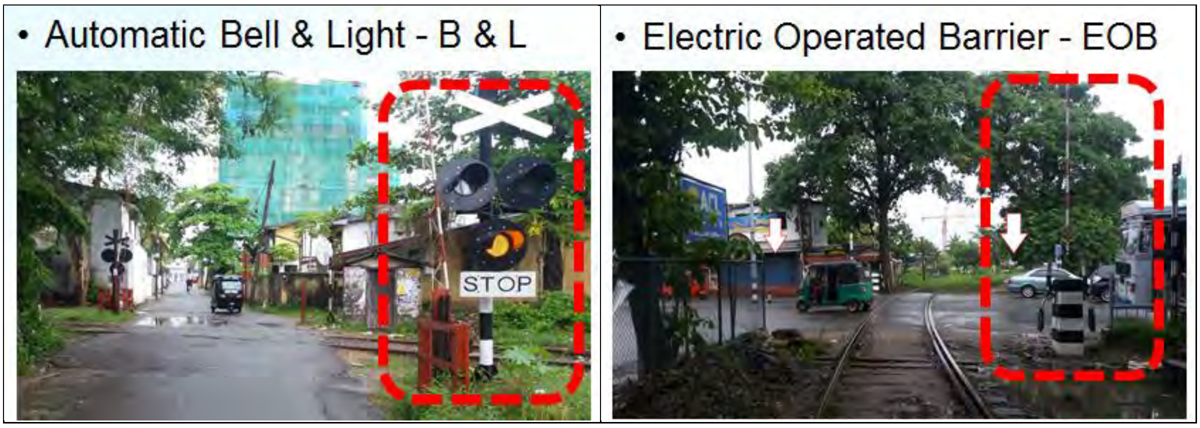
About the vertical alignment plan from Maradana to Padukka, section divided and reviewed Maradana ~ Makumbura North and Makumbura North ~Padukka sections based on frequency of train.

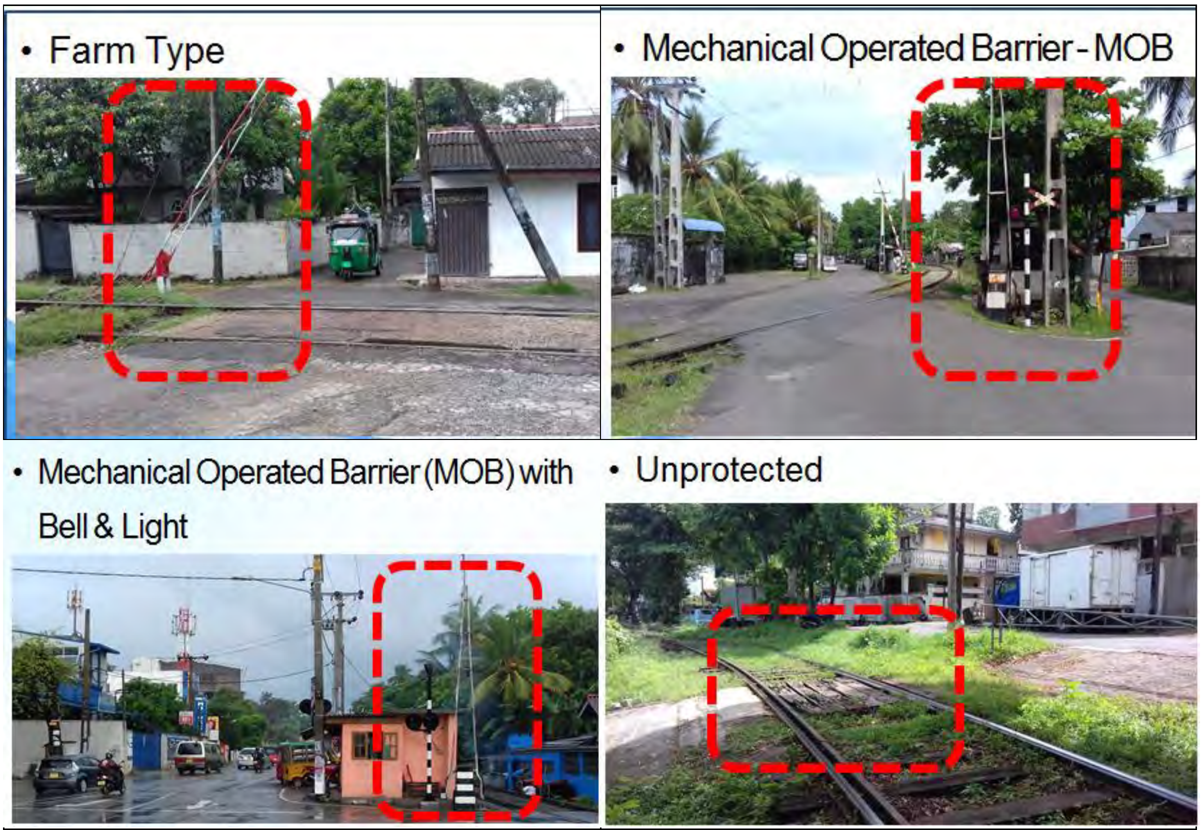
Section of Maradana~ Makumbura North is an urban densely area and there are so many level crossings. Also frequency of train is 7 min. So that it is proper to consider elevated as a vertical alignment.

Section of Makumbura North ~ Padukka is a suburban area and there are not so many level crossings. Also frequency of train is 14 min. So that it is proper to consider at grade as a vertical alignment.

5.3 Level Crossings

5.3.1. Existing Level Crossing Status





No.	Level Crossing TYPE	Nos	Remark
1	Automatic Bell & Light - B & L	23	
2	Electric Operated Barrier – EOB	6	
3	Mechanical Operated Barrier – MOB	15	
4	Mechanical Operated Barrier (MOB) with Bell & Light	19	
5	Unprotected	82	
	Total	145	

5.3.2. Level crossing Mitigation Plan

From Maradana to Malapalla is elevated and From Malapalla to Avissawella is at grade.

Level crossing Plan is as follows;

Plan 1 : All the LC to be eliminated in the elevated section.

Plan 2 : Install fly-over or underground box where the traffic volume is over ADT 20,000 or main road.

Plan 3 : Maintain LC with protection in local vehicle road.

Plan 4 : The distance between LC is less than 400m, eliminate 1 LC and install connection road.

Plan 5 : Small pedestal LC to be eliminated or install small box.

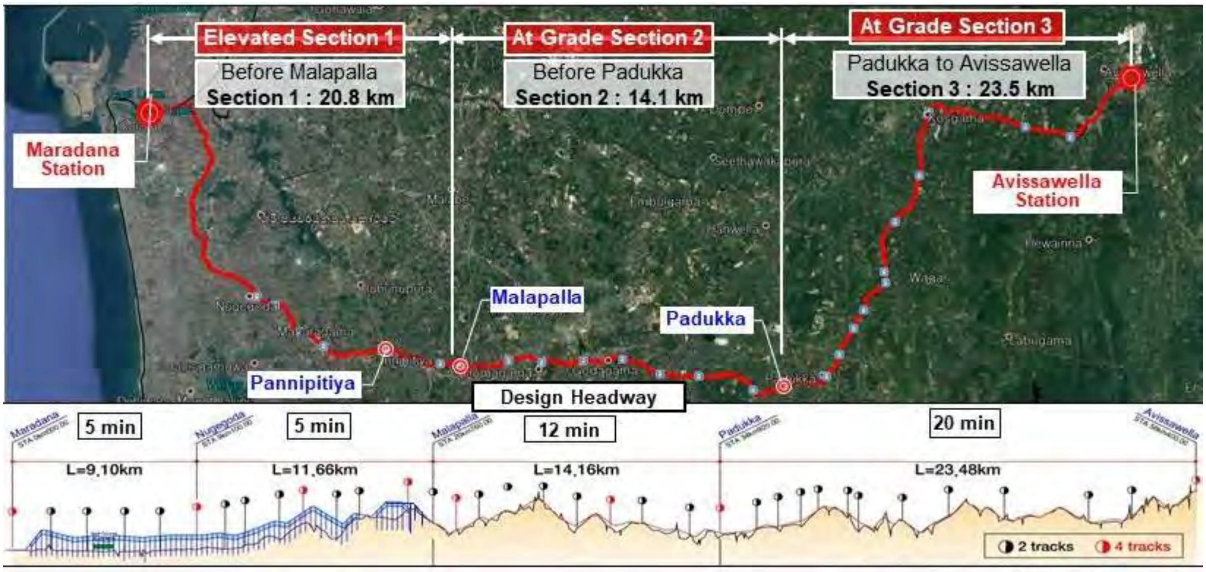
5.3.3. Conclusion of Level Crossing

From Maradana to Malapalla, this section is a populated urban area. Frequency of train is 7 min and there are so many level crossings. Therefore it is most advantageous to plan elevated.

As our design, alignment between Maradana to Malapalla section is elevated, existing 56 number of level crossings between this section will not pose any problems for the operations of the train service.

From Malapalla to Padukka, this section is a less populated suburban area. Frequency of the train is 14 min, and there are not so many level crossings. Therefore is most advantageous to plan at grade for the construction cost.

From Malapalla to Avissawella section will be operated with selected minimum number of level crossings with increased protection while providing the de tour parallel roads merging minor level crossings. The detail plan of the parallel roads, closing down of the minor level crossings and operating Level crossings will be identified during the detail design stage of the KV line.



Section	Existing	Plan
Section 1 : Before Malapalla	56 nos	NIL
Section 2 : Malapalla to Padukka	36 nos	19 nos
Section 3 : Padukka to Avissawella	53 nos	39 nos
Total	**145 nos**	**58 nos**

About the level crossings located at grade from Malapalla to Avissawella, the consultant discussed with the RDA and the results are as follows.

Table 5-19 Locations of Level Crossings at Grade

FS Design Alignment		Main Option	Existing type of the Level Crossing	Remarks
Chainage	**Road name**			
16+990	Battaramulla-Pannipitya Rd	• Pannipitiya existing road • Railway at grade	Flyover (ADT not investigated)	
17+095	Old Pannipitya Rd	• Install new flyover • Elevate Railway / Maintain existing road w/o protection / Demolish vicinity existing flyover • Close crossing / Install detour road	Mechanical Operated Barrier (MOB) with Bell & Light	(ADT 30000)
17+480	Pannipitya - Malabe	• Elevate Railway /	Mechanical Operated	(ADT Less

FS Design Alignment		Main Option	Existing type of the Level Crossing	Remarks
Chainage	Road name			
	Rd	Maintain existing road w/o protection / Demolish vicinity existing flyover • Close crossing / Install detour road • Maintain crossing / Impact railway operation	Barrier (MOB) with Bell & Light	than 20000)
19+380	Athurugiriya Rd	• Install new flyover • Elevate Railway / Kottawa station elevate	Mechanical Operated Barrier (MOB) with Bell & Light	(ADT 30000)
19+910	Kottawa-Malabe Rd	• Elevate Railway / Kottawa station elevate • Maintain level crossing / close on peaktime	Automatic Bell & Light - B & L	(ADT Less than 10000)
20+120	N/A	• Elevate Railway / Kottawa station elevate • Close level crossing / use existing detour road	Unprotected	
21+410	Pansala Rd	• Install box culvert / location change necessary	Mechanical Operated Barrier (MOB) with Bell & Light	Decision RDA
22+975	Hospital Rd	• Install underground pass way / automatic pumping necessary	Mechanical Operated Barrier (MOB) with Bell & Light	Decision RDA (3.5m for the underpass)
23+360	Galawila Rd	• Install new flyover • Maintain level crossing • Install underground pass way / automatic pumping necessary	Mechanical Operated Barrier (MOB) with Bell & Light	(ADT Less than 20000)
23+435	N/A	• Close level crossing / detour road	Unprotected	Galawila Rd
23+525	N/A	• Close level crossing / detour road	Unprotected	Galawila Rd
23+620	Wasana Mawatha Rd	• Close level crossing / detour road	Unprotected	Nagara Seema Rd
23+825	Nagara Seema Rd	• Maintain level crossing	Automatic Bell & Light - B & L	
24+380	Aturugiriya Rd	• Install new flyover • Install underground pass way / automatic pumping necessary	Mechanical Operated Barrier (MOB) with Bell & Light	(ADT 20000 over) Decision RDA (Underpass & Flyover)
24+920	Wimana Rd	• Close level crossing / detour road	Automatic Bell & Light - B & L	Decision RDA
26+220	Panagoda railway station Rd	• Maintain level crossing	Automatic Bell & Light - B & L	Decision RDA (Re alignment of the railway track.)
27+260	Godagamagewatta Rd	• Maintain level crossing	Automatic Bell & Light - B & L	
27+900	Station Rd	• Maintain level crossing /	Unprotected	Decision

FS Design Alignment		Main Option	Existing type of the Level Crossing	Remarks
Chainage	Road name			
		Station location change / Install protection		RDA
28+380	N/A	• Close level crossing / detour road	Unprotected	Samadhi Mawata Rd
28+570	N/A	• Close level crossing / detour road	Unprotected	Samadhi Mawata Rd
28+640	Samadhi Mawata Rd	• Maintain level crossing / Install protection	Unprotected	
28+840	Asiri uyana Rd	• Close level crossing / detour road	Unprotected	Puwakwaththa Rd
28+910	Puwakwaththa Rd	• Maintain level crossing	Mechanical Operated Barrier (MOB) with Bell & Light	Decision RDA
29+430	Meegoda station Rd	• Install Box calvert / automatic pumping necessary	Unprotected	RDA check
30+150	Udagewaththa Rd	• Close level crossing / detour road	Unprotected	Meegoda station Rd
30+630	N/A	• Close level crossing / detour road	Unprotected	Madulawa Rd
30+860	N/A	• Close level crossing / detour road	Unprotected	Madulawa Rd
31+030	Madulawa Rd	• Maintain level crossing	Automatic Bell & Light - B & L	RDA check
31+160	N/A	• Close level crossing / detour road	Unprotected	Madulawa Rd
31+700	Opathella Rd	• Maintain level crossing / Install protection	Unprotected	
31+850	N/A	• Close level crossing / detour road	Unprotected	Opathella Rd
32+200	N/A	• Close level crossing / detour road	Unprotected	32+645 Rd
32+330	N/A		Unprotected	
32+400	N/A		Unprotected	
32+645	N/A	• Maintain level crossing / Install protection	Unprotected	New development area
33+165	N/A	• Close level crossing / detour road	Unprotected	Kurugala Rd
33+470	Kurugala Rd	• Maintain level crossing	Automatic Bell & Light - B & L	
34+220	N/A	• Close level crossing / detour road	Unprotected	Polwathta Rd
34+440	N/A	• Close level crossing / detour road	Unprotected	Polwathta Rd
34+530	Polwathta Rd	• Maintain level crossing / Install protection	Unprotected	
34+620	N/A	• Close level crossing / detour road	Unprotected	Polwathta Rd
34+670	Padukka Rd	• Install new flyover	Mechanical Operated Barrier (MOB) with Bell & Light	(ADT Less than 10000) Decision RDA
35+080	Galagedera - Horana Rd	• Install underground pass way / automatic pumping	Mechanical Operated Barrier (MOB) with	Decision RDA

FS Design Alignment		Main Option	Existing type of the Level Crossing	Remarks
Chainage	Road name			
		necessary / To secure depot area	Bell & Light	
35+290	Puswali Mawatha Rd	• Close level crossing / detour road	Unprotected	Galagedera-Horana Rd
35+460	N/A	• Close level crossing / detour road	Automatic Bell & Light - B & L	Galagedera-Horana Rd
35+560	N/A	• Close level crossing / detour road	Unprotected	Galagedera-Horana Rd
35+980	Arukwatta - Piturrnpe Rd	• Maintain existing flyover	Flyover	
36+220	N/A	• Close level crossing / detour road	Unprotected	Arukwatta-Piturrnpe Rd
36+650	N/A	• Maintain level crossing / Install protection	Unprotected	
37+235	Cola Rd	• Maintain level crossing / Install protection	Unprotected	
37+730	Meepe-Ingiriya Rd	• Maintain level crossing / Angampitiya location change • nstall box culvert or underground pass way	Mechanical Operated Barrier (MOB) with Bell & Light	Angampitiya station
38+720	N/A	• Maintain level crossing / Install protection	Unprotected	
39+840	Wewalpanawa - Waga Rd	• Maintain level crossing / Install protection	Unprotected	
40+810	Kandewaththa Rd	• Maintain level crossing	Mechanical Operated Barrier (MOB) with Bell & Light	
41+755	N/A	• Maintain level crossing / Install protection	Unprotected	
43+675	N/A	• Close level crossing / detour road	Unprotected	Kaluaggala Labugama Rd
43+970	Kaluaggala Labugama Rd	• Maintain level crossing	Mechanical Operated Barrier - MOB	
44+820	N/A	• Maintain level crossing	Automatic Bell & Light - B & L	
46+200	N/A	• Maintain level crossing / Install protection	Unprotected	
48+050	Kosgama - Kadugoda Rd	• Maintain level crossing	Automatic Bell & Light - B & L	
48+460	N/A	• Maintain level crossing / Install protection	Farm Type	
48+830	N/A	• Maintain level crossing / Install protection	Unprotected	
49+550	N/A	• Maintain level crossing / Install protection	Unprotected	
50+135	N/A	• Close level crossing / detour road	Unprotected	Samadhi Mawata Rd
50+350	Samadhi Mawata Rd	• Maintain level crossing / Install protection	Unprotected	
50+485	N/A	• Close level crossing / detour road	Unprotected	Samadhi Mawata Rd
50+560	N/A	• Close level crossing / detour road	Unprotected	Samadhi Mawata Rd

FS Design Alignment		Main Option	Existing type of the Level Crossing	Remarks
Chainage	Road name			
50+895	N/A	• Close level crossing / detour road	Unprotected	50+915 Rd
50+915	N/A	• Maintain level crossing / Install protection	Unprotected	
51+110	N/A	• Close level crossing / detour road	Unprotected	50+915 Rd
51+305	N/A	• Maintain level crossing / Install protection	Unprotected	
51+370	N/A	• Close level crossing / detour road	Unprotected	51+305 Rd
51+570	N/A	• Close level crossing / detour road	Unprotected	51+305 Rd
51+645	N/A	• Existing Rd Level crossing maintain	Unprotected	
52+030	N/A	• Close level crossing / detour road	Unprotected	52+280 Rd
52+070	N/A	• Close level crossing / detour road	Unprotected	52+280 Rd
52+280	N/A	• Maintain level crossing / Install protection	Unprotected	
52+630	Colombo-Batticaloa Hwy	Re alignment by RDA	Mechanical Operated Barrier (MOB) with Bell & Light	
52+760	N/A		Unprotected	
52+990	N/A		Unprotected	
53+140	N/A		Unprotected	
53+340	N/A		Unprotected	
53+640	Eswatta - Ranwala Rd		Unprotected	
53+850	N/A		Unprotected	
54+260	N/A		Unprotected	
54+410	Colombo-Batticaloa Hwy		Mechanical Operated Barrier (MOB) with Bell & Light	
54+915	Colombo-Batticaloa Hwy		Mechanical Operated Barrier (MOB) with Bell & Light	
55+090	N/A		Automatic Bell & Light - B & L	
55+370	N/A		Unprotected	
55+510	Disuse		Unprotected	
56+130	Colombo-Batticaloa Hwy		Mechanical Operated Barrier (MOB) with Bell & Light	
56+750	N/A	• Maintain level crossing / Install protection	Unprotected	
57+320	N/A	• Maintain level crossing / Install protection	Unprotected	
57+635	N/A	• Maintain level crossing / Install protection	Unprotected	
57+955	N/A	• Maintain level crossing	Automatic Bell & Light - B & L	

5.4 Stations

5.4.1. Selection of Stations

5.4.1.1. Introduction

In order to plan the most suitable station locations of KV Line, various factors such as future traffic demand, distance between stations, future development plan, floating population, and current ROW, maintenance and train operation should be considered. Particularly to increase the commercial speed, it can be a proper method to increase distance between stations by reducing the number of stations. However this method may cause public complaints. Therefore, the Consultant considered to adding new stations where it is needed and to remove some existing stations where public demand is very low or no longer necessary.

From Maradana to Avissawella, there are 38 stations. Among them, 5 stations have not been used any more. In order to reduce construction cost and increase the Commercial speed and decrease travel time, the consultant decided to delete these 5 stations. The name stations to be removed in KV line are as follows:

Arapangama, Aluth Ambalama, Miriswaththa, Puwakpitiya New Town, and Kiriwandala

Regarding new stations, at the early stage of this review, the consultant considered to add 4 new stations. However considering of the distance between stations, commercial speed and economic weights for the stations, finally 2 stations (New 02 and New 04) have been selected as additional stations.

In summary, from Maradana to Avissawella, there will be a total of 35 stations in the KV line as per the consultant's preliminary study.

5.4.1.2. New stations

In the KV line from Maradana to Avissawella, 33 stations are currently in operation and will be maintained. In addition to the existing stations, the client proposed to review 11 more stations to create for more convenience for the public. Detailed study by the consultant in this scenario identified that the 7 new stations are located very close to each other with less than 800 m between stations. Detailed review on feasibility of adding four new stations and final selection of two stations as new stations are summarized in the following sections.

In order to select new stations with the surrounding terrain conditions, the consultant decided priority of each proposed station based on average daily traffic (ADT) in future, distance between stations, strategic importance (for military, public utility, multimodal, commercial and economic), population density, economic importance of stations (number of industries, number of schools, number of hospitals and government offices, number of markets, number of trade and service establishments around the station), multi and inter-modality possibility of stations, station development as future commercial and logistics hubs, economic aspects of facility location factors and economic aspects of land use planning considerations. Review of adding new stations are as below:

(1) Station New 01(Devananda)

Figure 5-21 Station New 01

The chainage of Station New 01 is 12+320 km. This site is highly populated with middle class dwellings and SME businesses are planning to utilize warehouses and offices around here. RDA A4 & B291 roads can be connected with this station. Since the alignment of near the New station 01 is composed of curve radius R = 140 m, R = 230 m, R = 150 m, it is not so recommended to establish a new station. As the result of economic weights for the station is quite low, the consultant decided to remove the station from the list of potential new stations.

(2) Station New 02(Dambahena)

Figure 5-22 Station New 02

The chainage of New 02 station is 15+890 Km. This site is located near the Maharagama Central College, more specifically, at the edge of the Maharagama town, and it has close access to the A4 and Old Kesbewa Road. It also gives access to the Maharagama Town and sub urban residential neighborhood. New Station 02 is located on the straight line. The condition for establishing station is very good. The result of economic weights for the station is relatively high, thus the consultant selected the station as a new station.

(3) Station New 03(Rukmale)

Figure 5-23 Station New 03

The chainage of New 03 station is 18+000 km. Major schools of Pannipitiya Darmapala College are located nearby. This site has close access to the A4 road and Old Kottawa road. It also has access to the sub-urban middle class neighborhood and SME business. The existing alignment of near the New station 03 is composed of four curve segments with radius of R = 120 m, R = 120 m, R = 120 m and R = 150 m. Therefore, it is not proper to establish as a new station. The result of Economic Weights for the station is also low, thus the consultant decided to remove the station from the list of potential new stations.

(4) Station New 04 (Makumbura North)

Figure 5-24 Station New 04

The chainage of New 04 station is 21+ 900 km. The proposed new station is ideally situated closer to the country's multi model transport connecting node, Malapalla. Therefore, the area is ideally suitable to locate turn back system. Furthermore, this station can provide access to the 'Maliban Biscuits Factory' and surrounding sub urban SME business and housing community with potential opportunities to develop as industrial and housing zones. The alignment of near the New station 04 is composed of straight line and curve radius R = 300 m. The condition of establishing station is proper.

The result of Economic Weights for Stations is so high, thus the consultant selected the station as a new station.

In summary, among the potential new stations, stations New 01 and New 03 were deleted from the list of potential new stations and the stations New 02 and New 04 were selected as new stations.

5.4.1.3. The distance between stations

The distance between stations of KV line is as follows:

Table 5-20 The distance between stations

NO	Alternative 01			
	Chainage	Distance	Station Name	Curve Radius on Station
1	0		Maradana Station	Straight
2	1900	1900	Baseline Road Station	Straight
3	3680	1780	Cotta Road Station	Straight
4	5540	1860	Narahenpita Station	Straight
5	7280	1740	Kirillapona Station	Straight
6	9100	1820	Nugegoda Station	Straight
7	10500	1400	Pangiriwatta Station	Straight
8	11480	980	Udahamulla Station	Straight
9	13180	1700	Nawinna Station	Straight - R=200
10	14340	1160	Maharagama Station	Straight
11	16000	1660	New-02 Station	Straight
12	17120	1120	Pannipitiya Station	R=200
13	19520	2400	Kottawa Station	Straight
14	20760	1240	Malapalla Station	Straight - R=140
15	21900	1140	New-04 Station	R=400 - Straight - R=1000
16	23020	1120	Homagama hospital Station	R=120 - Straight - R=150
17	24440	1420	Homagama Station	R=200 - Straight - R=150
18	26200	1760	Panagoda Station	R=120 - Straight - R=120
19	27860	1660	Godagama Station	R=1000
20	29500	1640	Meegoda Station	Straight
21	31080	1580	Watareka Station	Straight
22	33420	2340	Liyanwala Station	Straight
23	34920	1500	Padukka Station	Straight
24	36720	1800	Arukwathpura Station	Straight
25	37780	1060	Angampitiya Station	Straight
26	38900	1120	Uggalla Station	Straight
27	39760	860	Pinnawala Station	Straight
28	41220	1460	Gammana Station	Straight
29	41740	520	Molakele Station	R=160 - Straight
30	43920	2180	Waga Station	R=250 - Straight - R=200
31	46200	2280	Kadugoda Station	Straight - R=120 - Straight - R=120
			Arapangama Station	Not in use

NO	Alternative 01			
	Chainage	**Distance**	**Station Name**	**Curve Radius on Station**
32	48940	2740	Kosgama Station	Straight
			Aluth Ambalama Station	Not in use
			Miriswaththa Station	Not in use
33	53100	4160	Hingurala Station	R=300 - Straight - R=400
34	55240	2140	Puwakpitiya Station	Straight
			Puwakpitiya New Town Station	Not in use
			Kiriwandala Station	Not in use
35	58400	3160	Avissawella Station	Straight

5.4.1.4. General operation of each station

At the section from Maradana to Padukka, 21 stations are currently in operation. Average distance between stations is 1.67 km, which is not considered long. In KV line, 23 stations are planned including 2 new additional stations. This results in the average distance of 1.52 km between stations, which is 150 m shorter than that of currently operating railway. This also will cause more frequent acceleration and deceleration of train thereby causing overall decrease in Commercial speed. This option sustains existing stations even though the Commercial speed decreases, because it is expected to provoke many civil complaints around the stations if any existing station is closed. Shortened distance between stations also imposes many constraints on curved stations, station slope of less than 0.8% and so on, in planning the horizontal and vertical alignment. On the other hand, creating new stations can enhance passenger's accessibility to station and convenience in use. Thus, careful considerations should be given when it comes to installing new stations, which may cause decrease in commercial speed and increase in operation time.

First, TPS analysis was performed only for urban area, from Maradana to Padukka. As a result of TPS analysis on adding New stations, the Commercial speed from Maradana to Padukka is 34.70 km/h, and travel time is 60 minutes. The figure below is the TPS analysis graph:

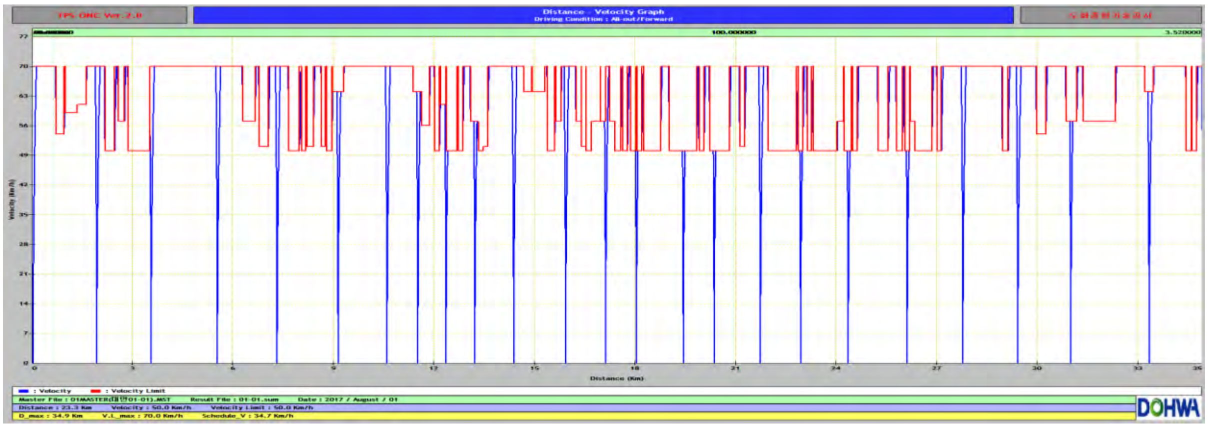


Figure 5-25 TPS Analysis Graph

5.4.1.5. Operation of express train

Operation of express train has been reviewed in order to increase in Commercial speed and passenger's convenience. Accordingly, it has been reviewed to install side track at the station where the express train stops and operate both normal and express trains. Stations where the express train will stop are reviewed as follows in consideration of traffic demand and distance between stations.

Table 5-21 Stations for express

No	Chainage	Distance(m)	Name	Remarks
1	0		Maradana Station	
2	9100	9100	Nugegoda Station	
3	14340	5240	Maharagama Station	
4	24440	10100	Homagama Station	
5	34920	10480	Padukka Station	

Average distance between stations in KV line are relatively short and it results in decrease of Commercial speed and passenger's use due to longer travel time. As a solution of such situation, express trains are operating in many countries in the world including the South Korea, Japan, France, Hong Kong, etc.

In case of operating the express trains only stopping at KV Line's Maradana station, Nugegoda Station, Maharagama Station, Homagama Station and Padukka Station, side track for normal trains should be installed.

TPS analysis of express trains indicates that schedule speed from Maradana to Padukka is 58.7km/h, and travel time is 35.6 minutes. Compared to normal trains which stop at every stations, this has the effect of 22.6 km/h increase in schedule speed and 22.4 minutes decrease in travel time.

Considering the cost increase of express line and the travel time reduction (13 min.) the express line will be operated in 2035 with additional side tracks in station. The extension mitigation in future of side track facilities will be considered in detail design phase.

5.4.2. Platform gap

On the curved station, the nominal distance from the track center to platform edge at the nominal heights shall be more than 50 mm. If the platform gap is too large, it will be dangerous for the passenger and if the platform gap is too narrow, it will be dangerous for the train. In the KV line, many stations are curved and it is difficult to enlarge the radius of curves because of the surrounding circumstances.

There are two types of vehicles: Articulated Type Bogie and General Type Bogie. The length of vehicles is either 20 m or 15 m. Based on the type and length of the vehicle, the result of study is as follows

In case of Articulated Type Bogie:

If the vehicle length L = 20 m, the radius of station is needed more than R = 500 m

If the vehicle length L = 15 m (3.12 m width), the radius of station is needed more than R = 230 m

In case of General Type Bogie:

If the vehicle length L = 20 m, the radius of station is needed more than R = 400 m

If the vehicle length L = 15m (2.8 m width), the radius of station is needed more than R = 120 m

Considering the above, in case of using 20m-long vehicle, the radius of curve on station should be larger than R = 400 m. But 10 stations (28%) of the total 35 stations in KV line where the radius of the station curve is less than R = 400 m. Extending the station radius is very difficult considering the surrounding situations such as land acquisition and resettlement.

In case of using 15 m-long and 2.8 m-wide vehicle, the radius of curve in station should be more than R = 120 m.

Therefore, on KV line, considering the given platform and station geometry, it is the most appropriate to adopt 15 m-long and 2.8 m-wide vehicle with general type Bogie.

Table 5-22 Comparison of Bogie Type

Item	Articulated Type Bogie			General Type Bogie		Remark
	L = 20m	L = 15m	L = 15m (Egis) (width 3.12 m)	L = 20 m	L = 15m (width 2.8 m)	
R=120m	+43 -19	+28 -3		-7(End)~33(Center) -9	-1~+22 +3	(+) clearance distance (-) lack of distance
R=150m	+36 -13	+25 0		-3~29 -5	+2 +5	
R=180m	+33 -9	+23 +2		-1~+27 -2	+19 +6	
Curve radius required for platform gap is 50mm	R=500m	R=230m	R=250m	R=400m	R=120m	

CHAPTER

6

Stations Architecture

Chapter 6 Stations Architecture

Chapter Summary

The architectural concept is divide into three items, first one is reflecting local culture, second is for securing identity of the total line and final one is harmony with surrounded environments.

In addition, the architectural design direction is divided into four categories: functionality, pleasant environment, harmony with surrounded environment, maintenance and energy saving aspects.

The space program for site plan and station building were decided after considering the convenience of the passengers, and the required area of the station was decided by applying international standards.

Passengers' facilities include general amenities for passengers as well as facilities for the disabled people according to Sri Lanka Act.

The total number of stations is 35, which are divided into large, medium and small stations. And the station grade is determined through consultation with the related parts such as signaling, operation, alignment and track.

The station is largely divided into an elevated and at grade station, each type of station was planned to be a large, medium, and small sized station according to the determined station grade.

The prototype site plan is divided into a platform, a station building, a square, and multimodal facilities. In elevated station, the platform is located at the upper part of the structure, the station building is located at the ground, and the pedestrian plaza and multimodal facilities are located. In case of at grade station, the platform and the station building are constructed on the ground, and the square and multimodal facilities are arranged on the front and side of the station.

The station planning is divided into a public space and a back of house area. Public spaces include waiting rooms, concourse area, ticket offices, and public toilets. Back of house area are divided into station control facilities and support rooms, mechanical & electrical equipment rooms, and signal & communication equipment rooms.

The size of the site plan and the program layout of the station building shall be planned in accordance with the condition of each station through consultation with related stakeholders and station masters during detail design.

6.1 General

6.1.1 Goal

- Preliminary survey and station proposal (Prototype site plan & station building planning) for a total length of 60 km, 35 Stations (for transport and freight demand)
- Provide better transporting service and transfer system (Passengers' flow plan & Transfer system with LRT, Railway, Bus, Taxi, Bike, Personal car (Kiss & Ride, Park & Ride), etc.)
- Planning a local space program that can contribute to regional development

6.1.2 Work scope

- Review and analysis for space programs and appropriate size for each rooms
- Site plans for 35 stations
- Building plan for prototype stations
- Amenities planning for passengers and disabled people

6.1.3 Architectural Concept

Table 6-1 Architectural Concept

Local Culture	Identity	Harmony
		
Reflecting cultural heritage of Sri Lanka and traditional characteristics, architecture, etc.	Ensuring the identity of total line and local station by using the shape, color or pattern those representative items from overall and local area	Harmony with surrounded environments (Natural situation, development of local area, commercial land use and local facilities, etc.)

6.1.4 Design Direction of Architectural Planning

Table 6-2 Design Direction of Architectural Planning,

Items	Contents
Functionality	• Centralize station functional room layout • Facility layout planning for efficient operation and maintenance • Secure sufficient space for waiting area for future extension • Establish the efficient transfer system with another mode of transportation system (LRT, Railway, Bus, Taxi, Bike, Kiss & Ride) • Barrier Free Design • Prepare the space for waiting and local communication space outside of the station:

Items	Contents
	pedestrian plaza, landscape, water pond, etc. • Increase the accessibility to the station (normal passengers and disabled people)
Pleasant Environment	• Increase maintenance efficiency by zoning the station facilities (E&M Equipment Rooms + Signal & Telecom Rooms + Power Supply Rooms, Station Crew Office + Operation Control Room + Station Support Rooms • Propose a natural ventilation for preventing greenhouse effect in hot summer season • Efficient space scale and reasonable facility layout
Harmony with Surrounded Environment	• Station construction that contribute to the development of local culture and industry • Station shape and elevation that harmonize with surrounded landscape • Give symbolic shape by the station grade • Reflect in the form of regional, cultural and historical characteristics • Color scheme for harmonizing with surrounded color of local area • Secure the line identity by applying station prototype
Maintenance and Energy Saving	• Intensive control system for reasonable operation • Spatial zoning for electrical & mechanical facilities • Material for reducing the load of cooling and heating • Material planning for efficient maintenance (Easy to get and keep) • Durable material for dust-proof and moisture-proof

6.2 Space Programs

6.2.1 Space Program for Site Plan

Figure 6-1 Space Program for Site Plan

- Community Space: Pedestrian Plaza, Community & Event Space, Landscape, Water Pond, etc.
- Multimodal Space: Bike Shelter, Bus Stop, Taxi Stand, Personal Car Zone (Kiss & Ride, Park & Ride)

6.2.2 Space Program for Station Building

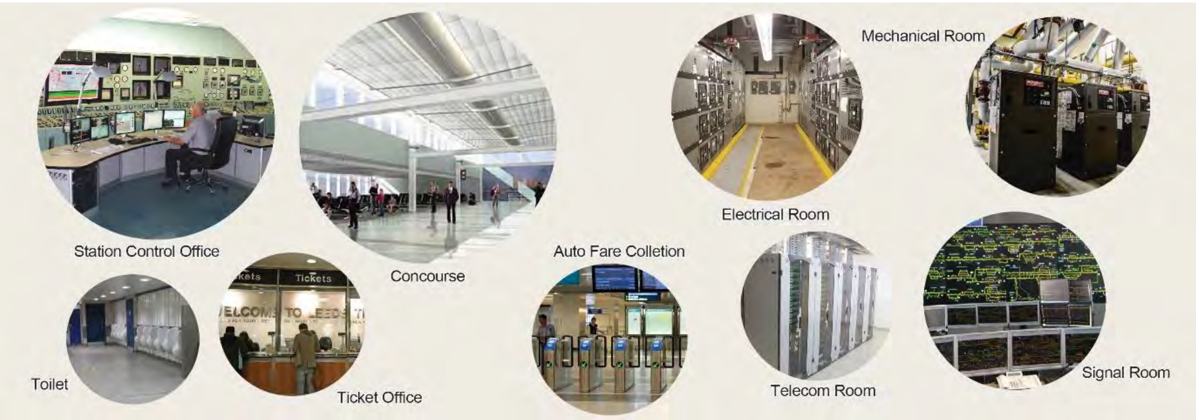


Figure 6-2 Space Program for Station Building

- Public Area: Station Crew Office (Control Office), M&E Equipment Room, Signal & Telecommunication Room
- Back of House Area: Station Support Rooms, Concourse Area & Corridor, Ticket Office, Toilet, Lounge and Storage

6.2.2.1 Area of Each Rooms

Table 6-3 Area of Each rooms

Items	Area (㎡)	Remarks
Waiting Area (Concourse & Platform)	Required personnel calculation: (2,035year) Max. PPHPD Kirillapona to Nugegoda: 20,973 Headway=7min.=>9times per hour 20,973/9=2,330 persons per headway	Applied LOS A: **2,713** ㎡ Planning for waiting area (each type of stations approximately) Large Station W.A: **2,746** ㎡
Station Crew Office, Operation Control Room	Station Crew: 8 ㎡/person, Computer Room: 20 ㎡, Bedroom: 35 ㎡, Lounge: 10 ㎡ Meeting Room: 20 ㎡, Information Desk: 10 ㎡	Assumed 5person = 135 ㎡ Flexibly applied according to the layout
Telecommunication Room	Normally 60 ㎡ ~ 100 ㎡	By equipment size and staff
Signal Equipment Room	80 ㎡(8m X 10m) ~ 96 ㎡(8m X 12m)	By equipment size and staff
Power Supply & Battery Room	4m X 6m = 24 ㎡	By equipment size
Electrical Room	Single Track: 8.4m X 9.5m = 79.8 ㎡ Double Track: 9.5m X 13m = 123.5 ㎡	By equipment size
Mechanical Room	Normally 100 ㎡ ~ 120 ㎡	By equipment size
Generator Room	18 ㎡ ~ 36 ㎡	By equipment size

- In Principle, the size of the concourse and station technical rooms shall confirm to the above standard and shall determine after consultation with the relevant parts.

6.3 Flow Plan and Estimation of Available Passenger Demand

6.3.1 Flow Plan

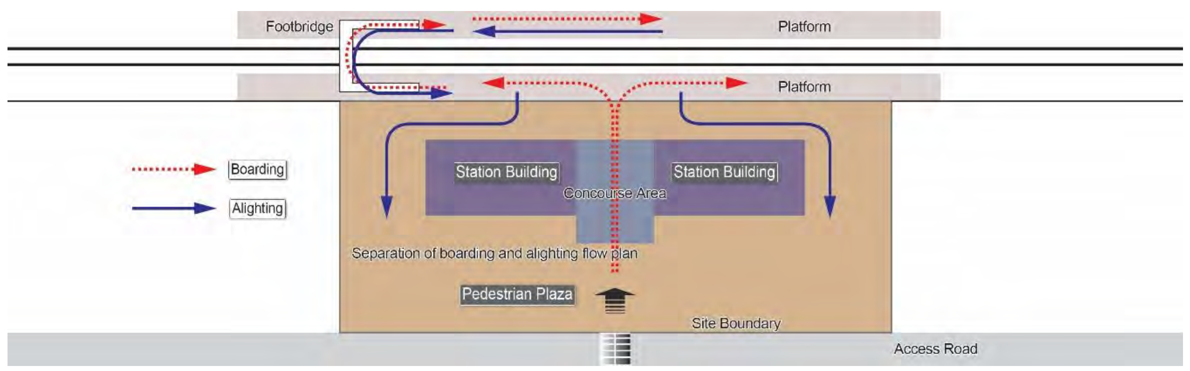


Figure 6-3 Flow Plan of Prototype Station

6.3.2 Estimation of Available Passenger Demand

6.3.2.1 General Service Level (Centered on Waiting Area)

Table 6-4 Level of Service on Waiting Area

Level of Service	Condition
A~B	Limit of Passing Territory (Diameter: 120Cm, Space Module: 1.3 ㎡)
C	Limit of Pleasant Territory (Diameter: 105Cm, Space Module: 1.0 ㎡)
D	Limit of Non-Contact Territory (Diameter: 90Cm, Space Module: 0.7 ㎡)
E~F	Limit of Contact Territory (Diameter: 60Cm, Space Module: 0.3 ㎡)

6.3.2.2 Service Level of Waiting Space

Table 6-5 Service Level of Waiting Space

Level of Service	Space Module(㎡/P)	Average Spacing (Cm)	Density (P/㎡)	Walking Condition
A	1.3 or higher	120 or higher	0.8 or less	Free passing
B	1.0~1.3	105~120	1.0~0.8	Can pass through others without difficulty
C	0.7~1.0	90~105	1.4~1.0	Disturbed when passing others
D	0.3~0.7	60~90	3.3~1.4	Possible to wait without contact with others
E	0.2~0.3	60 or less	5.0~3.3	Not possible to wait without contact with others
F	0.2 or less	Full	5.0 or higher	Stick with other, Psychologically unpleasant condition

6.3.2.3 Estimation of Available Passenger Demand

- Applied Service Level A
- Estimation of Available Passenger = Waiting Area ÷ 1.3 (A Level) = Available Passenger Number
- Estimation of Available Passenger Demand

Table 6-6 Estimation of Available Passengers Demand

Station Grade	Concourse Area (㎡)	Platform (㎡)	Pedestrian Plaza (㎡)	Total Waiting Area (㎡)	Available Commercial Space (㎡)	Available Passenger Inside (P)	Available Passenger Outside (P)	Total Number of Passengers (P)
Large	345.6	2,400.0	2,892.0	5,637.6	971.28	266	4,071	**4,337**
Medium	245.4	2,400.0	1,776.3	4,421.7	606.51	189	3,213	**3,402**
Small	91.8	1,200.0	357.0	1,648.8	134.64	71	1,198	**1,269**

6.4 Amenities

6.4.1 Amenities for Passengers

- Commercial Space (Coffee Shop, Food Store, Retail Kiosk, Convenience Shop, Restaurant, Book Shop, etc.)
- Chair, Trash Bin, Emergency Telephone, Signage, Information Map
- Locker, Advertisement Board, ATM, Vending Machine

6.4.2 Disabled People Facilities

- Confirm to Sri Lanka Regulation: the Protection of the Rights of Persons with Disabilities Act (No. 28 of 1996.)
- Applying Barrier Free and Universal Design Concept
- Ramp
- Tactile tile
- Lift and Escalator

6.5 Station Types & Grade of KV Line Stations

Table 6-7 Station Type & Grade of KV Line Stations

Station	STA	Type	PPHPO (2035)	Grade (S / O)	Remarks
Maradana	0Km 000.00			Large	
Baseline Road	1Km 920.00	Elevated	21,440	Medium	
Cotta Road	3Km 680.00	Elevated	20,518	Large	Future Development
Narahenpita	5Km 560.00	Elevated	21,369	Medium	For future extension
Kirillapona	7Km 280.00	Elevated	24,306	Medium	For future extension
Nugegoda	9Km 080.00	Elevated	25,039	Large	
Pangiriwatta	10Km 480.00	Elevated	24,222	Medium	For future extension
Udahamulla	11Km 480.00	Elevated	22,112	Small	
Nawinna	13Km 180.00	Elevated	20,622	Medium	Future Line, Shopping Mall
Maharagama	14Km 320.00	Elevated	19,878	Medium	For future extension
New02 Dambahena	15Km 940.00	Elevated	16,836	Small	
Pannipitiya	16Km 770.00	At Grade	17,013	Small	
Kottawa	19Km 420.00	Elevated	17,013	Medium	
Malapalla	20Km 760.00	At Grade	15,910	Small	Multimodal Hub
New04 Makumbura North	21Km 910.00	At Grade	12,011	Large	Stabling, Future Line
Homagama Hospital	23Km 050.00	At Grade	10,723	Small	
Homagama	24Km 420.00	At Grade	9,088	Medium	
Panagoda	26Km 190.00	At Grade	7,062	Small	
Godagama	27Km 950.00	At Grade	6,913	Small	
Meegoda	29Km 490.00	At Grade	6,204	Medium	
Watareka	31Km 070.00	At Grade	4,754	Small	
Liyanwala	33Km 370.00	At Grade		Small	
Padukka	34Km 890.00	At Grade	4,489	Large	Stabling, DMU-EMU
Arukwathpura	36Km 690.00	At Grade	3,824	Small	
Angampitiya	37Km 810.00	At Grade	3,798	Small	
Uggalla	38Km 850.00	At Grade	3,945	Small	
Pinnawala	39Km 710.00	At Grade	4,229	Small	
Gammana	41Km 310.00	At Grade	4,518	Small	
Morakele	41Km 810.00	At Grade	3,952	Small	
Waga	43Km 990.00	At Grade	3,995	Small	
Kadugoda	46Km 310.00	At Grade	3,948	Small	
Kosgama	49Km 080.00	At Grade	4,214	Medium	Future Line
Hingurala	52Km 900.00	At Grade	5,204	Small	
Puwakpitiya	55Km 580.00	At Grade	6,245	Small	
Avissawella	58Km 500.00	At Grade	6,255	Large	Terminus

6.6 Prototype Drawings

6.6.1 Basic Direction of Site Plan

- Reflect the local characteristics and historic legacy
- Considering future development of local area and other transportation systems
- Ensuring reasonable access road planning and transport square in station area

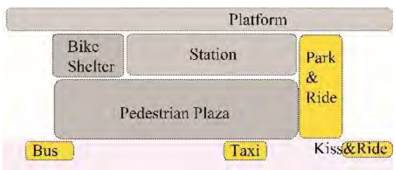
Table 6-8 Basic Direction of Site Plan

Symbolic Image	Connectivity	Functionality
		
Reflect local characteristics and special features	Consider future development and the other transportation system	Access road and appropriate space for passengers

6.6.2 Site Plan Concept

- Gathering space program for station, passengers and local residents
- Allocation of accessibility and usability for passengers
- Space organization for operation and maintenance aspects

Table 6-9 Site Plan Concept

Programs	Allocation	Space Organization
		
Space program for station, passengers and local residents	Allocation for accessibility and usability	Organization for operation and maintenance aspects

6.6.3 Prototype Site Plan

6.6.3.1 Elevated Station

(1) Large Station (Main)

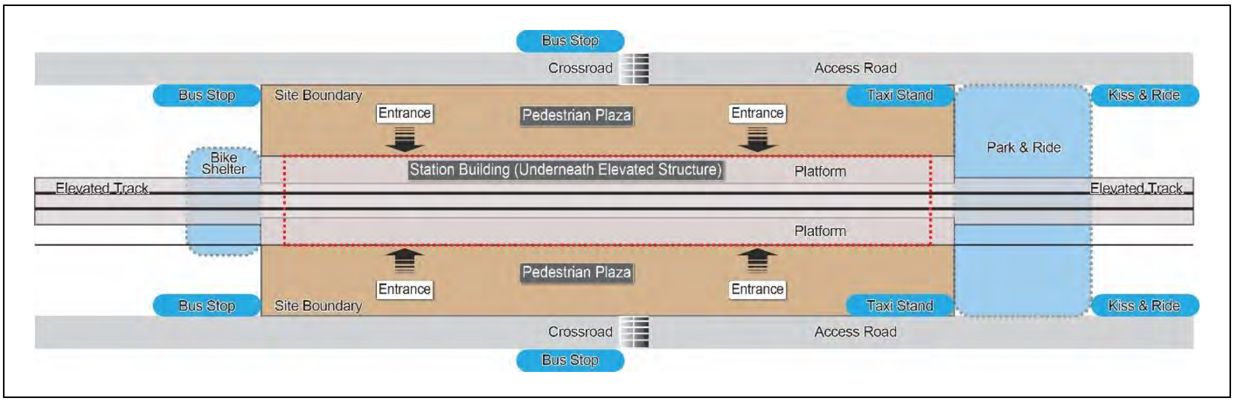


Figure 6-4 Prototype Site Plan of Elevated Type Large Station

(2) Medium Station (Sub)

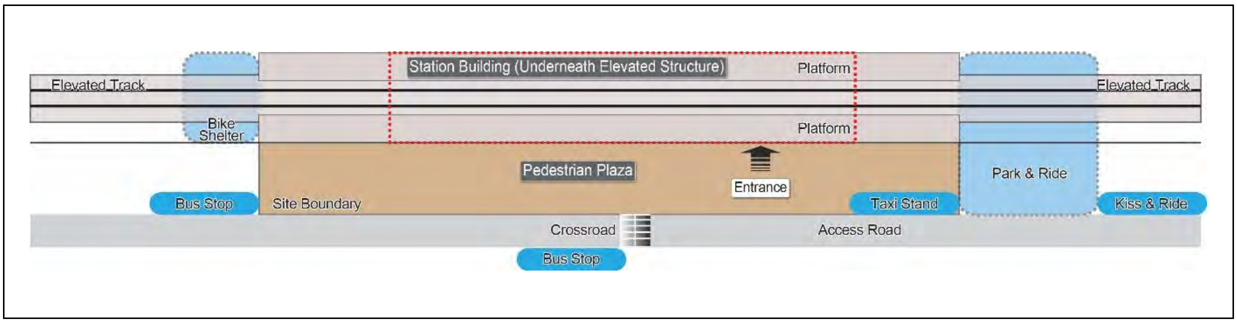


Figure 6-5 Prototype Site Plan of Elevated Type Medium Station

(3) Medium Station (Sub)

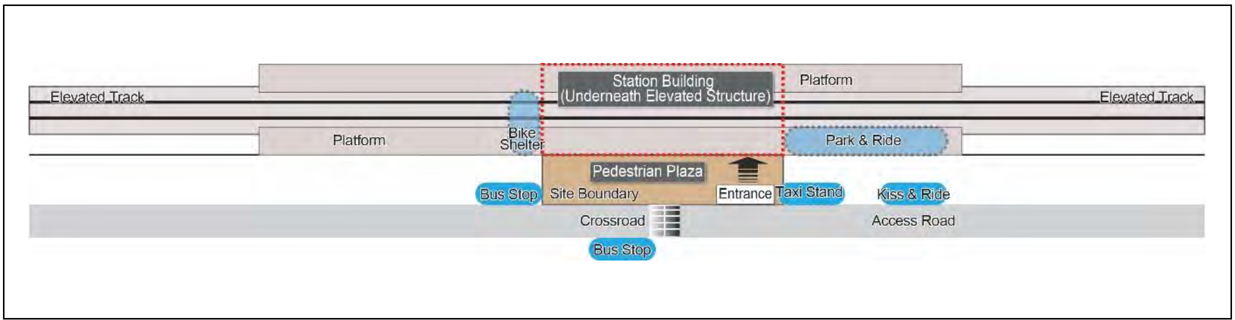


Figure 6-6 Prototype Site Plan of Elevated Type Small Station

6.6.3.2 At Grade Station

(1) Large Station (Main)

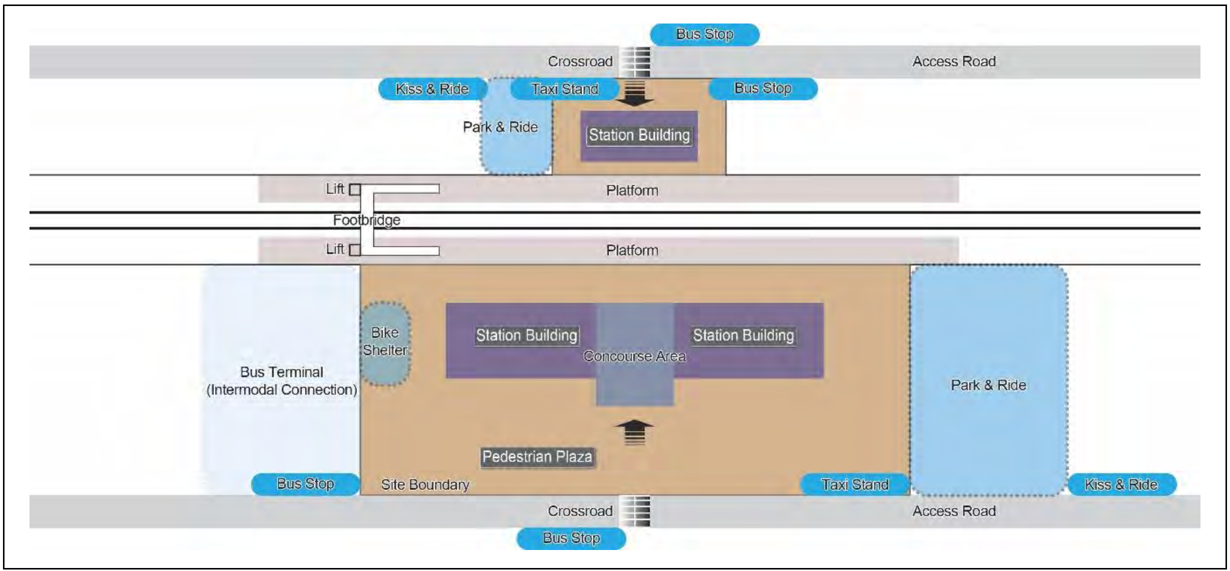


Figure 6-7 Prototype Site Plan of At Grade Type Large Station

(2) Medium Station (Sub)

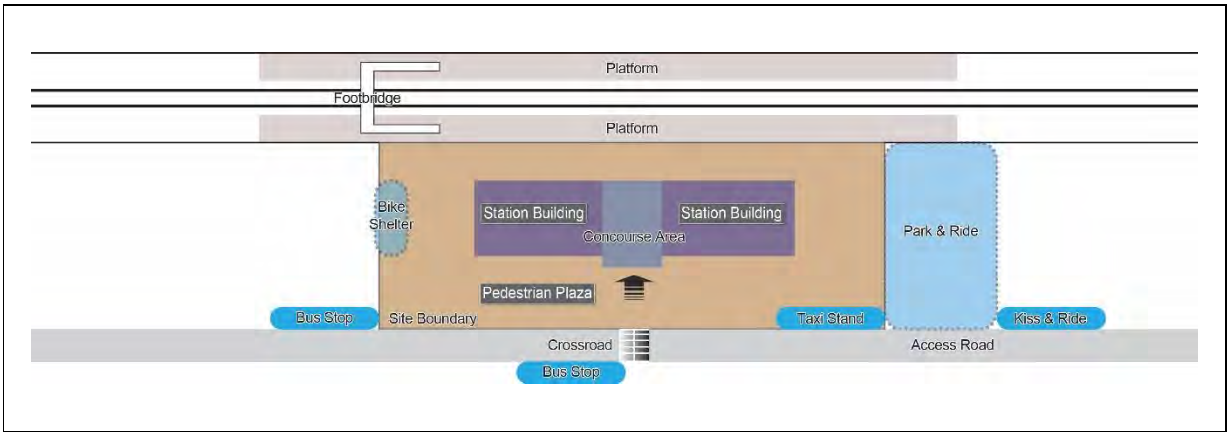


Figure 6-8 Prototype Site Plan of At Grade Type Medium Station

(3) Small Station (Halt)

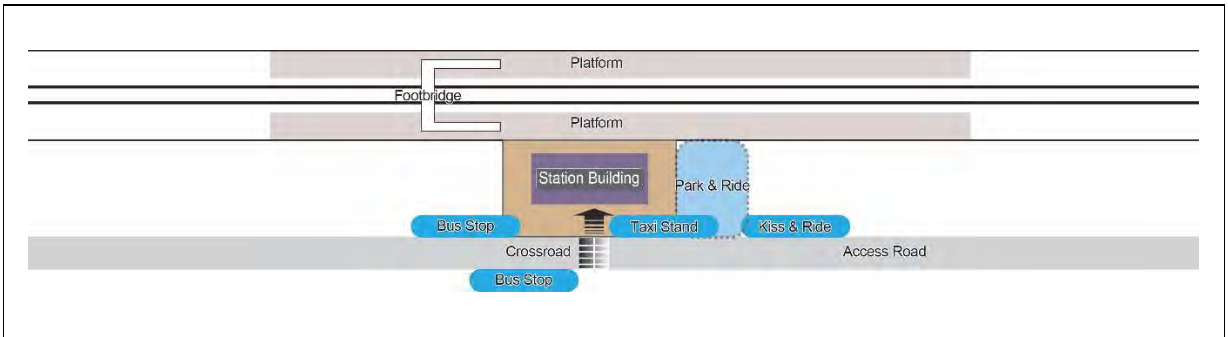


Figure 6-9 Prototype Site Plan of At Grade Type Small Station

6.6.3.3 Specific Site Plan

(1) Cotta Road Station

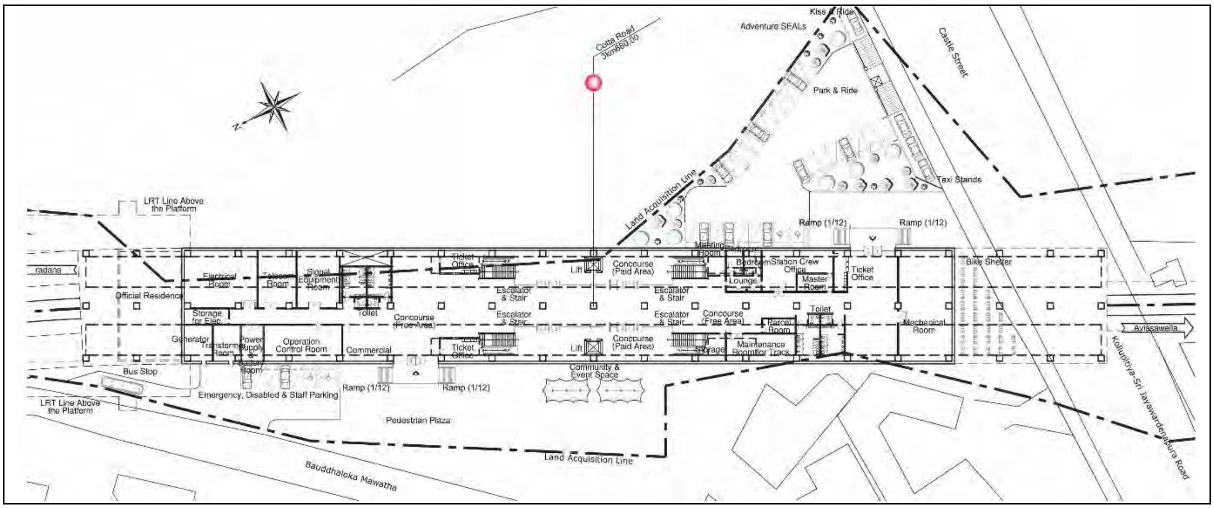


Figure 6-10 Cotta Road Station Site Plan

(2) Nugegoda Station

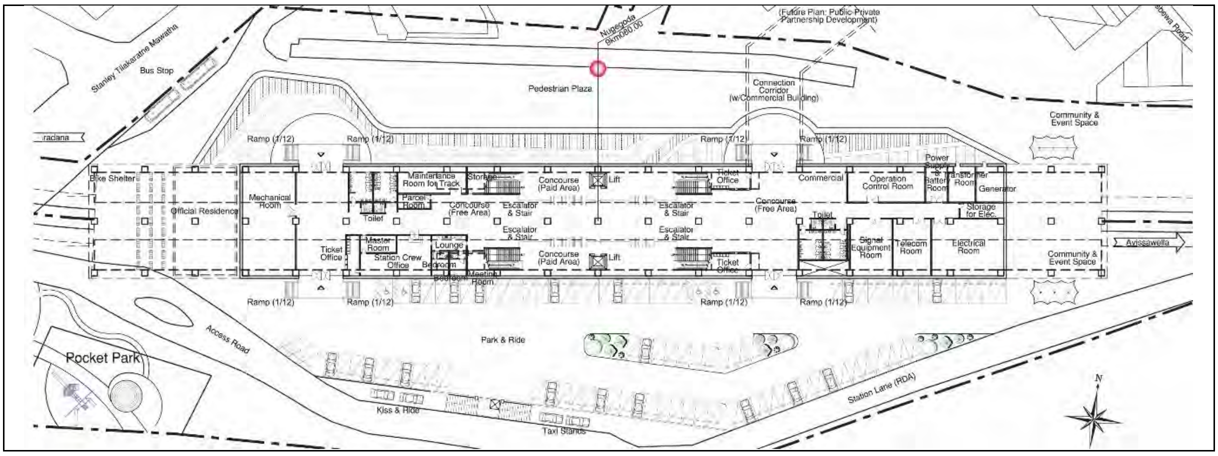


Figure 6-11 Nugegoda Station Site Plan

(3) Padukka Station

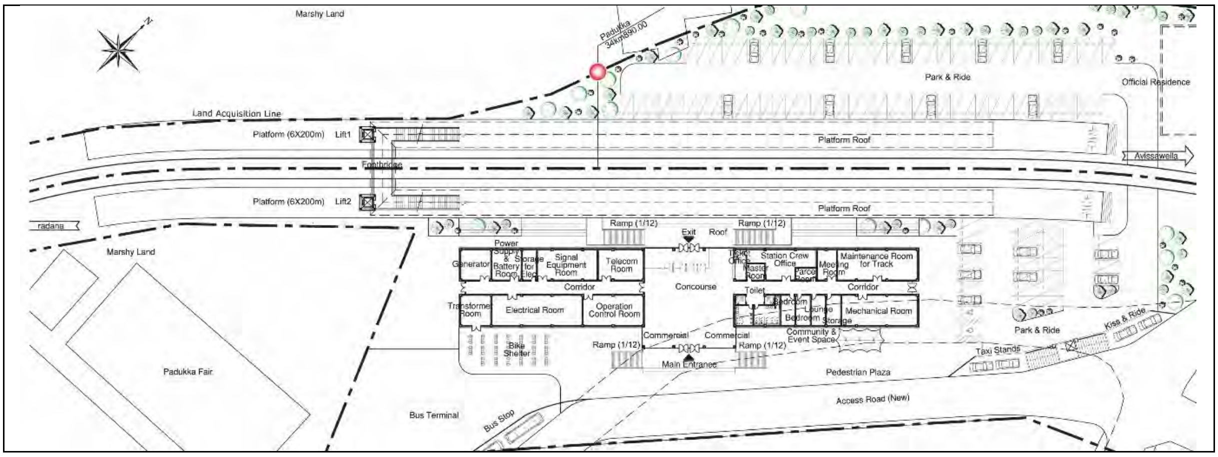


Figure 6-12 Padukka Station Site Plan

(4) Avissawella Station

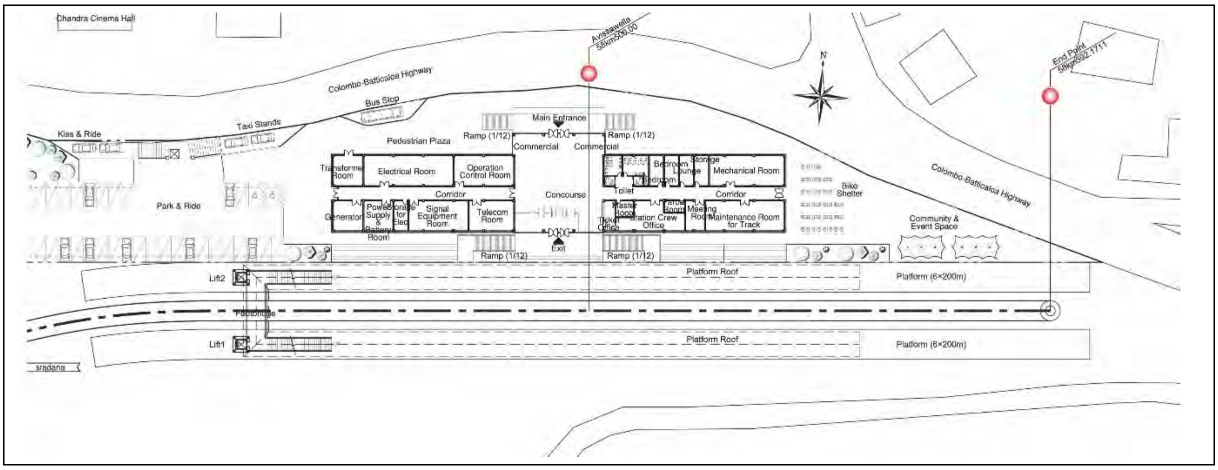


Figure 6-13 Avissawella Station Site Plan

6.6.4 Prototype Station Building Plan

6.6.4.1 Elevated Station

(1) Large Station (Main)

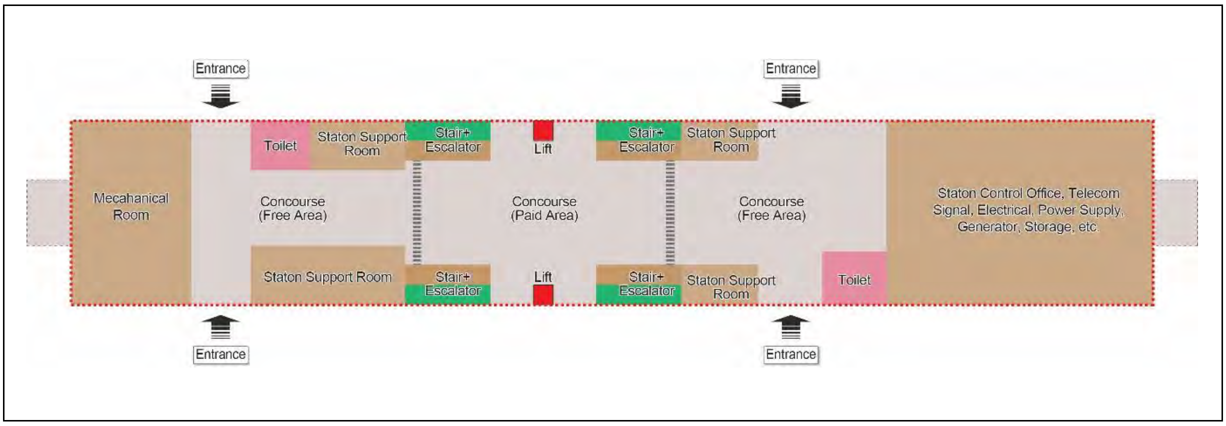


Figure 6-14 Prototype Station Building Plan of Elevated Type Large Station

(2) Medium Station (Sub)

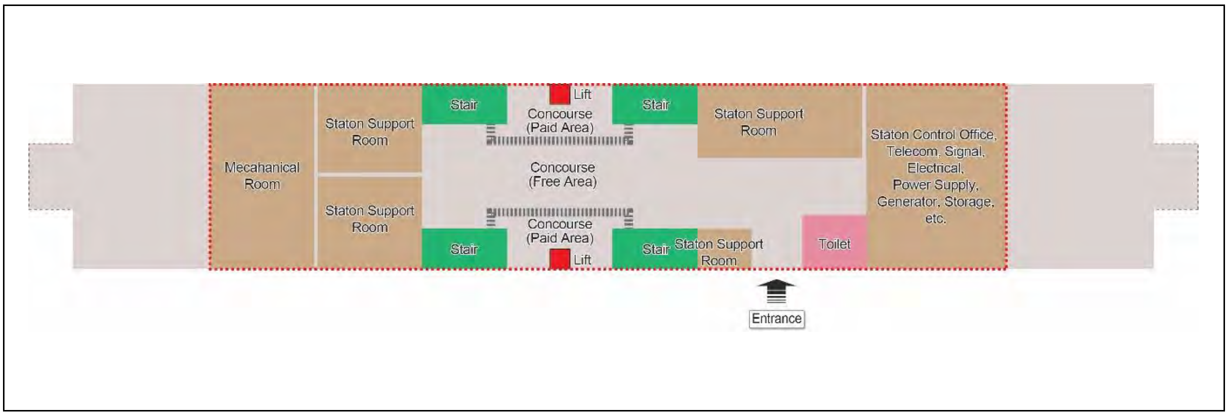


Figure 6-15 Prototype Station Building Plan of Elevated Type Medium Station

(3) Medium Station (Sub)

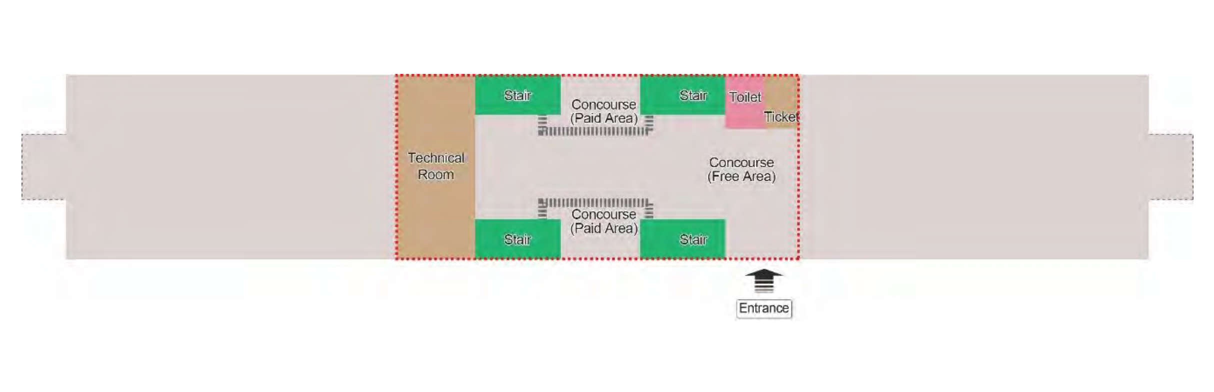


Figure 6-16 Prototype Station Building Plan of Elevated Type Small Station

6.6.4.2 At Grade Station

(1) Large Station (Main)

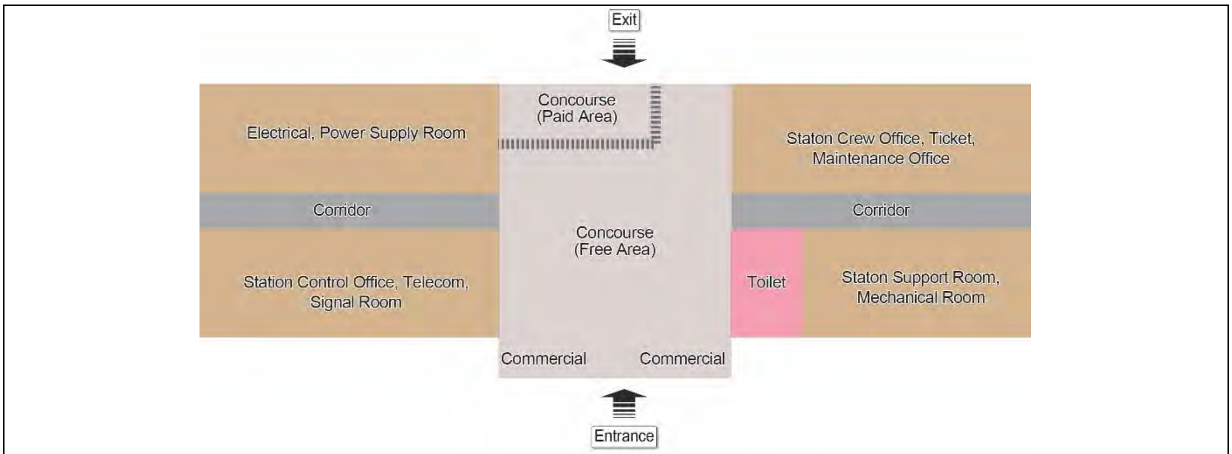


Figure 6-17 Prototype Station Building Plan of At Grade Type Large Station

(2) Medium Station (Sub)

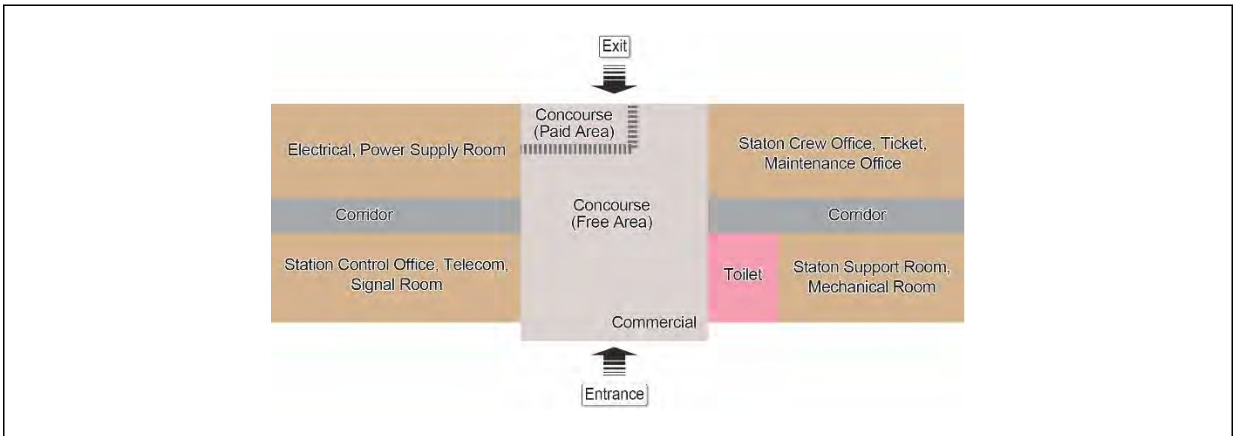


Figure 6-18 Prototype Station Building Plan of At Grade Type Medium Station

(3) Small Station (Halt)

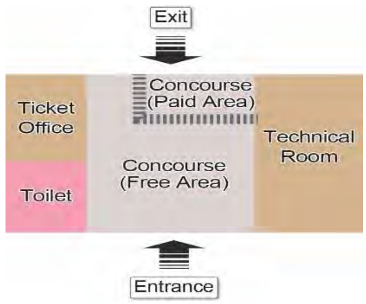


Figure 6-19 Prototype Station Building Plan of At Grade Type Small Station

6.7 Review of Existing Stations on KV Line

6.7.1 Maradana Main Station

6.7.1.1 Location Map

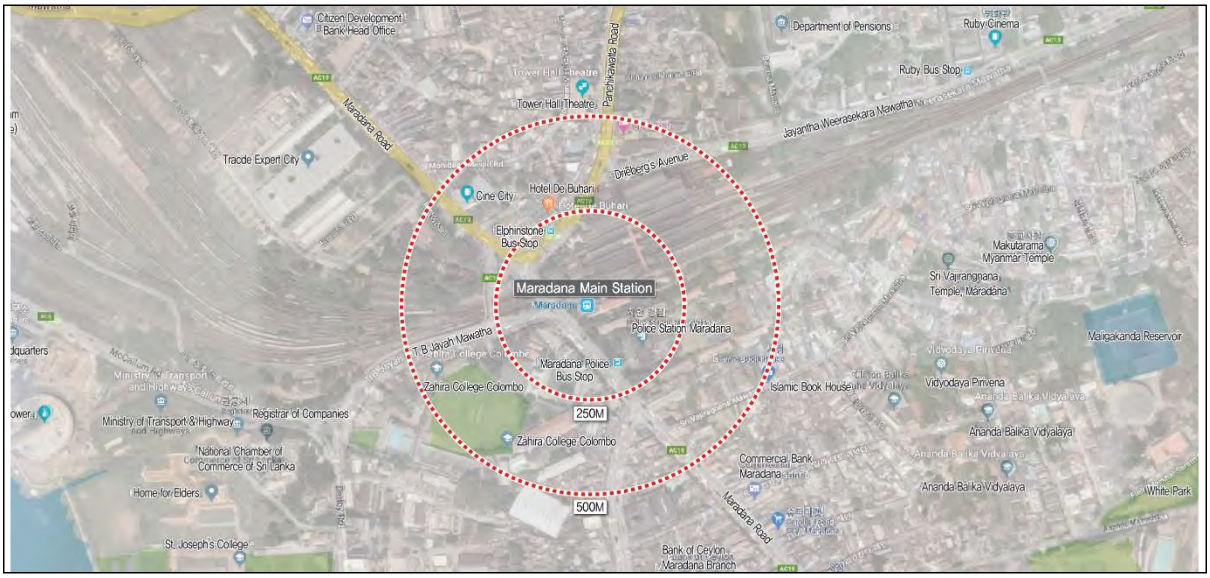


Figure 6-20 Location Map of Maradana Station

- Maradana station is located in the center of commercial district.
- Elphinstone bus stop, Maradana Police bus stop, Zahira College Colombo, Police Station Maradana

6.7.1.2 Station Photos

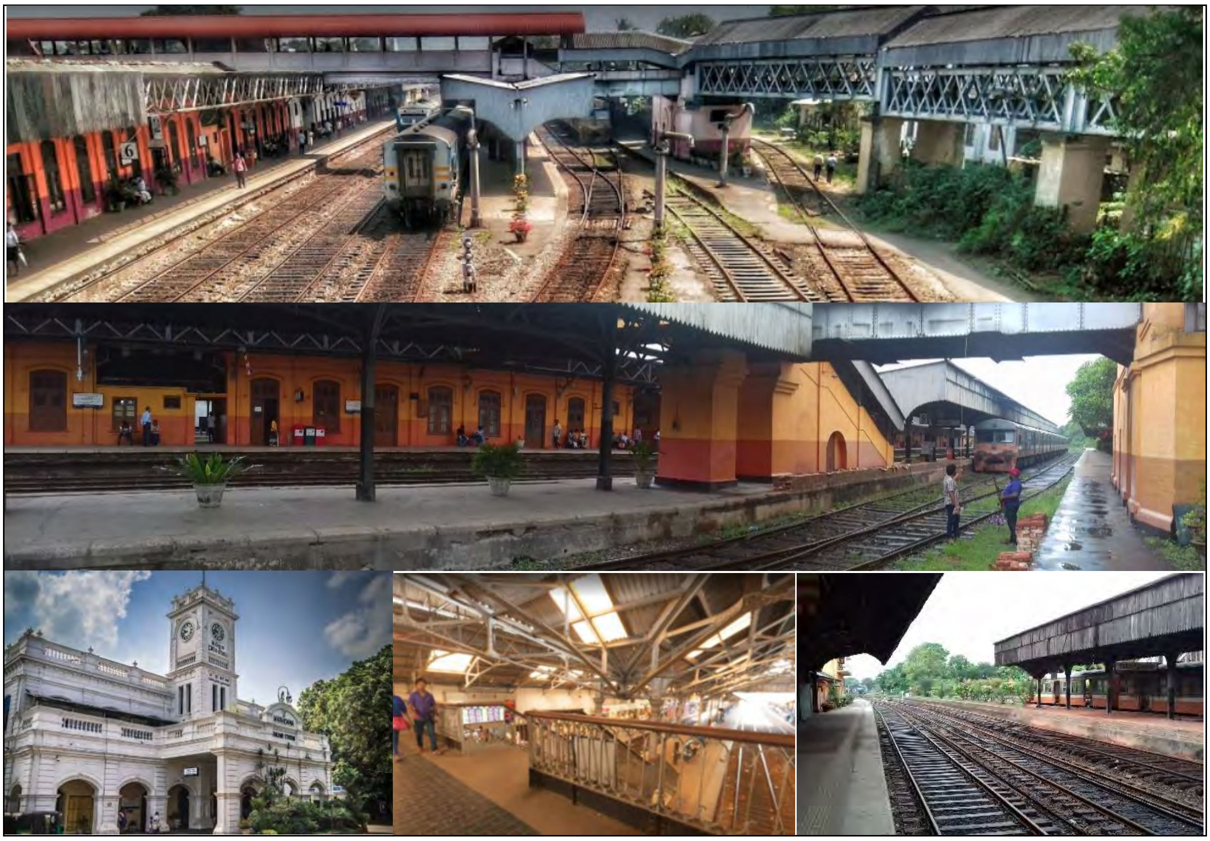


Figure 6-21 Station Photos of Maradana Station

6.7.1.3 Condition of the Station

Table 6-10 Condition of Maradana Station

Items		Contents
Road Condition		Maradana Road and Orabi Pasha Mawatha are located along the station.
Station	Platform Type and Roof	Side type & Island type, Multi tracks/ Extended from building
	Building	Multi stories large sized building
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike, LRT (Depend on MMC future planning)
Recommendation		The Maradana station is a valuable modern architecture in Sri Lanka, it is appropriate to maintain existing structures and improve facilities.

6.7.2 Baseline Road Sub Station

6.7.2.1. Location Map

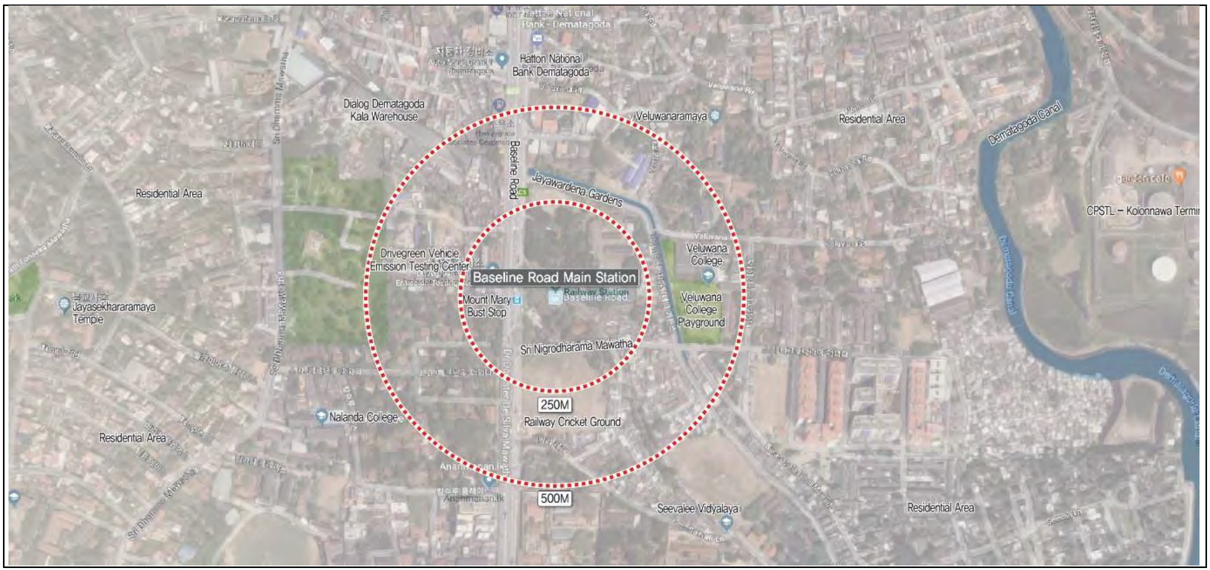


Figure 6-22 Location Map of Baseline Road Station

- Baseline Road station is located in commercial, residential and park area.
- Mount Mary bus stop, Railway Cricket Ground, Veluwana College

6.7.2.2. Station Photos

Figure 6-23 Station Photos of Base Line Road Station

6.7.2.3 Condition of the Station

Table 6-11 Condition of Base Line Road Station

Items		Contents
Road Condition		Baseline Road and Sri Nigrodharama Mawatha are located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Stand-alone platform roof
	Building	One story medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.3 Cotta Road Sub Station

6.7.3.1 Location Map

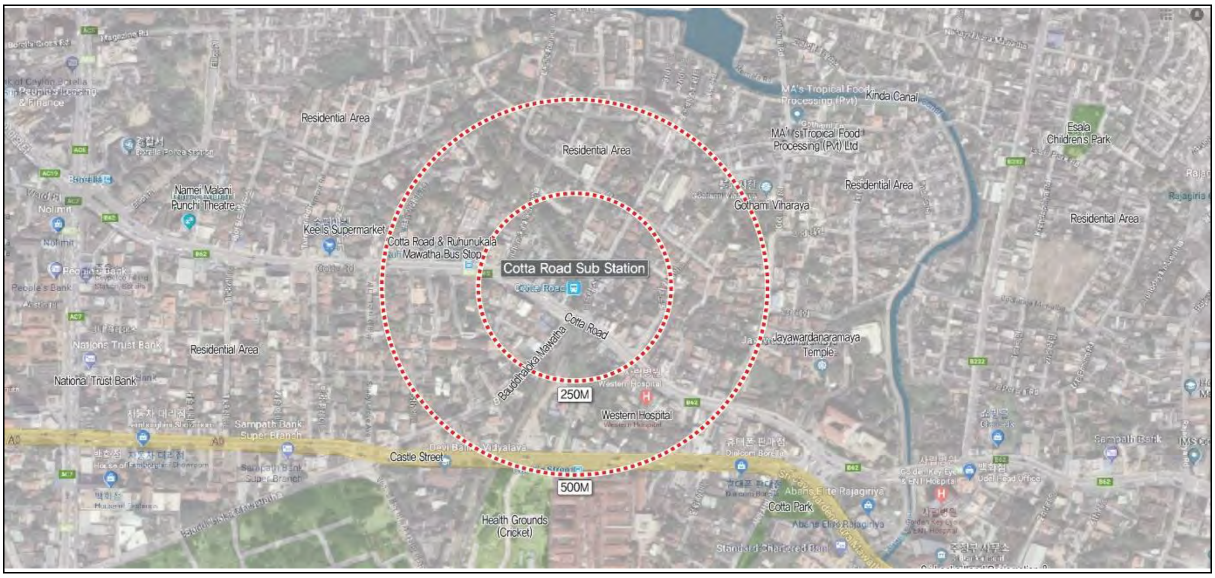


Figure 6-24 Location Map of Cotta Road Station

- Cotta Road station is located in commercial, residential area.
- Cotta Road & Ruhunukala Mawatha bus stop, Western Hospital, Residential Area

6.7.3.2 Station Photos

Figure 6-25 Station Photos of Cotta Road Station

6.7.3.3 Condition of the Station

Table 6-12 Condition of Cotta Road Station

Items		Contents
Road Condition		Cotta Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story small sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.4 Narahenpita Main Station

6.7.4.1 Location Map

Figure 6-26 Location Map of Narahenpita Station

- Narahenpita station is located in commercial, residential area.
- Oasis Hospital, Lumiere Residencies, National Vocational Training Institute

6.7.4.2 Station Photos

Figure 6-27 Station Photos of Narahenpita Station

6.7.4.3 Condition of the Station

Table 6-13 Condition of Narahenpita Station

Items		Contents
Road Condition		Narahenpita Road and Muhandiram E. Dabare road are located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	One story medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.5 Kirillapona Sub Station

6.7.5.1 Location Map

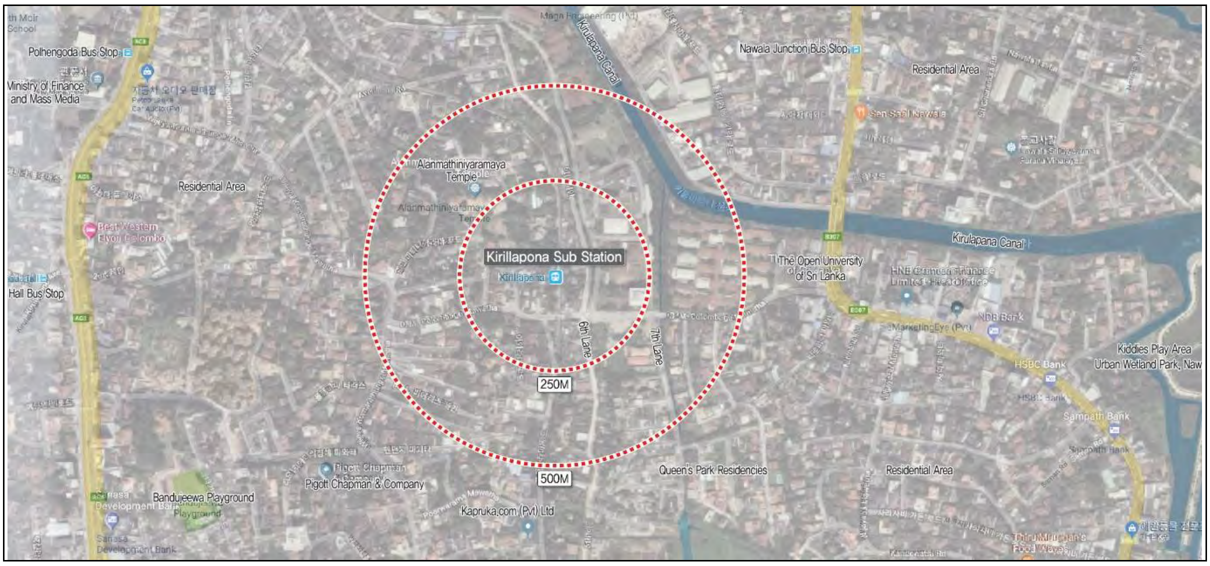


Figure 6-28 Location Map of Kirillapona Station

- Kirillapona station is located in residential area.
- Queen's Park Residencies, Open University of Sri Lanka, Residential Area

6.7.5.2 Station Photos

Figure 6-29 Station Photos of Kirillapona Station

6.7.5.3 Condition of the Station

Table 6-14 Condition of Kirillapona Station

Items		Contents
Road Condition		6th Lane is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.6 Nugegoda Main Station

6.7.6.1 Location Map

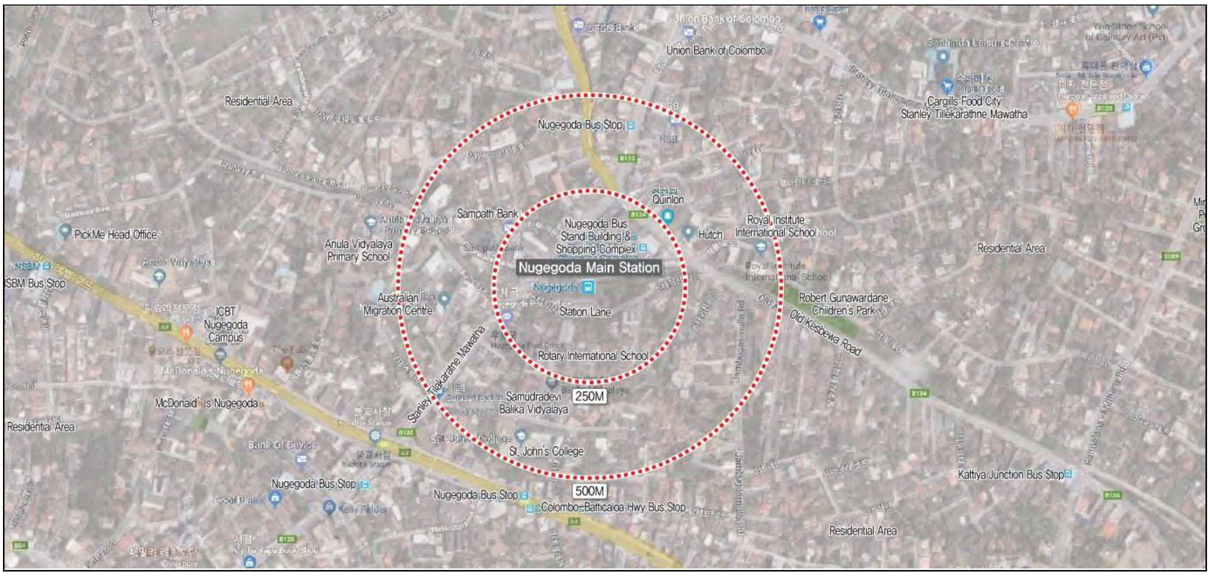


Figure 6-30 Location Map of Nugegoda Station

- Nugegoda station is located in commercial and residential area.
- Nugegoda Bus Standing Building & Shopping Complex, Nugegoda bus stop, Rotary International School, St. John's College

6.7.6.2 Station Photos

Figure 6-31 Station Photos of Nugegoda Station

6.7.6.3 Condition of the Station

Table 6-15 Condition of Nugegoda Station

Items		Contents
Road Condition		Station Lane is located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	One story medium sized building
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in accordance with the public-private partnership development plan.

6.7.7 Pangiriwatta Sub Station

6.7.7.1 Location Map

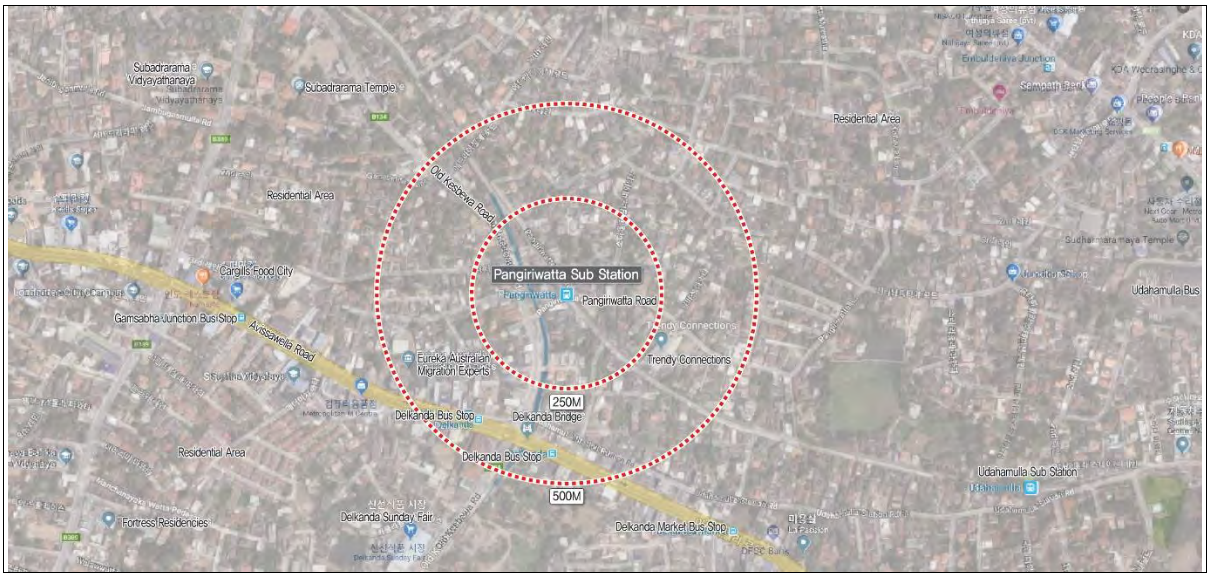


Figure 6-32 Location Map of Pangiriwatta Station

- Pangiriwatta station is located in residential area.
- Delkanda bus stop, Delkanda Sunday Fair, Residential Area

6.7.7.2 Station Photos

Figure 6-33 Station Photos of Pangiriwatta Station

6.7.7.3 Condition of the Station

Table 6-16 Condition of Pangiriwatta Station

Items		Contents
Road Condition		Pangiriwatta Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story small sized building (waiting & ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.8 Udahamulla Sub Station

6.7.8.1 Location Map

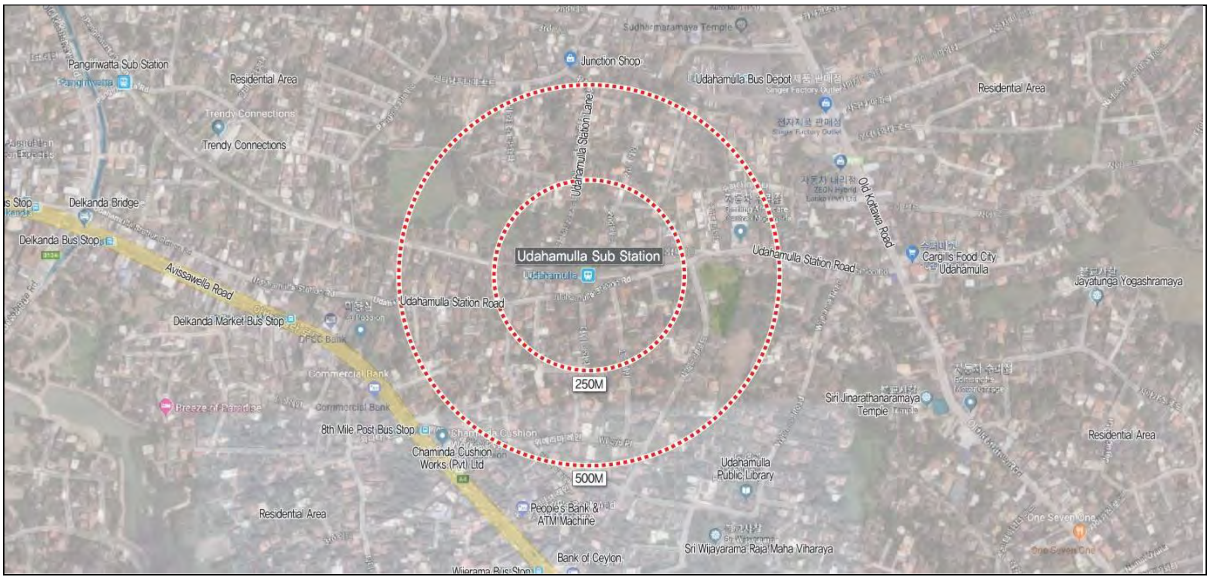


Figure 6-34 Location Map of Udahamulla Station

- Udahamulla station is located in residential area.
- Udahamulla Public Library, Residential Area

6.7.8.2 Station Photos

Figure 6-35 Station Photos of Udahamulla Station

6.7.8.3 Condition of the Station

Table 6-17 Condition of Udahamulla Station

Items		Contents
Road Condition		Udahamulla Station Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small-medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.9 Nawinna Sub Station

6.7.9.1 Location Map

Figure 6-36 Location Map of Nawinna Station

- Nawinna station is located in commercial and residential area.
- Nawinna Ground, National Institute of Traditional Medicine, Residential Area

6.7.9.2 Station Photos

Figure 6-37 Station Photos of Nawinna Station

6.7.9.3 Condition of the Station

Table 6-18 Condition of Nawinna Station

Items		Contents
Road Condition		Avissawella Road (high level) (Colombo-Batticaloa Highway) is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike, Park & Ride
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in accordance with the future transport plan (Bus Terminal) and Arpico Super Center.

6.7.10 Maharagama Sub Station

6.7.10.1 Location Map

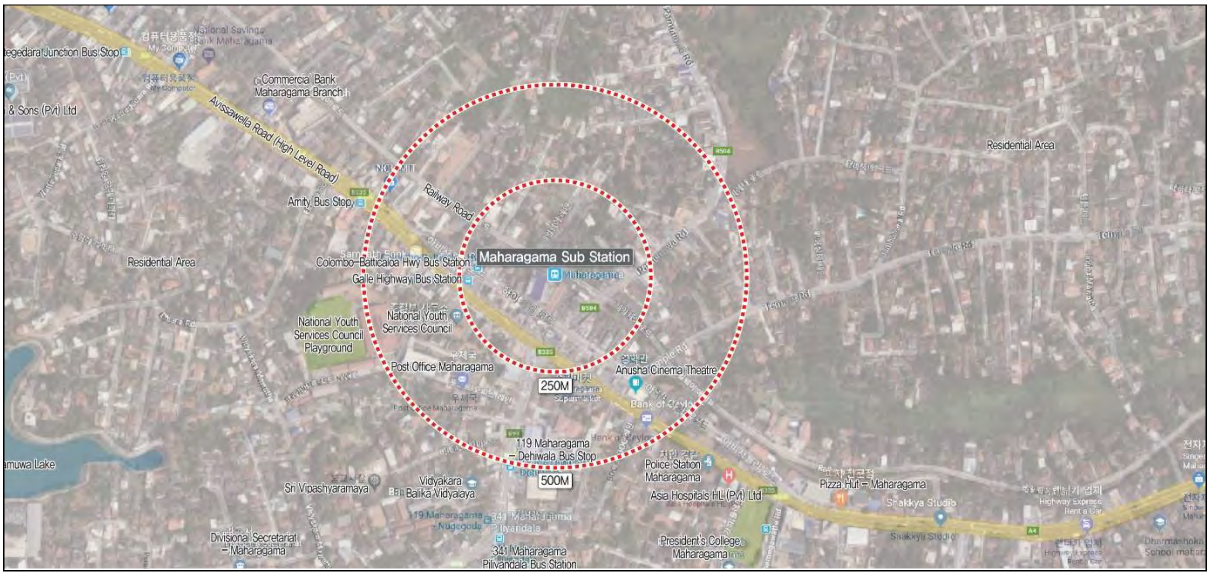


Figure 6-38 Location Map of Maharagama Station

- Maharagama station is located in commercial and residential area.
- Post Office Maharagama, National Youth Service Council, Anusha Cinema Theater, Residential Area

6.7.10.2 Station Photos

Figure 6-39 Station Photos of Maharagama Station

6.7.10.3 Condition of the Station

Table 6-19 Condition of Maharagama Station

Items		Contents
Road Condition		Railway Road is located along the station.
Station	Platform Type and Roof	Island type, Single track/ Extended from building
	Building	One story medium sized building and elevated building above track
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike, Park & Ride, Commercial Area Development
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.11 Pannipitiya Sub Station

6.7.11.1 Location Map

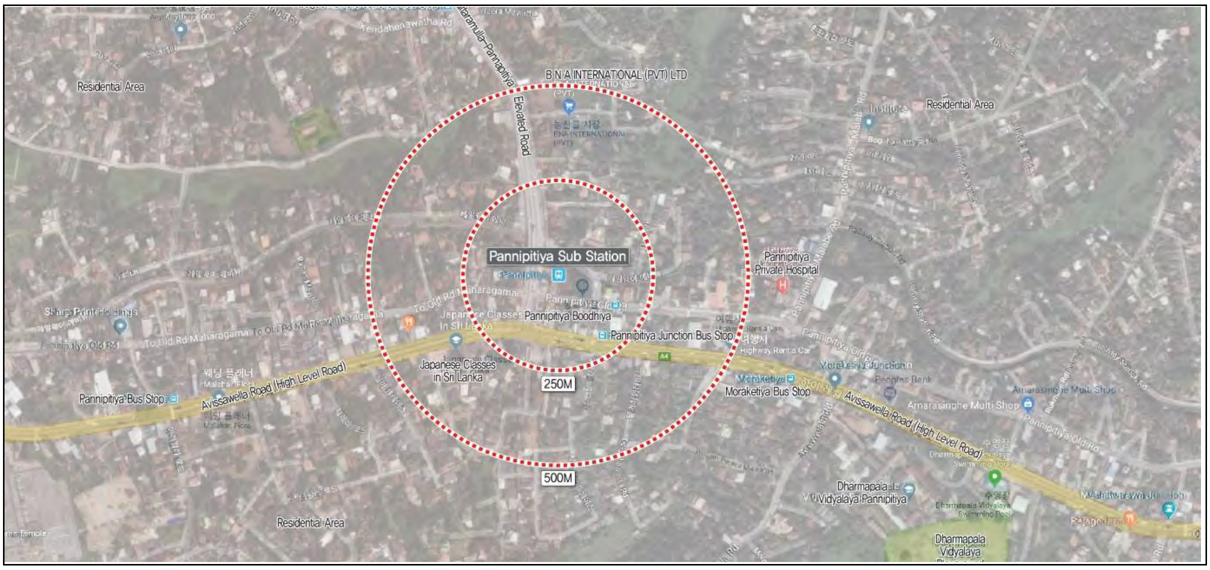


Figure 6-40 Location Map of Pannipitiya Station

- Pannipitiya station is located in commercial and residential area.
- Pannipitiya Junction bus stop, Pannipitiya Private Hospital, Residential Area

6.7.11.2 Station Photos

Figure 6-41 Station Photos of Pannipitiya Station

6.7.11.3 Condition of the Station

Table 6-20 Condition of Pannipitiya Station

Items		Contents
Road Condition		Battaramulla-Pannapitiya Elevated Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	Two stories medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.12 Kottawa Main Station

6.7.12.1 Location Map

Figure 6-42 Location Map of Kottawa Station

- Kottawa station is located in residential area.
- National Savings Bank, Kottawa Junction, Arpico Superstore, Residential Area

6.7.12.2 Station Photos

Figure 6-43 Station Photos of Kottawa Station

6.7.12.3 Condition of the Station

Table 6-21 Condition of Kottawa Station

Items		Contents
Road Condition		Ranasiri Mawatha is located along the station.
Station	Platform Type and Roof	Island type, Single track/ Extended from building
	Building	One story medium sized building
	Footbridge	yes
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.13 Malapalla Sub Station

6.7.13.1 Location Map

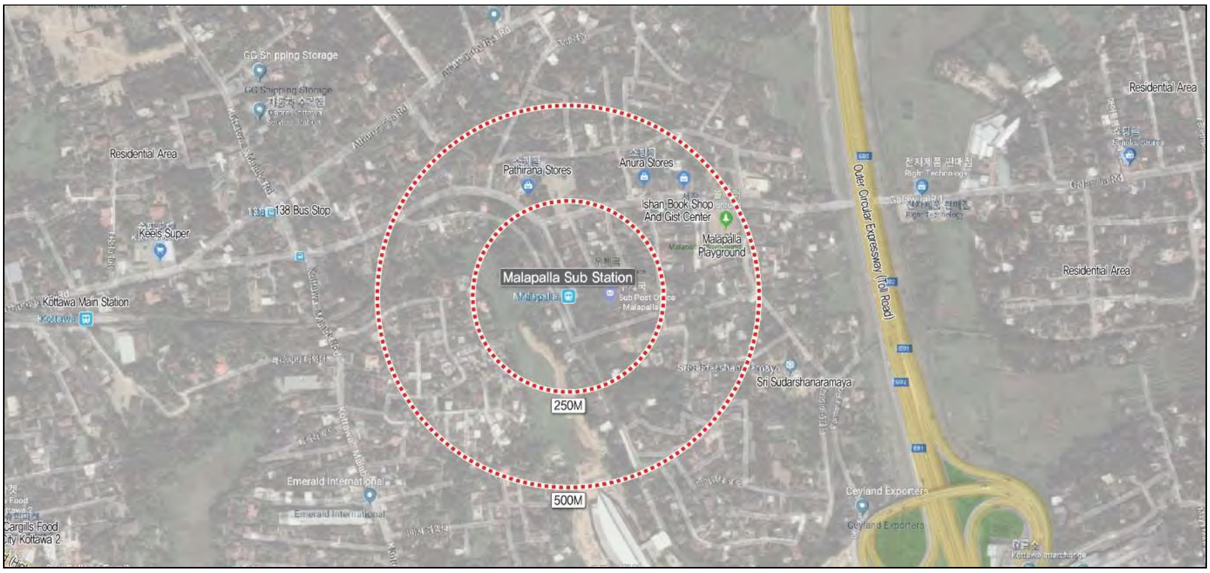


Figure 6-44 Location Map of Malapalla Station

- Malapalla station is located in residential area.
- Multimodal Hub, Malapalla Playground, Residential Area

6.7.13.2 Station Photos

Figure 6-45 Station Photos of Malapalla Station

6.7.13.3 Condition of the Station

Table 6-22 Condition of Malapalla Station

Items		Contents
Road Condition		Ranasiri Mawatha is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.14 Homagama Hospital Sub Station

6.7.14.1 Location Map

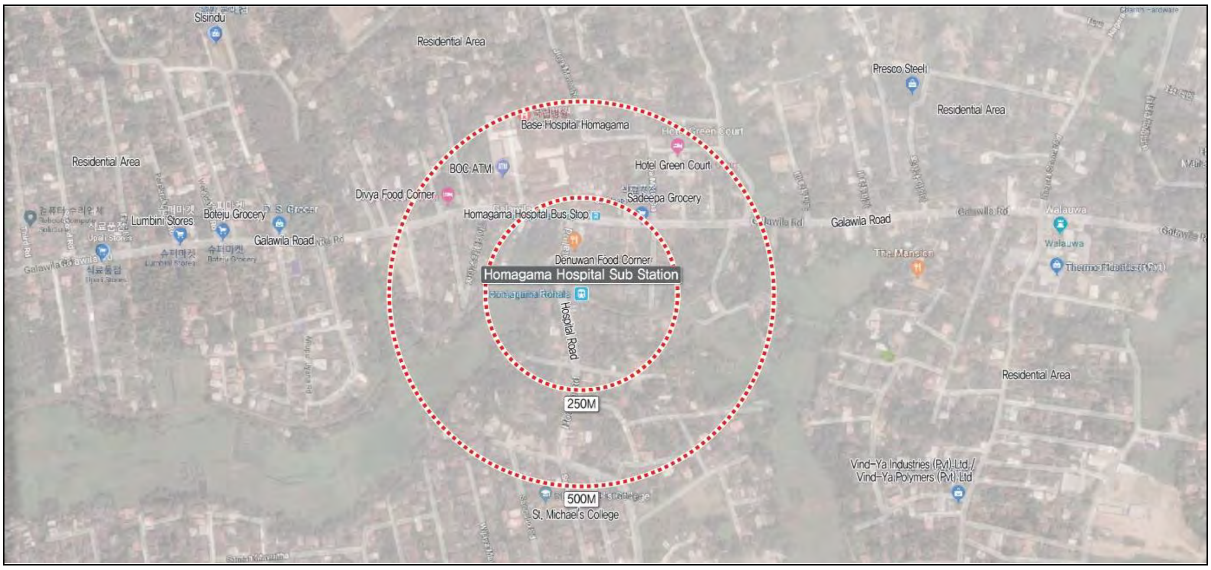


Figure 6-46 Location Map of Homagama Hospital Station

- Homagama Hospital station is located in residential area.
- St. Michael College, Base Hospital Homagama, Residential Area

6.7.14.2 Station Photos

Figure 6-47 Station Photos of Homagama Hospital Station

6.7.14.3 Condition of the Station

Table 6-23 Condition of Homagama Hospital Station

Items		Contents
Road Condition		Hospital road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.15 Homagama Main Station

6.7.15.1 Location Map

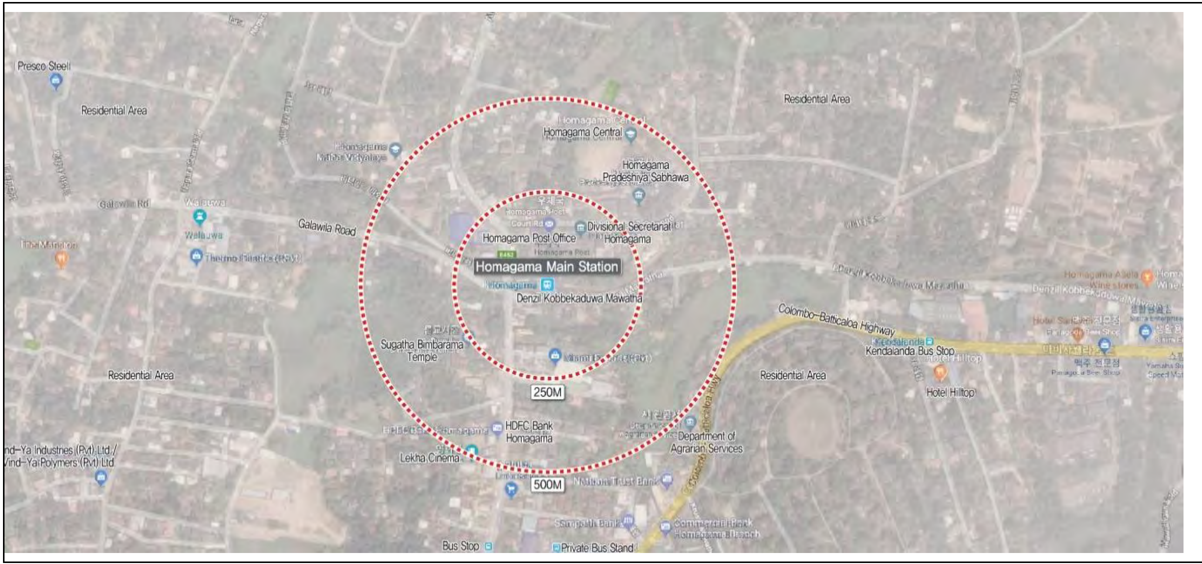


Figure 6-48 Location Map of Homagama Station

- Homagama station is located in commercial and residential area.
- Homagama Post Office, Homagama Central, Divisional Secretariat Homagama, Residential Area

6.7.15.2 Station Photos

Figure 6-49 Station Photos of Homagama Station

6.7.15.3 Condition of the Station

Table 6-24 Condition of Homagama Station

Items		Contents
Road Condition		Denzil Kobbekaduwa Mawatha is located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	One story medium sized building
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.16 Panagoda Sub Station

6.7.16.1 Location Map

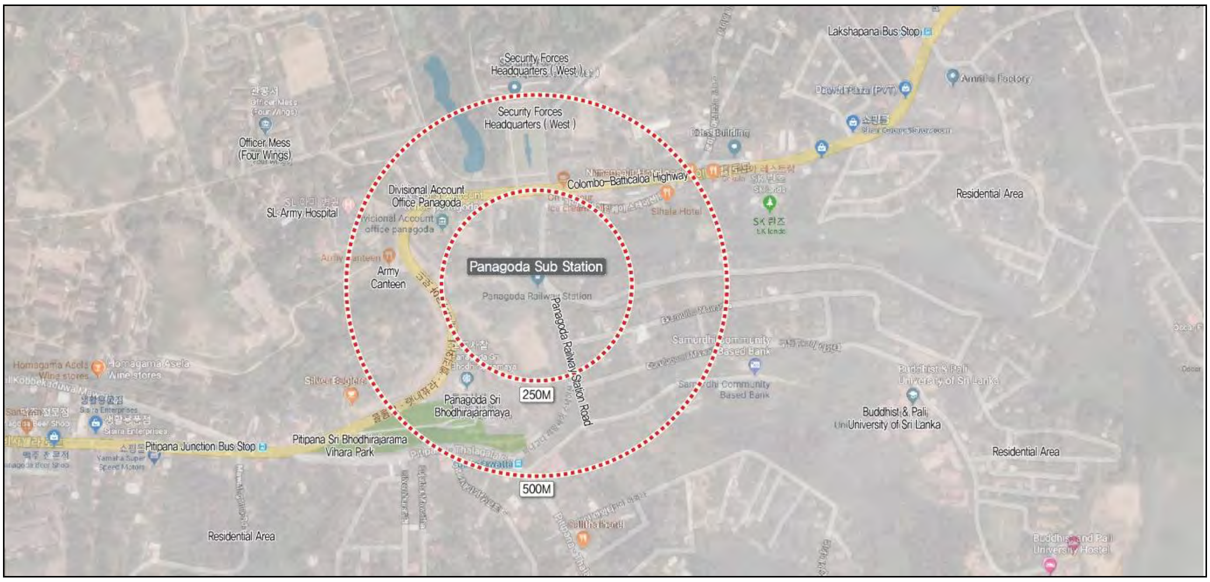


Figure 6-50 Location Map of Panagoda Station

- Panagoda station is located in rural residential area.
- Division Account Office Panagoda, Security Forces Headquarter, Residential Area

6.7.16.2 Station Photos

Figure 6-51 Station Photos of Panagoda Station

6.7.16.3 Condition of the Station

Table 6-25 Condition of Panagoda Station

Items		Contents
Road Condition		Panagoda Railway Station road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.17 Godagama Sub Station

6.7.17.1 Location Map

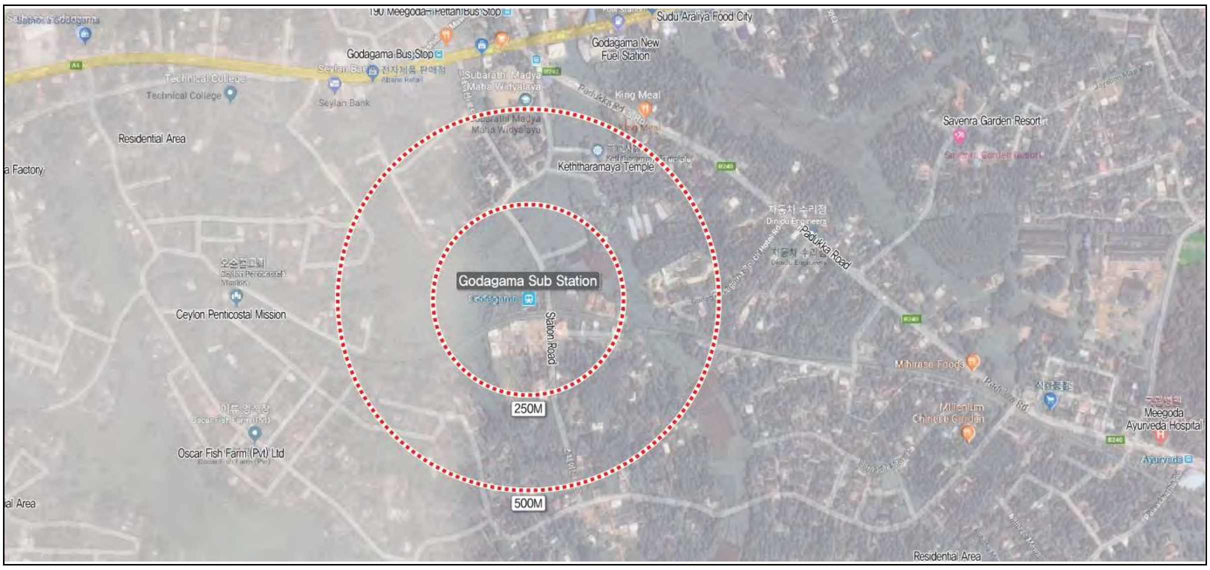


Figure 6-52 Location Map of Godagama Station

- Godagama station is located in rural residential area.
- Keththaramaya Temple, Residential Area

6.7.17.2 Station Photos

Figure 6-53 Station Photos of Godagama Station

6.7.17.3 Condition of the Station

Table 6-26 Condition of Godagama Station

Items		Contents
Road Condition		Station Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.18 Meegoda Main Station

6.7.18.1 Location Map

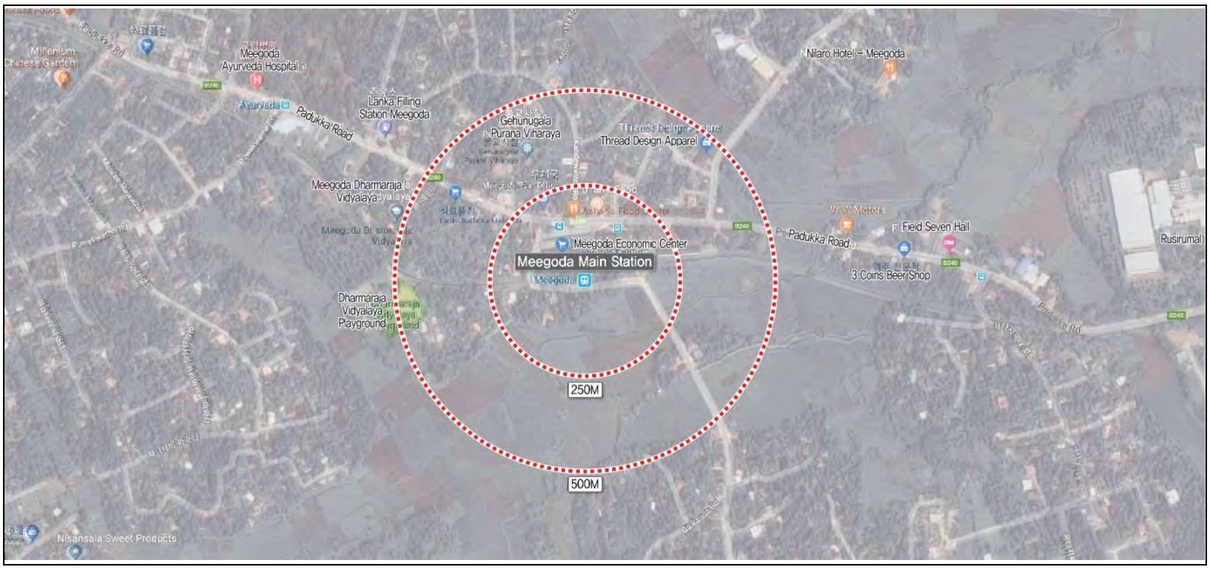


Figure 6-54 Location Map of Meegoda Station

- Meegoda station is located in commercial and residential area.
- Meegoda Economic Center, Seylan Bank, Meegoda Police Post, Residential Area

6.7.18.2 Station Photos

Figure 6-55 Station Photos of Meegoda Station

6.7.18.3 Condition of the Station

Table 6-27 Condition of Meegoda Station

Items		Contents
Road Condition		Padukka Road and Unnamed Road are located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	Two stories medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in accordance with the future commercial development plan (Economic Center & Commercial Center).

6.7.19 Watareka Sub Station

6.7.19.1 Location Map

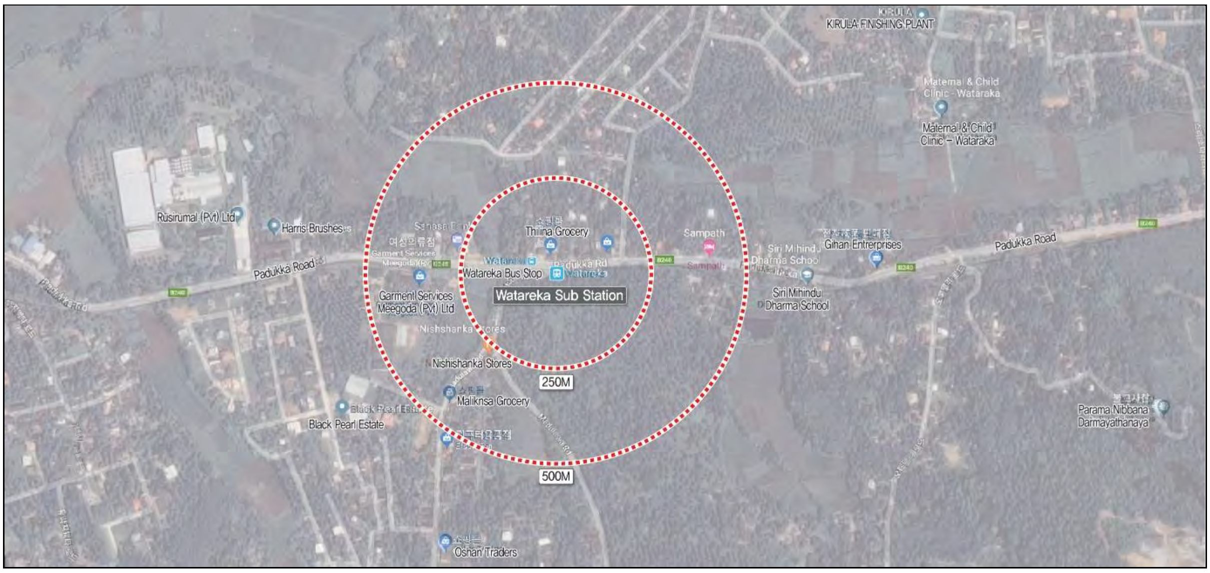


Figure 6-56 Location Map of Watareka Station

- Watareka station is located in rural commercial and residential area.
- Watareka bus stop, Thilina Grocery, Residential Area

6.7.19.2 Station Photos

Figure 6-57 Station Photos of Watareka Station

6.7.19.3 Condition of the Station

Table 6-28 Condition of Watareka Station

Items		Contents
Road Condition		Padukka Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

6.7.20 Liyanwala Halt Station

6.7.20.1 Location Map

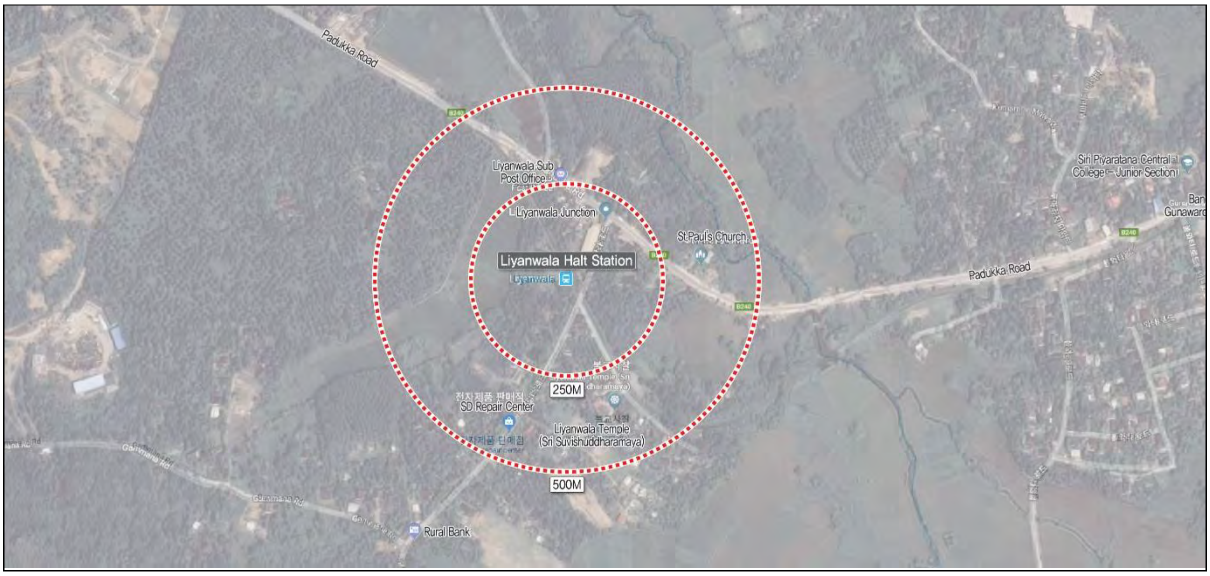


Figure 6-58 Location Map of Liyanwala Station

- Liyanwala station is located in rural area.
- Liyanwala Junction, Liyanwala Temple, St. Paul Church

6.7.20.2 Station Photos

Figure 6-59 Station Photos of Liyanwala Station

6.7.20.3 Condition of the Station

Table 6-29 Condition of Liyanwala Station

Items		Contents
Road Condition		Padukka Road and Kurugala Road are located along the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.21 Padukka Main Station

6.7.21.1 Location Map

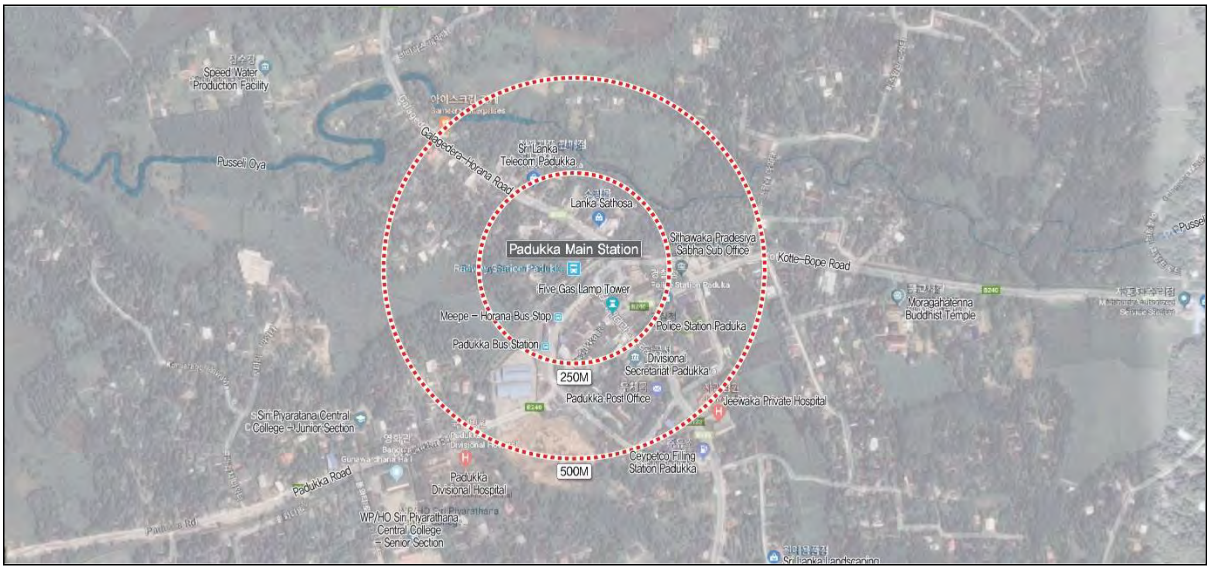


Figure 6-60 Location Map of Padukka Station

- Padukka station is located in commercial and residential area.
- Padukka bus station, Meepe-Horana bus stiop, Padukka Post Office, Five Gas Lamp Tower, Residential Area

6.7.21.2 Station Photos

Figure 6-61 Station Photos of Padukka Station

6.7.21.3 Condition of the Station

Table 6-30 Condition of Padukka Station

Items		Contents
Road Condition		Galagedera-Horana Road and Padukka Road are located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	One story small sized building (waiting, ticket)
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike, Park & Ride
Recommendation		It is appropriate to construct a new station to accommodate the additional rooms and systems as the changes of operation method.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.22 Arukwathpura Sub Station

6.7.22.1 Location Map

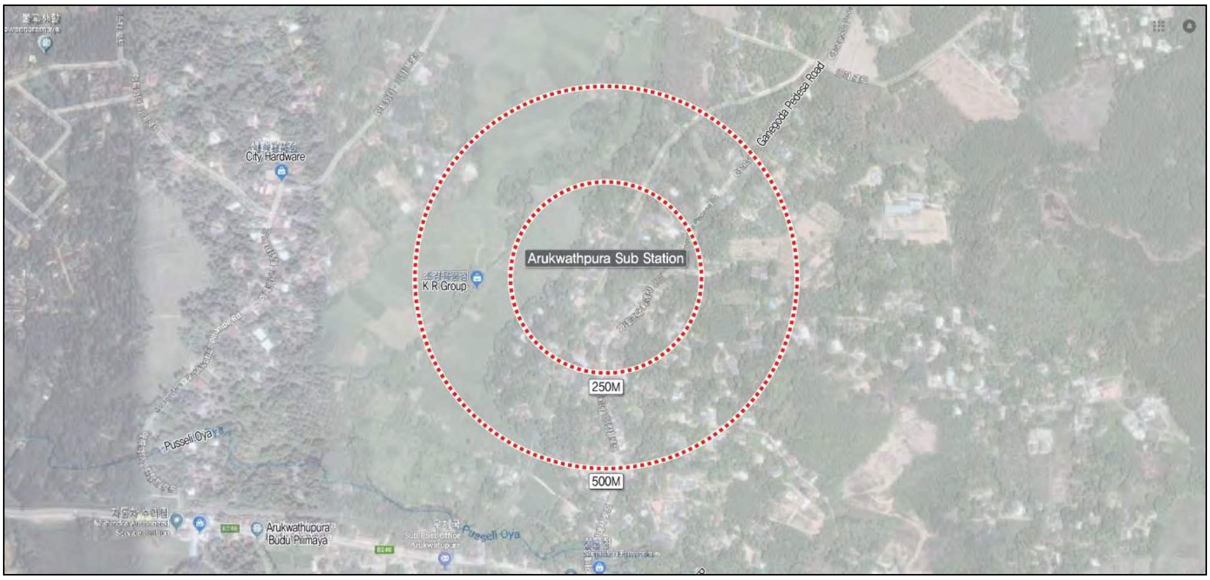


Figure 6-62 Location Map of Arukwathpura Station

- Arukwathpura station is located in rural commercial area.
- K. R Group, Post Office Arukwathpura

6.7.22.2 Station Photos

Figure 6-63 Station Photos of Arukwathpura Station

6.7.22.3 Condition of the Station

Table 6-31 Condition of Arukwathpura Station

Items		Contents
Road Condition		Ganegoda Pedesa Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.23 Angampitiya Sub Station

6.7.23.1 Location Map

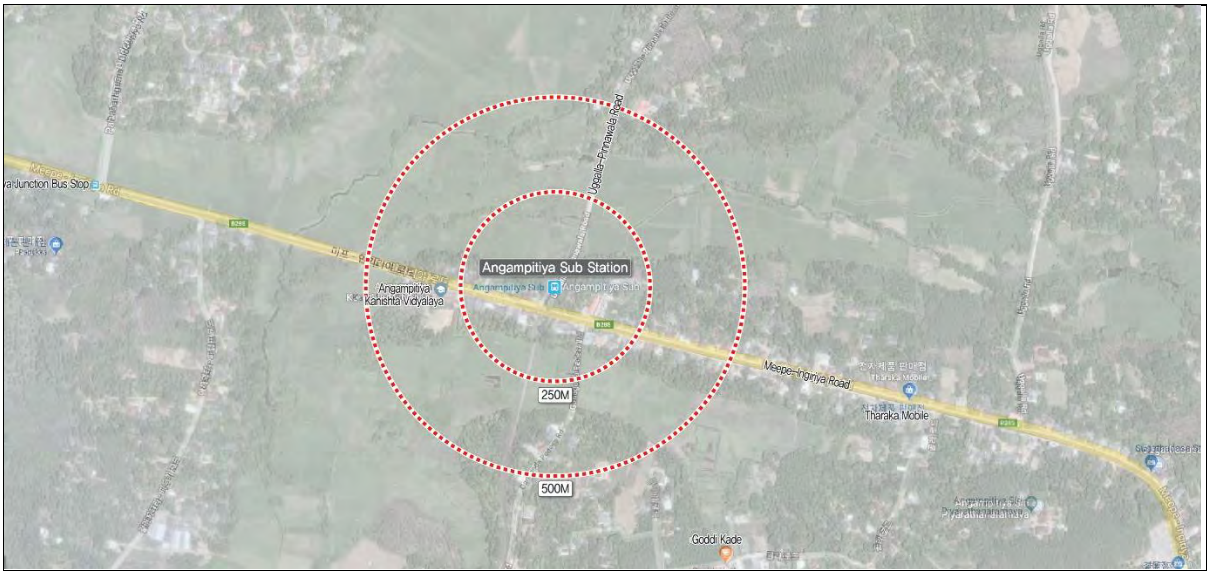


Figure 6-64 Location Map of Angampitiya Station

- Angampitiya station is located in rural residential area.
- Angampitiya Kanishta Vidyalaya

6.7.23.2 Station Photos

Figure 6-65 Station Photos of Angampitiya Station

6.7.23.3 Condition of the Station

Table 6-32 Condition of Angampitiya Station

Items		Contents
Road Condition		Uggalla-Pinnawala Road and Meepe-Ingiriya Road intersect around the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.24 Uggala Sub Station

6.7.24.1 Location Map

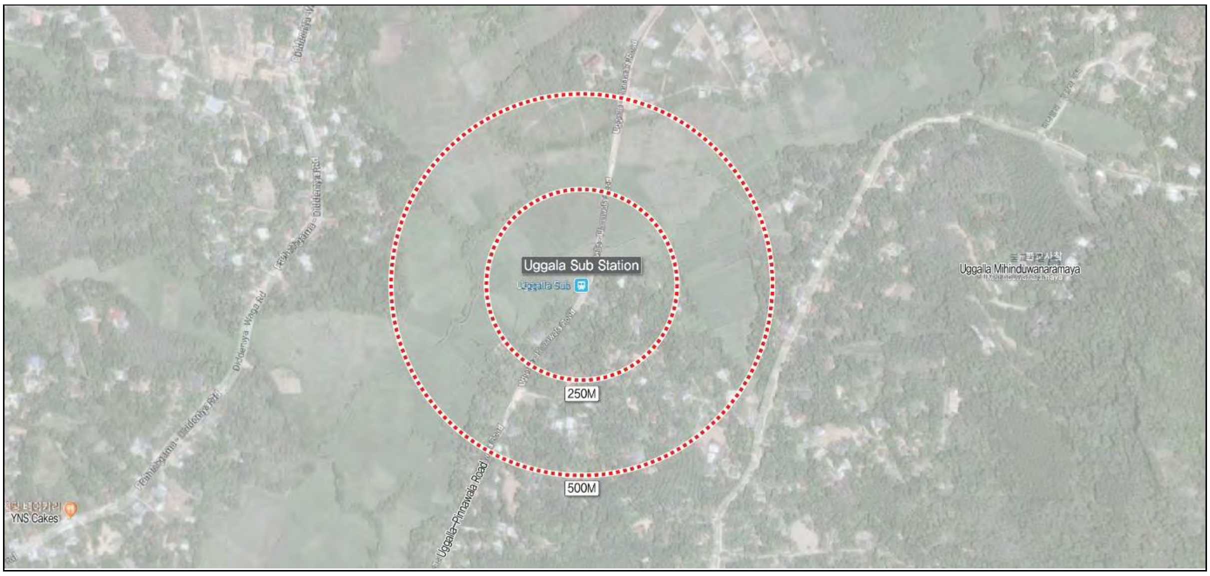


Figure 6-66 Location Map of Uggala Station

- Uggala station is located in rural area.
- Uggalla Mihinduwanaramaya

6.7.24.2 Station Photos

Figure 6-67 Station Photos of Uggala Station

6.7.24.3 Condition of the Station

Table 6-33 Condition of Uggala Station

Items		Contents
Road Condition		Uggalla-Pinnawala Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.25 Pinnawala Sub Station

6.7.25.1 Location Map

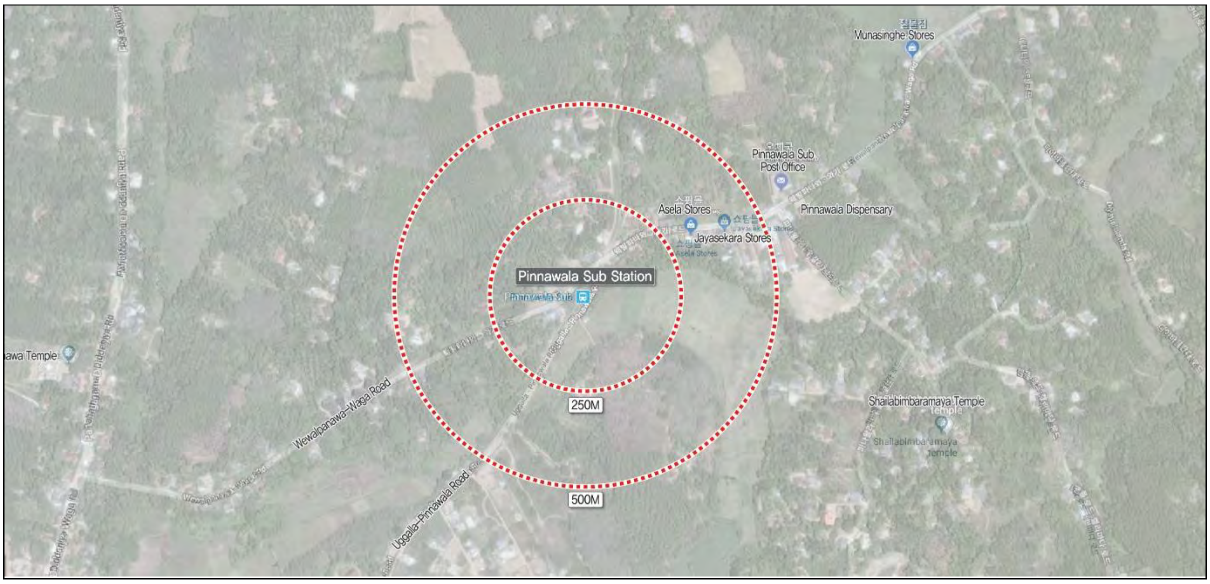


Figure 6-68 Location Map of Pinnawala Station

- Pinnawala station is located in rural area.
- Pinnawala Sub Post Office, Shailabimbaramaya Temple

6.7.25.2 Station Photos

Figure 6-69 Station Photos of Pinnawala Station

6.7.25.3 Condition of the Station

Table 6-34 Condition of Pinnawala Station

Items		Contents
Road Condition		Wewalpanawa-Waga Road and Uggalla-Pinnawala Road intersect around the station.
Station	Platform Type and Roof	Side type, Single track/ Extended from building
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.26 Gammana Sub Station

6.7.26.1 Location Map

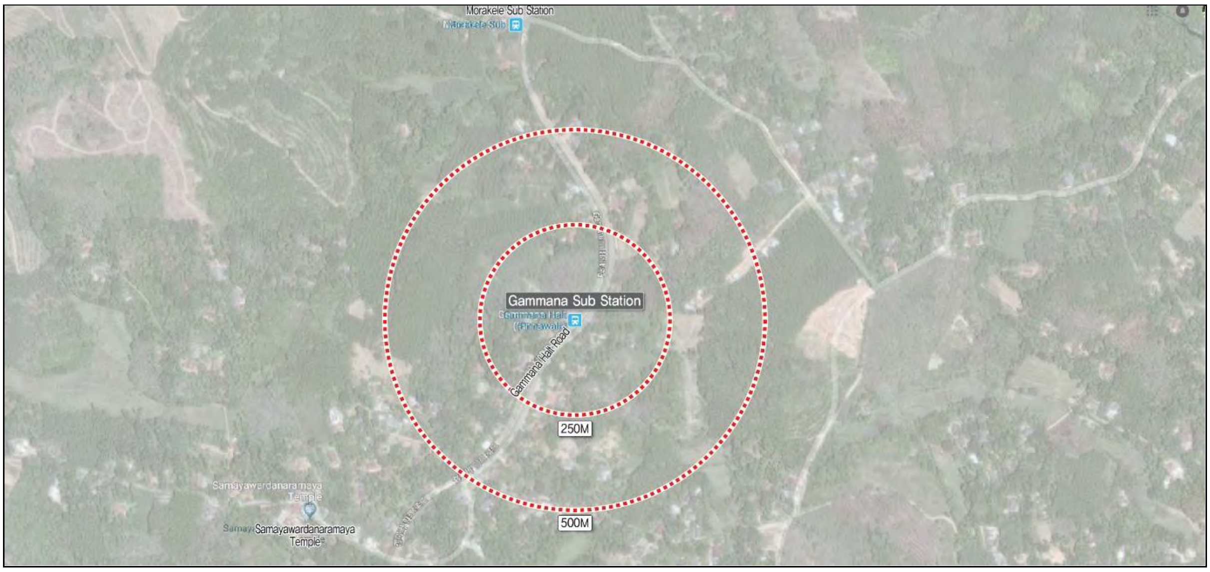


Figure 6-70 Location Map of Gammana Station

- Gammana station is located in rural residential area.
- Samayawardanaramaya Temple

6.7.26.2 Station Photos

Figure 6-71 Station Photos of Gammana Station

6.7.26.3 Condition of the Station

Table 6-35 Condition of Gammana Station

Items		Contents
Road Condition		Gammana Halt Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.27 Morakele Sub Station

6.7.27.1 Location Map

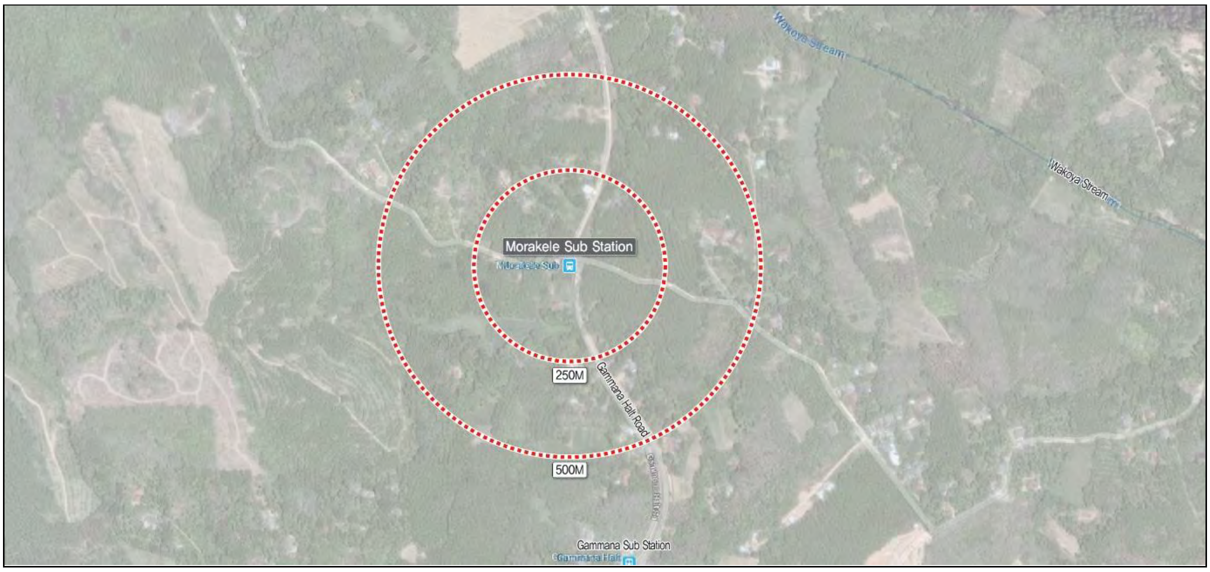


Figure 6-72 Location Map of Morakele Station

- Morakele station is located in rural area.
- There are no distinctive buildings in this area.

6.7.27.2 Station Photos

Figure 6-73 Station Photos of Morakele Station

6.7.27.3 Condition of the Station

Table 6-36 Condition of Morakele Station

Items		Contents
Road Condition		Gammana Halt Road is located along the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.28 Waga Main Station

6.7.28.1 Location Map

Figure 6-74 Location Map of Waga Station

- Waga station is located in rural commercial area.
- Waga Post Office, Kahahena St. Joseph's Church, People’s Bank

6.7.28.2 Station Photos

Figure 6-75 Station Photos of Waga Station

6.7.28.3 Condition of the Station

Table 6-37 Condition of Waga Station

Items		Contents
Road Condition		Kaluaggala-Labugama Road is located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	Two stories medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.29 Kadugoda Sub Station

6.7.29.1 Location Map

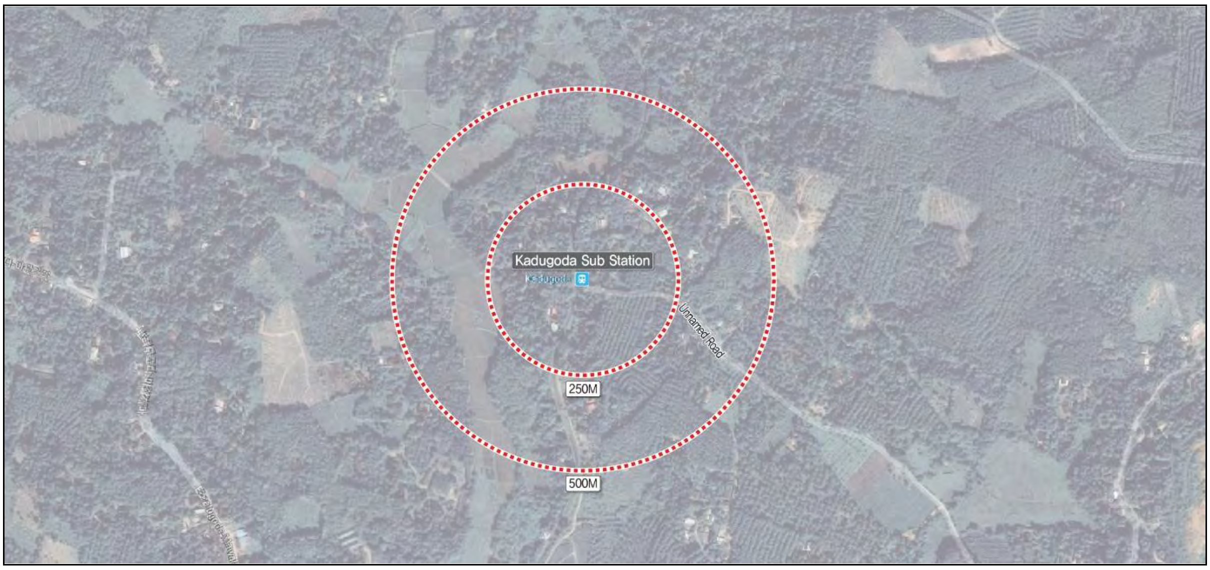


Figure 6-76 Location Map of Kadugoda Station

- Kadugoda station is located in rural area.
- There are no distinctive buildings in this area.

6.7.29.2 Station Photos

Figure 6-77 Station Photos of Kadugoda Station

6.7.29.3 Condition of the Station

Table 6-38 Condition of Kadugoda Station

Items		Contents
Road Condition		Unnamed Road is located vertically to the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	One story small sized building (waiting, ticket)
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.30 Kosgama Main Station

6.7.30.1 Location Map

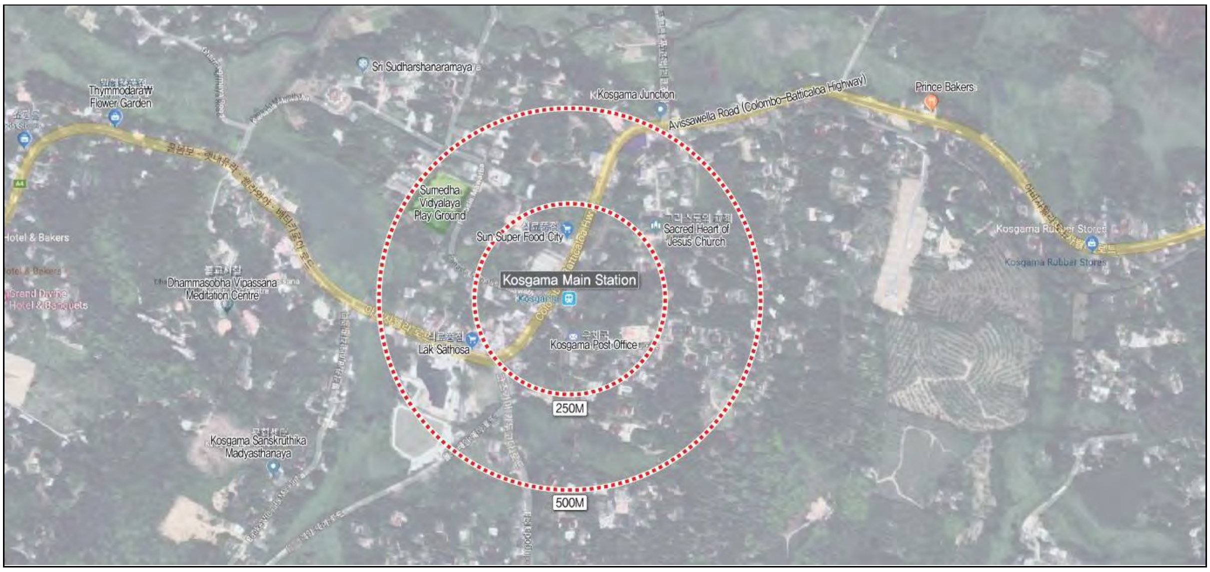


Figure 6-78 Location Map of Kosgama Station

- Kosgama station is located in rural commercial area.
- Kosgama Post Office, Sacred Heart of Jesus Church, Sumedha Vidyalaya Play Ground

6.7.30.2 Station Photos

Figure 6-79 Station Photos of Kadugoda Station

6.7.30.3 Condition of the Station

Table 6-39 Condition of Kosgama Station

Items		Contents
Road Condition		Avissawella Road (Colombo-Batticaloa Highway) is located along the station.
Station	Platform Type and Roof	Side type, Single & loop track/ Extended from building
	Building	One story medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

6.7.31 Hingurala Halt Station

6.7.31.1 Location Map

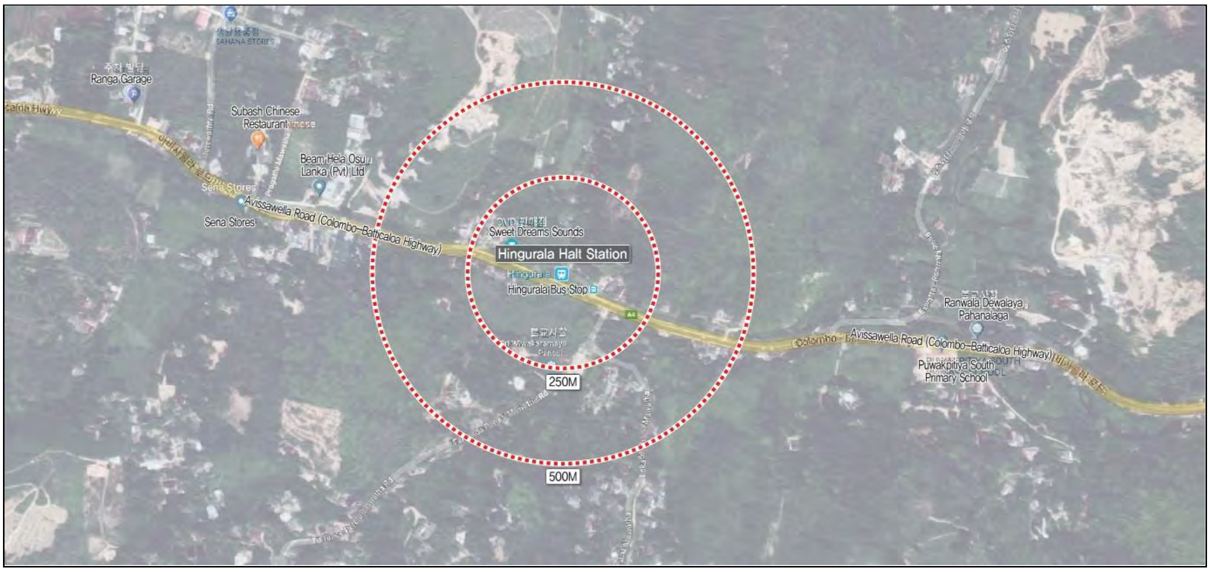


Figure 6-80 Location Map of Hingurala Station

- Hingurala station is located in rural area.
- Hingurala Bus Stop, Sweet Dreams Sounds

6.7.31.2 Station Photos

Figure 6-81 Station Photos of Hingurala Station

6.7.31.3 Condition of the Station

Table 6-40 Condition of Hingurala Station

Items		Contents
Road Condition		Avissawella Road (Colombo-Batticaloa Highway) is located along the station.
Station	Platform Type and Roof	Side type, Single track/ No
	Building	No
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.32 Puwakpitiya Sub Station

6.7.32.1 Location Map

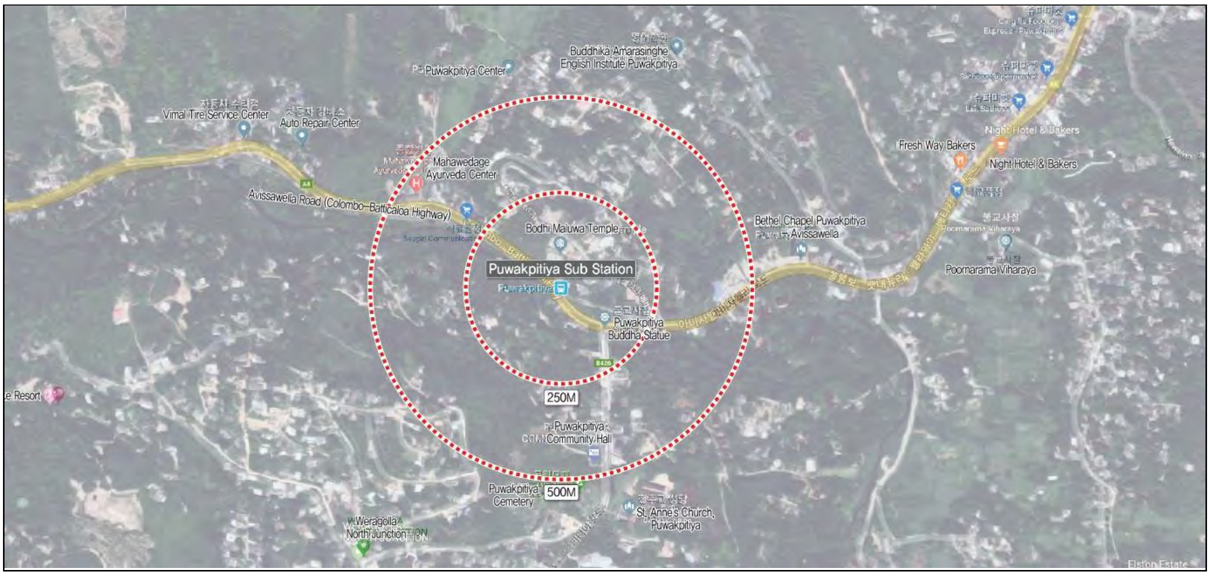


Figure 6-82 Location Map of Puwakpitiya Station

- Puwakpitiya station is located in rural commercial area.
- Puwakpitiya Buddha Statue, Bodhi Maluwa Temple, Mahawedage Ayurveda Center

6.7.32.2 Station Photos

Figure 6-83 Station Photos of Puwakpitiya Station

6.7.32.3 Condition of the Station

Table 6-41 Condition of Puwakpitiya Station

Items		Contents
Road Condition		Avissawella Road (Colombo-Batticaloa Highway) is located along the station.
Station	Platform Type and Roof	Side type, Single track/ Stand-alone platform roof
	Building	Two stories medium sized building
	Footbridge	No
Multimodal Opportunity		Bus, Taxi, Bike
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

6.7.33 Avissawella Main Station

6.7.33.1 Location Map

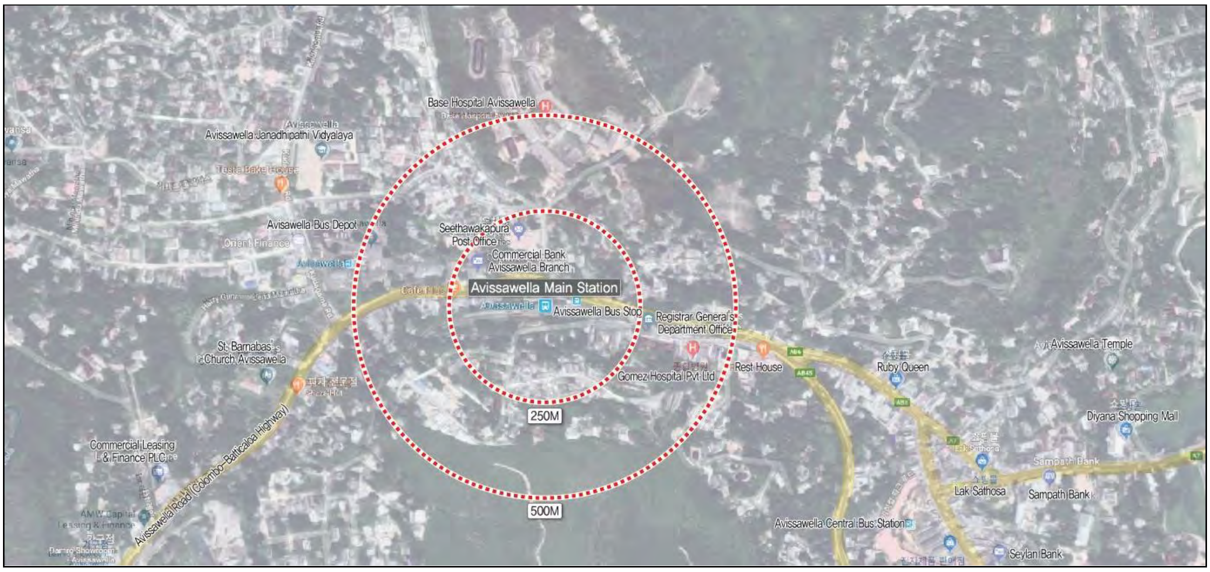


Figure 6-84 Location Map of Avissawella Station

- Avissawella station is located in commercial and residential area.
- Avissawella Bus Stop, Seethawakapura Post Office, Registrar General's Department Office

6.7.33.2 Station Photos

Figure 6-85 Station Photos of Avissawella Station

6.7.33.3 Condition of the Station

Table 6-42 Condition of Avissawella Station

Items		Contents
Road Condition		Avissawella Road (Colombo-Batticaloa Highway) is located along the station.
Station	Platform Type and Roof	Side type, Triple tracks, Terminus/ Extended from building
	Building	Two stories large sized building
	Footbridge	Yes
Multimodal Opportunity		Bus, Taxi, Bike, Park & Ride
Recommendation		It is necessary to build an operational building for waiting area, a ticket office and a technical room for service.

- It is necessary to establish a Transit-Oriented Development plan in RDA premises.

CHAPTER

7

Train Operation Plan

Chapter 7 Train Operation Plan

Chapter Summary

As per transport demand, Sri Lankan Railways has embarked on ambitious plans of improving the railway system in the Western Province, including the Colombo Metropolitan Region (CMR) with the aid of ADB. Egis had carried out Project Preparatory Technical Assistance (PPTA) report in February 2018. To validate the recommendations of the Egis study, Dohwa Engineering along with other JV partners have been assigned the responsibility of conducting Feasibility Study, Detailed Design and prepare Bid documents for up gradation of all the four lines in Colombo Suburban Railway System under the name of “Colombo Suburban Rail Project” (CSRP).

(1) The ADB required to initiate with the Kelani Valley Line (KV), which DOHWA JV has examined and prepared the Feasibility Report.

(2) Improvements as suggested for KV Line are:

- Doubling of track with OCS between Maradana and Padukka stations along with elevation from 0.900 km to 16.400 km and from 17.200 km to 19.880 km.
- Single track non-OCS between Padukka and Avissawella stations with rehabilated track and signal.
- Terminal facilities at Maradana, Padukka and Avissawella.
- Turn Back arrangement at Maradana, Makumbura North, Padukka and Avissawella.

Train Operations based on passenger demand assessment for 2025 and 2035 is planned in 3 segments as under:

(1) Maradana- Makumbura North 44 EMU trains service daily with 5+5 trainset (1988 Passengers per set) in 2025 and 6+6 train set (2404 passengers per set) in 2035 with interval of 7 minutes during peak direction and 30 to 60 minutes interval during non-peak periods.

(2) Makumbura North - Padukka 22 EMU trains service daily with 5+5 trainset in 2025 and 6+6 in 2035 with interval of 14 minutes during peak direction and 30 to 60 minutes interval during non-peak periods.

(3) Padukka-Avissawella DMU trains(S12) will be operated in accordance with 30 minutes headway both in 2025 and in 2035.

Accordingly, the Quantity of EMU is 20 trainsets(or 200 cars) in 2025 and 20 trainsets(or 240 cars) in 2035. The 20 EMU includes 3 EMU to prepare for maintenance and emergency.

The Quantity of DMU is 4 trainsets in 2025 and in 2035. The 4 DMU includes 1 DMU to prepare for maintenance and emergency.

The opinion of the consultants is that an appropriate Special Purpose Vehicle (SPV) for operation and maintenance is to be set up under Sri Lanka Railways for management of Colombo Suburban Railway System.

To achieve the goal of a Professional Safe and Efficient Transport Service Provider and generate additional source of revenue, it is essential for the SRL to undertake the following steps:

Separate Suburban Rail Organisation, exploring non-conventional source of revenue, securing ROW space of 20-meter-wide and used for maximum commercial exploitation, Updating of Railways Ordinance, 1902 as old as 116 years Accordingly, General Rules, Operation Rules, Signal and Telecom Rules, Track Manual, OCS manual, Disaster Management are to be recasted afresh.

7.1 Introduction to Existing Railway Operations of Sri Lanka

The erstwhile Ceylon Government Railways under British regime started its maiden journey on the 27thof December 1864 from Colombo to Ambepussa, a 54km stretch, for facilitating colonial trade of transporting tea and coffee to Colombo port. The basic aim of freight operations also encompassed passengers‟commuter operations in due course.

Now-a-days the renamed Sri Lanka Railways as a state-owned enterprise is primarily centered in intercity commuting service with broad gauge (1676mm) network of 1460.91km exclusively with diesel traction, with 396 daily train services through 405 stations, Sri Lanka Railways has the credit of 0.37million daily passenger ridership throughout the network.

Sri Lankan Railways is striving hard to its best ability in keeping pace with its mission of providing safe, reliable, economical, punctual rail transport services for both Passenger and Freight traffic efficiently.

Sri Lankan Railways has its corporate Headquarters at Colombo. It consists of three operating divisions as follows.

- Colombo: Comprising four lines, namely Coastal line Puttalam line, KV line and Main line
- Anuradhapura: Controlling Northern Line, Talaimannar Line, Batticaloa Line, Trincomalee Line and Mihintale Line
- Nawalapitiya: Controlling Matale Line, Badulla Line and Main Line beyond Rambukkana.
- Centralized Traffic Control (CTC) system located at Maradana station controls the train operations on Coastline, Puttalam line, Main Line and KV line up to Baseline station in suburban jurisdiction. The route is set from the CTC Centre in normal case, however, in case of failure, local panel can be activated by transferring control from CTC. The train operation on KV line beyond Base Line Road station is controlled with Tyers‟Tablet Block Instruments as means of Train Control and Communication.

At present, there are six train controller positions in Centralized Traffic Control Centre (CTCC)and it handles about 290 pairs of trains daily. It is considered as the heart of train operations in Colombo Metropolitan area.

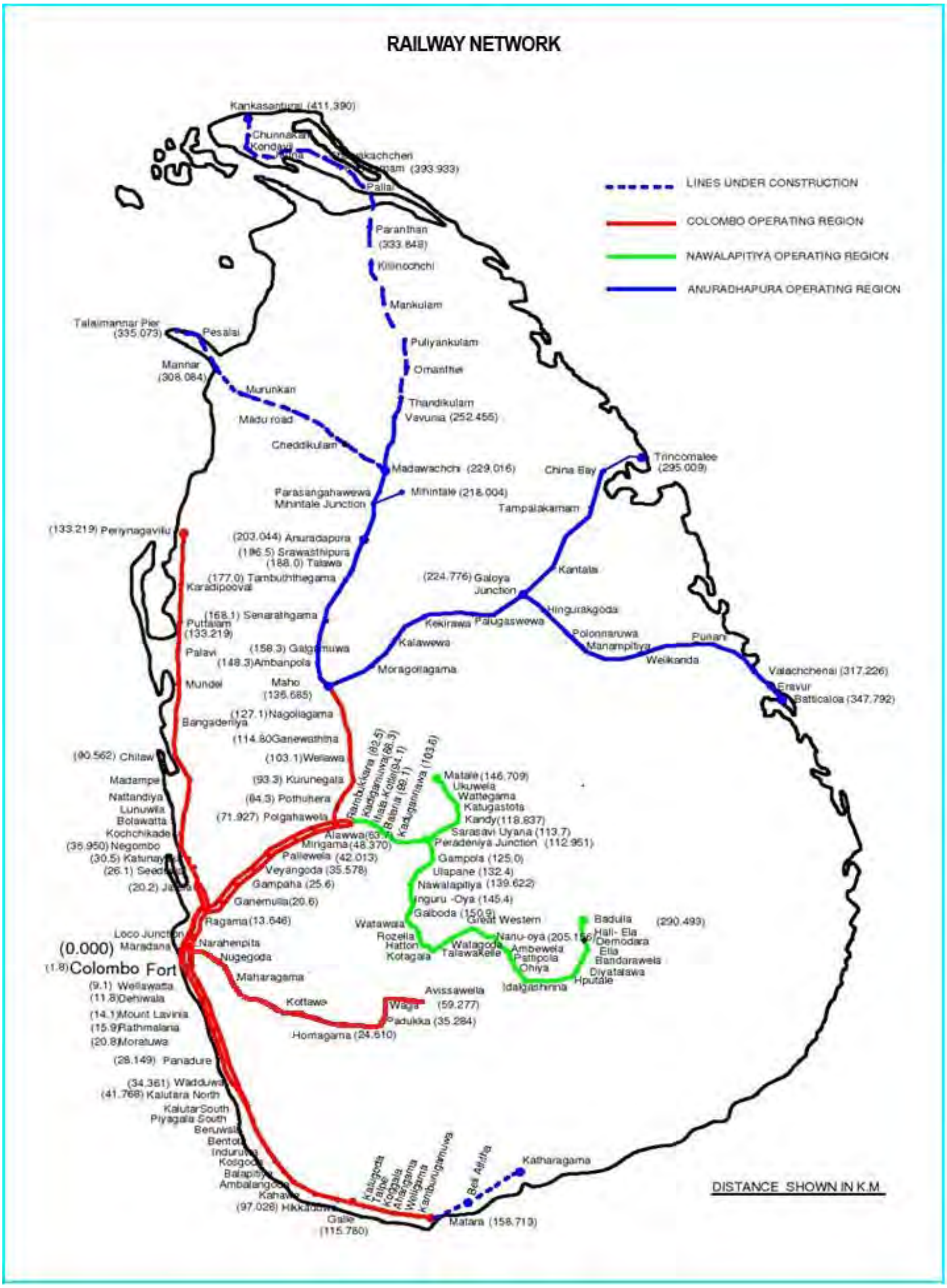


Figure 7-1 System Map of Sri Lanka Railway

7.2 The Kelani Valley Railway Line- Profile

Kelani Valley (KV) line extends from Maradana to Avissawella with the route length of 58.46 km with single line, diesel traction. Originally a narrow-gauge line, it was converted into broad gauge in 1997. The line connects the suburbs of Colombo district with the city. Spreading over 35 stations, including Maradana and Avissawella, KV line is served with following number of train services:

- In the UP direction away from Maradana, 16 passenger trains including 2 services of rail buses stopping at all stations; and
- In the DN direction towards Maradana, 18 passenger trains including 2 services of rail buses stopping at all stations.
- The abridge timings of up and down trains of KV line is as in Table 7-1.

Figure 7-2 Alignment of KV Line on Google map

Table 7-1 Existing Time Table - Colombo Fort to Avissawella

Up		**9253**	**9252**	**R/B1**	**9254**	**R/B2**	**R/B 04 daily**	**9260**	**9262 ns**	**9262A so**	**9263NS**	**9265ns**	**9264**	**9268**	**9269**	**9270**	**9271**
		SHED	**SHED**	**SHED**	**SHED**	**Form RB1**	**Form R/B 03**	**SHED**	**SHED**	**SHED**	**SHED**	**SHED**	**SHED**	**Form 9661**	**SHED**	**SHED**	**SHED**
FOT	A D				8:30			13.55	16:10	16:25	16:35	17:05	17:20	17:40	18:30	19:00	20:00
MDA	A D	4:00	4:15	4:30	80:34 08:50			13:59 14:00	16:14 16:15	16:29 16:30	16:39 16:40	17:09 17:10	17:24 17:25	14:44 17:45	18:34 18:35	19:04 19:05	20:04 20:05
PDK	A D	4:54			10:14 10:15	08:24 08:26	14:29 14:31	15:24	17:34 17:35	17:54 17:55	17:58 17:59	18:16 18:23	18:43 18:44	19:09	19:59 19:20	20:29	21:29 21:30
KSG	A D				10:52 10:53	9:04	15:08		18:10 18:11	18:30 18:32	18:30 18:32	18:48	19:19 19:20		20:37		22:05 22:06
AVS	A D				11:19					18:50			19:39				22:23

Down		9646 Daily	9647 NS/	9269	9649 nsu	9649S UO	9650 nsu	9652 NSU	9653ns	9651 Daily	RB3 Daily	9657 Daily	9661 ns/nsu	9661A so	RB 05 D	9662 NS	9663 ns/nsu	9673	RB06 Daily
AVS	A D	4:55			5:30	5:35				6:25		12:35				18:50			
KSG	A D	05:15 05:16		4:30	5:45 5:46	5.55 5.56		6:10		6:45 6:46	10:00	13.01 13:02			15:40	19:05 19:19			
PDK	A D	05.52 05.55	5:30	5.07 5.10	6.15 6.17	6.31 6.32	7:05	6.38 6.40		7.22 7.23	11.06 11:8	13.39 13:40	15:35	15:35	16.20 16:22	19:48	19:30	21:00	
MDA	A D	07.24 07.26	06:59 07:01	06:37 06:39	07:38 07:40	07:56 07:57	08:29 08:31	07:59 08:01	08:12 08:14	08:44 08:46		15:17 15:20	17:08 07:09	16:58 16:59				22:14	21:25
FOT	A D	7:30	7:05	6:43	7:44	8:01	8:35	8:05	8:18	8:50		15:24	17:13	17:03				SHED	SHED
		SHED	SHED	Form 1135	SHED	SHED	SHED	SHED	SHED	SHED		SHED	Form 9268	SHED					

7.3 Constraints of KV Rail Line

There are several operations constraints on the KV Line, which is not resulting in optimum utilization of the transport infrastructure, which are as follows:

- The line is a single track with passing loops at only 10 stations, excluding Maradana and Avissawella stations, being the terminal stations.
- There is heavy encroachment on the either side and there is no room for doubling the existing line.
- The line geometry is very winding with short radius curves limiting the maximum authorized speed and thus affecting the operating speed averagingless than 25 kmph for the whole section.
- There are as many as 146 level crossings on a 58.46 km section literally three level crossings in every km of track. Out of these 17-level crossing have very high traffic density roads. There are 52 unprotected level crossings, which are serious safety threat to seamless train operations.
- Old rolling stock with inadequate passenger comfort leads to poor co-efficient of rail ridership.
- Old signaling system with poor visibility of signals due to sharp curves and cuttings restrict the average speed of the train to 23.5 kmph for all stopping trains.
- To upgrade the services on KV Rail Line with improved headways and reduced travel time, several options have been considered:

7.4 New Initiatives to upgrade Colombo Suburban Railway System

Sri Lankan Railways has embarked on ambitious plans of improving the railway system in the Western Province, including the Colombo Metropolitan Region (CMR), which has a population of 5.8 million. The population growth of CMR is 1.5% per annum. So CMR is facing more traffic congestion. Currently, the railway system carries about 13% of Total passengers within the CMR.As a matter of fact, the transport capacity should be ahead of transport requirement. In the absence of this, there will be a less number of services, delay in transit, waste of time, development of crisis, and finally the system comes to a break down.

The population growth rate of CMR at 13% per annum shall have direct impact on the increase of passengers every year, and it will be directly proportionate to the growth rate. The road transport by its nature is in small number with congestion of roads, and it will not be able to provide the required transport services on par with growth rate. So, the public will look forward to Railway transport for their needs which causes high demand for Rail transport services. Existing railway system on KV Railway Line doesn‟t have the required potential to meet the demand.

Countries all over the world are looking forward for adopting railway system for their suburban and metro systems based on the inbuilt merits of Railway system. Namely,

- Safety
- Efficiency
- Rapid Movement
- Bulk Transport

- Economy
- Eco friendly

In ADB funded study, Egis had carried out Project Preparatory Technical Assistance (PPTA) report in February 2018.

To validate the recommendations of the Egis study, Dohwa Engineering along with other JV partners have been assigned the responsibility of conducting Feasibility Study, Detailed Design and prepare Bid documents for upgradation of all the four lines in Colombo Suburban Railway System under the name of “Colombo Suburban Rail Project” (CSRP).

The ADB required to initiate with the Kelani Valley Line(KV), which DOHWAJV has examined and prepared the Feasibility Report.

7.4.1 Improvement Suggested for KV Line

The train operation plan for the proposed corridor on Maradana- Avissawella section is based on the following propositions:

- The railway track will be double line with universal movement between Maradana and Padukka stations and remaining single line between Padukka and Avissawella stations.
- The line shall be of the existing Broad-Gauge concept (1676mm).
- The configuration of rail line from Maradana to Padukka and further up to Avissawella shall be as under:
    - From Maradana (0.000km) to 0.900 Km double line at grade with OCS
    - From 0.900 to 16.400km double line elevated with OCS
    - From 16.400 to 17.200 km double line at grade with OCS
    - From 17.200 km to Malapalla (19.880km) double line elevated with OCS
    - From Malapalla(19.880km) to Padukka (35.100km) double line at grade with OCS
    - From Padukka(35.100km) to Avissawella (58.690km) single line at grade without OCS
- On the 19.880km double line elevated section, there are two main lines only with 13intermediate halt/ Sub Stations1.
- On the 15.220 km double line section at grade between Malapalla and Padukka, there shall be 6halt stations,1 substation1 and 1 station(Meegoda) with sandwich loop. Makumbura North is nominated as Turn Back station with a dead end between the main lines without any passenger halt and other commercial facilities.
- On the 23.590km single line section of Padukka- Avissawella there are 3 stations with side track, namely at Arukwathpura, Waga and Kosgama, before Avissawella.
- Terminal Stations at Maradana, Makumbura North, Padukka and Avissawella shall have adequate facilities for trains turning back for their return journey.
- Running of mixed train services of Parcel during non-peak hours are considered.
- For train control, ERTMS Level II with LTE and track side signals have been considered between Maradana and Padukka dual lines section and Padukka-Avissawella single line section.

- CTCC/Maradana shall control the entire train operation from a single point on Maradana-Avissawella.

7.4.2 Salient Features of proposed train operation

The train operation plan for the proposed corridor on MARADANA- AVISSAWELLA section will be based on the following salient features:

- Train operation plan will be based on Alternative Studies of Colombo Suburban Railway Service – PPTA, July 2017 followed by Interim Report, May, 2018 and fresh demand analysis made by JV team.
- The track will be double line with dual directional movement of traffic on Maradana –Padukka station and single line on Padukka-Avissawella section.
- The alignment of track is relied as under: Maradana(at 0.900km) to km 16.400 and km 17.200 to Malapalla (at 19.880km) on elevation and Malapalla to Avissawella on surface.
- The system of working will be ERTMS Level II with LTE between Maradana and Avissawella.
- The entire stretch will be 58.69 km with terminal stations – Maradana, Makumbura North, Padukka and Avissawella and intermediate stations – Baseline Road, Cotta Road,Matha Road, Narahenpita, Kirillapona, Nugegoda, Pangiriwatta, Udahamulla, Nawinna, Maharagama, Dambahena, Pannipitiya, Kottawa, Malapalla, Makumbura North, Homagama Hospital, Homagama, Panagoda, Godagama, Meegoda, Watareka, Liyanwala, Arukwatta, Angampitiya, Ugalla, Pinnawala, Gammana, Morakele, Waga, Kadugoda, Kosgama, Hingurala, and Puwakpitiya.
- Maximum speed – 70kmph and Design Speed 80kmph.
- The frequency of Train services shall be optimized to provide sectional capacity commensurate with the peak direction traffic demand during peak hours
- Suburban Revenue Train EMU between Maradana –Makumbura North-Padukka will dwell at all the stations en route with the dwelling time of 60 seconds. Suburban Revenue Train DMU between Padukka and Avissawella will dwell at all the stations en route with the dwelling time of 120 seconds.
- The frequency of services shall be regulated to meet the growing traffic demand in horizon years.
- Basic unit selected for EMU is four driving cars and six trailer cars (15.5mt x 3.12mt. per car) in 2025 and four motor cars and eight trailer cars in 2035 so that there will be flexibility to run single set in case of need.
- Basic unit selected for DMU is two driving cars and three trailer cars (16.383 mt x 2.895 mt. per car) in 2025 and four driving cars and six trailer cars in 2035.
- Frequency of train during peak period is normally 7 minutes between Maradana and Makumbura, 14 minutes between Makumbura and Padukka & 30 minutes between Padukka and Avissawella respectively during peak hours.
- Turn back system for trains at Maradana, Makumbura North, Padukka and Avissawella is planned.
- Broad Gauge concept (1676mm) is considered for this alignment.

- Makumbura North is only operating station for turning back of the train set. No commercial activities and passenger amenities are provided at this station.
- Electrified territory with OCS (25KV) is considered between Maradana and Padukka.
- The length of Clear Standing Room (CSR) of all the lines in the stations is 361.5 mt. with platform length of 200 mt.

7.5 Operations Plan for KV Line

The Operations Plan is prepared considering the best interest of the travelling public to provide them safe, fast and convenient train services round the year. Operations plan shall guide other disciplines to create adequate infrastructure, such as track, side tracks, turnouts, signaling and communications, etc. and the rolling stock and their maintenance facilities.

Operations Plan is based on the following Train Service Timings:

7.5.1 Passenger Train Commercial Services

- EMU Train on Maradana-Makumbura North- Padukka section
- DMU Train on Padukka-Avissawella Section.
- Timings of the Daily Passengers Service – 5 hrs to 23 hrs all seven days a week
- Peak Periods and Peak Direction
    - Morning 6:30 to 9:30 hrs; from Avissawella end, and
    - Evening 16:30 to 19:30 hrs., from Maradana end
- Passenger from Maradana end intending to travel beyond Padukka shall change over the EMU train to DMU Train at Padukka. Similarly passenger from Avissawella end intending to travel beyond Padukka shall change over the DMU train to EMU Train at Padukka.

7.5.2 Parcel Train, other Service Trains

- Parcel Train, other service can be operated between Padukka and Avissawella.

7.5.3 Maintenance timings

Maintenance timings for all kinds of Predictive maintenance on the entire section shall be from 23 hrs to 5 hrs next day and in no case normal maintenance shall be done in the Commercial Operations time zone from 5 hrs to 23 hrs. During this period all departments shall adopt to the Integrated Maintenance Regime through pre-determined schedule duly notified well in advance from a weekly notification to all concerned. However, if there is an urgent corrective maintenance is required due to any failure, etc. the same shall be undertaken with a minimum disruption to commercial train services. In case any planned urgent maintenance is required, the same shall be undertaken during Non-Peak Period from 9:30 hrs to 16:30 hrs.

7.6 Passenger Demand Assessment

Table 7-2 shows the passenger demand forecast for the years 2025 and 2035 of the Alternate Modelling Scenario 3 which is Medium Growth Megapolis Development Scenario on the basis of chapter 2 Traffic Studies and Ridership for Demand Forecast.

Table 7-2 Passenger Demand Forecast on KV Line

Station Name	Station Name	Daily Passenger Volume, both directions		Peak Passengers Per Hour Per Direction (PPHPD)	
		Year 2025	Year 2035	Year 2025	Year 2035
Maradana	Baseline	133,771	168,893	13,912	17,565
Baseline	Cotta Road	132,807	160,817	13,812	16,725
Cotta Road	Narahenpita	144,468	170,352	15,025	17,717
Narahenpita	Kirillapone	169,559	194,403	17,634	20,218
Kirillapone	Nugegoda	176,969	201,662	18,405	20,973
Nugegoda	Pangiriwatta	173,328	197,899	18,026	20,581
Pangiriwatta	Udahamulla	156,471	180,373	16,273	18,759
Udahamulla	Navinna	140,155	166,655	14,576	17,332
Navinna	Maharagama	131,353	160,494	13,661	16,691
Maharagama	New1_Dambahena	102,406	133,684	10,650	13,903
New1_Dambahena	Pannipitiya	100,224	134,653	10,423	14,004
Pannipitiya	Kottawa	100,224	134,653	10,423	14,004
Kottawa	Malapalla	88,547	127,291	9,209	13,238
Malapalla	Makumbura	85,306	96,574	8,872	10,004
Makumbura	Homagama Hospital	77,267	85,359	8,036	8,877
Homagama Hospital	Homagama	68,704	72,049	7,145	7,493
Homagama	Panagoda	54,888	55,077	5,708	5,728
Panagoda	Godagama	53,683	53,965	5,583	5,612
Godagama	Meegoda	48,727	48,378	5,068	5,031
Meegoda	Watareka	37,529	36,477	3,903	3,794
Watareka	Padukka	35,781	34,564	3,721	3,595
Padukka	Arukwathupura	31,122	30,014	3,237	3,121
Arukwathupura	Angampitiya	29,750	29,617	3,094	3,080
Angampitiya	Uggalla	29,036	30,596	3,094	3,080

Station Name	Station Name	Daily Passenger Volume, both directions		Peak Passengers Per Hour Per Direction (PPHPD)	
		Year 2025	Year 2035	Year 2025	Year 2035
Uggalla	Pinnawala	30,444	32,690	3,166	3,400
Pinnawala	Gammana	31,868	34,925	3,314	3,632
Gammana	Morakele	26,509	30,289	2,757	3,150
Morakele	Waga	26,823	30,644	2,790	3,187
Waga	Kadugoda	24,235	30,695	2,520	3,192
Kadugoda	Kosgama	23,728	32,402	2,468	3,370
Kosgama	Hingurala	19,906	38,900	2,070	4,046
Hingurala	Puwakpitiya	25,744	46,401	2,677	4,826
Puwakpitiya	Avissawella	25,132	43,787	2,614	4,554

7.6.1 Maximum number of ridership for Alternate Modelling Scenario 3

Daily passenger ridership estimation is based upon Alternate Modelling Scenario 3 which is Medium Growth Megapolis Development Scenario. The maximum number of ridership has been recorded on the Kirillapona- Nugegoda section on a given day and during the Peak Hour period, which comes out to be 176,969 daily Passenger with maximum being 18,405 Per Hour Per Direction for the year 2025.The corresponding numbers for the year 2035 come to 201,662 daily passengers with 20,973 being Per Hour Per Direction for the year 2035. (Refer to Table No:7-2).

7.6.2 Assessment of Number of Trains Service

The total number of trains to be run per day is arrived by dividing total volume of passenger traffic per day by the carrying capacity of train adopted on the section considering of the number of cars in each train set and the passengers capacity of each car.

Based on the above, the total number of trains service thus arrived per day is 44 + 15 each way, which are indicated as under.

7.6.3 Year 2025 to Year 2035

For start of Commercial Train services, a 10 car EMU train with 5 cars +5 cars configuration has been assumed with a carrying capacity of 1988 passengers per train set of 10 cars. Also following assumptions are made to arrive at number of trains services in each direction:

i) In Peak Period as specified in Table 7.2 above– Due to imbalance of number of passengers travelling i.e. in the morning- 80% towards Maradana direction and only 20% in the return direction; and in the evening 80% away from Maradana and 20% in the return direction.

ii) Non-Peak Hours as specified in Table 7.2 above – Same number of services shall run in both directions;

iii) Since trains shall be required to pick up their trips in the morning from Padukka (after all the car sets parked at this station leave their respective originating point), some services from

Maradana shall run in the return direction even if they are less occupied. However, few car sets after completing their services up to Maradana shall be parked at Dematagoda yard to pick up evening peak services.

So, for the calculation of number of train services to meet the daily passenger carrying demand, a factor of 80% occupancy has been assumed. Based on this following train services shall be required in the year 2025.

7.6.4 Maradana – Makumbura North Section

44 EMU train services each way of 10 (5+5) cars consist with carrying capacity of 1988 passengers per train shall be available between Maradana and Makumbura North with halt at every station. Out of these:

- 22 train services will run during morning peak period of 6:30 to 9:30 hrs arriving at Maradana and same numbers in evening peak period from 16:30 to 19:30 hrs leaving from Maradana.
- Rest of the services shall be available for non-peak period.
- Frequency of services during morning from Makumbura North and evening peak from Maradana shall be 7 minutes in average.
- Frequency of services during non-peak period shall be 30-60 Minutes.

7.6.5 Makumbura North - Padukka Section

 - o 22 EMU trains each way of (5+5) cars with carrying capacity of 1988 passengers per train shall be available between Makumbura North and Padukka stations with halt at every station. Out of these:

- 11 train services will run during morning peak of 6:30 to 9:30 hrs arriving at Maradana and evening peak of 16:30 to 19:30 hrs leaving from Maradana.
- Rest of train services shall be available during non-peak period.
- Frequency of services available from Padukka during morning shall be 14 minutes and same shall be in the evening peak.
- Frequency of services during non-peak period shall be 30-60 Minutes.

7.6.6 Padukka – Avissawella

15 DMU trains service each way set between Padukka and Avissawella, stopping at all the stations has been planned. It is worthwhile to mention that the PPHPD on Puwakpitiya- Avissawella has been assessed as 3,314 in the year 2025 based on through rail transportation. Empirically, in case of transshipment at Padukka, the assessment may be proved enthusiastically estimated.

 - o 15 number of train services in each direction shall run between Padukka and Avissawella with all stop at an interval of 30 to 60 minutes.
 - o Parcel trains (Rail Buses) can be operated between Padukka and Avissawella.

7.6.7 Year 2035 Onwards

From the year 2035 onwards, train length is increased to 12 cars(6+6) to accommodate 2404 passengers per trains. However, frequency of the train services remains the same. Based on the ridership projections, following train services shall be required in 2035 onwards.

7.6.8 Maradana – Makumbura North Section

- 44 EMU trains each in average way of 12 (6+6) cars with carrying capacity of 2404 passengers per train shall be available between Maradana and Malapalla with halt at every station. Out of 60 trains services:
- 22 train services will run during morning peak period of 6:30 to 9:30 hrs. arriving at Maradana and same numbers in evening peak period from 16:30 to 19:30 hrs leaving from Maradana.
- Rest services shall be available for non-peak period.
- Frequency of services during morning from Makumbura North and evening peak from Maradana shall be 7 minutes.
- Frequency of services during non-peak period shall be 30-60 Minutes.

7.6.9 Makumbura North - Padukka Section

- 22 EMU trains each way of 12(6+6) cars with carrying capacity of 2404 passengers per train between shall be available between Makumbura North and Padukka stations with halt at every station.
- 11 train services will run during morning peak of 6:30 to 9:30 hrs. arriving at Maradana and evening peak of 16:30 to 19:30 hrs leaving from Maradana.
- Frequency of services available from Padukka during morning peak shall be 14 minutes and same shall be in the evening peak.
- Frequency of services available in non-peak period shall be 30-60 Minutes on this section.

7.6.10 Padukka – Avissawella Section

With the growing popularity as trade Centre, the PPHPD of Avissawella- Puwakpitiya in 2035 has been increased significantly from 3,314 to 4,826, perhaps on the apprehension of conventional through rail transportation.

- o 15 number of train services in each direction shall run between Padukka and Avissawella with all stop at an interval of 30 to 60 minutes.
- o Parcel trains (Rail Buses) can be operated between Padukka and Avissawella.

7.7 Severe Curves on KV Line Impacting Commercial Speed

On the entire KVL, the rail alignment is on sharp curves, as sharp as of 100-meter radius and it was an opportunity to examine these curves during Feasibility Study. The table below shows the total distance of 58.285 km split based on track distance on curves impacting operating speed of the train services:

Table 7-3 Showing Maximum Speed Limits due to Sharp Curves

Distance in kms	Speed Limit Bracket in kmph	Percentage of the Total
10.892	40-50	18.7%
5.695	50-60	9.7%
3.793	60-70	6.5%
37.898	70-80	65.0%
58.285	----	100%

Note:

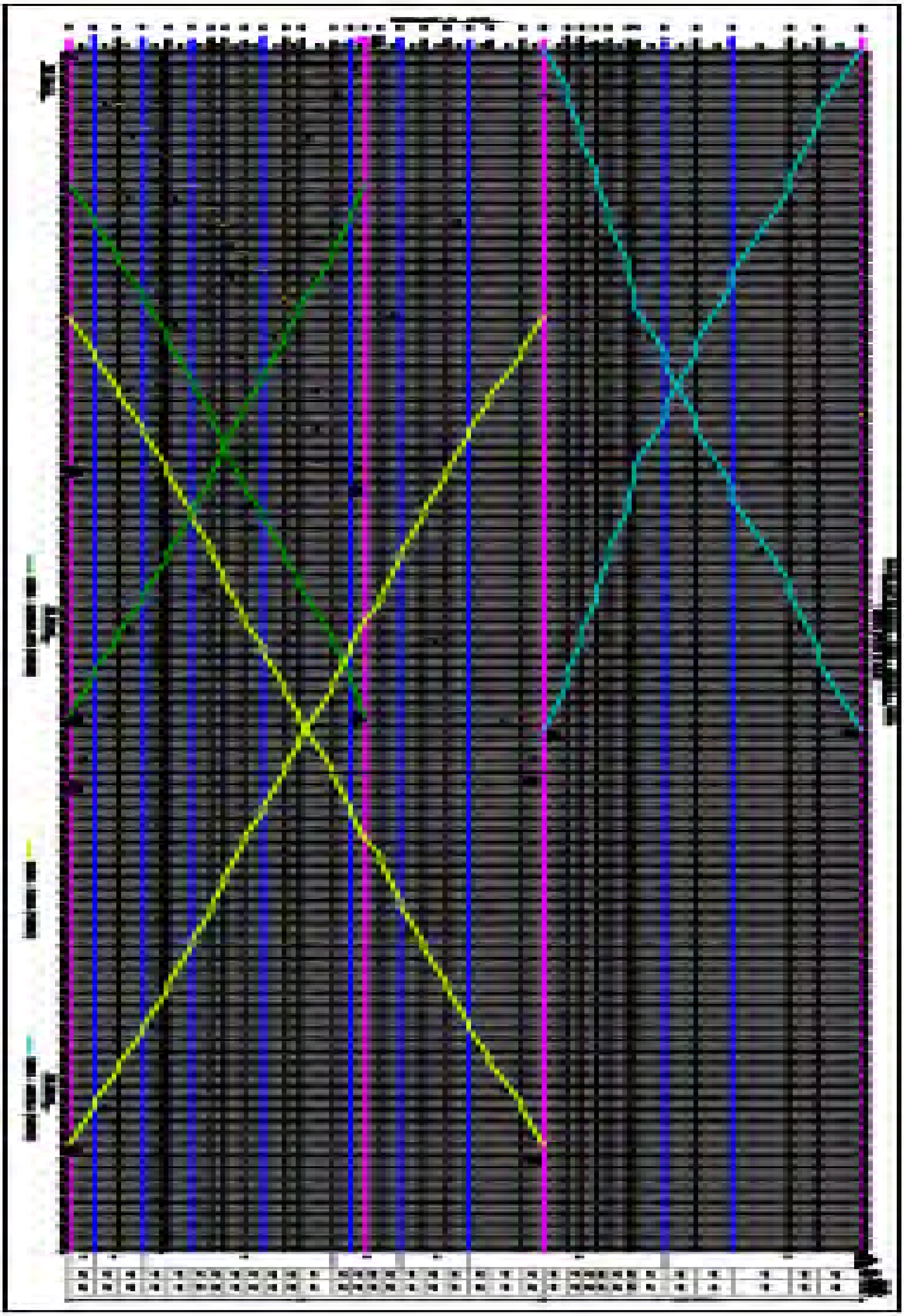
1. It may be noted that most of the section of 37.898 km where train can technically run between 70-80 kmph, lies near of the stations for stopping trains.

2. It may therefore be advisable to examine the sharp curves over the entire alignment at the time of Detailed Design, particularly on a double line section where easing of curves shall have direct benefit to train running resulting in better commercial speed.

7.8 Simulation Chart for KV Line

- Based on engineering designed curve parameters as shown in Chapter 05 Alignment Selection, Train Performance Simulation has been carried out on KV Railway Line to arrive at inter-station running times for preparation of Master Chart and Time Table.
- Simulation chart of the KV Railway Line is as follows:

Table 7-4 Showing Simulation Chart



- Though the section is designed for 80 kmph and Maximum permissible speed (MPS) is shown as 70kmph, the MPS of 70 kmph could not be taken throughout the section because of Permanent speed restrictions (PSR) in the section are less than MPS due to various sharp curves. To arrive at the maximum permissible speed, the entire section is divided into sub sections. Average Sub sectional speeds are arrived by Averaging the existing PSR in the sub section. The sub sectional speed arrived between Maradana to Avissawella section is tabulated in the following Table.

Table 7-5 Sectional Speed of KV Line

S.No	From Station	To Station	Speed in kmph
1	Maradana	Baseline Road	55 kmph
2	Baseline Road	Narahenpita	60 kmph
3	Narahenpita	Kottawa	50 kmph
4	Kottawa	Homagama	45 kmph
5	Homagama	Meegoda	50 kmph
6	Meegoda	Waga	55 kmph
7	Waga	Avissawella	50kmph

- To arrive at bare running time between stations (IRST-1), the inter stations distance is divided by the sub sectional speed.
- To arrive at Inter station running time (ISRT - 2) A 30 seconds dwell time is provided at stations for EMU services and 60 seconds dwell time is provided at stations for DMU services.
- Based on the Inter station running times arrived as above the values are plotted on the simulation chart to arrive at required data for preparation of Master Chart. Dwell times of 30 sec and 60 sec for EMU and DMU services respectively are shown in the Master chart.

Table 7-6 Commercial Speed Chart

DN Direction Services

S.No	Name	From	To	Type	Traction	Distance in Km	Running Time	Commercial Speed inkmph
1	DN S.No.3	Makumbura North	Maradana	All stops (EMU)	OCS	22.10	42“:00”	32.34
2	DN S.No.4	Padukka	Maradana	All stop (EMU)	OCS	35.10	64“:00”	32.91
3	DN S.No.5	Avissawella	Padukka	All stop (DMU)	Diesel	23.59	51“:00”	27.75

UP Direction Services

S.No	Name	From	To	Type	Traction	Distance in Km	Running Time	Commercial Speed inkmph
1	UP S.No.3	Maradana	Makumbura North	All stop (EMU)	OCS	22.100	41“:00”	32.34
2	UP S.No.4	Maradana	Padukka	All stop (EMU)	OCS	35.100	64“:00”	32.91
3	UP S.No.5	Padukka	Avissawella	All stop (DMU)	Diesel	23.590	51“:00”	27.75

7.9 Proposed Track Alignment

The revised Passenger Demand analysis has stated that level of train services shall enhance many fold to meet the demands of the travelling public. Also during peak hours, headway of the trains coming to Maradana in the morning and returning from Maradana in the evening shall need to be reduced to 7 minutes.

It is recommended to have doubling of track on the elevated corridor at least for the section from Maradana to Malapalla and further double line at grade from Malapalla to Padukka. The existing single line from Padukka to Avissawella will be maintained to meet the increasing level of services.

7.10 System Design

The key design features of the KV line shall be as under:

- The track will be double line with universal working of traffic on Maradana – Padukka section and existing single line on Padukka – Avissawella section.
- The Design standards are confirming to 22ton Axle Loading.
- Track Centre between the two adjoining lines shall be 4.30 m.
- Track and superstructures shall fit for 22 ton Axle Load.
- The length of Clear Standing Room (CSR) of all the lines at the stations shall be 361.5m with a platform length of 200 m and a width of 6 m.
- Track is with long welded rails with ballast in the At Grade portion and-on Elevated portion, 60 Kg rails and PSC sleepers.
- The track is designed to a Maximum speed of 80kmph.
- OCS with 1x25 KV on the Maradana – Padukka section.
- 46 numbers of level crossings between Malapalla and Avissawella – all interlocked with colour light signals.

7.11 Classification of Stations

Based on the number of tracks, availability of crossovers and terminal handling facilities, the stations are classified as under:

- **Halt Station** : Where no crossover and no side track are provided.
- **Sub Station** : With side Track for arranging precedence on a double line section and giving crossings on the single line section.
- **Sub Station** 1 : Crossover between main lines and no side track.
- **Main Station** : With facilities of side tracks with Turn Back and siding arrangements.
- The name of the stations between the Maradana – Avissawella section with their classification of station type, inter distance and availability of number of platforms are enumerated as below.

Table 7-7 Classification of Stations on KV line

S.No	Classification of Station Plan	Name	Centre Line (km)	Inter distance(km)	No. of Lines
1	MAIN	Maradana,	0.00	0	11
2	SUB1	Baseline Road	1.975	1.975	2
3	HALT	Cotta Road	3.675	1.700	2
4	HALT	Matha Road	5.02	1.34	2
5	SUB1	Narahenpita	5.990	0.97	2
6	HALT	Kirillapona	7.24	1.25	2
7	HALT	Nudegoda	9.12	1.88	2
8	SUB1	Pangiriwatta,	10.50	1.25	2
9	HALT	Udahamulla	11.50	1.00	2
10	HALT	Nawinna	13.24	1.74	2
11	SUB1	Maharagama	14.44	1.20	2
12	HALT	Dambahena	15.96	1.52	2
13	HALT	Pannipitiya	16.80	0.84	2
14	HALT	Kottawa	19.44	2.64	2
15	HALT	Malapalla	20.78	1.34	2
16	MAIN	Makumbura North	22.10	1.32	3
17	HALT	Homagama Hospital	22.76	0.66	2
18	HALT	Homagama	24.50	1.74	2
19	SUB1	Panagoda	26.33	1.83	2
20	HALT	Godagama	28.00	1.67	2
21	SUB	Meegoda	29.70	1.70	3
22	HALT	Watareka	31.06	1.44	2
23	HALT	Liyanwala	33.33	2.27	2
24	MAIN	Padukka	35.10	1.77	4
25	SUB	Arukwathpura	36.70	1.60	2
26	HALT	Angampitiya,	37.79	1.09	1
27	HALT	Uggalla	38.86	1.07	1
28	HALT	Pinnawala	39.73	0.87	1
29	HALT	Gammana	41.33	1.60	1
30	HALT	Morakelle	41.81	0.48	1
31	SUB	Waga	43.96	2.15	2
32	HALT	Kadugoda	46.32	2.36	1
33	MAIN	Kosgama	49.00	2.68	2
34	HALT	Hingurala	53.22	4.22	1
35	HALT	Puwakpitiya	55.68	2.46	1
36	MAIN	Avissawella	58.69	3.01	3

7.12 Train Operations

Universal double line shall be available between Maradana and Padukka for efficient and safe of operations by establishing directional of traffic. The Station Managers, in charge at Maradana, Makumbura North, Padukka and Avissawella shall ensure that sufficient trainsets are available for starting the train services as per the published time table. The SMs shall ensure placement of empty trainset on the relevant / nominated Platform well in time and ensure starting of train at the right time. The CTCC shall manage trains operations in coordination with other operation staff and respective Station Masters shall keep platforms lines vacant as nominated for admission of inward trains.

The Station Manager at Makumbura North may receive incoming trains on the dead end line so that other UP and DN lines will be free for movement of trains bound to Padukka and back.

Station Manager at Padukka shall take incoming trains from not only Maradana but also Avissawella so that passengers can transfer between EMU and DME.

Train Control Management shall be managed from Centralized Train Control(CTC) to be established at Maradana for the section Maradana- Avissawella. All yard operations, including shunting etc. shall be managed centrally from CTC by the train operations managers working in shifts. In addition, the CTC shall have the following disciple heads for coordination of train operations round the clock, including start of operations in the morning from each parking yards and till the close of working hours, i.e. 11 pm. The CTC shall also manage night time operations, when /material train services shall be operating in addition to scheduled maintenance activities.

7.13 Train Turn-back Facility

To pick up the return trip towards Maradana in case of EMU and parking facilities at the following stations shall be available, where EMU/DMU car sets shall be parked in non-peak period/night hours.

- Maradana,
- Makumbura North
- Padukka and
- Avissawella.

Table 7-8 Number of Train Services to Each Direction in 2025 and 2035

Train characteristics	Between Stations	No. of Services	Total Running Time	No. of Stoppages	No. of Services in Peak Period each way
EMU all stops	Maradana – Makumbura North	44 trains each way	41 minutes	14	22
EMU all stops	Makumbura North – Padukka	22 trains each way	23minutes	7	11

7.14 Master Chart

Direction of Movement is as follows:

- Down Direction - From Avissawella/Padukka/Makumbura North towards Maradana; and
- UP direction – From Maradana/ Makumbura North /Padukka to Avissawella.

Master charts have been prepared taking in view the maximum speed allowed in each section, permanent speed restrictions, acceleration, deceleration and the Separate mater charts have been prepared for i) Maradana – Padukka (with OCS); and Padukka to Avissawella with Diesel traction. Since the services are commencing from 5:00 hrs and closing at 23:00 hrs. Train paths are drawn from 5:00 to 23.00 hrs on the Master Chart. The time between 23:00hrs and 5:00 hrs has been shown as time for integrated maintenance.

Since Padukka station shall serve as changeover station for the passengers arriving by EMUs from Maradana side and travelling towards Avissawella and vice versa. Care has been taken to schedule the train services in such a way that there is minimum waiting period for the passengers requiring changing over at Padukka.

Frequency of passenger trains in peak period both morning and evening is as follows:

- 7 Minutes between Maradana and Makumbura North;
- 14 Minutes between Makumbura North and Padukka; and
- 30 Minutes between Avissawella and Padukka.

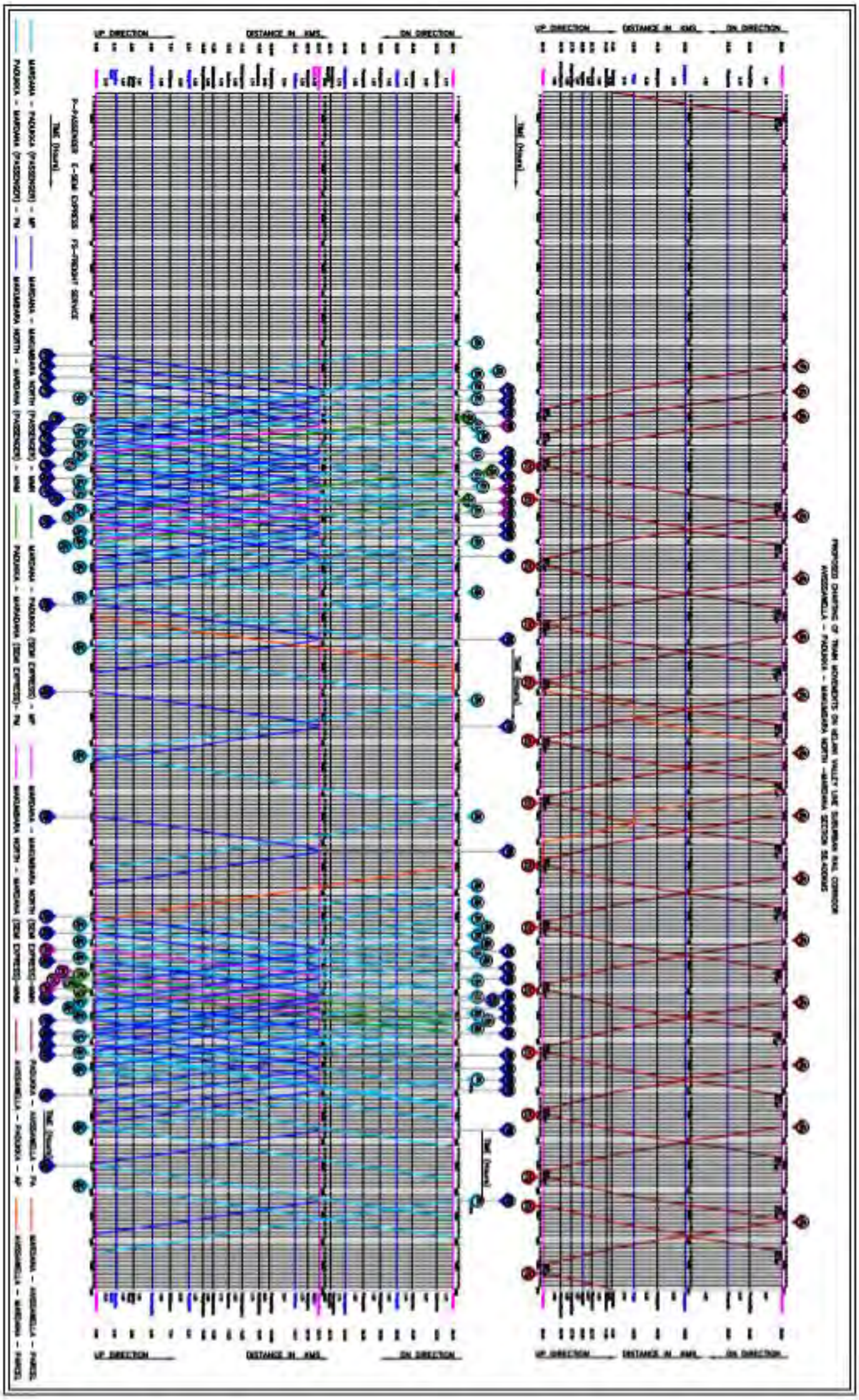
Dwell time is 60 seconds for DMU and 30 seconds for EMU services.

Parcel trains (Rail Buses) can be operated between Padukka and Avissawella.

The master chart is used as reference while calculating running time, No. of train paths and time available for maintenance between the train services.

The Master Chart for 24 hrs is as follows.

Table 7-9 Showing Master Chart



7.15 Platform Occupation Chart

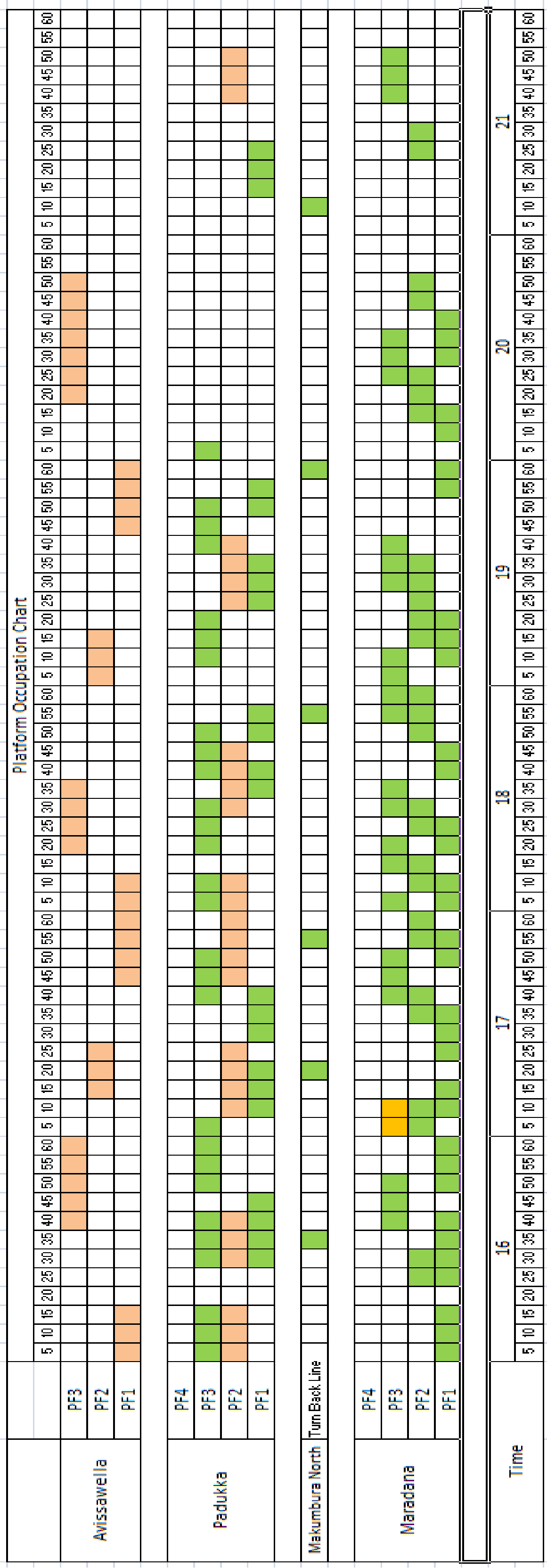
Platform Occupation Charts are prepared for all major stations where trains stop for a longer period due to originating/termination of services, changeover, maintenance, etc. to avoid clashing of schedules of various services. Normally, if trains services are maintained according to the train schedules, even Platforms can be nominated for UP or DN trains for the convenience of the passengers. However, in case of late running or reschedule services, platforms can be changed after due advance notice to the travelling public.

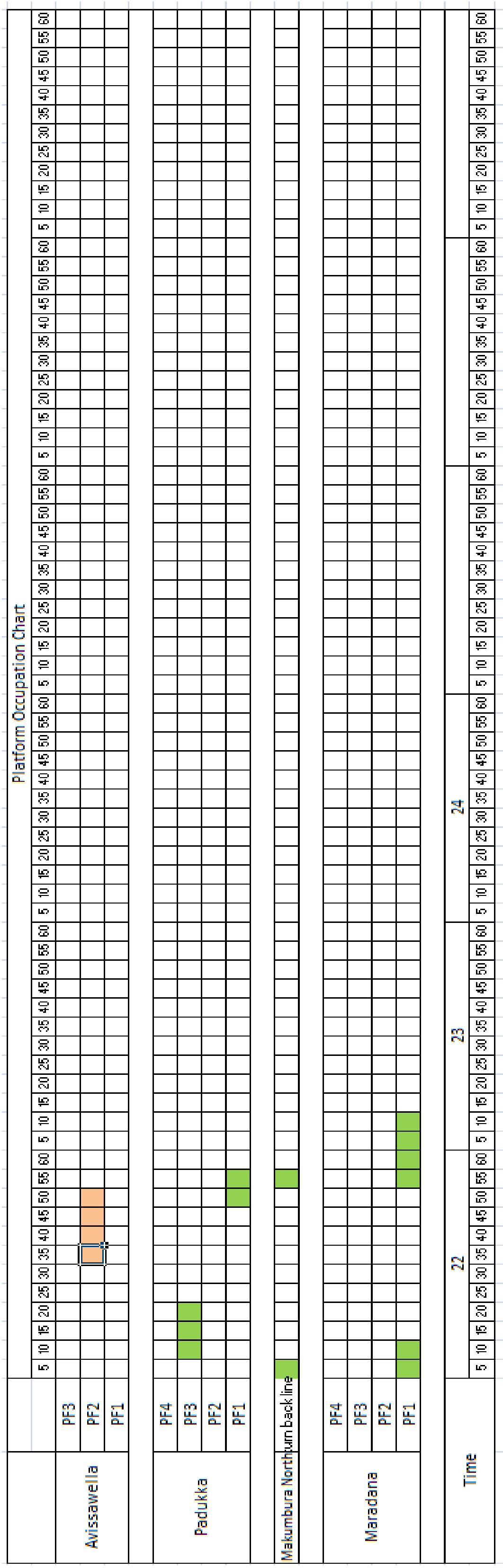
Platform Occupation Charts have been prepared based on Master Chart for the following stations:

- Maradana;
- Makumbura North;
- Padukka; and
- Avissawella.

Platform Occupation Charts are shown below.

Table 7-10 Showing Platform Occupation Charts





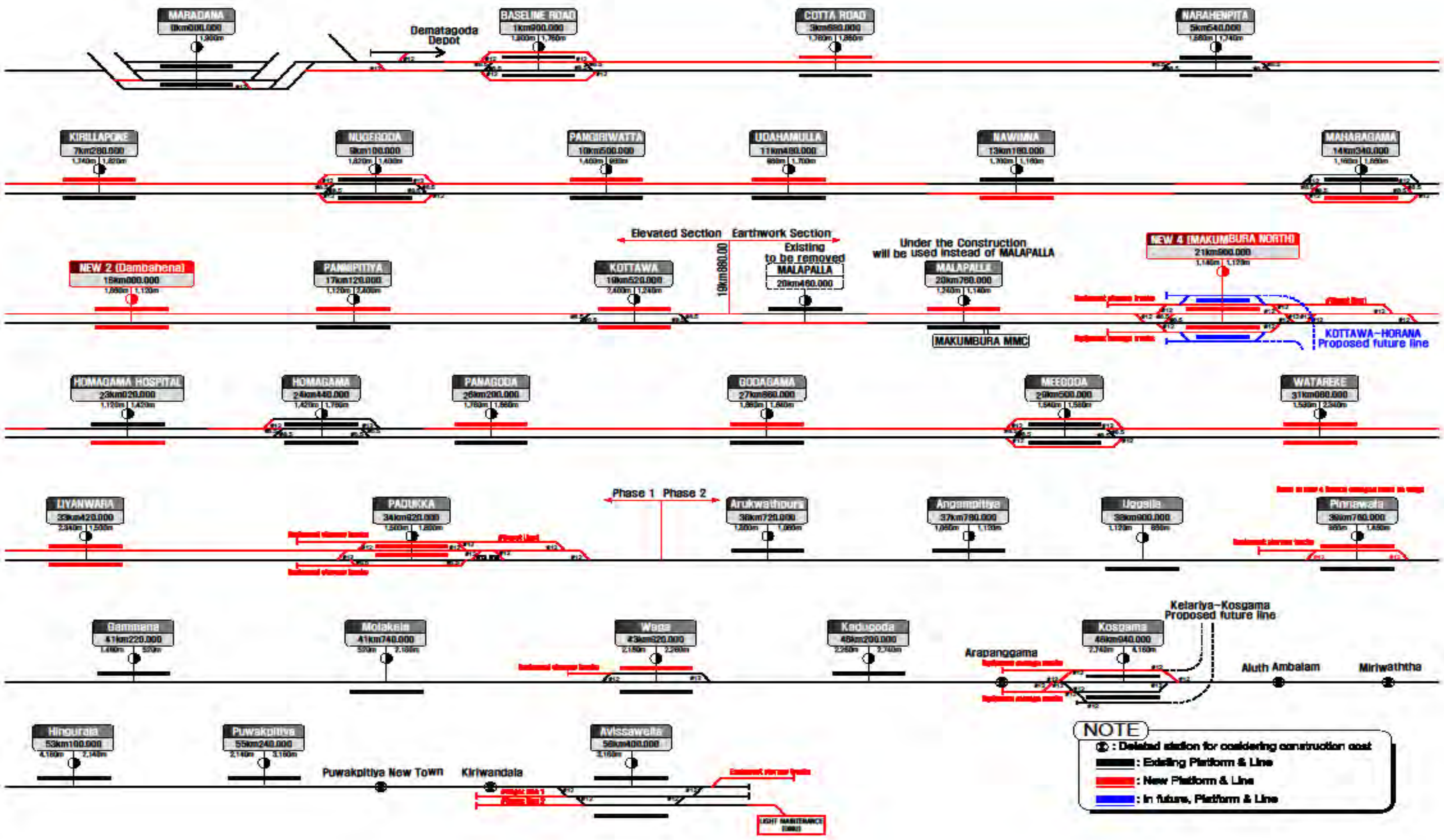


Figure 7-3 The Schematic Diagram of the Railway Stations on KV Line

Table 7-11 Train Parking Plan for KV Line

Phase	Rolling stock No.	Side track of Main Line	Depot	Reference Unit
1(2025)	20Train sets(EMU)	5 trainsets including Makumbura North and Padukka	15 Train sets	EMU(10 cars/train)
2(2035)	20Train sets(EMU)	5 trainsets including Makumbura North and Padukka	15 Train sets	EMU(12 cars/train)

- Padukka ~ Avissawella: The existing train(DMU) will Operate single line till final phase

  2025: No. of trainsets(DMU):4.

  2035: No. of trainsets(DMU):4.

  DMU Parking station: Avissawella(2), Depot(2).

7.16 Rolling Stock

7.16.1 Functional Specifications of the Passenger Cars

For using maximum moving dimensions available on Broad Gauge line, it is suggested to use EMU cars with 15.5 m long and 3.12 m width. However, given the number of high level platforms shall be on the sharp curves on the double line section with OCS, it was not found technically feasible to run existing DMU services of 16.383 m long and 2.895 m width on the OCS territory. Hence such S12(DMU) shall run on isolated section of Padukka and Avissawella. Also, the light maintenance facilities of such DMUs shall be set up at Avissawella only. However, for heavy maintenance, such DMUs can be taken to Rathmalana where all vehicle heavy maintenance facilities shall be available.

Following are the types of Rolling Stock running on various sections.

- EMU services (15.5mX 3.12 m) between Maradana and Padukka
- DMU services (16.383mX2.895m) between Padukka and Avissawella

7.16.2 Design of Rolling Stock

The design of the Rolling Stock should be based on the following key criteria:

- Safe, efficient and reliable for operation
- Lightweight and elegant
- High technological standard
- Minimum maintenance cost and time
- Modular design

In addition, the Rolling Stock shall be fitted with Automatic Train Control so that all trains will be capable of being driven manually under ATP supervision. The Rolling Stock shall fulfill the conditions as per UIC 512 for smooth operation of track circuits and treadles. The design features of the Rolling Stock shall be compatible with all other systems utilized in the Rail System. The Rolling Stock shall be safe to operate under all climatic conditions in the operating environment without damage, and also under all operating conditions. The Rolling Stock shall be compatible with the traction supply system and shall be designed to operate safely in the range of voltage of the power supply.

The speed control system should meet operational safety in normal operation and should behave satisfactorily in abnormal situations. Trains should have adequate access and doors for dealing with the heaviest User demand. The interiors should be designed to provide a safe and convenient environment for users and should minimize harm in case of an emergency or accident. The Rolling Stock should be designed for minimum risk of fire and with adequate emergency egress in case of fire. The Train shall have the latest microprocessor based integrated diagnostic system. All-important diagnostic information with fault correction instruction shall be displayed on the VDU. The diagnostic system shall provide for carrying out other diagnostic investigations by connecting a portable PC to the system. The Rolling Stock must be able to operate irrespective of weather conditions and the temperature inside the Train parked in the sun.

7.16.3 Fleet Size Calculation

For calculation of rolling stock fleet size, following assumptions are made:

i) In 2025, a train set shall have 5+5 passenger cars with driving cabs on each side of 5 car set.

ii) In 2035, a train set of 6+6 passenger cars is assumed.

iii) Each EMU train set, once given light maintenance at Dematagoda shall make a minimum of 44 round trips between Maradana and Padukka every day, and while in parking yard shall be attended by the conservancy staff for cleaning and watering, etc.

iv) Each train set shall be taken for light maintenance at Dematagoda yard which requires to be attended to mechanical, electrical and onboard communication system, and a maintenance certificate is issued.

Only for heavy maintenance, Car sets are driven to Rathmalana workshop where they will be given periodic and predictive intensive examination.

v) To take care of light and heavy maintenance, a 15% provision has been made in number of passenger car sets while estimating the requirement of Rolling Stock in 2025 and 2035.

7.16.4 Rolling Stock Maintenance

The rolling stocks have to be operated daily with safety and reliability. Thus, suitable maintenance service is necessary to maintain the reliability and safety of the vehicles by reducing any potential failure. Maintenance of vehicles are largely classified as:

- Preventive Maintenance: Periodic inspection shall be performed strictly in accordance with the preventive maintenance schedule in order to assure the safety of trains operation and passengers.
- Corrective Maintenance: Repairs after random failures which could not be detected during preventive maintenance shall be carried out as corrective maintenance.

Regarding light maintenance, this Consultant has deemed the Dematagoda as the optimized location and will develop the depot layout through discussions with all of the concerned stakeholders.

However, if final decision on the Dematagoda during the detailed design stage, this Consultant will come up with other alternatives.

Regarding heavy maintenance, the location of heavy maintenance depot will be determined later because it is necessary in 2028 and requires high cost for heavy maintenance facilities. Therefore, EMU heavy maintenance depot for the total 4 suburban railways will be prudently reviewed through discussions with all the concerned stakeholders including PMU and SLR.

7.17 Passenger Address System

At each station, electronic passenger information display boards shall exhibit the train running position, which will be linked directly from CTC and position shall be updated on line with no human interface. Each EMU coach shall have a display board showing train running position and next approaching halt station. Also, for emergency public announcement, CTC and each station shall have a provision of Public Address System to communicate with the passengers and the railway staff. At the entry points of each station, electronic display boards shall show the position of train running and expected arrival and departure times for the easy notice of the commuters.

7.18 Safety in Train Operations

For every successful transportation system, there are certain requirements, which should be met. The safety must be kept in mind while planning, designing, construction, testing, commissioning and during train operations and the maintenance of the infrastructure.

The objectives of safety provisions shall be that: -

- In all yards, main lines and all other running line should be isolated from non-running line;
- There should be adequate clearances for public, trains, infrastructure, and maintenance, both in normal and emergency conditions;
- The railway system should be protected against unwanted intrusion and unauthorized access;
- Signaling and Tele communication should be a fail proof and with safety integrity level of higher range;
- The signaling system should provide for the safe routing, spacing and control of trains, even in degraded conditions;
- The systems used for the guidance, control and communication interface of a train shall be compatible and not give rise to danger;
- The track and its supporting structure should provide for the safe guidance and support of the train;
- Station platforms and access ways shall be appropriately sized for the volume of people using them, including during degraded and emergency conditions.
- The implementation of Fire and Life safety systems;
- Traction and Rolling Stock should be of approved and standard design;
- During an emergency there should be coordinated control between the railway, the emergency services and neighboring communities;
- The railway should provide for the safe and secure stabling, marshaling and maintenance of the trains;
- Railway workers should be provided with high visibility clothing, so they can be seen both during the days and at night;
- Railway workers shall be provided with a means of communication with the railway controllers;
- The interiors of trains should provide a safe environment for people and their possessions;
- Trains shall have a safe means of entry and exit including during a train evacuation to trackside situation;
- The train should be provided with an effective means of communication between the driver, train attendant or central controller and the passengers;

- The railway system shall have a safety management system which details the arrangements for providing safe systems of work and safe working environments;
- Each railway operator should undertake a thorough risk assessment and identify how each risk will be controlled;
- Safety targets and safety monitoring and audit will aim to continuously improve the safety systems and procedures;
- The provision of safety related training to staff, maintainers and operators with appropriate competence assessment should be implemented; and
- Those persons who fulfill key safety critical roles such as signalers, station master and track inspectors shall be regularly assessed, refreshed and provided with update training.

7.18.1 Separate Safety Dept for SLR

As Sri Lanka Railways is set to enter new generation with massive investment plan to modernize its operations with improved track, rolling stocks, S&T equipment and OCS, it is essential to have a separate Safety department. Safety is an ethos that should pervade all activities of railway operations and maintenance. This ethos has to be instilled and nurtured. It is not an attribute that is likely to be evident merely because rules are reiterated, or instructions issued. The concern for safety has to be all pervasive in the functioning of the Sri Lanka Railways.

Responsibility for ensuring safety is entirely of different departments and their accountability in this regard cannot be diluted. The safety organization has essentially to be a coordinating service department helping the concerned departments to discharge their safety functions effectively.

Changes in policies pertaining to recruitment, training and redeployment considering modern developments and ensuring a code of conduct for safety staff will be the thrust areas in the Corporate Plan period. The safety organization will also be involved in investment planning for safety-related works. A safety action plan based on defined and acceptable levels will be prepared and its implementation will be the joint responsibility of the executive departments concerned and the safety wing.

Following areas have been identified, being of importance, for which targets are to be laid down:

- Passenger safety
- Road users"safety
- Quantitative reduction in accidents
- Improving asset reliability
- Prompt rescue and relief operations and accident enquiries

The departmental head in apex level shall be Chief Safety Officer assisted by 3 Assistant Officers of Track, S&T and Mechanical Dept. They should be further assisted by sufficient inspectorial and ministerial staff. The Chief Safety Officer is directly responsible to General Manager of SLR.

7.19 Train Passenger Capacity Calculation and Rolling Stock Estimation

To calculate the seating and standing capacity of a passenger car, assumptions were made on the seating and standing areas of the car as well as the number of seats and standing spaces as shown in the following figures. Occupation of the space in standing position is taken as 6 persons per sqm (150% congestion) for ascertaining capacity of the car. The consultants have reviewed the operation of single set and dual set of train consist and the sequel is as follows:

Table 7-12 Option I for 2025 & 2035 (EMU 15.5 m x 3.12 m)

Characteristics	2025	2035
Composition	5 cars(2 TC+ 3 MT) +5 cars(2 TC+ 3 MT)=10	6 cars(2 TC+ 4 MT) +6 cars(2 TC+ 4 MT)=12
Transport Capacity with congestion % 150 (6per SQM)	1988 passengers	2404 passengers
Merits	a) Easily detachable to make two train sets of 5 or 6 cars each, in case of disability of 1 car of any consist b) On non-working day/ Non- Peak hrs, single set train of 5 or 6 cars can be run. c) Flexibility in operations d) Maintenance may be made on single set.	
Demerits	a) Reduction of transport capacity b) Additional Capital cost for installation of Signaling& Telecommunication equipment for each set	

Table 7-13 Option II for 2025 & 2035 (EMU 15.5 mx 3.12 m)

Characteristics	2025	2035
Composition	10 cars (2 TC+ 8 MT) =10	12cars (2 TC+ 10 MT) =12
Transport Capacity with congestion % 150(6per SQM)	2034 passengers	2450 passengers
Merits	a) Higher Transport capacity b) Only 2 sets S&T equipment per train	
Demerits	a) Rigid in operations b) Waste of Rolling stock capacity during maintenance as full set of 10 or 12 cars shall be taken together for maintenance. c) Waste of capacity or resources during non-peak hours	

7.19.1 Estimation of Rolling Stock

Looking over all factors, Option I is considered better and has been adopted for the Feasibility Study.

- The trains will consist of 5+5cars in 2025 and 6+6cars in 2035 and their composition of the trains will be as follows:
    - 5+5car train: TC–MT–MT–MT–TC-TC–MT–MT–MT–TC
    - 6+6 car train: TC–MT–MT–MT–MT-TC -TC–MT–MT–MT–MT-TC

Passenger Capacity of Cars:

Transportation capacity for 15.5m x 3.12m EMU car					**Two couples**				
Seating persons							**Standing area**		
Tc	0	7	7	3	17	34		25.13	m^2
M/T	3	7	7	3	20	40		27.98	m^2
Persons/m^2		6		Length	15.5	m	Width	3.12	m

Transport capacity for car								
Type	Seating	Standing	Total					
Tc	34	151	185					
M/T	40	168	208					
Transport capacity for Train set								
Type	Persons	Amount	Total		Type	Persons	Amount	Total
Tc	185	4	740		Tc	185	4	740
M/T	208	6	1,248		M/T	208	8	1,664
Total		10	1988		Total		12	2404

- Result Value Total seats per TC 34 + 1-wheel chair
- Total seats per M/T 40 + 1-wheel chair. Total standees per TC at 6 persons 151per m2
- Total standees per M/T at 6 persons per 168m2
- Total capacity of TC 185 + 1-wheel chair
- Total capacity of M/T 208 + 1-wheel chair
- Passenger Capacity of Trains
- No. of cars:5+5 Total capacity 1988+ 10wheel chairs
- No. of cars: 6+6 Total capacity 2404+ 12wheel chairs

Table 7-14 Quantity of Passenger Cars

KV LINE (COMMERCIAL SPEED 32.86KMPH) ALL STOPS (5+5 Trainset 15.5 m x 3.12 m) for 2025

Loop	Section	Length	Run Time(Min)	Total Reversal time	Frequency of Train (mins)	No. of trains required (Bare)		Avg Speed KM
1	MARADANA-MAKUMBURA NORTH	22.10	41.00	5	7	13	EMU	34.7
	MAKUMBURA NORTH-PADUKKA	13.00	23.00	5	14	4	EMU	34.7
2	PADUKKA-AVISSAWELLA	23.59	55.00	5	30	3	DMU	25.61
EMU Total: (1)						17	EMU	
Total Rakes (15% Maintenance & Reserve): (2)						3	EMU	
						1	DMU	
Total (5+5 cars/trainset) which consists of (1) and (2)						20	EMU	200 cars
						4	DMU	

KV LINE (COMMERCIAL SPEED 32.86KMPH) ALLSTOPS (6+6 Trainset 15.5 mt x 3.12 mt) for 2035

Loop	Section	Length	Run Time(Min)	Total Reversal time	Frequency of Train (mins)	No. of trains required (Bare)		Avg Speed KM
1	MARADANA-MAKUMBURA NORTH	22.10	41.00	5	7	13	EMU	34.7
	MAKUMBURA NORTH-PADUKKA	13.00	23.00	5	14	4	EMU	34.7
2	PADUKKA-AVISSAWELLA	23.59	55.00	5	30	3	DMU	25.61
EMU Total: (1)						17	EMU	
Total Rakes (15% Maintenance & Reserve): (2)						3	EMU	
						1	DMU	
Total (6+6 cars/trainset) which consists of (1) and (2)						20	EMU	240 cars
						4	DMU	

7.20 Manpower Assessment for Operations

The present crew pattern for every passenger train of Sri Lanka Railways is as follows:

- Driver: One
- Driver Assistant: One
- Guard: One

On introduction of ERTMS Level II with GSM-R and track side Signals system on Maradana-Padukka-Avissawella, the requirement of crew in each train shall change due to improved telecommunication and on-board equipment, which shall provide extra trains‟ safety and driving comfort. As such in EMU trains with doors being auto close type, only one Driver per train has been assumed, as per the standard practice.

However, in case of DMU a provision of Assistant Loco Pilot has been kept in addition to Driver and Guard in each train to ensure that the passengers are safely boarded, and doors are closed before train leaves the platform. Accordingly, manpower planning is as follows:

Table 7-15 Man Power Requirement

	Maradana-Makumbura North	**Maradana- Padukka**	**Padukka-Avissawella**
No. of Trains service in each direction	44	22	
Nature of Train	EMU with auto door closure, vestibules & air conditioned	EMU with auto door closure, vestibules & air conditioned	DMU Conventional S12
Requirement of crew for each train set	Only Driver	Only Driver	Driver, Driver Assistant & Guard

For operation of the network, requirement of staff has been estimated under the following two heads namely:

- Running staff
- Operating and Commercial staff

7.20.1 Running Staff

The requirement of the running staff for operation of trains, comprising drivers (as applicable in EMU) and driver, assistant loco pilot and guard(as applicable in DMU) is based on number of train during peak hours, which is reproduced below.

Table 7-16 Turn Back at Makumbura North, Padukka & Avissawella

Loop	**Section**	**Length**	**Run Time (Min)**	**Total Reversal time**	**Frequency of Train (Min)**	**No. of trains required (Bare)**	
	MARADANA-MAKUMBURA NORTH	22.10	41.00	5	7	13	
	MAKUMBURA NORTH-PADUKKA	13.10	23.00	5	14	4	

Loop	Section	Length	Run Time (Min)	Total Reversal time	Frequency of Train (Min)	No. of trains required (Bare)	
	PADUKKA-AVISSAWELLA	23.59	55.00	5	30	3	
						17	EMU

7.20.2 Requirement of Running Staff

For each shift of 8hrs, 17 working post of EMU driver, 3 working posts of DMU Driver, 3 working post of DMU Driver Assistant, 3 working post of Guard for DMU are required. If the duty hours are divided into 2 shifts with break of duty during non-peak hours, the total requirement will be as under:

Table 7-17 Requirements of Running Staff

	Working Post	Leave Reserve 30%	Trainee Reserve 10 %	Total
Driver EMU Driver DMU Driver Asstt.DMU	34(12+12+10 broken shifts) 6 6	10 2 2	3 - -	57 08 08
Guard	6	2	-	08
Rail Bus Driver+ Guard	2	-	-	02
Supervisor	1x4			04
Total				**87**

Crew lobbies shall be established at Maradana, Makumbura North, Padukka and Avissawella for booking of crew and their monitoring.

The total staff required inclusive of Driver, Driver Assistant., Guard and Lobby staff for four depots = 87

- The HQ of Crew for EMU is to be made at Maradana and for DMU at Avissawella.
- Crew Rest Room facility to be made at Makumbura North, Padukka (for EMU& DMU)

7.20.3 Operating and Commercial Staff

The requirement of operating and commercial staff for KV Railway Line has been made in view of the level of train services on each section. Broadly following assumptions are made:

For Train Operations Duties:

- At every Railway station having turn back facility, such as Maradana, Makumbura North, Padukka and Avissawella, there shall be a Supervisory Station Manager in day duty, in addition to one Assistant Station Manager in 8 hrs shift.
- At all other stations with side track and cross over facility to have precedence or crossing facility, there shall be an Assistant Station Manager in every 8 hr shift.
- At all other stations on elevation, having no side track or cross over facility, there shall be no Assistant Station Manager, However, there shall be a Station Supervisor in each 8 hrs shift.
- Stations at grade, having no side track or cross over facility, there shall be no operating staff. Only outsourced commercial staff shall manage the station.

- In addition, shunting operation, points man‟s work and platform porter‟s work shall be outsourced through approved agency.

For Commercial Operations Duties:

- At all four major stations, there shall a Commercial Manager in day shift as in-charge of the Commercial functions. In addition, in each shift there shall be a Dy Commercial Manager in each 8 hrs shift.
- At all other stations at elevation, one Dy Commercial Manager in each 8 hrs shift shall be there to supervise commercial and public interface duties.
- In addition, all ticketing and fare collection work shall be outsourced to the suitably trained agencies. There shall be self-ticket vending machines and face to face ticket issue counters at each station.

Table 7-18 Station Wise Staff Position

S. No.	Classification	Stations	Elevation /Grade	No. of Operating staff	No. of Commercial staff	No. of outsourced staff	Total Staff
1	CTCC	Maradana		4	3	3	10
1	MAIN	Maradana,	Grade	4	4	18	26
2	SUB1	Baseline Road	Elevation	3	3	15	21
3	HALT	Cotta Road	Elevation	3	3	6	12
4	HALT	Matha Road	Elevation	3	3	6	12
5	SUB1	Narahenpita	Elevation	3	3	6	12
6	HALT	Kirillapona	Elevation	3	3	6	12
7	HALT	Nugegoda	Elevation	3	3	15	21
8	SUB1	Pangiriwatta,	Elevation	3	3	6	12
9	HALT	Udahamulla	Elevation	3	3	6	12
10	HALT	Nawinna	Elevation	3	3	6	12
11	SUB1	Maharagama	Elevation	3	3	15	21
12	HALT	Dambahena	Elevation	3	3	6	12
13	HALT	Pannipitiya	Grade	3	3	6	12
14	HALT	Kottawa	Elevation	3	3	6	12
15	HALT	Malapalla	Grade	3	3	15	21
16	MAIN	Makumbura North	Grade	4		6	10
17	HALT	Homagama Hospital	Grade			6	6
18	HALT	Homagama	Grade	3	3	12	18
19	HALT	Panagoda	Grade			3	3
20	HALT	Godagama	Grade			3	3
21	SUB	Meegoda	Grade	3	3	6	12
22	HALT	Watareka	Grade			3	3
23	HALT	Liyanwala	Grade			3	3
24	MAIN	Padukka	Grade	4	4	12	20
25	SUB1	Arukwathpura	Grade	3		3	3
26	HALT	Angampitiya,	Grade			3	3
27	HALT	Uggalla	Grade			3	3
28	HALT	Pinnawala	Grade			3	6
29	HALT	Gammana	Grade			3	3
30	HALT	Morakelle	Grade			3	3
31	SUB	Waga	Grade	3		3	6
32	HALT	Kadugoda	Grade			3	3

S. No.	Classification	Stations	Elevation /Grade	No. of Operating staff	No. of Commercial staff	No. of outsourced staff	Total Staff
33	MAIN	Kosgama	Grade	3	3	3	9
34	HALT	Hingurala	Grade	3		3	6
35	HALT	Puwakpitiya	Grade			3	3
36	MAIN	Avissawella	Grade	4	4	15	23
			Total	**80**	**66**	**243**	**389**

Table 7-19 Running, Operating & Commercial Staff Costing& Consumable & Stationery

Staff	No. of Staff	Add10% for adm, estt. finance, stores etc	Costing for 2025@ 4337 perstaff,p.a USD excl. outsource 2169USD	Costing for 2035@ 5287 perstaff, p.a USD excl. outsource 2644USD
Running	85	93	403341	491691
Operating	80	88	381656	465256
Comml.	66	73	316601	385951
Outsourcing	243	267	579123	1377524
Total	474	521	1680721	2720422
Consumable& stationery5%			84036	136021
		Grand Total Operating & Comml. Cost	**1,765,000 USD**	**2,856,000 USD**

Source:

i) Overhead of staff @ 10%& Staff cost as per SLR Administrative Report 2016

ii) Consumable & Stationery @ 5% as assessed by Consultants

7.21 Integrated Mechanized Maintenance Block During Night

As there is less margin during day time for regular/preventive/ planned maintenance of track, Signal and Telecommunication and Overhead Catenary System in suburban Rail System, the concept of integrated night maintenance between the closure of revenue services and resumption of revenue services has been developed world wide as an ideal Rail Care Solutions. Integrated Mechanized Block means blocking the portion of a line for maintenance work by more than one Department. Authorized Track Engineer shall apply for „line block‟ to the Operating Branch to issue „Circular Notice‟ to all concerns showing weekly programmed between 24:00 hrs to 04:00 hrs on every Friday for programmed commencing from next Sunday. Operating Branch through CTCC shall issue „all-concerned‟ message one day in advance to the actual commencement of work to the Officials mentioned in the Circular Notice.

The Track Official in charge shall arrange for protection of the work site and adequate illumination accordingly. The sequence of track machines, PQRS, Overhead Car and Material Train to be put on track shall be decided by Track Official in charge. A safety distance of 150 m shall be maintained in between two vehicles / trains and the speed permitted is restricted to 45 kmph. The radio communication system and other interlocking are to be operative for smooth and safe working. Only one Material Train is permitted, and all the units shall return to the same station from where they started. On completion of work, the Track Official in charge shall remit in written that track and OCS are safe for normal working of train to CTCC who shall acknowledge the same.

7.22 Organization Structure of the SPV

Operations and maintenance of the Colombo Metropolitan Rail Network (CMRN) once augmented shall require a dedicated team and the organization, which is capable to handle independently the level of services desired to be operated most efficiently and safely.

The considered opinion of the consultants is that an appropriate Special Purpose Vehicle (SPV) is set up under Sri Lanka Railways for management of Colombo Suburban Railway System.

The organizational structure of the SPV has, therefore, been formed keeping in mind need for economy and efficiency of the organization. The SPV shall have Board of Directors and a full time Managing Director.

To deliver on the objectives envisaged, the SPV visualized here will have a very strong structural empowered by specially selected individuals having excelled in their respective fields. The SPV shall be responsible for the execution of the project and shall take over the management of operations as and when project line is commissioned.

CMRN shall have a defined boundary limits and all functions within the limits are managed by the SPV and Sri Lanka Railways under Ministry of Railways shall have regulatory control and shall not involve in day to day operations of the CMRN. The SPV proposed above will have a Board of Directors as under:

i) Managing Director or CEO
ii) Director (Operations and Marketing)
iii) Director Projects
iv) Director Finance
v) Company Secretary cum Executive Assistant to the CEO
vi) Director representing Ministry of Transport, and
vii) General Manager/SLR and Ex-Officio Director

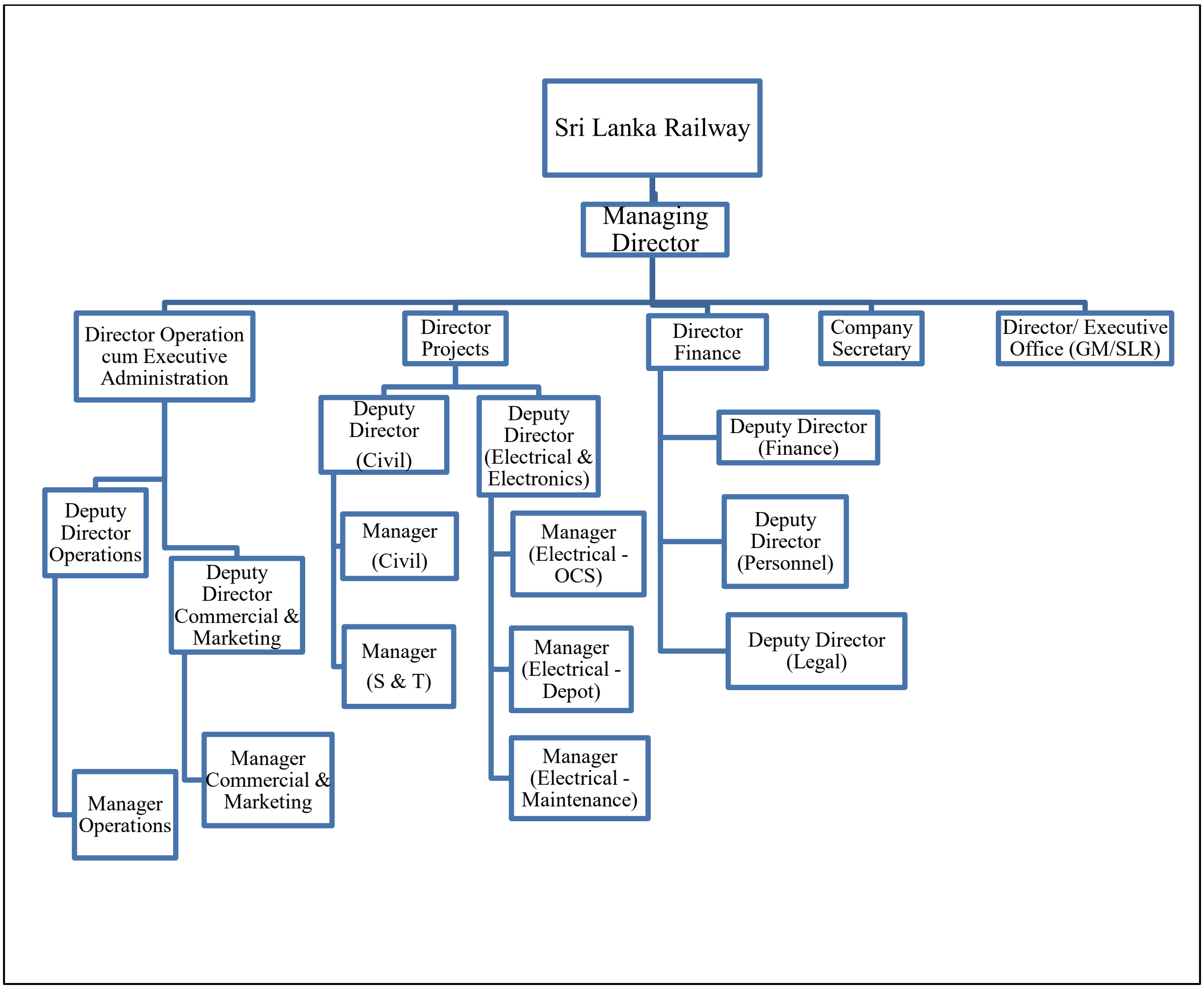


Figure 7-4 Organization Structure of the SPV

7.23 Way Forward

Since Sri Lanka Railway is set to conceive the new generation suburban Railway system in Colombo Metropolitan Region, by way of massive investment plan, to make it sustainable, SPV needs to have non-revenue sources of income as the revenue from fare collection shall not be enough to meet the lenders requirement after meeting operating cost. Therefore, for safe and efficient management of metropolitan region rail network, all out efforts to be made to create avenues of the non-fare revenue in the business plan of the SPV.

To achieve the goal of a Professional Safe and Efficient Transport Service Provider and generate additional source of revenue, it is essential for the SRL to undertake the following steps:

- Exploring non-conventional source of revenue by means of advertisement on rolling stock and station premises.
- Stations building and circulating area should also be developed to attract commercial exploitation, The ROW space of 20-meter-wide under elevated track is to be secured properly from foreign encroachment and used for maximum commercial exploitation.

- Sri Lanka Railway is governed by Railways Ordinance, 1902 as old as 117 years. As the technology has changed since then and for effective operations and maintenance it requires fresh legislation on the lines of latest operations practices and maintenance protocol.
- Accordingly, General Rules, Operation Rules, Signal and Telecom Rules, Track Manual, Disaster Management need updating in line with technology upgrades and traffic requirement.
- As SLR is entering OCS territory for the first time, it requires framing of OCS Manual on Operations and Maintenance.
- Separate SPV for overall maintenance and development of CSRP.

CHAPTER

8

Civil / Infrastructure Structures

Chapter 8 Civil / Infrastructure Structures

Chapter Summary

Option Study for Structure Type

A heavily loaded section between Maradana and Makumbura North is up to 18,405 passengers per hour per direction in 2025, up to 20,973 pphpd in 2035. But passenger load from Homagama hospital until end of line (Avissawella) decrease slowly and progressively.

Therefore the consultant considered the type of structure for alignment by dividing into 3 sections Maradana - Makumbura North, Makumbura North -Padukka, Padukka - Avissawella according to the degree of traffic volume.

The frequency presented from operation part is 7 minutes at the section of Maradana to Makumbura North, 14 minutes at the section of Makumbura North to Padukka, 30 minutes at the section of Padukka to Avissawella. About the alignment from Maradana to Padukka is planned to double line, from Padukka to Avissawella is planned to single line.

Because there are so many level crossings in the KV line, the train headway has a great influence on the selection of the structure type for alignment. For 7 min.'s frequency section from Maradana to Makumbura North, 3 types of structure are considered as at grade, elevated, underground to eliminate level crossing.

At grade railway is not recommended because there are so many level crossings to impact train operation, it will cause heavy traffic jams in the populated urban areas and finally slowing down the entire operation. About the tunnel structure, it is difficult to construct structures underground due to obstacles and long construction period.

When congested section is elevated, there are many advantages as follows;

- Avoid separation of the city area. Freely come and go between regions
- Relieve from road traffic congestion in the highly dense urban area
- Also the space under the elevated viaduct can be utilized as exercise facility, resident convenience facility, parking lot, etc.

Elevated structure type will be Precast PC Beam considering constructability.

Geotechnical Studies

The feasibility of the Project as far as geotechnical aspects of the foundation sub grade, and evaluation of geotechnical parameters are considered under this Chapter.

In general the site sub soils and are comprised of man-made grounds, depositional soils and residual soils followed by the high grade metamorphic rocks.

The Ste of the project has been divided into three sections, according to the conceptual design of the Project viz:

1. Elevated section from Maradana to Malapalla with double tracks, which will be founded on the piled foundations.
2. At grade section from Malapalla to Padukka with double tracks, which will be founded on the existing ground or on the built up embankments,

   and,

3. At grade section from Padukka to Avissawella with single track, which will only the improvements to the existing track is considered, without new major constructions.

To begin with, a desk study has been carried out and all available engineering geological and geotechnical information of the Site area have been gathered, a reconnaissance survey has been conducted and the geotechnical study has been designed according to the conceptual design of the proposed improvements to the track. Then, a detailed site investigation program, which includes boring, field and laboratory tests and analyses of the data gathered, has been carried in order to evaluate the feasibility of the project and to evaluate the geotechnical parameters, required for the foundation design of the structures involved with the project.

Adverse engineering geological / geological features, which require extensive / expensive / high-tech remedial measures, do not exist in the site area.

According to the outcome of total site investigation it is concluded that the execution of the Project is feasible as far as the engineering geological and geotechnical aspects of the Site area are concerned, with adoption of different type of foundations, which are considered as ordinary options, and with moderate improvements to the foundation conditions.

Bridges and other Structures

KV line was constructed more than 100 years ago, and the line has several features having frequent sharp curves, many level crossings, narrow ROW, and passing through the urban area. The structure team of this project has investigated the status of current bridges, and proposes design directions for new structure systems.

Based on the field survey of current bridges and other structures, all the existing structures were categorized according to their sizes and types. All existing railway bridges are in steel type, and corrosions have been discovered on major bridge members and subsidiary facilities. Particularly, a few bridges have severe corrosions that may affect the performance of the bridge. Flyover bridges, constructed in recent years, have a tendency being constructed in Pre-Stressed Concrete Girder type.

The priority in the planning and design of new structures, especially for railway and flyover bridges, is to secure safety, sustain economic feasibility and constructability. Safety of the bridge structure has been considered in the sharply curved sections and long-span bridges, and economic feasibility has been reviewed to minimize the increase of bridge construction cost in urban area due to long length. And constructability has been considered to efficiently and rapidly construct the bridges and other structures in a limited time period and within the narrow RoW spaces.

Therefore, the superstructure of bridges in general section was planed to adopt the PSC Girder type which is good at economic feasibility and constructability. And for the sharped curved sections, Rahmen type was adopted for its outstanding safety and stability. And for the bridges over roads and streams, which needs long-span, Steel Box Girder type was selected.

The substructure was designed in contemplation of either of reverse T type pier or π-Type pier, which enables to utilize the space under the bridge. Foundation type was decided to utilize cast-in-place concrete pile in consideration of the ground condition, stability and economic feasibility. For station section, PSC Girder type and Rahmen type were utilized in accordance with its plan and purpose.

This Feasibility Study report includes proposals for structure plan in consideration of the characteristics of KV line, and the structural figures will be decided in the Detailed Design stage taking into account the field conditions.

8.1 Option Study for Alignment

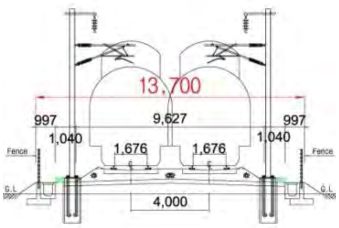
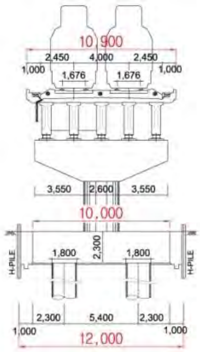
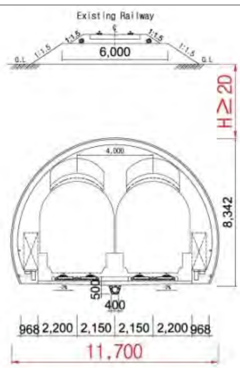
8.1.1 Typical Section

The railway structure should be planned in the most economical manner, and efficient structure should take consideration of train efficiency, topography, geological characteristics, and environmental characteristics.

Therefore, considering the characteristics of KV Line, three options of 1) At Grade 2) Elevated and 3) Underground have been studied in order to select the optimal railway structure considering economy, constructability, maintenance and right of way.

The comparison table for three different structure types of 1) At Grade, 2) Elevated and 3) Underground is as following.

Table 8-1 Typical Sections for Railway Track-Bed Structures

Classification	Option-1	Option-2	Option-3
Structure Type	At Grade	Elevated	Underground - Tunnel
Typical Section			
	Figure 8-1 Typical at grade railway	Figure 8-2 Typical elevated railway	Figure 8-3 Typical underground railway
Application	• Areas where traffic volume is low and level crossing is possible • Economical in areas with sufficient working space and good soil condition • Depending on the ground condition whether it needs to be reinforced, construction costs can be increased.	• Areas with heavy traffic and difficult to install the level crossing • The foundation type is divided according to the soil condition as following; • Good soil: Spread foundation • Soft soil: Pile foundation	• Areas with heavy traffic and difficult to construct structures on the ground due to obstacles • Applied to the zone where the soil condition is soft rock or hard rock • Soft ground requires additional reinforcement
Construction Cost	11 million USD/km	25 million USD/km	37 million USD/km
Construct ability	Good	Medium	Bad
Min. Land Acquisition Width	13.7m	12.0m	N/A

8.1.2 Option comparison

8.1.2.1 Option Study from Maradana to Makumbura North

Table 8-2 Option Comparisons for Track-Bed Section from Maradana to Makumbura North

Classification	Option-1 (At grade)	Option-2 (Elevated)	Option-3 (Underground)
Alignment	Not recommended because, at grade railway will have many level crossings, heavy traffic jams in the populated urban areas and finally slowing down the entire operation	Elevated railway is recommended because it will be faster avoiding urban traffic congestion	Not recommended, it is expensive and it has complex construction for long time If the construction cost is similar to Option-2 (Elevated), Option-3 can be recommended
Social/ Resettlement/ Gender	Option 1 is less favorable since the negative impact on vulnerable Households in this section can be minimized by Option 2	Option 2 is recommended as the best option for than Section 1 of the KV Line considering the favorable impact on vulnerable Households.	Option 3 is not recommended for the Section 1 since it will have negative impact on the complex associated structures on the ground level
Environment	Option 1, has average highest impact compare to the other two options.	Option 2, has average lowest impact compare to the other two options.	Option 3, has moderate average impact compare to other two options.
Comments	Not recommended	Recommended	Not recommended

Summary of option study through multi-scoring method for the tract bed section Maradana to Makumbura North is presented in the following Table 8-3.

Table 8-3 Weightage for Section from Maradana to Makumbura North

Classification	Weights	Option-1 (At grade)	Option-2 (Elevated)	Option-3 (Underground)
Alignment	40	18	23.6	22.4
Social/Resettlement/Gender	25	15.8	20	17.5
Environment	20	13	14.2	13.8
Transport Economy	15	9.8	10.8	9.7
Average Weight	100	56.6	68.6	63.4

After calculating the individual average weights on Alignment, Social/Resettlement/Gender, Environment, and Transport Economy, they are summarized for final evaluation in Table 8-3. From the calculation made in the Table 8-3, the Consultant recommends Option 2 for section from Maradana to Makumbura North, which is elevated railway.

8.1.2.2 Option Study from Makumbura North to Padukka

(1) Option comparisons for track-bed

Option comparison from Makumbura North to Padukka is as follows:

Table 8-4 Option Comparisons for Track-bed Section from Makumbura North to Padukka

Classification	Option-1 (At grade)	Option-2 (Elevated)	Option-3 (Underground)
Alignment	This section is less populated suburban area. Traffic volume at the level crossing is significantly less than that of Maradana to Makumbura North section. Considering the construction cost, it is proper to construct at grade in this section.	This section is a less populated suburban area. In this section, traffic congestion is not expected in the future. It is reasonable to consider reducing the construction cost by establishing overfly road bridge only where there is particularly heavy traffic place.	It is not proper to construct underground because of high construction cost, payment of compensation, bad conditions of soil and constructability, etc.
Social/ Resettlement/ Gender	Option 1 is recommended as the best option for Makumbura North to Padukka section of the KV Line considering the favorable impact on rural Households.	For the Makumbura North to Padukka section is suitable to rural area Option 2 is not recommended.	For the Makumbura North to Padukka section is suitable to rural area Option 3 is not recommended
Environment	Option 1 poses moderate impact than the other two options.	Option 2 has the lowest impact compared to the other two options.	Option 3 has the highest impact on environment compared to the other two options.
Comments	Recommended	Not recommended	Not recommended

Table 8-5 provides the summary of the overall weight analysis for the track bed section from Makumbura North to Padukka. The best option is recommended based on the outcome of this overall calculation.

Table 8-5 Weightage for Section from Makumbura North to Padukka

Classification	Weights	Option-1	Option-2	Option-3
Alignment	40	24	24	24
Social/Resettlement/Gender	25	12.8	10	10.8
Environment	20	12	12	12.8
Transport Economy	15	12.3	12	11.7
Average Weight	100	61.1	58	59.3

It is seen that overall average weight of Option-2 is higher than others. As all the items considered in this evaluation as listed in Table 8-5 have higher score for Option-1, it is expected that Option-1 has the highest feasibility compared to others.

(2) Construction cost comparison (Railway elevated vs Railway & Road flyover)

From Makumbura North to Padukka is planned double line and headway is 14 minutes. In this suburban area, there are not so many level crossings. It will be possible to control the road traffic by using the electrical operated barrier.

Nowadays the traffic demand forecast on level crossings from Homagama to Padukka was finished, and the result of ADT was as follows:

Among of them Road Traffic >4,000 ADT is 6 places, RT>3,000 is 7 places, ADT RT>2,000 ADT is 10 places.

Table 8-6 Road Traffic Investigation Result

Level crossing	Station	ADT	Level crossing	Station	ADT
Homagama Station	**24km440**				
58 Wimana Rd	25km010	4,101	67 Meegoda Station Rd	29km600	8,379
59 Panagod Station Rd	26km330	5,193	68 Udagewathta Rd	30km300	2,370
60 Godagamagewatta Rd	27km360	2,070	69 M.adulawa Rd	30km820	5,390
61 Godagama Station Rd.	28km050	1,870	70 Opathella Rd	31km850	783
62 Level crossing	28km530	160	71 Kurugala Rd	33km630	3,010
64 Palpolawatta Rd	28km790	1,571	74 Polwatta Rd	34km650	2,148
65 Asiri Uyana	28km980	410	75 Padukka Rd	34km900	11,914
66 Puwakwatta Rd	29km060	8,527	**Padukka Station**	**34km920**	

Homagama~ Padukka is suburban area. In this section the traffic volume will not be increased as much as urban area. The consultant reviewed to establish road flyover on the assumption that the traffic volume increase 5 times in the future.

Because regularly congested traffic is more than 20,000ADT, considering to increase future traffic volume 5times, currently the level crossing more than 4,000ADT can be considered to construct road flyover.

The level crossings (Road Traffic >4,000 ADT(6ea)) are as follows:

-Padukka Rd(11,914 ADT) is considered as Big Scale Road

-Puwakwatta Rd(8,527 ADT), Meegoda Station Rd(8,379 ADT) are considered as Middle Scale Road

-Wimana Rd(4,101 ADT), Panagoda Station Rd (5,193 ADT), Madulawa Rd(5,390 ADT) are considered as Small Scale Road

The traffic volume of the other 9 level crossings is less than 4,000 ADT and operation frequency is 14 minutes in this section. It will be possible to control the road traffic by using the electrical operated barrier.

The result of construction cost comparison is as follows. On this section railway at grade is advantageous& road flyover rather than elevated railway.

Table 8-7 Homagama to Padukka Section Result of Construction Cost Comparison

Location	Elevated (A)	At grade & Road flyover(B)	(B)-(A)
From 24km 440 to 34km 920	262 Million$	226.61 Million$	-35.39Million$

8.1.2.3 General Conclusion

There are many level crossings in KV line. According to the traffic demand increases, level crossings greatly affects the selection of railway structure type in the urban area.

According to the operation study, the frequency by sections and the type of railway structure is as follows:

- It is 7 minute frequency from Maradana to Makumbura North and to be planed double line. The viaduct structure type to be planed from Maradana to Kottawa. Number of trains comes to 26EMU trains per hour with number of passenger 25,039 during peak hours. On this section railway elevated has many advantageous such like decrease of construction cost or avoid separation of downtown.

  (1) Makumbura North station is under construction behind of 300m Malapalla station. Future Makumbura North station will play a roll instead of Malapalla station.

  (2) The viaduct structure is planned until Kottawa station. Kottawa station is located in front of Malapalla station

  (3) There is proposed future line Makumbura North ~Horona.

- It is 14 minute Head Way from Makumbura North to Padukka, and to be planed double line at grade. Number of trains comes to 26 trains per hour with number of passenger 10,723 during peak hours. On this suburban section, it is advantageous railway at grade in terms of saving construction cost. The necessary place for road flyover from Homagama to Padukka was selected by using the traffic demand forecast on level crossings.

8.2 Geotechnical Studies

8.2.1 Introduction

The section between Maradana and Malapalla, which is a heavily loaded section, will be constructed as an elevated section founded on piled foundations. The section between Malapalla and Padukka will be founded on the existing sub grade. Only improvements to the existing track will be attended in the section between Padukka and Avissawella.

Therefore the consultant considered the requirements of investigations, according to the anticipated alignment sub divided into 3 sections, viz: Maradana - Malapalla, Malapalla - Padukka, Padukka - Avissawella.

The intended studies are aimed to evaluate the extent of feasibility of the project as far as geotechnical aspects of the Site fallen under the Kelani Valley railway line is concerned. The site area covers the stretch of the Right of Way (RoW) of the Kelani Valley Railway line from Maradana to Padukka.

8.2.2 Methodology of the Study

The site investigation program is designed on the following pre- conceptions.

(1) Elevated section, from Maradana to Malapalla, will be founded either on the sub soils where the bearing capacity and stability is sufficient for the purpose through shallow foundations, or on/in the basement rock, through a piled foundation. The width of shallow foundations (or embankments) will be decided on the strength parameters of the sub soils. Approximate load of a pile is in the order of 4,000kN - 5,000kN, and the approximate diameter is in the order of 1.0m – 2.0m.

(2) The second track on the at grade section, from Malapalla to Padukka, will be founded on the existing sub grade, on sub grade with improved soil conditions or on filled embankment as it suits the ground conditions. The required pavements will be designed according to loading conditions of the structure and the strength parameters of the sub soils.

(3) Only improvements to the track will be attended to the Padukka – Avissawella Section. Further subsurface investigations for such improvements are not required.

The study has been undertaken under the following three categories.

(1) Desk study of the geological / engineering geological / geotechnical aspects of the Site area.

(2) Reconnaissance Survey of the Site area.

(3) Detailed geotechnical investigations of the Site area in relation to the proposed conceptual design of the Project.

8.2.3 The Desk Study

It is essential to carry out a desk study as the first stage of the site investigation. The primary objectives of the desk study are to evaluate the ground conditions based upon available information, and to plan the scope of the subsequent stages of investigations. Following documents and information are, gathered during desk study.

(1) Available site survey plans and topographic & contour plans, geological maps, aerial photographs, natural drainage features, aerial obstructions such as transmission lines etc, underground obstructions, bench marks and meteorological information.

(2) Data on statutory restrictions, if there are, in areas under the consideration.

(3) Data on exiting underground services, tunnels and mine works, ancient monuments, burial grounds and other socially and historically important features.

(4) Data on ground stability conditions of the site.

(5) Data on existing contaminated lands and hazardous lands.

(6) Data on approaches and access to the site.

(7) Seismicity of the site.

(8) Permissions to gain access to the Site from the relevant authorities.

8.2.3.1 Morphology of the Site Area

In general the Site area is formed of morphological features such as flat land, low and medium ridges and valleys, which are cut across by canals, streams and rivers.

The site in between Maradana and Padukka, where the geotechnical studies are concentrated to, can be considered as flat morphological terrain with rolling grounds, comprised of slightly elevated high grounds and low lying grounds, with occasional existence of marshy areas. The site in between Padukka and Avissawella, where geotechnical studies are not conducted, can be considered as rolling morphological terrain comprised of slightly - moderately elevated high grounds with medium ridges with occasional low lying grounds.

8.2.3.2 Climatic Conditions of the Site Area

The Site area falls under the South Western Monsoonal Climatic Zone.

8.2.3.3 Regional and General Geology of the Site Area

A. Regional Geology

Nine tenths of Sri Lanka is made up of highly crystalline, non fossili-ferrous rocks of Precambrian Age belonging to one of the most ancient and stable part of the Earth's crust, which is called Indian Shield (P.G COORAY-1984). This Precambrian basement is divided into three major tectonic units, namely Highland, Wanni and Vijayan Complexes. The project area falls within the Highland Complex, and Wanni Complex which is characterized by thick sequences of gneisses, dominated by hard coarse grained Charnockitic Gneisses inter-bedded with softer fine grained Para-Gneisses and soluble Calc Gneiss. The major rock types found within the rail line alignment are Charnockitic Gneisses, and Garnetiferrous Quartzo Feldspathic Gneisses, Garnet Silimanite Biotite Gneiss and Quartzo Feldspathic Gneiss. These formations exhibit a high metamorphic gneissic foliation and local stretching foliation, which indicate the intense layering associated with the earliest stage of deformation. These rocks are overlain by residual soils and alluvium. Lateritic soil which derived from in-situ weathering of the crystalline basement rocks, which have been later subjected to chemical transformations, is quite well developed, especially toward the southern half of the track alignment.

Hanwella Antiform, Oruwala Antiform and Nawagama Synform can be identified as major Structural Geological features in the region, which are associated with major fault zones and shear zones. Few fault / shear zones can be observed in Maradana, Narahenpita, Pannipitiya, Homagama and Avissawella areas cut across the railway line.

B. Geology in Kelani Valley Railway Line Alignment

The soil overburden of the Site area is comprised of

a. Filled Earth

b. Alluvium soils

c. Residual soils

d. Laterite

The soil overburden is followed by the basement rock.

In general the filled earth exists in the Site area, is restricted to the sub base fill and embankment fill where the existing track is placed. No information are available of the material used for filling, of the process adopted for filling, of methods of compaction and the degree of compaction of the fills.

The alluviums are found in the valleys formed by the natural streams run across the Site. The upper most layers of these valleys are formed of recent alluvial deposits, which belong to Quaternary age. Clay, silty clay, clayey silt, sandy clay, clayey sand, peat and organic clay layers are found within alluvial deposits.

The residual soils are encountered overlaying bedrock represents the complete range of weathering from the parent bedrock to completely decomposed products in the form of soils.

Exact boundaries of various zones of weathering are not very prominent as the soil overburden is the gradual transition from this Laterite to sound bedrock. Well developed lateritic layers could be observed on the ground surface mainly between Nugegoda and Meegoda.

The basement rock is predominantly comprised of metamorphic rocks such as Biotite Gneisses and Charnokitic gneisses and occasional existence of calc gneiss. The bedrock at site exists in the different form of weathering grades varying from highly weathered through, moderately weathered and slightly weathered, to fresh rock.

In general the residual soils and granular alluvium soils, other than soft clays, organic clay and peat in the site area can be considered as good sub grade material.

8.2.3.4 General Problematic Soils

The subsurface conditions beneath the valley floors were found to be variable from one valley to another. In some of them, sub surface soils contain more fine grained soils comprising silty clays, organic clays and peat which are medium to highly compressible and tend to undergo consolidation settlements. These compressible soils are considered as problematic soils, as it undergo slow consolidation process leading to long term undesirable settlements of the structures, under additional stresses exerted by the foundations, and therefore, such soils to be treated or replaced to improve the structural capacity of railway embankment, so that the rail track will not be subjected to undesirable consequences.

Peat is formed as a result of decomposition of vegetable matters buried with the soils. Peats, which are rarely found in the site area are in grayish black, blackish brown and black in color. It exists in fibrous and amorphous state depends on its degree of decomposition and this nature reflects its age and deposition environment. Fibrous structure of peat exhibits a sponge like nature combined with the very high moisture content and very high void ratio, and therefore possessing very high compressibility. The method of improvement / treatment of such soils to achieve a reasonable sub grade should be decided upon the results of the detail investigation.

8.2.3.5 Problematic Basement Rock

The basement rock is highly deformed and therefore subjected to fracturing by shearing, faulting and folding. The extent of fracturing is highly variable. The fracturing could create problems, due to their poor bearing capacity and intolerable settlements, for foundations of the structure depending on the extent of fracturing.

Also, one or two very thin soluble rock layers, such as marble or calc gneiss, are identified in the site area. Occasionally cavities and caverns are found within such rocks, which could be subjected collapse leading to ground subsidence. But such situations are rare in the site area.

8.2.3.6 Steep Slopes and Soil Movements

Steep slopes, which can be prone to collapsing in the form of creeping or sliding, have not been identified.

Collapses, landslides, faults / shear movements seismic activities etc, which can have adverse effect on the proposed development, within the site area, have not been recorded in the recent past.

8.2.4 Site Reconnaissance.

At an early stage, a thorough visual examination should be made of the site. The existing KV Railway line traverses through from Maradana to Padukka at grade. The geological conditions, in general, are demarcated during the traverse and recorded.

It was noted that there are no serious stability issues along the railway line, except very few cuts made to accommodate the rail track, as far as ground stability is concerned. The road cuts are not deep and those have become naturally stabilized with the time. Ground contamination and mining activities which could affect the proposed development have not been found.

Some alluvium deposits, which could contain problematic compressible soils have been identified. However, it was noted that there were very few such problematic areas exist along the KV line from Nugegoda up to Padukka. Some such areas were found in the stretch between Maradana and Narahenpita, but they do not pose serious impacts for deep foundations such as piles.

Active geological features, such as potential landslides, active fault / shear zones etc. were not observed.

The existing structures along the KV line, whose sites were to be investigated, were also identified.

Locations where there are underground services along the site have been identified, so that those will not get disturbed by the investigation program.

General ground water levels were observed during the traverse from the existing wells. It was noted that the ground water level in the most of the areas are moderately shallow in the range of 2m – 7m, and in some areas it is at very shallow levels in the rage of 0 – 2m. In some other areas ground water table is almost at the existing ground surface or just above it making the area soggy. This will be sufficiently complemented by the detail investigation.

There are no quarries situated in the close vicinity of the KV line.

No signs of adverse seismic activities occurred in the Site area were observed.

A special consideration was taken to find out access to the investigation locations during the reconnaissance survey, and it was concluded that sufficient access for all locations of investigation area available.

It was found that there were no private or state properties that can be affected by the investigation works.

Tentative locations for field investigations have been identified, according to the ground conditions, so that that all geotechnically different areas of the Site are satisfactorily represented.

The outcome of the visual observation along the KV line is presented in the Table A-1, under Appendix A to the Report.

8.2.5 Detailed Site Investigation.

A detailed Site investigation should be conducted in order to evaluate the impact of the geotechnical conditions and to:

a. Determine the strength parameters of sub soils and basement rock required for the detail design,
b. Designing methods of improvement of soil and rock conditions if those are weak and unsuitable,
c. Take necessary remedial stability measures if the ground conditions are unstable,
d. Design suitable foundations for then track and the associated structures.

It has been pre-conceived, by the information gathered from the Desk Study and the Reconnaissance Survey and according to the loading and ground conditions, that the elevated section should be founded on the hard bedrock through a piled foundation and the at grade section, the track is placed on existing sub grade or built up embankments as found to be necessary. Piled foundations should be adopted for some structures such as bridges too. Also, it may be necessary to improve the soil conditions prior to construction of embankment at some locations.

Geotechnical parameters of the basement rock are more important in the elevated section as the intended foundation is a piled foundation socketted into the bedrock. It is also anticipated, according to the structural designers that the diameter of a pile will be in the order of 1.0m – 2.0m and the design loads on a pile is in the order of 4,000kN – 5,000kN.

The geotechnical parameters of the soil sub grade is more important in the at grade section as the embankments will be founded on the sub soils.

Also, the foundations of some structures such as culverts too should be placed on the sub soils, both in elevated and at grade sections.

The geotechnical investigation program has been designed, in order to achieve required geotechnical parameters for the detailed design of the railway line and associated structures, based on the above mentioned design concepts.

Site investigation works will be undertaken in accordance with relevant Code of Practices. Purpose of site investigation is to assess the site suitability for the construction of railway line and of acquiring knowledge of the characteristics of a site that affect the design and construction of such work and the safety of neighboring lands and properties. It has been assumed that in the selection of construction sites due regard has been paid to the wider environmental and economic considerations affecting the community generally. The detailed site investigation, in general, is comprised of the following.

a. Preliminary consideration.

b. Detailed geotechnical field investigations.

c. Laboratory investigations and description of soils and rocks (logging).

d. Interpretation and reporting.

Preliminary considerations deal with those matters of technical, legal or environmental characters that have usually to be taken into account in related to the selected site and in preparing the design of the Works. Ground investigations deal with planning of ground investigations, including the influence of general conditions and ground conditions of the selection of methods of investigation.

Field Investigations covers the necessary field tests and collection of soil, rock and ground water samples required for the laboratory tests.

Laboratory Investigations covers the laboratory tests that should be conducted on soil, ground water and rock samples, in order to obtain the geotechnical parameters, necessary for carrying out the detailed design.

Description of soils and rocks (logging) deals with the terminology and systems recommended for use in describing and classifying soil and rock materials and rock masses for engineering applications.

Interpretation and reporting covers the preparation of comprehensive report including field data, results of laboratory tests and the interpretation of the data leading to obtain the necessary geotechnical parameters for the detailed design.

8.2.5.1 Detailed Geotechnical Field Investigation

The objectives of the investigation are to obtain reliable information on subsurface soil / rock condition, ground water condition and to obtain engineering soil / rock strength parameters required to produce an economic and safe design and to assess any hazards (physical or chemical) associated with the ground.

The detailed geotechnical field investigation is comprised of following activities:

a. Conducting bore holes along the KV railway line with Standard Penetration Test (SPT) at specified regular intervals and at sites of structures.

b. Obtaining undisturbed / disturbed soil samples, ground water samples and rock cores from the boreholes.

c. Conducting Dynamic Cone Penetration Tests (DCPT) at specified locations

d. Conducting Mackintosh Probing Tests (MPT) at specified locations.

e. Conducting Laboratory test on selected representative soil, ground water and rock samples.

f. Interpretation of collected data, and making recommendations necessary for the detailed design.

Anticipated geotechnical parameters, in general, to be obtained for specific structures by detailed geotechnical investigation are as follows. However, this could vary according to the site conditions and the design requirements.

a. Natural moisture content

b. Particle size distribution

c. Unit weight

d. Atterberg limits

e. Consolidations characteristics of compressible soils

f. Cohesive strength of fine grained soils

g. Angle of internal friction

h. Modulus of sub grade reaction

i. Allowable bearing capacity

j. Skin friction of sub soils and basement rock

k. Chemical conditions of sub soils and ground water

l. Elevation of the ground water table

m. Permeability of sub soils

8.2.5.2 Test Procedures and Standards

All field and laboratory tests were conducted in accordance with international standards and codes of practices as listed in Section 4.2.1 of the Requirement and Rule Book.

8.2.5.3 Proposed Field and Laboratory Testing

Ideally, it requires carrying out geotechnical field testing at every 200m (minimum) intervals along the proposed railway line alignment as recommended in EN-1997-2-annex B.3, in order to get the geotechnical parameters to produce economical and safe design and to assess any hazards (physical or chemical) associated with the sub grade and surrounding. However considering budget constraints in the project, accessibility issues and time tested nature of the existing project site, the extent of investigation is limited to the following.

a. Total number of boreholes with associated field testing: 144

b. Total Number of Field Dynamic Cone Penetration tests: 20

c. Total number of Mackintosh Probe Tests: 15

d. Necessary laboratory physical, mechanical and chemical tests as required decided upon the ground conditions, and according to the design requirements.

The general distribution of the locations of field tests is as follows.

a. One borehole per 200m distance in the elevated track section (Maradana – Malapalla) drilled down to bedrock with Standard Penetration Tests at regular intervals. The bedrock will be cored down to minimum of 3m, and further rock drilling will be attended if necessary.

b. Approximately two boreholes at the each abutment at each structure will be drilled, where necessary, down to bedrock at the necessary structures identified. The bedrock will be cored down to minimum of 3m.

c. One borehole per 500m distance in the at grade track section (Malapalla – Padukka), which has been time tested by the existing track, will be drilled down to bedrock.

d. The Mackintosh Probe tests and DCP tests are conducted to supplement the data obtained from the boreholes in the at grade section.

e. If any additional investigation is found to be required while the data being gathered during the planned program, it will be promptly attended to.

The geotechnical investigation program was commenced on 01.07.2018.

The investigation program will be completed within a period of 90 days.

Additional investigation will be carried out, if found necessary during the detail design stage. Otherwise, additional investigation is recommended to attend during the construction phase, by the Contractor.

8.2.6 Extent of Field Work.

8.2.6.1 Elevated Section

Boreholes have been conducted at 200m intervals from Chainage 0+ 000 (Maradana) to Chainage 22+500 (Malapalla) with bedrock coring. The field data obtained from these boreholes, which have been finalized, are given in Figures B-1 – B-28 under Appendix B.

8.2.6.2 At Grade Section

Boreholes are proposed to be conducted at 500m intervals from Chainage 23+ 000 (Malapalla) to Chainage 35+000 (Padukka) without bedrock coring.

The field data obtained from these boreholes are given in Figures B-29 – B-31, under Appendix B.

In addition to the above Dynamic Cone Penetration Tests (DCPT) and Mackintosh Probe Tests (MPT) are to be conducted at the following locations in order to evaluate the California Bearing Ration of the sub grade.

A. DCPT

Chainage 22+140	Chainage 22+580	Chainage 23+240	Chainage 23+860 L
Chainage 23+860 R	Chainage 24+340	Chainage 25+060	Chainage 25+720
Chainage 26+200	Chainage 26+820	Chainage 27+660	Chainage 28+840
Chainage 30+020	Chainage 31+080	Chainage 32+020	Chainage 32+520
Chainage 33+000	Chainage 34+420	Chaiange 35+445	

The raw data gathered from those investigations have not been processed yet.

B. MPT

Chainage 22+085	Chainage 22+320	Chainage 23+645	Chainage 24+020
Chainage 24+880	Chainage 25+390	Chainage 25+800	Chainage 27+320
Chainage 27+920	Chainage 32+220	Chainage 336+360	Chainage 33+800

The raw data gathered from those investigations have not been processed yet.

8.2.6.3 Structures

Boreholes are to be conducted at major structures and at present, data for following two bridges are available Figure B-32 – B-33, under the Appendix B to the Report.

8.2.7 Extent of Laboratory Work.

The details of the laboratory tests results are presented in the Table C-1 under the Appendix C to the report.

8.2.8 Analyses of Data and Inferences

A complete geotechnical analysis could not be carried out, by the time of preparation of this Report, due to the reason that all necessary data are not available as the investigation program is still in progress. However, the data available at present is sufficient to decide on the feasibility of the project.

It can be concluded that the elevated track should be founded in the hard basement rock through piled foundations, with incorporation of socketting. There may be very few instances of need of avoiding fractured / sheared zones as foundations in the rock by taking the base of the piles further into the basement rock than the required socketting length. But, in general, the basements rock would not pose any serious issues as far as foundation conditions are concerned.

The embankment for at grade section can be constructed on the existing ground in the form of shallow foundations, without improvement, except at very few places, where some ground improvement needed to be attended. Such ground improvement techniques are not sophisticated expensive methods, but ordinary methods such as compaction of existing foundation material, replacement of weak soils and forced consolidation of compressive soils. There is no necessity of adoption of deep foundations for the at grade section.

Other than, very minor features observed, that there are no dominant geological / engineering geological / geotechnical features have been observed, as factors having adverse impact on the design and implementation of the proposed development.

8.2.9 Conclusions & Recommendations

(1) According to the data collected prior to the detailed geotechnical site investigation, and according to the available data of the detail investigation, it can be concluded that the design and construction of the proposed development is feasible as far as the geotechnical conditions of the sub grade area of the Kelani Valley Railway Line, from Maradana to Padulkka is concerned.

(2) The detailed site investigation, as outlined in this report, should be completed, in order to obtain all necessary geotechnical parameters required for the detail design.

(3) The final geotechnical investigation report under the preparation will be attached later as an Appendix of the detail design report.

(4) It is recommended to conduct 1/2 boreholes at each pier location in order to check the adequacy of the detail design, if a necessity arises.

8.3 Bridges and Other Structures

8.3.1 Investigation of the Existing Bridges and Structures

8.3.1.1 Bridges and Other Structures Inventory

The scope of this section is to identify the condition of existing bridges, culverts and drainage structures by visual inspection, along with the Kelani Valley railway line from Maradana to Avissawella. Table 8-8, Table 8-9 and Table 8-10 in the following are tabulated summary of the existing bridges, culverts and other drainage structures visually inspected by a walk-through survey from Maradana to Avissawella.

Table 8-8 List of Existing Bridges

No.	Chainage	Description	Span (m)	No. of Span	Total Length (m)	Width (m)	Type of Structure
1	0km700	Railway Bridge	7.50	1	7.50	31.50	Steel Deck with Closed Ribs
2	5km220	Railway Bridge	12.00	1	12.00	5.05	Steel Plate Girder Semi-Trough
3	6km410	Railway Bridge	30.40	2	51.40	5.10	Steel Lattice Girder Semi Trough
	6km440	Railway Bridge	21.00			5.30	Steel Plate Girder Semi-Trough
4	17km020	Overhead Bridge	16.00	4	64.00	14.00	PSC Beam, Clearance = 5.90m
5	21km550	Overhead Bridge	25.00	1	25.00	37.20	PSC I-Girder, Clearance = 5.3m
6	26km100	Overhead Bridge	25.00	1	25.00	22.80	PSC Beam, Clearance = 6.9m under construction
7	26km380	Railway Bridge	5.40	1	5.40	3.70	Steel Plate Girder - Rail Top
8	30km010	Railway Bridge	14.15	1	14.15	2.30	Steel U-Beam Deck
9	31km590	Railway Bridge	8.50	1	8.50	6.20	Stone Masonry Arch
10	33km390	Railway Bridge	6.20	1	6.20	4.60	Steel Plate Girder Semi-Trough
11	34km060	Railway Bridge	5.90	1	5.90	2.00	Steel Trough Span – Rail Top
12	34km160	Railway Bridge	19.25	2	38.50	5.20	Steel Lattice Girder Semi Trough
13	34km760	Overhead Bridge	10.00	2	20.00	2.50	PSC Beam, Clearance = 5.3m, Walkway Bridge
14	35km040	Railway Bridge	5.40	1	5.40	3.70	Steel Plate Girder Semi-Trough
15	35km944	Railway Bridge	5.80	1	5.80	2.10	Steel U-Beam Deck
16	36km364	Railway Bridge	5.90	1	5.90	2.00	Steel U-Beam Deck
17	36km634	Railway Bridge	18.10	1	18.10	5.30	Steel Lattice Girder Semi Trough
18	36km754	Railway Bridge	13.65	2	27.30	1.80	Steel Plate Girder

No.	Chainage	Description	Span (m)	No. of Span	Total Length (m)	Width (m)	Type of Structure
19	37km984	Railway Bridge	6.20	1	6.20	2.10	Steel Plate Girder Semi-Trough
20	38km184	Railway Bridge	5.90	1	5.90	2.00	Steel Plate Girder Semi-Trough
21	38km244	Railway Bridge	12.90	1	12.90	2.00	Steel Plate Girder Semi-Trough
22	42km044	Railway Bridge	10.20	1	10.20	5.10	Steel Plate Girder with 'X' Girder Pocket Plate Deck
23	43km784	Railway Bridge	30.10	1	30.10	5.30	Steel Lattice Girder Semi Trough
24	45km064	Railway Bridge	18.00	1	18.00	5.00	Steel Plate Girder Semi-Trough
25	45km814	Railway Bridge	5.80	1	5.80	-	Steel Plate Girder Center Two Trough
26	50km324	Railway Bridge	13.10	1	13.10	5.10	Steel Plate Girder with 'X' Girder Pocket Plate Deck
27	51km844	Railway Bridge	6.00	1	6.00	2.00	Steel Semi-Trough Rail Top
28	54km184	Railway Bridge	30.10	2	60.20	5.40	Steel Lattice Girder Semi Trough
29	55km184	Railway Bridge	8.80	1	8.80	2.80	Steel Plate Girder Semi-Trough
30	57km264	Railway Bridge	14.30	1	14.30	5.00	Steel Plate Girder with 'X' Girder Pocket Plate Deck
31	57km884	Railway Bridge	5.90	1	5.90	2.80	Steel Plate Girder Semi-Trough
32	58km794	Railway Bridge	10.70	1	10.70	4.60	Steel Plate Girder with 'X' Girder Pocket Plate Deck

Following figures describe the type of bridge structures in the Kelani Valley Line.

Steel Lattice Girder

Plate Girder with 'X'-girder pocket plate deck

Steel Deck Plate Girder

Steel U-beam deck

Pre-stressed Concrete Beam

Pre-stressed I-Girder Bridge

Figure 8-4 Existing Bridge Structures of Kelani Valley Line

Table 8-9 below describes the chainage, span and section name of the existing culvert structures of Kelani Valley line. In addition to that, Figure 8-5 shows the types of culvert structures in the Kelani Valley Line. Most of the culvert structures are functioning well and, some of the culvert structures are identified as abandoned after visual inspection.

Table 8-9 List of Existing Culvert

No.	Chainage	Span (m)	Width (m)	Type of Structure
1	1km610	3.80	2.00	Steel Plate Girder - Rail Top
2	2km010	1.30	3.70	Steel Plate Girder - Rail Top
3	2km870	3.00	3.90	Steel Plate Girder - Rail Top
4	3km190	2.80	4.20	Steel Plate Girder - Rail Top
5	3km620	2.30	9.00	Concrete Deck and Ballast Packed
6	3km890	2.00	4.00	Concrete Deck and Ballast Packed
7	4km385	2.87	4.60	Concrete Deck and Ballast Packed
8	5km995	2.70	3.80	Steel Plate Girder - Rail Top
9	6km710	3.50	3.85	Steel Plate Girder - Rail Top
10	7km680	1.30	4.50	Concrete Deck and Ballast Packed
11	8km417	1.20	4.80	Concrete Deck and Ballast Packed
12	10km070	1.30	6.30	Concrete Deck and Ballast Packed
13	10km200	1.30	3.55	Hume Pipe
14	10km440	3.60	-	Hume Pipe
15	10km900	2.90	-	Steel Plate Girder - Rail Top
16	12km020	3.00	3.90	Rail Top with Semi-Trough Span
17	12km845	2.00	-	Stone Masonry with Steel Deck and Ballast Packed
18	13km110	1.40	-	Concrete Deck and Ballast Packed
19	13km410	1.80	5.40	Hume Pipe
20	14km070	1.40	4.60	Stone Masonry with Steel Deck and Ballast Packed
21	14km795	1.20	5.30	Concrete Deck and Ballast Packed
22	16km790	1.20	6.60	Stone Masonry with Steel Deck and Ballast Packed
23	20km195	3.30	3.70	Rail Top with Semi-Trough Span
24	20km270	1.40	4.50	Concrete Deck and Ballast Packed
25	20km635	1.10	9.60	Stone Arch
26	20km775	1.20	4.60	Stone Arch
27	20km960	1.00	5.90	Stone Arch
28	21km200	3.00	4.10	Concrete Deck and Ballast Packed (1.0m width twin cell)
29	21km490	2.00	3.90	Stone Arch (1.0m Opening)
30	21km600	2.80	5.50	Concrete Deck and Ballast Packed (2.8 width tri cell)
31	22km105	1.30	6.10	Concrete Box
32	22km190	1.20	-	Stone Masonry with Steel Deck and Ballast Packed
33	22km330	3.10	4.00	Stone Arch (1.3m Hume Pipe Twin Cell)
34	22km745	4.50	4.00	Steel Plate Girder - Rail Top
35	23km000	1.40	4.00	Stone Masonry with Steel Deck and Ballast Packed
36	23km480	2.90	3.90	Stone Arch
37	23km630	4.20	4.80	Stone Masonry with Steel Deck and Ballast Packed
38	25km050	2.50	4.40	Hume Pipe (0.70m Rectangular Opening Twin Cell)
39	25km390	1.70	6.10	Hume Pipe
40	25km960	2.00	-	Hume Pipe (0.6m Single)
41	27km105	2.80	3.80	Stone Arch
42	27km290	1.50	6.50	Stone Arch
43	27km870	1.80	5.00	Stone Arch
44	28km200	3.20	4.40	Concrete Arch with Rubble Masonry Abutments
45	28km590	1.50	0.60	Hume Pipe (0.75m Diameter Opening)

No.	Chainage	Span (m)	Width (m)	Type of Structure
46	29km470	2.90	5.20	Stone Arch
47	30km180	2.90	3.60	Rail Top with Trough Span
48	30km480	1.10	4.30	Concrete Box
49	30km520	2.90	3.40	Stone Arch
50	31km100	3.40	4.60	Stone Arch
51	31km830	2.20	4.60	Stone Masonry with Steel Deck and Ballast Packed
52	31km900	1.30	4.40	Concrete Deck and Ballast Packed
53	32km290	1.30	4.20	Stone Masonry with Steel Deck and Ballast Packed
54	33km470	1.70	4.30	Concrete Box
55	33km700	1.00	5.70	Hume Pipe (0.60m diameter)
56	35km434	4.50	2.10	Steel U-Beam Deck
57	37km084	6.50	-	Stone Masonry with Steel Deck and Ballast Packed
58	37km584	4.50	2.00	Rail Top with Trough Span
59	37km874	2.00	4.90	Stone Masonry with Steel Deck and Ballast Packed
60	39km244	2.70	3.60	Steel Plate Girder - Rail Top
61	39km304	3.10	3.80	Steel Plate Girder Semi-Trough
62	39km444	1.70	3.60	Stone Masonry with Steel Deck and Ballast Packed
63	39km894	2.80	2.10	Steel Plate Girder Semi-Trough
64	40km444	1.90	4.30	Stone Masonry with Steel Deck and Ballast Packed
65	40km634	3.60	3.40	Stone Masonry with Steel Deck and Ballast Packed
66	40km824	2.40	3.50	Stone Masonry with Steel Deck and Ballast Packed
67	40km844	1.30	7.20	Stone Arch
68	41km654	2.60	3.50	Stone Masonry with Steel Deck and Ballast Packed
69	42km184	4.50	1.90	Steel Plate Girder Center Two Trough
70	42km414	1.20	12.00	Hume Pipe (0.60m diameter)
71	42km674	1.30	3.70	Stone Arch
72	42km904	2.70	5.30	Stone Masonry with Steel Deck and Ballast Packed
73	42km984	3.20	8.00	Stone Masonry with Steel Deck and Ballast Packed
74	43km344	2.10	5.20	Stone Masonry with Steel Deck and Ballast Packed
75	43km464	1.40	4.80	Stone Arch
76	43km604	1.60	5.00	Stone Arch
77	43km944	2.00	6.00	Stone Arch
78	44km944	4.70	3.75	Stone Arch
79	45km374	3.20	3.80	Stone Arch
80	45km644	2.00	4.30	Concrete Box
81	46km084	1.20	10.50	Hume Pipe (0.60m diameter)
82	46km324		6.30	Stone Arch (No Access)
83	46km844	2.00	4.30	Stone Masonry with Steel Deck and Ballast Packed
84	46km914	2.00	5.40	Stone Arch (1.00m Opening)
85	47km294	1.80	5.20	Stone Arch
86	47km704	2.00	4.80	Stone Arch
87	48km104	1.20	5.00	Concrete Box
88	48km204	3.50	3.60	Stone Masonry with Steel Deck and Ballast Packed
89	48km274	3.20	2.00	Steel Plate Girder Center Two Trough
90	49km084	-	7.60	Stone Arch (No Access)
91	49km144	3.50	5.30	Concrete Box
92	49km444	12.00	-	Stone Arch

No.	Chainage	Span (m)	Width (m)	Type of Structure
93	49km644	3.00	7.00	Stone Arch
94	50km144	1.60	4.20	Stone Arch
95	50km504	2.00	8.20	Stone Arch
96	50km744	2.00	4.20	Stone Masonry with Steel Deck and Ballast Packed
97	51km034	1.80	5.80	Concrete Deck and Ballast Packed
98	51km284	1.90	5.80	Stone Masonry with Steel Deck and Ballast Packed
99	51km534	1.80	3.90	Stone Masonry Drain Opening
100	51km924	1.80	3.90	Stone Masonry with Steel Deck and Ballast Packed
101	52km884	2.00	4.20	Concrete Deck and Ballast Packed
102	53km044	1.50	4.60	Stone Masonry with Steel Deck and Ballast Packed
103	53km194	1.60	3.90	Stone Masonry with Steel Deck and Ballast Packed
104	53km524	2.90	4.90	Stone Masonry with Steel Deck and Ballast Packed
105	54km694	2.00	5.30	Concrete Box
106	54km874	3.00	4.800	Concrete Box
107	54km944	2.80	4.00	Stone Masonry with Steel Deck and Ballast Packed
108	55km544	2.00	6.80	Stone Masonry with Steel Deck and Ballast Packed
109	55km744	1.50	4.10	Concrete Deck and Ballast Packed
110	56km564	3.00	6.80	Stone Masonry with Steel Deck and Ballast Packed
112	56km764	2.50	7.00	Stone Masonry with Steel Deck and Ballast Packed
113	58km564	2.00	7.00	Stone Masonry with Steel Deck and Ballast Packed
114	58km914	3.50	7.50	Concrete Deck and Ballast Packed

Rail Top (Concrete Abutments)

Rail Top with Center two troughs

Stone Arch

Stone Masonry

Figure 8-5 Existing Culvert Structures of Kelani Valley Line

Table 8-10 is showing other drainage structures that mostly drain across the Kelani Valley line.

Table 8-10 List of Existing Drainage Structures

No.	Chainage	Span (m)	Width (m)	Type of Structure
1	2+610	0.50	3.60	Cemented Drain
2	9+220	1.00	-	Steel Plate Girder Semi-Trough Span
3	9+310	0.30	-	Rectangular Concrete Drain
4	10+130	1.00	9.80	Concrete Deck and Ballast Packed
5	10+170	1.00	6.10	Concrete Deck and Ballast Packed
6	10+241	0.90	5.40	Hume Pipe
7	11+310	0.80	3.30	Cemented Drain
8	11+600	1.00	4.90	Cemented Drain
9	15+520	0.60	3.70	Stone Masonry with Steel Deck and Ballast Packed
10	17+190	0.50	5.70	Hume Pipe
11	17+255	0.60	6.10	Hume Pipe
12	17+415	1.00	6.10	Stone Arch
13	17+780	0.60	5.40	Hume Pipe
14	18+110	0.80	5.40	Concrete Drain
15	18+190	0.80	5.00	Stone Masonry with Steel Deck and Ballast Packed
16	18+500	1.00	-	Stone Arch
17	20+090	0.60	4.40	Stone Masonry with Steel Deck and Ballast Packed
18	20+400	0.60	7.40	Concrete Box
19	24+360	0.30	3.10	Cemented Drain
20	25+240	0.50	5.80	Hume Pipe
21	26+550	0.60	-	Hume Pipe
22	26+705	0.70	5.30	Hume Pipe
23	27+790	0.80	6.60	Hume Pipe
24	29+770	0.70	7.90	Concrete Box
25	32+500	0.60	4.30	Hume Pipe Culvert
26	39+694	0.50	4.40	Stone Masonry Drain
27	40+964	0.90	11.10	Stone Arch
28	41+454	0.50	3.80	Stone Masonry with Steel Deck and Ballast Packed
29	45+584	0.70	3.70	Stone Arch
30	46+464	0.60	5.30	Stone Masonry Drain
31	46+634	1.00	10.60	Stone Arch
32	47+964	0.50	3.80	Cemented Drain
33	49+314	0.50	9.10	Hume Pipe Culvert
34	50+804	0.50	3.60	Stone Masonry Drain
35	50+954	0.80	3.60	Stone Masonry Drain
36	51+594	0.40	3.40	Stone Masonry Drain
37	53+624	0.60	4.80	Concrete Drain
38	53+794	1.00	3.90	Concrete Deck and Ballast Packed
39	54+524	0.40	4.30	Stone Masonry Drain
40	54+584	0.40	4.20	Concrete Drain
41	55+904	0.40	3.50	Concrete Drain
42	56+224	0.50	6.80	Concrete Drain

No.	Chainage	Span (m)	Width (m)	Type of Structure
43	57+594	0.50	6.30	Hume Pipe
44	58+104	0.50	6.40	Concrete Drain
45	58+184	1.00	5.50	Stone Masonry with Steel Deck and Ballast Packed
46	58+324	1.00	5.30	Concrete Box


Concrete/Masonry Drain


Hume Pipe

Figure 8-6 Open Drain across the Railway Line

8.3.1.2 The Existing State of Subsidiary Facilities

(1) Bearing

Bearings are the critical part of a bridge. If they do not function as intended, structural damage may occur to the bridge structure. Bearings are requested to be periodically inspected and repaired for continuous maintenance. The recently built bridges are in good condition. In contrast, old bridges have inferior bearing performance and some bridges are damaged due to the heavy corrosion.


STA.5km 220 Plate Girder Bridge


STA.6km 410 Lattice Girder Bridge

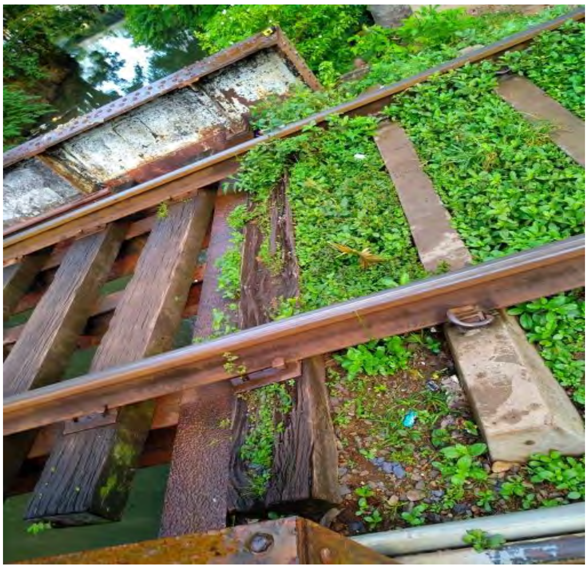
STA.38km 244 Plate Girder Dec Bridge

STA.34km160 Lattice Girder Bridge

Figure 8-7 Bearings of Existing Bridge Structures

(2) Expansion Joint

In the ballast system, the expansion joint is an essential component to provide the safety for train operation to avoid the displacement of girder and endpoint under temperature changes. Owing to the non-ballast system, existing bridges do not need an expansion joint. In the case of a flyover bridge at 17km020, it was found that the expansion joints were not installed.



STA.5km220 Plate Girder Bridge

STA.17km020 Flyover Bridge

Figure 8-8 Expansion Joint of Existing Bridge Structures

(3) Drain facilities

Most of the existing railway bridges have no drainage system due to the non-ballast system, and some bridges with deck plate type are drain off through the holes in the bottom of the deck plate. In the flyover bridge, drainage facilities are installed to drain of storm water.

STA.6km440 Plate Girder Bridge

STA.17km020 Flyover Bridge

Figure 8-9 Drain Facilities of Existing Bridge Structures

(4) Handrails and Walkways

Most of the existing bridges have handrails and walkways to use for maintenance works, and in some sections lots of corrosion and damage are encountered during the site inspection.

STA.6km410 Lattice Girder Bridge

STA.34km160 Lattice Girder Bridge

Figure 8-10 Handrails and Walkways of Existing Bridges

8.3.2 Utilization and Evaluation of Major Existing Bridges

8.3.2.1 Utilization Plan of Major Existing Bridges

When designing bridges for new railway lines, Design Loads, such as Ballast load, Slab load, Live load and etc., shall be considered. In the case of the existing bridges, securing the load carrying capacity may be difficult due to the increased weight. Moreover, due to the difference of durability between the existing, and newly established bridges, the situation such as the replacement of the existing bridges during operation, difficulties may occur. In this case, the operation of the KV Line will come to a halt. For these reasons, utilizing existing bridges for the newly established line is not recommended. Existing bridges can be utilized as the following.

Table 8-11 Measures to Utilize the Major Existing Bridges

Classification		Utilization Method	Remark
Bridge with serious damage		• Demolish and sell as scrap metal	
Bride in common Condition	Utilize as temporary bridge for construction	• Safety must be secured through strict structural evaluation	Shall be determined after thorough consultation with related stakeholders
	Utilize as pedestrian bridge	• Increase of convenience for neighboring residents • New alignment avoiding existing bridges must be designed, leading to the increase in ROW	
	Utilize as railway history monument	• Utilize as monument for promoting the history of Sri Lankan Railway • Relocate to other location	
	Demolish and sell as scrap metal	• When safety assurance is difficult and utilization method is nonexistent	

8.3.2.2 Evaluation of Major Existing Bridges

The change of design criteria has effect on existing bridges. And the existing bridges are evaluated for the following reasons: the change from a single track to double crack, increase of the design traffic load, life cycle and corrosion.

Table 8-12 Evaluation of Major Existing Bridges

No.	Chainage	Description	Span (m)	No. of Span	Total Length (m)	Evaluation	Remark
1	5km220	Railway Bridge	12.00	1	12.00	Demolishment	- Heavy Corrosion - Interference with new structure
2	6km410	Railway Bridge	30.40	2	51.40	Demolishment	- Heavy Corrosion - Interference with new structure
	6km440	Railway Bridge	21.00				
3	21km550	Overhead Bridge	25.00	1	25.00	Preservation	- Highway Bridge
4	26km100	Overhead Bridge	25.00	1	25.00	Preservation	- New Bridge (Under Construction)
56	30km010	Railway Bridge	14.15	1	14.15	Replacement	- Change from a single track to double track
7	34km160	Railway Bridge	19.25	2	38.50	Replacement	- Change from a single track to double track
8	36km634	Railway Bridge	18.10	1	18.10	Replacement	- Heavy Corrosion - Change of Design Criteria
9	36km754	Railway Bridge	13.65	2	27.30	Replacement	- Heavy Corrosion - Change of Design Criteria
10	38km244	Railway Bridge	6.45	2	12.90	Replacement	- Heavy Corrosion - Change of Design Criteria
11	42km044	Railway Bridge	10.20	1	10.20	Replacement	- Heavy Corrosion - Change of Design Criteria
12	43km784	Railway Bridge	30.10	1	30.10	Replacement	- Excess over Life Cycle

No.	Chainage	Description	Span (m)	No. of Span	Total Length (m)	Evaluation	Remark
13	45km064	Railway Bridge	18.00	1	18.00	Replacement	- Corrosion - Increase Design Traffic Load
14	50km324	Railway Bridge	13.10	1	13.10	Replacement	- Corrosion - Change of Design Criteria
15	54km184	Railway Bridge	30.10	2	60.20	Replacement	- Excess over Life Cycle
16	57km264	Railway Bridge	14.30	1	14.30	Replacement	- Heavy Corrosion - Change of Design Criteria
17	58km794	Railway Bridge	10.70	1	10.70	Replacement	- Corrosion - Change of Design Criteria

8.3.3 Bridge Type Selection

The detailed plan of the bridge is shown in Table 8-13 below.

Table 8-13 Railway bridge list

No.	Chainage	Plan Curve (m)	Slope (‰)	Type	Span Length (m)	Nos. of Span	Bridge Length (m)	Width(m)	Found -ation	Remark
1	0km 900	R=180	+12	Rahmen	10.0	17	170.0	10.9	Pile	
	1km 070	R=∞	+12	PSC	25.0	5	125.0	10.9	Pile	
	1km 195	R=210	+12	STB	40.0	2	80.0	10.9	Pile	4-Lane Road
	1km 275	R=210	+12	Rahmen	10.0	10	100.0	10.9	Pile	
	1km 375	R=∞	+12	PSC	25.0	5	125.0	10.9	Pile	
	1km 500	R=500, 300	-3	Rahmen	10.0	16	160.0	10.9	Pile	
	1km 690	R=300	-3	STB	50.0	1	50.0	10.9	Pile	6-Lane Road
	1km 740	R=300	-3	Rahmen	10.0	6	60.0	10.9	Pile	
	1km 800	R=∞	-3	PSC	25.0	8	200.0	20.5	Pile	Baseline Road Station
	2km 000	R=∞	-3	PSC	25.0	4	100.0	10.9	Pile	
	2km 100	R=400	-3	Rahmen	10.0	10	100.0	10.9	Pile	
	2km 200	R=∞	-3	PSC	25.0	6	150.0	10.9	Pile	
	2km 350	R=150, 200	-3	Rahmen	10.0	24	240.0	10.9	Pile	
	2km 790	R=200	-3	STB	40.0	1	40.0	10.9	Pile	4-Lane Road
	2km 830	R=200	-3	Rahmen	10.0	9	90.0	10.9	Pile	
	2km 920	R=∞	-3~+1	PSC	25.0	20	500.0	10.9	Pile	
	3km 420	R=150	+1	Rahmen	10.0	12	1200	10.9	Pile	
	3km 540	R=150	+1	STB	40.0	1	40.0	10.9	Pile	4-Lane Road
	3km 580	R=∞	+1	PSC	25.0	8	200.0	20.5	Pile	Cotta Road Station
	3km 780	R=∞, 700	+1	STB	50.0	1	50.0	10.9	Pile	6-Lane

No.	Chainage	Plan Curve (m)	Slope (‰)	Type	Span Length (m)	Nos. of Span	Bridge Length (m)	Width(m)	Found-ation	Remark
										Road
	3km 830	R=700	+1~-1	Rahmen	10.0	10	100.0	10.9	Pile	
	3km 930	R=∞	-1	PSC	25.0	11	275.0	10.9	Pile	
	4km 205	R=450	-1	Rahmen	10.0	26	260.0	10.9	Pile	
	4km 465	R=∞, 1100	-1~ +2~-1	PSC	25.0	29	725.0	10.9	Pile	
	5km 190	R=∞	-1	STB	50.0	1	50.0	10.9	Pile	River
	5km 240	R=250	-1	Rahmen	10.0	20	200.0	10.9	Pile	
	5km 440	R=∞	-1	PSC	25.0	8	200.0	20.5	Pile	Narahenp-ita Station
	5km 640	R=∞, 1500	-1	PSC	25.0	18	450.0	10.9	Pile	
	6km 090	R=∞	-1	STB	50.0	1	50.0	10.9	Pile	6-Lane Road
	6km 140	R=∞, 1500	-1~+1	PSC	25.0	9	225.0	20.5	Pile	
	6km 365	R=∞	+1	STB	50.0	2	100.0	10.9	Pile	River
	6km 465	R=∞	+1	PSC	25.0	3	75.0	10.9	Pile	
	6km 540	R=200	+1	Rahmen	10.0	30	300.0	10.9	Pile	
	6km 840	R=∞	+1	PSC	25.0	5	125.0	10.9	Pile	
	6km 965	R=160	+1	Rahmen	10.0	22	215.0	10.9	Pile	
	7km 180	R=∞	+1	PSC	25.0	8	200.0	20.5	Pile	Kirillpon-a Station
	7km 380	R=500, 450	+1	Rahmen	10.0	30	300.0	10.9	Pile	
	7km 680	R=∞	L	PSC	25.0	8	200.0	10.9	Pile	
	7km 880	R=∞, 150, 160, 250, 130	L	Rahmen	10.0	97	970.0	10.9	Pile	
	8km 850	R=130	L	Rahmen	10.0	8	80.0	32.7	Pile	Nugegod-a Station
	8km 930	R=130	L	STB	50.0	1	50.0	32.7	Pile	6-Lane Road
	8km 980	R=∞, 250	L~+2	Rahmen	10.0	36	360.0	32.7	Pile	Nugegod-a Station
	9km 340	R=250	+2	STB	40.0	1	40.0	10.9	Pile	4-Lane Road
	9km 380	R=∞, 2000	+2	PSC	25.0	24	600.0	10.9	Pile	
	9km 980	R=400	-2	Rahmen	10.0	30	295.0	10.9	Pile	
	10km 275	R=∞	-2	PSC	25.0	5	125.0	10.9	Pile	
	10km 400	R=∞	-2	PSC	25.0	8	200.0	20.5	Pile	Pangiriw-atta Station
	10km 600	R=550	-2~+4	Rahmen	10.0	48	480.0	10.9	Pile	
	11km 080	R=∞	+4	PSC	25.0	8	200.0	10.9	Pile	
	11km 280	R=400	+4	Rahmen	10.0	10	00.0	10.9	Pile	

No.	Chainage	Plan Curve (m)	Slope (‰)	Type	Span Length (m)	Nos. of Span	Bridge Length (m)	Width(m)	Found-ation	Remark
	11km 380	R=∞	+4	PSC	25.0	8	200.0	20.5	Pile	Udahamu-lla Station
	11km 580	R=250	+4	Rahmen	10.0	7	70.0	10.9	Pile	
	11km 650	R=∞	+4	PSC	25.0	4	100.0	10.9	Pile	
	11km 750	R=∞, 200, 230	+4~+5	Rahmen	10.0	66	660.0	10.9	Pile	
	12km 410	R=∞	+5	PSC	25.0	7	175.0	10.9	Pile	
	12km 585	R=∞, 150, 155	+5~-2	Rahmen	10.0	50	495.0	10.9	Pile	
	13km 080	R=∞, 155, 200	-2	Rahmen	10.0	20	200.0	20.5	Pile	Nawinna Station
	13km 280	R=∞, 200, 150, 160	+8	Rahmen	10.0	38	380.0	10.9	Pile	
	13km 660	R=∞, 1200	+8	PSC	25.0	17	425.0	10.9	Pile	
	14km 085	R=∞, 1200, 400	+8~-7	Rahmen	10.0	51	505.0	32.7	Pile	Maharag-ama Station
	14km 590	R=350	-7	Rahmen	10.0	11	110.0	10.9	Pile	
	14km 700	R=∞	-7	PSC	25.0	4	100.0	10.9	Pile	
	14km 800	R=250	-7	Rahmen	10.0	15	150.0	10.9	Pile	
	14km 950	R=∞	-7	PSC	25.0	10	250.0	10.9	Pile	
	15km 200	R=250	-7	Rahmen	10.0	20	200.0	10.9	Pile	
	15km 400	R=∞	-7	PSC	25.0	4	100.0	10.9	Pile	
	15km 500	R=∞, 130, 200	-7~-1	Rahmen	10.0	30	300.0	10.9	Pile	
	15km 800	R=∞	-1	PSC	25.0	4	100.0	10.9	Pile	
	15km 900	R=∞	-1	PSC	25.0	8	200.0	10.9	Pile	NEW02 Station
	16km 100	R=∞, 400, 200	-1	Rahmen	10.0	28	280.0	10.9	Pile	
	SUM						16,230.0			
2	17km 200	R=∞, 200, 125, 120	+12~ +2.5~-2	Rahmen	10.0	121	1,210	10.9	Pile	
	18km 410	R=∞	-2	PSC	25.0	5	125.0	10.9	Pile	
	18km 535	R=∞, 120, 130, 150	-2~+6	Rahmen	10.0	76	760.0	10.9	Pile	
	19km 295	R=∞	+6	PSC	25.0	5	125.0	10.9	Pile	
	19km 420	R=∞	+6	PSC	25.0	8	200.0	20.5	Pile	Kottawa Station
	19km 620	R=∞	-12	PSC	25.0	10	250.0	10.9	Pile	
	SUM						2,670.0			

No.	Chainage	Plan Curve (m)	Slope (‰)	Type	Span Length (m)	Nos. of Span	Bridge Length (m)	Width(m)	Found-ation	Remark
3	29km 861	R=∞	+8	Rahmen	8.0	2	16.0	10.9	Pile	Stream
4	30km 014	R=∞	+8	Rahmen	10.0	1	20.0	10.9	Pile	Stream
5	33km 911	R=∞	+9	STB	40.0	1	40.0	10.9	Pile	River
6	36km 300	R=∞	+1	STB	50.0	1	50.0	6.0	Pile	River
7	41km 644	R=∞	-8	Rahmen	10.0	1	10.0	20.5	Pile	Stream, Molakele Station
8	41km 781	R=∞	-8	Rahmen	10.0	1	10.0	20.5	Pile	Stream, Molakele Station
9	43km 336	R=∞	-10	STB	40.0	1	40.0	6.0	Pile	River
10	44km 637	R=∞	-8	PSC	25.0	1	25.0	6.0	Pile	Stream
11	49km 843	R=∞	+3	Rahmen	10.0	2	20.0	6.0	Pile	Stream
12	53km 692	R=∞	+2	STB	40.0	2	80.0	6.0	Pile	River
13	54km 720	R=∞	-2	PSC	25.0	1	25.0	6.0	Pile	Stream
Total Sum							**19,236.0**			

8.3.4 Culvert

Culvert structures are mainly used to satisfy the two purposes. Those are as a drainage structures and give-way structures (underpass structures) to build-up the facility of travelling vehicles through the structure when the railway line goes top of the culvert. The typical dimensions of the culvert structures for road are given in below. Figure 8-11, represents the cross section details of a typical culvert structures proposed for the KV line.

Cross Section of Culvert

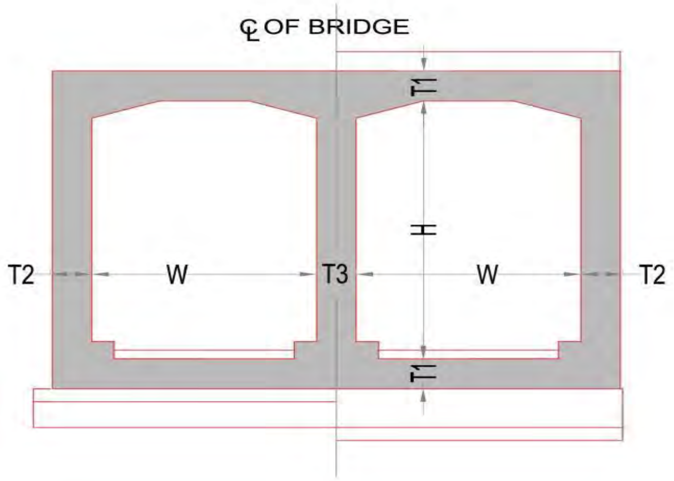


Figure 8-11 Typical Cross section of Culvert for Road and Waterway

The Minimum size of box culvert is suggested as follows

- Main Road Crossing Culvert

- Inner height (H): 4.5m ~ 5.1m (according to the road class)
- Width (W): 4.0m ~ 6.0m (2cell)
- The minimum covered depth (fill): 0m (recommended over 1m)
- Number of cell: 2cell (Double Box)

- Water Culvert
  - Inner height (H): 2.0 ~ 3.0m
  - Width (W): 2.0 ~ 3.0m
  - The minimum covered depth (fill): over 1m
  - Number of cell: 1 ~ 3 cell

The following requirements shall be considered when planning culvert as main factors (Table 8-14).

Table 8-14 Main Factors and Considerable Items of Planning a Culvert

Main Factors	Considerable Item
Regulation, rule, specification, design standard	Latest relevant regulation, specification and applying the standard
Composition of cross sections	Structure stability, economic feasibility and constructability
Composition of crossing	Estimation of gradient in surface of slope according to stability review in surface of slope
Minimization of earthwork-volume	Minimization of earthwork-volume in alignment plan
Minimization of environmental damage	Minimization of social complaint and selection of right type per section
Drainage system	Minimization of maintenance and planning the drainage structure

The consultant suggests an optimal culvert type and size in consideration of purpose of use, site conditions, inner section, size, ground foundation conditions, constructability, economic feasibility and maintenance. Analytical model of structure shall be idealized according to the model which is capable of interpreting structure differences by ground foundation on the bearing for both ground and rock site. For proper drainage of existing water flows, culverts for waterway (channel) shall be planned. The location and width and height for each culvert shall be finalized by site survey and by collected data. Minimum skew angle shall be decided to 45degree by rearranged the waterways, to avoid extra-long water way culverts regarding construction cost and maintenance ability.

8.3.5 Flyover Bridge

The passage of railways cuts off traffic to both areas. It is essential to keep the function of existing road to ensure the passage of vehicles and people. Thus, the consultant proposes to change the existing major level crossing to the fly over bridges where the ADT is over 20,000 or main road.

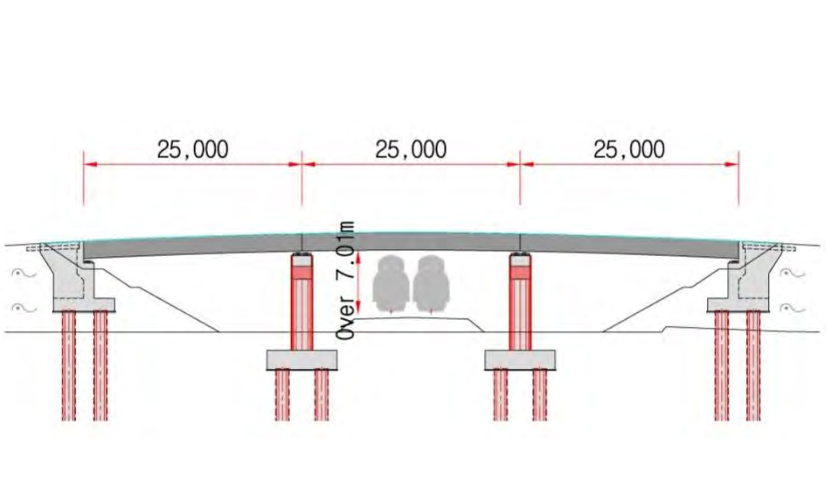
The following requirements tabulated in Table 8-15 shall be considered when planning fly-over bridges.

Table 8-15 Main Factors and Considerable Items of Planning a Flyover Bridge

Main Factors	Considerable Item
Regulation, rule, specification, design standard	Latest relevant regulation, specification and applying the standard
Current Status	Surveying on the functions provided by the roads, the features of the existing road and the terrain, the traffic volume, width of the road, geopolitical feature and etc.
Road Plan	Geometric design is carried out in consideration of traffic volume and future road plans.
Bridge Plan	Type of bridge, such as type of superstructure, substructure and foundation, shall be proposed in consideration of site conditions, ground foundation conditions, constructability, economic feasibility, maintenance and drainage.
Secure the Clearance	Ensuring clearance of 7.01m or more from R.L. in case of installing overhead trolley line
Selection of the Pavement Type	Generally, the road pavement includes asphalt concrete pavement and concrete pavement. The pavement type is selected considering environment, traffic, soil condition, economical efficiency, construction ability, and maintenance.
Minimization of environmental damage	Minimization of social complaint and selection of right type per section

The consultant suggests typical cross section of two-lane bridge and securing space between soffit of the bridge and railway line. The consultant suggests the typical bridge type of PSC Girder with 25m single span in consideration of constructability, maintenance and economic feasibility.

<Longitudinal Section and Clearance>



<Cross Section>

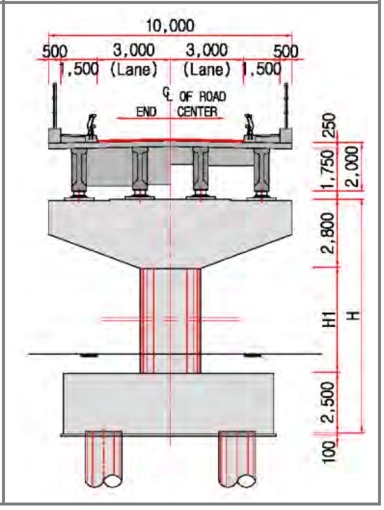


Figure 8-12 Typical Flyover Bridge

The detailed plan of the fly over bridge is shown as follows.

Table 8-16 Flyover bridge list

No.	Fly Over Name	Chainage (Cross Point)	Span Arrangement	Bridge Length (m)	Type of Superstructure	Width (m)	Type of Foundation	Remark
1	FO1	24km 380.00	25.0m x 12	300	PSC	8	Pile	
2	FO2	34km 660.00	25.0m x 12	300	PSC	8	Pile	
3	FO3	35km 080.00	25.0m x 18	450	PSC	10	Pile	
4	FO4	37km 730.00	25.0m x 12	300	PSC	8	Pile	
5	FO5	52km 620.00	25.0m x 12	300	PSC	6	Pile	
6	FO6	54km 410.00	25.0m x 12	300	PSC	6	Pile	
7	FO7	54km 920.00	25.0m x 12	300	PSC	6	Pile	
8	FO8	56km 130.00	25.0m x 12	300	PSC	6	Pile	

8.3.6 Structure Design

8.3.6.1 Superstructure Design

(1) PSC-I Girder Design

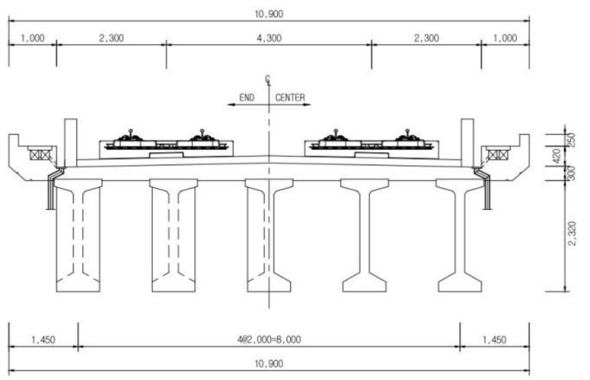
Material Specifications

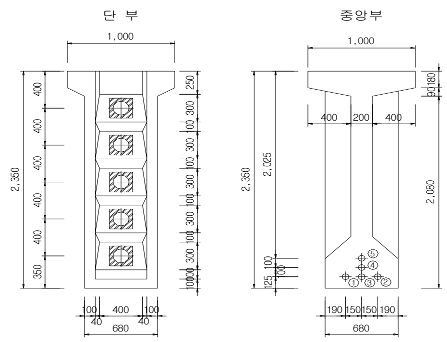
Concrete			PS Steel	SWPC 7B φ12.7×10EA
	Molds	f_{ck} =40 MPa		
	Slabs	f_{ck}= 30 MPa		

I. Structure Review Summary

Bridges Width	B = 10.9m	Horizontal Alignment	R = straight

Cross-section



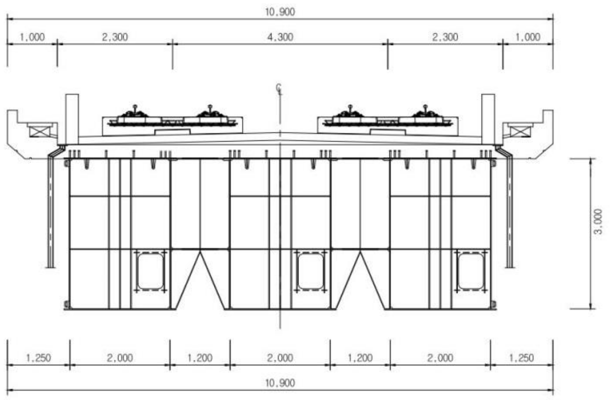


Slab section review		Category	Cantilever portion	Intermediate portion	Cantilever portion (main train section)
	$M_n, \varphi M_n$ (KN.m)		36.6 < 99.9	87.0 < 99.9	86.7< 141.0
	As (㎜²)	Req'd	770.0	1143.0	1,138.8
		Used	H16 @ 150 = 1,324.0	H16 @ 150 = 1,324.0	H19 @ 150 = 1,910.0

Girder Section Review	Category (MPa)	Immediately after prestressing		Working load during operation			Remarks
		Girder top edge	Girder lower edge	Floor top surface	Girder stage	Girder lower edge	
	An inner girder	-0.85	14.13	3.87	4.90	1.66	G3
	Outer girder	-0.85	14.13	4.87	6.14	0.31	G1
	Allowable stress	-1.41	17.60	12.00	16.00	0.00	(-) Tension (+) Compression

Sag	Dead load	Live load	Sum	Allow deflection	Remarks
	-	6.73mm	6.73mm	17.1mm (L / 1,400)	

(2) ST BOX Girder Design

Bridges width	B = 10.9m	Curvature		R = straight
Cross-section		Slope		S = -5‰
		steel		HSB500L
		Section Specification	absence	standard
			Top Fr.	2240 × 28
			Web	3000 × 16
			Lower Fr.	2240 × 34

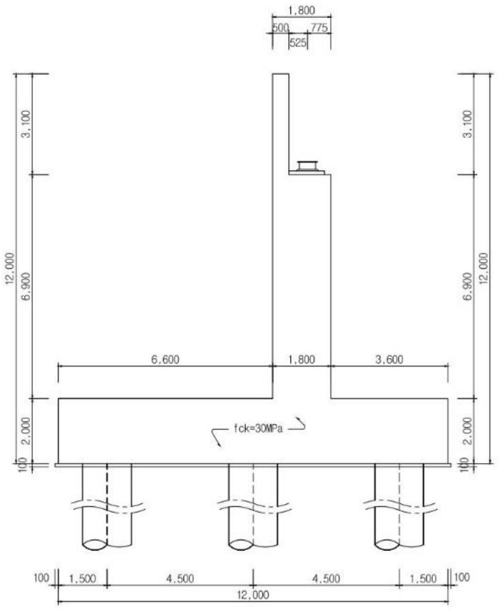
Slab section review	Category		Cantilever portion	Intermediate portion	Cantilever portion (main train section)
	$M_n, \varphi M_n$ (KN.m)		31.8 < 99.9	85.8 < 99.9	54.3 < 99.9
	As (㎟)	Req'd	770.0	1,198.7	770.0
		Used	H16 @ 150 = 1,324	H16 @ 150 = 1,324	H16 @ 150 = 1,324

Section review	Category (MPa)			Bending stress	Shear	Synthesis stress	Allowable stress	Remarks
	Main load combination	Decks	Top	-3.75 / 12.00	-	-	12.0	G1 (a central portion) Tension + - Compression
			Bottom	-2.54 / 12.00	-	-	12.0	
		Steels	Top	-145.71 / 230.0	6.74 / 130	0.64 / 1.2	230.0	
			Bottom	168.18 / 230.0		0.73 / 1.2	230.0	
	Temperature load combination	Decks	Top	-4.93 / 13.80	-	-	13.8	
			Bottom	-3.94 / 13.80	-	-	13.8	
		Steels	Performances	-160.05 / 264.5	6.74 / 149.50	0.61 / 1.2	264.5	
			The lower edge	170.91 / 264.5		0.65 / 1.2	264.5	

Sag	Dead load	Live load	Sum	Allow deflection	Remarks
	-	17.2mm	17.2mm	24.4mm (L / 2,000)	G1

8.3.6.2 Substructure Design

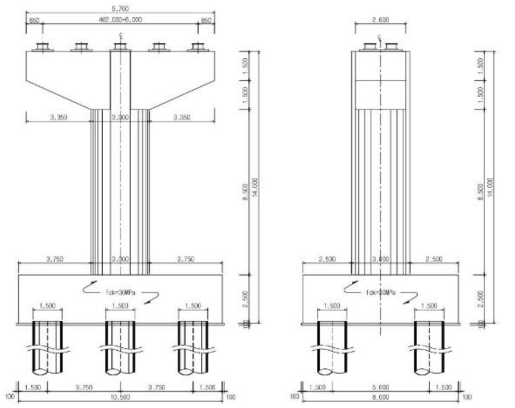
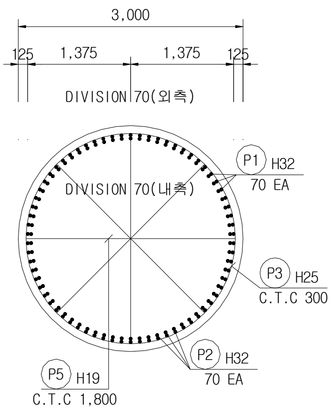
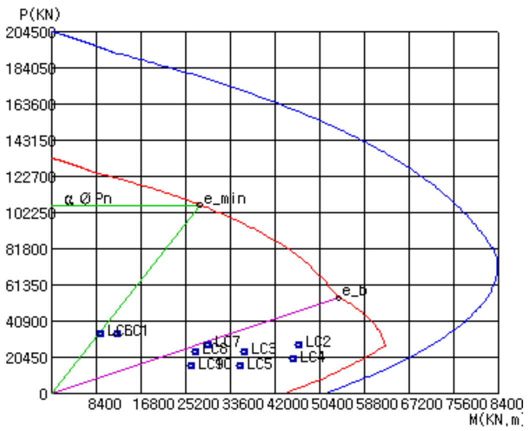
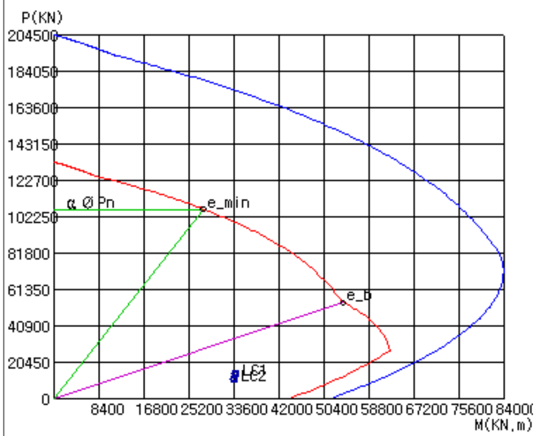
(1) Abutment

<table>
<tr><th>Abutment type</th><th colspan="2">Reverse-T-type</th><th>Superstructure type</th><th colspan="2">PSC BEAM</th><th>Foundation type</th><th colspan="2">File basics</th></tr>
<tr><td rowspan="10">Cross section</td><td colspan="3" rowspan="10">
</td><td rowspan="10">Design overview</td><td rowspan="3">Top Reaction force</td><td colspan="3">R_D = 11,241 kN</td></tr>
<tr><td colspan="3">R_L = 6,972 kN</td></tr>
<tr><td colspan="3">ΣR_{D+L} = 18,213 kN</td></tr>
<tr><td rowspan="2">weight</td><td>Ballast</td><td colspan="2">q_d = 15 kN /㎡</td></tr>
<tr><td>Live load</td><td colspan="2">q_{LS} = 28kN /㎡</td></tr>
<tr><td rowspan="2">Backfill material</td><td>Unit weight</td><td colspan="2">20 kN /㎥</td></tr>
<tr><td>friction angle</td><td colspan="2">35°</td></tr>
<tr><td rowspan="3">Soil pressure coefficient</td><td>Stability</td><td colspan="2">0.271</td></tr>
<tr><td rowspan="2">For section calculation</td><td>Normal</td><td>0.251</td></tr>
<tr><td>EQ</td><td>0.323</td></tr>
</table>

<table>
<tr><td rowspan="3">Stability Review</td><td colspan="2">Reaction force due to normal loading (pile)</td><td colspan="2">Reaction force due to seismic loading (pile)</td></tr>
<tr><td>Max vertical force (KN /pile)</td><td>Allowable bearing capacity (KN /pile)</td><td>Max vertical force (KN/pile)</td><td>Allowable bearing capacity (KN /pile)</td></tr>
<tr><td>7,338</td><td>7,614</td><td>10,728</td><td>11,418</td></tr>
</table>

<table>
<tr><td rowspan="5">Section review</td><td>Category</td><td>Parapet wall</td><td>wall</td><td>Toe</td><td>Heel</td><td>Wing wall</td></tr>
<tr><td>$M_u, \varphi M_n$</td><td>81 <222</td><td>3481 <3792</td><td>1996 <3903</td><td>2952 <4015</td><td>1285 <1942</td></tr>
<tr><td>A_s (mm^2)</td><td>H16 @ 125-1-layer= 2,805</td><td>H22 @ 125-2- layer = 6,193</td><td>H22 @ 125-2-layer= 6,193</td><td>H22 @ 125-2-layer = 6,193</td><td>H32 @ 125-1-layer = 6,354</td></tr>
<tr><td>$S_u, \varphi S_n$</td><td>68 < 310</td><td>637 <1358</td><td>1830 <2369</td><td>710 <1435</td><td>588 <698</td></tr>
<tr><td>A_s (mm^2)</td><td>-</td><td>-</td><td>H16-2EA
s = 250mm</td><td>-</td><td>-</td></tr>
</table>

(2) Pier

<table>
<tr><th colspan="3">Superstructure type</th><th colspan="2">PSC 25.0</th><th colspan="2">Foundation type</th><th colspan="2">Pile Foundation</th></tr>
<tr><td>Pier type</td><td colspan="4">T type</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Pillar</td><td colspan="4">Normal</td><td colspan="4">Seismic (elastic)</td></tr>
<tr><td colspan="2">Axial (KN)</td><td colspan="2">Moment (KN.m)</td><td colspan="2">Axial(KN)</td><td colspan="2">Moment (KN.m)</td></tr>
<tr><td>effort</td><td colspan="2">33,484</td><td colspan="2">39,990</td><td colspan="2">13,907</td><td colspan="2">29,826</td></tr>
<tr><td>Typical structural section and reinforcement diagram</td><td colspan="4"></td><td colspan="4">
</td></tr>
<tr><td>Force Moment diagram</td><td colspan="4">
</td><td colspan="4">
</td></tr>
<tr><td>Review of results</td><td colspan="4">φP_n= 53,775 kN, φM_n= 53,920 kN · m</td><td colspan="4">φM_n= 26,504 kN, φM_n= 92,864 kN · m</td></tr>
<tr><td rowspan="3">Section review</td><td>Category</td><td colspan="2">$M_u, \varphi M_n$</td><td colspan="2">A_s (mm^2)</td><td colspan="2">A_s (mm^2)</td><td>$S_u, \varphi S_n$</td></tr>
<tr><td>Copping</td><td colspan="2">22,591 <35,877</td><td colspan="2">H25-25EA-3 layer = 38,002</td><td colspan="2">H29 @ 125-2only+ H25 @ 125-1layer = 39,413</td><td>12,514 <15,468</td></tr>
<tr><td>Foundation</td><td colspan="2">4554 <6,283</td><td colspan="2">H25 @ 125 + H25 @ 125 =8,107</td><td colspan="2">H25 @ 125-2 layer = 8,107</td><td>1385 <1,526</td></tr>
<tr><td rowspan="3">Stability review</td><td colspan="4">Pile reaction for normal loading</td><td colspan="4">Pile reaction due to seismic loading</td></tr>
<tr><td colspan="2">Acting force (KN / m²)</td><td colspan="2">Allowable force (KN / m²)</td><td colspan="2">Acting force (KN / m²)</td><td colspan="2">Allowable force (KN / m²)</td></tr>
<tr><td colspan="2">599</td><td colspan="2">700</td><td colspan="2">579</td><td colspan="2">4,411</td></tr>
</table>

CHAPTER

9

Track Design

Chapter 9 Track Design

Chapter Summary

- Train Operation Plan and No. of Train Sets.
  - Maximum passenger ridership section is between Kirillapona station and Nugegoda station.

    For year 2025, Maradana~Makumbura North section is 18,405 PPHPD, frequency of train is 7.0 min. Makumbura North~Padukka section is 8,036 PPHPD, frequency of train is 14 min.

    No. of Rolling Stock is 20 EMU train sets. For year 2035, Maradana~Makumbura North section is 20,973 PPHPD, frequency of train is 7.0 min. Makumbura North~Padukka section is 8.877 PPHPD, frequency of train is 14.0 min. No. of Rolling Stock is 20 EMU train sets. And then Padukka~Avissawella section will be operate single line by DMU till final phase. This section is 3,314 PPHDP, frequency of train 30.0 min, No. of Rolling Stock 4 DMU train sets for year 2025. For final target year 2035, this section is 4,826 PPHDP, frequency of train 30.0 min, No. of Rolling Stock 4 DMU train sets.
- Track Layout Plan
  - Track Layout Plan considered the following:
    - Smooth Operation of Train Operation/ Mixed Operation of Express and Slow Train
    - Turn back Operation of Start and Terminal station/ Mid-Turn back Operation
    - Connection with other railway lines and other Transportations
    - Train Parking at the end of Train Operation/ Emergency Parking.: Installed turn out
- Track Material
  - Rails : Main Track-UIC 60 kg, Side Track/ Single : 52kg/m
  - Sleepers: PC sleeper, Main Track- space 600 mm, Side Track- space 650 mm.
  - Turn Out: Main Track -12#, Side Track -8.5#.
- Track Structure Type : Ballasted type
  - Factors affecting this decision are initial investment costs, long-term maintenance costs and ease of construction work/ maintenance.

9.1 Introduction

9.1.1 Outline of Track in KV Line

- The KV line has a number of sharp curves with radius less than 200 m, because this line was built as a narrow gauge for the purpose of rubber plantations and upgraded to a broad gauge in 1996.
- Track component is aged and track maintenance is very poor and bad elasticity. All three types of sleepers, Wooden, Steel and PSC were in use, however, there is not enough gravel under sleepers and insufficient in ballast thickness.

9.1.2 Existing Facilities

- All three types of sleepers (Wooden, Steel and PC) were in use. Sleeper span is 600 mm ~ 700 mm.
- Two types of rails are 80lb and 88lb. The fastener is two types, dog spike in wooden sleeper and Pandrol clip in PC and Steel sleepers. Track fasteners were missing, for every PC sleeper against 4 pandrol clips, only 2 were found to secure the rails. Insufficient gravel under sleepers and insufficient ballast thickness has been identified. Track maintenance is very poor, which has led to the bad elasticity of the aged track components.

Wooden Sleeper	**PC sleeper**	**Steel Sleeper**
		

Figure 9-1 Track Condition in Main line and Stations

9.1.3 Depot and Workshop

- There is not enough gravel under sleepers and ballast thickness is insufficient.
- Poor drainage has deteriorated the track by sleeper damage and water intrusion in to the ballast.

Track maintenance is very poor and bad elasticity in Maradana, Maligawatte, Dematogoda and Ratmalana. Track components are aged and reduced permanency due to contamination.

Figure 9-2 Track condition in depots and workshop

9.2 Operation and Track Layout

9.2.1 Train Operation Plan and No. of Train Sets

Table 9-1 For Year 2025

Section	Length (km)	PPHPD*	Train Capacity (person)	Frequency of Train (min)	Commercial Speed(km/h)	No. of Rolling Stock
Maradana ~ Makumbura North	21.7	18,405	1,988(150%)	7.0	34.7	20 EMU Sets (17+3)
Makumbura North ~ Padukka	13.02	8,036		14		

Table 9-2 For Year 2035

Section	Length (km)	PPHPD*	Train Capacity (person)	Headway (min)	Commercial Speed(km/h)	No. of Rolling Stock
Maradana ~ Makumbura North	21.7	20,973	2,404(150%)	7.0	34.7	20 EMU Sets (17+3)
Makumbura North ~ Padukka	13.02	8,877		14		

* PPHPD – Passengers per Hour per Direction

- Maximum Passenger Ridership Section: Kirillapone station and Nugegoda Station
- Train units: 10-cars trainsets EMU (1,988 person/trainset), 12-cars trainsets EMU (2,404 person/trainsets).
- Spare Rolling stock at Maintenance and Emergency: 15%
- Padukka ~ Avissawella: The existing train (DMU) will Operate single line till final phase

* The Frequency of Train and Nos. of Rolling Stock can be adjusted according to the operation plan.

9.2.2 Track Layout Plan for KV Line

- Background.

  -Smooth Operation of Train Operation/ Slow Train

  -Turn back Operation of Start and Terminal station/ Mid-Turn back Operation

  -Connection with other railway lines and other Transportations

  -Train Parking at the end of Train Operation/ Emergency Parking.

- Track Layout

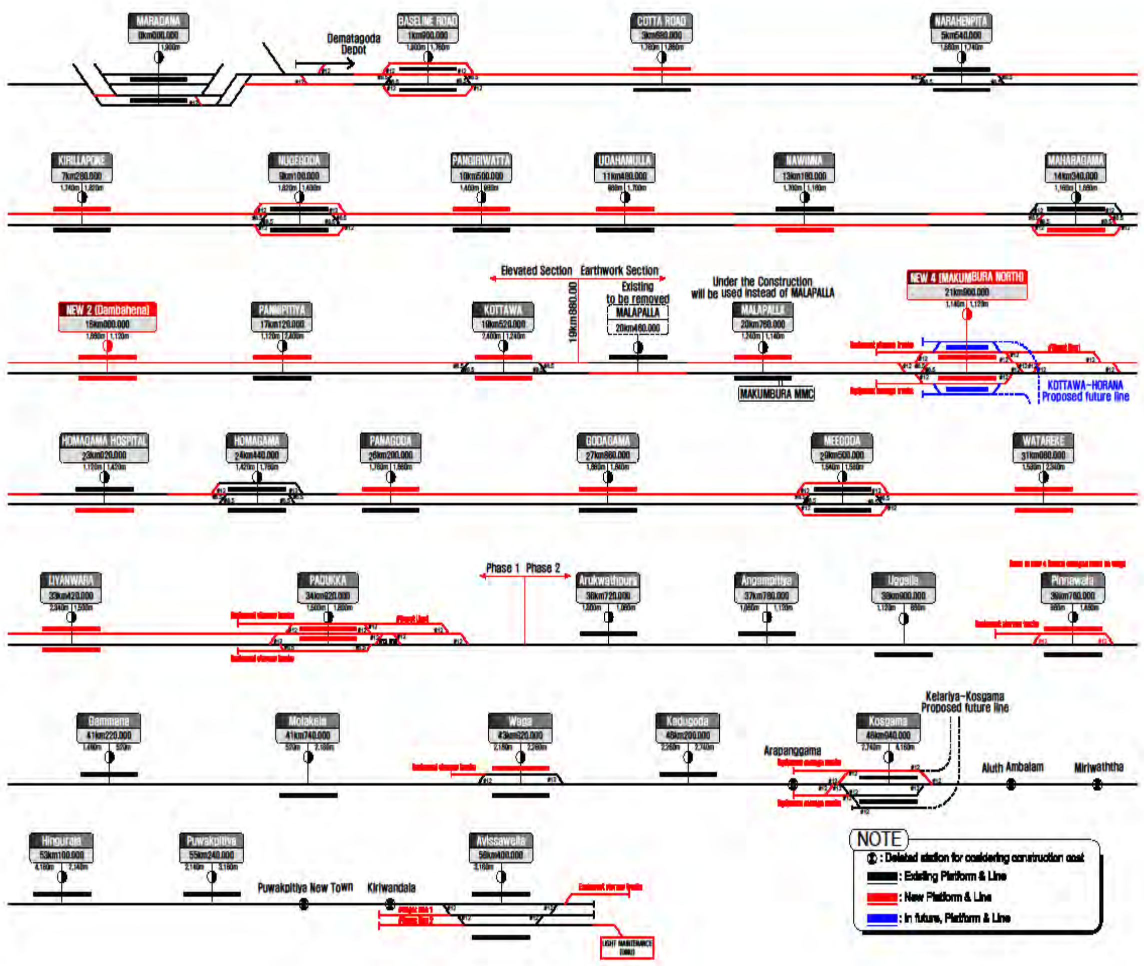


Figure 9-3 Track Layout

*It is preferable to install the terminal station in the Malapalla station considering the connection with other railway lines and other means of transportation. However since the rear part of Malapalla station has a steep curve, Terminal station is planned in the next station (Makumbura North Station).

* Track Layout Plan can be adjusted according to the train operation plan and alignment/ structure plan.

9.3 Track Material Criteria

9.3.1 Rails

Table 9-3 Design Criterions of Rails

Classification	Criteria
(1) Ordinary rail	• Main line: UIC 60 kg • Side line/ Single: 52kg/m • Length of 1 rail : L=25.0 m
(2) Hardened rail	• Principle main track and subsidiary main track: Using R350HT in the section of R<800 m. - Within the section of R≦500 m in main track, inner rail, outer rail and turnout rail - Outer rail in the section of 501 m ≦R<800 m at main track
(3) Insulation rail	• Right angle glued-insulation rail • UIC 60 kg/m, L=25.0 m • 52 kg/m, L= 25 m • The number of using the insulation rail can be referred on the track circuit map of signal part.
(4) Compromise rail	• Connecting section of UIC 60 kg rail with 54EI rail • Length of 1 rail : L= more than 10.0 m

9.3.2 Rail Fastener

Table 9-4 Design Criterions of Rail fastener

Classification	Criteria
(1) PC sleeper	• Pandrol e-clip as double elastic fastening device
(2) Inspection pit section	• H-beam fastening device
(3) PC sleeper for joint	• Joint fastening device for PCT
(4) PC sleeper for insulted joint	• insulted joint fastening device for PCT

9.3.3 Sleepers

Table 9-5 Design Criterions of Sleepers

Classification	Criteria		
(1) Standard	(width)×(thickness)×(length)		
a) PC sleeper	• 250 × 210 × 2750 mm		
b) PC sleeper for joint	• 260 × 210 × 2750 mm		
c) PC sleeper for insulted joint	• 260 × 210 × 2750 mm		
d) Switch PC sleeper	• 260 × 210 × 2750~ 4900 mm		
e)PC sleeper for expansion joint device	• 260 × 210 × 2950 mm		
(2) Number of PC sleeper layout (for every 1 km)	Section	Main track	Side track
	Gravel ballast	1,660 ea/km (S=600 mm)	1,540 ea/km (S=650 mm)

9.3.4 Turnout

Table 9-6 Turnout

Classification	Criteria
Standard (1) Main track (2) Side track/Single	• UIC 60 kg of turnout (manganese crossing, for PCT) • 52kg/m of turnout (manganese crossing, for PCT)
Criteria of installation (1) Main track and crossover (2) Side track	• More than 12# • More than 8.5#

9.3.5 C.W.R and Longer Rails

Table 9-7 C.W.R and Longer rail

Classification	Criteria
1) Section	
a) C.W.R	• R≥300 m of curve in the main track
b) Longer rail	• R<300 m of curve in the main track and subsidiary

9.4. Track Structure Plan

9.4.1 Track Design Requirement

9.4.1.1 General Conditions

- Consideration of track safety, cost efficiency, maintainability and constructability
- Material compatibility with neighboring section of the same route
- Track structure which is adjustable for minor modification during installation or operation
- Suggestion of maintenance method when adopting special track structure

9.4.1.2 Major requirements

- Compatibility with other disciplines (civil work, signaling, electrical & communication)
- Ballast track over entire route, irrespective of track spacing
- Plus 30% of ballast for at-grade section
- A simple and rigid fastening force and elastic material for rail fastener
- Other safety facilities including rail sign post and buffer stop

9.4.2 Comparison review of Ballasted and Non-ballasted (Slab) Track

The ballasted bed type consist layer of loose, coarse grained material which can absorb considerable compressive stresses as a result of internal friction between the grains, but not tensile stresses. The bearing strength of the ballast bed in the vertical direction is considerable, but in the lateral direction it is clearly reduced. Although most of the current railway tracks are still using traditional ballasted track, recent applications shows higher use of non-ballasted type. The major advantages of non-ballasted (slab) track are low maintenance, high availability, low structure height, and low weight. But, Concrete Slab use ready mixed concrete car during construction, it might be very difficult to construct the concrete slab track. And then, it might be very difficult to maintain concrete slab crack and subsidence caused by the difference of the extension length between bridge and concrete slab. In the case of soft ground, it takes a lot of maintenance cost when it subsides and maintenance is very difficult. Also, construction period is more than 6 months longer than the Ballasted track type.

Table 9-8 Advantages and disadvantages of ballasted and non-ballasted (Slab)track

Items	Ballasted Track	Non-ballasted(Slab) track
View of the track		

Items	Ballasted Track	Non-ballasted(Slab) track
Advantages	• Proven technology; • Relatively low construction cost • (2.0 billion USD/double, km, In Korea) • Simple replacement of track components • Relatively simple correction of track geometry • Good drainage properties • Good elasticity • Good damping of noise	• The track is maintenance free. • Maintenance work like tamping, ballast cleaning is not necessary • Maintenance costs are less than • ballasted track • Increased service life
Dis-advantages	• Pollution of the ballast grains in the ballast bed resulting in particles damaging the rail and wheels; • Reduced permeability due to contamination, the wear of the ballast and intrusion of the fine from subgrade.	• Higher construction costs • (3.0 billion USD/double, km, In Korea) • Higher airborne noise reflection; • In case of derailment, repair works will take much more time and effort • In the case of soft ground, it takes a lot of maintenance cost when it subsides and maintenance is very difficult. • Use ready mixed concrete car during construction, it might be very difficult to construct the concrete slab track. • And then, it might be very difficult to maintain concrete slab crack and subsidence caused by the difference of the extension length between bridge and concrete slab. • Construction period is more than 6 months longer than the Ballasted track type.

9.4.3 Track Structure Plan

In this section, track type and design criterions for the modernization of KV line are illustrated. In general, ballasted and non-ballasted, both will be placed in consideration for the specified section of the KV line. Crucial design criterions on rail, C.W.R. (Continuous Welded Rail), rail fastener, sleeper and turnout are presented herein. Finally, Option study is carried out to determine the best solution among different types of option. Different types of options include mainly the type of track like ballasted or non-ballasted, on elevated/ Tunnel, at grade.

9.4.3.1 Typical Cross-section of Tracks

In this section, the design specifications of different typical cross-section of tracks are illustrated. For KV line, any of the following standard section or a combined approach can be selected for any part of the full length of KV line.

(1) Standard of Ballasted Double Track on Earth Work

- Track spacing: 4.0 m, Rail: UIC 60, Sleeper: PC sleeper(L=2750 mm)
- Ballast depth: minimum 300 mm, Ballast slope: 1:1.6

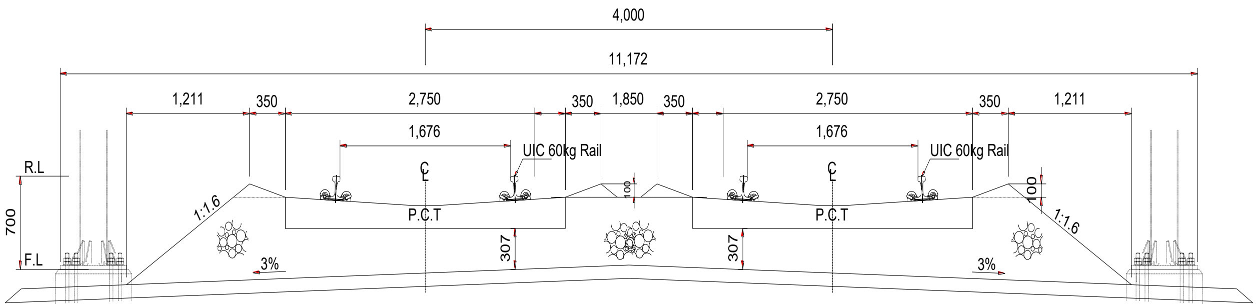


Figure 9-4 Cross-section of Ballasted Double Track on Earth Work

(2) Standard of Non-ballasted (Slab) Double Track on Earth Work

- Track spacing: 4.0 m, Rail: UIC 60, Sleeper: Twin-block sleeper
- Dimension of Track Concrete Layer: width 3000 mm, thickness 240 mm
- Dimension of Hydraulically Bonded Layer: width 3600 mm, thickness 300 mm

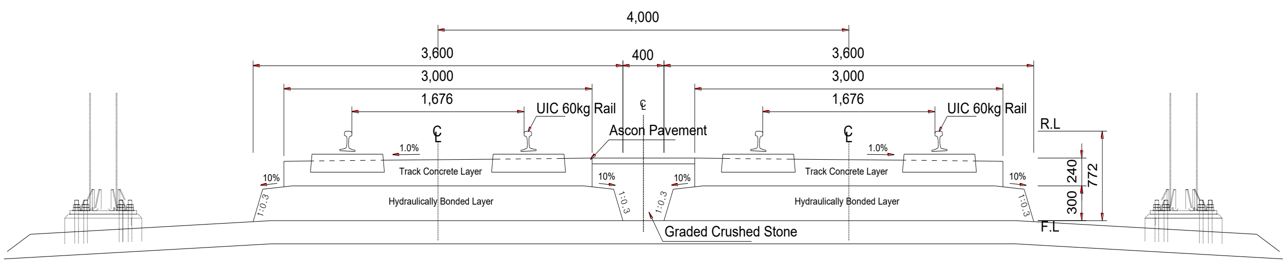


Figure 9-5 Cross-section of Non-Ballasted (Slab) Double Track on Earth Work

(3) Standard of Ballasted Double Track on Elevated/Tunnel

- Track spacing: 4.0 m,
- Rail: UIC 60,
- Sleeper: PC sleeper(L=2750 mm)
- Ballast depth: minimum 300 mm,
- Ballast slope: 1:1.6

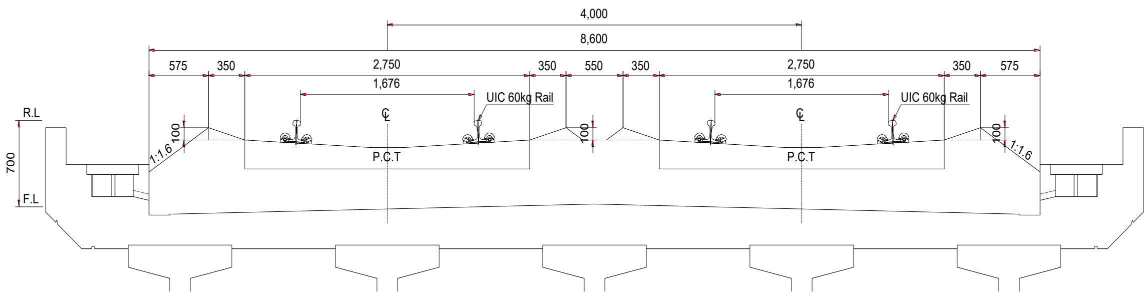


Figure 9-6 Cross-section of Ballasted Double Track on Elevated

(4) Standards of Non-Ballasted (Slab) Double Track on Elevated/Tunnel

- Track spacing: 4.0 m
- Rail: UIC 60
- Sleeper: Twin-block sleeper
- Dimension of Track Concrete Layer: (i) Width 3000 mm,
  (ii) Thickness 301~355 mm
- Dimension of Protective Concrete Layer: thickness 150 mm

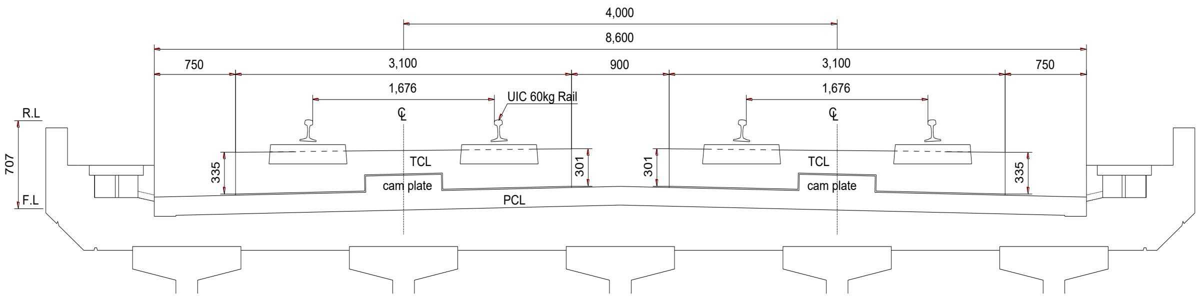


Figure 9-7 Cross-section of Non-Ballasted Double Track on Elevated

(5) Standard of Ballasted Single Track on Earth Work(2 Phase: Padukka~Avissawella)

- Rail: 54E1, Sleeper: PC sleeper(L=2750 mm)
- Ballast depth: minimum 300 mm, Ballast slope: 1:1.6

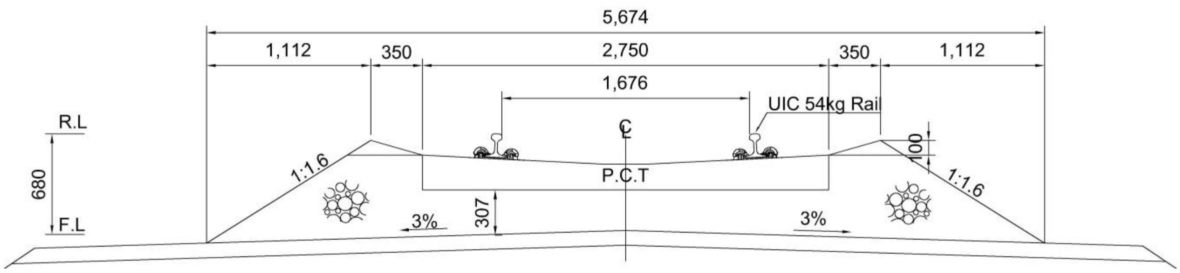


Figure 9-8 Cross-section of Ballasted Single Track on Earth Work (2Phase)

9.4.4 Optional Study

9.4.4.1 Track type

(1) Introduction

The main objective of this Option study is the assessment of various tracks to select the best option for KV line's track bed construction. The weights are assigned based on the scale of high (07-10), middle (04-06) and low (0.0-3.0) values. These values will be added with other important influencing factors for this option screening study and later total value will be averaged and the highest total value option will be recommended as best option for implementation. In general, this multi-weighted scoring method uses several factors to select competing railway options by looking at various important factors.

- Track type Weights

The following table defines the weight assigning procedure on several influential criteria for three different cases. These three different cases are: 1) High, 2) Moderate and 3) Low. The type of track gets the highest weighted score for the mentioned criteria below, will be considered as the best option for KV line.

Table 9-9 Factors for Track type Options

Criteria	Indicator (Measurable)	High	Moderate	Low
Ride Quality	Good, Medium, Poor	10-07	04-06	0-3.0
Noise and Vibration Reduction	Good, Medium, Poor	10-07	04-06	0-3.0
Initial Investment costs	Construction Costs	10-07	04-06	0-3.0
Long-term Investment Costs	Maintenance Costs	10-07	04-06	0-3.0
Ease of Construction work	Equipment use, Accessibility, etc.	10-07	04-06	0-3.0
Ease of Maintenance work	Equipment Use, Maintenance Method	10-07	04-06	0-3.0
Average (total weight/number of factors)		10-07	04-06	0-3.0

- Optional Study on Track types

Segments of KV line will be assessed into two sections considering the elevation of track construction. These two sections are: 1) At grade, 2) Elevated. All these options are reviewed again for the following two sections (structures):

-Ballasted type Option

-Non-ballasted(Slab) type Option

(2) Section 1: At grade

Table 9-10 Weights for Track type factors

Criteria	Indicator (Measurable)	Option I (Ballasted - Weights)	Option II (Non-ballasted - Weights)
Ride Quality	Good, Medium, Poor	10	09
Noise and Vibration Reduction	Good, medium, Poor	10	08
Initial Investment cost	Construction Costs	10	07
Long-term Investment Costs.	Maintenance Costs	03	10
Ease of construction work.	Equipment use, accessibility, etc.	08	03
Ease of Maintenance work.	Equipment Use, Maintenance Method	08	03
Average Weight		8.17	6.70

Table 9-11 Summary of Weights for Section 1

Classification	Option-1	Option-2
Track type factor weights	**8.17**	**6.70**

Therefore, the highest weighted option for the track bed of Section 1 is ballasted, recommended as the best option. The main factors affecting this decision are easy of construction work, ease of maintenance work and long-term maintenance costs. Construction works of Option2 "in existing line is very difficult because of grade" section. On the other hand, local survey information showed that there is soft ground around the Section 1. If the track subsidize after construction of Option 2, the maintenance cost will be extremely high.

(3) Section 2 (Elevated)

Table 9-12 Weights for Track type factors

Criteria	Indicator (Measurable)	Option I (Ballasted - Weights)	Option II (Non-ballasted - Weights)
Ride Quality	Good, Medium, Poor	10	09
Noise and Vibration Reduction	Good, Medium, Poor	10	08
Initial Investment cost	Construction costs	10	07
Long-term Investment Costs.	Maintenance costs	03	10
Ease of Construction Work.	Equipment use, Accessibility, etc.	10	05
Ease of Maintenance Work.	Equipment use, Maintenance method	05	07
Average Weight		8.00	7.67

Therefore, the highest weighted option for the track bed of Section 2 is ballasted, Recommended as the best option. Factors affecting this decision are Initial Investment costs, long-term maintenance costs and ease of construction work/maintenance. Option 2 has to use ready mixed concrete car during construction, it might be very difficult to construct the Concrete Slab Track. And then, it might be very difficult to maintain Concrete Slab crack and subsidence caused by the difference of the extension length between bridge and concrete slab. Also, the construction period of Concrete Slab will be more than 6 months longer than the Ballasted track type. Then, Option 1 will be better than Option 2.

CHAPTER

10

Power Supply and Electrification

Chapter 10 Power Supply and Electrification

Chapter Summary

This Chapter covers the study of the technical viability of electrification of the Kelani Valley (KV) line. It begins with assessment of the relevant standards, basic types of railway electrification and various configurations of traction power supplies – proposing a classic single-phase transformer feeding arrangement with a 25 kV Overhead Catenary System (OCS).

The Ceylon Electricity Board (CEB) 132 kV power transmission network is reviewed, including its future generation plans and daily demand curve, to determine how railway electrification can be adequately supplied with electrical power.

Preferred electricity supply points from the CEB 132 kV grid are identified along the KV line to determine a viable power feeding configuration based on proximity of CEB facilities, chain age of the railway and blackout recovery scenarios.

All 4 railway sectors under the CSRP were studied to ensure the optimum CEB 132 kV feeding points which were identified and coordinated for accommodation of the planned future expansions.

Sri Lankan Electricity Regulations are reviewed to determine the need for enhancements in respect of the unique application of a 25 kV OCS electrification system.

Minor 25 kV switching stations are introduced and described as part of the system major feeding for the line. Indicative arrangements of a traction substation, OCS and the Supervisory Control and Data Acquisition (SCADA) sub system are also discussed along with proposing equipment lists for the railway electrification subsystems. The importance of the power system studies and earthing and bonding studies are introduced.

An overview of anticipated interfacing and coordination with other disciplines are also presented for further discussion. The final section introduces operation and maintenance expectations for the electrification subsystems.

At the end of this chapter, a technical conclusion is presented.

10.1 Introduction

The Maradana–Avissawella, Kelani Valley (KV) railway line will include provision for electrification of the double track section from Maradana up to Padukka (34.9 km) and possible electrification of the single track section from Padukka to Avissawella (23.5 km). This section describes the conceptual design, specifications and standards of power supply system and electrification components that will be required.

10.1.1 Electrification Necessity and Viability

Electrification of railways is a widespread practice globally and provides additional levels of flexibility and diversity in a number of key aspects:

- Electric trains can deliver significantly higher levels of traction power than their diesel counterparts as their capacity is not constrained by the limited power of any "on-board" prime movers such as combustion engines. This aspect is of vital importance for high speed trains where the required power would be difficult to produce from an on-board source.
- Electrical power can be sourced from a variety of elemental sources, i.e. fossil fuel, nuclear generation, renewable energy, etc. These sources can change over time with zero impact on the consuming trains. It is significant to note that Sri Lanka presently has approximately 33% of its national power demand satisfied from renewable sources and considerable future growth in renewable power generation.
- Electric trains have zero pollution emissions at the point of consumption and reduced noise emissions compared to diesel powered trains. This is extremely important in terms of environmental impact and also in underground railway and major conurbation applications.
- Electrified rail networks offer the capability and benefits of regenerative braking systems that allow recovered energy from electric braking to be re-absorbed by other trains, keeping energy within the rail system and reducing overall electrical power demand from the utility authority and the associated costs. Regenerative braking usage reduces dependence on use of friction braking which in turn can precipitate longer periods between maintenance and associated downtime of trains.
- Electric trains are supplied with power continuously in real time and do not generally carry fuel on board. This makes their tare weights less than diesel trains and provides superior operating flexibility as electric trains since they do not need to be re-fueled routinely at dedicated fueling facilities.

Availability of suitable electrical supplies have to be assessed and this is covered in section 11.4 of this report.

The final stage is to undertake a cost benefit analysis as part of the feasibility study. This must recognize the additional CAPEX for the electrification subsystems along with the related OPEX costs. There are two key factors to be embraced here:

- In some countries where diesel operation is the existing basis of operations, fuel cost dispensations are granted in the form of tax exemption or price discount in the interests of the national economy. Furthermore, initial discussions with Ceylon Electricity Board (CEB) have identified that there is not an established tariff for railway electrification supplies currently.

- The introduction of Overhead Catenary System (OCS) electrification to a railway necessarily introduces a new engineering department and a new operator responsibility. This represents a significant number of dedicated staff to provide the required attendance and workload cover. As the KV line is a modest size of railway with only around 70 to 100 single track km of electrification, the electrification department is likely to be under-utilized. The quantum of electrified railway could be easily doubled but still operated and maintained by the same number of staff.

10.2 General Specifications and Standards

The following is the initial listing of European standards that shall be the reference and specifically when there are equivalents in IEC:

- EN 50163: Railway applications – Supply voltages of traction systems
- EN 50388: Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
- EN 50329: Railway applications – Fixed installations – Traction transformers
- EN 50119: Railway applications – Fixed installations – Electrical traction overhead contact lines
- EN 50121: Railway applications – Electromagnetic compatibility
- EN 50122: Railway applications – Fixed installations – Electrical safety, earthing and the return circuit
- EN 50124: Railway applications – Insulation coordination – Overvoltage and related protection
- EN 50149: Railway applications – Fixed installations – Electric traction – Copper and copper alloy grooved contact wires
- EN 50152: Railway applications – Fixed installations – Particular requirements for AC switchgear – Single-phase disconnectors, earthing switches and switches with Un above 1 kV
- BS EN 50126: Railway Applications. The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
- EN 50155 - Railway applications - Electronic equipment used on rolling stock
- IEC 61000 series - Electromagnetic compatibility (EMC)
- IEEE 80 - Guide for Safety in AC Substation
- IEEE 81 - Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System
- IEEE 998-2012 - Guide for Direct Lightning Stroke Shielding of Substations.
- IS 2309-2005 - Protection of Buildings and Allied Structures against Lightning

10.3 Conceptual Electrification Scheme

There are a number of generic types of OCS electrification systems in service globally and consideration has been given to the established options as follows:

10.3.1 Direct Current Systems

Direct Current systems operate at voltages of typically 750V or 1500V, with the former often being presented as a third rail rather than OCS. The lower operating voltage and consequent higher current flows renders feeding points quite close together and such railways either have many autonomous infeed points from the public network or take bulk supply feeds and then distribute power through a medium voltage lineside cable network to the various traction rectifier locations.

Such systems are not deemed appropriate for this project as they would incur significant additional costs for the increased numbers of traction power substations and related interconnecting MV cable network.

10.3.2 Alternating Current Systems

There are three basic systems in general use, as summarized below:

(1) Autotransformer System (also known as a 2 x 25 kV or 25-0-25 kV system)

These systems transmit power at 50 kV from the infeed points but the center-tapping through autotransformers provides 25 kV on the OCS equipment, with return current flowing through the running rails to the nearest autotransformer where it is diverted to the return balancing 25 kV conductor. Normally these are associated with high speed train operations where individual train demands are very high or in regions where public utility supplies are not readily available.

(2) Booster Transformer System

These systems transmit power at 25 kV from the infeed points and distribute it to trains through the OCS equipment, with return current flowing from the trains into the running rails. In order to maintain acceptable running rail voltages and to mitigate against electromagnetic emissions from the single phase AC system, booster transformers are installed at regular frequencies along the system and which force return current from the running rails into an aerial return conductor and thence back to the feeding point. These systems are rarely implemented nowadays as the growth of fiber-based communications has reduced the numbers of potential EMI victim circuits in the railway zone of influence. In fact, many systems that were installed as booster transformer systems have been modified to booster-less (or Classic) systems.

(3) Classic 25 kV System

These systems are the simplest available and transmit power at 25 kV from the infeed points and distribute it to trains through the OCS equipment, with return current flowing from the trains into the running rails. An aerial return earth wire is installed along the system and this is connected to the running rails at pre-determined intervals so that a proportion of the return current will be diverted from the running rails such that acceptable running rail voltages are maintained and that a degree of EMI compensation is achieved from the return earth wire flow.

A classic single phase 25 kV OCS system is proposed for this project, as depicted in the Figure 10-1. Single phase fixed ratio 132/25 kV transformers would be preferred with the return earth wire mounted on the OCS poles.

The connection of a single phase load to a three phase network has the propensity to introduce a degree of phase unbalance to the network and the level of unbalance is a function of the size of the single phase load and the fault level of the three phase network at the point of interconnection. Early railway electrification schemes utilized traction power transformers that were designed to distribute electrical loads more evenly across all phases of the utility, i.e. Scott or Le Blanc transformers, to reduce the levels of unbalance.

As power utility networks they are continuously improving their fault levels and so they become less vulnerable to the unbalance effects of single phase loads. Furthermore, the development and application of power electronics have facilitated the introduction of more effective unbalance counter-measures, such as SVCs (Static Var Compensators) and SFCs (Static Frequency Converters). These allow for a very simple transformer design to be adopted with external mitigation measures deployed as required.

Modern railway practice is to carry out formal power system studies and evaluate unbalance expectations against established international standards, with mitigation included by the railway, if the agreed criteria cannot be met.

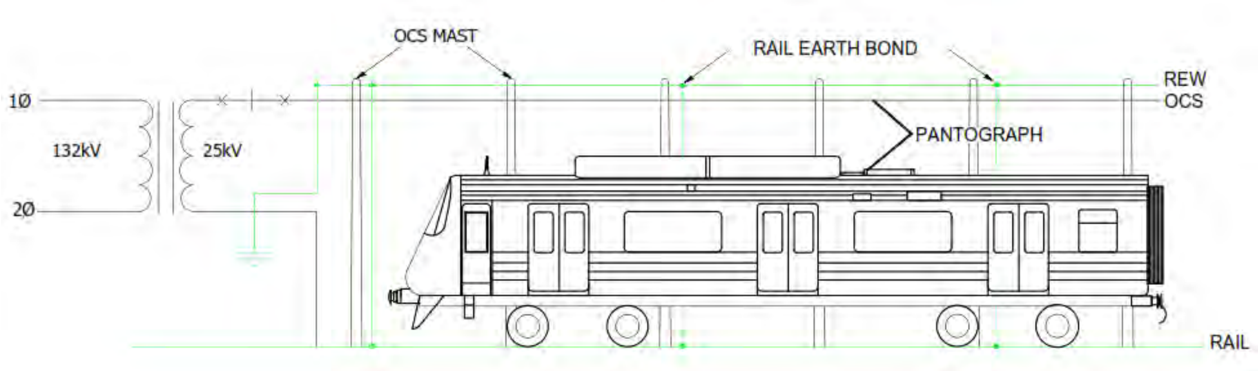


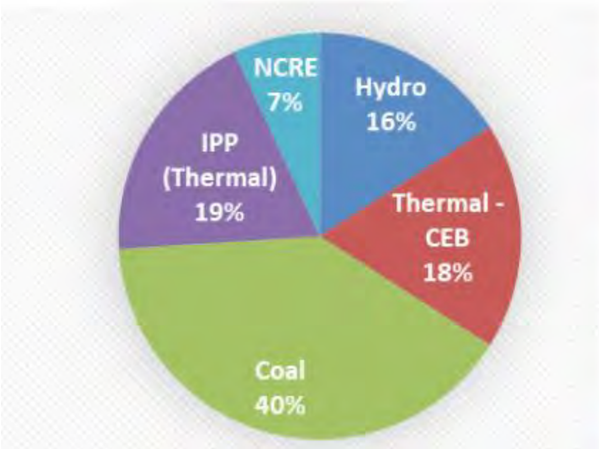
Figure 10-1 Classic 25 kV Rail System

10.4 Existing Power Utility Network Capacity and Demand

As per earlier studies ("A proposal for Railway Electrification", by The Institution of Engineers, Sri Lanka) in June 2008, and more recently power system performance stats published by Ministry of Power and Renewable Energy and CEB Long-term Generation Expansion Plan, it has concluded that CEB has sufficient capacity to satisfy the demands of an electrified suburban railway.

Currently Sri Lanka has a total installed capacity of around 4,000 MW. Out of this capacity all large scale power plants have been owned and operated by CEB. Other than that, there are thermal power plants owned and operated by Independent Power Producers (IPPs) and around 200 numbers of renewable power plants operated by Small Power Producers (SPPs) including mini-hydro plants, solar power plants, wind power plants and biomass power plants.

Installed electricity generation capacity of the national power grid is 4,043 MW as at August 2017, which is a 0.6% increase from year 2016.



Source	Capacity	No. of Power Plant
Major Hydro	1,364 MW	17
Thermal		
Coal	900 MW	1
CEB	604 MW	7
IPP	611 MW	5
Renewable Energy		
Mini Hydro	356 MW	182
Wind	128 MW	15
Solar	51 MW	8
Biomass	29 MW	9
Total Capacity	**4,043 MW**	244

Figure 10-2 Generation Capacity Mix in Sri Lanka as August 2017

During the first half of 2017, the demand for electricity was increased by 2.9% while the maximum demand recorded during this period was 2,523.2 MW as against 2,452.9 MW during year 2016. In Figure 10-2 presents the Generation Capacity Mix in Sri Lanka as August 2017 which is published in "Performance of 2017 and Programmes for 2018" by Ministry of Power and Renewable Energy.

For upcoming years, the electricity generation and demand forecast based on CEB Long Term Generation Expansion Plan 2018-2037 is as shown in Table 10-1.

Table 10-1 CEB Base Load Forecast

Year	Demand		Net Losses	Net Generation		Peak Demand
	(GWh)	Growth Rate (%)	(%)	(GWh)	Growth Rate (%)	(MW)
2018	14588	6.8%	9.88	16188	6.8%	2738
2019	15583	6.8%	9.84	17285	6.8%	2903
2020	16646	6.8%	9.81	18456	6.8%	3077
2021	17478	5.0%	9.77	19370	5.0%	3208
2022	18353	5.0%	9.73	20331	5.0%	3346
2023	19273	5.0%	9.69	21342	5.0%	3491
2024	20242	5.0%	9.65	22404	5.0%	3643
2025	21260	5.0%	9.61	23522	5.0%	3804
2026	22332	5.0%	9.58	24697	5.0%	3972
2027	23459	5.0%	9.54	25933	5.0%	4149
2028	24639	5.0%	9.50	27225	5.0%	4335
2029	25867	5.0%	9.46	28570	4.9%	4527
2030	27164	5.0%	9.42	29990	5.0%	4726
2031	28388	4.5%	9.38	31328	4.5%	4939
2032	29637	4.4%	9.35	32692	4.4%	5157
2033	30926	4.3%	9.31	34099	4.3%	5381
2034	32251	4.3%	9.27	35546	4.2%	5612

Year	Demand		Net Losses	Net Generation		Peak Demand
	(GWh)	Growth Rate (%)	(%)	(GWh)	Growth Rate (%)	(MW)
2035	33642	4.3%	9.23	37063	4.3%	5854
2036	35090	4.3%	9.19	38642	4.3%	6107
2037	36613	4.3%	9.15	40302	4.3%	6372
2038	38165	4.2%	9.12	41992	4.2%	6642
2039	39733	4.1%	9.08	43699	4.1%	6915
2040	41324	4.0%	9.04	45431	4.0%	7193
2041	42967	4.0%	9.02	47227	4.0%	7481
2042	44700	4.0%	9.00	49121	4.0%	7784
5 Year Average Growth	5.9%			5.9%		5.1%
10 Year Average Growth	5.4%			5.4%		4.7%
20 Year Average Growth	5.0%			4.9%		4.5%
25 Year Average Growth	4.8%			4.7%		4.4%

As per Long Term Generation Expansion Plan: 2018-2042, there is a significant positive impact on the national grid demand profile by introducing electrified railway system to Sri Lanka. As per latest O&M proposal under Chapter 7.5.1, the peak demand for the proposed electrified railway system occurs during 6.30 am to 9.30 am in the morning and 4.30 pm to 7.30 pm in the evening.

The annual peak demand profile of Sri Lanka national grid displays dips during the year 2016 in the day as shown in Figure 10-3. Since the railway traction power demand will be occurred during these dips in the load curve, the utility supplier does not require additional generation capacity to cater the increased power demand of the railway electrification. In a national point of view, it is economically viable to operate trains by electricity supplied from utility supplier where they produce electricity from most efficient power plants rather than operating diesel trains powered by diesel engine.

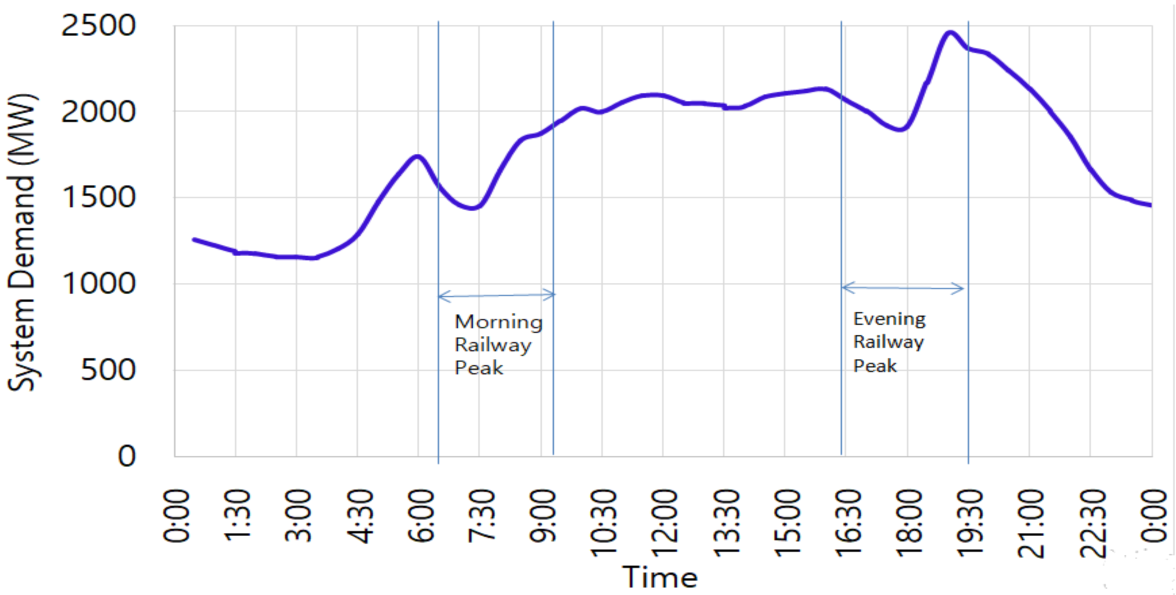


Figure 10-3 Annual Peak Demand Curve for 2016

10.4.1 Prospective CEB High Voltage Electricity Supply Points for the KV Line

Sri Lanka has a significant 132 kV transmission network, owned and operated by CEB and which has been assessed to determine prospective traction power supply points for an electrified KV railway system.

The initial step taken was to highlight the KV railway alignment on a relevant Google Map so a meaningful overview of the alignment can be available. The next stage was to map existing CEB 132 kV transmission lines and related substations in the Colombo area and in the proximity of the railway alignment, using CEB published transmission line layouts. These substation locations have been added to the marked up Google Map accordingly and the results are shown in Figure 10-4.

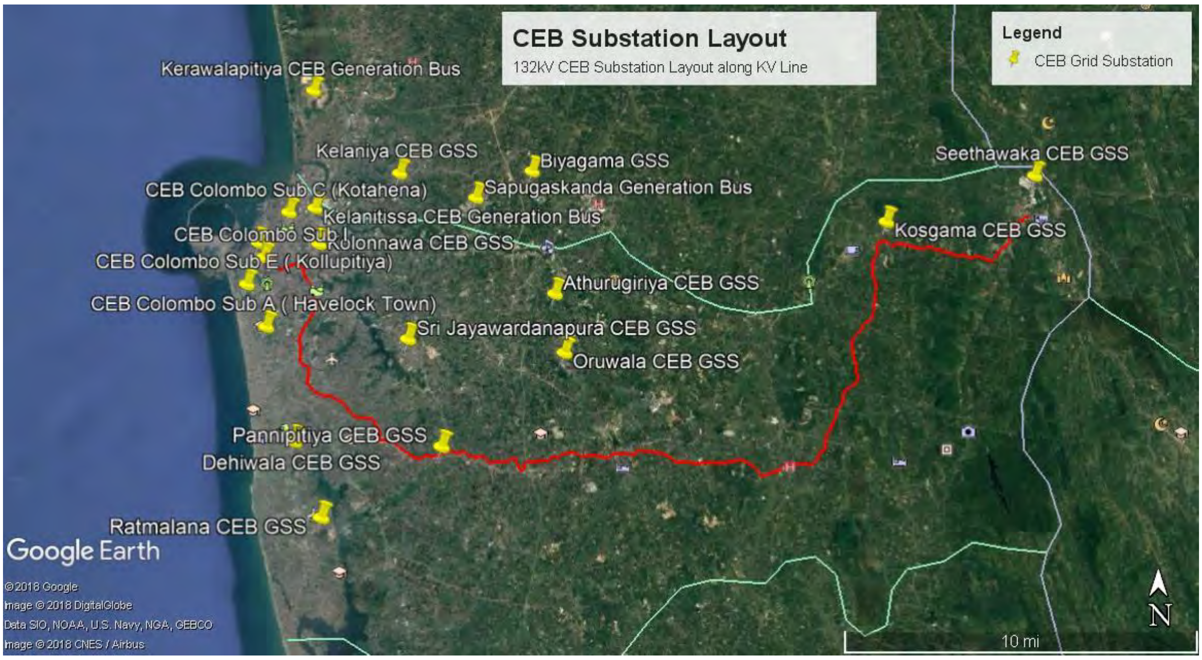


Figure 10-4 Existing CEB Substation Layout along KV Line

The costs of providing a 132 kV supply connection from CEB to the railway comprise of 3 basic elements:

- Firstly, there is the cost of works at the CEB source. This is highly dependent on available space and the method of connection selected by CEB. This is basically a CEB choice.
- Secondly, there is the cost of the power receiving equipment at the railway end of the supply. This is expected to be a standard arrangement and cost for any chosen location along the railway Right Of Way, subject to suitable land plots being available.
- The final element is the cost of interconnection between the CEB source and the railway feeder station location. This may be open transmission line or buried cable but in either case the cost is proportional to the 132 kV supply route length. Hence minimizing these lengths must be a priority in supply point selection.

From a Power System Quality perspective, it is also important to note that the supply source selection also considers the existing (and projected) CEB fault levels as higher fault levels, which will mitigate the potential adverse effects of unbalance arising from the single phase electric traction loads.

From a railway electrification perspective, the electrification feeder station locations are generally selected on the basis that a viable 25 kV feed can be made for a distance of around 20 km from the feeder station in each direction, which may be extended under major failure conditions, i.e. total loss of a double circuit feeder station. Feeder stations are targeted as double transformer installations so that outage of one circuit has no adverse impact on electric train operations.

For the KV railway line which is approximately 60 km in length, the ideal infeed locations would therefore be at approximately 25% and 75% points along the route, which would be at locations just east of Pannipitiya and just west of Kosgama respectively.

Figure 10-4 clearly shows that Pannipitiya and Kosgama GSS satisfy the criteria for close proximity to the railway and appropriate longitudinal railway location. On this basis a meeting was held with senior CEB personnel to discuss the prospective sources and glean CEB’s view on the viability of these two locations. CEB indicated general acknowledgement that these sites could be used and that proposals need developing further in detail design. CEB also introduced a future 132 kV GSS which is referred to as Colombo sub I and had not been included in Figure 10-4 but could be considered as a prospective bulk supply source.

CEB subsequently confirmed their existing fault levels of 8 kA at Kosgama, 21 kA at Pannipitiya and 21.2 kA at Colombo sub I. These levels will be used in power supply studies accordingly.

These discussions are summarized in Figure 10-5 which also includes the Colombo I GSS. Although this is slightly beyond the western geographical limit of the KV line project, this is a major area of railway activity concentration and will be taken into consideration in developing a power feeding scheme.

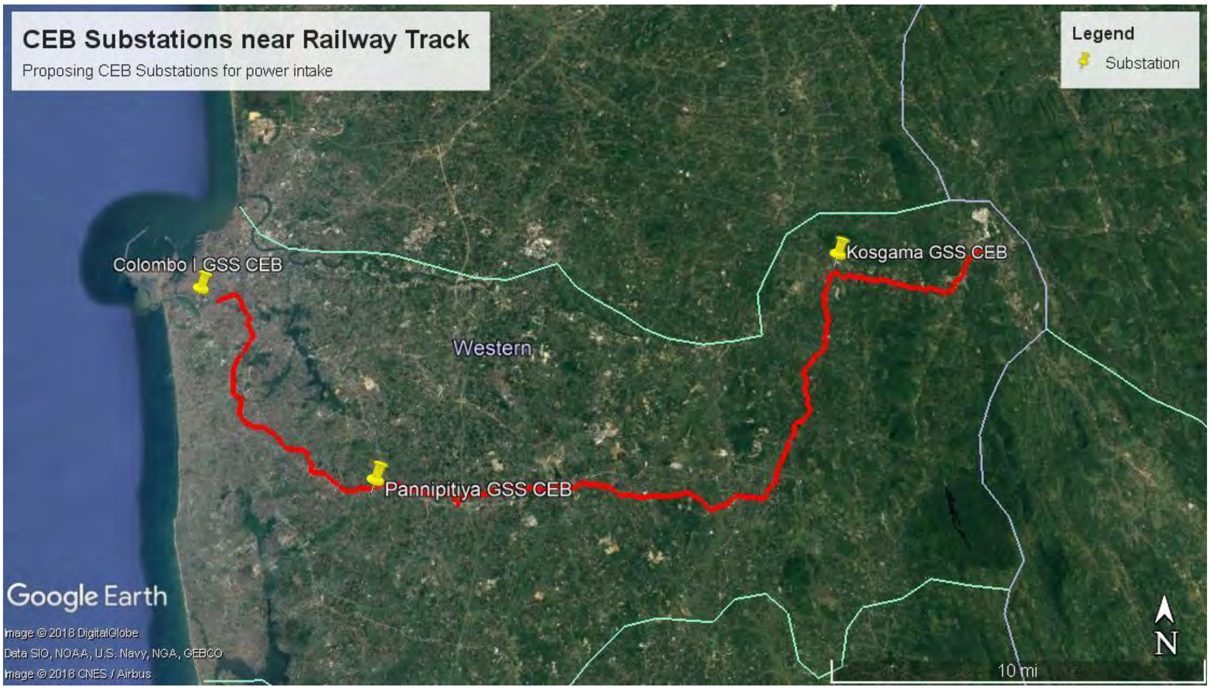


Figure 10-5 Proposing Substation for Power Intake

Major power feeding proposals are therefore being developed for the KV line project based on these potential supply sources.

Further holistic development of major power feeding configurations will be made based on addition of Coastal Line and Main Line upgrade/electrification projects to the KV line.

10.4.2 Prospective KV Railway Feeder Stations

10.4.2.1 General Locations of Feeder Substations

The prospective locations for the KV Line railway feeder stations are identified as follows.

Pannipitiya and Kosgama GSSs are ideal for power in-takes which are located at approximately 16 km and 54 km along the KV line. Both GSSs are located close to the KV line (ie. 200 m for Pannipitiya GSS and 250 m for Kosgama GSS).

The proposed method of 132 kV incoming feeder for the Pannipitiya traction substation is loop in/ loop out of double line from the available two 132 kV circuits which are from Kollannawa to Pannpitiya grid substation as indicated in Figure 10-6. Connectivity from two separate 132kV circuits will enhance the reliability and effectiveness of the power supply for the traction substation. The similar connection method is proposed for the 132 kV feeders tapping at Kosgama grid substation as well as shown in Figure 10- 7.

Figure 10-6 Proposed Feeder Stations- Pannipitiya

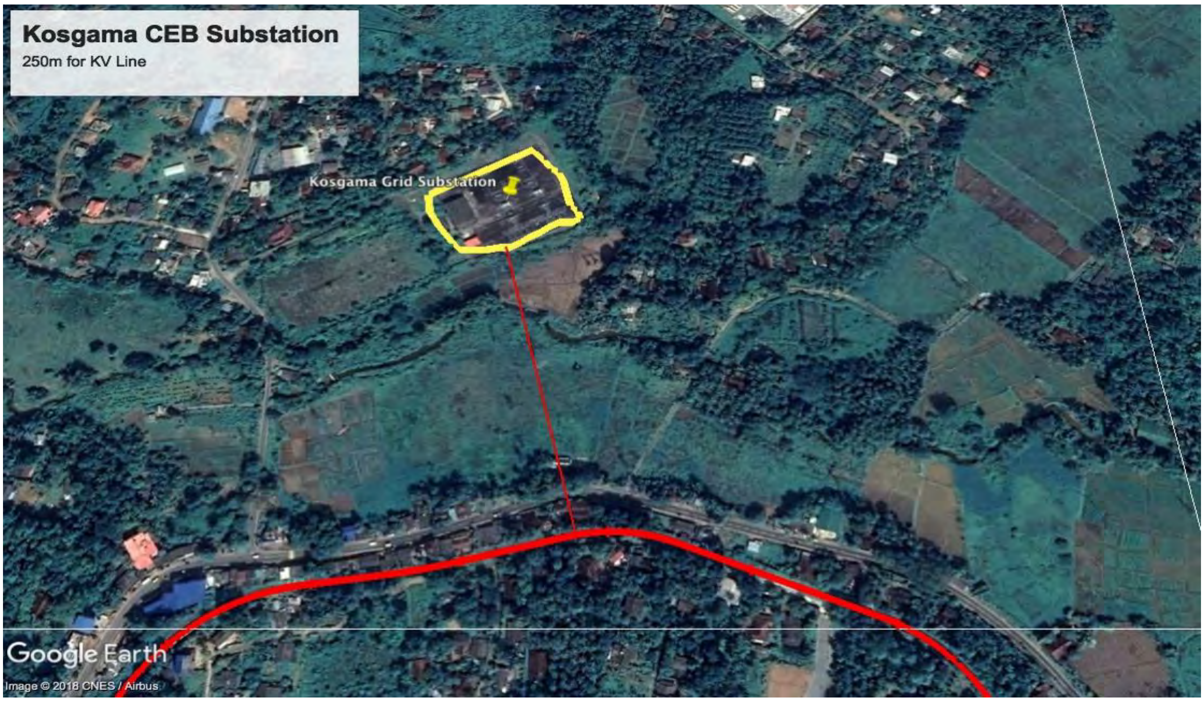


Figure 10-7 Proposed Feeder Stations- Kosgama

There is also a prospective feeder station location close to Maradana Depot which could be considered for any future extension of the electrified railway westwards as shown in Figure 10-8.

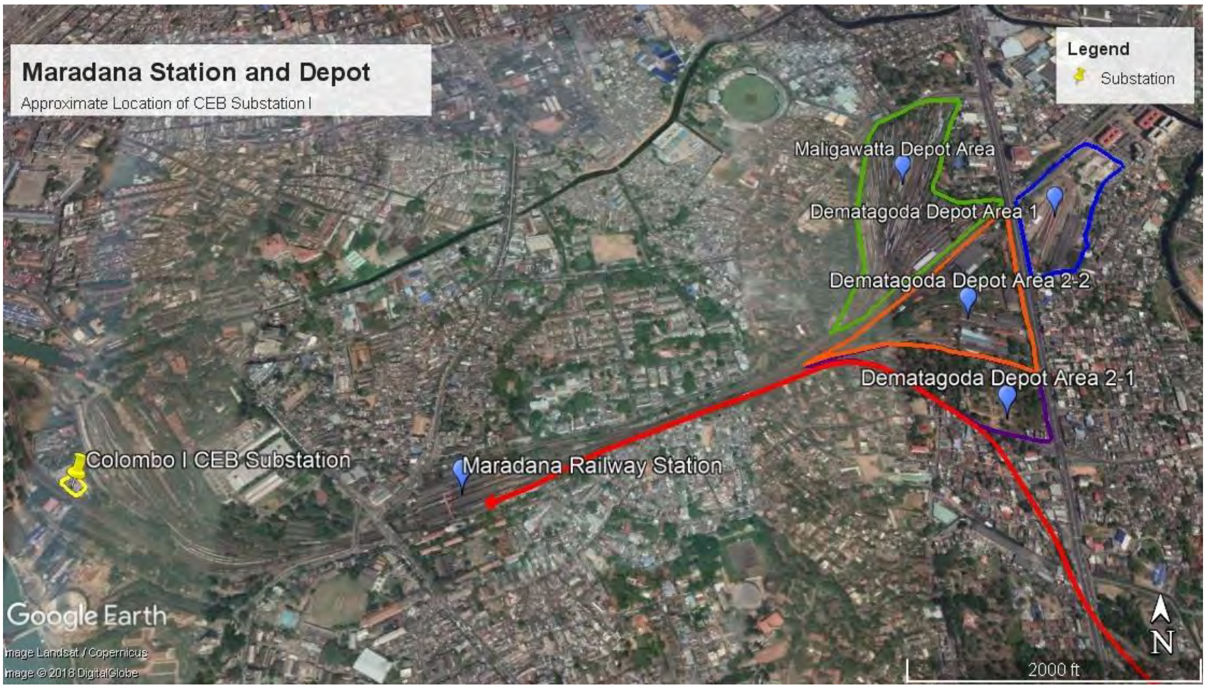


Figure 10-8 Proposed Feeder Stations- Near Maradana Depot

10.4.2.2 Electrification Feeding Recommendation for the KV Line.

By analyzing prospective electricity supply points, it is possible to determine a feeding configuration that could be applied to the upgraded railway.

A major influence on this assessment has been the target track layouts in terms of double track versus single track sections. Long single track railway sectors present unique challenges for electrification in terms of loads being focused through a single catenary system rather than being shared through multiple tracks and are therefore not considered in this evaluation.

Figure 10-9 shows how a fully double tracked KV line could be electrified as a conventional feeding configuration by providing a high levels of redundancy. This is included for reference purposes only against which the initial stage recommendation can be assessed and which should be aspired in the future, when double tracking of the section from Padukka to Avissawella is undertaken.

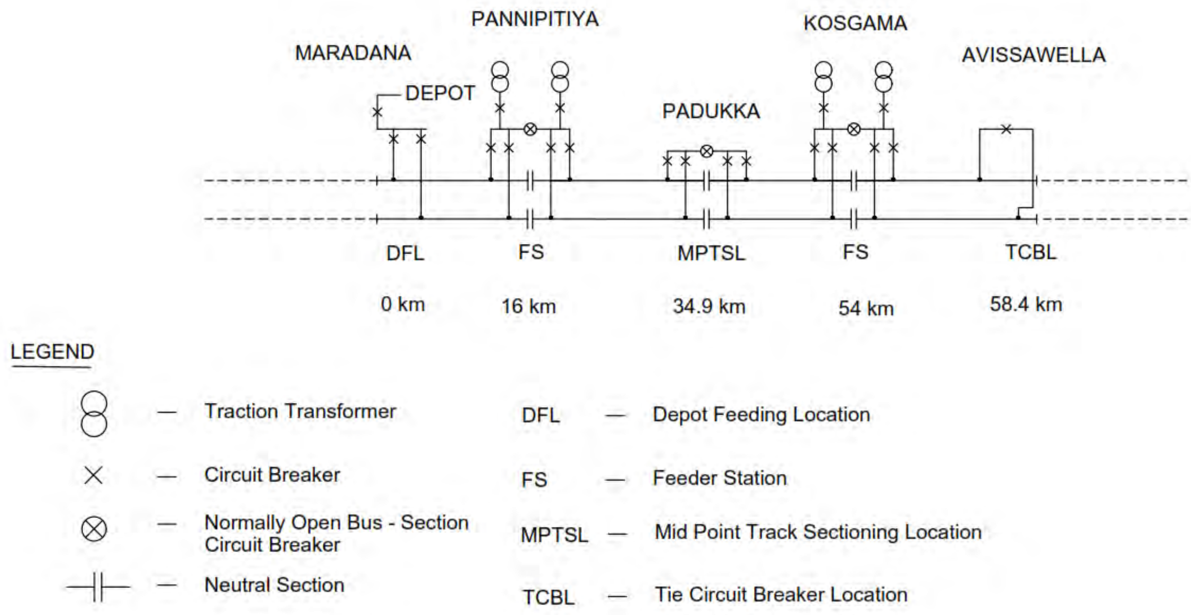


Figure 10-9 Optimum Major Feeding SLD for fully Double Tracked KV Line

The following assessment has been made on the basis of initial double track implementation from Maradana to Padukka only, with the remainder of the line to Avissawella being single track with strategic passing loop locations.

For the double track section Maradana to Padukka, the feed would be through a double transformer feeder station at Pannipitiya as indicated in Figure 10-10 below. This would represent a typical feeding arrangement for a double track railway (approximately 17 km in each direction from the feeding point), which can be replicated as a basic electrification feeding arrangement and is commensurate with future system expansion plans – e.g. the introduction of Kosgama feeder station to support the Avissawella extension.

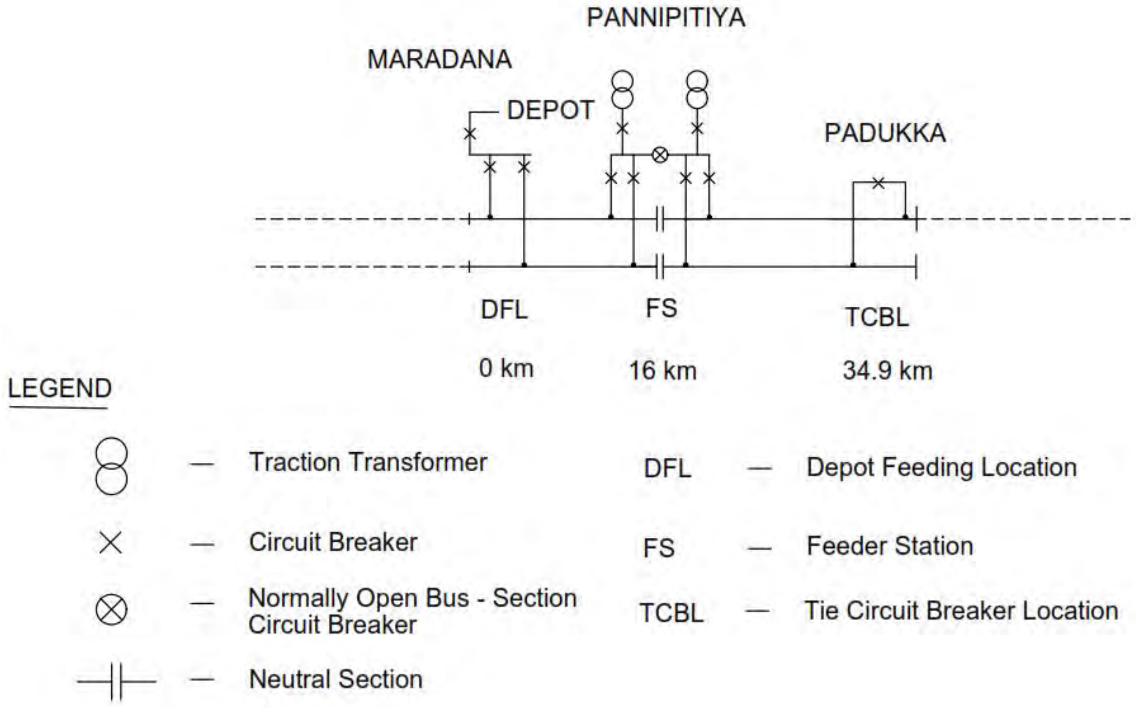


Figure 10-10 Typical Double Track Section Feeding Arrangement

A Depot Feeding Location at Maradana would be derived from both main line tracks to parallel the main lines and to give a dedicated circuit breaker for fault discrimination purposes within the Depot area.

For Padukka it would be sufficient to install a Tie Circuit Breaker only at this stage, but ensure option land is reserved for a full Mid-Point Sectioning Location to support any future electrification extension eastwards from Padukka.

The reliance on a single feeding location at Pannipitiya, albeit with maximum electrical segregation of the supply derivation points within the CEB facilities, does carry the risk of a major key event disrupting the total traction power supply to the electrified railway. This risk can be mitigated by deriving an alternative traction supply from Colombo I, which would not normally be in use but could be called upon to provide traction power to the Sri Lanka Railways (SLR) system in the case that Pannipitiya supplies are unavailable. This alternative source will hereafter be referred to as Black Out Relief (BOR).

As the SLR electrified network is enhanced through the execution of upgrade extension contracts, additional permanent railway traction feeder stations will be commissioned and provided greater levels of redundancy and fault-tolerance. However, it is considered that the BOR capability from Colombo I would be a valuable contingency asset for the future and therefore it should be perpetuated and configured into the SLR traction power network as it grows incrementally.

10.4.2.3 Black-Out Relief Study

This Blackout Relief capability would be retained as the CSRP electrified network grows as it is central to the convergence points of the SLR lines, which are targeted for electrification and provides a diverse back-up source for any major power loss in the emerging holistic electrified network.

Electric train operations rely completely on very high availability and reliability of the traction power from the CEB through the interconnection points between the railway Feeder Stations and the related GSS locations. If this electrical supply is interrupted unexpectedly then electric trains will lose their power source which will render each train incapable of powering itself and also shutting down key on-board facilities such as air conditioning. However, the affected trains will be able to coast (freewheel) and brake but are likely to be carrying passengers who will quickly become distressed if they are trapped inside a stranded train with no air-conditioning.

It must be accepted that the railway signaling and communications subsystems will have a degree of power supply autonomy that maintains their functionalities in times of major CEB disturbance – through dedicated UPS and diesel generator back-up systems.

Unplanned power supply disruptions can happen at any time of day and clearly if this is in the middle of the night there may be no electric trains running. However, if such an event happens during peak traffic hours a lot of trains will be affected. If and when an interruption occurs each driver will be aware of loss of power to his train through indications on his control desk and he will continue to coast towards the next station – subject to movement authority from the signaling system of course. He can then stop and de-train his passengers safely – although the train cannot go anywhere immediately. Some trains may not be able to coast to a station and it is these that would benefit from BOR capability as the only options would be to;

- Dispatch a rescue locomotive but with many electric trains stranded at stations there may not be a path for the locomotive to reach its target stranded train, or
- Detrain passengers where train is located, or
- Wait for power to be restored and stable.

These three options are not attractive and would definitely provoke “bad press”. Thus a viable means of BOR needs to be determined.

Historical CEB data has been made available to CSRP in the form of “Summary of 132kV busbar outages due to trippings (2013 – 2017)”. For this initial project stage it is Pannipitiya GSS that is of key interest.

It is noted that Total System Failure has not been experienced since March 2016. This is an encouraging point and suggests the network stability has been improved significantly. For comparison sake the Malaysian TNB network has only had 1 major total 132kV system failure (in 1996 where traction power was not available for around 2 days) in its 23 years of supplying power at 132kV for electric train operations. It must be noted that the Malaysian railway has no BOR capability but initially had 5 different supply points so single supply failure could be swiftly mitigated by introducing “extended feeding” within the railway system.

The outage duration times show that localised outages are generally more swiftly dealt with and normalised in a far shorter time than Total Failures. This is not surprising but provokes an assessment of how long it would take any type of BOR to be brought into service and effect the rescue of stranded electric trains on a one-by one basis as well as allow air-conditioning on all crippled trains to be used.

The major issue here is that when an event occurs there is no immediate information available as to whether it will take minutes or hours to trace and remedy – so contingency must be initiated as swiftly as possible.

A Standard Operating Procedure (SOP) is clearly needed for SLR and CEB that would be enforced during major power supply interruptions.

Negotiations with CEB in-order to obtain prioritized power supply for Colombo sub I (from Kelanitissa Gas Turbine Power Plant via Kolonnawa GSS) during restoration process after a total blackout are underway. These discussions will highlight the emergency switching procedure to be undertaken in each specific case and the maximum time taken to restore power to specified levels to allow various stages of degraded mode operation. During discussions CEB has highlighted that projects are currently underway to secure reliability of the network. Details of these projects that are underway and planned future enhancements to the system will investigated and benefits highlighted in the next stages of CSRP Feasibility studies.

BOR Options

There are options for how BOR can be provided:

1. Temporary reduced capacity supply from unaffected CEB source to allow limited power supply to the railway. This is likely to require grid network reconfiguration around a GSS that is separate from the affected part of the 132 kV grid system (i.e. from Colombo I if Pannipitiya GSS is unavailable). As this relies on existing generation and transmission assets the on-costs of 132Kv connection, step down transformer and related control/protection would be quite modest compared to options 2 and 3 below, relying on assets that are generally in everyday use.

2. Autonomous generating plant could be considered but as the required output is single phase 25kV this equipment could serve no real purpose in normal times when no Blackout is manifest. Likely to be expensive and rarely used.

3. Autonomous stored energy plant could be considered but also likely to be expensive and rarely used. Whichever option is selected every effort must be made to ensure the power demand under BOR contingency feeding is minimized to keep equipment ratings and capacity as low as reasonably practical, i.e. reduce train traction demand, limit electric movements to 1 train at a time, shut down trainsets when clear of passengers.

Hence option 1 is considered the most practical and cost-effective – therefore recommended.

10.4.2.4 Recommendation – Half Electrification with Pannipitiya and Maradana as Feeding Sources

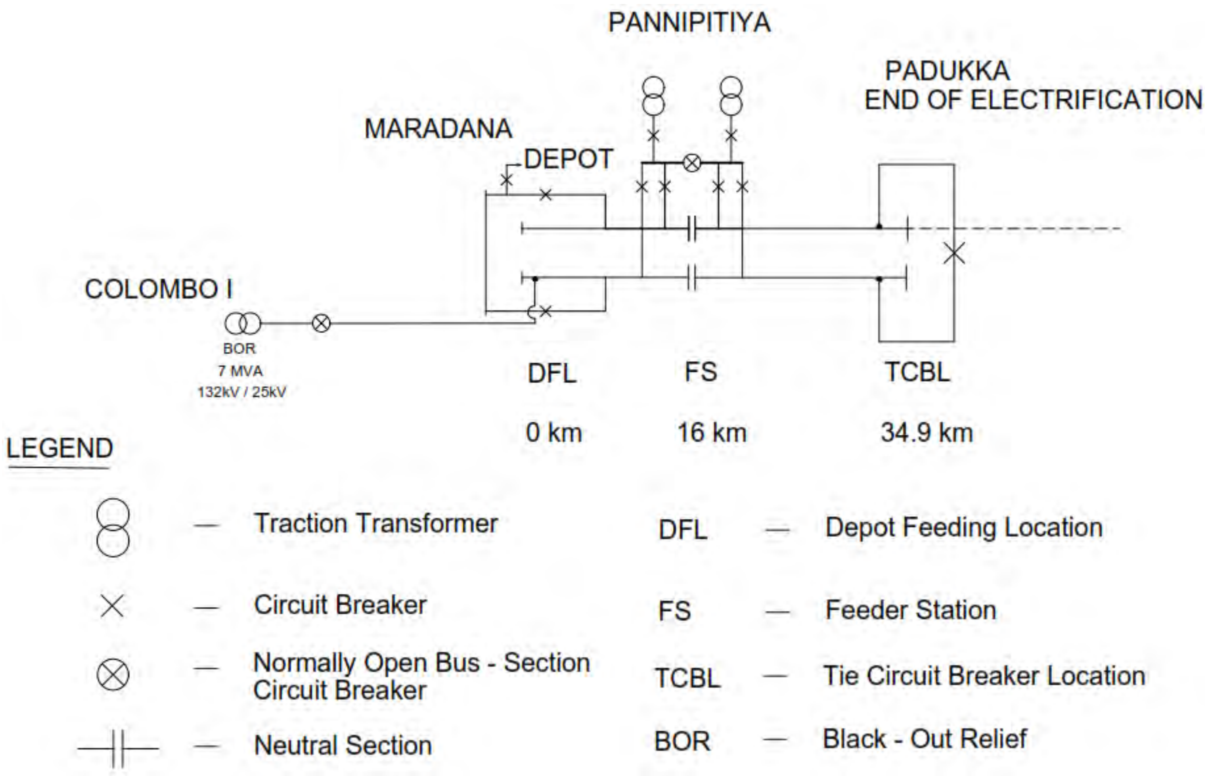


Figure 10-11 Major Feeding SLD for Half Electrified and Double Tracked KV Line with Colombo Substation I BOR

It is therefore recommended that Blackout Relief is included and that Colombo substation I would be used as an alternative source in the case that Pannitipiya is to lose both supply sources – as depicted in Figure 10-11 above. The Black Out Relief capacity is chosen so that stranded passenger-carrying electric trains can be effectively fed with electric power and moved under their own power, one at a time, instead of awaiting rescue locomotives.

10.4.2.5 KV Line Power Feeding Options

When discussing only KV Line isolated from CSRP is relatively small and electrification of this may not be demonstrated as feasible, especially in respect of the need to create a new department in SLR to manage this new railway subsystem. However, if this line is linked to a second stage of upgrade, i.e. Coastal or Main Lines, then economies of scale will be manifest accordingly and feasibility will be significantly improved. It is expected that the electrification will be incrementally enhanced with further stages while increasing O&M efficiency for the new SLR Electrification Department.

10.4.2.6 CSRP Holistic Traction Power System

The review of the draft report with the CSRP Steering Committee resulted in a request for the feasibility exercise to assess the holistic traction power supply network for the complete project network comprising all four designated lines, i.e.:

- Kelani Valley Line
- Coastal Line
- Main Line
- Puttlam Line

A similar approach to that, which used on the KV Line was adopted for this extended exercise, also including the recommendations from the pre-feasibility study. The findings of CEB potential sources are summarized in Figure 10-12 below.

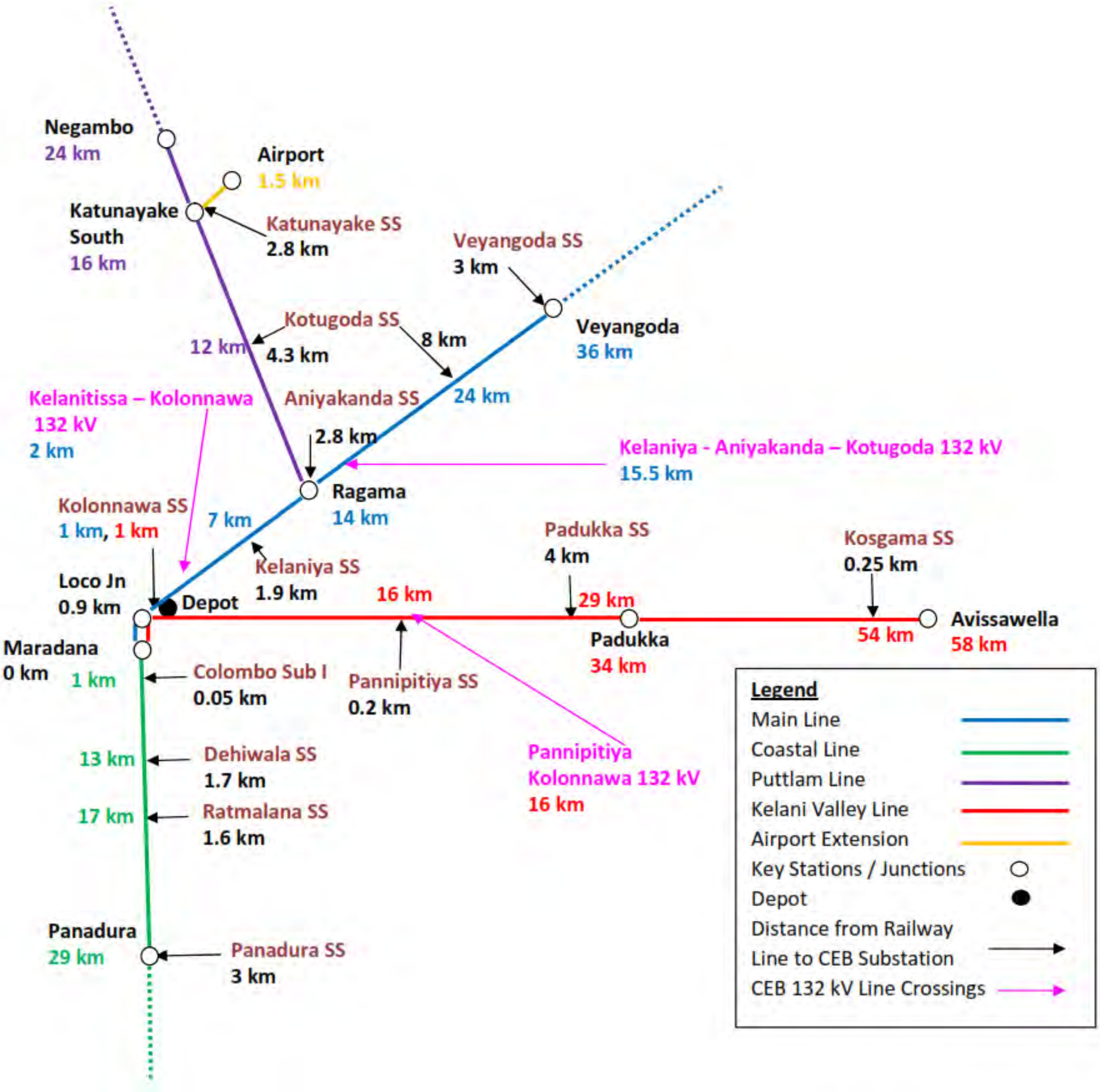


Figure 10-12 CSRP Feeding Options

Each of these CEB network nodes were assessed in terms of availability of independent supply circuits and related diversity of supplies within the grid network. The preferred supply feeding points were identified as follows:

Coastal Line

Ratmalana had been identified as a potential source during the pre-feasibility study. But investigations identified this to be a single source within CEB with no diversity. However, Dehiwala was found to have better diversity. Discussions with CEB revealed a prospective "win-win" situation by selecting a location midway between the two grid substations that could provide the necessary diversity and reliability for the railway, whilst also allowing CEB to strengthen their 132 kV grid by interconnecting their Ratmalana and Dehiwala GSS nodes.

Main Line and Puttlam Line

It is noted that the pre-feasibility study gave a recommendation to derive a supply from Kelaniya GSS. But this seems too close to the feeding sources proposed for both the Coastal Line and Kelani Valley lines.

The railway junction at Ragama would clearly be an ideal feeding point into the railway network as it would serve both of the railway lines. During joint discussions, CEB expressed their concern on the fault level at Aniyakanda CEB GSS which is adjacent to Ragama junction, is not particularly high. Hence special measures may be needed to ensure that the network disturbance is suitably mitigated.

The summary feeding network is therefore provisionally determined as in Figure 10-13 below. It is suggested to retain the feed from Colombo I as part of the total network as a Black Out Relief contingency.

The proposed feeding configuration will be translated into a railway major feeding diagram once the track numbers and the layouts have been finalized.

The conclusion is that the detailed proposal for the KV Line upgrade is indeed commensurate with the holistic proposal for the CSRP with no short-term or abortive works as the system in KV line can be grown incrementally as the other lines are electrified.

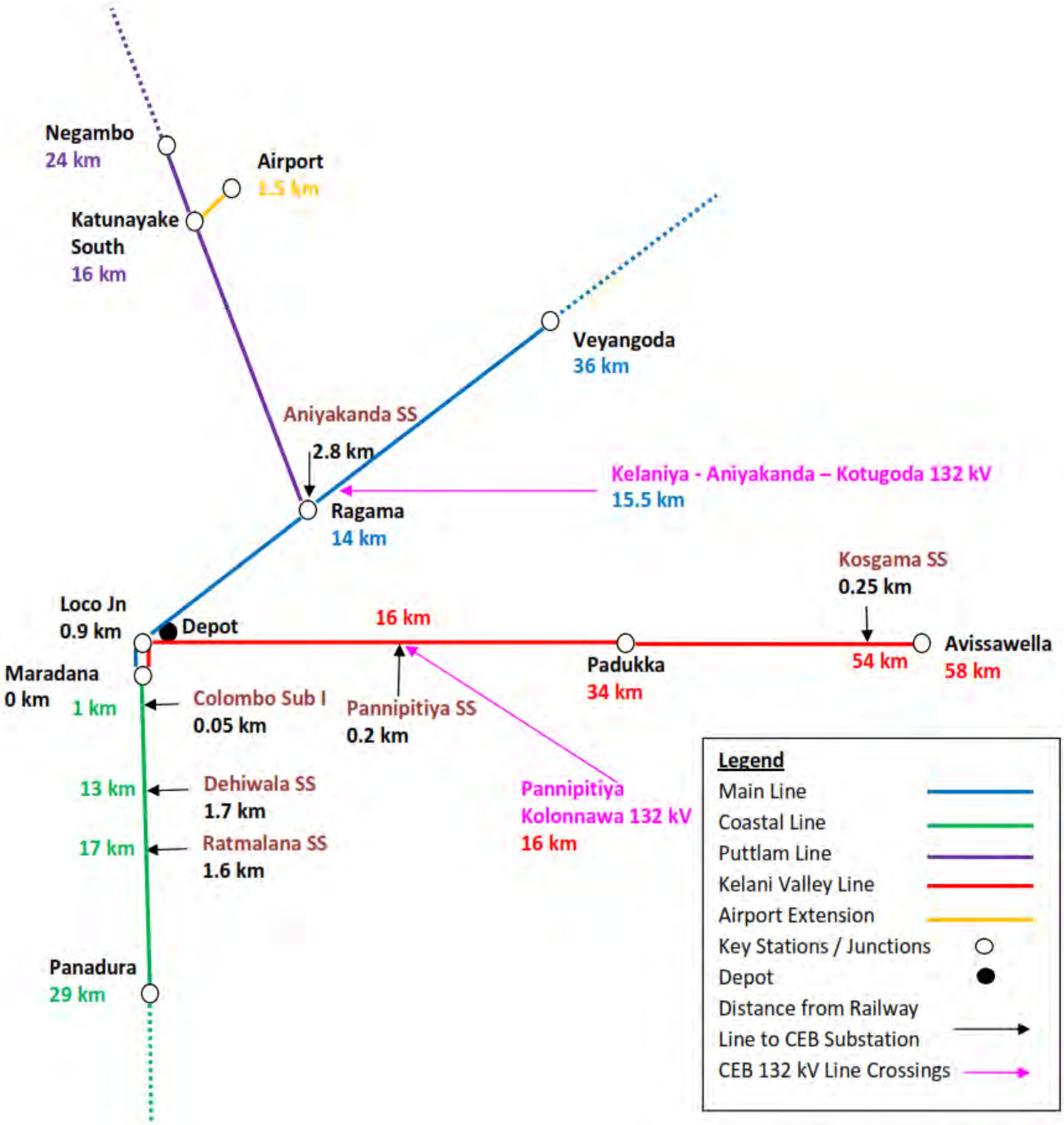


Figure 10-13 Selected CSRP Feeding Locations

10.5 Review of Existing Electricity Regulations and Legislations

It is general that the initial introduction of railway electrification to a country requires a review of relevant laws and regulations as these are based on public utility supply networks which generally have different operating voltages and defined safety clearances that are not associated with a moving load using a direct contact means of current collection.

An initial review of Sri Lanka’s electricity regulations has identified that existing regulations are not “railway electrification ready” and so a full review will be required to identify enhancements that will be required to facilitate implementation of any OCS electrification scheme.

A good example is the table of minimum allowable clearance from ground for transmission and distribution voltages shown in Table 10-2, where the railway standard 25 kV single phase voltage is not defined explicitly. It must be remembered that 25 kV single phase voltage is equivalent to 43.3 kV 3-phase voltage and therefore the established 33 kV clearance requirements cannot be automatically adopted.

Extracts from current regulations in Sri Lanka are as shown in Table 10-2,

Table 10-2 Allowable Minimum Ground Clearances

Single Please Voltage	3-Phase Voltage	Minimum Allowable Ground Clearance
6.35 kV	11 kV	5.2 m
19.05 kV	33 kV	6.1 m
76.75 kV	132 kV	6.7 m

Here does not appear to be any provision for determining utility lines that should or should not cross above an OCS electrified railway and related minimum vertical clearances between the uppermost part of any railway OCS system and any allowable utility line that crosses above the railway.

It is also noted that there are numerous road level crossings throughout this rail corridor and it is expected that a number of these will be retained. The introduction of a 25 kV OCS system at any residual level crossing will need to be addressed at this stage as a prospective hazard to road users and managed accordingly.

It is understood that Sri Lanka's electricity regulations are currently under review, so it would be very timely to factor railway requirements into the review process in order to prepare the regulations for railway electrification at any future point in time.

Discussions with Public Utilities Commission Sri Lanka (PUCSL) have identified an additional regulatory process that will need to be embraced by CSRP in respect of Power Distribution Licensing. PUCSL will provide the existing procedure for review by the project electrification team and also assist in guiding CSRP compliance with this procedure.

10.6 Prospective Locations of Minor 25kV Switching Stations for KV Line

Minor 25 kV switching stations are locations where there are no incoming traction electricity supplies from CEB but where switchgear and other related equipment are located to provide load distribution and operational sectioning for the electrified railway. These are located strategically alongside the railway and have direct connection at 25 kV to the OCS, whilst being remotely monitored and controlled from the OCC by way of the power SCADA subsystem. These locations are approximated and can be adjusted to ensure land availability, access for O & M purposes as well as availability of domestic electrical supply for building services and auxiliary power.

10.6.1 Tie Breaker Location

A tie breaker will be located close to the extremities of an electrified railway and will connect the two main line OCS sections. Its purpose is to share any loads between the two electrical subsections to mitigate against any voltage drop that may be experienced if any one of the lines is heavily loaded electrically. It also has suitable protection relays to ensure that in the case of a fault, only the affected section will trip, while leaving healthy sections energized so that the impact of any tripping event is limited.

10.6.2 Mid-Point Sectioning Location

A mid-point sectioning location will be installed approximately midway between adjacent feeder stations. Its main purpose is to provide robust segregation between the different feeder station main supplies, which are likely to be of different electrical phases. It will have a split busbar with a bus-section circuit breaker between the two busbar sections. This bus section circuit breaker is normally open but can be closed in the event of unavailability or loss of a main incoming feeder station circuit to allow for extended feeding to be brought into force. This will have protection to prevent the two live bus bar sections being connected and introducing a major fault for inadvertent phase to phase connections. There will also be circuit breakers connecting to each line's OCS on each bus section. These will provide load sharing between all tracks and also provide effective discrimination during the case of any electrical faults, by ensuring only disconnection of affected electrical sections. In the event of faults whilst leaving healthy sections energized, thus minimizing operational impact of any system perturbations.

The OCS will be equipped with a phase break or neutral section arrangement in this vicinity to ensure undesirable out of phase connection, which cannot be made by a passing pantograph.

10.6.3 Intermediate Track Sectioning Location

Intermediate track sectioning locations may be required to assist in sharing the loads between the main lines and also in increasing the flexibility of the power system in terms of containing the effects of any incidents and thus increasing the resilience of train operations. These basically comprise a suite of circuit breakers connected to a single busbar which are directly connected to the various OCS track equipment. OCS equipment would include related insulation to complement the sectioning arrangements.

These could be located at key junction areas to provide operational segregation of the different routes or midway between a feeder station and a midpoint sectioning location if predicted power flows as required.

10.6.4 Depot Feeding Location

Depot feeding locations may be required in the case that electrified maintenance depots/yards are distant from the feeder stations and can only be supplied with traction power through the main line OCS equipment. Such an installation would comprise three circuit breakers connected to a single busbar – one connected to each of the two main line OCS equipment with the third connected to the depot/yard OCS equipment.

This gives operating flexibility to maintain a supply to the depot in the event of unavailability of either main line and the inclusion of appropriate electrical protection would ensure that any fault within the depot/yard could be cleared by operation of the yard circuit breaker and have no impact on main line operations.

10.7 SCADA

A Supervisory Control and Data Acquisition (SCADA) subsystem will be included as a conventional means of real time operation of the electrification network from a workstation within the Operational Control Centre (OCC). This subsystem allows for the duty of Electrical Control Operator to monitor and control the entire electrification network from a dedicated workstation by observing equipment status, receiving alarms and indications from all outstation equipment and effecting control of operable devices. Thus any event is instantly reported and acknowledged allowing for appropriate action (such as network reconfiguration) to be undertaken swiftly in accordance with Standard Operating Procedures and Emergency Procedures. It also facilitates routine switching operations to be conducted from a single central location to effect planned isolations and outages for routine maintenance activities.

The SCADA subsystem comprises servers and workstations situated at the OCC which communicate with the various electrification outstations through the main fiber-optic data transmission system of the railway.

10.8 Forecasted Traction Load for Each Substation

The traction load of each substation will be calculated using proposing rolling stock data and railway time table. Forecasted railway traffic for KV line corridors is obtained with referring to the currently available data, additional data collected from the demand analysis and existing traffic on the corridors. Based on the forecasted railway traffic data, proposed railway timetable for the peak hours is generated. Peak hours for the morning peak as 6.30 am to 9.30 am and evening peak as 4.30 pm to 7.30 pm are considered for the simulation purposes.

Proposed EMU for the system consisted with parameters as presented in Table 10-3.

Table 10-3 EMU Parameters

EMU Parameter	Unit	Value
Empty mass	ton	To be Advised (TBA)
Passenger capacity	nos	To be Advised (TBA)
Number of car/trarinset based on 2035 year	nos	12
Maximum electrical power	MW	To be Advised (TBA)
Power factor	Cos θ	0.9
Maximum operation speed	km/hr	70
Acceleration	ms-2	0.83
Deceleration	ms-2	0.97

Train traction load modeling will be done based on the forecasted timetable and optimum power requirement for the traction load will be calculated using simulation software.

Load flow results gained from the simulation to be tabulated as in Table 10-4 and considering the future expansion of the system, proposed traction transformer power capacities shall be given as in Table 10-5.

Table 10-4 Proposing Format of Loading for the Traction Transformers

Time	Pannipitiya Traction Substation			Kosgama Traction Substation		
	Active power (MW)	Reactive power (MVar)	Apparent power (MVA)	Active power (MW)	Reactive power (MVar)	Apparent power (MVA)
1 min average						
10 min average						
1h average						

Table 10-5 Proposed Format of Power Capacity for the Traction Transformers

Traction Substation	Apparent Power (MVA)	Apparent Power with 10 % Margin (MVA)	Proposed Traction Transformer Capacity (MVA)
Pannipitiya Traction Substation			
Kosgama Traction Substation			
Maradana Traction Substation			

10.9 Typical Layouts for Traction Substations

A traction substation is equipped with all the necessary equipment to transform and control the AC power from the utility supplier into the traction power feeding system for the electric trains. A typical layout of a traction feeder substation is divided into the 132 kV high voltage side and the 25 kV medium voltage railway power feeding side as shown in Figure 10-14.

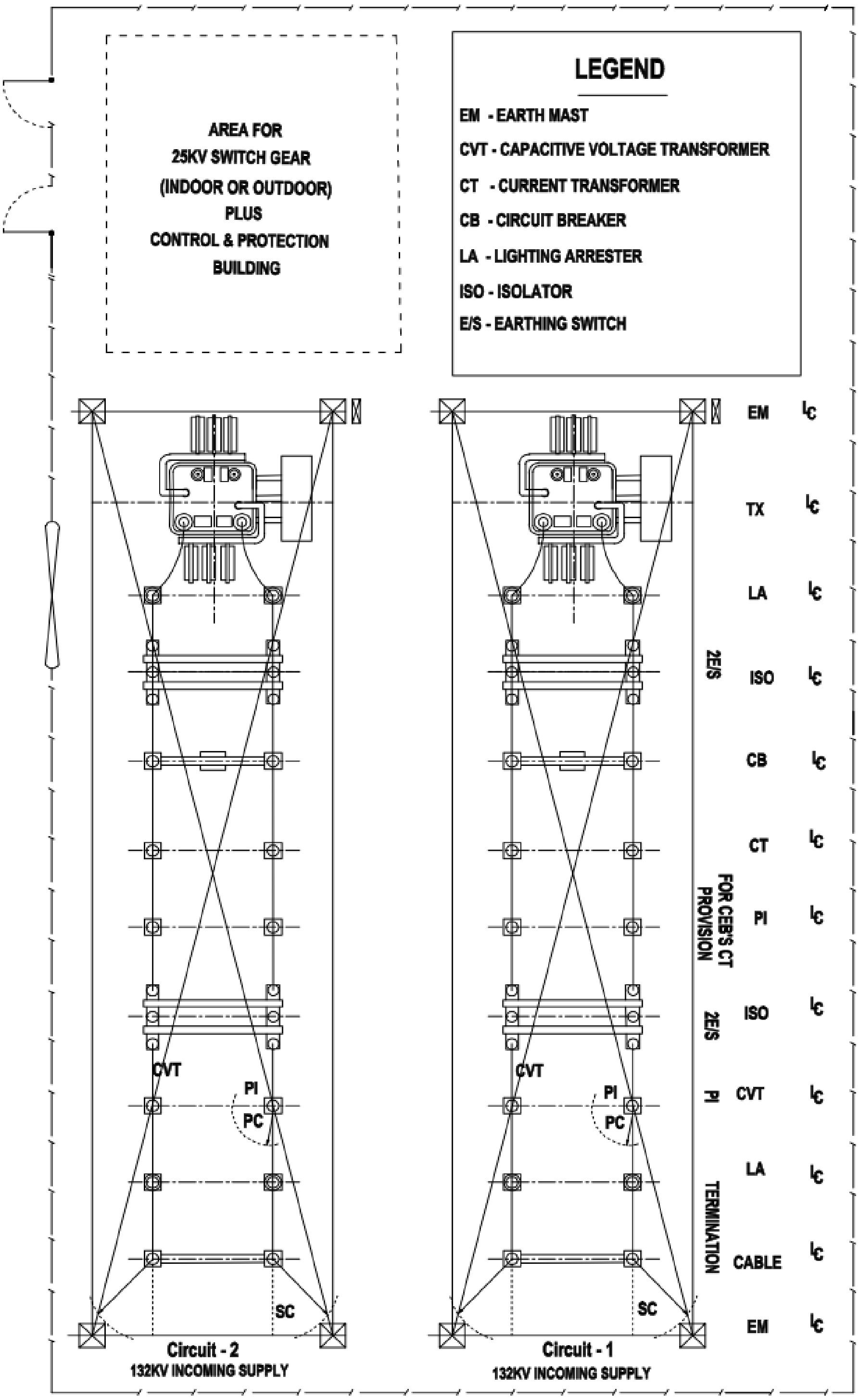
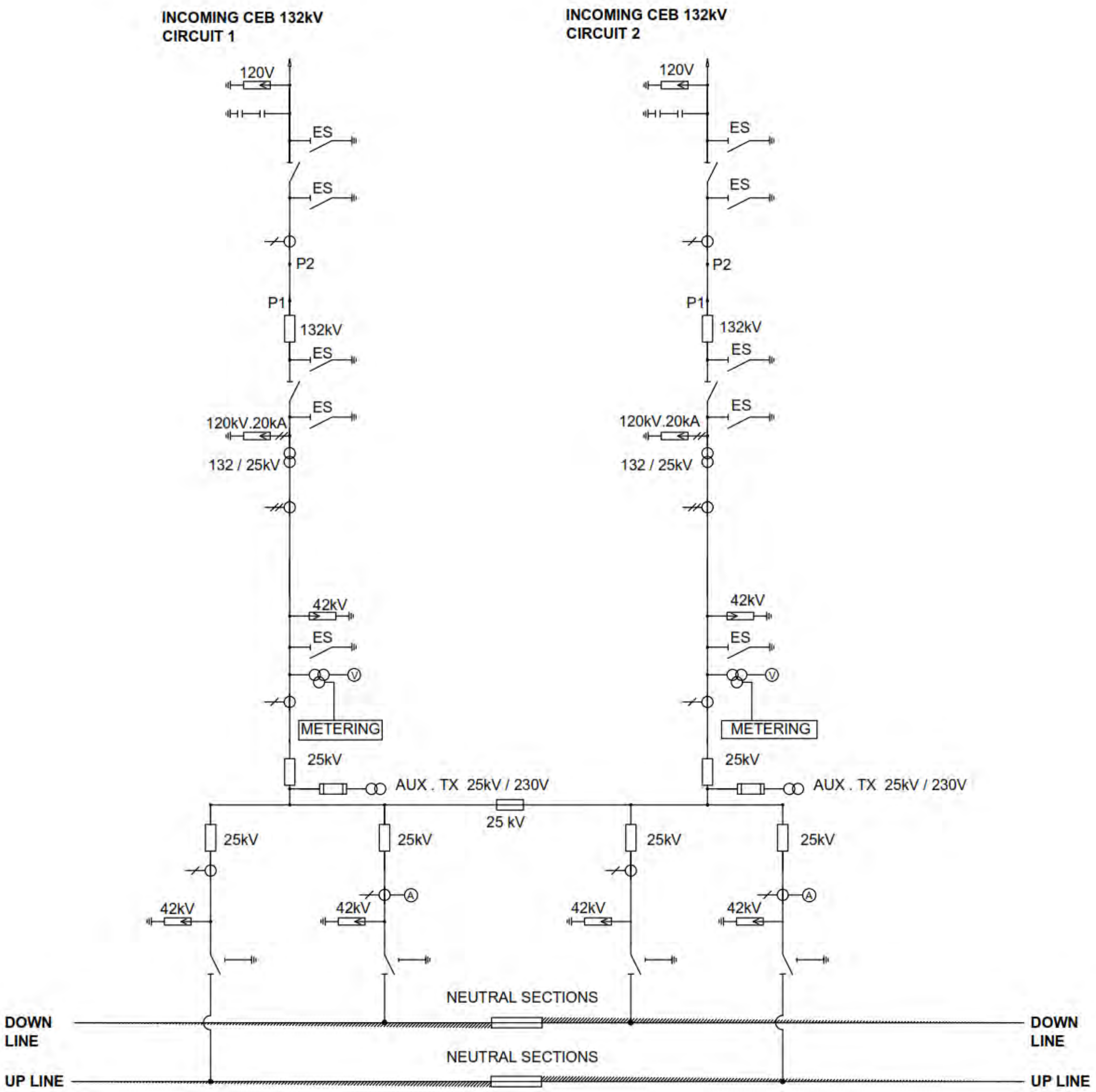


Figure 10-14 Proposed Feeder Station Layout



LEGEND :

SYMBOL	DESCRIPTION
	SURGE ARRESTORS
	CIRCUIT BREAKER
	CURRENT TRANSFORMER
	CAPACITIVE VALTAGE TRANSFORMER
	ISOLATER WITH 2E/S
	25kV THREE POSITION ISOLATER
	POWER TRANSFORMER
	EARTHING SWITCH

SYMBOL	DESCRIPTION
	POTENTIAL TRANSFORMER
	25kv TWO SECTION INSULATOR TYPE NEUTRAL SECTION
Ⓐ	AMMETER
Ⓥ	VOLTMETER
	ELECTRICAL INTERLOCKING
	RELAY OPERATION
	25kV HRC FUSE
	ISOLATOR

Figure 10-15 Simplified Indicative Single Line Diagram for Traction Substation

The design is based on an Open Terminal 132 kV switchyard as this is more cost-effective than indoor but does require a larger land footprint.

There is a choice available for either indoor 25 kV switchgear or outdoor type as both are available in the market. The simplified indicative single line diagram for traction substation is given in Figure 10-15.

10.9.1 Equipment List for Feeder Substations

Traction sub stations are the most important features of an electrified railway system which convert the 132 kV two phase power in to 25 kV, 50 Hz single phase power supply for the OCS. A Traction substation is designed based on the power capacity predicted from the load calculations and two traction transformers are expected in each feeder station to provide the required level of redundancy. The proposed traction transformer for the system is a classic single phase 132/25 kV fixed ratio type, which ensures the delivery of the required power effectively.

Typically, a feeder station will comprise of the following key equipment:

- 132 kV cable landing gantry
- 132 kV outdoor busbars132 kV isolators/Earth Switches
- 132 kV circuit breakers
- 132 kV/25 kV main transformers
- 132 kV voltage transformers and current transformers
- Lightning arrestors
- Aerial earthing wires for lightning protection
- Earth grid
- Floodlights
- Security compound fencing
- 7 x 25 kV circuit breaker
- Voltage and current transformers for protection purposes
- 25 kV auxiliary supply transformer
- Incoming auxiliary supply from utility company
- Auxiliary supply changeover panel
- Control and protection panel
- Battery charger and UPS
- SCADA RTU and related marshalling cubicle
- AC power distribution panel
- DC power distribution panel
- Telephone
- Desk and cabinet for manuals

- Special tools and equipment
- Air conditioning equipment
- Fire detection system
- Intrusion detection system

10.9.2 Equipment List for Mid-Point Sectioning Station

Typically, a midpoint sectioning location will comprise of the following key equipment:

- 5 or more 25 kV circuit breakers
- Voltage and current transformers for protection purposes
- 25 kV auxiliary supply transformer
- Incoming auxiliary supply from utility company
- Auxiliary supply changeover panel
- Control and protection panel
- Battery charger and UPS
- SCADA RTU and related marshalling cubicle
- AC power distribution panel
- DC power distribution panel
- Telephone
- Desk and cabinet for manuals
- Special tools and equipment
- Air conditioning equipment
- Fire detection system
- Intrusion detection system

10.9.3 Equipment List for Tie Breaker Sectioning Location

Typically, a tie breaker location will comprise of the following key equipment:

- 1 x 25 kV circuit breaker
- Current transformer for protection purposes
- 25 kV auxiliary supply transformer
- Incoming auxiliary supply from utility company
- Auxiliary supply changeover panel
- Control and protection panel
- Battery charger and UPS
- SCADA RTU and related marshalling cubicle

- AC power distribution panel
- DC power distribution panel
- Telephone
- Desk and cabinet for manuals
- Special tools and equipment
- Air conditioning equipment
- Fire detection system
- Intrusion detection system

10.9.4 Equipment List for Depot Feeding Location

Typically, a depot feeding location will comprise of the following key equipment:

- 3 x 25 kV circuit breaker
- Voltage and current transformers for protection purposes
- 25 kV auxiliary supply transformer
- Incoming auxiliary supply from utility company
- Auxiliary supply changeover panel
- Control and protection panel
- Battery charger and UPS
- SCADA RTU and related marshalling cubicle
- AC power distribution panel
- DC power distribution panel
- Telephone
- Desk and cabinet for manuals
- Special tools and equipment
- Air conditioning equipment
- Fire detection system
- Intrusion detection system

10.9.5 Equipment List for Intermediate Track Sectioning Location

Typically, an intermediate track sectioning location will comprise of the following key equipment:

- 4 x 25 kV circuit breakers
- Voltage and current transformers for protection purposes
- 25 kV auxiliary supply transformer
- Incoming auxiliary supply from utility company
- Auxiliary supply changeover panel
- Control and protection panel
- Battery charger and UPS
- SCADA RTU and related marshalling cubicle
- AC power distribution panel
- DC power distribution panel
- Telephone
- Desk and cabinet for manuals
- Special tools and equipment
- Air conditioning equipment
- Fire detection system
- Intrusion detection system

10.10 Proven Design of System

The outline design for the traction power system and OCS are based on similar operational electrified railways in various countries. Final dimensioning of the various elements will be confirmed as outputs from the formal system studies that will take place as part of the Detailed Design (DD) stage.

Electrified railways Systems that use OCS electrification systems have complete compatibility between the operation of electric trains and the operation of diesel trains and the CSRP system will be designed and implemented accordingly. There are no operational constraints for diesel traffic beneath live OCS conductors. All SLR staff whose duties take them into electrified areas will be trained in the necessary safety precautions and operating regulations.

10.10.1 Traction Substations

Traction substations shall be located near to the railway line and shall also be close to the grid substation of the utility supplier. The substations must be constructed above the predicted 100-year flood level.

Electrical braking is a standard feature of modern electric traction units with traction motors being used as electrical generators to convert kinetic energy into electrical energy when braking. Rheostatic braking involved the burning of this recovered electrical energy in onboard resistors. However, in recent times the industry trend is to use regenerative braking whereby the energy is fed back into the system to be used by other electric trains or passed back to the utility grid. This gives maximum system receptivity and increases the life of the train's friction brake equipment

The formal studies should include a comparison of system performance with and without regenerative braking, so its benefits can be fully assessed.

25 kV track sectioning locations will be located adjacent to the railway and at locations which are commensurate with their target chainage, as used in the formal studies and taking account of land availability and road access capabilities.

10.10.2 Overhead Catenary System (OCS)

An industry standard simple catenary (comprising a contact wire supported by a catenary/messenger wire) will be suitable for this railway. In depots and yards, a single regulated contact (SRC) could be used to keep the system as simple as possible and reduce interface requirements on the depot buildings.

A wind survey of the electrified route will be required so that wind loading factors are adequately embraced within the system design.

Automatic tensioning of the OCS equipment will be used with balance weights acting either through a pulley wheel system or a drum and cable system to provide mechanical advantage to achieve the required tensions.

Additional operational sectioning of the OCS will be provided by the inclusion of line side isolators at appropriate locations, such as main line crossovers, to support and facilitate single line working and other contingency modes of operation.

In the case that any single line electrification is considered then there may be a need for addition of an electrical reinforcing conductor to lower the system impedance and thus mitigate any possibility of voltage drop causing operational problems at the system extremity, especially under heavy line loading conditions. Typical Configuration of OCS components is indicated in Figure 10-16.

OCS will generally be supported by steel masts which have foundations in the ground for at-grade sections of the railway or incorporated into the civil structure in the case of viaducts or long bridge sections.

If tunnels are used, then the OCS will have to be supported by drop-tubes from the tunnel roof but due allowance will have to be made for electrical clearances and equipment niches for accommodation of tensioning devices and disconnectors. Consideration may be given for the use of a rigid beam OCS support system. This would be more expensive than conventional OCS, but could eliminate niches from the civil tunnel work scope.

The main components of OCS are identified as follows

1. **Post**

- Foundations
- Mast
- Back stays
- Portal structures
- Head spans

- Isolators (manual/motorized)

2. Cantilever

- Stay tube
- Bracket tube
- Insulators
- Registration arm
- Steady arm

3. Wiring

- Contact wire
- Messenger wire
- Dropper
- Jumper
- Returns earth wire (REW)
- Lightning earth wire (LEW)
- Tensioning devices
- In running section insulators
- Neutral section

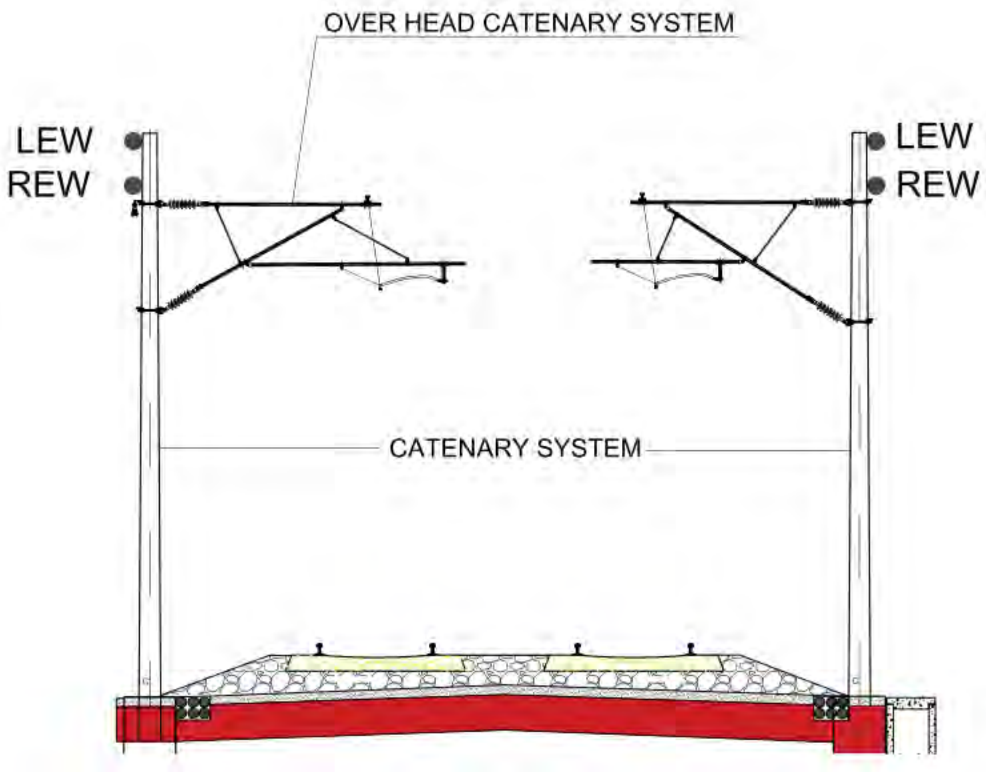


Figure 10-16 Typical Configuration of OCS components

10.10.3 Earthing and Bonding Scheme

Safety of rail users, rail staff and outside parties is a paramount concern. In order to provide a guaranteed safe environment for all people associated with the railway, a robust earthing and bonding system for the railway will be designed and implemented.

For the traction feeder stations, an earthing grid will be designed to safeguard against excessive step and touch potentials in accordance with principles set out in IEEE 80 – 2000 Standard and IEEE 81-2000.

An earthing and bonding study for the railway system will be undertaken that will define the bonding requirements such that rail voltage rise does not exceed limits established in the standards for both normal operating and fault conditions. The earthing and bonding system must be tolerant of defined bonding defect scenarios.

The earthing and bonding system will also ensure that any electrical faults are effectively short circuits to earth such that operation of protective devices are swift and minimized the possibilities of damage to electrical equipment.

Protection against lightning must also be assessed as part of the earthing and bonding scheme. Lightning must be taken directly to earth to ensure its rapid energy dissipation whilst avoiding any risk of conducting the lightning energy to sensitive electrical equipment.

10.11 System Studies

Several offormal studies will be undertaken to support and validate the detailed design of the electrification system. These are described below.

Final demonstration that the systems achieve their performance objectives will be undertaken during System Integration Testing and will include key activities such as HV sort circuit tests.

10.11.1 Power System Study

A power System Study will be undertaken which will initially model electric train operations based on a pre-agreed operation scenario (timetable) across the final alignment. This will combine the concurrent electrical performance of each train to determine the following key parameters:

- Current flows within the OCS – to check equipment ratings are adequate.
- OCS voltages at extremities of feeding sections – to ensure minimum voltage requirements of electric trains are not compromised
- Power demand on supply points – to validate transformer ratings and system capacity levels
- This study will take account of incoming circuit outage conditions to demonstrate that planned outages will be transparent to electric train operations.

The second part of this study will be to determine the impact of the railway loads upon CEB at the Point of Common Coupling (PCC) in respect of

- Power Factor
- Unbalance (Negative Phase Sequence (NPS))
- Harmonic Intrusion

- Voltage Flicker

This will identify any compensation equipment that may be required to avoid breaching CEB power quality standards.

The phase balance of the power system is to be satisfied by connecting traction transformers to the power system with transposition. Figure 10-17 indicates the connection of two identical traction transformers connected to the 132 kV side by transposition, with the final phase allocations being determined by CEB after taking account of their grid loading symmetry.

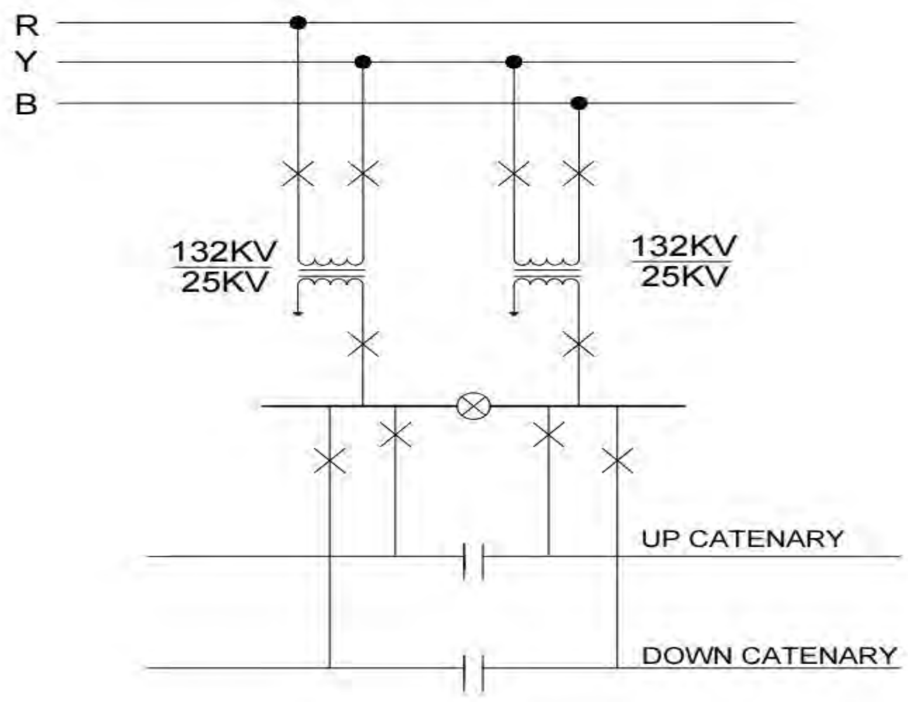


Figure 10-17 Typical Phase Distribution of Traction Power Supply

10.11.2 Earthing and Bonding (E&B) / Immunization Study

An earthing and bonding study will be undertaken to determine the intervals between running rail traction bonds to ensure the system meets international standards for accessible voltages under normal operations and under electrical fault conditions. This study will include scenarios of loss of critical bonds as a result of failure or theft.

The immunization aspect will be achieved by modeling the current flows in the OCS and traction return systems to evaluate the net electromagnetic emissions from the electrified railway and their prospective influence on railway and third-party equipment and networks. Figure 10-18 indicates the proposing OCS earthing arrangement in viaduct sections.

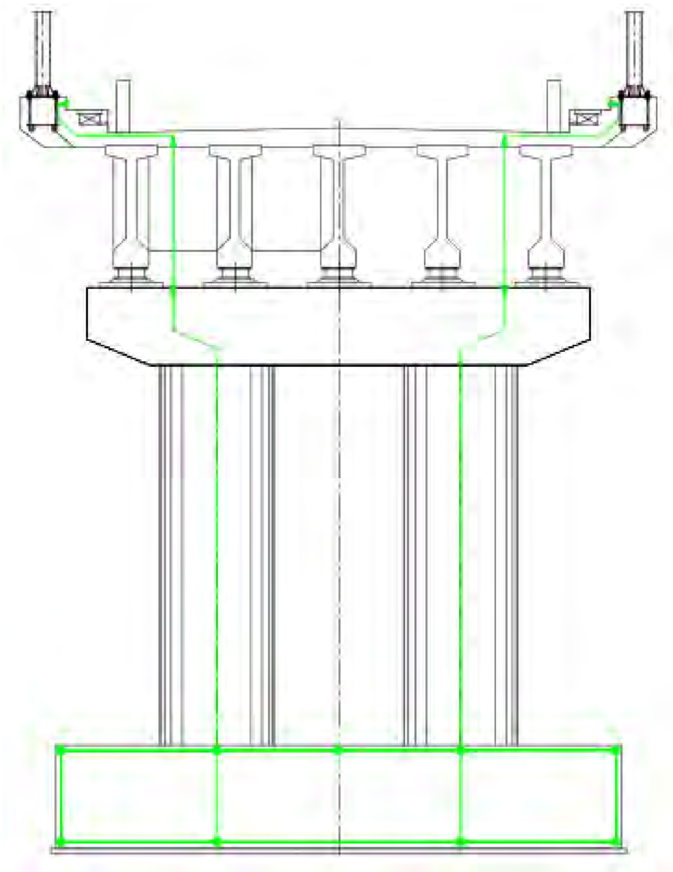


Figure 10-18 Proposing OCS Earting Arrangement in Viaduct Sections

10.11.3 Pantograph/OCS Dynamic Studies

The interface between train pantographs and OCS will be demonstrated by way of simulation studies. This will show the mechanical interaction between these key elements and demonstrate that there is no adverse impact between pantograph properties of contact points at expected train speeds. When multiple pantographs are used, such interactions are arising from the disturbance of the contact wire by the leading pantograph.

10.12 Power Systems and OCS Interfaces

10.12.1 Rail Operations

Sectioning of the OCS will be determined to complement the final track configuration such that any incident can swiftly be isolated from the rest of the system and allow rail operations to continue around the perturbation site. Motorized isolators will be used such that necessary switching can be undertaken from the OCC through the SCADA system to enable temporary feeding configurations to be implemented.

Special rules and regulations will need to be developed and promulgated with respect to the presence of AC electrification.

New signage will be required for various operating reasons, e.g. advising drivers since they are about to enter an electrified area.

10.12.2 Interfacing with CEB

Interfacing with CEB will be necessary and significant and is likely to include the following issues in the design of the feeder stations:

- Coordination of incoming cable landing gantry requirements (assuming CEB supply the cable and the project supplies the landing gantry).
- Determination of earthing or gapping requirements between railway feeder station and grid substation.
- Coordination of 132 kV incoming differential protection
- General protection coordination with CEB
- Coordination of type and location of metering CT and VT for CEB use
- Access to switch yard for CEB operation staff
- Location of CEB metering cubicle
- Tariff agreement (commercial issue, likely to be the system operator responsibility with CEB)
- Development of joint Operation and Maintenance Agreement between railway and CEB. This normally defines equipment ownership, operating responsibilities and maintenance responsibilities which are generally not the same.
- 132 kV equipment designations – expectation is to follow CEB convention.

10.12.3 Track

The OCS design must include provision for routine track maintenance activities. This is commonly achieved by defining and agreeing track maintenance tolerances, which are limits within which track may be adjusted without reference to OCS geometry.

- Track formation must include for Under Track Crossings (UTX) for cross track cabling from any of the subsystem cabling requirements.
- Methods of attaching permanent systems cables to running rails (bonding, etc) must be determined and agreed.
- Methods of attaching cables to sleepers must be determined.
- Methods of attaching other devices (e.g. APC Magnets) to sleepers/rails must be coordinated.

10.12.4 Alignment

10.12.4.1 Overline Structures

Electrical clearances must be defined and maintained at all overline structures. New structures should be built to achieve these clearances but retained existing structures may need special OCS design solutions to avoid expensive structure replacements or enhancements.

Special requirements may be required such as flashover protection to avoid any propensity for electrical flashover to non-metallic structure members.

There may be requirements to support OCS from large overline structures which will need coordinating with the owner of the structure.

Safety screening of overline structures will be required to prevent structure users from inadvertently accessing the OCS hazard zone. Minimum standards must be developed and complied by structure builders and also owners of any retained existing structures.

10.12.4.2 Underline Structures

For short underline structures the OCS design will avoid locating support mats as far as practicable.

For any others there will be a need to have embedded earthing capability to effectively bring “earth” to bridge/viaduct/structure deck level.

A method of fixing for OCS masts must be developed so that these can be included in the civil works – whether these are needed for the present project or as a future addition.

Undertrack crossings need to be considered as shallow bridge/viaduct decks are often problematic for inclusion of necessary ducts.

10.12.5 Rolling Stock

There are several areas of interface between the electrification system and the rolling stock that need developing and controlling:

- Inclusion of a main Circuit Breaker (CB) on the train sets. This will allow for a train fault to be cleared by the on board CB and therefore not affect the OCS system or the operation of other train sets.
- Neutral section strategy. There are various genres of neutral section (Phase Breaks) and the determination of which is to be used has influence on the configuration of the on board HV equipment and connectivity between pantographs.
- Pantograph operating parameters. This is essential input for the OCS/Pantograph dynamic study to ensure that multiple pans can operate effectively without propagating unacceptable physical interactions and poor electrical contact continuity.
- Traction package characteristics are vital for successful power system studies.
- Pantograph head dimensions and vehicle “sway” characteristics. These are essential in determining robust OCS stagger limits for both tangent track and curved track.

10.12.6 Signaling

The signaling equipment must be inherently immune to the effects of operating in a 25 kV AC zone of influence.

The strategy of train detection could create a major area of interfacing between signaling and electrification. If balanced audio frequency track circuits are used, there is likely to be a major coordination effort required for traction bonding design. If single rail track circuits or axle counters are used, the coordination requirement will be significantly reduced.

Coordination will also be required to ensure the signaling system which cannot bring a train to a halt in a position where pantographs should not be static, i.e. neutral sections.

Other interfacing aspects that will need consideration of followings:

- Physical signal locations must also be coordinated with OCS design to avoid physical conflict with OCS tail wires or mid-point anchors.

- Physical signals may need inclusion of safety screening to allow maintenance access whilst avoiding hazards of live OCS.
- Remote OCS motorized isolators may need to derive power from nearby signaling sources.
- Earthing and Bonding
- Standby signal supply source for OCS

10.12.7 Communication

The immunization study will demonstrate compatibility between the electrification system and the communications equipment. This will be validated through the execution of short circuit tests which will demonstrate compatibility.

The power SCADA system will use the communications network as a means of functional connectivity between its various outstations and the main operating hub at the OCC, thus a significant interface.

10.12.8 Depot

Within the maintenance depot, there will be a means of access to the roof area of electric trainsets. It is reasonably expected that this will be in the form of permanent catwalks and access stairs. These will be screened and protected by interlocking with OCS equipment to ensure access can only be made when OCS is isolated and earthed in accordance with a formal Depot Isolation Procedure that will be developed.

- Depot structure earthing will need to be coordinated into the integrated system common earthing system.
- Depot structure will need to support OCS terminations and support from roof beams.
- Depot wash plant may need to have its OCS isolation for maintenance activities.

10.12.9 Stations

Station earthing design must accommodate possibility of OCS flashover from any roof supports. Station structure must be examined for any OCS support requirements.

Pedestrian footbridge between platforms safety screening and OCS clearances must be taken into account.

10.13 Future Proofing of the Railway

The railway is expected to have an operational lifetime of at least 30 years. It is therefore imperative that the design of the railway takes account of all dimensions in the anticipated growth during this lifetime in terms of:

- Ridership increases as the railway matures
- Geographical expansion of the upgraded railway through extensions into adjacent railway sectors.
- For electrification this can be achieved by assessing the following aspects
    - Installing main power transformers as ONAN (Oil Natural Air Natural) units that can have radiator cooler fans added later to up rate the transformer to ONAF (Oil Natural Air Forced) and thus increase their operating capacity by up to 20%.
    - Identifying prospective feeder station locations beyond the existing project boundaries so that extension plans are already known and do not required major re-works of the KV infrastructure when such extensions are undertaken.
    - Ensuring adequate provision is made for expanding any short-term single track sectors to double track by adding the necessary equipment to existing installations at the time of implantation.

It is important that all subsystems are engineered and designed to achieve a common operating objective. The power system and signaling system must be designed for the same traffic levels.

10.14 Staging Works against an Operational Railway Background

The strategy for implementation of the railway upgrade works can have a significant influence on the project delivery costs, noting that the project Terms Of Reference (TOR) require minimal impact on existing train operations within the project corridor. The project corridor is heavily constrained by encumbrances which are likely to prevent construction activities progressing without significant intrusion into existing rail operations.

Therefore, a project delivery strategy must be developed which is acceptable to all stakeholders.

10.15 Operations and Maintenance

The Colombo Suburban Railway Project will introduce electrification as a railway subsystem for the first time in Sri Lanka and this will necessitate a new dimension for rail operations and maintenance. New operating rules will need to be introduced to provide a framework for safety of staff, passengers and the general public. Specialist engineering teams will be needed to operate and maintain the electrification subsystems in accordance with the new equipment and related procedures.

An indicative outline electrification organization is shown in figure 10-19 to simply provoke thoughts and discussion on this new department. Key generic roles and responsibilities are detailed below.

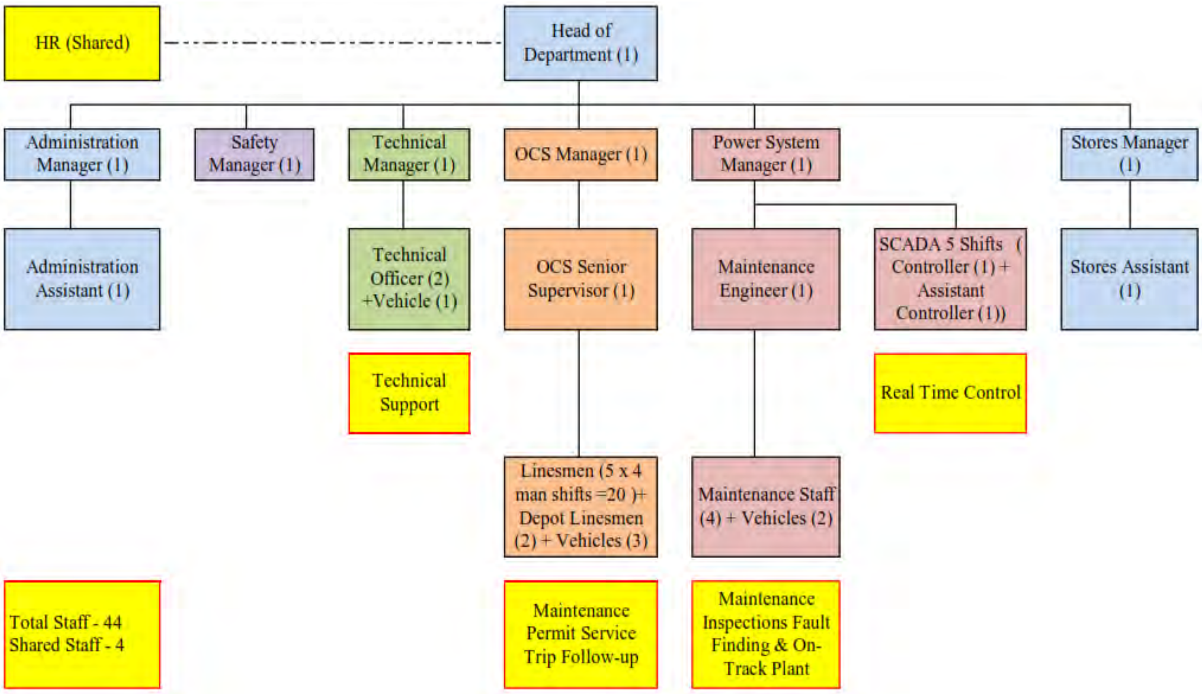


Figure 10-19 Proposing Electrical O&M Staff

10.15.1 Sri Lanka Railways Rules and Regulations

It is general for any electrified railway to create a set of regulations that are applicable to the electrified area to cater for the additional operational requirements and these are often named "Working Instructions for AC Electrified Lines" or equivalent.

This document could be structured in 3 parts to simplify applicability and familiarization training:

- General Requirements: This section would be intended for all SLR staff whose duties require them to work within the electrified area. Content would include safety considerations such as how to avoid hazards, how to get the traction power switched off in emergency, how to report observations of damage, first aid, etc.
- Isolation Process: This section would be intended for all electrification staff and key staff from other departments whose duties would require them from time to time to work under isolated OCS conditions. Key content here would be how to formalize the suspension of electric train operations within an agreed area, how to remove power from sections of OCS, how to test the OCS, apply portable earths and issue "Permits-To-Work".
- Depot/workshop Process: This section would describe the special delegated authority that would be given to the Depot Supervisors so that they can routinely execute their own isolations for the purpose of accessing the roof area of electric trains in a safe and controlled manner.

A further key document would be the "Electric Control Room Instructions" which would be issued and trained for all power SCADA operators. This document would include protocols such as all the necessary processes to effectively manage the electrification system in real-time, how to respond to emergency and non-emergency requests, how to implement and cancel formal isolations, how to interact with CEB Grid Control, etc.

10.15.2 Power SCADA

The Power SCADA subsystem is the nerve center of the electrification systems and will be located in the CTCC alongside all of the other centralized operational control work stations. It must be manned continuously – 24 hours a day and 7 days a week. The SCADA system gives real time control and indication of the status of all of the 25 kV equipment in the defined electrified area as well as the interface with CEB. The Electric Controller is often supported by an assistant so that there is always somebody ready and available to take an emergency call or report. The staff must be familiar with the equipment and related procedures as well as the railway operating rules.

10.15.3 Power System Operations and Maintenance

The power system staff is consisted with technicians and assistants who will undertake routine equipment inspections and maintenance for all power supply equipment including follow-up activities on non-debilitating alarms that are generated through the SCADA system. Maintenance of the SCADA system is also their responsibility. As the power system has high levels of redundancy, these staff are normally allocated for day shift only along with a capability to be called out after working hours during any incident occur.

10.15.4 OCS Operations and Maintenance

The OCS staff will be responsible for a number of key activities:

- OCS patrols and maintenance
- Provision of isolation and permit service to other railway departments
- Removal of obstructions from OCS
- Providing advice to others in respect of same systems of working
- Responding to operational perturbations

These staff are first line responders and therefore need to have a presence continuously, 24 hours a day, 7 days a week. They will be arranged in shifts of around 4 staff so they can adhere to safety rules when accessing the tracks. They will generally use a road vehicle which contains sufficient equipment to allow them to deal effectively with most incidents that may occur.

10.15.5 General Support Services

Co-location of the electrification staff with other staff groups (i.e. at the main depot/workshop area) would allow economies of scale to be realized through sharing of support services such as stores management, human resources and security.

10.15.6 Special Tools and Equipment

Special tools and equipment requirements will be developed for inclusion in the DD stage but is likely to include the following major items:

- Portable earths and applicator poles
- Obstruction removal insulated tools
- Live line testers

- Road vehicles
- Facilities for transporting and erecting replacement OCS poles
- Rail mounted cable drum carriers for running OCS conductors
- Rail mounted staff access platforms for OCS inspections
- Electrical test equipment
- Loose lifting equipment
- Tensiometer
- Battery loco for tunnel operations

10.15.7 Electrification Network Size

The electrified KV Line is a small network compared to many railways around the world and it is difficult to promote it from an Operations & Maintenance perspective as the new organization of around 40 staff are likely to be under-utilized.

To illustrate this further the addition of the Coastal Line as an electrified sector of SLR, would probably not require any additional staff for the proposed carder to the KV Line alone. Therefore, KV Line and the Coastal Line together equate to a viable network for the proposed O & M organization.

10.16 Conclusion

CSRP's preliminary investigations and development of the Feasibility Study for the electrified railway have identified the following salient points:

(1) The Sri Lanka national electricity authority, CEB have enough capacity in their network to supply electricity and support a modern electrified railway system. In fact, they are very excited by the idea and have expressly stated their willingness to participate in determining cost-effective solutions for establishing viable energy supply points for the electrified railway.

The Sri Lanka national electricity regulatory body, Public Utilities Commission Sri Lanka (PUCSL) have valid rules and regulations for general safety of electrical supply equipment but these do not anticipate a 25 kV single phase 50 Hz AC overhead catenary system (OCS) as since such a system has never existed in Sri Lanka before. It is therefore vital that regulations shall be reviewed and those appropriate amendments shall be proposed. Such amendments must address a number of key parameters:

- Minimum vertical height of 25 kV bare OCS equipment above ground level, especially noting the propensity for road/rail level crossings to be retained after the railway upgrade is completed.
- Minimum vertical clearance above a 25 kV OCS electrified railway, which must be clear vertical height to any type of utility crossing. This is likely to determine which utilities are not allowed to cross above a 25 kV OCS electrified railway system.
- Minimum vertical clearance above a 25 kV OCS electrified railway to an allowable utility crossing, e.g. a CEB HV transmission line.
- Public safety protection requirements at any over-line crossing above the electrified railway.

Studies of the CEB grid network and the KV railway route have identified a number of rail system major feeding electrification options which have been evaluated.

It is expected that the modest extent of the initial KV upgrade project area does not yield an electrified area which is financially viable, but this of course is subjected to economic evaluation. Future extensions will help improve this viability at zero on-cost as the electrified rail network grows.

The fact that this is likely to be the first phase of a programme of railway upgrades which has not been overlooked and therefore studies at extending beyond the KV boundaries are being undertaken so that a holistic view on electrification across a larger element of Sri Lanka Railways can be taken to ensure that appropriate future-proofing can be embraced.

As per the ADB TOR, railway electrification is to be part of a future initiative. Therefore, any railway upgrade works must be "electrification-ready". To satisfy this requirement significant efforts are being made to define the related interface requirements between the various railway subsystems so that key interfacing elements (such as embedded earthing in major under-line structures) are included in the delivery of any initially non-electrified railway and hence addition of electrification at a future stage can be achieved with zero, or minimal, intrusion into the operating railway.

Detailed technical specifications are being developed to enable the procurement of the necessary electrification subsystems of Traction Power Supply, Power SCADA and OCS at any point in the future.

CSRP must proceed with finalisation of proposals for enhancing Electricity Regulations so that the project can proceed accordingly and be able to quantify any while all alterations to existing utilities and their associated costs can be taken on board as part of the total project costs.

CHAPTER

11

Signaling and Train Management Systems

Chapter 11 Signaling and Train Management Systems

Chapter Summary

Introduction

New signalling and train management systems will substitute all existing single-line block sections with new, virtual, Moving Blocks over the entire route, including integration with the existing station signalling system at Maradana. This new signalling and train management system will manage train operations at optimum headways, automatically calculated as and when required, to meet both the actual traffic conditions and the forecasted future traffic demand.

For the purposes of the feasibility study, UIC standards had been adopted as the norm, which had mandated a consideration of signalling options using the European Railway Train Management System (ERTMS) as the design basis. ERTMS comprises two main components, European Train Control System (ETCS) and, specifically, the radio system known as Global System for Mobile Communications – Railway (GSM-R) to the exclusion of all others. However, SLR had determined that future telecommunications system would use Long Term Evolution (LTE) radio system, which thereby excluded ERTMS, but not ETCS, from consideration.

Electronic devices known as balise or Eurobalise will be fitted, as duplicate in case of failure, to the sleepers, and will be loaded with electronic data, which will identify the particular balise and inform the train via an on-board transponder of the balise location to enable train's on-board equipment to correlate / correct the calculated location.

One further provision will utilise a hybrid version of Level 3 by installation of an axle counter section on each main line at Baseline Road and Kosgama, with provision for future installations at Nawinna, Makumbura North, Padukka and Waga. These provisions will enable verification of the train length data manually entered into the cab signalling equipment by drivers at start of journey or prior to entry into the KV Line, and will be applied in particular to passenger and freight trains that are locomotives.

KV Line Train Operations

Train service operations along the KV Line will primarily be by electric multiple-units (EMUs), but diesel multiple units (DMUs) will continue to operate through to Avissawella. Additionally, some long-distance passenger services may operate along the KV Line, together with locomotive-hauled freight trains. Each type of train will have different characteristics that produce large variations in speed, acceleration and braking distances, which latter from shortest to longest are EMUs, DMUs, loco-hauled passenger trains and loco-hauled freight trains; however, loading and length of consist may also contribute these critical distances.

Block Section Length and Operational Headway

For the proposed KV Line train schedule a7-minute headway has been proposed, which for the Main Line would be relatively straightforward task with block lengths fixed at, say 1 km. However, the infrastructure on the KV Line presents a very different scenario and task with multiple PSRs in fairly quick succession. Add to this the varying characteristics if the various train types and a very complex set of calculations are required, which result in a simple question of preference. Headway may usually be provided by block sections of fixed length, but which will result in variable times to pass through depending upon the number, lengths and values of the PSRs in combination with each train's differing characteristics, but would fail to guarantee the required operational headway. But, by varying the block length the various trains may be seen to pass through the section in consistent times. Fixing the block length, whilst allowing the block section to move progressively with the train could provide the required operational headway.

Financial Considerations

By consideration of the requirements of the relevant ERTMS Levels 1, 2 and 3, it can be understood that requirements for signalling equipment located along the right-of-way (ROW) with diminish as the levels increase. The level of capital expenditure (CAPEX) necessary to provide that equipment will also be reduced as levels increase. Less equipment also means less maintenance and a reducing level of operational expenditure (OPEX).

Fleet Considerations

Discussions with major stakeholders had identified the existing fleet, together with procurement plans for fleet renewal as a major consideration. However, some of the existing fleet would require ongoing access to the KV Line and, as a consequence, retro-fitting of that equipment, which will be an extra task implemented as part of fleet member maintenance schedules. A decision for early adoption of LTE technology was amended to enable provision of GSM-R initially, with migration to LTE later.

Recommended Option for Signalling

On the basis of the reasons outlined above, a Radio Block Train Management System, equivalent to ERTMS Level 2 is recommended for the KV Line with GSM-R radio system that will be substituted by LTE at a later date. Provision of train detection and fixed signals will be reviewed in Detail Design.

Train service operations will be managed from the new Colombo Train Control Centre (CTCC) building, Maradana, where a dynamic video display mimic will display all tracks, signals, etc., in real time with possibility to interrogate. Upon first start-up, train drivers will transmit information, via radio link, concerning their train to CTCC, which will respond by sending movement authorities to the train. On-board Global Positioning System (GPS) equipment, an odometer and a speedometer will calculate train position and speed, which data is transmitted to CTCC and used to calculate the movement authority for the following train. Collisions are prevented by CTCC maintaining a safety distance between any two consecutive trains. Movement authorities, target speed and distance to go are amongst the information displayed in the driver’s cab.

In a similar manner trains may request lowering of level crossing barriers on approach to a crossing and, after passing over the crossing will transmit data to inform the level crossing, and the barriers will raise unless a second train is already within the striking-in distance. CTCC may also manually or automatically initiate closure of level crossing barriers.

Operations and Maintenance

The provision of a new high-technology signalling system will require changes not only to the asset management system, but also to maintenance methods and systems and the organisational structure.

In coordination with ICT, a new network-wide, computer-based Asset Management System (AMS) will be provided to record each signalling asset broken down into component parts to the lowest level at which procurement may be possible. One immediate consequence will be substitution of the current paper-based processes with fully electronic systems that will accelerate the procurement of replacement and spare parts, etc.

A new maintenance organisation is recommended under the leadership of a senior manager and based in the new CTCC building. The new organisation will assume control of new infrastructure and systems on a phased basis as construction progresses.

As part of the new maintenance organisation, two new branches of the Workshops are proposed, one for signalling equipment in the CTCC building, and the other(s) for train on-board equipment located near or at the Train Maintenance Depot(s).

Assessment of Risk and Delay Costs at Level Crossings

This chapter concludes with a consideration of a risk assessment strategy for level crossings and calculations for cumulative delay times and costs for level crossings. A worked example is based on actual observation at a UK level crossing, equipped with CCTV and obstacle detection. Tabulated data is included for KV Line level crossings in the section Maradana (MDA) – Padukka (PDK).

Headline Results:

For Elevated Section: (From Table 11-15)	Level Crossing Survey Data Available	16 nr. Level crossings
	Risk Assessment: Unacceptable - Grade Separate	16 nr. Level crossings
	Risk Assessment: Acceptable – Protect	NIL nr. Level Crossings

For Elevated Section: (From Table 11-16)	Estimated 3 minute Total Daily Delay Time	18,688,911 minutes per day
	Estimated 4 minute Total Daily Delay Time	33,224,368 minutes per day

For Elevated Section: (From Table 11-16)	Estimated 3 minute Delay Costs for road users	$31,580,799	per year
	Estimated 4 minute Delay Costs for road users	$56,143,029	per year

Conclusions and Recommendations

The KV Line is somewhat unique in origins, history and current challenges for the future. These include the speed restrictions due to track alignment, the mixed traffic types and short operational headway.

The existing SLR organisation structure and procurement processes were considered inadequate for management of the new technologies proposed.

A Moving Block System for train operations is recommended to achieve specified headways.

An ERTMS Level 2 Equivalent is recommended comprising ETCS Level 2 or equivalent for train control with GSM-R train data radio system, which may be migrated across to LTE at a later date.

Level 2 is recommended to provide axle counter sections as confirmation of train length for locomotive-hauled passenger and freight trains.

A new maintenance organisation, together with a computer-based AMS, is recommended to manage the new high-technology signalling systems.

Migration from the existing maintenance organisation to the new maintenance organisation is recommended to be a phased process over the life-cycle duration of the KV Line project and any subsequent project for Main Line, Puttalam Line and Coastal Line.

Part A. General

11.1 General

11.1.1 Introduction and Background

At present the KV Line is single track Maradana – Avissawella, with 9 Main stations and 31 sub-stations / halts, excluding Maradana.

The Project will propose partial re-construction of the KV Line as double-track Maradana – Padukka (35 km) with refurbishment of the remaining 23.5 km Padukka - Avissawelle single-track section. The new second track will be connected to the existing KV Line platforms 9/10 at Maradana station. The new track layout arrangement will include 9 Main stations and 31 substations, as listed in Table 11-1.

Two Main stations, Narahenpita and Homagama, have been down-graded to sub-stations due to the new layout, with one new Main station Makumbura North added. Manning Town, Malapalla, together with 5 sub-stations in Padukka – Avissawella section are proposed for closure, with addition of a new sub-station at Dambahena.

The proposed signalling and train management systems will substitute all existing block sections with new, virtual, Moving Blocks in the section Maradana – Avissawella, including the integration to the existing station signalling system at Maradana. The new signalling and train control system will manage the newly proposed track layout with suitable headways automatically calculated, as and when required, to meet the forecasted future traffic demand.

11.1.2 Structure of the Report

This chapter is sub-divided into four parts, this first section, Part A, provides a brief background and description of the objectives of the FS from a signalling and train management perspective. This will necessarily be a wide scope with numerous interfaces to other systems and infrastructure. Part A also provides lists of the various abbreviations used, general environmental conditions. The international and national standards to be applied are also referenced here.

Existing signaling arrangements along the single-track Kelani Valley (KV) Line are described in Part B. The various options available are considered in Part C, together with examples of their application and use world-wide. The preliminary design concept for signalling and train management systems is detailed in Part D. Construction, operations and maintenance are covered in Part E, together with some proposals for organizational change.

Part B. Review the Existing Condition

11.2 Present Status of Signaling on KV line

Three of the twelve Main stations, Baseline Road, Narahenpita and Nugegoda (refer Table 11-1), are equipped with locally controlled multi-aspect colour light signals and a relay interlocking. Control of Maradana station is by Maradana Centralized Traffic Control (CTC) with emergency local control panels.

Table 11-1 List of Existing Stations on KV line

No.	Name	Code	Location (km.m)	Class	Station Layout
1	Maradana	MDA	0.000	Main	Multiple Tracks
2	Baseline Road	BSL	1.884	Sub	Single & 1 Loop
3	Cotta Road	CRD	3.545	Sub	Single & 1 Loop
4	Manning Town			Halt	Single Track
5	Narahenpita	NHP	5.615	Main	Single & 1 Loop
6	Kirillapone	KPE	7.363	Sub	Single Track
7	Nugegoda	NUG	9.145	Main	Single & 1 Loop
8	Pangiriwatta	PRW	10.671	Sub	Single Track
9	Udahamulla	UHM	11.521	Sub	Single Track
10	Nawinna	NWN	13.291	Sub	Single Track
11	Maharagama	MAG	14.460	Sub	Single Track
12	Dambahena		16.000	No Station	Proposed Station
13	Pannipitiya	PAN	17.112	Sub	Single Track
14	Kottawa	KOT	19.408	Main	Single & 1 Loop
15	Malapalla	MPL	20.598	Sub	Single Track
16	Makumbura		20.760	No Station	Proposed Station
17	Makumbura North		21.900	No Station	Proposed Station
18	Homagama Hospital	HHR	22.400	Sub	Single Track
19	Homagama	HMA	24.610	Main	Single & 1 Loop
20	Panagoda	PNG	26.385	Sub	Single Track
21	Godagama	GGA	28.217	Sub	Single Track
22	Meegoda	MGD	29.743	Main	Single & 1 Loop
23	Watareke	WAK	31.255	Sub	Single Track
24	Liyanwala		33.420	Halt	Single Track
25	Padukka	PDK	35.284	Main	Single & 1 Loop
26	Arukwathpura	ARW	36.840	Sub	Single Track
27	Angampitiya	AGP	37.920	Sub	Single Track
28	Uggala	UGL	38.860	Sub	Single Track
29	Pinnawala	PNW	40.169	Sub	Single Track
30	Gammana	GMA	41.200	Sub	Single Track
31	Morakele	MRK	42.000	Sub	Single Track
32	Waga	WGG	44.399	Main	Single & 1 Loop
33	Kadugoda	KDG	46.460	Sub	Single Track
34	Arapanggama		47.844	Halt	Single Track
35	Kosgama	KSG	49.437	Main	Single & 1 Loop

No.	Name	Code	Location (km.m)	Class	Station Layout
36	Aluth Ambalama		50.904	Halt	Single Track
37	Miriwaththa		52.184	Halt	Single Track
38	Hingurala		53.520	Halt	Single Track
39	Puwakpitiya	PWP	55.404	Sub	Single Track
40	Puwakpitiya New Town		56.274	Halt	Single Track
41	Kiriwandala		57.434	Halt	Single Track
42	Avissawella	AVS	59.144	Main	Terminal 3 Tracks

The remaining eight Main stations are provided with none-interlocked multi-aspect colour light home signals. Tablet token system is in force for block working throughout the KV Line, Baseline Road – Avissawella (refer Table 11-2 for details).

Table 11-2 Signaling Systems on KV line

No.	Station	Signalling	Block system
1	Maradana	Fully interlocked, multi-aspect colour light signals, normally dark and under Centralized Traffic Control.	Absolute Block – Single Line with track circuits
2	Baseline Road	Locally controlled multi-aspect colour light signals, normally dark, with relay interlocking, electric point machines and, track circuits in the station yard.	Tablet Token Block
3	Narahenpita		
4	Nugegoda		
5	Maharagama	Two locally controlled, none-interlocked, multi-aspect colour light Home signals with manually-operated spring points.	
6	Kottawa		
7	Homagama		
8	Meegoda	Two manually-operated semaphore signals, none-interlocked, with manually-operated spring points.	
9	Padukka	Two locally controlled, none-interlocked, multi-aspect colour light Home signals with manually-operated spring points.	
10	Waga		
11	Kosgama		
12	Avissawella		

11.3 Maradana CTC

Entry to and egress from the single-track KV Line is currently controlled from Maradana CTC for the section Maradana – Loco Junction by absolute block with track circuits. A Local Control Panel is also provided at Maradana station for emergency use during failure conditions.

Figure 11-1 Maradana CTC

Control of KV Line is provided as computer workstation with four 24" monitors for dynamic display of track and signal layout Colombo Fort – Maradana – Loco Junction. An overview display panel is provided by a set of 49" monitors above and behind the dispatcher's workstations.

11.4 Review of Existing Level Crossing Arrangements on KV Line

The presence of a high number of level crossings is one major problem affecting operational safety and efficiency of the present train operations along the KV line. Out of a total number of 147 level crossings, 40 are fully protected either with barriers that are electrically or mechanically operated, a further 24 level crossings are protected at a lower level with warning bells & light systems, the other 83 level crossings being without protection. A summary of level crossing details is given in Table 11-3.

Table 11-3 Summary of Level crossings on KV Line

No.	Type of Protection	Number	Remarks
1	Electrically Operated Barriers	9	
2	Mechanically Operated Barriers	31	
3	Warning Bells and Flashing Red Lights	24	
4	Unprotected	83	
5	Total Level Crossings – All Types	137	

11.5 Problems with the Existing Signalling System

Major problems and drawbacks of the present signalling system are mentioned below.

- Only three stations are provided with interlocked signalling systems;
- Hand operated points, spring points and none-interlocked signalling situations are not suitable for running fast suburban trains;
- Poor visibility of signal during day time due to filament lamp and double lens lantern units;
- Limited line capacity, tablet token system /absolute block system cannot meet the estimated headway requirements;
- Movement authority for the trains at crossing stations is given by the station master and this system is causing delays to train service, especially in the peak hours;
- As the system is not connected to CTC system, there is serious drawback in train management function;
- Configuration of some wayside signals are not compatible with existing SLR codes;
- Signalling circuits are not compatible with 25 kV 50 Hz AC Electrification;
- In general the present system does not provide required safety and efficiency to an acceptable level for operating trains at higher speeds and with higher frequency.

11.6 Existing Signal & Telecommunications Organization Structure

Management of maintenance activities of both signalling and telecommunication systems are carried out by the Signal & Telecommunications (S&T) sub department of Sri Lanka Railways. Chief Signal and Telecommunication Engineer (CSTE) is the head of the Telecommunication sub department who is directly responsible to the General Manger of Railways for maintaining and development of the Signalling and Telecommunication systems in SLR. Main office of this sub department, signal workshops and the related stores are located at Dematagoda, Colombo 09.

There are two Deputy Chief Signal & Telecommunication Engineers (DSTE) to assist the CSTE in maintenance operation and Planning & Development.

Maintenance operations are further divided across four divisions – Central, North, Upper and South – each functioning under a designated Signal Engineer.

Similar to arrangements for Operation & Maintenance division, Planning and Development division oversees all functions of Radio Telecommunications and Signal Workshop, in addition to Planning & Construction of Signalling systems.

11.6.1 Operations & Maintenance Division

Table 11-4 S&T Sub-Department Divisional Boundaries

Division	Line	Boundary Stations
Northern Division	Northern Line	Maho – Kankasanturai
	Mannar Line	Medawachchiya – Talaimannar
	Batticoloa Line	Maho – Batticoloa
	Trincomalee Line	Galoya Junction – Trincomalee
Upper Division	Main Line	Rambukkana – Badulla
	Matale Line	Peradeniya Junction - Matale
Central Division	Main Line	Colombo Transfer Sidings – Rambukkana
	Northern Line	Polgahawela – Maho
	Puttalam Line	Ragama – Puttalam
Southern Division	Coast Line	Matara – Colombo Transfer Sidings
	Kelani Valley Line	Maradana – Avissawella

Maintenance Divisions are further divided into small sections through which the routine / periodical maintenance activities are carried out by the sectional Signal& Telecommunications Inspectors (STIs) with their staff. District Signal & Telecommunications Inspectors (DIRs) act between the Divisional Engineer and the STIs, to assist with maintenance management activities, whilst also attending to the major repair works and half yearly inspection in their division.

As indicated above, operation and maintenance of Signalling and Telecommunication systems is divided into four geographical areas and boundaries of the divisions are as shown in Table 11-4.

S&T staffs within these divisions are responsible for all types of maintenance and repair works, including any major repairs due to derailments, accidents, etc.

11.6.2 Existing Maintenance Arrangements for the KV line

Signalling maintenance activities for the KV line falls under SE (S)

There are two maintenance depots, located at Maradana and Pannipitiya, and two STIs along with their supporting staff assigned for maintenance of KV Line signalling systems as shown below:

- **STI(Tracks) Section:** From Dematagoda (including Dematagoda Level Crossing) to Maharagama (include Maharagama yard & Temple Road Level Crossing)
- **STI(Pannipitiya) Section:** From Maharagama (Kottawa side, Block Instrument only) to Avissawella

Part C. Explore the Options

11.7 General Considerations

11.7.1 Stations and Track Alignment

The Project will propose partial re-construction of the KV Line as double-track Maradana – Padukka (35 km) with refurbishment of the remaining 23.5 km Padukka - Avissawelle single-track section. The new second track will be connected to the existing KV Line platforms 9/10 at Maradana station. The new track layout arrangement will include 11 Main stations and 24 substations, as listed in Table 11-5, with the remaining 7 sub-stations and halts proposed for closure. A road improvement project in the Kosgama – Kiriwandala area will result in closure of 5 of those 7 stations, the others being Manning Town and Malapalla.

Two Main stations, Narahenpita and Homagama, have been down-graded to sub-stations due to the new layout, with one new Main station Makumbura North added. Manning Town, Malapalla, together with 5 sub-stations in Padukka – Avissawella section are proposed for closure, with addition of a new sub-station at Dambahena.

One of the stations proposed to be down-graded from Main to Sub is Nawinna, which station has been identified, by another project during the course of this study. as a junction station for a proposed new connecting line from Padukka to Rathmalana. Two other proposed new lines have also been identified – and considered by this FS – from Makumbura North to Horama and from Kelaniya to Kosgama, of which both KV Line stations are designed to accommodate the proposed new junctions.

Table 11-5 List of New and Modified Stations on KV line

No.	Name	Code	Location (km.m)	Class	Station Layout	
					Tracks	Loops
1	Maradana	MDA	0.000	Main	Multiple	
2	Baseline Road	BSL	1.884	Main	Double	Crossovers
3	Cotta Road	CRD	3.545	Sub	Double	
4	Manning Town			Closed	Double	
5	Narahenpita	NHP	5.615	Sub	Double	
6	Kirillapone	KPE	7.363	Sub	Double	
7	Nugegoda	NUG	9.145	Main	Double	Two
8	Pangiriwatta	PRW	10.671	Sub	Double	
9	Udahamulla	UHM	11.521	Sub	Double	
10	Nawinna	NWN	13.291	Sub	Double	
11	Maharagama	MAG	14.460	Main	Double	Two
12	Dambahena		16.000	Sub	Double	
13	Pannipitiya	PAN	17.112	Sub	Double	
14	Kottawa	KOT	19.408	Main	Double	
15	Malapalla	MPL	20.598	Closed	Double	
16	Makumbura		20.760	Sub	Double	
17	Makumbura North		21.900	Main	Double	Two
18	Homagama Hospital	HHR	22.400	Sub	Double	
19	Homagama	HMA	24.610	Sub	Double	
20	Panagoda	PNG	26.385	Sub	Double	

No.	Name	Code	Location (km.m)	Class	Station Layout	
					Tracks	Loops
21	Godagama	GGA	28.217	Sub	Double	
22	Meegoda	MGD	29.743	Main	Double	Two
23	Watareke	WAK	31.255	Sub	Double	
24	Liyanwara		33.420	Halt	Double	
25	Padukka	PDK	35.284	Main	Double	Two
26	Arukwathpura	ARW	36.840	Sub	Single	
27	Angampitiya	AGP	37.920	Sub	Single	
28	Uggala	UGL	38.860	Sub	Single	
29	Pinnawala	PNW	40.169	Main	Single	One
30	Gammana	GMA	41.200	Sub	Single	
31	Morakele	MRK	42.000	Sub	Single	
32	Waga	WGG	44.399	Main	Single	One
33	Kadugoda	KDG	46.460	Sub	Single	
34	Arapanggama		47.400	Halt	Single	
35	Kosgama	KSG	48.880	Main	Single	One
36	Aluth Ambalama		50.460	Closed	Proposed Deviation	
37	Miriwaththa		51.740	Closed	Proposed Deviation	
38	Hingurala		53.070	Closed	Proposed Deviation	
39	Puwakpitiya	PWP	54.930	Sub	Proposed Deviation	
40	Puwakpitiya New Town			Closed	Proposed Deviation	
41	Kiriwandala		56.715	Closed	Proposed Deviation	
42	Avissawella	AVS	58.400	Main	Triple	Terminus

11.7.2 Design Considerations

The proposed signalling and train management systems will substitute all existing block sections with new, virtual, Moving Blocks in the section Maradana – Avissawella, including the integration to the existing station signalling system at Maradana. The new system will manage the newly proposed track layouts with suitable headways automatically calculated in real-time by the control computers, as and when necessary. The under-mentioned points will be considered as preliminary design concepts for a proposed signalling system appropriate to the new track layout to be constructed. Proposed signalling system shall:

- Be suitable for trains capable of working at speeds up to 80 kph;
- Be suitable for any lengths of train, e.g. 2 x 6 cars x 15.5 m length per car;
- Fulfill /exceed the estimated service headway requirement of the new line;
- Be interfaced with the existing / future signalling system at Maradana station;
- Facilitate interoperability with other lines;
- Provide train protection system in order to prevent driving at excessive speeds;
- Be connected to CTC system at Maradana OCC and future OCC;
- Provide positive Identification / detection of trains throughout the whole of the KV Line;
- Facilitate simplified bi-directional signalling (simbids) in double-track sections;

- Be designed to perform without any disturbances or unsafe situation in a 25 kV 50 Hz AC electric traction with return wire environment, during normal operations and under fault conditions;
- Include equipment monitoring system for efficient asset and maintenance management;
- Be based on International standards for safety and performance.
- Reduce OPEX by considering low energy / maintenance equipment and systems.hen required, to meet the forecasted future traffic demand.

11.8 Train Service Patterns

Existing train operations are Inbound during morning peak and Outbound during evening peak, with a few trains during the working day.

Post-project train operations may provide equally balanced services Inbound and Outbound during morning and evening peaks with a regular service during the day. SLR have indicated preference for diesel multiple units (DMUs) and electric multiple units (EMUs) with two rakes to facilitate splitting and / or joining of some services, which may require additional sidings for DMUs / EMUs that are diagrammed to leave service.

However, passenger travel patterns may not immediately respond to the new services provided, and in any case will always favour travel to work in the city central zone.

The required headways for normal direction train operations for KV Line are as shown in Table 11-6.

SLR Operations requirements include simbids operations on both main lines and passing loops. Termination of trains at intermediate stations should preferably be at loop platforms and not block a main line. These require a track layout design for stations that provides a facility to switch from loop or main line to either main line and vice versa.

Table 11-6 Required Minimum Headways on KV Line

No.	Section	Service Headway	Safety Margin	Design Headway
1.	Maradana – Makumbura North	7 minutes	25% - 1.4 minute	5.6 minutes
2.	Makumbura North – Padukka	14 minutes	25% - 2.8 minutes	11.2 minutes
3.	Padukka - Avissawella	30 minutes	25% - 6 minutes	24 minutes

11.9 Train Management Considerations

11.9.1 Locomotives and Rolling Stock

In the short-term, train operations will continue to be provided by DMUs until such time as electrification is complete, through to Avissawella. However, electrification only as far as Padukka will be proposed by this FS as further electrification will not be pursued until economic development of the area beyond Padukka has progressed sufficiently. For the foreseeable future DMUs will continue to operate KV Line services between Padukka and Avissawella.

The abundance of small radius curves has restricted rolling stock (DMUs / EMUs) to 15.5m long by 2.8m wide, whereas standard rolling stock is 20m long by 3.2m wide. Since this project will ease only some of the small radius curves, restrictions on rolling stock size may remain.

Re-construction of KV Line that includes underground section with stations, would rule out possible continued use of DMUs and diesel locomotives, whereas tunnels without stations would not cause any such issues. However, the majority of DMUs and diesel locomotives have been in service a long time (in excess of 10 years) and may be expected to be retired or re-assigned.

Discussions with major stakeholders had identified the existing fleet, together with procurement plans for fleet renewal as a major consideration. Electrification of the KV Line would include procurement of new EMUs that could be equipped with the requisite signalling and telecommunications systems and equipment. However, some of the existing fleet would require ongoing access to the KV Line and, as a consequence, retro-fitting of that equipment, which task will be assessed during Detail Design. As retro-fitting would become an additional task during heavy maintenance, this would be implemented over time based on fleet member maintenance schedules / requirements. A decision for early adoption of LTE technology was amended to facilitate provision of on-board GSM-R initially, with migration across to LTE later as a potential half-life upgrade.

11.9.2 Operational Constraints on Signalling System Design

The large number of permanent speed restrictions will impact upon service braking distances and could result in uneven and irregular signal spacing.

The variety of motive power units will result in variations of acceleration rates and deceleration rates, which is particularly noticeable between EMUs and diesel locomotives hauling freight services. This variation will result in either excessive signal spacing for passenger services or inadequate signal spacing for freight services, necessitating double-block lengths for such services with need for a fourth (second yellow) aspect.

Whereas the maximum line speed may be eighty kilometres per hour (80 kph), actual operational line speeds, and service speeds, may be significantly lower in order to eliminate excessive accelerations / decelerations thereby optimising driving requirements.

There would remain a number of instances where trains could be stopped by red signals whilst a preceding train is negotiating a long speed-restricted segment. This could result in following trains closing the gap with the preceding train with a higher probability of encountering a red signal and potential for excessive delay. During peak periods this cycle could repeat disrupting train operations with consequential negative reactions amongst passengers.

The KV Line may be considered as self-contained with connections to other lines only at Maradana. However, plans are noted for construction of two future connecting lines, at Makumbura North to Horana and Kosgama to Kelaniya. Whilst allowance for the future extensions must be included, the future signalling arrangements are not currently a concern since necessity would mandate systems that would be compatible with those systems provided by this project and, which would facilitate inter-operability of rolling stock.

11.10 Preliminary Design Basis for Train Management System

The degree of flexibility required to optimise train operations for the above considerations would be provided by a moving block system, which could also serve to reduce signalling field equipment, if implemented as a radio-based train management system. The current global leader is the European Railway Train Management System (ERTMS), but that system may not be offered due to the very specific system architecture. There are two components to ERTMS of which European Train Control

System (ETCS) is the signalling component and, the Global System for Mobile Communications (GSM-R) – which is unacceptable for this project – is the telecommunications (radio) component. GSM-R is old technology with limited data capacity and will ultimately be replaced by the Long Term Evolution – Railways (LTE-R) system.

For the purpose of this FS, a Train Data Radio System (TDRS) will be mentioned as the safety-critical radio component. Additionally, use of a different radio system, Radio Block Train Management System (RBTMS), in substitution for ERTMS, will leave the choice of radio system open, thereby avoiding any possibility for misinterpretation.

For reasons of clarity and ease of understanding this discussion will specifically mention ERTMS and ECTS, which are pan-national standards based on European Union practice, to illustrate the operation principles. However, brief descriptions of systems to other standards – Positive Train Control (PTC), USA, Chinese Train Control System (CTCS), China, Advanced Train Administration System (ATACS), Japan and Advanced Train Management System (ATMS), Australia, are included both to provide more options and to demonstrate the development and use of similar systems outside Europe.

11.11 Preliminary Signaling Proposals for RBTMS

In order to obtain smoother train operations use of a moving block signalling system is considered. In practice, RBTMS Level 3 would be equivalent to ERTMS Level 3, but which also has equivalence in other standards. For the KV Line, direct radio communication between OCC and trains is proposed, using a dedicated, safety-critical, voice and data system. For determination of the train location the VOB equipment will include odometers, GPS, balise readers and a train control / management computer for determination of position and speed. OCC and train will communicate on a continuous basis and, OCC will transmit an LMA to the train. A current location of the front of the train will be calculated to determine the LMA, which will then be sent to the train, whereas the rear of the train will be calculated from known and proven train length (vehicle on-board system or device) for calculation of the LMA for a following train.

Should the need arise, an emergency stop command, together with Cancellation of LMA instruction, may be transmitted direct to the train at any time regardless of location, whereas in fixed block systems reliance is placed upon signal replacement, but which may be too late depending upon the location of signal in relation to the train.

The proposed system has no essential requirement for line-side signals, track circuits or axle counters, potentially reducing CAPEX and OPEX requirements. However, the KV Line is a mixed traffic line and locomotive-hauled passenger and freight services, which may not be fitted with equipment that can prove completeness of train consist, need to be considered. There are a number of options – not all viable – that should be explored by a separate study, including the following:

- Special Regulations for train consists without integral proof of completeness equipment; this could be high risk strategy as it is dependent upon human resources for safe implementation;
- The train operator's written confirmation that a rake has a very low risk of separation en-route and may be deemed as always complete; this could be medium-to-high risk strategy;
- A portable device placed on the last vehicle in the consist, and which shall communicate with the VOB systems in the locomotive; portable devices are removable, thus are a medium risk;

- The use of axle counter systems placed at strategic locations may be used to confirm train is complete by correlation with original train data input by the driver – a lower risk strategy.

For KV Line signalling RBTMS L3 is proposed with RBTMS L2 at Maradana – Loco Junction and at protected level crossings. Axle counter sections are proposed for verification that freight train consists are complete at, as a minimum provision, the following locations:

- Baseline Road station;
- Makumbura North station, Maradana side of proposed future junction to Horana Valley;
- Padukka station;
- Kosgama station, Maradana side of proposed future junction to Kelaniya.

This proposal for axle counters at strategic locations may be considered as a modern alternative to the heritage method for operations staff at signal boxes to visually confirm train complete by observation of the tail lamp. Once a viable technical solution to the issues concerning proof of completeness for freight train rakes has been implemented, the axle counters may be removed. However, full provision of train detection by axle counters over the entire KV Line will be considered during Detail Design.

11.12 Development Strategy

Modernisation of the other 3 lines, Coastal Line, Northern Line and Main Line, will, as a minimum, provide RBTMS Level 2 signalling. This project will assume that over time the train management and signalling systems provided for the Colombo Suburban Railway Project will be extended in similar format across the entire SLR network. By this assumption, and the requirement to provide full-inter-operability, all EMUs, DMUs, electric and diesel locomotives will necessarily be equipped with on-board cab signalling systems through a rolling programme integrated within the heavy maintenance schedules.

Although it has been demonstrated, by successful operation of Senseki Line ATACS system, that train detection systems together with fixed signals need not be provided, there may be circumstances where either or both may be desirable as an interim or long term measure. For example, Colombo Fort and Maradana stations may require fixed signals to assist platform staff. Furthermore, the complexity of existing track layout arrangements in Colombo Fort – Maradana – Loco Junction section may require some form of train detection to bring greater confidence to train operations as a secondary back-up to RBTMS. However, re-configuration of the track layout could change the operational perspective.

Signalling in depots is proposed as Level 1, although for some depots and stabling sidings Level 2 or 3 may be appropriate.

However, it is reasonable to assume that RBTMS Level 2 or equivalent may be rolled out elsewhere across the entire SLR network. For example, the recently re-commissioned Northern Line has new signalling and a long life-cycle before even mid-life refurbishment can be considered. In this case, fitting of ATP / TPWS equipment may be justified to enhance protection levels to ERTMS Level 1 equivalence. Signalling systems on other lines may already have matured, but are not yet approaching life expiry and could be equipped to ERTMS Level 2 with balises provided and fixed signals removed.

For the reasons stated above, RBTMS Level 2 or equivalent is recommended for the KV Line signalling / train management system. RBTMS Level 2 or equivalent system is considered for the

Maradana to Loco Junction section, but the implications for use of ATO with moving block – for which Level 3 would be proposed – will be considered as part of the Main Line FS Report.

The new Light Maintenance Depot will be provided with an independent RBTMS Level 2 signalling system, together with a Depot Protection System (DPS) to protect the workforce.

11.12.1 ERTMS Levels as Options for RBTMS

The RBTMS operational levels, which may be adopted and adapted for the KV Line, and then rolled out across the CSRP area, are as shown by the map in Figure 11-2.

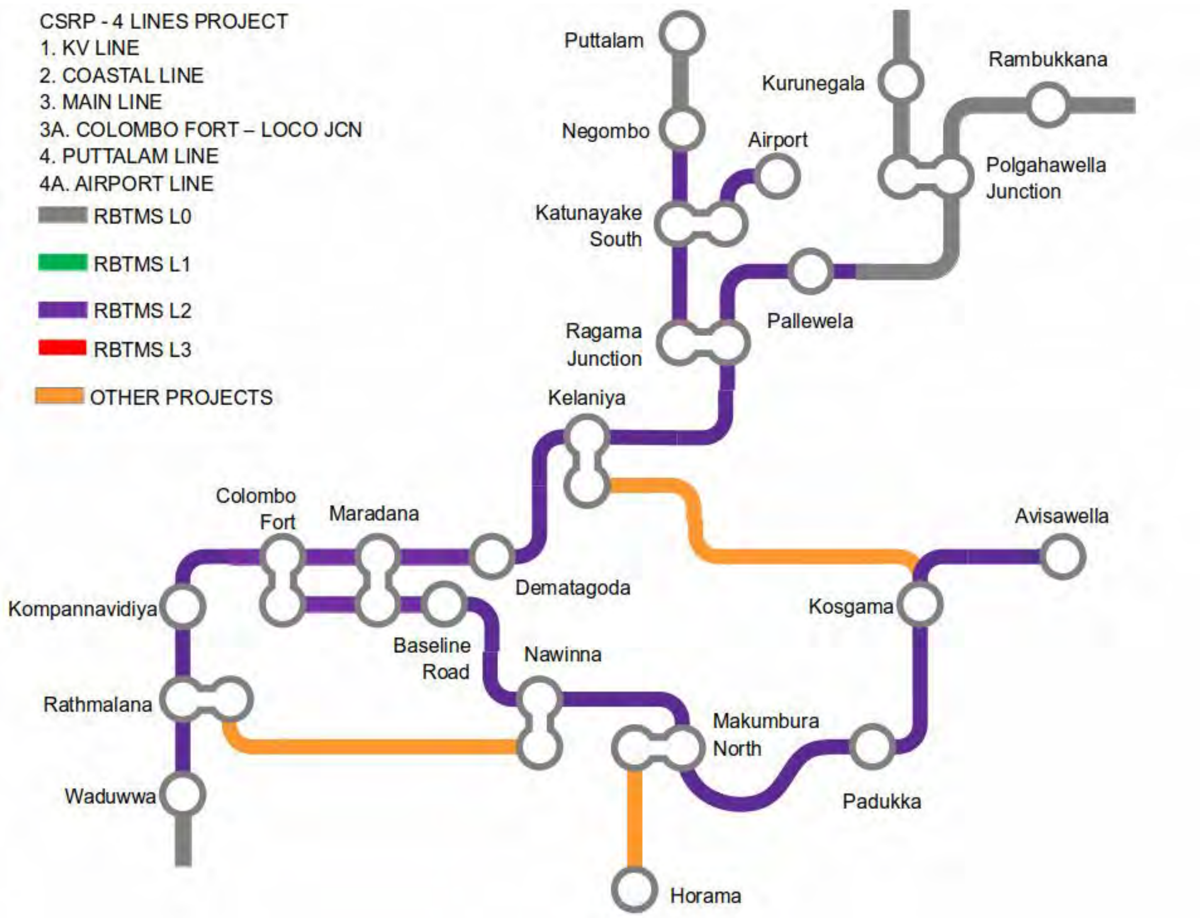


Figure 11-2 RBTMS Development Strategy Map for CSRP Area

The three "buffer stations" of Kompannavidiya, Dematagoda and Baseline Road to the congested city area are identified on the map in Figure 11-2. Each of these stations should have additional tracks to accommodate trains, should the need arise, during peak hours. Also, the additional tracks could be used for parking trains that are not required for off-peak operations.

11.12.2 Route Availability Considerations

With the introduction of radio-block, virtual moving block, technology, the need for a consequential adjustment to vehicle route availability will also be required. Table 11-7 below summarizes the route availability restrictions that should be applied to existing and future rolling stock, locomotives, freight wagons and mechanised maintenance vehicles.

Table 11-7 Route Availability

Vehicle Equipment		Route Equipment Level			
Level	Type Summary	0	1	2	3
3	RBC+ATP+ATO+ATC+ARV	√	√	√	√
2	ATP+ATO	√	√	√	X
1	ATP	√	√	X	X
0	No Equipment	√	X	X	X
Note:	Route Level 0 is SLR National Standard				

Table 11-7 demonstrates that where vehicle equipment is equal to or in excess of route equipment level then full access is available. However, it follows that vehicles equipped to lower levels than the route have no access to that route. One implication of this is relevant to DMUs planned to operate the Padukka – Avissawella section, which must be equipped to RBTMS Level 2 for independent, i.e. self-propelled, access. In the event that those DMUs remain non-equipped, then a pilot locomotive or attachment to a route-equipped reversible train will be necessary.

Part D. Preliminary Design Concepts

11.13 Train Control System Design Concepts

11.13.1 RBTMS Overview

The preliminary design concept will provide a centralised RBTMS with three distinct components, ground-based control systems, vehicle-on-board systems and the train data radio system, which has capability for voice and data communications, all of which components are safety-critical. These are illustrated by the concept diagram, in Figure 11-3; for RBTMS Level 2, train detection system would also be provided.

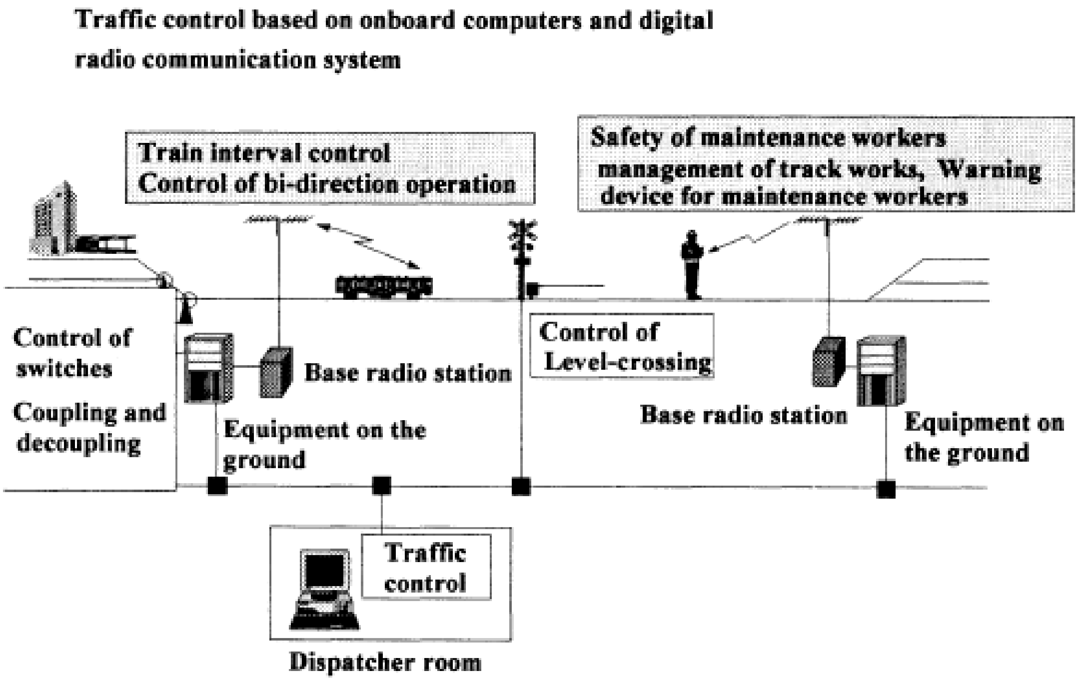


Figure 11-3 Preliminary Concept Diagram for RBTMS Level 3 (ATACS, 1996)

11.13.1.1 Ground-Based Control Systems

The ground-based control systems comprise several major sub-systems, which can be classified as Central Equipment and Line-side Equipment, as follows:

a. Central Equipment

- TMS - train monitoring system that displays dynamic status of the railway in real-time;
- TCS – train control system that manages train movement authorities;
- TESS – train existence supervision system that confirms existence and locations of trains;
- TNIS – train number identification system that allocates unique numbers to trains;
- TD – train describer that tracks train movements and assures train identities are known;
- CTC – centralized traffic control system for intervention control of the railway;
- DCS – Data Communications System, including OFC systems.

b. Line side equipment

- RBC – Radio Block Centre;
- Line-side Antennae;
- Balise;
- GCS – Ground Controller System;
- LED Signals;
- Point Machines;
- Axle Counters;
- Level Crossings;
- DCS – Data Communications System, including OFC system.

Although listed as separate systems, these may be provided as such or in some combination that may be decided during Detail Design Stage. The above list is not intended as comprehensive, but adequate to describe the preliminary concept design requirements.

11.13.1.2 Vehicle On-Board Systems

The vehicle-on-board systems comprise several major processor-based sub-systems, including:

- Balise reader system, including transponders;
- Location self-detection system – odometer and GPS;
- In-cab display system;
- Driver assistance system;
- Speed control system;
- Brake control system.

Again, the above list is general, and some of these may be provided as such or in some combination that may be decided during Detail Design Stage. Vehicle specific systems provided by the rolling stock supplier are not considered.

11.13.1.3 Train Data Radio System

The train data radio system comprises several major processor-based sub-systems, including:

- Central Radio Block Centre System, including Antennae;
- Field Radio Block Centre Base Station;
- Line-side Antennae;
- VOB train data radio system;
- VOB Antennae.

The central radio base station communicates on a continuous basis with all field base stations via the OFC data transmission highway. Further information relating to the train data radio system, voice capabilities, recording and archive data and radio base stations may be referenced through telecommunications, with which systems complete compatibility and inter-operability is mandatory.

11.13.2 Location Self-Detection System

The train detection system may best be described as a vehicle-on-board self-detection system, in other words the train knows where it is at all times and, conveys that information to RBTMS continuously. This is achieved with the aid of fixed in-track equipment, which may be an active balise, a passive balise or a control loop, all of which provide location (and other) data to the train via the on-board transponder.

The train will measure distance travelled by odometer, check the reading against GPS data and advise RBTMS of dynamic location. The accuracy of the position depends primarily upon the odometer tolerances, which must be no greater than 2% (100 m ± 2 m).

Although maximum line speed is a notional 80 kph, in addition to points and crossings at stations, the KV Line has a large number of speed restricted sections and level crossings, which may require provision of a balise to prompt an update of LMA and speed profile. Whereas fixed signals may be located at approximate 1 km intervals, it is usual practice to also provide a balise at mid-point. The actual intervals will be determined during detail design, but may be approximately 500-600 metres.

11.13.3 System Architecture

The concept design for system architecture, which is shown in Figure 11-4, is a typical block diagram that illustrates a potential requirement for an Infill Radio Block Centre (I-RBC) at Alum Ambalam, which is located on the Kosgama – Kiriwandala Section that is proposed for reconstruction on a new alignment as part of a road improvement project. The term generic term Radio Block Centre describes the location of signalling systems that control train movements within a pre-determined geographical area, and does not refer to any particular block section. The RBTMS servers are located at the OCC, and are connected via a dual-redundant DCS network RBCs at each station and infill locations (refer to following paragraph). For the KV Line, there is an option to provide a single interlocking at the OCC with object controllers (shown as field controllers in Figure 11-4) at stations. As may also be seen, a further dual LAN connects the ground controller, field controller and radio base station.

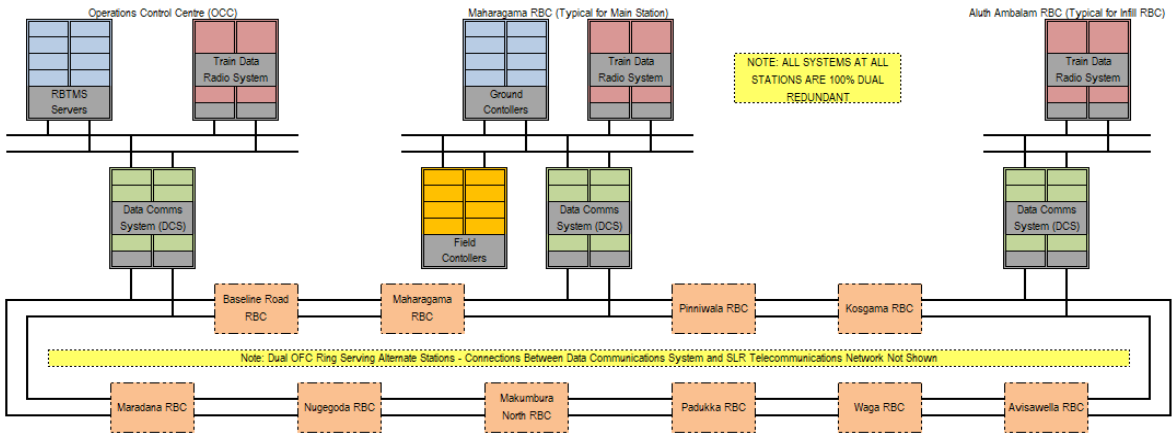


Figure 11-4 RBTMS System Architecture

Point machine operations are controlled by the field controller, which responds to commands from the ground controller, which is, in turn, responding to commands from the train control system. A route request will normally be generated automatically by automatic route setting system, which has acted upon the dynamically updated location of the Train Identity (ID). However, since trains also know their current location, a route request can also be generated automatically by the train. As with fixed block systems the route may be absolute, permissive (proceed on sight) or shunting.

RBSs will typically provide coverage over an area of 3 km with some overlap to ensure adequate signal strength. Antennae may be distributed along the ROW spaced at intervals of 300m – 500m. Additionally, multiple frequency ranges (4 should be adequate for KV Line) are used to avoid mutual interference between adjacent base stations.

The capability for simplified bi-directional signaling may be provided with facilities to switch to contra-flow directions at each station equipped with crossover facilities.

Whereas present situation in SLR is permissive block in normal direction and absolute block in the wrong (contra-flow) directions, a moving block system could safely accept following trains, travelling in the [same] wrong direction, between stations. RBTMS as proposed may use virtual block, although the use of marker boards will facilitate fixed block working during conditions of degraded operations. The Detail Design will consider application of permissive block for normal direction operations and absolute block over long routes in the contra-flow direction (simbids).

Point machines will be controlled via a local interlocking (IXL) or GCS, with capability for emergency operation from train dispatcher's workstations in local stations, but this will be considered during the Detail Design Stage. Where provided, an axle counter system should be provided as separate systems for Up and Down Lines, each of which interface to the IXL.

All signalling systems and equipment will be compatible for use in 25 kV ac electrified areas and resistant to EMI generated by the traction power supply system and the local environment.

11.14 Proposed Operations Control Centre

Subject to SLR strategic decision and Master Plan, the proposed Operations Control Centre (OCC) in the new CTCC building may be designed and constructed to supervise and / or control the entire SLR network, in which eventuality the KV Line would be the foundation, upon which train management systems will be built, for the future.

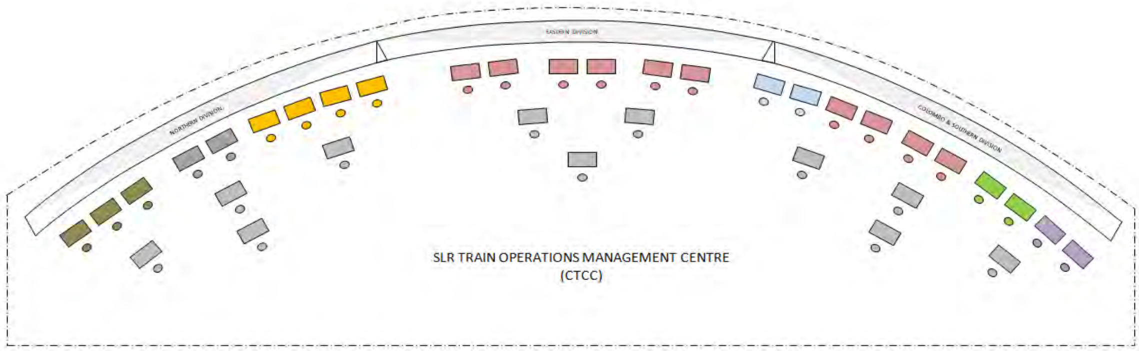


Figure 11-5 CTCC Building – Operations Control Centre (OCC) Layout

The optimum solution for the future would house all train management systems in such a manner, as shown in Figure 11-5, that a single unified Operations Room may be established. The room size may be estimated by consideration of the Video Wall Overview Display Mimic for the whole network and the number of workstations required for signalling / train operations management and traction power.

Figure 11-6 OCC Showing Video Wall Overview Display (IRSE, 2010)

For that exercise some assumptions must be made such that the Video Overview Display Wall, as shown in Figure 11-6, may be formed as an arc consisting of 70" monitors arranged as a matrix of rows and columns, for optimum visibility by all dispatchers, including section chief. This assumes that each of the current operational divisions remains into the foreseeable future, and will require separate displays of their areas of responsibility:

- Anuradhapura Division;
- Nawalapitiya Division;
- Maradana (Colombo) Division.

A concept design for the Colombo Suburban Railway OCC is shown in Figure 11-7.

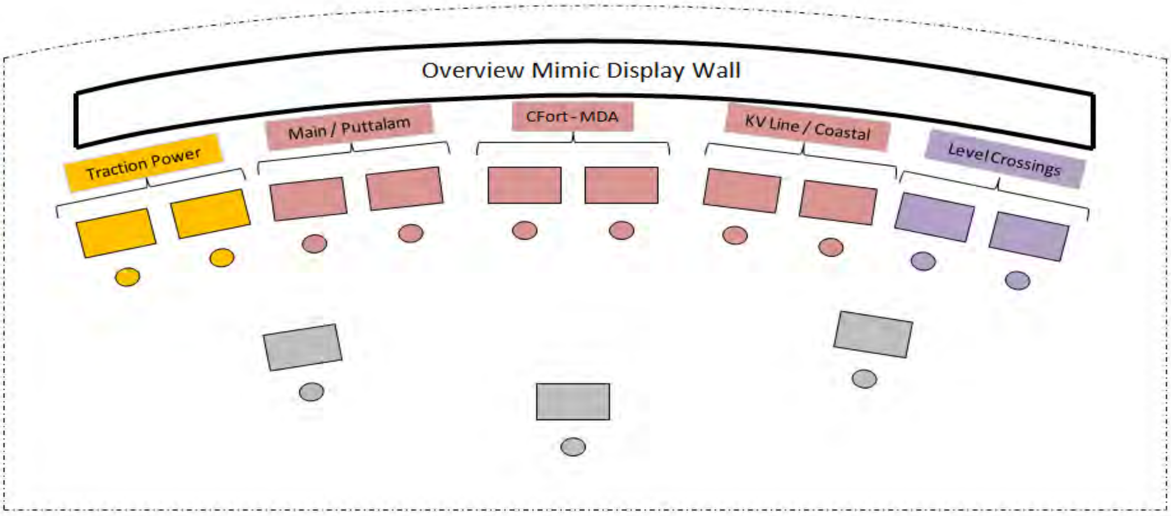


Figure 11-7 Colombo Suburban Railway OCC Layout

That study of the CTCC building is ongoing and will continue as a de facto separate sub-project. This report will continue to focus on the KV Line requirements with the above considerations as potential and useful background information.

11.14.1 OCC Systems and Equipment

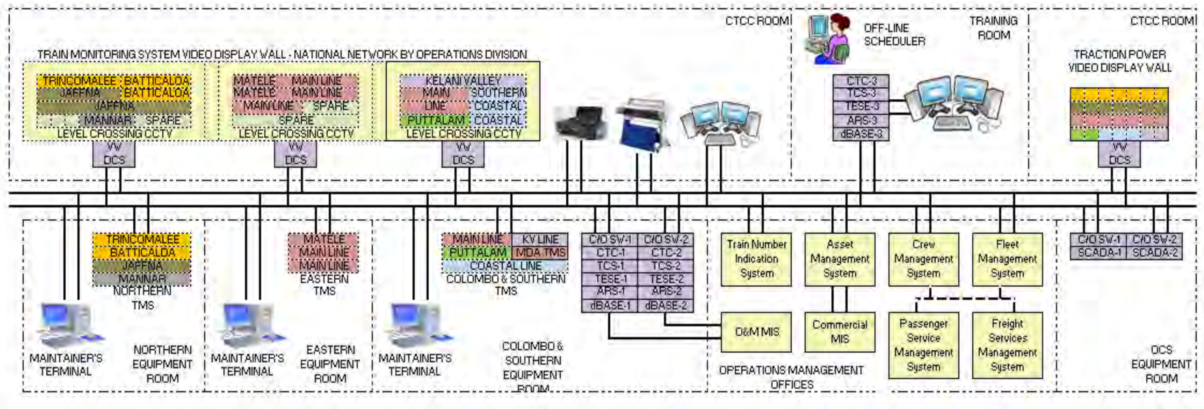


Figure 11-8 OCC Systems and Equipment Rooms

The primary systems to be provided in the OCC, shown in Figure 11-8, include Train Control System (TCS), Train Monitoring System (TMS), Video Wall Display System (VWDS), Train Number Indication System (TNIS) and Data Communications System (DCS). All databases and all primary systems servers will be duplicated as main / hot standby with automatic change-over on failure.

A virtual map of the railway (i.e. KV Line), gradient profile, track alignment and permanent speed restriction data will reside in the TMS database, together with performance databases for each type of train / vehicle / locomotive with access rights to the KV Line. Train crew (driver) will enter / confirm the train ID, which action will be transmitted from the train to TCS and will activate the train schedule for the particular train / vehicle. The TCS will transmit an LMA and speed profile to the train, which will calculate an optimum journey profile and display at the Driver-Machine Interface (DMI) in the train. The VOB computer will correlate odometer readings with GPS data to determine location and, upon receipt of location information for an in-track balise, will adjust calculated location results. Continuous transmissions between train and control centre will assure the train's location is known at all times and correctly displayed to the dispatcher.

The virtual map will be displayed as a dynamic display on the monitors at the dispatcher workstations and, together with other stations and lines, on the Video Wall Overview Mimic Display. Dispatcher Workstations will comprise duplicated processors and 4 x 24" monitors. The monitors may display the whole line or any station or block section, with zoom facilities possibility to change display size. Any monitor may display all stations and block sections for the whole line and, subject to decision by SLR during Detail Design Stage, may display any station and block section on the Colombo suburban network, divisional network or the complete island network.

The Video Wall Overview Mimic provides a dynamic overview of traffic conditions across the CSR network, without repeating the same level of detail as available at the workstation monitors. Details such as shunt signals and yard will be omitted, since the principal focus is on train service operations, not the signalling system.

Although under RBTMS L2 and L3 locations of trains are continuously detected and known to a tolerance of a few metres, to display such level of detail on an overview screen is not reasonable. Instead, display will adopt an optimised practice between stations and may use a single section between marker boards as a basis, which would approximate to section lengths of 1-2 km.

Roll-out of RBTMS to cover all SLR lines will be implemented in accordance with a flexible, pre-planned schedule, availability of data highway capacity and signalling status information for each station and line. This roll-out will be simultaneous with the progress of a rolling program of railway modernisation as envisaged by the SLR Master Plan.

The TCS will enable dispatcher manual control of train operations along the KV Line, excluding the Maradana – Baseline Road section, which will be jointly controlled with Maradana CTC pending the modernisation of the Main Line as a later phase of CSRP. The manual control facilities will include interventions in the TNIS and active Schedule. However, under normal operations procedures, the TCS will respond to Automatic Route Setting (ARS) commands generated in conformance to the active schedule. The dispatcher will control train operations by exception, in other words, monitor and intervene only when necessary to manage / arrange line blocks / unblocks for engineering possessions, resolve delays, operational conflicts and incidents.

11.14.2 OCC Level Crossing Supervision

A new position of responsibility will be added for a Level Crossing Supervisor, who will normally monitor the operation of CCTV controlled level crossings, which along with other protected level crossings will be interfaced to TCS. The large numbers of level crossings on the KV Line – and other lines are sufficient to justify a separate workstation dedicated to supervision of level crossings. This workstation would be located close to or adjacent to the KV Line dispatchers in the CTCC to facilitate close coordination in the event of incidents and accidents. One style of level crossing controller may be seen in use in Figure 11-9.

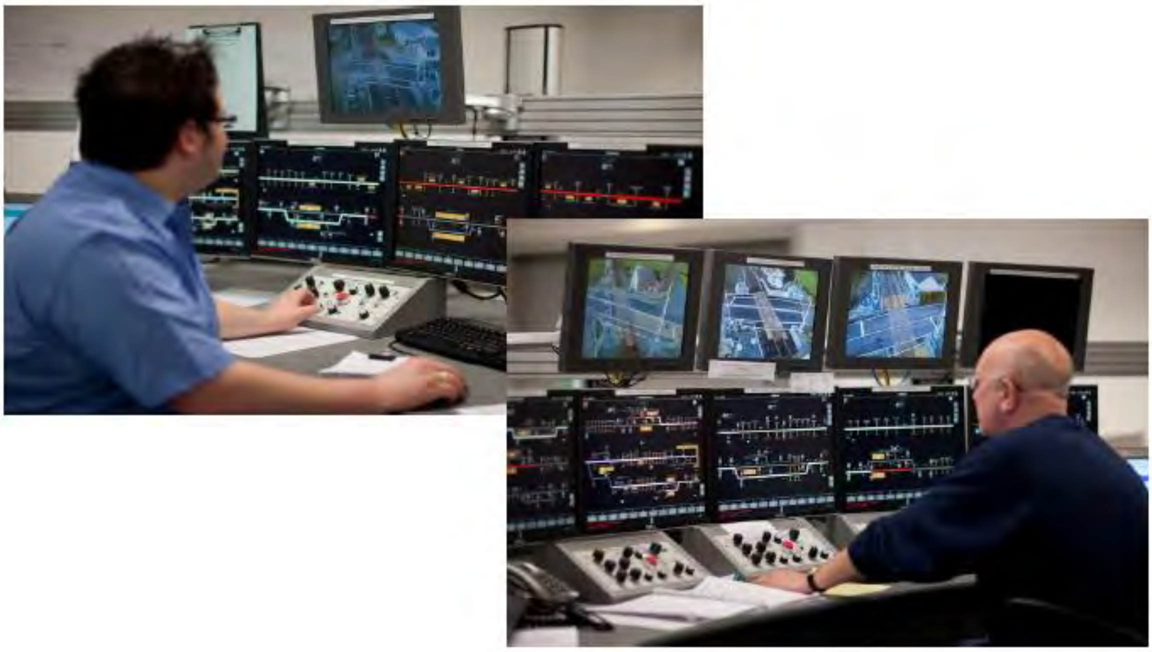


Figure 11-9 Machynlleth CTC showing Level Crossing CCTV (Cambrian, 2011)

The RBTMS will be expanded to cover all lines as and when re-signalling schemes or refurbish / re-control schemes are completed, and sufficient data highway capacity becomes available.

11.14.3 OCC Interfaces

The RBTMS will interface with Passenger Information System (PIS), Freight Operations System (FOS), via Data Communications System (DCS) system for data exchange with local stations, including via TDRS for data exchange with VOB equipment.

Information data provided for PIS will include:

a. Platform Departure Display – assumed 3 trains, train formation (number of cars, location of 1st Class, etc.) and stopping places mentioned only for first listed departure:
    - Train ID
    - Schedule Departure Time / Formation / Stopping Places
    - Expected Departure Time
    - List of Stopping Places

b. Terminal Stations Arrivals / Departure Listings Display, train formation (number of cars, location of 1st Class, etc.) and stopping places mentioned only for first listed departure:
    - Train ID
    - Scheduled Departure Time / Formation / Stopping Places / Arrival Time
    - Expected Departure / Arrival Time

PIS will be expanded to cover all lines as and when re-signalling schemes or station reconstruction or refurbishment schemes are completed, and data highway capacity becomes available.

Other systems will include Management Information System (MIS), Off-Line Scheduler Workstation, Fleet Management System (FMS) and Crew Management System (CMS), Training Workstations, Maintainer's Terminal with diagnostics system and an Asset Management System (AMS).

Field located workstations for TNIS, FMS and CRS may be provided at designated stations and locations along the KV Line. These locations will be determined as appropriate to suit the operational requirements finalized during the Detail Design Stage.

11.15 Signaling Systems, Equipment, Components and Materials

11.15.1 Requirements for Supply

As a minimum, the supply of system components should include the following items:

- All hardware components required to achieve the specified system performance;
- All Application and Operating Software and Firmware;
- Appropriate licenses for all Application and Operating Software and Firmware;
- Tools and testing Equipment;
- Programming and fault diagnostic tools;
- Spare parts;

- Training equipment.

11.15.2 System Supplier Responsibilities

The system supplier shall assure that their expert services shall be provided during:

- Design, Procurement and Inspection Stage;
- Construction and Installation Stage;
- Verification &Validation (V&V), Installation Testing and Integration Testing Stage;
- Commissioning and Setting to Work Stage;
- Operation and Maintenance Stage (Warranty Period).

11.16 Power Supply

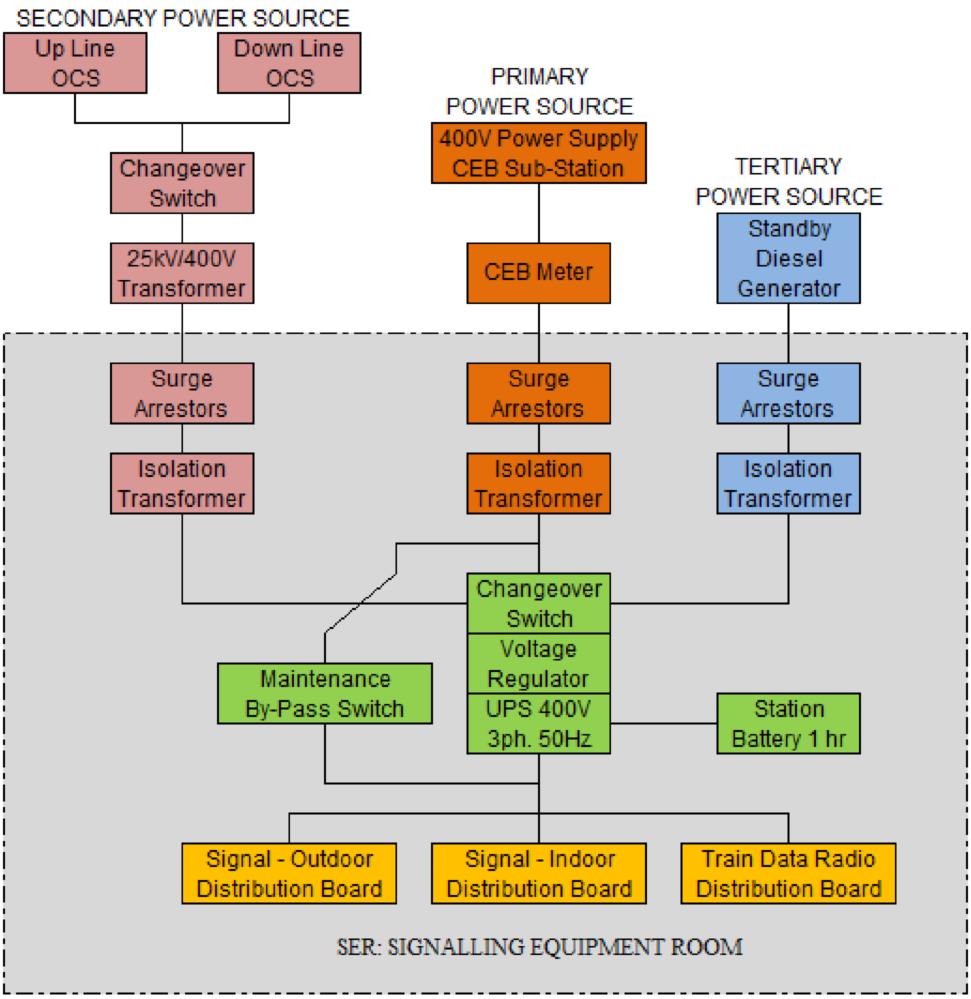


Figure 11-10 Preliminary Power Supply Block Diagram

Signalling power supplies, including at the OCC, will be provided with three sources of power, as shown in Figure 11-10, and as follows:

- From local electricity utility company;

- From traction power supply;
- From emergency standby diesel generator set.

Power supply may be derived directly from traction power supplies at sub-stations, where available, but otherwise from the OCS for each main line track. The two supplies shall be connected via an auto-changeover switch to provide a single source of power to signalling system.

Power supply system design will be arranged such that failure of the active power supply shall result in automatic changeover to the next available power supply. Voltage regulators / stabilisers will be provided, as necessary, together with UPS with 1-hour battery and maintenance by-pass sub-system.

All power supply equipment will be designed and supplied to minimise generation of EMI and, will be resistant to all forms of EMI that may be generated by the traction power supply system and in the local environment.

11.17 Vehicle On-Board Systems and Equipment

11.17.1 Inter-operability Considerations

DMUs, EMUs and locomotives allocated for use on KV Line will be equipped with on-board cab signalling systems and, where economically viable, VOB systems may be retro-fitted to an existing fleet. Although dedicated to the KV Line, these units will also be able to operate across non-equipped lines with on-board equipment set at ETCS Level 0.

The train length (of the preceding train) is used to calculate / assure a safe separation distance for a (following) train. Consequently, non-equipped DMUs and / or locomotives needing access to KV Line should operate as subordinate units to a Pilot Loco or DMU equipped with cab-signalling (quantity of equipped locomotives will be decided during detailed design). Train crew would make the necessary inputs to the VOB via the DMI.

It is considered that 3 locomotives (2 in use, 1 standby) may be an appropriate fleet size for the KV Line. Depending upon public service schedules, crew availability, service delays, etc., loco-hauled long-distance passenger services could either change locomotives at Maradana / Colombo Fort or a Pilot Locomotive may be attached at the same location.

For this reason also, freight trains should be equipped with a suitable means to confirm continuous completeness of the train. There are a number of options discussed earlier in sub-section 11.15 Train Management Proposals. For this project, an interim alternative option for provision of axle counter sections at strategic locations has been proposed, which locations are proposed below:

- Baseline Road – start of KV Line to confirm and correlate driver data input;
- Makumbura North – prior to / subsequent to proposed junction to Horana Valley Line;
- Padukka – start of KV Line metro service from Avissawella direction;
- Kosgama - prior to / subsequent to proposed junction to Kelaniya Line.

11.18 Vehicle-On-Board (VOB) Systems and Equipment

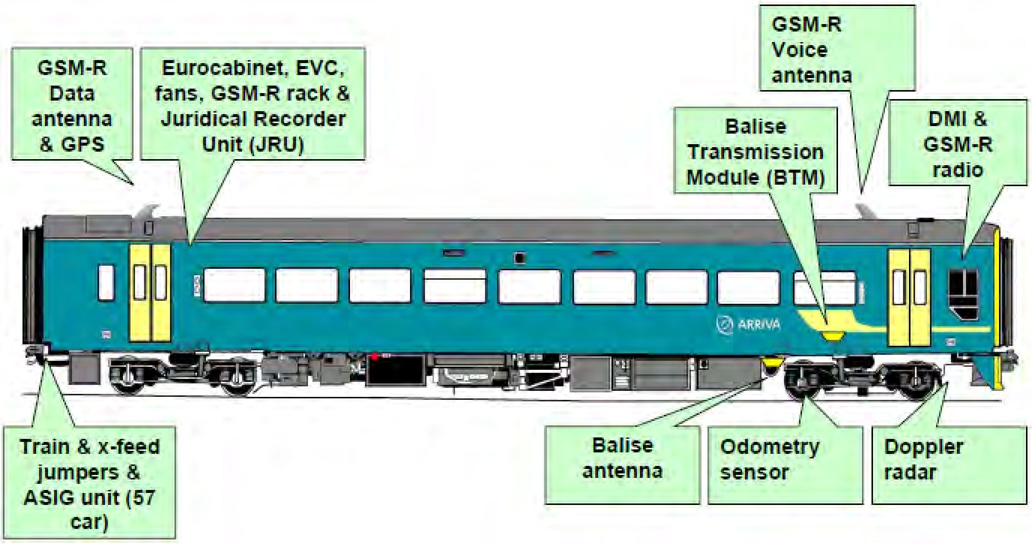


Figure 11-11 UK Class 158 DMU ERTMS VOB Equipment Retro-Fit (Arriva, 2011)

The vehicle, shown in Figure 11-11, forms one half of a then 20-year old, 2-car DMU retro-fitted with vehicle on-board (VOB) equipment suitable for ERTMS Level 2 operation. As may be expected, and as expressed by SLR, retro-fitting equipment to vehicles of that age is somewhat problematic. Quite apart from the difficulty of finding unused space in existing rolling stock, for the case of Cambrian Line retro-fitting has also raised some issues and caused a number faults. By contrast, JR East had implemented multiple simulations of wayside and VOB systems prior to fitting equipment into trains for integration testing. Contrary to implications of the schematic diagram in Figure 11-12, equipment was mounted beneath the train, except for the radio antenna, and not inside the cars.

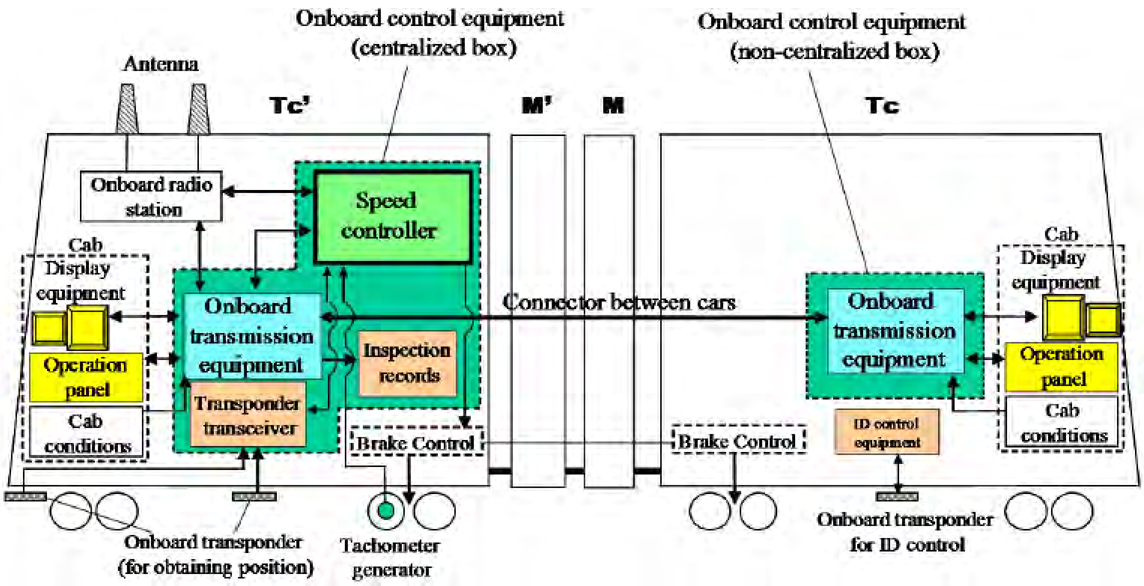


Figure 11-12 VOB Equipment Schematic (ATACS, 2014)

A virtual map of the railway (i.e. KV Line and any other ETCS controlled line to which access rights may be granted), gradient profile, track alignment and permanent speed restriction data will reside in the VOB control equipment computer, together with the specific performance database for the train /

vehicle. Train crew (driver) will enter / confirm the train ID, which action will activate the train schedule for the particular train / vehicle. The TCS will transmit an LMA and speed profile to the VOB computer, which will calculate an optimum journey profile and display at the DMI. The VOB computer will correlate odometer readings with GPS data to determine location and, upon receipt of location information for an in-track balise, will adjust calculated location results. Continuous transmissions between train and control centre will assure the train's location is known at all times and correctly displayed to the dispatcher at the CTC / CTCC.

The VOB will continuously monitor train performance and intervene with braking application, should the need arise, e.g. due to excessive speed, approaching end of LMA, cancellation of LMA or receipt of emergency stop command. The intervention will cease upon driver responding by reducing speed or stopping the train.

Only one DMI will be active at any time, with the other DMI being in sleep mode.

11.18.1 Inter-operability

Any requirement for full inter-operability is a matter for SLR consideration due to implications for CAPEX and OPEX, together with operational considerations, e.g. age / condition of rolling stock. Retro-fitting of rolling stock will consider two major factors:

- Space availability – ease of installation and maintenance access;
- Mutually Assured EMC – Electro-Magnetic Compatibility.

Rail vehicles equipped with cab-signaling and VOB train management systems would have access to all lines across the SLR network due to the additional facility for selection of Level 0 / STM (Specific Transmission Module, i.e. National network) modes. However, those rail vehicles not equipped for cab signaling or equipped, but for a lower level, will not have access to equipped lines or lines that are equipped at a higher level. Engineering trains, for example, must either be equipped or work in tandem with an equipped Pilot locomotive.

11.19 Level Crossings

Table 11-8 Summary of Level crossings on KV Line

No.	Type of Protection	Number	Remarks
1	Electrically Operated Barriers	9	All to be closed
2	Mechanically Operated Barriers	31	Majority to be closed; some to be upgraded to full protection
3	Warning Bells and Flashing Red Lights	24	Some to be upgraded to full protection
4	Unprotected	83	Some closed; some to be protected by level crossing speed restrictions

Wherever possible, level crossings will be permanently closed and substituted by appropriate grade-separated crossings. Where some doubt may exist, tools such as Road-Rail Exposure Index (RREI) and Delay Cost will be used. An example of those calculations is included in Part E, Section 7.35. As a rule of thumb, double-tracking and a three-fold increase in service frequencies will increase RREI to such an extent that substitution by grade-separated crossings may be necessary. Those level crossings already protected to the greatest extent can be assumed as candidates for closure, and forms the premise for the remarks in Table 11-8, which information may be revised during Detail Design Stage. The general arrangement plan for a fully protected level crossing is shown as Figure 11-13.

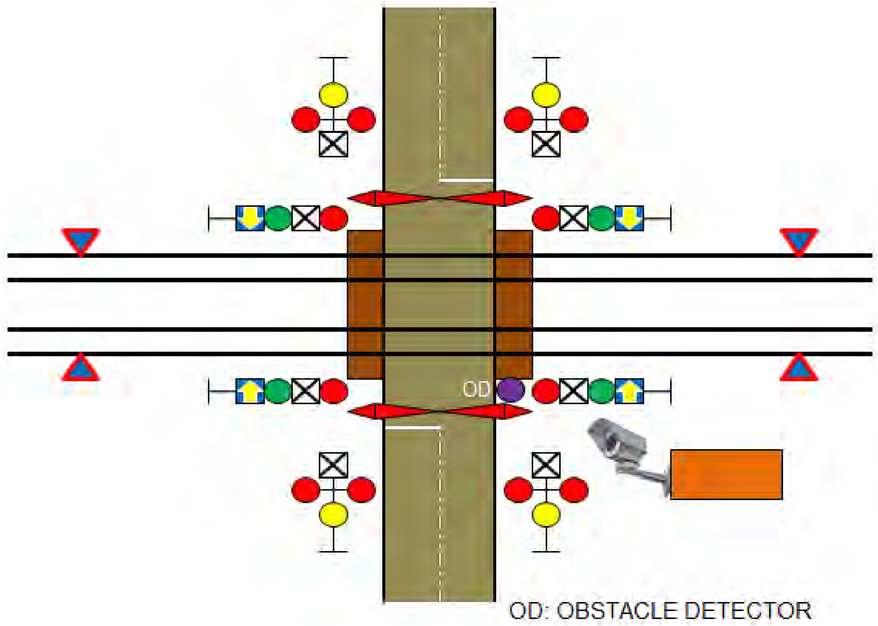


Figure 11-13 R-EOB-OD Protected Level Crossing with CCTV

With regards to other level crossings, the degree of protection will be assessed on a site-by-site basis during detail design in order to properly consider all relevant factors, including usage, clear view and road classification.

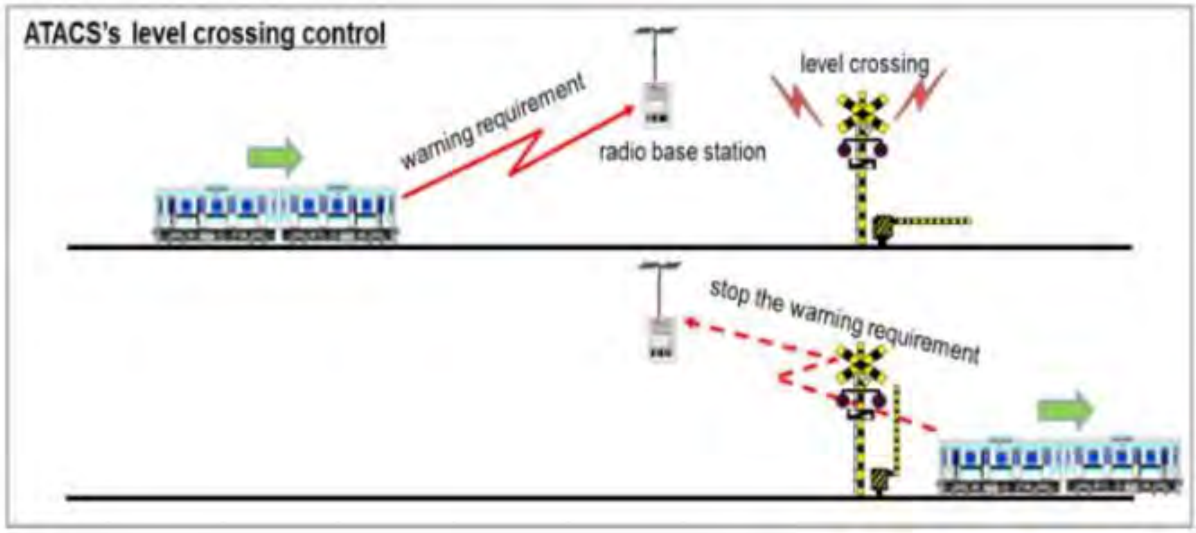


Figure 11-14 Radio Control of Level Crossings (IRJ, 2016)

Each level crossing will be interfaced with the RBTMS in order to enhance safety, even for level crossings that are currently unprotected. As a minimum level of protection a Temporary Speed Restriction (TSR) could be imposed through the medium of RBTMS by change to a parameter held on the system database. The use of radio control for level crossings has been proven by ATACS, Japan (IRSE, 2016), as shown in Figure 11-14. The list of level crossing types is given in Table 11-9.

Appropriate levels of protection for level crossings will be considered during the Detail Design Stage.

Table 11-9 Summary of Level Crossing Types

No.	Type	Description
1	R-EOB-OD (Upgraded)	Fully Protected Remote Controlled Barriers with Warning System, CCTV and Obstacle Detection System;
2	AHB:	Fully Protected Automatic Half-Barriers with Warning System;
3	LOHB:	Locally Operated Half Barriers with Warning System (Community not SLR);
4	AOLC:	Automatic Open Level Crossing without Barriers with Warning System;
5	MHB:	Manually Operated Half-Barriers with Warning System;
6	MFB:	Manually Operated Full- Barriers with Warning System;
7	R-OLC	Open Level Crossing with RBTMS Temporary Speed Restriction

11.20 Maradana Station – Loco Junction – Dematagoda Depot

11.20.1 Maradana CTC Interim Arrangements

Different work planning and schedules for modernization of the KV Line and the SLR Main Line may require interim arrangements, particularly so in the event that construction of the new CTCC building is to a third, different work schedule.

11.20.2 Maradana Station – Loco Junction

Figure 11-15 Maradana Station – Loco Junction

The necessary track layout changes for the KV Line double-tracking and electrification are considered as advance works for the rationalization and electrification project Colombo Fort – Maradana – Loco Junction, including Colombo Port branch. As such, these works will implement minimum changes to track layout commensurate with the final track layout to be provided at a later stage, and may include installation of turnouts for future use, but clipped and padlocked out of use in this stage. An existing siding that currently finishes behind the tree (centre of photo) may be extended and connected into the existing KV Line, whilst a new line to be constructed will extend the ROW to the right of Figure 11-15.

During an interim period when KV Line modernization has been completed and modernization of SLR Main Line has not progressed sufficiently, then control of entry to and exit from KV Line will remain with Maradana CTC. The new KV Line CTC, which will control Baseline Road – Avissawella together with the new TMS, both at the new OCC, may be commissioned utilizing data provided by the existing Maradana CTC and the new data transmission system.

Modernization of the SLR Main Line Colombo Fort – Maradana [– Coastal Line] will enable existing Maradana CTC to be decommissioned and relocated to the new CTCC building. During this change-over period the final integration and commissioning phase of KV Line may be implemented. A move to the new CTCC building may be brought forward if subsequent investigation during Detail Design demonstrates a need for re-control of Maradana station interlocking due to compatibilty issues with existing systems and equipment and the new immunization requirements for electrified areas.

11.20.3 Depots and Workshops

Depots and workshops will be provided with two systems:

- Depot Signalling System (DSS);
- Depot Protection System (DPS).

11.20.3.1 Depot Signalling System

The design basis for the signalling system is proposed as RBTMS Level 2 with fixed signals and train detection to enable depot access for non-equipped trains. Control of the DSS will be exercised from the Depot Control Room, which will include a free-standing mosaic-tile control panel for route-setting and points control, together with a mosaic-tile mimic diagram depicting status of depot signalling system and storage tracks. Train ID numbers will be indicated on a limited basis to cover Reception Line, Departure Line and related tracks. Facilities for depot personnel to allocate and enter Train ID numbers will be considered during Detail Design Stage.

Information will also be transmitted to trains via active and passive balises mounted in-track nearby signals and at other strategic places. Each active balise will be connected to their relevant signal via an LEU mounted in a wayside cabinet. Train data will also be exchanged with DPS via the TDRS.

In the event that VOB equipment may be discovered as faulty, then the affected train would be taken out of service and returned to the depot for diagnostic analysis and exchange or repair of the faulty sub-system or component.

Facilities for driverless operation of some trains for movements entirely within the depot and only on designated tracks are proposed for depot personnel utilising hand-held control units and TDRS.

The design for the DSS will be site specific and developed during Detail Design Stage.

11.20.3.2 Depot Protection System

The design basis for the Depot Protection System is proposed to allow trains access to maintenance tracks and depot whilst protecting personnel from potential injury from moving trains. Control of the DPS will be exercised at each point of access to a depot maintenance track and managed from Depot Control Room, which will include a control panel, together with mimic diagram depicting DPS status of protected tracks.

The DPS will be will be site specific and developed during Detail Design Stage.

11.21 Interface Considerations

11.21.1 Overhead Contact System (OCS) Interface

Electrification of the KV Line may be implemented simultaneously with re-signalling or at a future date as an OCS with return earth wire system at an operating voltage of 25 kV ac. All signalling systems, equipment and cabling will require protection against EMI generated by the OCS and other sources in the surrounding environment. Signalling systems must be ac immune and designed for minimal generation of EMI to avoid causing issues for other nearby systems and equipment. Suppliers should implement a coordinated EMC survey with OCS, Information and Communications Technology (ICT) and telecommunications suppliers to confirm system EMC performance levels, and to plan their coordinated testing strategy.

The provision of track circuits for train detection purposes should be carefully considered with design, installation, testing and use coordinated with OCS, especially in regard to requirements for traction bonding. Signals, where provided, should be equipped with an appropriate screen to deter and prevent unintentional physical contact with potentially live OCS structures, wires or anchor points.

Physical location of the neutral section(s) will constrain the positioning of any fixed signals that may be provided. However, these are also an important factor for a moving block system, such as ETCS Level 3, as proposed for the KV Line, and must be incorporated into the virtual map as contained in the CTCC signalling database. Location of the neutral section must be coordinated to eliminate any possibility for trains to stop with pantographs positioned such that re-starting may be compromised.

In electrified areas, signalling power supply should be derived from the OCS with one feeder from each of the Up Line OCS and Down Line OCS reducing to a single feeder via a change-over switch. Additionally, some remotely located OCS motorized isolators may derive power from the signalling power supply. Both requirements should be coordinated for protection against transients and other fault currents.

Earthing and bonding design for signalling systems and equipment should be coordinated with OCS as part of an integrated design for earthing and bonding.

11.21.2 Telecommunications Interface

Communication between the control centres and crossing stations will use dark fibres in fibre-optic cables arranged in dual-redundant ring formation. Ideally these would be laid either side of the ROW to assure diverse routing; however, telecommunications facilities are provided by separate contracts. As a consequence there may be only one fibre-optic cable within the ROW with the diverse route via a third-party network. In this eventuality, then encryption of signalling data may be necessary, which possibility will be explored and resolved during Detail Design Phase.

Data communications between the OCC, RBCs, trains and level crossings require a safety-critical radio network. Additionally, reliance on radio may increase the amount of verbal communications between train dispatchers and drivers. Since there is a risk of misunderstandings during conversations, these too should be considered as potentially safety-critical and utilise a similar radio network.

The safety-critical radio system should operate across a frequency band with availability of at least four frequency-bands for the KV Line. The number of frequency-bands may need to be increased for Maradana – Loco Junction section to cater for the multiple tracks, which will be determined during Detail Design Stage.

Video communications are necessary for the monitoring of level crossing operations with CCTV cameras that are remotely controlled from the OCC.

11.21.3 Rolling Stock Interface

Data communications between the OCC, RBCs, trains and level crossings require a safety-critical radio network. It is essential to assure that the same technology and protocols are adopted as for train data radio system.

Additionally, reliance on radio may increase the amount of verbal communications between train dispatchers and drivers. Since there is a risk of misunderstandings during conversations, these too should be considered as potentially safety-critical and may necessitate a similar radio network.

The VOB database for each MU rake or locomotive should store a virtual map of the routes over which the set / unit is permitted to operate and, that map may be updated frequently for changes to operating conditions. However, there will be a size limitation, not just on the storage media, but also the physical space available for hardware within the rolling stock. The possibilities for exchange of maps and other data with databases in the OCC will be explored during Detail Design Stage.

Facilities for automatic train operation and automatic turn-back, both with driver present, should be proposed. Additionally, facilities for remote driverless operation should be proposed to enable depot staff to move empty trains on designated lines entirely within the depot area.

Health monitoring of On-Board systems should be provided to the greatest extent possible, facilitate event recording and incorporate remote interrogation facilities.

Whereas fitting of VOB equipment to new rolling stock is relatively straightforward as a design issue, the same is not necessarily true for existing rolling stock. There are several major considerations when considering the equipping of existing rolling stock, including those mentioned below:

Required route availability for foreseeable future in operational service;

Available space for driver consoles, and VOB systems and equipment;

Mutual EMC (electro-magnetic compatibility) between proposed new systems and existing systems;

Financial viability considering remaining life-cycles and refurbishment possibilities for rolling stock under consideration.

11.21.4 Depot Interface

11.21.4.1 VOB System Test Tracks

VOB System Test Tracks are necessary within depot areas and serve two different functions, which implies that more than one Test Track may be required depending upon design of track arrangements within the depot. Following completion of maintenance at either a Light Maintenance Depot or Heavy Maintenance Depot, the VOB systems may need re-calibration, re-correlation or re-commissioning, for which purpose the test track should be located within the depot area rather than stabling sidings in the operational area.

As a daily routine, drivers of trains stabled in sidings will activate the VOB systems and undertake the required data entry and exchange with RBTMS. Whilst this may be thought adequate to demonstrate the functionality of the majority of the VOB systems, the driver still needs to check the balise reader / transponder system by passing over a Test Balise before entering service.

In the event of the VOB systems not responding as expected, a failure will be declared and the train would be taken out of service and removed from the Departure Line back into the depot. This requires the Test Balise be located en route to the exit point of the stabling area, but with a convenient escape facility to avoid causing congestion on the main line by leaving the depot with faulty equipment.

11.21.5 ICT Interface

11.21.5.1 Asset Management System

The train control system requires route availability, dimensional, loading and performance data for rolling stock, which will be resident in the Asset Management database for motive power and rolling stock. TCS should be able to access that data on a read-only basis. This will be especially important when a non-resident locomotive / multiple unit wishes to access the KV Line.

From an infrastructure perspective it may be argued that the relevant sections of the AMS should be categorized as safety-critical since the database contains information necessary for safe operation of the railway. As an example, rolling stock performance and route availability are used for scheduling purposes. This data is then accessed for calculations of braking and safe distances by the signalling system and for granting right of access to lines and stations, which could lead to unsafe conditions or incidents where platform edges may be struck by over-size rolling stock. One potential solution could split the AMS into "Operational" and "Commercial" parts. This discussion will form a necessary part of Detail Design Stage.

11.21.5.2 Crew Management System / Fleet Management System

These closely-related systems will require access to real-time information from the live schedule that will be resident on the train control system. Access on a read-only basis will be arranged for both the systems. From a train operations perspective CMS includes safety-critical requirements for driver, who must possess licenses, be competent to drive the assigned rolling and "know the road", all of which should be considered as "Operational" rather than "Human Resources" requirements. Similar arguments may be considered for FMS. This discussion will form a necessary part of Detail Design Stage.

11.21.5.3 Management Information System

An MIS, similar to AMS, should perhaps be categorized as "Operational" and "Commercial" since a large part of the functionality is directly relevant to train operations and the remainder to commercial activities and administration tasks. The operational functions review performance data for trains and other assets, which may feed into commercial activities. Again, this discussion will form a necessary part of Detail Design Stage.

11.21.5.4 Passenger Information System

This system will require access to real-time information from the live schedule that will be resident on the train control system. Access on a read-only basis will be arranged for this system.

Part E. Construction, Operations and Maintenance

11.22 Construction Planning

A proposal for construction method utilising a system of blockades has been proposed in conjunction with consideration of options for underground or elevated sections. This section considers possibilities for use of a different construction method. Construction of the KV Line may be considered as four distinct phases or sectors, identified below, and which may be constructed simultaneously:

- Maradana – Loco Junction: Modifications for Additional Track; At Grade;
- Loco Junction – Malapalla: New Double-Track Elevated Section;
- Malapalla – Padukka: Double-Tracking; At Grade;
- Padukka – Avissawella: Rehabilitation of Single Track; At Grade.

A brief description of the procedures for each section follows, but the final concept will be developed during Detail Design Stage.

11.22.1 Maradana – Loco Junction Double Tracking

The limits of this section may be defined as Maradana Station, platforms 9 and 10, but excluding connections from the Main Lines, Colombo Fort side, and the start of the ramp for the new elevated section.

Between these two limits a new second track will be constructed for the KV Line, platforms 9 and 10 rehabilitated, new connections from platforms 1-8 provided, and a new connecting line will be constructed to the new light maintenance depot, Dematagoda. Upon completion, the new track layout will be integrated into the then-existing railway, which may mean continuance as single-track operation until such time as the new elevated section is complete. Upgrade to double track could be implemented stage-wise along the new elevated section pending completion through to Kottawa and Makumbura North.

11.22.2 Loco Junction – Kottawa Elevated Section

The limits of this section may be defined as the start of the ramp for the new elevated section near Loco Junction and the end of the ramp for the elevated section at Malapalla. However, the logistical end will actually be at Kottawa station, which is the end station for the single line section.

Between these two limits a new elevated section of double- track railway will be constructed for the KV Line. In order to maintain train services throughout the construction period, additional land may be required to facilitate construction of temporary track deviations. Upon completion, the elevated section could be brought into use in one or two stages, which are:

- A new alignment substituting for the existing single-track railway;
- A new double track Maradana – Makumbura North railway.

The final choice will consider the progress of construction works on both adjoining sections.

11.22.3 Kottawa – Padukka Double-Tracking

The limits of this section may be defined as the end of the ramp for the elevated section at Kottawa and Padukka station limits on the Avissawella side of the station. In the event that a decision is taken for construction of a new depot near Arukwathpura station, these limits could be extended.

Between these two limits a new second track will be constructed alongside the existing railway, and will be complete with all loops, sidings, passenger station facilities and, where required turnouts for future use as a double-track railway. Upon completion of the new track, the existing track will be cut and slewed into the new track at Kottawa and at Padukka. In the event that the new elevated track and Maradana – Loco Junction sections are ready for use, then the new alignment would be directly joined to the elevated section in preparation for the switch-over from existing to new single-tracks. Dismantling and reconstruction of the existing single-track railway would then proceed until final completion of the new double-track Maradana – Padukka railway.

This construction method has potential to compensate for any unanticipated delays in construction works at Maradana – Loco Junction section with the possibility for double-track operation between Padukka and Baseline Road, then change trains to the low level station and continue the journey to Maradana via the existing railway. Similar arrangements could be implemented for delays at Kottawa - Padukka section. The final options will consider the progress of construction works on all three adjoining sections.

11.22.4 Padukka – Avissawella Rehabilitation

The limits of this section may be defined as Padukka station limits and Kosgama station limits, in both cases the limits are on the Avissawella side of the stations. In the event that a decision is taken for construction of a new depot near Arukwathpura station, these limits could be shortened. Also, from Kiriwandala station limits on the Kosgama side of the station and the end of the KV Line at Avissawella station. The Kosgama – Kiriwandala section will be reconstructed as a new railway on a new alignment by a Road Development Authority (RDA) project, and may be excluded from the Scope of Works.

Between these four limits the existing section of single- track railway will be rehabilitated, as far as possible without interruption to services. However, the strong possibility of short-duration closures (for track / bridge reconstruction or signalling changeover) during overnight, week-end and national holiday periods should not be discounted.

11.23 Testing and Commissioning

A comprehensive Testing and Commissioning procedure will be followed in three stages as follows:

- Pre-delivery Testing
- Site Testing

Integration Testing, Trial Operations and Commissioning

11.23.1 Pre-Delivery Testing

In order to minimise site testing activities, development and pre-delivery testing using modelling techniques are proposed. These should be carried out by the system suppliers to demonstrate the predicted performance of the train management systems, preferably under laboratory conditions and subjected to the levels of EMI specified in the relevant international standards. The duration of these off-shore testing activities may be expected to cover several months.

These modelling tests may be considered as additional to verification and validation activities (V&V), which should also be implemented.

Additionally, some integration testing of VOB signalling systems will be implemented off-shore at the vehicle supplier's manufactory. In a similar manner some integration testing of signalling with radio systems may be implemented off-shore at either supplier's test facility.

The appointment of an Independent Safety Assessor (ISA) is strongly recommended to assure system safety and review the System Safety Case.

11.23.2 Site Testing

There are several important Site Testing activities, which will be developed during Detail Design Phase, but which include those listed below:

- Incoming Materials Inspection;
- Post Installation Check-Out (PICO);
- Equipment and Cable Testing;
- Sub-system Testing;
- System Testing.

11.23.3 Integration Testing, Trial Operations and Commissioning

Systems Integration Testing will be undertaken only after completion of all prior testing by all parties who will participate in these activities, e.g. signalling, telecommunications, OCS, ICT, track, etc.

A pre-commissioning phase will facilitate a period of Trial Operations over a designated section of the KV Line, and for which use of the Elevated Section is proposed. Being elevated few interruptions may be anticipated and, train operations are unlikely to adversely affect others to any great extent.

Trial Operations, which could extend over a 1-3 months period, are essential for reasons stated below:

- The RBTMS signalling system is new to Sri Lanka;
- The VOB systems are new to Sri Lanka;
- The train data radio system is new to Sri Lanka;
- The OCS is new to Sri Lanka.

Completion of Trial Operations, including completion the Safety Case may permit Provisional Hand-over to SLR for all or part of the KV Line, and Final Commissioning. The Warranty Period, normally two years, but for some projects three years, would commence with the main contractor, together with their suppliers, acknowledging and accepting responsibility for system maintenance for the full duration of the Warranty Period, include supply of any necessary equipment in exchange for faulty equipment.

11.24 Systems Health and Performance

11.24.1 RAMS

RAMS performance requirements will be developed in accordance with the standards specified in Requirement and Rule Book Section 6.1.1, during the Detail Design Stage, but will be appropriate to SIL4.

The suppliers will be required to demonstrate through theoretical, design, manufacture, delivery and construction at site, testing, commissioning and operations that RAMS performance levels are in full conformance with the technical requirements.

The requirements for preparation of a System Safety Case and appointment of an Independent Safety Assessment will be developed during the Detail Design Stage.

11.24.2 System Health Monitoring

System faults and non-critical failures affect the system performance and there is a need for the health of systems and components to be continuously monitored and recorded to the greatest extent possible. This includes the provision of Health Monitoring Systems for the following facilities:

- Central System and Equipment;
- Radio Transmitting Stations;
- Ground Controller and Field Controller;
- Vehicle-On-Board Systems;
- In-Track Balise, preferably a Vehicle-Borne System;
- Point Machines;
- Level Crossings;
- Power supply system.

All health monitoring systems should facilitate event recording and incorporate remote interrogation facilities.

11.24.3 Maintainer's Terminal

Maintainer's Terminal with full facilities will be provided at the OCC; however, such facilities will not include the issue of Movement Authorities.

11.25 Degraded Operations

Degraded operation will be implemented in order to operate trains during period of a failure of the RBTMS, a sub system or equipment

There are several scenarios, under which degraded operations may be necessary, including those listed below:

- Failure of VOB systems or equipment;
- Failure of track-side systems or equipment;

- Data Communication Failure – partial or complete;
- Total System Failure.

11.25.1 VOB Systems or Equipment Failure

In a worst-case scenario of total failure of VOB systems, but with system power unaffected, then the driver would isolate the TCS systems, enter Isolation (IS) Mode, contact the dispatcher and agree the LMA (voice, text message) as prescribed in Block regulations, and proceed in IS Mode to the nearest EOA Marker Board. The driver will again contact dispatcher to agree further LMAs until arriving at the nearest crossing station, where the train may be parked in a loop platform pending repair or recovery. Repair may be accomplished in-situ by exchange of faulty equipment unit.

11.25.2 Track-Side Systems or Equipment Failure

In this scenario, issue of an LMA will not be possible, due for example, to loss of points detection. The driver would enter Staff Responsible (SR) Mode, contact the dispatcher and agree LMA (voice, text message) and proceed in SR Mode to the nearest EOA. The driver will again contact dispatcher to agree further LMAs until clear of the failure zone, where the driver will re-enter Full Supervision (FS) Mode and the train may proceed as normal to destination.

11.26 Operations & Maintenance (O&M)

11.26.1 Existing Maintenance Systems

Current maintenance practices on the KV Line generally follow legacy methods tried and tested over time. However, these traditional means trouble-shoot faults at site under operational conditions and, which will inevitably result in delays to train services until the fault has been identified and corrective action implemented. The KV Line is predominantly signalled in accordance with mechanical practices albeit some signals are in fact multi-aspect colour light signals.

The maintenance regime will perforce undergo changes in organization, work practices and levels of skills, also types of skills in order to meet the challenges of modern computer-based signalling.

11.26.2 Maintenance Considerations

Modern maintenance practice recognises three maintenance regimes – preventive, predictive, reactive – together with four means of implementation – diagnostic tests, corrective action at site, equipment exchange and workshop repairs. Reactive maintenance responds to critical failures and carries a high risk of financial penalties consequential to resultant delays to train services.

Predictive maintenance is predominantly a desk-based function that will review historical failures to identify potential system weaknesses, equipment in need of special or extra attention, and equipment due for exchange or servicing.

Preventive maintenance comprises sets of routine tasks that are implement as part of a daily, weekly or monthly schedule.

Reactive maintenance refers to all actions undertaken in response to a system or equipment failure, an incident involving damage to equipment or some other cause where attendance of maintenance staff is necessary or desirable.

More detailed information is shown in Figure 11-16, which also shows the complementary tasks allocated to each of those maintenance regimes and the workshops.

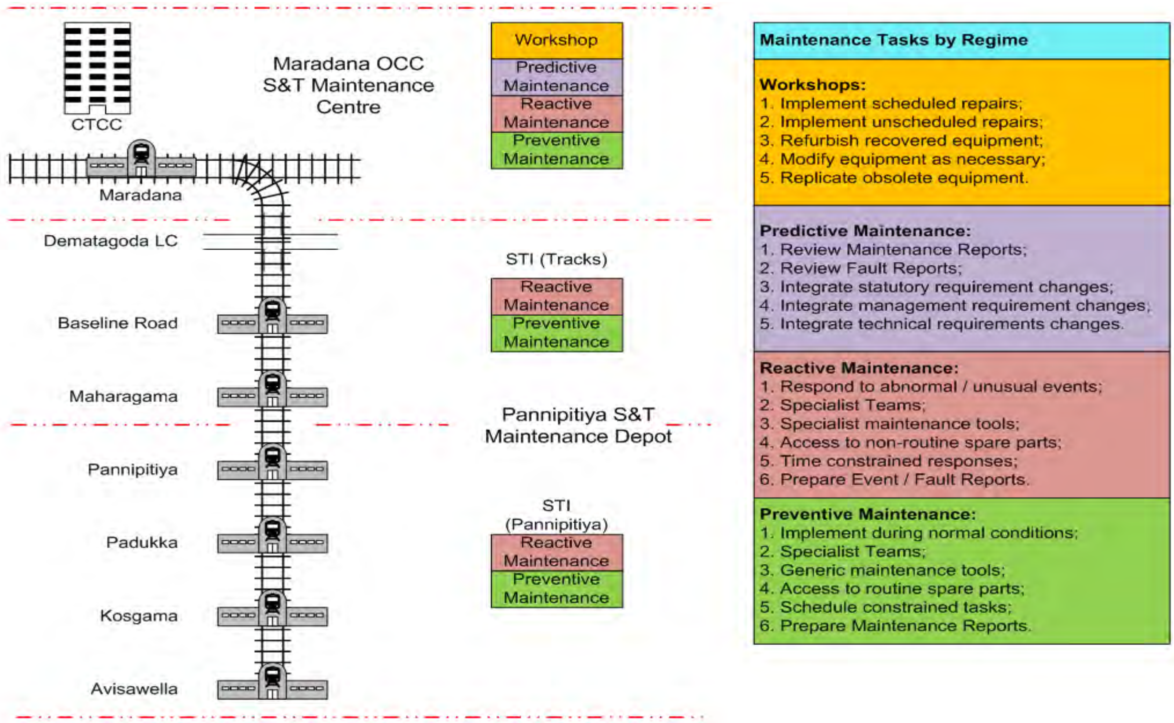


Figure 11-16 Site Maintenance Regimes and Tasks

The style of workshop proposed is designed and equipped for modern signalling practices with exchange for repair concept for trouble-shooting at site. This workshop will be provided in addition to the existing signal workshop at Dematagoda, with the consequence that responsibilities will be shared.

System	Component																							
	Ground Based Control System																Vehicle On Board Equipment							
	Central equipment			Line side Equipment																				
	CTC/TMS/TD/TNIS	TESS/TCS/Central Int. Lock	Data Transmission	Ground Cont./Field Int. Lock	Wheel detector	Axle Counter/	Passive Balise	Active Balise	LEU	Signals	(Relays+ Rectifiers)	Point Machines	LX Signals	Barrier Machines	Copper cables	OFC	Radio Equipment	On Board Antenna	Balise Reader	Odometer+ GPS	In-Cab Display	Diver assistance System	Speed Control system	Brake Control system
Level 3	X	X	X	X	0	X	X	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X
Level 2	X	X	X	X	X	X	X	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Level 1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0	0	X	X	X	0	X	X
Status of Technology	New									Existing							New							
Preferred Repair Location	OCC Building				Outside OCC Building												Closer to EMU Depot							
Proposed Location for Testing and repair Centre	OCC Building - Near Equipment Rooms				Adjoining the EMU Depot																			
Category of Equipment	Central				Field												Radio & Vehicle System (R&VS)							
No. of Technicians NVQ L4	01				01					01					02		02			02				
No. of Technicians NVQ L3	02				02					04					02		03			02				
No. of Technical Officers (STIs) NVQ L6	01				-					-							01			01				
No. of Technical Officers (STIs) NVQ L5	-				01					01					01									
Stores – SKs – 3 Nos.	A				B					C							B							
No. of DIRs	DIR (OCC WS)				DIR (W/S) Electrical - 01												DIR (R & VS) -01							
Engineer Responsible	SE (TMS)				SE(EWS)												SE(R&VS)							
Note: Repairs & Production facilities for Mechanical Items to be shifted to a suitable Location and will operates under SE (MWS)																								

Figure 11-17 Proposed Division of Workshop Maintenance Responsibilities

The existing signal workshop will retain responsibilities for existing systems and equipment, with the new signal workshop within the CTCC Building taking responsibility for new systems and equipment.

Figure 11-17 indicates the division of responsibilities between the existing and new workshops. The new workshop will require organizational change also, which is reflected in Figure 11-18. Over time further exchanges of responsibilities may be implemented as part of the natural growth cycles, with the possibility for relocation of the existing signal workshop to another, more convenient, site.

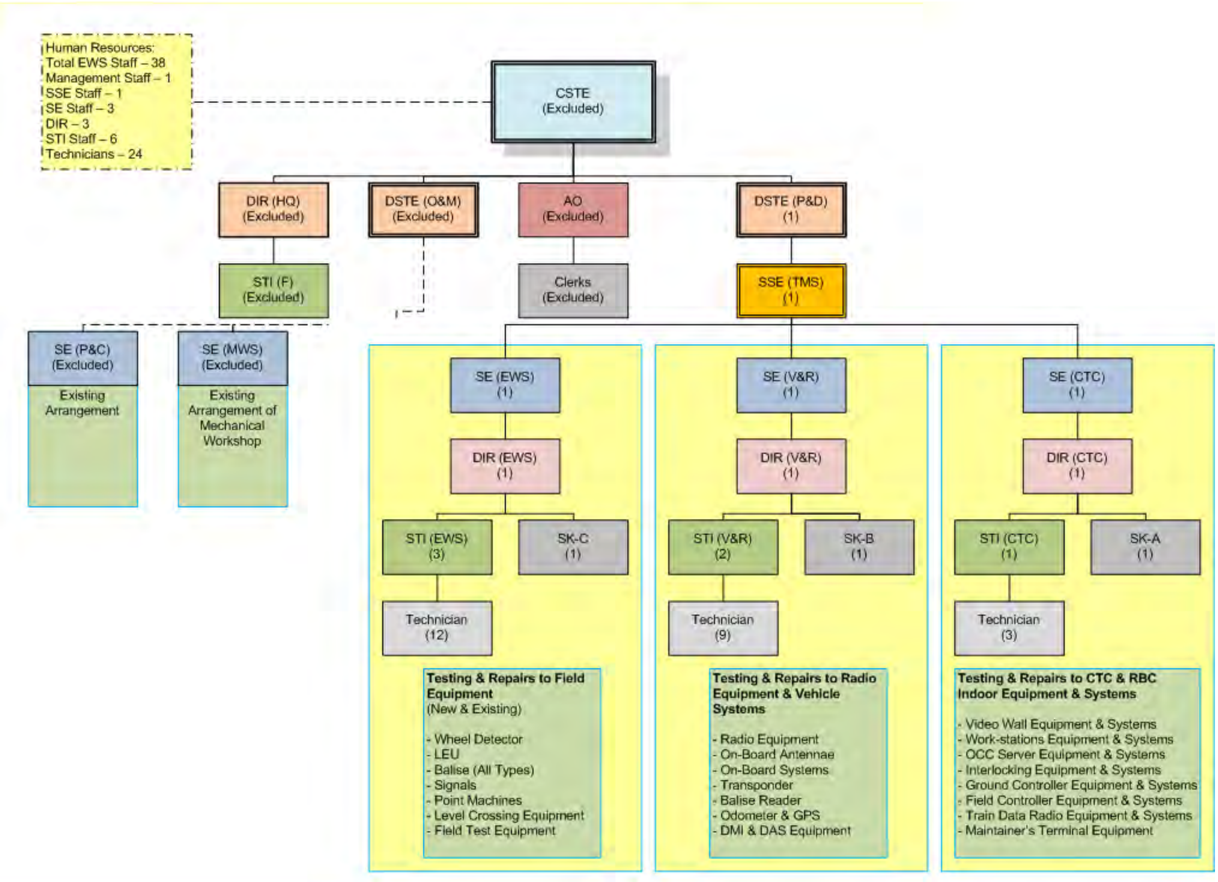


Figure 11-18 Proposed New Workshops Organization Chart

11.26.3 A Preliminary Concept for the Maintenance Organization

The new signalling system for the KV Line, and in due course the other lines in Colombo division, will require the existing maintenance organisation to adapt and modernize to meet the challenges of a new generation of digital-based systems. This will necessarily change working environments, tools, methods, and bring new opportunities to the workforce. The new CTCC building will become a hub for the network and will be at the centre and focus of the signalling maintenance organization. Some site depots will remain in the same location, but perhaps acquire new premises, whilst others may in time be phased out. Those questions will be explored in greater detail during the Detail Design Stage, but a preliminary concept has been prepared to start the conversation.

The preliminary concept organization chart is shown in Figure 11-19 and has arranged signalling maintenance into three integrated work groups – Line Maintenance, OCC and Workshops – all of which ultimately report to a single management function, the Deputy Chief Engineer (Signal).

For the purposes of this Feasibility Study the various roles have been given titles in alignment with current SLR organization structures and job descriptions.

Within the OCC complex, four teams of three technicians plus one STI will each be managed by one of four SEs, who will also act as mentors during the early years following commissioning and system training. Three teams will work three rotating shifts, each of 8 hours duration, with the team resting between their rostered duties.

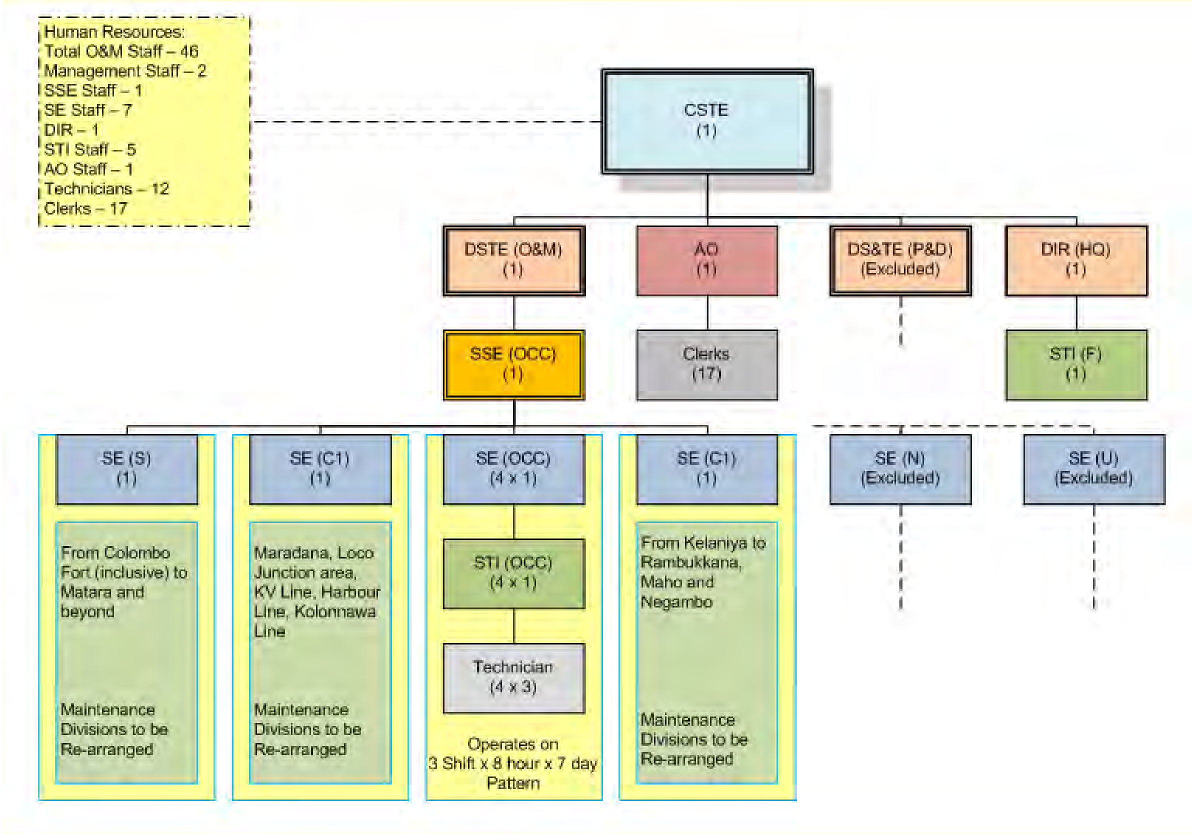


Figure 11-19 Proposed New KVL O&M Organization Chart

Line maintenance will follow a similar pattern to the existing system of small teams based in stations at strategic locations – Rathmalana, Padukka, Maradana and Ragama – across the network. Two teams, one each at Maradana and Ragama will work 3 shifts, whilst the remainder will cover only two shifts.

Although separate workgroups these will both be managed by the same function, SSE (OCC) in order to assure an integrated response to maintenance issues.

The third workgroup will be Workshops, which, as may be seen from Figure 11-17, is sub-divided into responsibilities as below:

- Field Equipment: point machines, signals, etc.;
- Vehicle Systems: DMI, balise reader, etc.;
- Signal Systems: computer equipment, RBTMS equipment, etc.

Approximate staffing levels for the Colombo region have been calculated for each workgroup. The signaling maintenance organization will be developed further during Detail Design Stage.

11.26.4 Maintenance During Construction and Warranty Periods

In common with standard industry practice for re-signalling projects, maintenance tasks for KV Line will be implemented by the system supplier during the warranty period; maintenance responsibility for existing / heritage systems will remain with SLR.

Maintenance activities will be organised on first, second third and fourth line basis with response times within 2 hours (local), within 24 hours (overseas), within 48 hours (workshops) and within 7 days (manufacturer). Any spare parts utilized by the supplier will be replaced at no additional cost.

During the construction period, SLR technicians would be receive appropriate training and some on-the-job experience of installation works to assist better understanding of the functioning of the new systems and equipment. In the lead-up to and then subsequent to commissioning, the supplier will lead all maintenance activities, train and mentor SLR teams throughout the warranty period. The supplier will arrange independent assessment of skills and competence levels such that appropriate licenses may be issued SLR maintenance staff on individual basis.

11.26.5 Maintenance Interface to Asset Management System

An Asset Management System (AMS) will record design, procurement and maintenance information for all railway infrastructure, systems and components, including the signalling system. Provision of AMS field workstations is proposed for OCC and signalling maintenance depots and workshops. A typical arrangement of interface devices is shown in Figure 11-20.

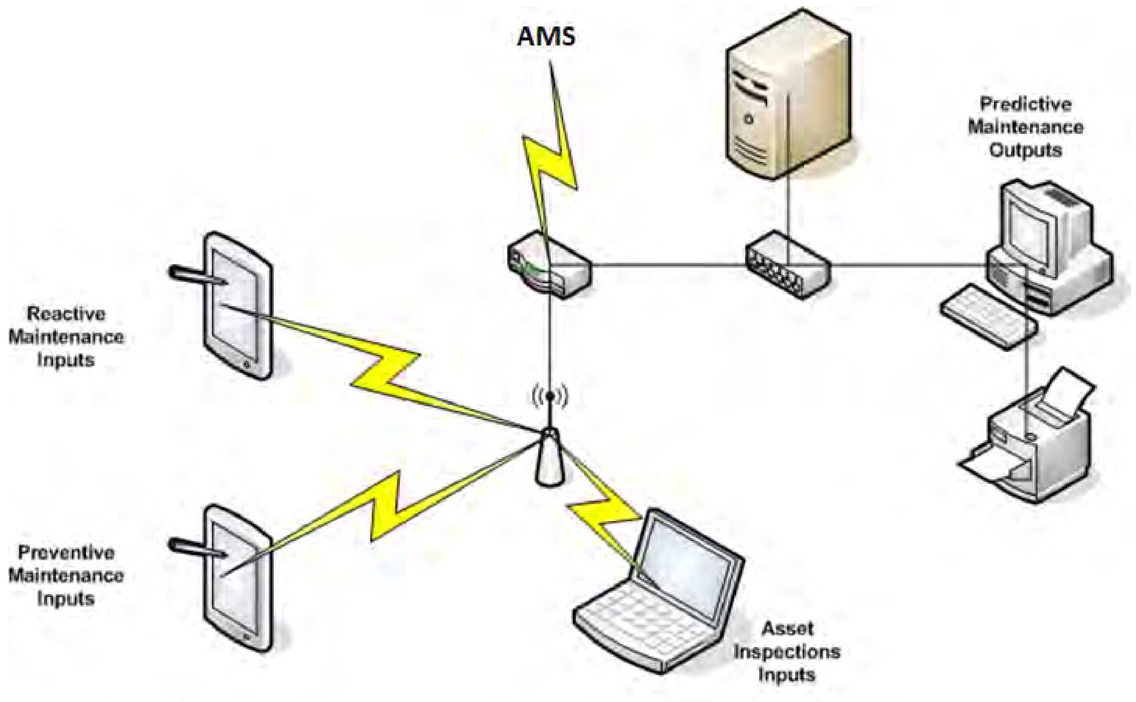


Figure 11-20 Typical Site Maintenance Interface to AMS

Maintenance staff will be able to use portable electronic hand-held terminals (tablets, smart-phones, etc.) to receive failure notifications, assistance and access to full documentation. Information available through AMS terminals will include installation instructions, testing methods and maintenance manuals. A full suite of general arrangement drawings, wiring and circuit diagrams will also be available.

First line, second line and third line trouble-shooting together with diagnostics tools and techniques will also be included in the database, which is summary form below:

- Inspection and Test Reports;
- Installation manuals;
- Operating Manuals;
- Maintenance Manuals;
- Trouble-shooting Guide;
- Failure Reports and History;
- Workshop Manuals;
- System Descriptions;
- Training Handbooks;
- Layout Diagrams;
- Circuit Diagrams;
- Specification details;
- Original Technical brochures of equipment;
- Procurement Requests.

The current system of paper forms for procurement will be replaced by the AMS. Future procurement requests may be generated at site for electronic approved by site managers / supervisors and processed for issue of purchase orders in a transparent paperless manner. Incoming inspection records, delivery of components to site, etc., will be recorded, along with refurbishment and renewal dates, version numbers and other life-cycle events for all assets.

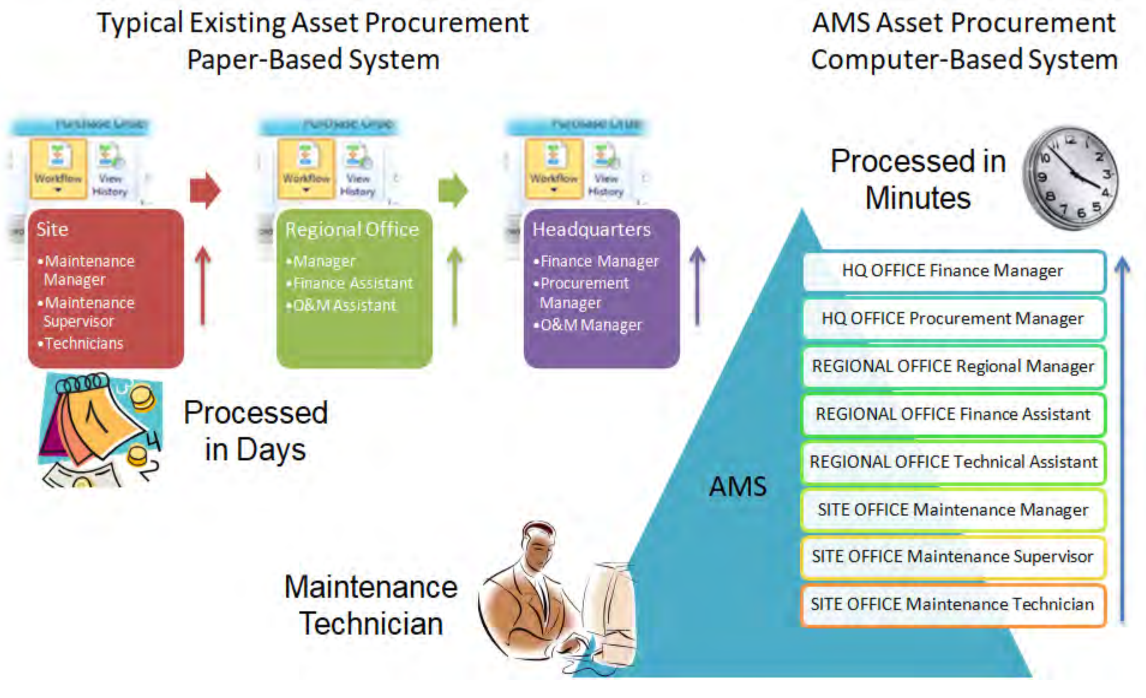


Figure 11-21 Paperless Procurement via AMS

In order for the AMS to be effective a standard format for breakdown of equipment into the basic assets, identified as the lowest level that may be procured, will be defined. Figure 11-22 is an example of an asset analysis exercise, in this instance for an electronic interlocking.

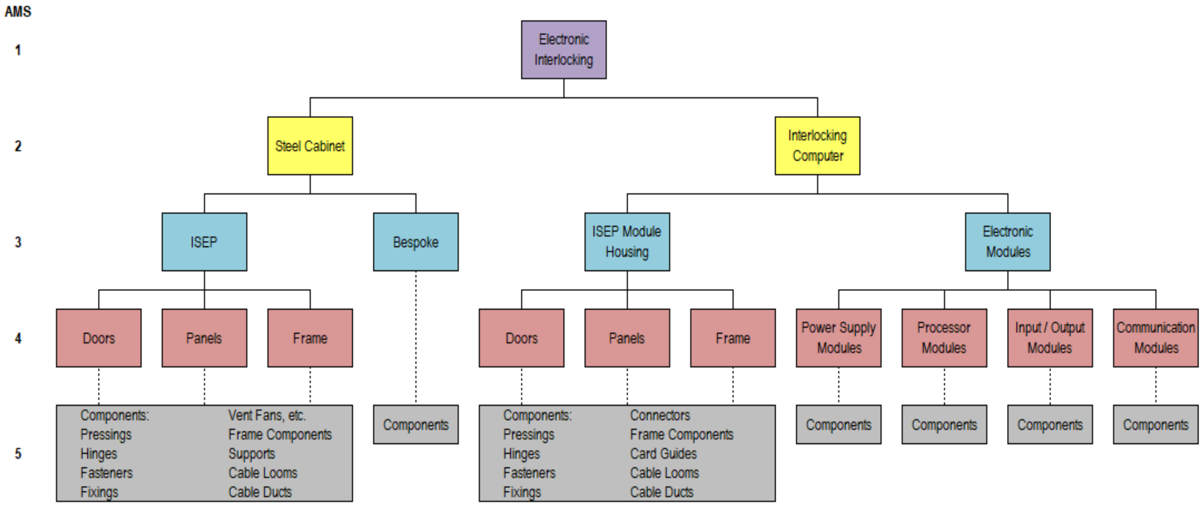


Figure 11-22 Asset Analysis for Electronic Interlocking

In the example shown, the electronic interlocking is broken down into 4 or 5 levels. The enclosures can be further broken down for some of the components, by for example, sub-dividing into electrical and mechanical components. The deepest level at which procurement would be possible could be at Level 6 or 7. Although the electronic interlocking breaks down to Level 4 with the actual modules and, individual components can potentially be procured, this may not be practical, and Level 4 would be the deepest level for procurement.

11.27 Training and Technology Transfer

11.27.1 RBTMS – A Paradigm Change

The proposed new RBTMS signalling arrangements represent a paradigm change in train operations philosophy and practice within Sri Lanka Railways. As a consequence, the level, breadth and depth of proposed training courses should reflect those changed O&M requirements.

11.27.2 Training Courses

11.27.2.1 Training courses

Training courses in the new technology should be provided by experts from the system suppliers and include new technology and other topics relevant to the following client-nominated personnel groups:

- Signal design office;
- Construction supervision;
- Signal testing and commissioning;
- Signal maintenance;
- Train operations;

- Station supervisors;
- Train crew;
- Rolling stock VOB systems maintenance.

11.27.2.2 Staff Training

Training courses will be prepared and / or adapted to the specific needs of personnel, and will be proposed as follows:

- Operator Training for Top level and middle level officers involved in the train operation;
- Maintainer Training (Equipment) for Engineers, Technical officers and Technicians;
- System Management Training for Engineers and Technical officers.

As and where appropriate, all training schemes would include some form of hands-on training to enhance the practical skills of the trainees.

11.27.3 On-the-Job Training

The various contractors, suppliers and consultancies are proposed as participants in an On-the-Job training programme throughout the Project Life Cycle. The intention of these training programmes are two-fold, firstly, to provide a solid foundation for an experienced person not only to build their future career upon but, secondly, to provide an appropriate levels of skills and technical knowledge to enable the trainee to progress both as a mentor to other experienced colleagues and, potentially to facilitate a future in training of future generations of engineers and technicians.

Much of this on-the-job training would be available to maintainers due to the contract requirements for supplier support throughout the Warranty Period, which for signalling, is normally two years.

11.27.4 Continuous Professional – and Personal – Development

The new skills and learning acquired will be wasted unless each member of staff assumes a personal and continuous responsibility for their own professional development. Development of new training facilities and methods, whilst adapting their procedures, policies and regulations to become more responsive to reasonable aspirations and requests from their teams, must be undertaken by SLR.

Adoption of new technologies will often mandate increased levels of educational attainments as a prerequisite for new appointments to technically demanding roles. Once in post, it will then be the joint responsibility of the post-holder and their SLR line managers to ensure their achievement of the requisite levels of competence, to assure the maintenance and enhancement of those competence levels throughout their professional career. Furthermore, all personnel – new and existing – would acquire, and should implement mentoring skills as a means to transfer their knowledge and experience to their peers and ultimate successors.

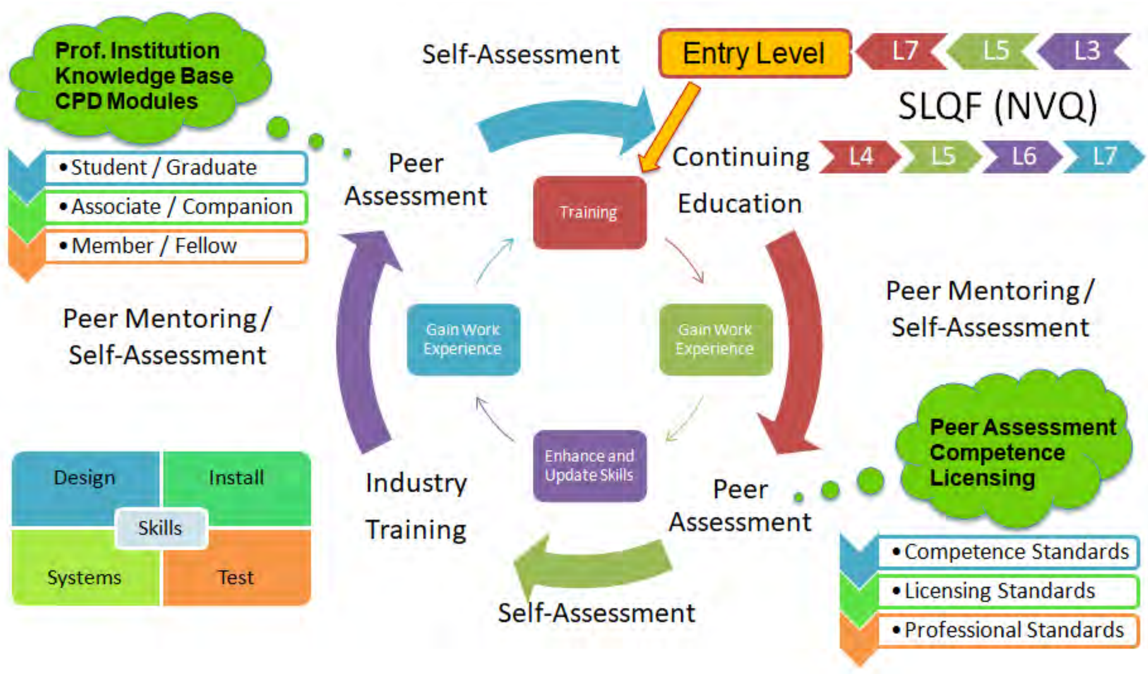


Figure 11-23 Continuous Professional Development of Education, Skills and Competence

11.28 Assessment of Risk and Delay Costs for Level Crossings

11.28.1 Scope and Purpose

The following sub-section, 11.28.2, provides a worked example for the assessment of risk and delay costs at a level crossing in the UK. These calculations performed, although including an informal, unofficial site survey, have been over-simplified by some assumptions concerning the road vehicles, drivers, passengers and their earning power. The costs of fuel for rail and road vehicles have been disregarded, as have delays to rail passengers.

Other costs disregarded include operations and maintenance costs for the level crossing at Smithy Bridge, which is CCTV supervised and equipped with an obstacle detection system. No account has been taken of the numbers of pedestrians and schoolchildren who use the crossing. The numbers of passengers who use rail services has not been researched, and consequences of their missing their chosen service due to the unexpected closure or failure to open are not considered.

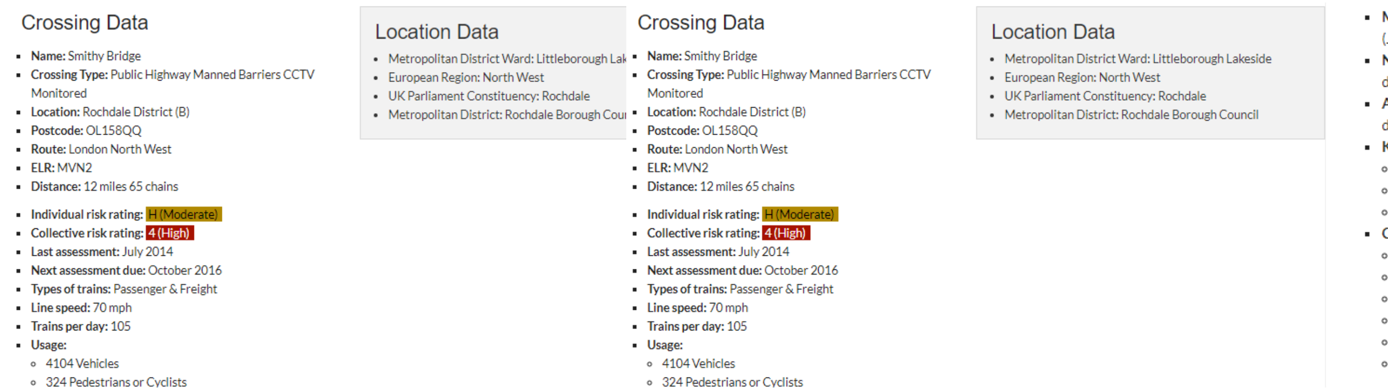
The sole purpose of these calculations is to demonstrate that even a very basic exercise can result in delay costs into six figures, whereas the true cost to the local economy must be considerably higher.

Following on from sub-section 11.28.2, sub-section 11.28.3 provides calculated results for delay times and costs at KV Line level crossings for line section Maradana (MDA) – Padukka (PDK). However, these are performed with less accuracy due to lack of detail in the survey data, which has required use of some additional assumptions concerning road vehicle data.

11.28.2 Character of the Level Crossing

Figure 11-24 Aerial View of Smithy Bridge Level Crossing (ABC, 2018)

The railway runs on embankment through Smithy Bridge station, at the eastern end of which the road of the same name crosses north-to-south on a steeply graded ascent over the railway and the adjoining Rochdale Canal. The crossing is protected by four electrically-operated barriers and with an obstacle detector system. Although considered a minor road, there are nevertheless many large and / or heavy goods vehicles into and out of the nearby Cleland McIver factory, shown in Figure 11-24, and which often cross the railway en route to the motorway. General statistics for the level crossing are shown in Figure 11-25.



Crossing Data

- **Name:** Smithy Bridge
- **Crossing Type:** Public Highway Manned Barriers CCTV Monitored
- **Location:** Rochdale District (B)
- **Postcode:** OL158QQ
- **Route:** London North West
- **ELR:** MVN2
- **Distance:** 12 miles 65 chains
- **Individual risk rating:** H (Moderate)
- **Collective risk rating:** 4 (High)
- **Last assessment:** July 2014
- **Next assessment due:** October 2016
- **Types of trains:** Passenger & Freight
- **Line speed:** 70 mph
- **Trains per day:** 105
- **Usage:**
  - 4104 Vehicles
  - 324 Pedestrians or Cyclists

Location Data

- Metropolitan District Ward: Littleborough Lakeside
- European Region: North West
- UK Parliament Constituency: Rochdale
- Metropolitan District: Rochdale Borough Council

Figure 11-25 Smithy Bridge Level Crossing Record and Statistics (ABC, 2018)

11.28.3 Risk Assessment of Level Crossing

Level crossings are the single highest risk element for any railway, anywhere in the world. The first objective must be to reject any proposals to install new at-grade level crossings. A second objective is to eliminate all existing level crossings from the network, for which purpose risk assessment and cost-benefit analysis are useful tools. A full cost-benefit analysis is not considered here, but a simple assessment of delay costs.

Table 11-10 Operations Survey Results for Smithy Bridge Level Crossing

Smithy Bridge Station Level Crossing					10:40:00 11:57:00	Off-Peak		Friday 2018-04-27	
No. Of	Audible	Train Direction & Type						Barriers	Closing Time
Trains	Alarm	Outbound	Inbound	Operator	Service		Type	Raising	00:01:00
1	10:50:00	10:52:00		Northern	Passenger	Stopping	DMU	10:52:00	00:03:00
2	11:03:00	11:04:00		Northern	Passenger	Express	DMU	11:05:00	00:03:00
3	11:06:00		11:09:00	Northern	Passenger	Express	DMU	11:09:00	00:04:00
4	11:14:00	11:17:00		Northern	Passenger	Stopping	DMU	11:17:00	00:04:00
5	11:18:00	11:20:00		Northern	Passenger	Stopping	DMU		
6			11:22:00	Northern	Passenger	Express	DMU	11:22:00	00:05:00
7	11:32:00	11:33:00		Northern	Passenger	Express	DMU		
8			11:35:00	Northern	Passenger	Stopping	DMU	11:35:00	00:04:00
9	11:38:00		11:41:00	Railfreight	Freight	Express	Loco-Haul	11:42:00	00:05:00
Record	01:17:00	Recorded Observation Times							00:28:00
%	100.00%	Observation Time -v- Total Road Closed Time							36.36%
Base	01:00:00	Base Time 1 hour						Adjusted Closed Time / hour	00:21:49

A site survey had been implemented that recorded the number of trains, number and types of road vehicles, together with opening and closing times for the crossing barriers, commencing at hearing the alarm until the barriers started to raise. The Average Daily Traffic (ADT) rate is quoted as 4104 vehicles on the data sheet in Figure 11-25.

Table 11-11 Road User Survey Results for Smithy Bridge Level Crossing

Smithy Bridge Station Level Crossing						10:40:00 11:57:00	Off-Peak			Friday 2018-04-27
Time Period	1 Pedestrians & Children	2 Pedal Cycle	3 Mobility Scooter	4 Motor Cycle	5 Car / Taxi Cat. M1	6 LGV Cat. N1	7 MGV Cat. N2	8 PCV Cat. M2/3	9 HGV Cat. N3	10 Artic-PCV Cat. M3
01:17:00	24	4	0	0	429	109	20	2	5	0
01:00:00	19	3	0	0	334	85	16	2	4	0
PCU Factor	0.10	0.20	0.20	0.40	1.00	1.00	1.50	2.00	2.30	3.20
PCUs / hour	2	1	0	0	334	85	24	4	10	0
Totals / hour	460									

During processing of the results, the actual time was adjusted to a "standard" one hour with other results also adjusted. Results of the road traffic survey, which results are somewhat under-recorded, are shown as Table 11-11.

The passenger car unit (PCU), as defined by Transport for London (TfL, 2018) was adopted to simplify the processing and calculations. Some additional vehicle types, e.g. Mobility Scooter, are added with an assessed PCU factor, in order to obtain the final PCU total of 460 PCUs per hour. These were adjusted for peak hours with an assumption of 25% additional vehicles, as shown in Table 11-12, for calculation of the Road-Rail Exposure Index (RREI).

Table 11-12 Risk Assessment Calculation for Smithy Bridge Level Crossing

Hours	Period	% Extra	Trains	Period	% Extra	PCUs	Period	% Extra	RREI
1	Base	0%	8	Base	0%	460	Base	0%	3,680
12	Off-Peak	0%	96	Off-Peak	0%	5,520	Off-Peak	0%	529,920
6	Peak	25%	60	Peak	25%	3,450	Peak	25%	207,000
18	Day	Total	156	Day	Total	8,970	Day	Total	736,920

Referring to Table 11-12, the number of trains is taken from data in Table 11-10 and PCUs from Table 11-11. One further assumption was made for hours of operation as 6 peak hours, 18 off-peak hours, and the remaining 6 night hours were disregarded. This simplification may not be valid for routes with significant train operations at night. Both values for trains and PCUs were multiplied by the number of hours to obtain values for off-peak and peak hours, with their results multiplied together to obtain RREI values for the respective time periods. Summation provided the necessary value of RREI, which at 736,920 far exceeded the 200,000 limit used by Canadian Pacific (CP Rail, 2014). This provided the first evidence to support grade separation of road and rail.

11.28.4 Assessment of Delay Costs for Level Crossings

There are four elements that taken together comprise the costs of delays caused by level crossings, which are as follows:

- Costs of delays to road vehicles (family, passenger, freight, utility);
- Costs of delays to drivers and passengers of those vehicles, including cyclists and pedestrians;
- Costs of delays to trains (passenger, freight, locomotive, special, O&M;
- Costs of delays to rail passengers.

This analysis considers only delays to the first two categories – road users; delays to rail users are not considered here, but could be assessed in a similar manner. Survey results have provided appropriate numbers for road vehicles; however, no vehicle occupancy details were recorded and assumptions had been necessary. These considered most cars as only one occupant – the driver – but taxis at least two, suggesting 1.5 persons as a suitable compromise, with two during peak hours. Public buses may carry few passengers (abbreviated as PAX) off-peak, but may be full during peak hours. The assumptions made are shown in Table 11-13.

Table 11-13 Assessment of Delay Costs for Smithy Bridge Level Crossing

Hours	Period	Delay min	Delay hr	PCUs	Delay hr	Delay day	Rate / day	Day - Cost ($) - Year	
1	Base	4	0.07	168	11	0.47	150	70	25,550
12	Off-Peak	48	0.80	2,016	1,613	67.20	150	10,080	3,679,200
6	Peak	60	1.00	1,260	1,260	52.50	150	10,150	3,704,750
18	Day	108	1.80	3,276	2,873	119.70	150	20,230	7,383,950

Table 11-14 Assessment of Delay Costs for Smithy Bridge Level Crossing

Smithy Bridge Station Level Crossing					10:40:00 11:57:00	Off-Peak			Friday 2018-04-27	
Time Period	1 Pedestrians & Children	2 Pedal Cycle	3 Mobility Scooter	4 Motor Cycle	5 Car / Taxi Cat. M1	6 LGV Cat. N1	7 MGV Cat. N2	8 PCV Cat. M2/3	9 HGV Cat. N3	10 Artic-PCV Cat. M3
01:17:00	24	4	0	0	429	109	20	2	5	0
01:00:00	19	3	0	0	334	85	16	2	4	0
PCU Factor	0.10	0.20	0.20	0.40	1.00	1.00	1.50	2.00	2.30	3.20
PCUs / hour	2	1	0	0	334	85	24	4	10	0
Total PCUs / hour	460									
Occupancy	1	1	1	1	1.5	2	2	20	2	2
Total PAX	19	3	0	0	501	170	32	40	8	0
Total PAX /hr Off-Pk	773									
Peak Factor	2	2	2	10	2	1.25	1.25	50	1.25	1.25
Occupancy	38	6	0	0	668	107	20	100	5	0
Total PAX /hr Peak	944									
Total PAX / day	456	72	0	0	10,020	2,682	504	1,080	126	0
Total Persons /day	14,940									
Delay Costs	PAX / hr	PAX / day	PAX-Delay	Delay min	Delay hr	Delay day	Rate / hr	Day - Cost ($) - Year		
Off-Peak	773	9,276	3,373	0.80	2,698	112.44	$160	17,990	6,566,284	
Peak	944	5,664	2,060	1.00	2,060	85.82	$160	13,731	5,011,782	
Totals / day	1,717	14,940	5,433	1.80	4,758	198.25	$320	31,721	11,578,065	

The average duration of closure of the level crossing, calculated from Table 11-10, was 4 minutes, and is assumed constant throughout the day, although it may vary, for example, when two trains pass at or near the level crossing. Off-peak and peak hour rates were calculated for the delay times, trains and PCUs. The product of delay times and PCUs (converted to days), provided the total delay times that multiplied by the rate for local car hire (LKR20,000 ≈ $150) resulted in total delay costs for road-users. A more accurate calculation would consider the value of the service provided by each vehicle (value of freight carried, etc.), but that is not considered here. The costs for delays incurred by drivers, their passengers and pedestrians are as calculated, and shown, in Table 11-14.

These calculations are basically similar to those for road-user vehicles and need no further discussion.

Headline results are summarized below.

From Table 11-13:	Delay Costs for road users (vehicles):	$7,383, 950 per year
From Table 11-14:	Delay Costs for passengers (PAX):	$11,578,065 per year
Total Delay Costs for Road Users & Passengers:		$18,962,015 per year

11.29 Assessment of Risk and Delay Costs for KV Line Level Crossings

This section considers the assessment of risk and delay costs for KV Line level crossings, although the availability of data was not as detailed as that provided for the UK example. Data provided for these level crossings was limited to Average Daily Traffic (ADT), from which assumptions were made to derive values for Peak and Off-Peak levels.

A further assumption is that the ADT number equated to PCUs, as defined in the previous section. Data was available for a substantial number of level crossings in the Maradana – Padukka, but not for the Padukka – Avissawella section, which is perforce excluded from the delay cost calculations. Peak and Off-Peak values for ADT / PCU and RREI are listed in Table 11-15.

Table 11-15 Assessment of Risk (RREI) Factors for KV Line Level Crossings (MDA-PDK)

Stn.	Route Section Name	LC	Location (km.m)			Map	Survey Data	ADT	Peak	6 hours	Off-Peak	12 hours	RREI	Proposed LC
Ref.	Level Crossing Name (SLR)	Ref.	Existing	Design	Survey	Ref.	Road Name	2017	Rail	Road	Rail	Road	200,000	Protection
1	Dematagoda		1.270	1.240	1.240	1	Dematagoda Rd	33,834	56	13,195	32	20,639	1,399,380	Grade Separate
2	Baseline Road		1.720	1.720	1.700	2	Baseline Rd	83,895	56	32,719	32	51,176	3,469,904	Grade Separate
3	Sri Nigrodharama Road		1.920	1.880	1.900	3	Sri Nigrodharama Mw	12,544	56	4,892	31	7,652	511,176	Grade Separate
4	Serpentine Road		2.830	2.810	2.827	5	Leslie Rangala Mw	23,916	56	9,327	31	14,589	974,591	Grade Separate
5	Unidentified		3.390	3.380	3.360	6	Ruhunukala Mw	8,168	56	3,186	31	4,983	332,858	Grade Separate
6	Cotta Road		3.550	3.550	3.550	7	Cotta Rd	88,867	54	34,658	32	54,209	3,606,217	Grade Separate
7	Castle Street		3.820	3.800	3.800	8	Sri Jayawardenapura Mw	19,895	54	7,759	32	12,136	807,357	Grade Separate
8	Narahenpita Station Road		5.490	5.470	5.490	13	Muhandiram Rd	19,895	54	7,759	32	12,136	807,357	Grade Separate
9	Kirimandala Road		5.830	5.810	5.820	14	Kirimandala Mw	18,503	57	7,216	30	11,287	749,943	Grade Separate
10	Nawala Road		6.110	6.100	6.110	15	Narahenpita Nawala Rd	30,203	57	11,779	30	18,424	1,224,126	Grade Separate
11	Kirillapone Station Road		7.360	7.345	7.350	18	D.M. Colombage Mw	18,027	56	7,030	32	10,996	745,587	Grade Separate
12	Stanley Tilakarathna Road		8.980	8.960	8.950	22	B120 at Nugegoda	49,701	56	19,384	32	30,318	2,055,648	Grade Separate
13	Old Kesbewa Road		9.280	9.260	9.270	23	Old Kespbewa	28,390	56	11,072	31	17,318	1,156,906	Grade Separate
14	Kattiya Junction		9.940	9.920	9.930	24	Mirihana Rd	25,004	56	9,752	31	15,252	1,018,911	Grade Separate
15	KVL 16		13.370	13.350	13.370	31	Old Kottawa Rd	26,233	58	10,231	30	16,002	1,073,453	Grade Separate
16	Pamunuwa Road		14.470	14.450	14.470	33	Pamunuwa Rd	17,378	57	1,130	30	16,248	551,836	Grade Separate
17	Hokandara Road		17.510	17.480	17.520	41	Pannipitiya Malabe Rd	14,519	57	944	36	13,575	542,510	Grade Separate
18	Athurugiriya Road		19.400	19.370	19.400	46	Athurugiriya Rd	26,918	57	1,750	36	25,169	1,005,804	Grade Separate
19	Makumbura Road		19.930	19.910	19.930	47	Kottawa Malabe Rd	8,049	55	523	33	7,526	277,133	Grade Separate
20	Pinketha Road	54	23.420	23.380	23.420	52	Galawila Rd	10,759	26	699	19	10,059	209,311	Grade Separate
21	Unidentified		23.890	23.825	24.460	57	Athurugiriya Rd 2	20,141	26	1,309	19	18,832	391,842	Grade Separate
22	Wilmana Road	58	25.010	24.910	25.010	58	Wimana Rd	3,468	27	1,352	17	2,115	72,480	AOLC
23	Panagoda Station Road	59	26.220		26.330	59	Panagoda Station Rd	4,391	26	1,713	17	2,679	90,069	EOB-OD
24	Godagama Watta Road	60	27.360		27.360	60	Godagamagewatta Rd	1,491	26	582	17	910	30,587	AOLC
25	Godagama Watta Station Road	61	28.050	27.900	28.050	61	Godagama Station Rd,	1,454	26	567	17	887	29,813	AOLC
26	Unidentified	62	28.530	28.380	28.530	62	Level Crossing C3	117	26	46	17	71	2,400	PSR
27	Unidentified		28.720	28.570	28.720	63	Samadhi Mw	39	26	15	17	24	807	PSR
28	Palpola Watta Road	64	28.790	28.640	28.790	64	Palpolawatta Rd	1,364	26	532	17	832	27,983	AOLC
29	Asiri Uyana	65	28.985	28.840	28.980	65	Asiri Uyana Rd	319	26	124	17	195	6,541	PSR
30	Puwakwatta Road	66	29.070	28.910	29.060	66	Puwakwatta Rd	7,407	26	2,889	17	4,518	151,911	EOB-OD
31	Meegoda Station	67	29.580	29.430	29.600	67	Meegoda Station	8,618	26	3,361	17	5,257	176,763	EOB-OD
32	Udagewathta Road	68	30.300	30.130	30.300	68	Udagewatte Rd	2,032	25	792	17	1,239	40,876	AOLC
33	Madulawa Road	69	30.790	30.630	30.820	69	Madulawa Rd	5,482	25	2,138	17	3,344	110,306	EOB-OD
34	Opathella Road	70	31.850	31.700	31.850	70	Opathaella Rd	1,722	25	671	18	1,050	35,691	AOLC
35	Kurugala Road	71	33.630	33.470	33.630	71	Kurugala Rd	2,546	25	993	17	1,553	51,217	AOLC
36	Unidentified		34.440	34.220	34.440	72	Level Crossing C4	No Data	25	No Data	17	No Data	No Data	No Data
37	Unidentified		34.660	34.440	34.660	73	Polwatta Rd C1	No Data	25	No Data	17	No Data	No Data	No Data
38	Polwatta Road	74	34.750	34.530	34.750	74	Polwatta Rd C2	1,816	25	708	17	1,108	36,543	AOLC
39	Padukka Hospital Road	75	34.900	34.670	34.900	75	Padukka Road	11,165	25	4,354	17	6,811	224,642	Grade Separate

In order to calculate delay costs, similar assumptions were made to those in the previous section, but, with delay times of 3 and 4 minutes for road users and, a delay cost of $150 per day for vehicles – based on local published rates for hire of a passenger car (PCU). No attempt has been made to include passengers or drivers in any road vehicles for the reason that a breakdown of vehicle types was not available for any level crossing; in addition, the numbers of pedestrians, cyclists and animal-powered vehicles, etc., who may have experienced some delay have not been considered. The calculations for delay costs have been tabulated in Tables 11-16 (summary totals), 11-17 (sub-totals for peak periods) and 11-18 (sub-totals for off-peak).

The calculations performed in the tables that follow are, for reasons detailed above, not intended to be a definitive manner for calculations nor represent the actual cumulative delay times nor actual delay costs. These are compiled to assist in understanding one option for financial assessments of the impact of level crossings on the wider community, thereby facilitating decisions in principle.

Table 11-16 Assessment of Delay Costs for KV Line Level Crossings (MDA-PDK)

Line No.	Route Section Name / Level Crossing Name (SLR)	LC Ref.	Map Ref.	Survey Data / Road Name	ADT (PCUs) 2017	Estimated Costs for 3 minute Delay				Estimated Costs for 4 minute Delay			
						Daily Total Delay (min)	Road User Delay Costs ($)			Cumulative Delay (min)	Road User Delay Costs ($)		
							Day (18 h)	Month (30 d)	Year (365 d)		Day (18 h)	Month (30 d)	Year (365 d)
Start	Elevated Section												
1	Dematagoda		1	Dematagoda Rd	33,534	1,295,736	6,013	180,380	2,194,623	2,305,672	10,688	320,649	3,901,225
2	Baseline Road		2	Baseline Rd	83,895	3,220,200	14,905	447,250	5,441,542	5,724,960	26,504	795,133	9,674,122
3	Sri Nigrodharama Road		3	Sri Nigrodharama Mw	12,544	475,425	2,201	66,032	803,385	845,288	3,913	117,401	1,428,380
4	Serpentine Road		5	Leslie Rangala Mw	23,916	906,516	4,197	125,905	1,531,844	1,611,705	7,462	223,845	2,723,488
5	Unidentified		6	Ruhunukala Mw	8,168	309,705	1,434	43,015	523,349	550,360	2,548	76,439	930,006
6	Cotta Road		7	Cotta Rd	88,867	3,220,440	14,909	447,283	5,441,947	5,725,256	26,506	795,174	9,674,622
7	Castle Street		8	Sri Jayawardenapura Mw	19,695	721,032	3,338	100,143	1,218,411	1,281,920	5,935	178,044	2,166,207
8	Narahenpita Station Road		13	Muhandiram Rd	19,695	721,032	3,338	100,143	1,218,411	1,281,920	5,935	178,044	2,166,207
9	Kirimandala Road		14	Kirimandala Mw	18,503	713,175	3,302	99,053	1,205,139	1,267,880	5,869	176,067	2,142,144
10	Nawala Road		15	Narahenpita Nawala Rd	30,203	1,164,015	5,389	161,669	1,966,970	2,069,400	9,581	287,417	3,496,903
11	Kirillapone Station Road		18	D.M. Colombage Mw	18,027	691,944	3,203	96,103	1,169,257	1,230,016	5,695	170,836	2,078,499
12	Stanley Tilakarathna Road		22	B120 at Nugegoda	49,701	1,907,760	8,832	264,967	3,223,761	3,391,584	15,702	471,053	5,731,149
13	Old Kesbewa Road		23	Old Kespbewa	28,390	1,076,097	4,982	149,458	1,818,405	1,913,028	8,857	265,698	3,232,663
14	Kattiya Junction		24	Mirihana Rd	25,004	947,778	4,388	131,636	1,601,569	1,684,960	7,801	234,025	2,847,304
15	KVL 16		31	Old Kottawa Rd	26,233	1,040,430	4,817	144,504	1,758,134	1,849,616	8,563	256,891	3,125,509
16	Pamunuwa Road		33	Pamunuwa Rd	17,378	274,617	1,271	38,141	464,052	487,980	2,259	67,775	824,596
End Elevated Section					504,456	18,688,911	86,523	2,595,682	31,580,799	33,224,368	153,817	4,614,496	56,143,029
Start At-Grade Section													
17	Unidentified			# Road User Data (RUD) Not Available	-	-	-	-	-	-	-	-	-
18	Borella Road				-	-	-	-	-	-	-	-	-
End At-Grade Section					-	-	-	-	-	-	-	-	-
Start Elevated Section													
19	Hokandara Road		41	Pannipitiya Malabe Rd	14,519	296,496	1,373	41,180	501,023	527,304	2,441	73,237	891,046
20	Athurugiriya Road		46	Athurugiriya Rd	26,918	549,801	2,545	76,361	929,062	977,520	4,526	135,767	1,651,828
End Elevated Section					41,438	846,297	3,918	117,541	1,430,085	1,504,824	6,967	209,003	2,542,874
Start At-Grade Section													
21	Makumbura Road		47	Kottawa Malabe Rd	8,049	142,065	658	19,731	240,064	252,560	1,169	35,078	426,780
22	Pinketha Road	54	52	Galawila Rd	10,759	57,228	265	7,948	96,705	101,720	471	14,128	171,888
23	Unidentified		57	Athurugiriya Rd 2	20,141	107,139	496	14,880	181,045	190,400	881	26,444	321,741
24	Wimana Road	58	58	Wimana Rd	3,468	32,274	149	4,483	54,537	57,448	266	7,979	97,076
25	Panagoda Station Road	59	59	Panagoda Station Rd	4,391	38,628	179	5,365	65,274	68,684	318	9,539	116,063
26	Godagama Watta Road	60	60	Godagamagewatta Rd	1,491	13,092	61	1,818	22,123	23,320	108	3,239	39,406
27	Godagama Watta Station Road	61	61	Godagama Station Rd,	1,454	12,807	59	1,779	21,641	22,768	105	3,162	38,474
28	Unidentified	62	62	Level Crossing C3	117	1,035	5	144	1,749	1,828	8	254	3,089
29	Unidentified		63	Samadhi Mw	39	336	2	47	568	552	3	77	933
30	Palpola Watta Road	64	64	Palpolawatta Rd	1,364	11,979	55	1,664	20,242	21,388	99	2,971	36,142
31	Asiri Uyana	65	65	Asiri Uyana Rd	319	2,820	13	392	4,765	4,968	23	690	8,395
32	Puwakwatta Road	66	66	Puwakwatta Rd	7,407	65,148	302	9,048	110,088	115,772	536	16,079	195,633
33	Meegoda Station	67	67	Meegoda Station	8,618	75,756	351	10,522	128,014	134,780	624	18,719	227,753
34	Udagewathta Road	68	68	Udagewatte Rd	2,032	16,863	78	2,342	28,495	29,956	139	4,161	50,620
35	Madulawa Road	69	69	Madulawa Rd	5,462	45,462	210	6,314	76,822	80,888	374	11,234	136,686
36	Opathella Road	70	70	Opathaella Rd	1,722	14,766	68	2,051	24,952	26,260	122	3,647	44,375
37	Kurugala Road	71	71	Kurugala Rd	2,546	21,135	98	2,935	35,714	37,596	174	5,222	63,530
38	Unidentified		72	Level Crossing C4 #RUD N/A	-	-	-	-	-	-	-	-	-
39	Unidentified		73	Polwatta Rd C1 # RUD N/A	-	-	-	-	-	-	-	-	-
40	Polwatta Road	74	74	Polwatta Rd C2	1,816	15,078	70	2,094	25,479	26,840	124	3,728	45,355
41	Padukka Hospital Road	75	75	Padukka Road	11,165	92,607	429	12,862	156,459	164,724	763	22,878	278,353
End At-Grade Section					92,381	768,218	3,547	106,419	1,294,767	1,362,452	6,308	189,229	2,302,292

Table 11-17 Assessment of Peak Delays for KV Line Level Crossings (MDA-PDK)

Line No.	Route Section Name Level Crossing Name (SLR)	LC Ref.	Map Ref.	Survey Data Road Name	ADT (PCUs)	Estimated Cumulative Delays – Peak Period – 6 hours (360 minutes)									
						Off-Peak Vehicles		LC Closed – 3 Min		Road Vehicle Delays		LC Closed – 4 Min		Road Vehicle DelayK	
Start	Elevated Section				2017	Rail	Road	Minutes	% Pk Min	PCU	Min day^-1	Minutes	% Pk Min	PCU	Min day^-1
1	Dematagoda		1	Dematagoda Rd	33,534	56	13,195	168	46.67%	6,158	1,034,544	224	62.22%	8,210	1,839,040
2	Baseline Road		2	Baseline Rd	83,895	56	32,719	168	46.67%	15,269	2,565,192	224	62.22%	20,359	4,560,416
3	Sri Nigrodharama Road		3	Sri Nigrodharama Mw	12,544	56	4,892	168	46.67%	2,283	383,544	224	62.22%	3,044	681,856
4	Serpentine Road		5	Leslie Rangala Mw	23,916	56	9,327	168	46.67%	4,353	731,304	224	62.22%	5,804	1,300,096
5	Unidentified		6	Ruhunukala Mw	8,168	56	3,186	168	46.67%	1,487	249,816	224	62.22%	1,982	443,968
6	Cotta Road		7	Cotta Rd	88,867	54	34,658	162	45.00%	15,596	2,526,552	216	60.00%	20,795	4,491,720
7	Castle Street		8	Sri Jayawardenapura Mw	19,895	54	7,759	162	45.00%	3,492	565,704	216	60.00%	4,656	1,005,696
8	Narahenpita Station Road		13	Muhandiram Rd	19,895	54	7,759	162	45.00%	3,492	565,704	216	60.00%	4,656	1,005,696
9	Kirimandala Road		14	Kirimandala Mw	18,503	57	7,216	171	47.50%	3,428	586,188	228	63.33%	4,570	1,041,960
10	Nawala Road		15	Narahenpita Nawala Rd	30,203	57	11,779	171	47.50%	5,595	956,745	228	63.33%	7,460	1,700,880
11	Kirillapone Station Road		18	D.M. Colombage Mw	18,027	56	7,030	168	46.67%	3,281	551,208	224	62.22%	4,374	979,776
12	Stanley Tilakarathna Road		22	B120 at Nugegoda	49,701	56	19,384	168	46.67%	9,046	1,519,728	224	62.22%	12,061	2,701,664
13	Old Kesbewa Road		23	Old Kespbewa	28,390	56	11,072	168	46.67%	5,167	868,056	224	62.22%	6,889	1,543,136
14	Kattiya Junction		24	Mirihana Rd	25,004	56	9,752	168	46.67%	4,551	764,568	224	62.22%	6,068	1,359,232
15	KVL 16		31	Old Kottawa Rd	26,233	58	10,231	174	48.33%	4,945	860,430	232	64.44%	6,593	1,529,576
16	Pamunuwa Road		33	Pamunuwa Rd	17,378	57	1,130	171	47.50%	537	91,827	228	63.33%	715	163,020
End	Elevated Section				504,456	895	191,090	2,685		88,680	14,821,110	3,580		118,236	26,347,732
Start	At-Grade Section														
17	Unidentified			# Road User Data (RUD) Not Available	-	57	-	171	47.50%	-	-	228	63.33%	-	-
18	Borella Road				-	57	-	171	47.50%	-	-	228	63.33%	-	-
End	At-Grade Section				-	114	-	342		-	-	456		-	-
Start	Elevated Section														
19	Hokandara Road		41	Pannipitiya Malabe Rd	14,519	57	944	171	47.50%	448	76,608	228	63.33%	598	136,344
20	Athurugiriya Road		46	Athurugiriya Rd	26,918	57	1,750	171	47.50%	831	142,101	228	63.33%	1,108	252,624
End	Elevated Section				41,438	114	2,693	342		1,279	218,709	456		1,706	388,968
Start	At-Grade Section														
21	Makumbura Road		47	Kottawa Malabe Rd	8,049	55	523	165	45.83%	240	39,600	220	61.11%	320	70,400
22	Pinketha Road	54	52	Galawila Rd	10,758	26	699	78	21.67%	152	11,856	104	28.89%	202	21,008
23	Unidentified		57	Athurugiriya Rd 2	20,141	26	1,309	78	21.67%	284	22,152	104	28.89%	378	39,312
24	Wimana Road	58	58	Wimana Rd	3,468	27	1,352	81	22.50%	304	24,624	108	30.00%	406	43,848
25	Panagoda Station Road	59	59	Panagoda Station Rd	4,391	26	1,713	78	21.67%	371	28,938	104	28.89%	495	51,480
26	Godagama Watta Road	60	60	Godagamagewatta Rd	1,491	26	582	78	21.67%	126	9,828	104	28.89%	168	17,472
27	Godagama Watta Station Road	61	61	Godagama Station Rd.	1,454	26	567	78	21.67%	123	9,594	104	28.89%	164	17,056
28	Unidentified	62	62	Level Crossing C3	117	26	46	78	21.67%	10	780	104	28.89%	13	1,352
29	Unidentified		63	Samadhi Mw	39	26	15	78	21.67%	3	234	104	28.89%	4	416
30	Palpola Watta Road	64	64	Palpolawatta Rd	1,364	26	532	78	21.67%	115	8,970	104	28.89%	154	16,016
31	Asiri Uyana	65	65	Asiri Uyana Rd	319	26	124	78	21.67%	27	2,106	104	28.89%	36	3,744
32	Puwakwatta Road	66	66	Puwakwatta Rd	7,407	26	2,889	78	21.67%	626	48,828	104	28.89%	834	86,736
33	Meegoda Station	67	67	Meegoda Station	8,618	26	3,361	78	21.67%	728	56,784	104	28.89%	971	100,984
34	Udagewathta Road	68	68	Udagewatte Rd	2,032	25	792	75	20.83%	165	12,375	100	27.78%	220	22,000
35	Madulawa Road	69	69	Madulawa Rd	5,482	25	2,138	75	20.83%	445	33,375	100	27.78%	594	59,400
36	Opathella Road	70	70	Opathaella Rd	1,722	25	671	75	20.83%	140	10,500	100	27.78%	187	18,700
37	Kurugala Road	71	71	Kurugala Rd	2,546	25	993	75	20.83%	207	15,525	100	27.78%	276	27,600
38	Unidentified		72	Level Crossing C4 #RUD N/A	-	25	-	75	20.83%	-	-	100	27.78%	-	-
39	Unidentified		73	Polwatta Rd C1 # RUD N/A	-	25	-	75	20.83%	-	-	100	27.78%	-	-
40	Polwatta Road	74	74	Polwatta Rd C2	1,816	25	708	75	20.83%	148	11,100	100	27.78%	197	19,700
41	Padukka Hospital Road	75	75	Padukka Road	11,165	25	4,354	75	20.83%	907	68,025	100	27.78%	1,210	121,000
End	At-Grade Section				92,381	568	23,370	1,704		5,121	415,194	2,272		6,829	738,224

Table 11-18 Assessment of Off-Peak Delays for KV Line Level Crossings (MDA-PDK)

Line No.	Route Section Name / Level Crossing Name (SLR)	LC Ref.	Map Ref.	Survey Data / Road Name	ADT (PCUs) 2017	Estimated Cumulative Delays – Off-Peak Period – 12 hours (720 minutes): Off-Peak Vehicles: Rail	Off-Peak Vehicles: Road	LC Closed – 3 Min: Minutes	LC Closed – 3 Min: % Pk Min	Road Vehicle Delays: PCU	Road Vehicle Delays: Min day^-1	LC Closed – 4 Min: Minutes	LC Closed – 4 Min: % Pk Min	Road Vehicle DelayK: PCU	Road Vehicle DelayK: Min day^-1
Start Elevated Section															
1	Dematagoda		1	Dematagoda Rd	33,534	32	20,639	96	13.33%	2,752	264,192	128	17.78%	3,669	469,632
2	Baseline Road		2	Baseline Rd	53,895	32	51,176	96	13.33%	6,823	655,008	128	17.78%	9,098	1,164,544
3	Sri Nigrodharama Road		3	Sri Nigrodharama Mw	12,544	31	7,652	93	12.92%	988	91,884	124	17.22%	1,318	163,432
4	Serpentine Road		5	Leslie Rangala Mw	23,916	31	14,589	93	12.92%	1,884	175,212	124	17.22%	2,513	311,612
5	Unidentified		6	Ruhunukala Mw	8,168	31	4,983	93	12.92%	644	59,892	124	17.22%	858	106,392
6	Cotta Road		7	Cotta Rd	88,867	32	54,209	96	13.33%	7,228	693,888	128	17.78%	9,637	1,233,536
7	Castle Street		8	Sri Jayawardenapura Mw	19,895	32	12,136	96	13.33%	1,618	155,328	128	17.78%	2,158	276,224
8	Narahenpita Station Road		13	Muhandiram Rd	19,895	32	12,136	96	13.33%	1,618	155,328	128	17.78%	2,158	276,224
9	Kirimandala Road		14	Kirimandala Mw	18,503	30	11,287	90	12.50%	1,411	126,990	120	16.67%	1,881	225,720
10	Nawala Road		15	Narahenpita Nawala Rd	30,203	30	18,424	90	12.50%	2,303	207,270	120	16.67%	3,071	368,520
11	Kirillapone Station Road		18	D.M. Colombage Mw	18,027	32	10,996	96	13.33%	1,466	140,736	128	17.78%	1,955	250,240
12	Stanley Tilakarathna Road		22	B120 at Nugegoda	49,701	32	30,318	96	13.33%	4,042	388,032	128	17.78%	5,390	689,920
13	Old Kesbewa Road		23	Old Kespbewa	28,390	31	17,318	93	12.92%	2,237	208,041	124	17.22%	2,983	369,892
14	Kattiya Junction		24	Mirihana Rd	25,004	31	15,252	93	12.92%	1,970	183,210	124	17.22%	2,627	325,748
15	KVL 16		31	Old Kottawa Rd	26,233	30	16,002	90	12.50%	2,000	180,000	120	16.67%	2,667	320,040
16	Pamunuwa Road		33	Pamunuwa Rd	17,378	30	16,245	90	12.50%	2,031	182,790	120	16.67%	2,708	324,960
End Elevated Section					504,456	499	313,366	1,497		41,015	3,867,891	1,996		54,691	6,876,636
Start At-Grade Section															
17	Unidentified			# Road User Data (RUD) Not Available	-	31	-	93	12.92%	-	-	124	17.22%	-	-
18	Borella Road				-	36	-	108	15.00%	-	-	144	20.00%	-	-
End At-Grade Section					-	67	-	201		-	-	268		-	-
Start Elevated Section															
19	Hokandara Road		41	Pannipitiya Malabe Rd	14,519	36	13,575	108	15.00%	2,036	219,888	144	20.00%	2,715	390,960
20	Athurugiriya Road		46	Athurugiriya Rd	26,918	36	25,169	108	15.00%	3,775	407,700	144	20.00%	5,034	724,896
End Elevated Section					41,438	72	38,744	216		5,811	627,588	288		7,749	1,115,856
Start At-Grade Section															
21	Makumbura Road		47	Kottawa Malabe Rd	8,049	33	7,526	99	13.75%	1,035	102,465	132	18.33%	1,380	182,160
22	Pinketha Road	54	52	Galawila Rd	10,759	19	10,059	57	7.92%	796	45,372	76	10.56%	1,062	80,712
23	Unidentified		57	Athurugiriya Rd 2	20,141	19	18,832	57	7.92%	1,491	84,987	76	10.56%	1,988	151,088
24	Wilmana Road	58	58	Wimana Rd	3,468	17	2,115	51	7.08%	150	7,650	68	9.44%	200	13,600
25	Panagoda Station Road	59	59	Panagoda Station Rd	4,391	17	2,679	51	7.08%	190	9,690	68	9.44%	253	17,204
26	Godagama Watta Road	60	60	Godagamagewatta Rd	1,491	17	910	51	7.08%	64	3,264	68	9.44%	86	5,848
27	Godagama Watta Station Road	61	61	Godagama Station Rd,	1,454	17	887	51	7.08%	63	3,213	68	9.44%	84	5,712
28	Unidentified	62	62	Level Crossing C3	117	17	71	51	7.08%	5	255	68	9.44%	7	476
29	Unidentified		63	Samadhi Mw	39	17	24	51	7.08%	2	102	68	9.44%	2	136
30	Palpola Watta Road	64	64	Palpolawatta Rd	1,364	17	832	51	7.08%	59	3,009	68	9.44%	79	5,372
31	Asiri Uyana	65	65	Asiri Uyana Rd	319	17	195	51	7.08%	14	714	68	9.44%	18	1,224
32	Puwakwatta Road	66	66	Puwakwatta Rd	7,407	17	4,518	51	7.08%	320	16,320	68	9.44%	427	29,036
33	Meegoda Station	67	67	Meegoda Station	8,618	17	5,257	51	7.08%	372	18,972	68	9.44%	497	33,796
34	Udagewathta Road	68	68	Udagewatte Rd	2,032	17	1,239	51	7.08%	88	4,488	68	9.44%	117	7,956
35	Madulawa Road	69	69	Madulawa Rd	5,482	17	3,344	51	7.08%	237	12,087	68	9.44%	316	21,488
36	Opathella Road	70	70	Opathaella Rd	1,722	18	1,050	54	7.50%	79	4,266	72	10.00%	105	7,560
37	Kurugala Road	71	71	Kurugala Rd	2,546	17	1,553	51	7.08%	110	5,610	68	9.44%	147	9,996
38	Unidentified		72	Level Crossing C4 #RUD N/A	-	17	-	51	7.08%	-	-	68	9.44%	-	-
39	Unidentified		73	Polwatta Rd C1 # RUD N/A	-	17	-	51	7.08%	-	-	68	9.44%	-	-
40	Polwatta Road	74	74	Polwatta Rd C2	1,816	17	1,108	51	7.08%	78	3,978	68	9.44%	105	7,140
41	Padukka Hospital Road	75	75	Padukka Road	11,165	17	6,811	51	7.08%	482	24,582	68	9.44%	643	43,724
End At-Grade Section					92,381	378	69,011	1,134		5,635	351,024	1,512		7,516	624,228

Headline results are summarized below.

For Elevated Section: (From Table 11-16)	Estimated 3 minute Delay Costs for road users	$31,580,799	per year
	Estimated 4 minute Delay Costs for road users	$56,143,029	per year

For Elevated Section: (From Table 11-16)	Estimated 3 minute Delay Costs for road users	$31,580,799	per year
	Estimated 4 minute Delay Costs for road users	$56,143,029	per year

For Elevated Section: (From Table 11-16)	Estimated 3 minute Delay Costs for road users	$31,580,799	per year
	Estimated 4 minute Delay Costs for road users	$56,143,029	per year

11.30 References

Many of the sketches contained in this chapter have been prepared by signal engineering experts of the Joint Venture Study Team; the remainder has been sourced from technical publications.

Where the latter has been the case, each instance has been cited and full details of the reference sources are listed in the following table.

Table 11-19 Full Details of the Reference Sources

Reference		Source
ABC 2018	Fig. 11-24, p.11-49 Fig. 11-25, p.11-49	ABC Railway Guide, 2018, "Smithy Bridge Level Crossing," ABC Railway Guide Website; http://abcrailwayguide.uk/smithy-bridge-public-level-crossing-rochdale#.W3vbb-gzbIU, accessed: 16.05.2018, 20:19 +00:00 UTC
Arriva, 2011	Fig. 11-11, p.11-28 (qv Slide 6)	Leppard, P., 2011, "Cambrian Level 2: In service experience – a Train Operator's perspective," Arriva Train Wales, UK, IRSE ERTMS Seminar, 15 November 2011; http://www.irse.org/knowledge/publicdocuments/6_CPH%20ERTMS%20P%20Leppard.pdf, accessed: 31.05.2018, 13:09 +05:30 UTC
ATACS, 1996	Fig. 11-2, p.11-16 (qv Fig. 1, p.204);	Kobayashi, T., Iba, O., Inage, H., Tateishi, Y., 1996, "ATACS (Advanced Train Administration and Communication System)," Technical Development and Research Department, Safety Research Laboratory, East Japan Railway Company, Japan, © WIT Transactions on The Built Environment, Vol. 18, 1996, www.witpress.com; https://www.witpress.com/Secure/elibrary/papers/CR96/CR96020FU2.pdf, accessed: 08.08.2018, 14:19 +05:30 UTC
ATACS, 2014	Fig. 11-12, p.11-28 (qv Fig. 3, p.178);	Miyaguchi, L., Uchiyama, D., Inada, I., Baba, Y., & Hiura, N., 2014, "The radio-based train control system ATACS," Department of Electrical & Signal Network Systems, East Japan Railway Company, Japan, © WIT Transactions on The Built Environment, Vol. 155, 2014, www.witpress.com; http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.735.5364&rep=rep1&type=pdf, accessed: 27.05.2018, 15:39 +05:30 UTC
Cambrian, 2011	Fig. 11-9, p.11-24 (qv Slide 7);	Furness, N., 2011, "Cambrian: In service experience – an Infrastructure Manager's perspective," Network Rail, UK, IRSE ERTMS Seminar, 15 November 2011; http://www.irse.org/knowledge/publicdocuments/5_IRSE%20ERTMS%20Seminar%20Cambrian%20151111v3.pdf, accessed: 31.05.2018, 13:20 +05:30 UTC
CP Rail, 2016	§11.28.3, p.11-49 (qv §4, pp.4-7)	Hussain, A., Chartier, G., 2014, "CP Rail Crossing at New Coronation Road Class EA Study, Project File Report, Appendix B, Transportation Report, Town of Whitby HMMI Project No. 327878," Hatch Mott MacDonald, Canada, October 2014. Website: https://www.whitby.ca/en/resources/ProjectFileReport.pdf, accessed: 09.10.2018, 14:27 UTC
IRJ, 2016	Fig. 11-14, p.11-30	Barrow, K. 2018, " Wireless level crossing control debuts in Japan," International Rail Journal, January 16, 2015, Paris, France; IRJ Website https://m.railjournal.com/index.php/signalling/wireless-level-crossing-control-debuts-in-japan.html, accessed: 29.06.2018, 17:54 UTC +5:30
IRSE, 2010	Fig. 11-6, p.11-22 (qv Slide 12);	Whitcher, T., 2010, "Telecoms and the Future Railway – IP Based Signalling Technology Opportunities," Invensys Rail Ltd., IRSE Seminar: Railway Telecommunications, London, UK, 16 November 2010; IRSE Knowledge Base, London, UK, http://www.irse.org/knowledge/publicdocuments/IRSE_Seminar_16_Nov_2010_web.pdf, accessed:31.07.2018, 14:42 UTC +5:30

Reference		Source
TfL, 2018	§11.28.3, p.11-49 (qv §2.4.3.1, pp.66-67 & Fig. 1, p.67)	Smith, Dr. J., & Blewitt, R. 2010, "Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance, Best Practice, version 3.0," Mayor of London, Transport for London, London, UK; http://content.tfl.gov.uk/traffic-modelling-guidelines.pdf, accessed: 07.05.2018, 00:50 +00:00 UTC

CHAPTER

12

Telecommunication Systems

Chapter 12 Telecommunication Systems

Chapter Summary

Introduction and Background

At present the Kelani Valley (KV) Line is single track Maradana – Avissawella, with 9 Main stations and 31 sub-stations / halts, excluding Maradana.

The Project will recommend partial re-construction of the KV Line as double-track Maradana (Loco Junction) – Padukka (35 km) with refurbishment of the remaining 23.5 km Padukka - Avissawelle single-track section. Between Maradana Station – Loco Junction, a new second track will be added, effectively providing double-track and connecting to the existing platforms 9/10, but actually being one additional bi-directional track within the Maradana station throat / approaches. This design will enable Main Line trains to utilise one track, when necessary, requiring KV Line to revert operations to single-track arrangements. The re-constructed KV line will serve 9 Main stations and 31 minor or Sub-stations.

The recommended telecommunications systems will substitute all existing systems and equipment over the entire route, including with the existing station telecommunications system at Maradana.

Telecommunications System Options

The proposed telecommunications systems will substitute all existing systems with modern digital systems built on an optical fibre backbone network in the section Maradana – Avissawella, including the integration to the national telecommunications network to be provided by others. The backbone network will support implementation of other railway systems, including Overhead Contact System (OCS), Information and Communications Technology (ICT), Signalling and Train Management, also, Vehicles (VOB), Workshops and Depots. The backbone network will be designed with provision for additional capacity and facilities for proposed future extensions and branch networks.

Various options for the train data radio system are considered, but decision has been deferred pending completion of the procurement process for the new national telecommunications network, which is anticipated during the Detail Design Phase. All other major sub-systems will be provided as industry standard, commercial “off-the-shelf” (COTS) systems and equipment without option selection requirements.

Optical Fibre Communication System

Optical Fibre is a modern state-of-the-art, cost-effective telecommunications medium for back-bone networks. For protection against fibre cuts, cable cuts or node failures, two optical fibre cables laid both the sides of right of way (ROW), providing path diversity, are proposed.

The whole optical fibre back bone network shall form a pair of closed rings, arranged for dual-redundancy, with the each cable terminating at fibre patch panels at each station and the OCC. However, either cable will connect to the telecommunications nodes at alternate station. The optical fibre cables (OFC) are proposed with 144 fibres, to be manufactured to ITU standard specifications and, be suitable for installation either buried or laid in-duct.

Data Transmission System (DTS)

The Data Transmission System (DTS) will implement transfer of data or digital streams over a point to point or point to multipoint, optical fibre network. The DTS proposed will use Internet Protocol (IP) based data transmissions, in accordance with international standards, such as ITU-T.

IP technology is a fully matured technology, for which all devices (such as Public Address (PA), Master Clock, and cameras) are available with an IP interface. IP based Private Automatic Branch Exchange (PABX) systems are also matured in the market. The bandwidth provided by the DTS will match the capacity requirements specified for the subsystem interfaces.

Telephone System

he telephone system will be a dedicated Digital Private Automatic Branch Exchange (PABX) and digital direct line telephone system network, which will offer highly reliable voice communication between OCC, stations, Depot, substations and radio communication users.

Central Voice Recorder System

The Central Voice Recorder System (CVRS) will provide the dedicated voice recording and storage facilities for „Mission-critical" and „Safety-critical' operational functions. However, all voice calls to Train Controllers / Dispatchers will be recorded regardless of actual critically level. The minimum storage capacity will be sufficient for at least 24 hours, but preferably 7 days.

Radio Communication System (RCS)

The objective of Radio system is to provide fully dedicated wireless voice communication channels to support operational and maintenance requirements on the Railway.

The RCS system will be configured with GSM-R technology, which will preferably conform to applicable EIRENE / 3GPP or equivalent standards.

Radio Dispatcher Workstation

A Radio Dispatcher Workstation (RDW) will be provided at the OCC and in Depots for the Train Controllers / Dispatchers to make radio communications with the train drivers on duty. RDWs will comprise a Liquid Crystal Display (LCD) monitor, a keyboard with mouse, a handset and a monitor speaker. The RDW shall be a redundant system. The RCS will allow a Train Controllers / Dispatchers in the OCC to make local or global announcements via the Central PA system. The RCS will enable O&M staff to communicate with one another or with the Traffic Dispatcher via hand-portable radio sets. Radio communications between Train Controllers / Dispatchers in the OCC, Depots and other radio users shall be recorded by the CVRS (Central Voice Recording System). Radio Base Stations at all stations shall automatically manage the call processing and the necessary channel assignments.

The candidate technologies for the proposed RCS are GSM-R, LTE / LTE-R and TETRA.

System Safety Considerations

The Radio Communications System, based upon data transmissions via wireless LTE technology and optical fibre cables, will be fully duplicated for reasons of availability. Dual-redundancy is a feature that can be used, in conjunction with other systems to demonstrate a degree of confidence necessary for system safety.

Train data radio and radio block centre radio functions are safety critical, which must be demonstrated in accordance with recognised international standards. As a consequence, it is strongly recommended that these systems be assessed by an Independent Safety Assessor (ISA), which body will also verify and validate the Safety Case for these systems and facilities.

As part of the new maintenance organisation, two new branches of the Workshops are proposed, one for signalling equipment in the CTCC building, and the other(s) for train on-board equipment located near or at the Train Maintenance Depot(s).

Closed-Circuit Television (CCTV)

The Closed-Circuit Television (CCTV) system uses an advanced video management system for camera control and monitoring, recording management, alarm handling and protocolling system events and user actions.

The Operators will have viewing access to the entire system of all stations centrally and can control the cameras with priority to the stations. Video analytics features are considered for the cameras at the important/ priority locations.

Conclusions and Recommendations

An optical fibre cable network with data transmission system is recommended for network-wide provision of voice, data and video services and facilities.

An ERTMS Level 2 Equivalent is recommended comprising ETCS Level 2 or quivalent for train control with GSM-R train data radio system.

A central voice recorder system is recommended to record “mission-critical” and “safety-critical” voice messages and conversions.

A new CCTV system is recommended to monitor all stations and depots and nominated other areas for security purposes.

Part A. General

12.1 General

12.1.1 Introduction and Background

At present the KV Line is single track Maradana – Avissawella, with 9 Main stations and 31 sub-stations / halts, excluding Maradana.

The Project will propose partial re-construction of the KV Line as double-track Maradana – Padukka (35 km) with refurbishment of the remaining 23.5 km Padukka - Avissawelle single-track section. The new second track will be connected to the existing KV Line platforms 9/10 at Maradana station. The new track layout arrangement will include 9 Main stations and 31 substations, as listed in Table 12-1.

Two Main stations, Narahenpita and Homagama, have been down-graded to sub-stations due to the new layout, with one new Main station Makumbura North added. Manning Town, Malapalla, together with 5 sub-stations in Padukka – Avissawella section are proposed for closure, with addition of a new sub-station at Dambahena.

The proposed telecommunications systems will substitute all existing systems with modern digital systems built on an optical fibre backbone network in the section Maradana – Avissawella, including the integration to the national telecommunications network to be provided by others. The backbone network will support implementation of other railway systems, including Overhead Contact System (OCS), Information and Communications Technology (ICT), Signalling and Train Management, also, Vehicles (VOB), Workshops and Depots. The backbone network will be designed with provision for additional capacity and facilities for proposed future extensions and branch networks.

12.1.2 Structure of the Report

This chapter is sub-divided into four parts, this first section, Part A, provides a brief background and description of the objectives of the FS from a telecommunications perspective. This will necessarily be a wide scope with numerous interfaces to other systems and infrastructure. Part A also provides lists of the various abbreviations used, general environmental conditions. The international and national standards to be applied are also referenced here.

The existing telecommunications arrangements along the single-track Kelani Valley (KV) Line are described in Part B, whilst Part C describes the preliminary design concept for telecommunications backbone network systems. Client systems and their interfaces, and interfaces to the proposed national telecommunications network for SLR are discussed in Part D. Part E considers some aspects of construction , operations and maintenance, together with some proposals for organizational change.

It is inevitable that some details may be duplicated in other Chapters of the FS Report, but this should be expected for fully-integrated systems.

12.2 Summary of Telecommunications Systems

The scope of telecommunications systems is perhaps the widest of all the infrastructure systems, including as it does support for train management (TMS), signalling (SIG), OCS, rolling stock (RS), stations (STN), depots (DPT), asset management (AMS), revenue collection (RC), safety & security (S&S) and general administration (ADM). This section seeks to clarify those different and differing functions, responsibilities interfaces and inter-dependencies.

System	TMS	SIG	OCS	RS	STN	DPT	AMS	RC	S&S	ADM
AMS	√	√	√	√	√	√	√	√	√	√
CCTV	√	√		√	√	√	√	√	√	
CDRS	√	√	√	√	√	√	√		√	
DLT	√	√	√		√	√	√		√	
DTS	√	√	√	√	√	√	√	√	√	√
MCS	√	√	√	√	√	√	√	√	√	√
OFCS	√	√	√	√	√	√	√	√	√	√
PABX					√	√	√	√	√	√
PAS	√			√	√		√			
RCS	√		√	√	√	√	√	√	√	
S&DS	√	√	√	√	√	√	√	√	√	√
SCADA	√		√				√			
TDRS	√	√		√		√	√			
Wi-Fi				√	√	√	√			√

* The matrix above is subject to change during the Detail Design Stage.

Part B. Review the Existing Condition

12.3 Present Status of Telecommunications on KV line

Table 12-1 List of Existing Stations on KV line

No.	Name	Code	Location (km.m)	Class	Station Layout
1	Maradana	MDA	0.000	Main	Multiple Tracks
2	Baseline Road	BSL	1.884	Sub	Single & 1 Loop
3	Cotta Road	CRD	3.545	Sub	Single & 1 Loop
4	Manning Town			Halt	Single Track
5	Narahenpita	NHP	5.615	Main	Single & 1 Loop
6	Kirillapone	KPE	7.363	Sub	Single Track
7	Nugegoda	NUG	9.145	Main	Single & 1 Loop
8	Pangiriwatta	PRW	10.671	Sub	Single Track
9	Udahamulla	UHM	11.521	Sub	Single Track
10	Nawinna	NWN	13.291	Sub	Single Track
11	Maharagama	MAG	14.460	Sub	Single Track
12	Dambahena		16.000	No Station	Proposed Station
13	Pannipitiya	PAN	17.112	Sub	Single Track
14	Kottawa	KOT	19.408	Main	Single & 1 Loop
15	Malapalla	MPL	20.598	Sub	Single Track
16	Makumbura		20.760	No Station	Proposed Station
17	Makumbura North		21.900	No Station	Proposed Station
18	Homagama Hospital	HHR	22.400	Sub	Single Track
19	Homagama	HMA	24.610	Main	Single & 1 Loop
20	Panagoda	PNG	26.385	Sub	Single Track
21	Godagama	GGA	28.217	Sub	Single Track
22	Meegoda	MGD	29.743	Main	Single & 1 Loop
23	Watareke	WAK	31.255	Sub	Single Track
24	Liyanwala		33.420	Halt	Single Track
25	Padukka	PDK	35.284	Main	Single & 1 Loop
26	Arukwathpura	ARW	36.840	Sub	Single Track
27	Angampitiya	AGP	37.920	Sub	Single Track
28	Uggala	UGL	38.860	Sub	Single Track
29	Pinnawala	PNW	40.169	Sub	Single Track
30	Gammana	GMA	41.200	Sub	Single Track
31	Morakele	MRK	42.000	Sub	Single Track
32	Waga	WGG	44.399	Main	Single & 1 Loop
33	Kadugoda	KDG	46.460	Sub	Single Track
34	Arapanggama			Halt	Single Track
35	Kosgama	KSG	49.437	Main	Single & 1 Loop
36	Aluth Ambalam			Halt	Single Track
37	Miriwaththa			Halt	Single Track
38	Hingurala		53.100	Halt	Single Track

No.	Name	Code	Location (km.m)	Class	Station Layout
39	Puwakpitiya	PWP	55.570	Sub	Single Track
40	Puwakpitiya New Town			Halt	Single Track
41	Kiriwandala			Halt	Single Track
42	Avissawella	AVS	59.277	Main	Terminal 3 Tracks

Table 12-1 above lists 42 stations on the KV Lines, from which the following totals are extracted as Table 12-2.

Table 12-2 Existing Telecommunications Provision

No.	Name	Total	Remarks
1	Main Stations	10	Public-Network Telephone; Tablet-Token Block System
2	Sub Stations	21	Public-Network Telephone; Tablet-Token Block System
3	Halt Stations	8	None
4	Proposed New Stations	3	None - Future Provision
5	Level Crossing Guard Huts	40	None

12.4 Existing Signaling and Telecommunications Systems

Signaling is one of the major client systems for telecommunications and as such must be taken into consideration whilst making an assessment of existing telecommunications systems, if any, and / or where provided.

12.4.1 Signaling and Telecommunications for Avissawella – Baseline Road

Tablet token system is in force for block working throughout the KV Line, Baseline Road – Avissawella (refer Table 12-3 for details). Eight Main stations are provided with none-interlocked multi-aspect colour light home signals. Some of the controlled level crossings are protected by signals, which in some locations are semaphore signals.

Table 12-3 Signaling Systems on KV line

No.	Station	Signaling	Block system
1	Baseline Road	Locally controlled multi-aspect colour light signals, normally dark, with relay interlocking, electric point machines and, track circuits in the station yard	Tablet Token Block
2	Narahenpita		
3	Nugegoda		
4	Maharagama	Two locally controlled, none-interlocked, multi-aspect colour light Home signals with manually-operated spring points	
5	Kottawa		
6	Homagama		
7	Meegoda	Two manually-operated semaphore signals, none-interlocked, with manually-operated spring points	
8	Padukka	Two locally controlled, none-interlocked, multi-aspect colour light Home signals with manually-operated spring points	
9	Waga		
10	Kosgama		
11	Avissawella		

12.4.2 Signaling and Telecommunications for Maradana – Baseline Road

Entry to and egress from the single-track KV Line is currently controlled from Maradana Operations Control Centre (OCC) via a Centralized Traffic Control (CTC) system for the section Maradana – Loco Junction by absolute block with track circuits. A Local Control Panel is also provided at Maradana station for emergency use during failure conditions.

Control of KV Line is provided as computer workstation with four 24" monitors for dynamic display of track and signal layout Colombo Fort – Maradana – Loco Junction. An overview display panel is provided by a set of 49" monitors above and behind the dispatcher's workstations.

12.4.3 Train Management Systems on KV Line

Train operations throughout the KV Line are managed from Maradana OCC, and the controllers are co-located within the same room, but separated from, the CTC at Maradana. Paper copies of station layouts, train graphs, etc., are still in use as management tools. Real-Time Train Graphs use heritage hand-drawn by the controller methods. Communications with stations utilize the Sri Lankan public network telephones.

12.5 Problems with the Existing Telecommunications Systems

These may be summarized very briefly as virtually non-existent and almost entirely based on those provided by the national public network. The Tablet Token Block System may be considered as part of the telecommunications network.

12.6 Existing Signal & Telecommunications Organization Structure

12.6.1 Operations & Maintenance Division

Table 12-4 S&T Sub-Department Divisional Boundaries

Division	Line	Boundary Stations
Northern Division	Northern Line	Maho – Kankasanturai
	Mannar Line	Medawachchiya – Talaimannar
	Batticoloa Line	Maho – Batticoloa
	Trincomalee Line	Galoya Junction – Trincomalee
Upper Division	Main Line	Rambukkana – Badulla
	Matale Line	Peradeniya Junction - Matale
Central Division	Main Line	Colombo Transfer Sidings – Rambukkana
	Northern Line	Polgahawela – Maho
	Puttalam Line	Ragama – Puttalam
Southern Division	Coast Line	Matara – Colombo Transfer Sidings
	Kelani Valley Line	Maradana – Avissawella

Maintenance Divisions are further divided into small sections through which the routine / periodical maintenance activities are carried out by the sectional Signal& Telecommunications Inspectors (STIs) with their staff. District Signal & Telecommunications Inspectors (DIRs) act between the Divisional

Engineer and the STIs, to assist with maintenance management activities, whilst also attending to the major repair works and half yearly inspection in their division.

As indicated above, operation and maintenance of Signalling and Telecommunication systems is divided into four geographical areas and boundaries of the divisions are as shown in Table 12-4.

S&T staffs within these divisions are responsible for all types of maintenance and repair works, including any major repairs due to derailments, accidents, etc.

12.6.2 Existing Maintenance Arrangements for the KV line

Signaling maintenance activities for the KV line falls under SE (S) and is organized as shown in Section 13.10.2, Figure 12-3 with abbreviations listed in Section 13.2.2.

There are two maintenance depots, located at Maradana and Pannipitiya, and two STIs along with their supporting staff are assigned for carrying out the maintenance of KV Line signalling systems as shown below:

- STI (Tracks) Section: From Dematagoda (including Dematagoda Level Crossing) to Maharagama (include Maharagama yard & Temple Road Level Crossing)
- STI (Pannipitiya) Section: From Maharagama (Kottawa side, Block Instrument only) to Avissawella

12.6.3 Inspection and Maintenance

12.6.3.1 Routine / Preventive Maintenance

Routine inspections and maintenance of the telecommunications system are carried out at regular intervals as follows:

- Weekly Inspection and Maintenance: Sectional Maintenance officer, STI with the assistance of their staff implement a programme of weekly inspections and maintenance of the wayside equipment, power supplies etc., and maintains the records appropriately.
- Monthly inspection: Testing of telecommunications equipment are implemented monthly, and records of the results are informed to the Sectional Engineer accordingly.
- Half-yearly Inspection and Maintenance: Carried out by DIRs as prescribed in the Special Instructions. Additionally, half-yearly maintenance of specified items is carried out by STIs.
- Yearly Testing and Inspection: Implemented by the Sectional Engineers, and yearly testing and inspections of specified items are performed by STIs and DIRs.

12.6.3.2 Predictive Maintenance

On the basis of routine Inspection / Test reports, Predictive Maintenance may be carried out, e.g. as listed below:

- Cable insulation Test report;
- Battery Test reports;

- Specific reports of Engineers and District Officers.

12.6.3.3 Breakdown / Reactive Maintenance

Breakdown maintenance is carried out under following situations:

- Power failures;
- Defective Rectifiers, Transformers;
- Damages to telecommunications equipment;
- Failures due to lightning and severe weather conditions.

12.6.4 Monitoring of Maintenance Activities and Analysis of Failures

A separate unit headed by DIR (Headquarters) functions directly under the CSTE in order to monitor and follow up of the smooth operation of maintenance works. DIR (HQ) is assisted by another STI designated as STI (Faults) in these activities.

All failures, defects and damages related to signal and telecommunications are communicated to the officer-in-charge in the area concerned, via written messages with copies to all concerned and to log books maintained at each Operations Control Centre (OCC) in the region. Once the defect / damage has been attended a written report is sent to Headquarters through the relevant DIR and SE. All inspection reports are reviewed in the unit and analysis of failures and follow up activities are initiated through this unit accordingly. They also conduct preliminary inquiries related to signaling and telecommunication matters, with the approval of CSTE.

Some of the reports analyzed in this unit are as follows:

- Fault Reports
- Accident Reports
- Special Incident reports
- Plant Inspection reports (Equipment rooms, Equipment Cabinets)
- Inspection Reports
- Cable Rest reports
- Tablet token Test reports
- Engineers‟Inspection Reports

12.6.5 Planning and Development Division

12.6.5.1 Signal Workshop: Repairs to Equipment and Material Supply

The signal workshop at Dematagoda is the main production and repair centre for the S&T sub-department, functions under SE (W/S), and has two main divisions each headed by DIRs, which are, Mechanical Section and Electrical Section, as shown in Section 13.10.3, Figure 12-4, with abbreviations shown in Section 13.2.3.

12.6.5.2 Signal Workshop: Mechanical Section

All repairs and testing of mechanical signaling gears, lever frames, over hauling of mechanical interlocking trays, production of mechanical signaling components, signal posts, level crossing barriers, steel cabinets for line-side equipment etc., are undertaken. In addition all vehicles and stores come under supervision of this section.

Four store divisions, designated as SK CS, SK RTS, SK SSW and SK Tools (Refer 13.8.5.4), together with Vehicles & Transport of Materials also fall within the jurisdiction of DIR (Mechanical)

Since most of the activities undertaken are related to areas outside of Colombo suburban area, better arrangements for the future could include moving to a different location.

12.6.5.3 Signal Workshop: Electrical Section

Repairs to electrical, electronic and telecommunications components are undertaken at this workshop.

However some work is related to old, obsolete telephone and telegraph equipment, now discontinued. Consequently, the present arrangement is mainly limited to repair and test of electrical and electronics signaling equipment and a few types of telephones.

- Electrical Repairs: Repairs and testing of power supply equipment, token instruments, relays, charging of alkaline and lead acid batteries, maintenance and repairs of standby generators etc. are undertaken;
- Electronic Lab: Repairs and testing of Printed circuit boards, other electronic devices, testing and splicing of optical fibre cables are undertaken.

12.6.5.4 Stores and Material Supply

All necessary materials are procured and supplied through the Railway Stores sub-department which operates under the Superintendent of Railway Stores (SRS). One of the stores sections (MM Section), which supplies materials connected with the signal and telecommunication system is located in the premises of S&T sub-department at Dematagoda.

Apart from stores branch of the Railway stores, four other stores units are handling materials required for the S&T sub-department, and are functioning under the supervision of CSTE:

SK CS:	Items for Colour light Signalling system
RTS:	Tablet token, Telegraph. Open wire telecommunication system
SSW:	Mechanical Signalling systems
SK Tools:	Tools and Instruments

All materials, Tools, spare parts etc. required for the maintenance and repairs are supplied through relevant stores unit at Dematagoda. Defective items are returned to stores on Maintenance Exchange Requisition (MER) basis.

A large number of items that are in the inventory have become obsolete with changes to technologies, therefore the asset management system needs to be reorganized and the inventory updated.

12.6.6 Procedures and Documentation Used for Materials Acquisition

12.6.6.1 Maintenance Exchange Requisition (MER)

The MER form is the basis for the procedures followed by the maintenance officers to exchange any defective equipment removed for repair from the operational systems. Completion of the transaction between the stores and the maintenance officer does not require approval of any other party.

12.6.6.2 Workshop Orders (WO)

Workshop Orders may be raised by the maintenance officers to get items made or procure services with the approval of the Sectional Engineers (SEs).

12.6.6.3 Job Card

A Job Card may be originated by a workshop officer and sent to the internal stores to obtain material for different jobs. Materials thus obtained may be used either for making a new item or for repairs to an existing, defective item.

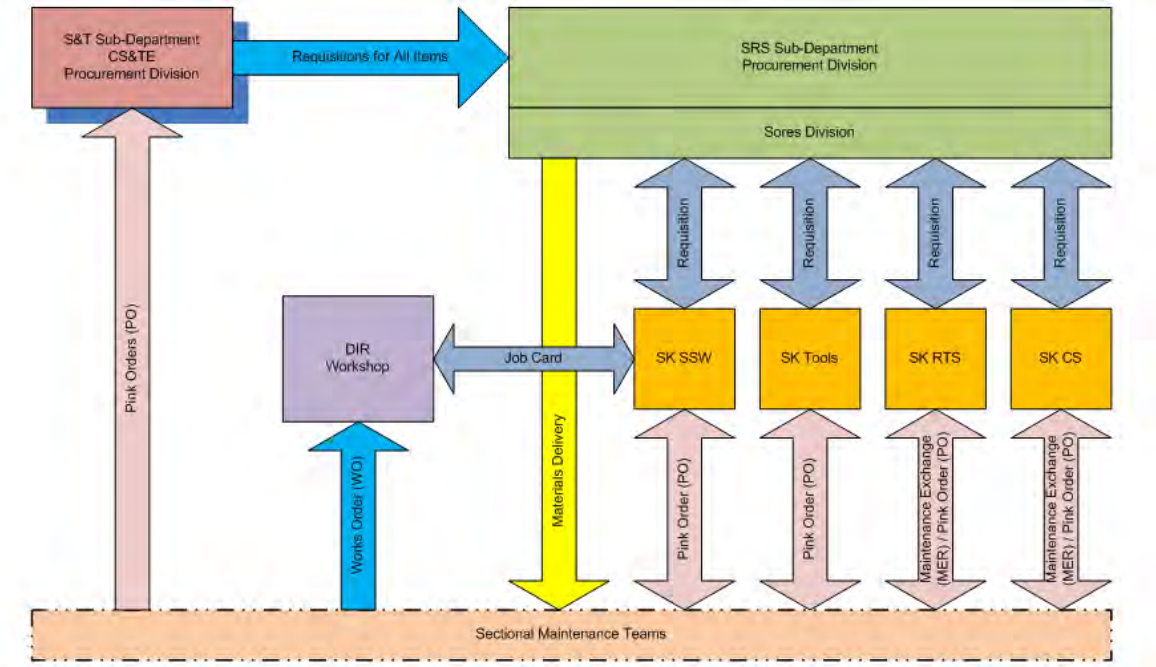


Figure 12-1 S&T Sub-Department Existing Process for Materials Procurement

12.6.6.4 Pink Order Requisition (PO)

Maintenance officers may complete a PO form to order for new materials for their maintenance and construction activities. If these items are available in the internal stores (SKCS, RTS, SK Tools, and SSW), then the items can be obtained from the relevant store once the requisition is approved by the Sectional Engineer (SE)

12.6.6.5 Stores Requisition

Stores Requisitions are raised by the CSTE‟s office, with the approval of CSTE, on receipt of POs in the event items are not available in the internal stores, and sent to Railway Store Department. When the items become available, these may be delivered or collected.

Table 12-5 Material Supply Procedure for S & T Sub-Department

Document	From	To	Description / Purpose
MER	STIs	SK CS, RTS	To exchange a defective item with a new item. This is purely transaction between the STI and the Store keeper without intervention of a third party
PO	STIs, DIRs	SK CS, RTS SSW, SK Tools	To obtain new items. Sectional Engineer approval of PO required.
	STIs, DIRs, SKCS, RTS SSW, SK Tools, Office staff	CSTE	To obtain new item from Railway stores which are not with SKCS, RTS, SSW or SK Tools. Sectional Engineer approval of PO required.
WO	STIs, DIRs	DIR W/S	To make any item not available in stores or to get service from the workshop. Sectional Engineer approval of WO required.
Job Card	DIR W/S	SK CS, RTS SSW, SK Tools	For fulfilling Workshop Orders
	SKCS, RTS	DIR W/S	To repair defective Items
Requisition	SRS	CSTE	Requisitions are raised by CSTE's Office on POs sent by Sectional Staff and Store Keepers to obtain: All signalling items for new works, excluding maintenance stocks Other general items

A large number of items that are in the inventory have become obsolete with changes to technologies, therefore the asset management system needs to be reorganized and the inventory updated.

12.6.7 Radio Communication Division

Radio Communication Division is functioning under SE (R) and assisted by DIR and STIs.

The maintenance of UHF / VHF networks, installation and maintenance of public address systems at stations are carried out.

Also, the repairs and testing of radio communications equipment and public address equipment used at stations are carried out at the radio workshop, Demetagoda.

12.6.8 Planning & Construction

Alterations, modifications and new construction of Colour light signalling system are carried out by the planning and construction division. This division functions under SE (P & C), who is assisted by DIR (Circuit Design), DOA and DIR (Construction) in these activities.

12.6.8.1 Planning

Preparation of Track & Signal Plans, Interlocking / Control tables and preparation of circuit diagrams are carried out DIR (Circuit Design) under the direct supervision of SE (P & C).

12.6.8.2 Construction and Commissioning

Installation of line-side equipment, interlocking and CTC equipment are carried out by DIR (Construction) with the assistance of STI (Construction), STI (Cables) and the workforce.

12.7 Staff and Training

The present Technical Staff of CSTE"s sub-department are classified as Engineers, Technical officers, skilled labour, non-skilled labour and administrative staff.

12.7.1 Recruitment and Initial Training of the Technical Staff

Engineers are appointed by the Sri Lanka Engineering Services Board, and receive a short induction training and on-the-job training

STIs are recruited with diploma level or equivalent qualifications and they are given a theoretical and practical training about the railway signalling and existing signalling and telecommunication systems and safety rules, administrative and financial rules and regulations, etc. On successful completion of an examination they will be sent to the various maintenance sections for further practical training, and upon completion of a specified period, they will be posted to maintenance divisions as STIs. However the newly appointed technical officers will be closely supervised by the area DIR.

Skilled grade technicians who possess certificate level technical qualifications are recruited from outside, while a greater percentage are recruited by promotion of semi-skilled and non-skilled workers after a trade test.

12.7.2 Further Training

In addition to the Initial / Induction and on-the-job training the following opportunities are also provided.

(1) Engineers and Technical Officers are sent for railway signalling and communications training over-seas, depending on the availability of relevant foreign resources.

(2) Equipment training for Engineers and Technical Officers, including technicians, may be given whenever a new system is procured.

(3) Technicians may also sent for over-seas training under different projects.

(4) Short term training through local organizations like Arthur C Clerke Centre for Modern Technologies and Railway German Technical Training Centre are also used for training of S&T personnel.

12.8 Organization Charts

12.8.1 S&T Sub-Department: Existing Organization Chart

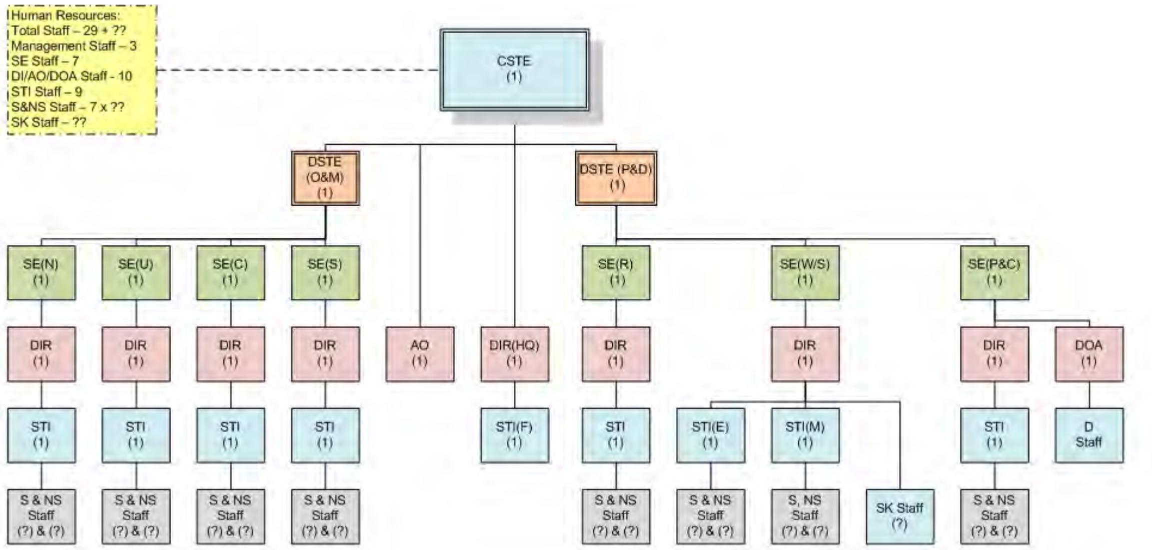


Figure 12-2 S&T Sub-Department: Existing Organization Chart

12.8.2 S&T Sub-Department: Existing Maintenance Organization for KV Line

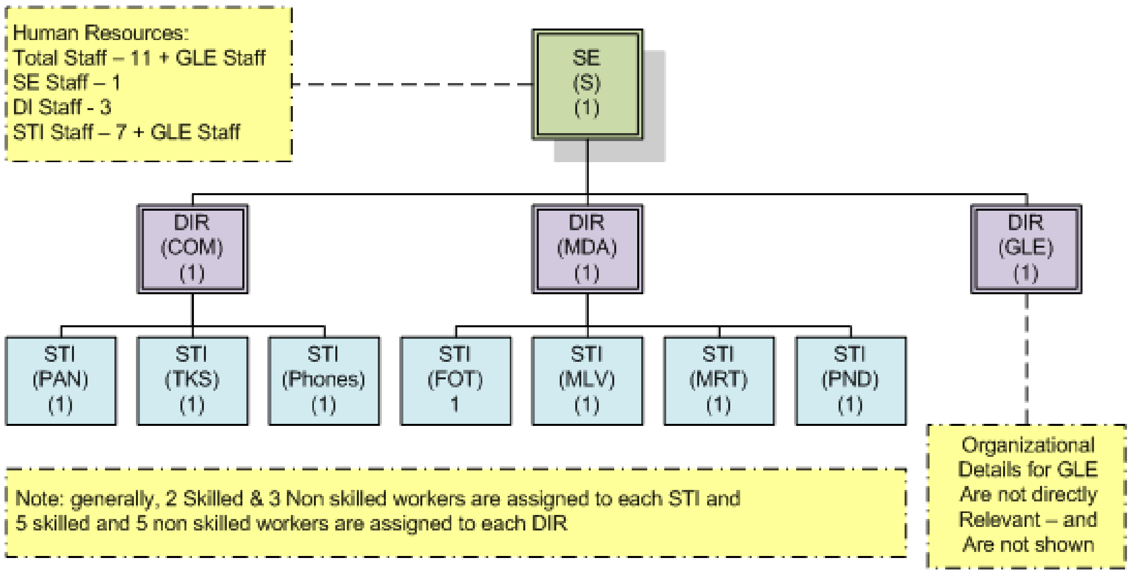


Figure 12-3 S&T Sub-Department: Existing Maintenance Organization for KV Line

12.8.3 S&T Sub-Department: Existing Organization of Signal Workshop

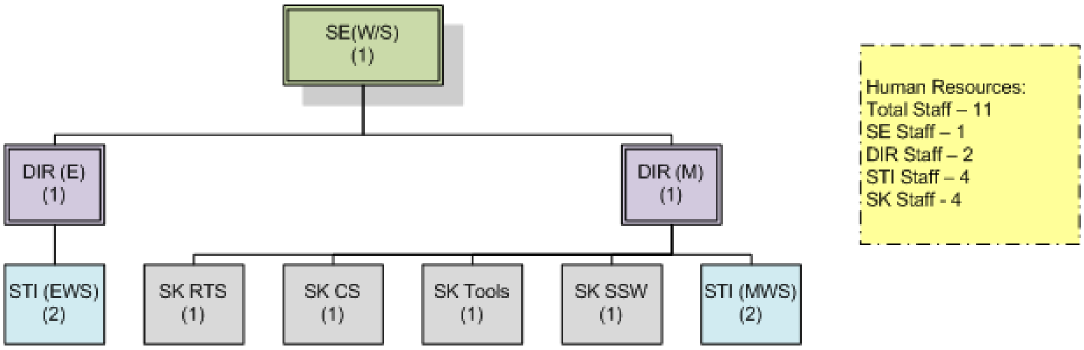


Figure 12-4 S&T Sub-Department: Existing Organization of Signal Workshop

12.8.4 S&T Sub-Department: Existing Organization of Central Division

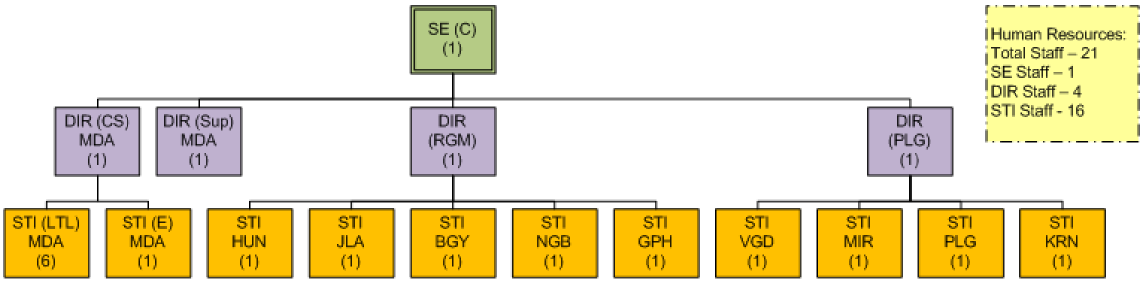


Figure 12-5 S&T Sub-Department: Existing Organization of Central Division

Part C. Preliminary Design Concepts

12.9 Telecommunications System

12.9.1 Introduction

The main purpose of the telecommunications systems provide voice and data transmission capabilities throughout the KV Line system to enable the efficient operation and management of the rail network. Instant communications independent from other means of communication are essential. Requirement, structure, dimension and sophistication of the chosen systems mainly depend on the structure of the railway network, density and type of train operations and working methods.

12.9.2 Existing Scenario

12.9.2.1 Control Communications

Access by trains to sections between stations is controlled by use of Tyers Tablet Token Block, with one exception – Maradana to Baseline Road where track circuits are used with inter-station the block telephones communications through underground cables. At present there is no dedicated system for train operations management communications. Train running information, recorded by station masters is reported to Maradana OCC via public service telephones.

There is no train radio communication between train drivers and Maradana OCC.

12.9.2.2 Telephone communications

Conventional circuit switched public telephone system is used.

12.9.3 Assumptions for the FS

(1) 35 Stations (20 Crossing Stations and 15 Halt stations) are considered by this FS Report.

(2) Radio Block Centres are proposed in substitution for existing signalling and accordingly the radio system must support the data transmission requirements for the signalling system.

(3) The KV line will be managed from a new OCC for achieving maximum operation reliability.

(4) Elevated track and stations between Loco Junction and Malapalla; ground level track and stations between Malapalla and Avissawella. It is assumed that in the elevated section stations will have concourse at ground level and platforms next higher level. The telecommunications subsystems are accordingly planned to include Vehicle On-Board (VOB) systems

12.9.4 Telecommunications Requirements

The purpose of the telecommunications systems and required telecommunications services support the business environment and safety and efficiency of train operations.

An overview of the service and general requirements for KV Line telecommunications is detailed by Table 12-6. The telecommunications services required for the KV Line are expanded as a matrix and shown in Table 12-7.

Table 12-6 Telecommunications General Requirements

Required Services	Required Functions	Required Systems
Telecommunications services for safety	1) Train Dispatching control 2) Emergency protection	1) Radio communication system 2) Closed Circuit Television (CCTV) system
Telecommunications services for passenger services	1) Monitoring of passengers 2) Information dissemination to passengers	1) Closed Circuit Television (CCTV) system 2) Passenger Information System (PIS) a) Public Address System (PAS) b) Passenger Information Display System (PIDS) 3) Clock System
Administrative and common telecommunications services	1) Communication among related parties 2) Common network service	1) Radio communication system 2) Telephone system 3) Backbone Transmission Network (BTN)

Table 12-7 Telecommunications Services Requirements

S. No.	Information Source	Information Sink	Normal Communication	Emergency Communication
1	OCC	Driver in Train	Radio	Radio
2	Driver in Train	OCC	Radio	Radio
3	Driver in Train	Passenger in Train	Train PA	Train PA
4	Passenger in Train	Driver in Train	Nil	Intercom
5	Driver in Leading Train	Driver in Following Train	Nil	Nil
6	Driver in Following Train	Driver in Leading Train	Nil	Nil
7	VOB System in Leading Train	VOB System in Following Train	Radio	Radio
8	VOB System in Following Train	VOB System in Leading Train	Radio	Radio
9	OCC	Passenger in Station	OFC(PA)	OFC(PA)
10	Passenger in Station	OCC	Nil	Intercom
11	Station Master	Train	Nil	Nil
12	Train	Station Master	Nil	Nil
13	SM	OCC	OFC	OFC
14	OCC	SM	OFC	OFC
15	OCC	Maintenance Coordinator	OFC	Radio
16	Maintenance Coordinator	OCC	OFC	Radio
17	Maintenance Team	OCC	Radio	Radio
18	OCC	Maintenance Team	Radio	Radio
19	Equipment Room	OCC	OFC	OFC
20	OCC	Equipment Room	OFC	OFC
21	OCC	Power SCADA	OFC	OFC
22	Power SCADA	OCC	OFC	OFC
23	OCC	Radio Block Centre (RBC)	OFC	OFC
24	Radio Block Centre (RBC)	OCC	OFC	OFC
25	OCC	Station Interlocking (IXL)	OFC	OFC
26	Station Interlocking (IXL)	OCC	OFC	OFC
27	OCC	Level Crossing System (LX)	OFC / Radio	OFC / Radio
28	Level Crossing System (LX)	OCC	OFC / Radio	OFC / Radio
29	OCC	Level Crossing Guard / User	OFC	OFC

S. No.	Information Source	Information Sink	Normal Communication	Emergency Communication
30	Level Crossing Guard / User	OCC	OFC	OFC
31	Depot Control Centre	Shunter	Radio	Radio
32	Shunter	Depot Control Centre	Radio	Radio
33	OCC	Station Slave Clock	OFC	OFC
34	OCC	Station PDIS	OFC	OFC
35	OCC	Station PDIS	OFC	OFC
36	OCC	Station PA	OFC	OFC
37	OCC	Train PA	Radio	Radio
38	OCC	Level Crossing PA	Radio	Radio
39	Station Video (CCTV)	OCC	OFC	OFC
40	Level Crossing Video (CCTV)	OCC	OFC	OFC
41	In-Train Video (CCTV)	OCC	Radio	Radio

Note: In the above Matrix the various columns indicate the following: -

Information Source	=	Source where Communication Originates
Information Sink	=	Source where communication terminates
Proposed Communication Arrangement	=	Indicates the communication arrangement between source and sink:
		Normal Case
		During Emergency / Failure

12.9.5 Description of Telecommunications Arrangements

From the Telecommunications Matrix, in Table 12-7, it emerges that there is a need for two types of communications arrangements, which are stated below:

(1) Back bone communications between OCC and fixed points along the alignment. This can be through optical fibre cable.

(2) Radio communication between fixed points (OCC, station, depot, etc.), moving trains, shunters, mobile units, etc.

12.9.5.1 The following are the main requirements

(1) The communications systems will support and facilitate the functioning of the KV line;

(2) The communications systems will be modern, with hardware and software with demonstrable reliability in a railway environment;

(3) The system will provide safe, efficient and reliable operation;

(4) The system will cater to communications needs of the following services:

a. Train management and control;

b. Features to supplement the signalling system;

c. Maintenance and emergency communications;

d. Passenger Information System (PIS);

e. Exchange of managerial information;

f. Clock system;

g. CCTV System;

h. Station management system, if any;

i. Train borne communication systems;

j. WI-FI systems for passengers at stations and on trains;

k. Dark fibres for client systems, including signalling, SCADA, AFC, etc.;

(1) The system will be demonstrably electromagnetically compatible with rolling stock, traction power, signalling systems;

(2) The system will be modular to permit easy expansion of all component systems by the addition of equipment and extension of networks with minimal effect on the operating systems;

(3) The network will be designed in such a way that it is protected against:

a. Node failure;

b. Fibre failure of OFC;

c. Single catastrophic failure of OFC Cable.

12.9.6 System Safety Considerations

The telecommunications backbone network, based upon data transmissions via optical fibre cables, in common with the majority of communications systems, is not inherently safe, but is fully duplicated for reasons of availability. Dual-redundancy is a feature that can be used, in conjunction with other systems to demonstrate a degree of confidence necessary for system safety.

Train data radio and radio block centre radio functions are safety critical, which must be demonstrated in accordance with recognised international standards. As a consequence, it is strongly recommended that these systems be assessed by an Independent Safety Assessor (ISA), which body will also verify and validate the Safety Case for these systems and facilities.

12.10 Optical Fiber Communication System

12.10.1 System Description

Optical Fibre is a modern state-of-the-art, cost-effective telecommunications medium for back-bone networks. For protection against fibre cuts, cable cuts or node failures, two optical fibre cables laid both the sides of right of way (ROW), providing path diversity, are proposed.

The whole optical fibre back bone network shall form a pair of closed rings, arranged for dual-redundancy, with the each cable terminating at fibre patch panels at each station and the OCC. However, either cable will connect to the telecommunications nodes at alternate station. The optical fibre cables (OFC) are proposed with 144 fibres, to be manufactured to ITU standard specifications and, be suitable for installation by one of the following methods:

- Laid in surface ducting: Steel armour protected type;
- Laid on cable hangers: Steel armour protected type;
- Buried underground: Steel armour protected type;
- Blown-in-duct: Non-armoured type;
- Suspended from OLE masts: Steel armour protected type, cottage-loaf style (with embedded suspension cable.

The proposed installation methods to be applied will be determined during Detail Design Stage.

12.10.2 Development Strategy

The first installation of the Telecommunications Backbone Network will be the KV Line, which will be followed by a rolling programme throughout the Colombo Suburban Railway Network. As may be seen from Figure 12-6, the KV Line is proposed as a key link in growing the SLR network for freight and passenger services.

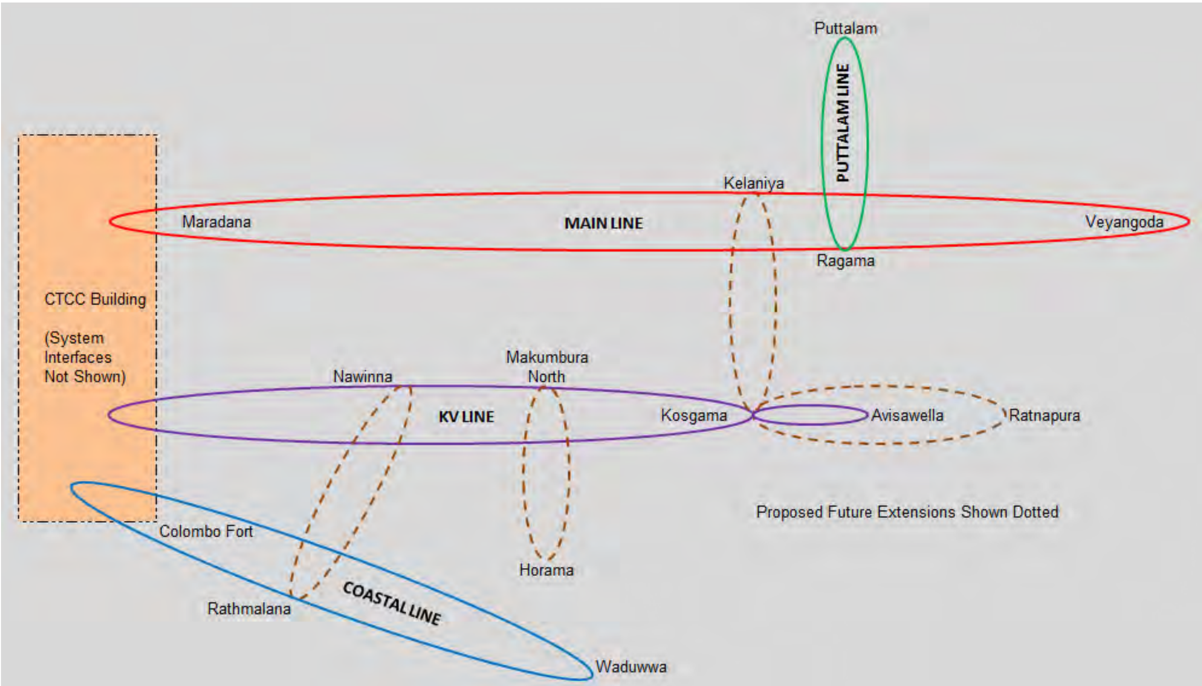


Figure 12-6 Telecommunications Network Development Strategy

These include new routes Rathmalana – Nawinna, Horama – Makumbura North and Kosgama – Kelaniya. A further proposal will re-construct Avissawella – Ratnapura and beyond to ultimately connect with the South Coast Railway, currently under construction. The proposed backbone network, together with the extensions mentioned above is illustrated by Figure 12-6.

12.10.3 Data Transmission System (DTS)

The Data Transmission System (DTS) will implement transfer of data or digital streams over a point to point or point to multipoint, optical fibre network. The DTS proposed will use Internet Protocol (IP) based data transmissions, in accordance with international standards, such as ITU-T.

IP technology is a fully matured technology, for which all devices (such as Public Address (PA), Master Clock, and cameras) are available with an IP interface. IP based Private Automatic Branch Exchange (PABX) systems are also matured in the market. The bandwidth provided by the DTS will match the capacity requirements specified for the subsystem interfaces.

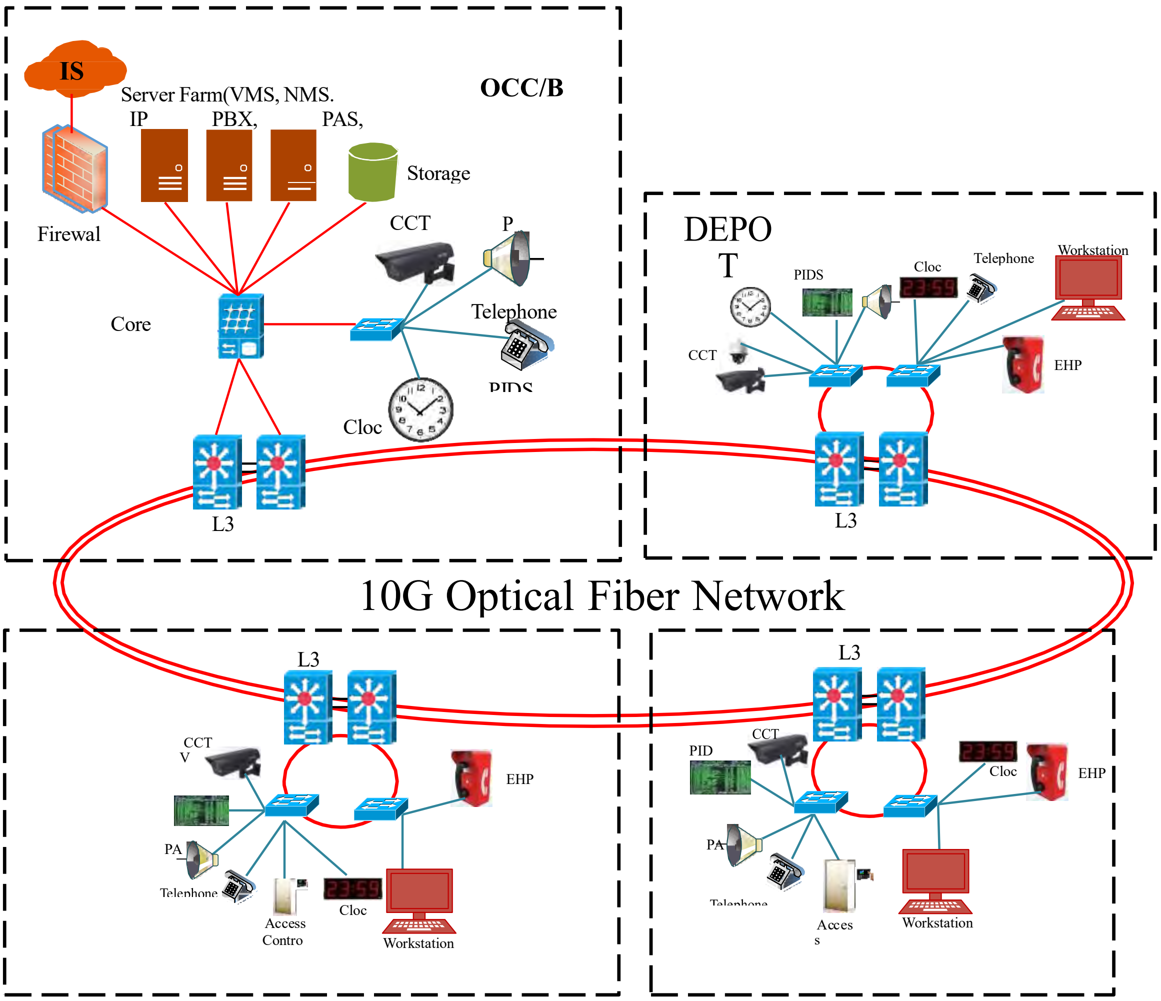


Figure 12-7 Telecommunications System Architecture

The DTS will support voice, data and video communications circuits or bandwidth for, but not limited to, the following systems:

- Public Address (PA) system
- Telephone (PABX) system
- Train Data Radio system
- Closed Circuit TV (CCTV)

- Passenger information display system (PIDS)
- Master Clock system
- Traction Power system (SCADA)
- Automatic Fare Collection (AFC) system
- Other data circuits or Ethernet ports as required.

The system architecture for the DTS is shown as Figure 12-7, which has excluded interfaces with the new SLR National Telecommunications Network currently under procurement process. The system connections to each of the above applications may need fire-walls between systems to provide the maximum security levels. Each station, sub-station, OCC and depot telecommunications nodes will be connected via a Local Area Network (LAN) to local data applications. The LAN will be provided to fast Ethernet standards.

At the new OCC, a Network Management System (NMS) will be provided with, but not limited to, the following functions:

- Real time monitoring and measurement need of telecom network status and performance;
- Facilities for prompt actions to control the flow of traffic, as and when necessary;
- Data collection for billing and financial management purposes.

12.11 Telephone System

The telephone system will be a dedicated Digital Private Automatic Branch Exchange (PABX) and digital direct line telephone system network, which will offer highly reliable voice communication between OCC, stations, Depot, substations and radio communication users.

The telephone system, with system architecture as shown in Figure 12-8, will consist of the following:

- Digital Private Automatic Branch Exchange (PABX) system;
- Digital Direct Line Telephone (DLT) system;
- Central Digital Voice Recorder;
- Interface and integration with PSTN (Public Switched Telephone Network), PA (Public Address) system and Radio Communication system.

12.11.1 Objectives of Telephone System

12.11.1.1 Digital Private Automatic Branch Exchange (PABX) System

The objective of the Digital Private Automatic Branch Exchange (PABX) System will provide SLR operational and administrative personnel with general, i.e. „non-Mission-critical' and 'non-Safety-critical,‟circuit communications requirements.

12.11.1.2 Digital Direct Line Telephone (DLT) System

The objective of Digital Direct Line Telephone (DLT) System will provide the dedicated voice communications for „Mission-critical" and „Safety-critical' operational functions.

12.11.1.3 Central Voice Recorder System

The Central Voice Recorder System (CVRS) will provide the dedicated voice recording and storage facilities for „Mission-critical" and „Safety-critical' operational functions. However, all voice calls to Train Controllers / Dispatchers will be recorded regardless of actual critically level. The minimum storage capacity will be sufficient for at least 24 hours, but preferably 7 days.

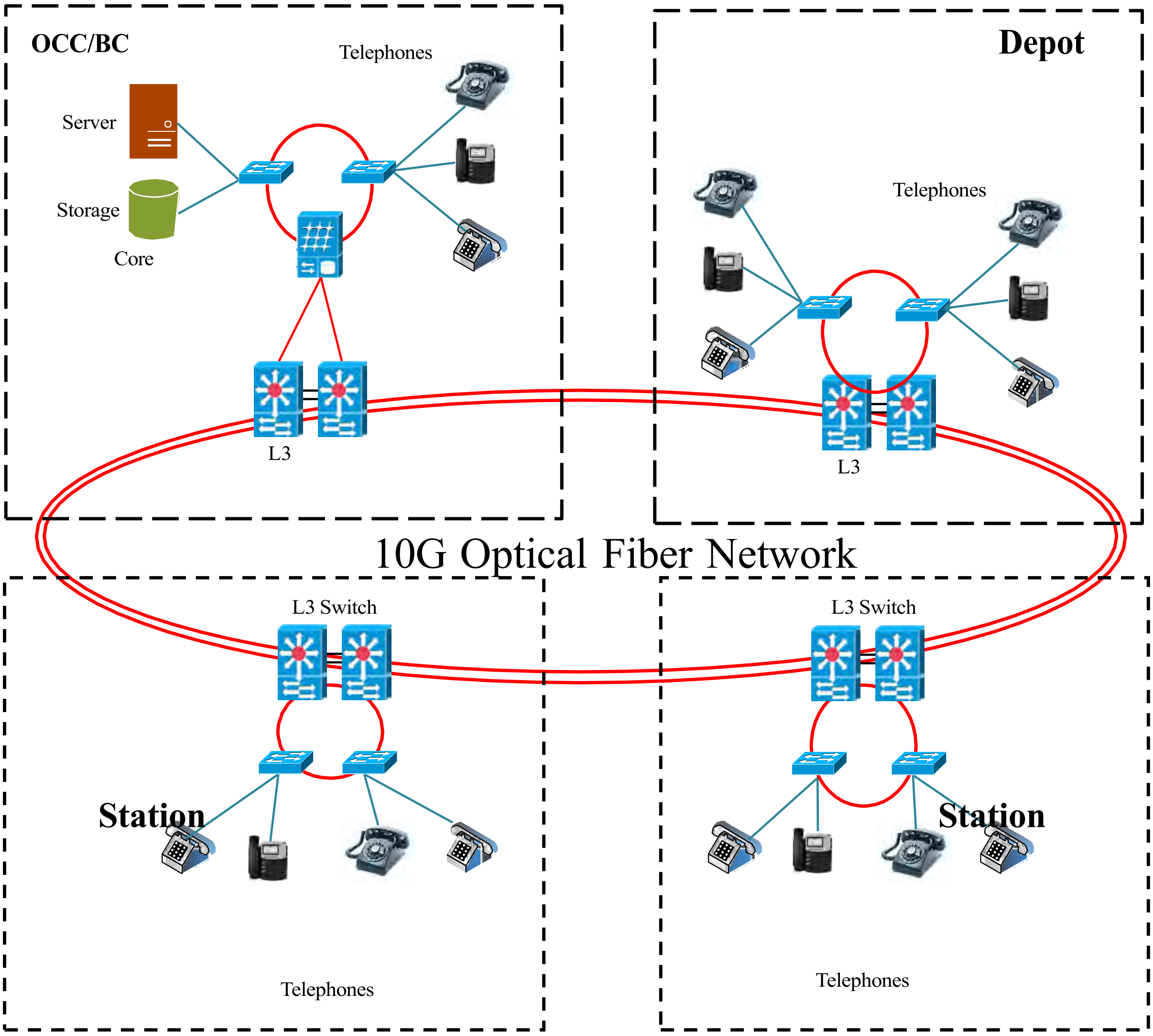


Figure 12-8 Telephone System Architecture

12.11.1.4 Telephone System Facilities

The telephone exchange system will cater to the following:

(1) Administrative telephone system:

- Telephone exchanges are proposed at the OCC and at selected stations to cater to local subscribers;
- These telephone exchanges will be interconnected through optical fibre communications;.
- The exchanges will be of IP PABX with industry-standard facilities for subscribers;
- Subscribers may be provided with either or both of an IP or digital telephone;
- The administrative telephone system will include conference facilities for subscribers.

(2) Operational telephone system:

- Train management, administration and control;
- Subscribers may be provided with either or both of a Direct line telephone or Dispatcher telephone system.
- This system caters to direct, single-button, communications between OCC Controllers, Station Masters, Level Crossing Guards and other selected subscribers, appropriate to their requirements;
- This system enables instant communication between agencies directly involved in train operations and infrastructure maintenance;
- Similarly, the Station Master / Level Crossing Guard may contact the OCC controller via single touch button.

12.12 Radio Communication System (RCS)

12.12.1 Objective of Radio System

The objective of Radio system is to provide fully dedicated wireless voice communication channels to support operational and maintenance requirements on the Railway.

12.12.2 Radio Communications System Configuration

The RC system may be configured with LTE or LTE-compatible technology, which will, preferably confirm to applicable EIRENE / 3GPP or equivalent standards.

Radio channels shall include at least the following facilities:

12.12.2.1 Train Dispatching Calls

- Between Train Controllers / Dispatchers in the OCC and drivers on trains in service, including awaiting departure from stabling yards;
- Between Train Controllers / Dispatchers in Depots and shunters in depots and stabling yards;
- Between Train Controllers / Dispatchers in Depots and drivers on trains in depots and stabling yards.

12.12.2.2 Data Transmission

- For transmission of safety-critical train control data between the OCC systems and the Vehicle-On-Board (VOB) systems on trains;
- For transmission of VOB systems monitoring data from Train Control Information Management (TIS) System to the OCC systems;
- For transmission of On-board CCTV system video streams to the OCC systems.

12.12.2.3 Maintenance calls

- Safety-critical conversations between Train Controllers / Dispatchers in the OCC and maintenance staff at the trackside (carrying hand portable radio sets);
- Safety-critical conversations between Train Controllers / Dispatchers in Depots and maintenance staff at the trackside (carrying hand portable radio sets);
- Conversations, which may be safety-critical, amongst Operations and Maintenance (O&M) staff with hand portable radio sets engaged on maintenance works at stations, trackside and depot areas.

12.12.3 Radio Dispatcher Workstation

A Radio Dispatcher Workstation (RDW) will be provided at the OCC and in Depots for the Train Controllers / Dispatchers to make radio communications with the train drivers on duty. RDWs will comprise a Liquid Crystal Display (LCD) monitor, a keyboard with mouse, a handset and a monitor speaker. The RDW shall be a redundant system. The RCS will allow a Train Controllers / Dispatchers in the OCC to make local or global announcements via the Central PA system. The RCS will enable O&M staff to communicate with one another or with the Traffic Dispatcher via hand-portable radio sets. Radio communications between Train Controllers / Dispatchers in the OCC, Depots and other radio users shall be recorded by the CVRS (Central Voice Recording System). Radio Base Stations at all stations shall automatically manage the call processing and the necessary channel assignments.

The candidate technologies and their attributes for the proposed Radio communication system are given in Table 12-8.

Table 12-8 Features of Radio Technologies

S.No.	Radio Technology	Features
1.	GSM-R	Well proven for train control and voice communications; Standards available (EIRENE); Suitable for Radio Block Control systems; Limited capacity; will be phased out by 2025.
2.	LTE-R	No standards yet available; Standardization by 3GPP by 2020; Some systems are existing eg: Korea, China, Ethiopia; Under procurement for SLR National Telecommunications Network.
3.	TETRA	Well proven for voice communication; Not suitable for Radio Block Control systems.

12.12.3.1 Choice of Train Radio Technology for CSRP:

The two competing radio technologies are

(i) GSM-R and

(ii) LTE-R

GSM-R is well proven and LTE-R is in experimental stage. The differences between the technologies are given below in Table 12-8(a)

Table 12-8 (a) Differences between GSM-R and LTE-R

S.NO	Feature	GSM-R	LTE-R
1	Capacity especially at major Railway station.	Insufficient max 23 trains & limited voice.	Sufficient band width
2	Network resource utilization	Not efficient, since circuit switched	Good. Packet switched.
3	Support for data services a. Bitrate b. Packet delay c. Support to modern data services such as video, internet access d. Rail IOT services e. Passenger internet	Limited a. 9.6 kbps b. 400ms c. Does not support d. No e. no	Wide bandwidth a. high through put 100 Mbps b. <50ms demonstrated c. Supports d. Yes e. Yes
4	Proven ness	well proven	Evolving Technology
5	Supports to ETCS signalling	Yes, well proven	Experimental stage but promising
6	Advance voice communication functionality such as broadcast, emergency call, location-based call process, functional addressing	Yes, well proven	Experimental stage but promising
7	Transmission quality of safety critical applications plus non-critical applications at the same time.	Well proven	Needs to be verified, Experimental networks commissioned.
8	Interoperability	Well proven	Evolving Technology
9	Frequency	Uplink 876-880 MHz Dnlink 921-925 MHz	450 MHz,800MHz,1.4GHz, 1.8GHz
10	Band width	0.2 MHz	1.4 – 20 MHz
11	Modulation	GMSK	QPSK/16QAM
12	Spectrum efficiency	0.33 bps/Hz	2.55 bps/Hz
13	Mobility	Max 500km/h	Max 500km/h
14	Hand over success rate	>99.5%	>99.9%
15	All IP	No	yes
16	obsolescence	Will be phased out in 2025	Emerging technology
17	Multiple access	TDMA	OFDM down link SC-FDM up link

As can be seen from the table, though GSM-R is well proven in ERTMS it has major limitations of capacity and obsolescence. UIC has issued FRMCS (Future Railway Mobile Communication Services) requirements which currently under adaptation by LTE (through 3GPP). Regarding LTE-R, requirement specification is not frozen and meanwhile it has been implemented in few places. If CSRP has to float tender now, we do not have a LTE-R spec to follow. However, it may evolve during the implementation stage of CSRP.

GSM-R is a proven system both for train control and voice communication, but may be replaced by LTE-R by year 2025. Also, LTE has been selected as the preferred technology for the SLR National Telecommunications Network, although there are no existing standards for LTE-R, these are expected to be finalized by year 2020.

Accordingly, GSM-R compatible technology is recommended for adoption.

12.12.4 System Safety Considerations

The Radio Communications System, based upon data transmissions via wireless LTE technology and optical fibre cables, will be fully duplicated for reasons of availability. Dual-redundancy is a feature that can be used, in conjunction with other systems to demonstrate a degree of confidence necessary for system safety.

Train data radio and radio block centre radio functions are safety critical, which must be demonstrated in accordance with recognised international standards. As a consequence, it is strongly recommended that these systems be assessed by an Independent Safety Assessor (ISA), which body will also verify and validate the Safety Case for these systems and facilities.

12.12.5 Voice services

12.12.5.1 Point-to-Point Voice Calls

Point-to-Point Call (PTP) is the same type of call as a normal GSM call. It is a voice call between any two parties where both parties can talk simultaneously.

12.12.5.2 Voice Group Call Services

Voice Group Call Services (VGCS), quite similar to walkie-talkie communication but with a single uplink handled by the network (only one person can speak at a time). Group voice calls provide voice communications between numbers of users in a predefined local area, all of whom are members of the same call group.

12.12.5.3 Railway Emergency Call

Railways Emergency Call (REC) is a special VGCS defined as 299 with the highest priority possible (0), dedicated to urgency. Emergency Area Broadcast is required to alert other railway staff in a specific area during an emergency situation.

12.12.5.4 Shunting Emergency Call

Shunting Emergency Call (SEC) is a special VGCS defined as 599 with the highest priority possible (0) for shunting group/members during an emergency situation.

12.12.5.5 Voice Broadcast Service

Voice Broadcast Services (VBS), like a VGCS but only the call initiator can speak (the other are only listeners). Broadcast voice calls provide one-way voice communications from a single user to multiple users in a pre-defined local area, all of whom are members of the same call group.

12.12.5.6 Multi-Party Voice Call

The system is supporting multi-party voice communications between up to six different parties. Any of the parties involved in a multi-party voice call shall be able to talk simultaneously.

- This Supplementary Service provides a mobile subscriber with the ability to have a multi-connection call, i.e. a simultaneous communication with more than one party.
- A precondition for the multi-party service is that the served mobile subscriber is in control of one active call and one call on hold, both calls having been answered. In this situation the served mobile subscriber can request the network to begin the multiparty service.
- Once a multiparty call is active, remote parties may be added, disconnected or separated (i.e. removed from the multiparty call but remain connected to the served mobile subscriber). The maximum number of remote parties is 5.

12.12.6 Data services

12.12.6.1 Text Message Bearer Service

The network will support transmission of point-to-point and point-to-multipoint text messages between subscribers.

12.12.6.2 Bearer Service for General Data Applications

The network will support range of data communications between subscribers, such as e-mail, etc.

12.12.6.3 Bearer Service for Automatic Fax

The network supports fax transmission between mobile users.

12.12.6.4 Bearer Service for Train Control Applications

The network will support safety-critical driver safety device and Radio Block Centre systems at Levels 2 and 3.

12.12.6.5 Bearer service for Locomotive Data Transmissions.

The network will support safety critical locomotive data transmissions via VOB systems.

12.12.7 System Architecture

The concept design for system architecture, shown in Figure 12-9, is a typical block diagram that illustrates a potential requirement for an Infill Radio Block Centre (I-RBC) at Aluth Ambalam, which is located on the Kosgama – Kiriwandala Section that is proposed for reconstruction on a new alignment as part of a road improvement project. The term generic term Radio Block Centre describes the location of signalling systems that control train movements within a pre-determined geographical area, and does not refer to any particular block section. The RBTMS servers are located at the OCC, and are connected via a dual-redundant DTS network with RBCs at each station and infill locations (refer to following paragraph). As may also be seen, a further dual LAN connects ground controller, field controller and radio base station (RBS).

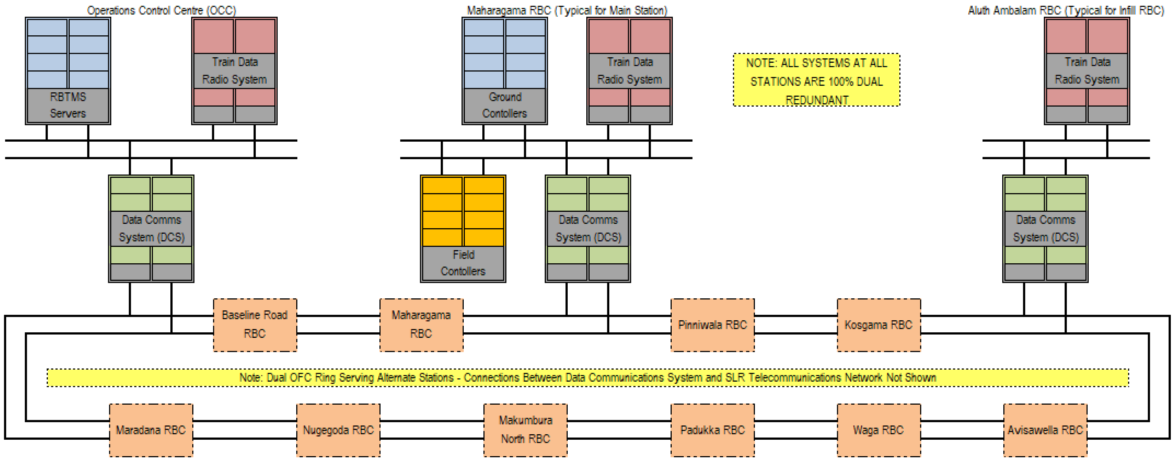


Figure 12-9 RBTMS System Architecture

RBSs will typically provide coverage over an area of 3 km with some overlap to ensure adequate signal strength. Antennae may be distributed along the ROW spaced at intervals of 300m – 500m. Additionally, multiple frequency ranges (4 should be adequate for KV Line) will be proposed to avoid mutual interference between adjacent base stations.

12.12.8 Frequency Bandwidths Used for Signalling Purposes

The proposed signalling system, described in Chapter 7, has been implemented in different countries and under differing regulatory requirements. The following sequence of illustrations, Figures 12-10 to 12-13, show the various frequency bandwidth demands for each system.

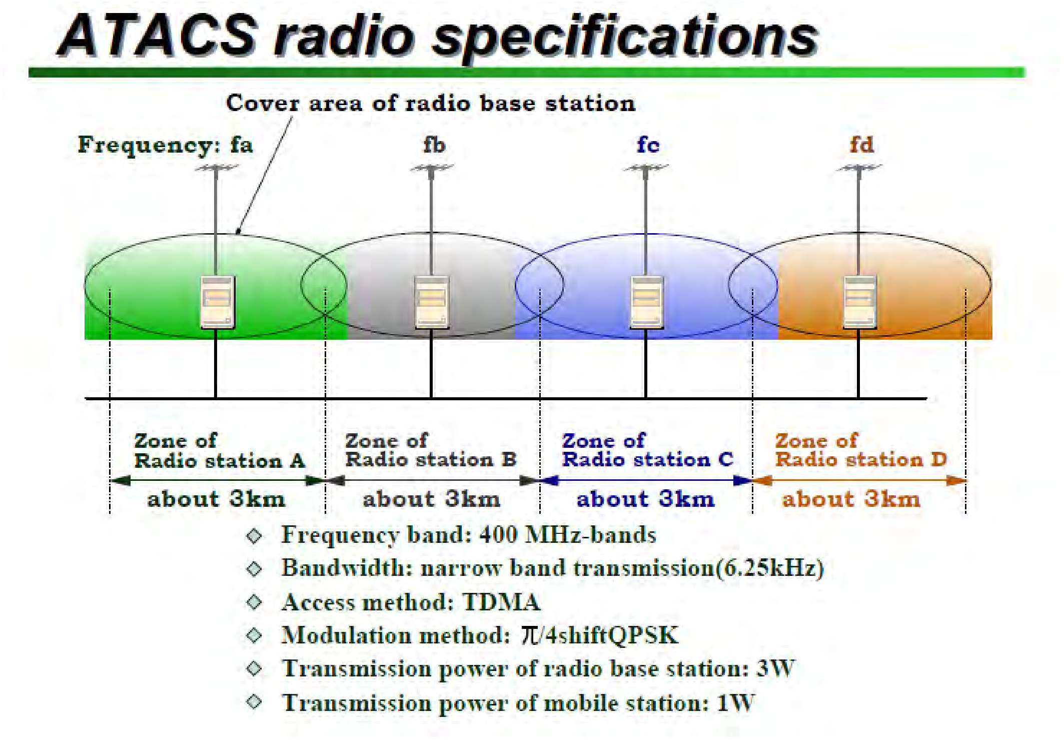


Figure 12-10 ATACS Radio Specifications (JR East, 2008)

4 Frequency bands and channel arrangement

i) Railways GSM 900 Band, R-GSM (includes Standard and Extended GSM 900 Band):

- for Railways GSM 900 band, the system is required to operate in the following frequency band:
  - 876 MHz to 915 MHz: mobile transmit, base receive;
  - 921 MHz to 960 MHz: base transmit, mobile receive.

ii) Extended Railways GSM 900 Band, ER-GSM (includes Standard and Extended GSM 900 Band):

- for Railways GSM 900 band, the system is required to operate in the following frequency band:
  - 873 MHz to 915 MHz: mobile transmit, base receive;
  - 918 MHz to 960 MHz: base transmit, mobile receive.

NOTE 1: The term GSM 900 is used for any GSM system, which operates in any 900 MHz band.

NOTE 2: The BTS may cover a complete band, or the BTS capabilities may be restricted to a subset only, depending on the operators needs.

The carrier spacing is 200 kHz.

Figure 12-11 GSM-R Frequency Bands (UIC, 2011)

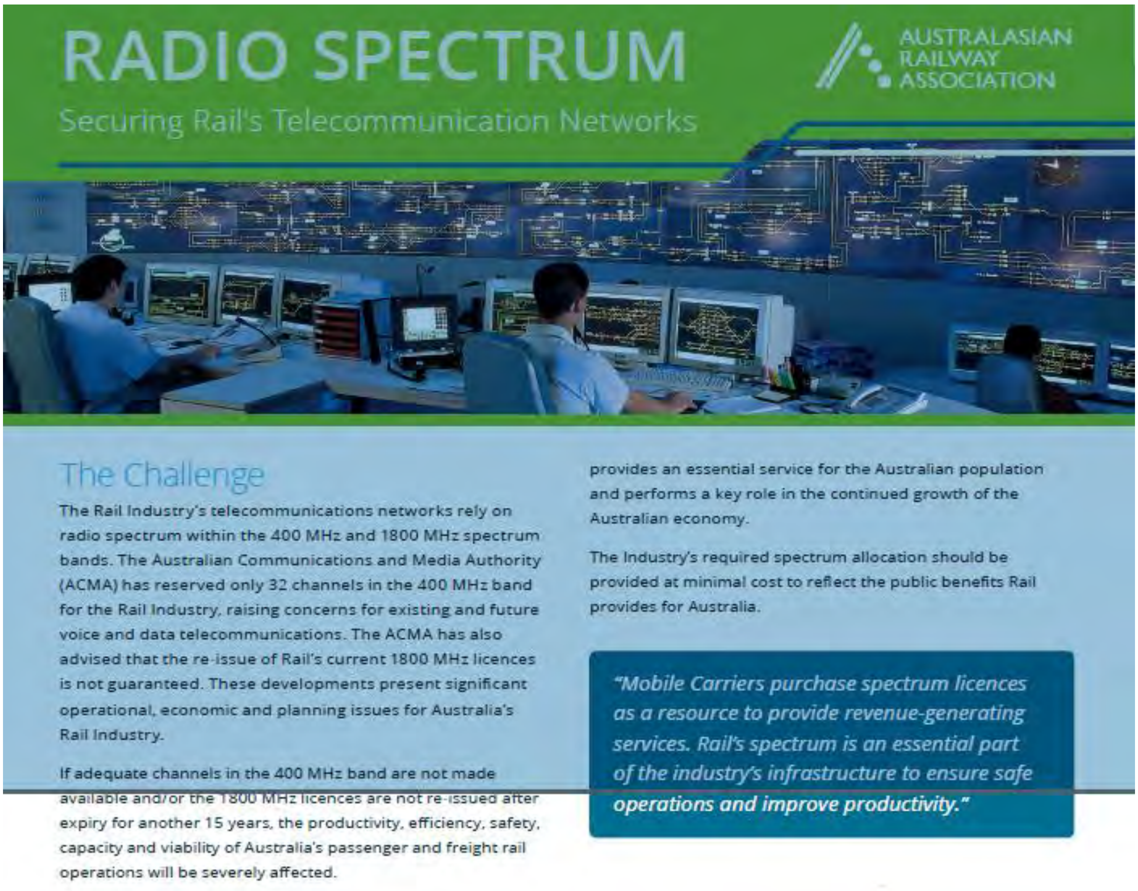


Figure 12-12 ATMS Radio Spectrum (IRSE, 2012)

PTC Technology Survey

- 5 PTC technologies were identified. Others are under development.
- Pending FRA Safety Certification.
  1. ITC / I-ETMS using the Meteorcomm PTC 220 radio with an RF bandwidth of 25 kHz (Freight and Passenger lines)
  2. ETMS uses 220 MHz or 160 MHz radios
  3. Modified Cab Signaling – Does not use a 220 MHz radio.
- FRA Safety Certified
  4. ACSES using the GE MDS TD220 Radio with an RF bandwidth of 12.5 kHz (Amtrak Lines). The reduced RF bandwidth of this technology where used, could impact the amount of spectrum needed.
  5. ITCS (i.e. Michigan Line)

Figure 12-13 PTC ETMS Technology Survey (APTA, 2012)

By comparison, CBTC in Europe utilizes a frequency of 5.9 GHz (5.875 – 5.925 GHz) for train data radio communications (UIC, 2016).

Appropriate frequency bandwidths for the KV Line, Main Line, Puttalam Line and Coastal Line will be determined during the Detail Design Stage.

12.12.9 Spectrum requirement for LTE-R for CSRP:

Frequency spectrum is needed to be allotted to SLR for implementation of CSRP Train Radio with LTE-R technology. The amount of spectrum required depends on the supported services and traffic volume of these services, used radio technology etc.

According to FRMCS the applications in Railways are

(i) Critical – Applications that are essential for train movements and safety, emergency communication, shunting, track maintenance, ATC etc.

(ii) Performance – applications that help to improve the performance of railway operations such as train departure, telemetry etc.

(iii) Business – applications that supports railway business operations such as wireless internet to passengers etc.

The spectrum has to cater to critical (max) requirement from the following segments

a) A reference railway stations (including shunting area, depot etc.)
b) A reference train(a train staff, on board system)
c) High density railway line segment (may parallel lines with high train density)

The maximum requirement of the above three are taken into account for spectrum estimation.

12.12.10 Method of Spectrum requirement estimation:

Method used as per FRMCS Architecture Technology Document No. FW-ATWG 1903/FM56 (17) 030.version 1.0.1.

As per this document, the traffic model parameters are taken. The traffic in mbps is estimated using the FRMCS document.

To calculate bandwidth requirement in MHz, spectrum efficiency of 2.5 bits/Hz has been assumed.

The critical location from bandwidth consideration is in and around the Maradana station. This is a three-way junction with nine lines total in three directions. It has 10 platforms.

A radio cell radius of 4KM can be consider at Maradana station. This radio cell will have the maximum telecom traffic and this cell will decide the bandwidth requirement. Accordingly, reference high-density rail segment as per table 5 of FRMCS report has been considered. As per this, table the bandwidth requirement for this cell of the three scenarios are as under in Table 12.8(b)

Table 12-8(b) Bandwidth requirement in LTE-R

Scenario	Traffic		Bandwidth(MHZ)	
	DN link	UP link	DN link	UP link
Traffic scenario Critical (ETCS, control to driver voice, emergency call, Telemetry, maintenance of the track etc.)	1.288 Mbps	1.08 Mbps	0.5 MHz	0.42 MHz
Traffic scenario performance (critical + real time video monitoring)	1.448 Mbps	74 Mbps	0.6 MHz	30 MHz
Traffic scenario Business (critical + performance + internet for passengers & railway staff)	45.6 Mbps	85.2 Mbps	18.2 MHz	34 MHz

- Recommendation:

A bandwidth of 34MHz in the UP link and 18.2 MHz in the DN link will be the requirement for LTE-R train radio system for CSRP project.

12.13 Closed-Circuit Television (CCTV)

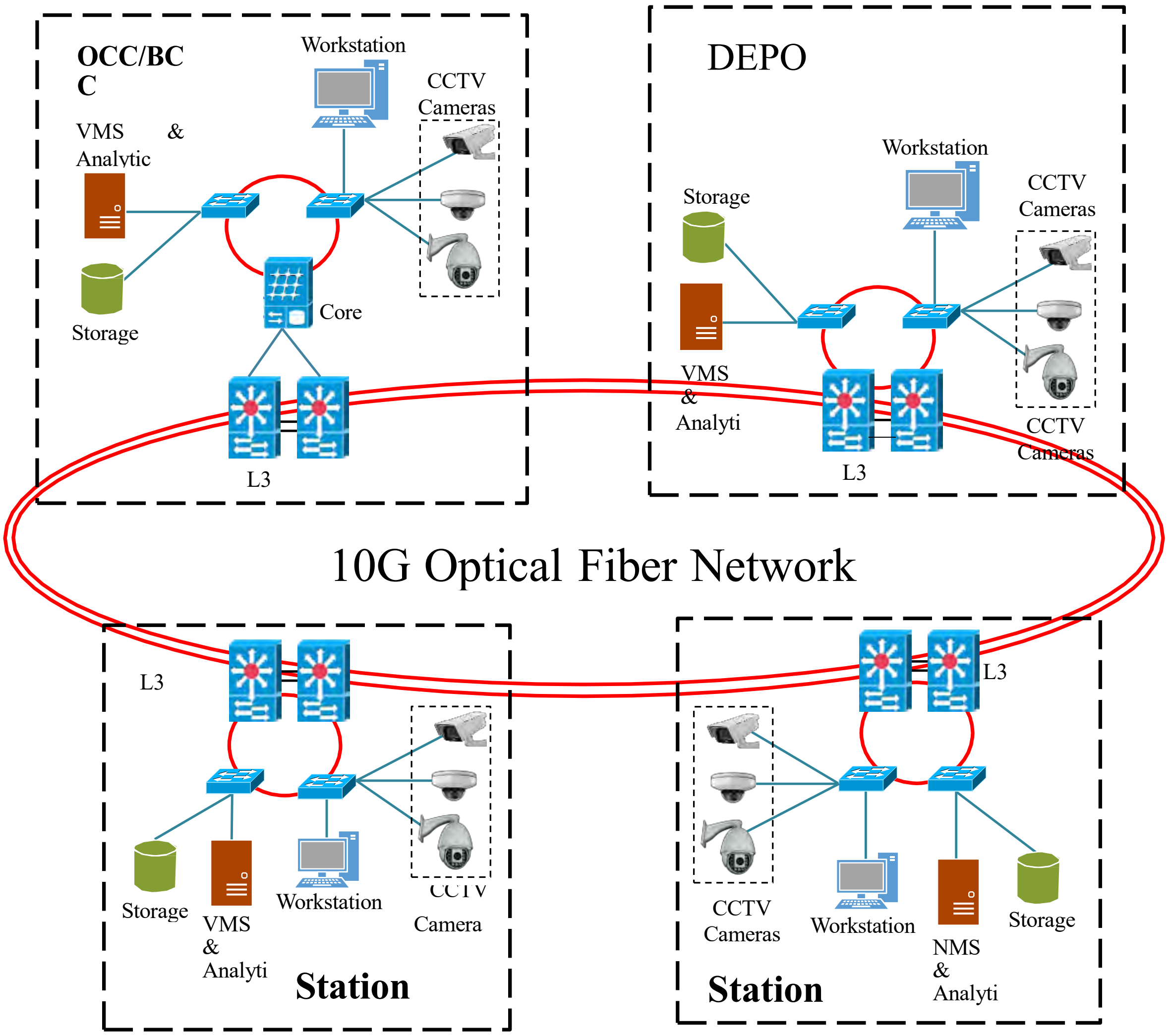


Figure 12-14 CCTV System Architecture

The Closed-Circuit Television (CCTV) system uses an advanced video management system for camera control and monitoring, recording management, alarm handling and protocolling system events and user actions, as shown in the generic system architecture of Figure 12-14. CCTV for VOB systems is not shown in Figure 12-14, but is considered below and one use of which is partly shown in Figure 12-15.

The Operator Clients have access to the entire system of all stations centrally and can able to control the cameras with priority to the stations. Video analytics features are considered for the cameras at the important/ priority locations.

12.13.1 Overview of the Proposed CCTV System

(1) Platform Surveillance – for monitoring of entraining and detraining of passengers at all platforms of all stations of KV line;

(2) Station Surveillance –for monitoring entire station area locally from concerned station and remotely from OCC / BCC;

(3) CCTV surveillance system for monitoring important locations in all depots of KV line both locally and remotely from OCC / BCC;

(4) CCTV surveillance system for monitoring important locations outside the stations, such as, Receiving sub-station, Parking and specifically identified theft prone areas etc., from station and remotely from OCC / BCC. Night vision IR illuminated cameras may be used as per special needs.

(5) The station surveillance CCTV System both live and recorded videos will be accessed simultaneously from the following locations:

- At station

  - Station Control Room

  - Station Security Control Room

- At OCC by OCC controllers (Traffic Controllers / Chief Controller / Deputy Chief Controllers etc.);

(6) The depot surveillance CCTV system both live and recorded videos will be accessed simultaneously from the following locations. This can be optional depending on the depot size and activities:

- Depot Control Center (DCC) and Security Control Room in Depot;

- Controllers at OCC.

(7) Video recording system provides primary recording locally at the respective stations and at nominated stations adjacent to halt stations for all KV line;

(8) For depots the local recording will be provided in the respective depots and mirror recording at the OCC or any other suitable location (optional);

(9) CCTV surveillance of level crossings will be recorded at the OCC and will be transmitted for display in driver's cabs of approaching trains, as shown in Figure 12-15.

12.14 Master Clock System

The Master clock system will be installed in the OCC, with sub-master and slave clocks installed at the stations.

Master Clock system will be synchronized to GPS with date/time. In the absence of valid GPS signal, the Master Clock system operates in free running mode with internal clock supplying the time signal. On restoration of the GPS signal the receiver validates the GPS signal automatically without any manual intervention.

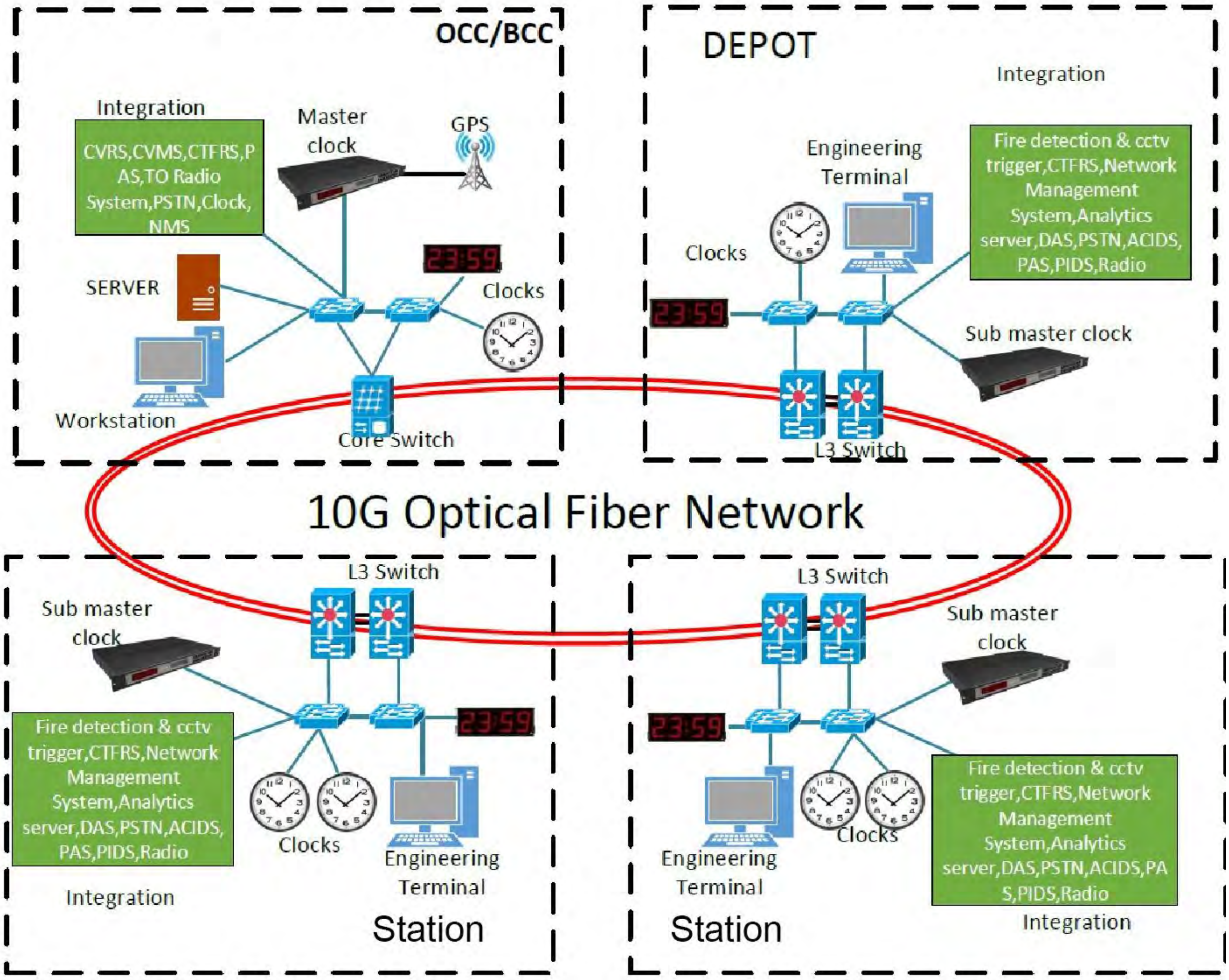


Figure 12-15 Master Clock System Architecture

The Master Clock will work as NTP Server and all equipment supporting NTP can use it as a time source.

Changing of time and date is done from the Master Clock. The actual time and date is shown on a display.

In case no time message is received from the Master Clock the Sub-Master Clocks, Analogue and Digital Slave Clocks automatically change to run on their own built in time reference. When the synchronization is restored, the Sub-Master Clocks, Analogue and Digital Slave Clocks automatically change to receive time from the Master Clock.

The Master Clock is equipped with an internal quartz oscillator as well as GPS Satellite receiver module that will give long-term accuracy stability. Manual change of time and date can be done at the Master Clock with a program function.

The slave clocks will be able to retrieve the time information from either of the best available Master Clock, which are synchronized to precise time through GPS sources.

12.14.1 Redundant Master Clock

A Master Clock is kept as stand by to act as a backup of the main Master Clock kept at OCC. In case of any failure of the main master clock, all digital and analogue slave clocks will receive synchronized time signals from this redundant master clock

The two master clocks operated in redundant mode automatically negotiate the master and slave status and synchronize each other precisely through an optical link. The clocks are synchronized by NTP in which additional telegram are transmitted to clocks in order to adjust the time for selectable time zones.

12.14.2 Sub-Master Clocks

Sub-Master Clocks will be installed at all the stations and depot. Each Sub-Master Clock Unit shall receive the time-of-day information via DTS, convert as necessary and distribute to display clock units. Each Sub-Master Clock Unit shall have an internal time-of-day clock to continue time- of-day distribution to display clock units if time-of- day information via DTS is lost. These clocks will distribute the synchronized signal to all slave clocks.

12.14.3 Slave Clocks

The slave clocks are programmable for 12 hours and 24 hours. These can be an analogue or a digital clock and outdoor and indoor type with suitable visibility.

12.14.4 Alternative to Distributed Clock System

GPS based decentralized clocks both digital and analogue are an attractive option to be considered during the design stage for economy. In this scheme individual clocks, which are very high accuracy, can be installed at requisite locations. Each clock runs in its own. In the FS estimates however the distributed clock system has been considered for cost estimate.

12.15 Public Address System

The public address system (PAS) will have to be designed specifically for rail applications. These must be IP65 rated and should be vandal resistant.

A centralized announcement system is proposed to make announcements remotely from OCC to all stations on the line. An auto announce feature is also proposed by taking data from the train control and signaling system. The proposed networked digital PA system and voice evacuation system will have to meet certain minimum speech transmission index criteria and total sound pressure level etc.

The proposed Integrated Public-Address System shall consist of the following sub-systems:

- A central system to manage the information for complete line located at OCC;
- A local system installed in each station.

In each station, the system is based on a Station server to simultaneously control the audio information inside the station. At the central position (OCC), the OCC servers give to the user the functions to manage the information in each station and to inform passengers in real time according to the Train movement information through signaling system.

Integrated Public Address System (PAS) having:

- OCC PAS server;
- Station PAS server;
- OCC Workstation Man-Machine Interface (MMI);
- Station Workstation MMI;
- Call stations;
- Audio Matrix Units;
- Amplifier units;
- Ambient Noise Sensors;
- Loudspeakers.

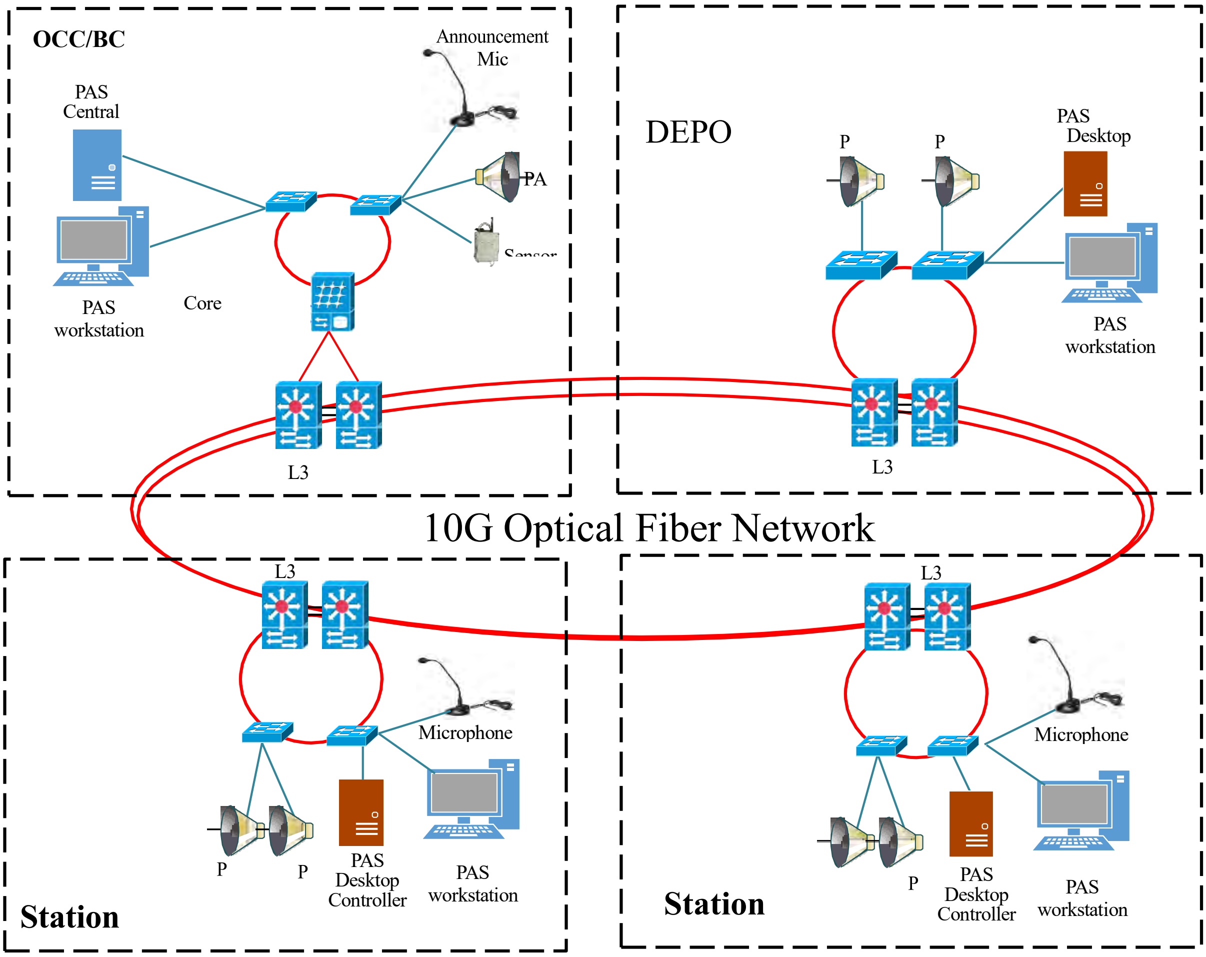


Figure 12-16 Public Address System Architecture

All the sub-systems and system components will be integrated with each other to provide required functionality of coordinated audio message broadcasting. The proposed system should be complying with BS 5839 part 8 and EN 60849 standards

12.15.1 Central Call Recording System

Voice Recording system / Centralized Digital Call Recording System (CDRS) system will provide multichannel voice recording and indexing of direct line communication including communication from all direct line consoles and emergency telephone lines, two-way radio communications, emergency or fire messages broadcast on station PAS initiated from OCC and on train borne PAS initiated from OCC.

12.15.2 System Description

Voice recording system can record multimedia interactions from IP telephony environments in Active recording mode across any number of locations. It provides the capability to capture, store, tag, and search and replay multiple interactions.

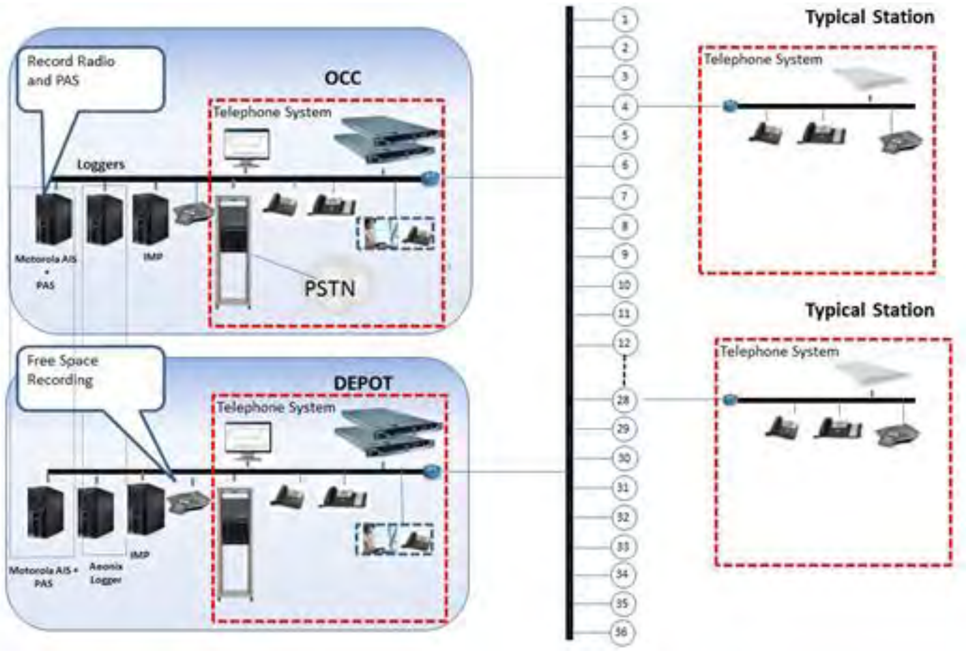


Figure 12-17 Central Call Recording System

A multichannel voice recording in duplication of recording servers is provided at OCC.

The recording will include multichannel voice recording and indexing of (typical):

- All RCS voice communications including all Public and Private Calls;
- All calls on direct line telephones provided in:

a. Stations and Station Control Room;

b. OCC;

c. Depots/DCC to OCC;

d. Emergency Telephones;

e. Traction and Receiving substations calls to OCC;

f. Any telephone connected on the IP PBX network.

- Calls on the dedicated, phones in the station control room, and OCC for contacting the emergency services;
- Incoming calls from the PSTN to public phones;
- Recording of free space voice conversations of all Controllers in OCC and station control room;
- All live PAS audio messages originating from PAS operators and Telephone-to-PAS operations.

12.15.3 Access Control System

Access control system (ACS) is used to restrict the entry by unauthorized persons into the sensitive rooms and areas and the same will be used for the staff attendance systems.

12.15.4 Design Considerations

The ACS for Sensitive rooms and areas will consist of the following:

- Standalone controller based Smart Card Reader;
- Smart card reader;
- Electro-magnetic Lock;
- Break Glass Unit;
- Exit Switch;
- Magnetic Door Sensor.

ACS will typically be provided at the locations detailed in the following sub-sections.

12.15.4.1 Platforms

- All Equipment Room Doors / External Face of All Emergency Exit Doors

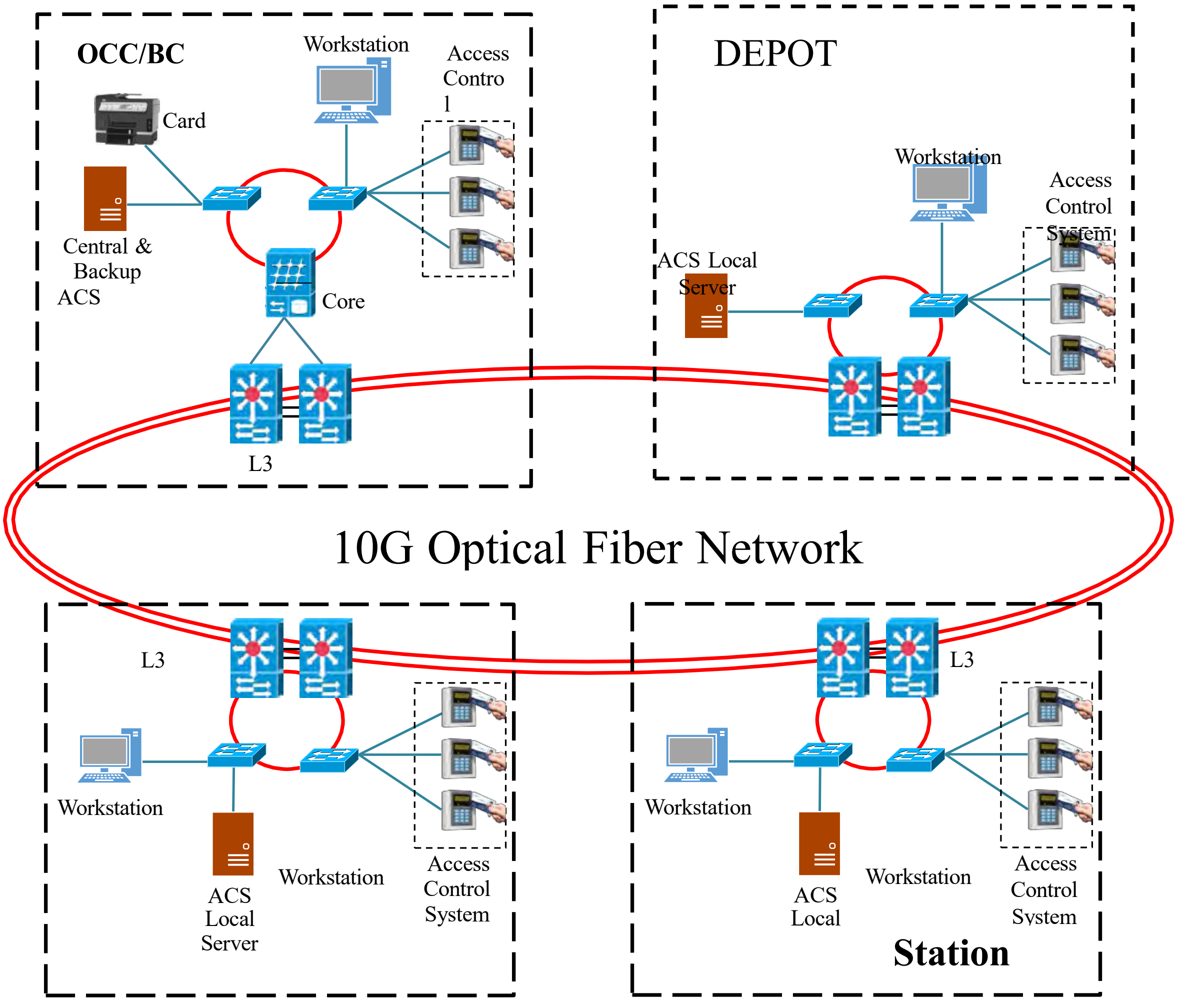


Figure 12-18 Public Address System Architecture

12.15.4.2 Concourse (in case of elevated stations)

- Station Control room
- Ticketing room
- Ticket Cash Room
- All Equipment Room Doors

12.15.4.3 Depot & OCC & BCC

- Depot Admin Building Equipment Room Doors
- OCC Room
- NMS Room
- Receive substation Entry Door
- Traction substation Entry Door

- Auxiliary substation Entry Door
- All Access Control Building Doors

Each Station and Depot will have two local ACS Servers. It will be connected to one workstation that will be installed in Station Telecom Equipment Room. One Central ACS server has been considered at OCC. Database of local staff access will have update facilities in OCC / DCC as appropriate.

12.16 Wi-Fi System

The Wi-Fi System, shown in Figure 12-19, will provide public access Wi-Fi coverage to stations, and is composed of multiple access points (APs) assuring radio coverage of all the required Sites and areas.

The Wi-Fi access points (APs) are connected to the LAN/WAN System using the routers and / or switches available in technical rooms or outdoor industrial switches. The LAN AP‟s are managed by connecting them to an Access Controller (AC) in order to provide the network with reliability, flexibility and scalability.

The Wi-Fi System is based on appropriate Wi-Fi internal antennas, connected to indoor APs, and external antennas, connected to outdoor APs.

Additional ACs can be added in order to extend the coverage area or increase the number of Staff wireless connections if necessary. Each outdoor switch has spare ports, which can be used to connect.

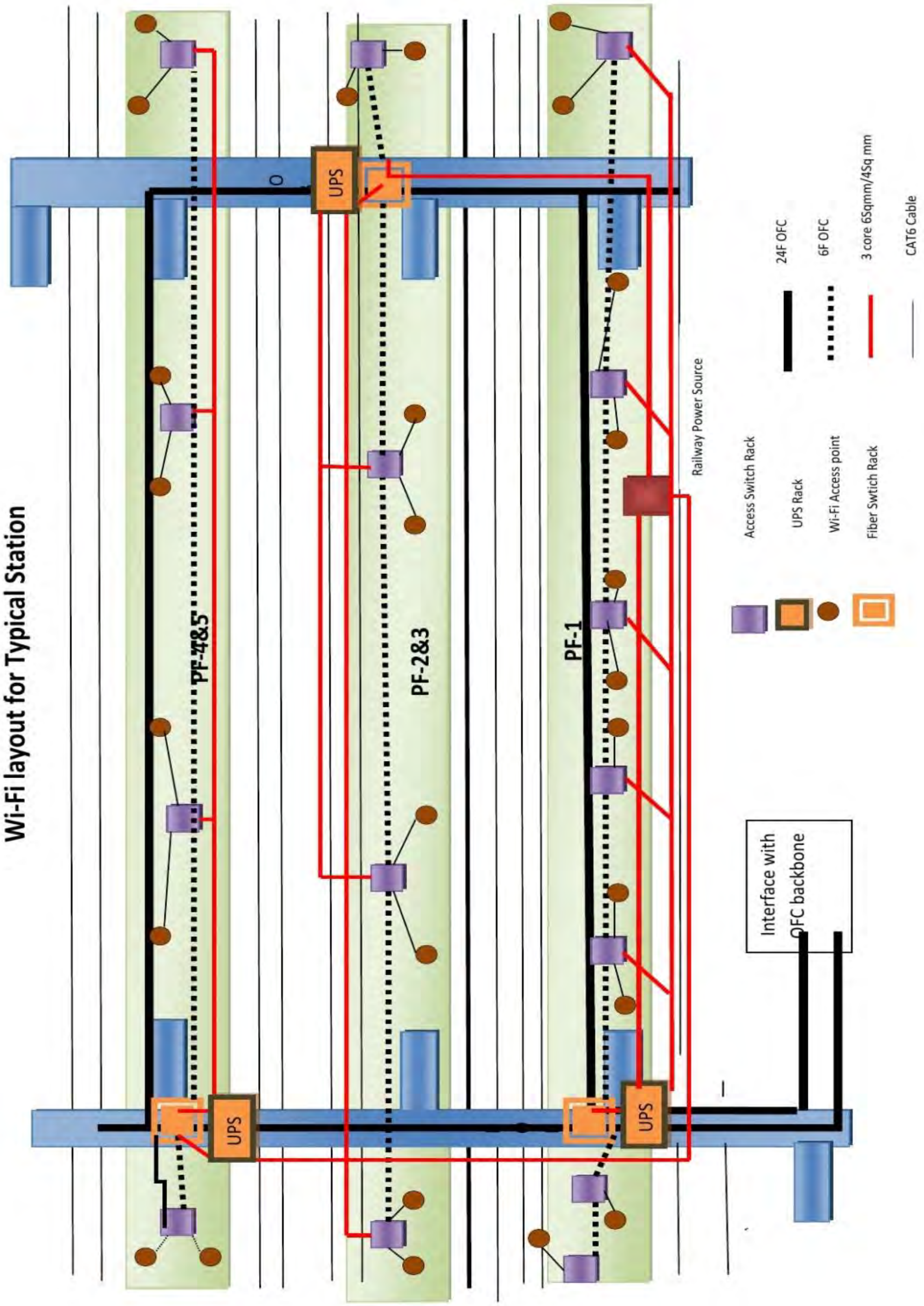


Figure 12-19 Wi-Fi System Architecture

12.17 Telecommunications Power Supply

At every station a 230V, 3-phase UPS power supply system is proposed for telecommunications equipment operation. For economy purpose a common UPS can be provided for signaling systems and telecommunications systems during Detail Design Stage. However, in the FS costing separate UPS for telecommunications is included.

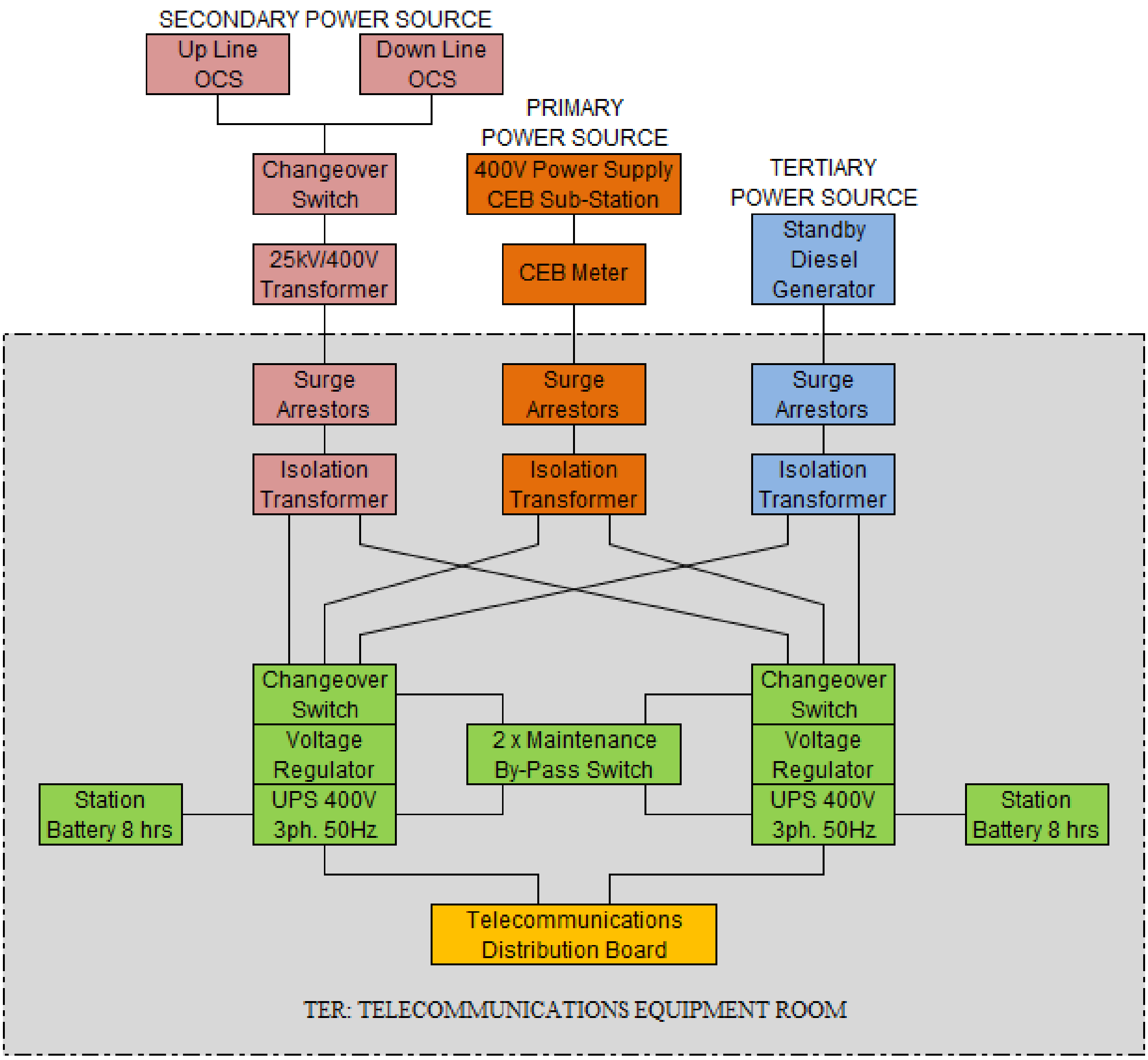


Figure 12-20 Preliminary Power Supply Block Diagram

12.17.1 System Description

The telecommunications UPS will consist of two identical UPS-inverter/rectifier, each with an identical battery set, connected so that one UPS-inverter/rectifier seamlessly backs up the other and one battery set seamlessly backs up the other.

The UPS system will draw input AC power from three alternate sources namely,

- Traction power supply
- Local electricity supply
- Emergency diesel generator.

The purpose of input electrical power supply and diesel generator power is to maintain charge on the telecommunications UPS batteries. The proposed design will maintain telecommunications systems power supply for at least 8 hours.

12.18 Telecommunications Equipment Rooms

A telecommunications equipment room will be provided in the station building for every station and in the OCC and Depot buildings. Separate equipment rooms for the National Telecommunications Network provider may be necessary at main and sub-stations to assure maximum security of systems.

The sizes of the rooms, which will accommodate the telecom equipment at different locations, will be decided during the Detail Design Stage.

12.19 Emergency Communications

Mobile Train Radio is proposed, which can be used in emergency from the train and also from track side using hand held radios.

12.20 Communication systems for Line Maintenance and OCS Maintenance

Radio hand sets are proposed to be used by the line maintenance and overhead electrification maintenance staff to communicate with OCC, station, depot etc.

12.21 Level Crossing Communications

Depending on the system of train working, the watchman / guard who operates level crossing gates may need to communicate with OCC or an adjoining station. This requirement can be met by either use of the radio system or by use of dedicated direct line telephones from the level crossing to the adjacent stations.

12.22 Service and Diagnostic System System Requirements

A Service and Diagnostic (S&D) system shall be provided for monitoring and supervision of health of telecommunications equipment to enable carrying out maintenance with optimum manpower, thereby reducing the MTTR of the equipment.

This system shall be able to predict failure of the equipment based on the deterioration of the parameters being monitored, thereby avoiding a potential future failure of Telecom system.

The S&D terminals shall be provided with the Telecom Maintainer ta the Stations and with the Telecom Fault Controller at the OCC. Each Telecom Maintainer‟s S&D terminal shall monitor health of Telecom equipment under his area of control.

The S&D computers shall analyze, link and evaluate indications such as status, fault, and event indications. With the help of such analysis and the specific fault conditions, the S&D computer shall identify the displayed faults. These faults shall be stored in a data-base separate for each system. Eliminated faults shall be stored for statistical evaluation at a later stage.

The system should create alarms and reports for equipment maintenance and trouble shooting. It shall also be possible to send the alarms in the form of SMS to technicians in the field.

12.23 Operations and Maintenance

The Maintenance philosophy shall have to investigate all failures, major failures, repeated failures, design defects and provide all necessary corrective actions.

Maintenance Plan shall be followed based on Maintenance Schedules, Operations and Maintenance (O&M) Manuals, etc. as part of O&M documents.

The Maintenance Plan shall consist of preventive and corrective maintenance of the system, including, but not limited to the following:

- Maintenance philosophy and approach.
- All necessary tasks for first line, second line, third line and corrective maintenance.
- Frequency of each maintenance task.
- The Maintenance Schedule shall consist of the following information on each task described in the Maintenance Plan:
- The equipment, sub-systems covered in the task.
- Step by step procedure to carry out the task.
- Tools and test equipment required for each task.
- Diagrams and flowcharts by illustration, if applicable.
- Adjustment procedures for all field adjustable units.
- Recovery procedures, if applicable.
- Precautions to be followed by maintenance personnel and
- Estimated duration and Manpower required.

O&M manuals shall be used as reference for maintenance philosophy.

12.24 Staff training

The telecommunications systems described above are all of current technologies and successful introduction of these technologies will depends on adequate staff training in these areas. Therefore, a detailed, coordinated and cooperative training program is essential.

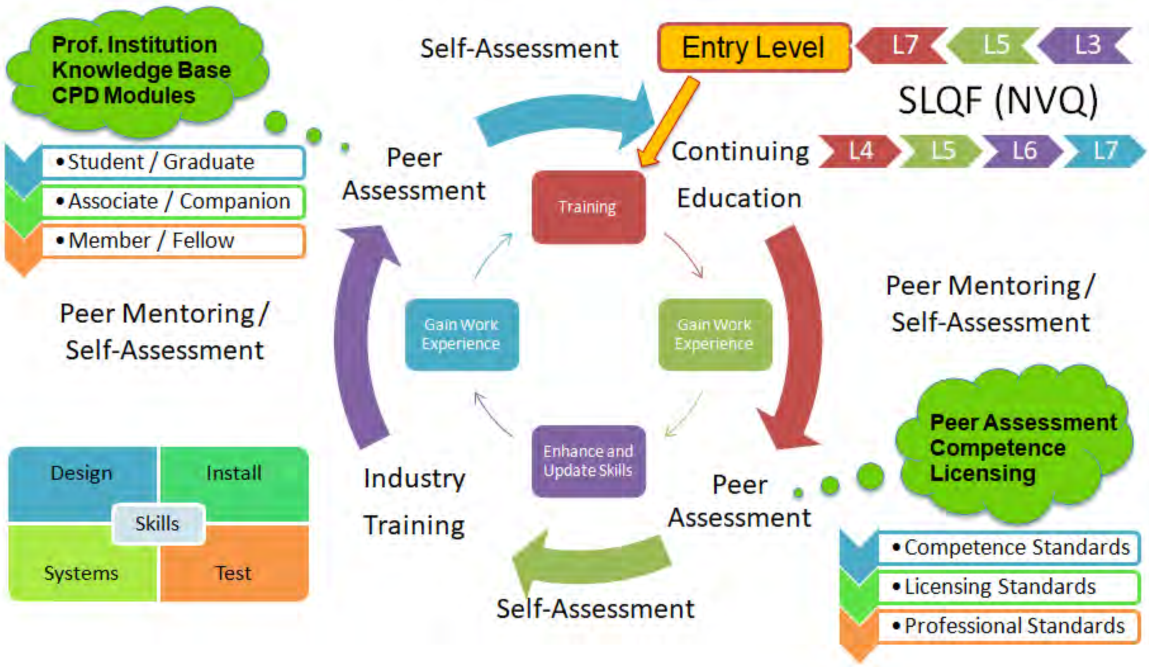


Figure 12-21 Continuous Professional Development of Education, Skills and Competence

These can be achieved by dedicative training courses targeted for each subsystem this will help the staff in charge of the sub system to receive intensive training on operations and maintenance. The probation of training courses should be the responsibility of individual sub-system suppliers the cost towards the training has been included in the cost estimate for the FS report.

The bid documents that will be prepared based on detailed design stage of the project should include requirements for training, for example the number of people to be train and duration of training etc.

Part D. Interface Considerations

12.25 Vehicle On-Board Systems and Equipment

12.25.1 Inter-operability Considerations

DMUs, EMUs and locomotives allocated for use on KV Line will be equipped with on-board cab signalling systems and, where economically viable, VOB systems may be retro-fitted to an existing fleet. Although dedicated to the KV Line, these units will also be able to operate across non-equipped lines with on-board equipment set at ETCS Level 0.

The train length (of the preceding train) is used to calculate / assure a safe separation distance for a (following) train. Consequently, non-equipped DMUs and / or locomotives needing access to KV Line should operate as subordinate units to a Pilot Loco or DMU equipped with cab-signalling (quantity of equipped locomotives will be decided during detailed design). Train crew would make the necessary inputs to the VOB via the DMI.

It is considered that 3 locomotives (2 in use, 1 standby) may be an appropriate fleet size for the KV Line. Depending upon public service schedules, crew availability, service delays, etc., loco-hauled long-distance passenger services could either change locomotives at Maradana / Colombo Fort or a Pilot Locomotive may be attached at the same location.

For this reason also, freight trains should be equipped with a suitable means to confirm continuous completeness of the train. There are a number of options as discussed in Chapter 7 Signaling and Train Management. For this project, an interim alternative option for provision of axle counter sections at strategic locations has been proposed, which locations are proposed below:

- Baseline Road – start of KV Line to confirm and correlate driver data input;
- Makumbura North – prior to / subsequent to proposed junction to Horana Valley Line;
- Padukka – start of KV Line metro service from Avissawella direction;
- Kosgama - prior to / subsequent to proposed junction to Kelaniya Line.

12.26 Vehicle-On-Board (VOB) Systems and Equipment

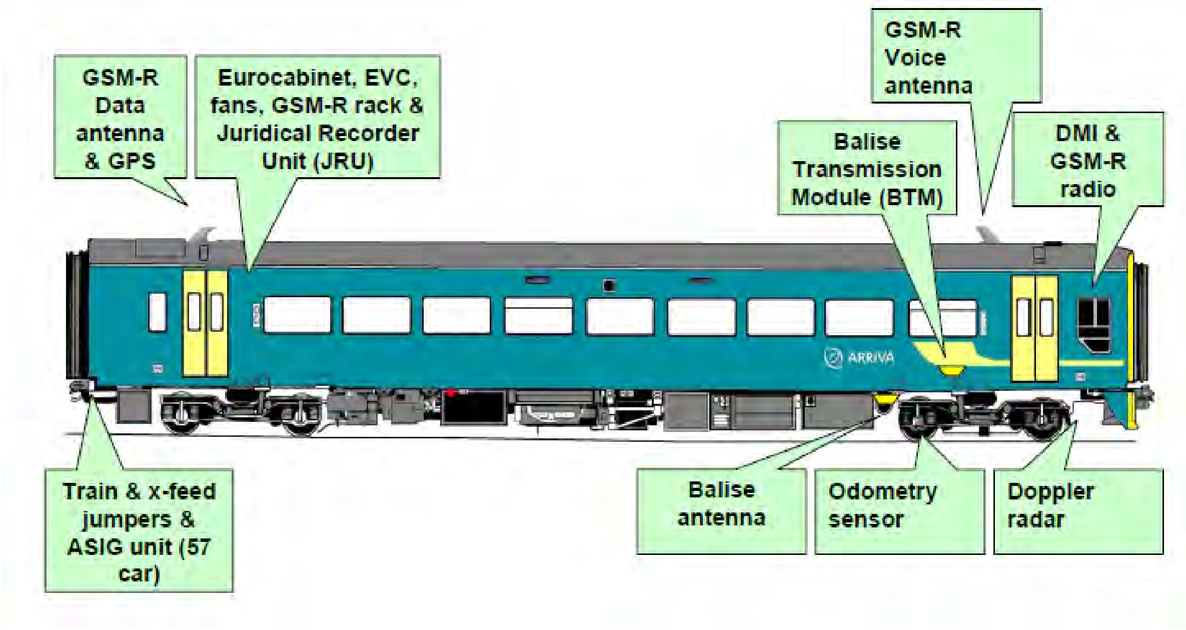


Figure 12-22 UK Class 158 DMU ERTMS VOB Equipment Retro-Fit (Arriva, 2011)

The vehicle, shown in Figure 12-22, forms one half of a 20-year old, 2-car DMU retro-fitted with vehicle on-board (VOB) equipment suitable for ERTMS Level 2 operation. As may be expected, and as expressed by SLR, retro-fitting equipment to vehicles of that age is somewhat problematic. Quite apart from the difficulty of finding unused space in existing rolling stock, for the case of Cambrian Line retro-fitting has also raised some issues and caused a number faults. By contrast, JR East had implemented multiple simulations of wayside and VOB systems prior to fitting equipment into trains for integration testing. Contrary to implications of the schematic diagram in Figure 12-22, equipment was mounted beneath the train, except for the radio antenna, and not inside the cars.

A virtual map of the railway (i.e. KV Line and any other ETCS controlled line to which access rights may be granted), gradient profile, track alignment and permanent speed restriction data will reside in the VOB control equipment computer, together with the specific performance database for the train / vehicle. Train crew (driver) will enter / confirm the train ID, which action will activate the train schedule for the particular train / vehicle. The VOB RCS will continuously transmit speed and location data to the OCC. The RCS at the OCC will respond by transmitting an LMA and speed profile via the RBC to the VOB computer, which will calculate an optimum journey profile and display at the DMI. The VOB computer will correlate odometer readings with GPS data to determine location and, upon receipt of location information for an in-track balise, will adjust calculated location results. Continuous transmissions between train and control centre will assure the train's location is known at all times and correctly displayed to the dispatcher at the OCC.

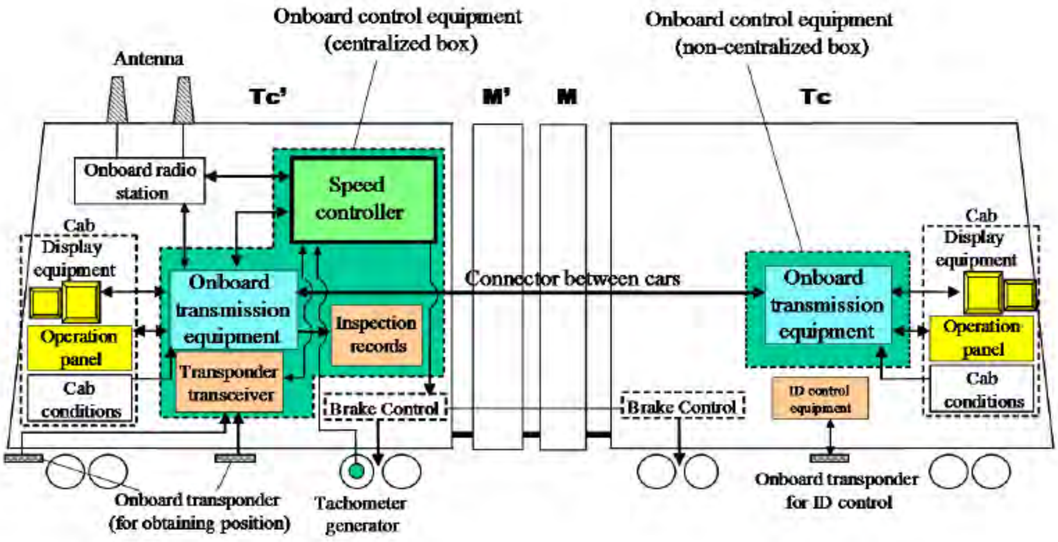


Figure 12-23 VOB Equipment Schematic (ATACS, 2014)

The VOB will continuously monitor train performance and intervene with braking application, should the need arise, e.g. due to excessive speed, approaching end of LMA, cancellation of LMA or receipt of emergency stop command. The intervention will cease upon driver responding by reducing speed or stopping the train. Only one DMI will be active at any time, with the other DMI being in sleep mode.

The safety-critical radio, RCS, is an essential and integral part of this train management and control system.

12.26.1 Rolling Stock Interface

Data communications between the OCC, RBCs, trains and level crossings require a safety-critical radio network. It is essential to assure that the same technology and protocols are adopted as for train data radio system., including the requirement for video streaming on the approach to level crossings and for passenger safety, internal and external security purposes.

Additionally, reliance on radio may increase the amount of verbal communications between train dispatchers and drivers. Since there is a risk of misunderstandings during conversations, these too should be considered as potentially safety-critical and may necessitate a similar radio network.

The VOB database for each DMU rake or locomotive should store a virtual map of the routes over which the set / unit is permitted to operate and, that map may be updated frequently for changes to operating conditions. However, there will be a size limitation, not just on the storage media, but also the physical space available for hardware within the rolling stock. The possibilities for exchange of maps and other data with databases in the OCC will be explored during Detail Design Stage.

Facilities for automatic train operation and automatic turn-back, both with driver present, should be proposed. Additionally, facilities for remote driverless operation should be proposed to enable depot staff to move empty trains on designated lines entirely within the depot area.

Health monitoring of On-Board systems should be provided to the greatest extent possible, facilitate event recording and incorporate remote interrogation facilities.

Whereas fitting of VOB equipment to new rolling stock is relatively straightforward as a design issue, the same is not necessarily true for existing rolling stock. There are several major considerations when considering the equipping of existing rolling stock, including those mentioned below:

- Available space for driver consoles, and VOB systems and equipment;
- Mutual EMC (electro-magnetic compatibility) between proposed new systems and existing systems;
- Financial viability considering remaining life-cycles and refurbishment possibilities for rolling stock under consideration.

12.26.2 Inter-operability

Any requirement for full inter-operability is a matter for SLR consideration due to implications for CAPEX and OPEX, together with operational considerations, e.g. age / condition of rolling stock. Retro-fitting of rolling stock will consider two major factors:

- Space availability – ease of installation and maintenance access;
- Mutually Assured EMC – Electro-Magnetic Compatibility.

Rail vehicles equipped with cab-signalling, VOB train management and communications systems would have access to all lines across the SLR network due to the additional facility for selection of Level 0 / STM (Specific Transmission Module, i.e. National network) modes. However, those rail vehicles not equipped for cab signalling or equipped, but for a lower level, will not have access to equipped lines or lines that are equipped at a higher level. Engineering trains, for example, must either be equipped or work in tandem with an equipped Pilot locomotive.

12.27 Level Crossings

Table 12-9 Summary of Level crossings on KV Line

No.	Type of Protection	Number	Remarks
1	Electrically Operated Barriers	9	All to be closed
2	Mechanically Operated Barriers	31	Majority to be closed; some to be upgraded to full protection
3	Warning Bells and Flashing Red Lights	24	Some to be upgraded to full protection
4	Unprotected	83	Some closed; some to be protected by level crossing speed restrictions

Wherever possible, level crossings will be permanently closed and substituted by appropriate grade-separated crossings. Where some doubt may exist, tools such as Road-Rail Exposure Index (RREI) and Delay Cost will be used. As a rule of thumb, double-tracking and a three-fold increase in service frequencies will increase RREI to such an extent that substitution by grade-separated crossings may be necessary.

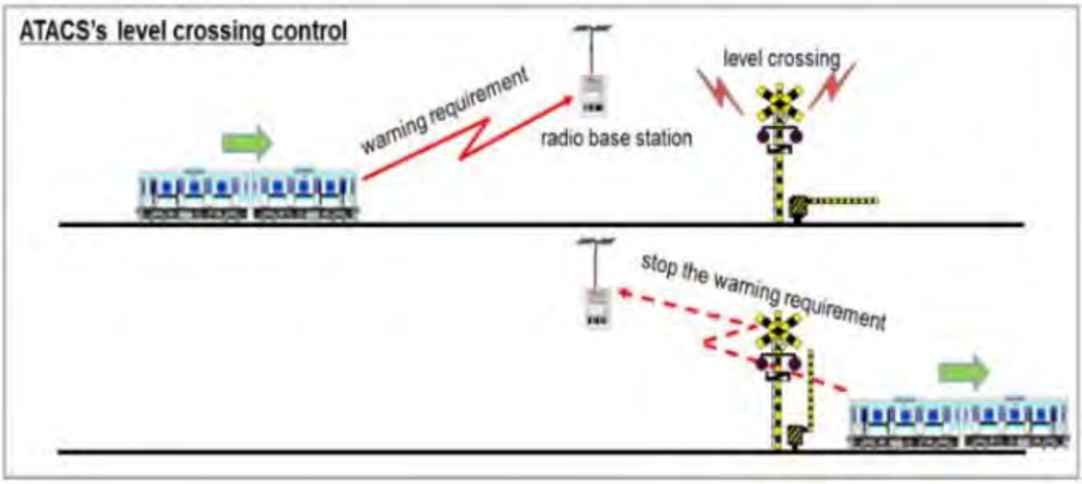


Figure 12-24 Radio Control of Level Crossings (IRJ, 2016)

Those level crossings already protected to the greatest extent can be assumed as candidates for closure, and forms the premise for the remarks in Table 12-9, which information may be revised during Detail Design Stage. The general arrangement plan for a fully protected level crossing is shown as Figure 12-25. CCTV, a critical control system for automatic level crossings, is shown attached to an equipment, although attachment to a radio tower or lamp standard may be more desirable.

Each level crossing will be interfaced with the Radio Block Train Management System (RBTMS) in order to enhance safety, even for level crossings that are currently unprotected. As a minimum level of protection a Temporary Speed Restriction (TSR) could be imposed through the medium of RBTMS by change to a parameter held on the system database. The use of radio control for level crossings has been proven by ATACS, Japan (IRSE, 2016), as shown in Figure 12-24. The list of level crossing types is given in Table 12-10.

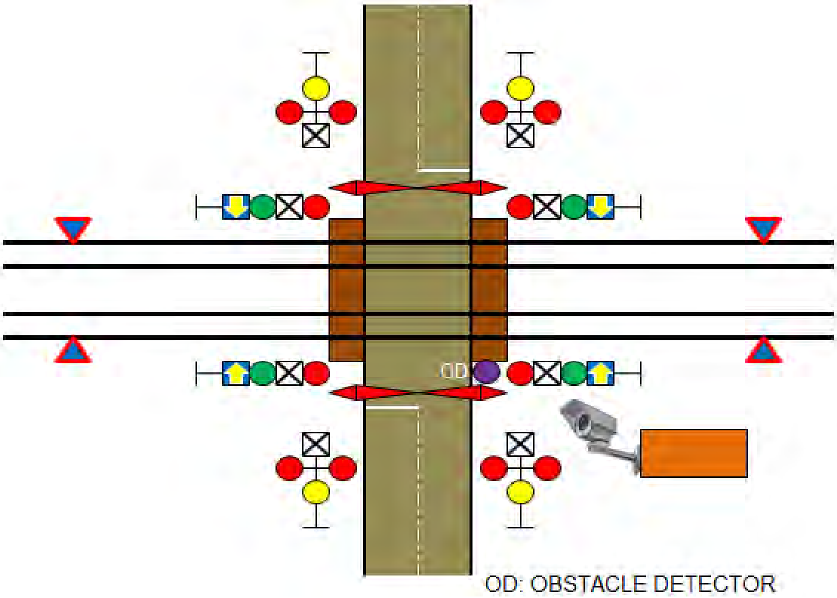


Figure 12-25 R-EOB-OD Protected Level Crossing with CCTV

With regards to other level crossings, the degree of protection will be assessed on a site-by-site basis during detail design in order to properly consider all relevant factors, including usage, clear view and road classification.

Appropriate levels of protection for level crossings will be considered during the Detail Design Stage.

Table 12-10 Summary of Level Crossing Types

No.	Type	Description
1.	R-EOB-OD (Upgraded)	Fully Protected Remote Controlled Barriers with Warning System, CCTV and Obstacle Detection System;
2.	AHB:	Fully Protected Automatic Half-Barriers with Warning System;
3.	LOHB:	Locally Operated Half Barriers with Warning System (Community not SLR);
4.	AOLC:	Automatic Open Level Crossing without Barriers with Warning System;
5.	MHB:	Manually Operated Half-Barriers with Warning System;
6.	MFB:	Manually Operated Full- Barriers with Warning System;
7.	R-OLC	Open Level Crossing with RBTMS Temporary Speed Restriction

12.27.1 Communications: Train VOB Systems to Level Crossing System

On the approach to an automatic level crossing or a guarded level crossing, the train VOB systems will send a request to initiate the closing sequence or warning of approach to inform the watchman / guard of the need to lower the barriers. After passing over the level crossing, the train VOB will send notification to open the level crossing for road-users. These requirements can be met by use of the safety-critical radio system.

On the approach to an automatic level crossing, the train VOB systems will send a request to the level crossing for CCTV coverage of the road approaches to assist the train driver to adjust his speed to suit prevailing traffic levels. These requirements may be met by video streaming information either via the OFC and DTS or via the safety-critical radio system.

12.27.2 Communications: Level Crossing CCTV to Train VOB Systems

Figure 12-26 Driver's Cab Level Crossing CCTV Display (Prom-Electronica, 2007)

12.28 Depots and Workshops

Depots and workshops will be provided with two systems:

- Depot Signalling System (DSS);
- Depot Protection System (DPS).

12.28.1 Depot Train Movements

Facilities for driverless operation of some trains for movements entirely within the depot and only on designated tracks are proposed for depot personnel utilising hand-held control units and TDRS. The facilities will include use of the safety-critical RCS for control and movement of a train by a shunter at the trackside and voice communications with the Depot Controller.

The design for the DSS will be site specific and developed during Detail Design Stage.

12.28.2 Depot Protection System

The design basis for the Depot Protection System is proposed to allow trains access to maintenance tracks and depot whilst protecting personnel from potential injury from moving trains. Control of the DPS will be exercised at each point of access to a depot maintenance track and managed from Depot Control Room, which will include a control panel, together with mimic diagram depicting DPS status of protected tracks. Each local control point will be equipped with access control and video intercom system for communications with the Depot Controller.

The DPS will be will be site specific and developed during Detail Design Stage.

(1) Overhead Contact System (OCS) Interface

(2) Electrification of the KV Line may be implemented simultaneously with re-signalling or at a future date as an OCS with return earth wire system at an operating voltage of 25 kV ac. Telecommunications systems, equipment and cabling will require protection against EMI generated by the OCS and other sources in the surrounding environment. These must be a.c. immune and designed for minimal generation of EMI to avoid causing issues for other nearby systems and equipment. Suppliers should implement a coordinated EMC survey with OCS, Information and Communications Technology (ICT) and telecommunications suppliers to confirm system EMC performance levels, and to plan their coordinated testing strategy.

(3) In electrified areas, telecommunications power supply should be derived from the OCS with one feeder from each of the Up Line OCS and Down Line OCS reducing to a single feeder via a change-over switch. Additionally, some remotely located OCS motorized isolators may derive power from the signaling power supply. Both requirements should be coordinated for protection against transients and other fault currents.

(4) Earthing and bonding design for telecommunications systems and equipment should be coordinated with OCS as part of an integrated design for earthing and bonding.

12.28.3 Signaling Interface

Communication between the control centres and crossing stations will use dark fibres in fibre-optic cables arranged in dual-redundant ring formation. Ideally these would be laid either side of the ROW to assure diverse routing; however, telecommunications facilities are provided by separate contracts. As a consequence there may be only one fibre-optic cable within the ROW with the diverse route via a third-party network. In this eventuality, then encryption of signalling data may be necessary, which possibility will be explored and resolved during Detail Design Phase.

Data communications between the OCC, RBCs, trains and level crossings require a safety-critical radio network. Additionally, reliance on radio may increase the amount of verbal communications between train dispatchers and drivers. Since there is a risk of misunderstandings during conversations, these too should be considered as potentially safety-critical and utilise a similar radio network.

The safety-critical radio system should operate across a frequency band with availability of at least four frequency-bands for the KV Line. The number of frequency-bands may need to be increased for Maradana – Loco Junction section to cater for the multiple tracks, which will be determined during Detail Design Stage.

Video communications are necessary for the monitoring of level crossing operations with CCTV cameras that are remotely controlled from the OCC.

12.28.4 Depot Interface

12.28.4.1 VOB System Test Tracks

VOB System Test Tracks are necessary within depot areas and serve two different functions, which implies that more than one Test Track may be required depending upon design of track arrangements within the depot. Following completion of maintenance at either a Light Maintenance Depot or Heavy Maintenance Depot, the VOB systems may need re-calibration, re-correlation or re-commissioning, for which purpose the test track should be located within the depot area rather than stabling sidings in the operational area.

As a daily routine, drivers of trains stabled in sidings will activate the VOB systems and undertake the required data entry and exchange with RBTMS. Whilst this may be thought adequate to demonstrate the functionality of the majority of the VOB systems, the driver still needs to check the balise reader / transponder system by passing over a Test Balise before entering service.

In the event of the VOB systems not responding as expected, a failure will be declared and the train would be taken out of service and removed from the Departure Line back into the depot. This requires the Test Balise be located en route to the exit point of the stabling area, but with a convenient escape facility to avoid causing congestion on the main line by leaving the depot with faulty equipment.

12.28.5 ICT Interface

12.28.5.1 Asset Management System

The train control system requires route availability, dimensional, loading and performance data for rolling stock, which will be resident in the Asset Management database for motive power and rolling stock. TCS should be able to access that data on a read-only basis. This will be especially important when a non-resident locomotive / multiple unit wishes to access the KV Line.

From an infrastructure perspective it may be argued that the relevant sections of the AMS should be categorized as safety-critical since the database contains information necessary for safe operation of the railway. As an example, rolling stock performance and route availability are used for scheduling purposes. This data is then accessed for calculations of braking and safe distances by the signalling system and for granting right of access to lines and stations, which could lead to unsafe conditions or incidents where platform edges may be struck by over-size rolling stock. One potential solution could split the AMS into "Operational" and "Commercial" parts. This discussion will form a necessary part of Detail Design Stage.

12.28.5.2 Crew Management System / Fleet Management System

These closely-related systems will require access to real-time information from the live schedule that will be resident on the train control system. Access on a read-only basis will be arranged for both the systems. From a train operations perspective CMS includes safety-critical requirements for driver, who must possess licenses, be competent to drive the assigned rolling and "know the road", all of which should be considered as "Operational" rather than "Human Resources" requirements. Similar arguments may be considered for FMS. This discussion will form a necessary part of Detail Design Stage.

12.28.5.3 Management Information System

An MIS, similar to AMS, should perhaps be categorized as "Operational" and "Commercial" since a large part of the functionality is directly relevant to train operations and the remainder to commercial activities and administration tasks. The operational functions review performance data for trains and other assets, which may feed into commercial activities. Again, this discussion will form a necessary part of Detail Design Stage.

12.28.5.4 Passenger Information System

This system will require access to real-time information from the live schedule that will be resident on the train control system. Access on a read-only basis will be arranged for this system.

Part E. Construction, Operations and Maintenance

12.29 Construction Planning

A proposal for construction method utilising a system of blockades has been proposed in conjunction with consideration of options for underground or elevated sections. This section considers possibilities for use of a different construction method. Construction of the KV Line may be considered as four distinct phases or sectors, identified below, and which may be constructed simultaneously:

- Maradana – Loco Junction: Modifications for Additional Track; At Grade;
- Loco Junction – Malapalla: New Double-Track Elevated Section;
- Malapalla – Padukka: Double-Tracking; At Grade;
- Padukka – Avissawella: Rehabilitation of Single Track; At Grade.

A brief description of the procedures for each section follows, but the final concept will be developed during Detail Design Stage.

12.29.1 Maradana – Loco Junction Double Tracking

The limits of this section may be defined as Maradana Station, platforms 9 and 10, but excluding connections from the Main Lines, Colombo Fort side, and the start of the ramp for the new elevated section.

Between these two limits a new second track will be constructed for the KV Line, platforms 9 and 10 rehabilitated, new connections from platforms 1-8 provided, and a new connecting line will be constructed to the new light maintenance depot, Dematagoda. Upon completion, the new track layout will be integrated into the then-existing railway, which may mean continuance as single-track operation until such time as the new elevated section is complete. Upgrade to double track could be implemented stage-wise along the new elevated section pending completion through to Kottawa and Makumbura North.

12.29.2 Loco Junction – Kottawa Elevated Section

The limits of this section may be defined as the start of the ramp for the new elevated section near Loco Junction and the end of the ramp for the elevated section at Malapalla. However, the logistical end will actually be at Kottawa station, which is the end station for the single line section.

Between these two limits a new elevated section of double- track railway will be constructed for the KV Line. In order to maintain train services throughout the construction period, additional land may be required to facilitate construction of temporary track deviations. Upon completion, the elevated section could be brought into use in one or two stages, which are:

- A new alignment substituting for the existing single-track railway;
- A new double track Maradana – Makumbura North railway.

The final choice will consider the progress of construction works on both adjoining sections.

12.29.3 Kottawa – Padukka Double-Tracking

The limits of this section may be defined as the end of the ramp for the elevated section at Kottawa and Padukka station limits on the Avissawella side of the station. In the event that a decision is taken for construction of a new depot near Arukwathpura station, these limits could be extended.

Between these two limits a new second track will be constructed alongside the existing railway, and will be complete with all loops, sidings, passenger station facilities and, where required turnouts for future use as a double-track railway. Upon completion of the new track, the existing track will be cut and slewed into the new track at Kottawa and at Padukka. In the event that the new elevated track and Maradana – Loco Junction sections are ready for use, then the new alignment would be directly joined to the elevated section in preparation for the switch-over from existing to new single-tracks. Dismantling and reconstruction of the existing single-track railway would then proceed until final completion of the new double-track Maradana – Padukka railway.

This construction method has potential to compensate for any unanticipated delays in construction works at Maradana – Loco Junction section with the possibility for double-track operation between Padukka and Baseline Road, then change trains to the low level station and continue the journey to Maradana via the existing railway. Similar arrangements could be implemented for delays at Kottawa - Padukka section. The final options will consider the progress of construction works on all three adjoining sections.

12.29.4 Padukka – Avissawella Rehabilitation

The limits of this section may be defined as Padukka station limits and Kosgama station limits, in both cases the limits are on the Avissawella side of the stations. In the event that a decision is taken for construction of a new depot near Arukwathpura station, these limits could be shortened. Also, from Kiriwandala station limits on the Kosgama side of the station and the end of the KV Line at Avissawella station. The Kosgama – Kiriwandala section will be reconstructed as a new railway on a new alignment by a Road Development Authority (RDA) project, and may be excluded from the Scope of Works.

Between these four limits the existing section of single- track railway will be rehabilitated, as far as possible without interruption to services. However, the strong possibility of short-duration closures (for track / bridge reconstruction or signaling changeover) during overnight, week-end and national holiday periods should not be discounted.

12.30 Testing and Commissioning

A comprehensive Testing and Commissioning procedure will be followed in three stages as follows:

- Pre-delivery Testing
- Site Testing
- Integration Testing, Trial Operations and Commissioning

12.30.1 Pre-Delivery Testing

In order to minimise site testing activities, development and pre-delivery testing using modelling techniques are proposed. These should be carried out by the system suppliers to demonstrate the predicted performance of the train management systems, preferably under laboratory conditions and subjected to the levels of EMI specified in the relevant international standards. The duration of these off-shore testing activities may be expected to cover several months.

These modelling tests may be considered as additional to verification and validation activities (V&V), which should also be implemented.

Additionally, some integration testing of VOB signalling systems will be implemented off-shore at the vehicle supplier's manufactory. In a similar manner some integration testing of signalling with radio systems may be implemented off-shore at either supplier's test facility.

The appointment of an Independent Safety Assessor (ISA) is strongly recommended to assure system safety and review the System Safety Case.

12.30.2 Site Testing

There are several important Site Testing activities, which will be developed during Detail Design Phase, but which include those listed below:

- Incoming Materials Inspection;
- Post Installation Check-Out (PICO);
- Equipment and Cable Testing;
- Sub-system Testing;
- System Testing.

12.30.3 Integration Testing, Trial Operations and Commissioning

Systems Integration Testing will be undertaken only after completion of all prior testing by all parties who will participate in these activities, e.g. signalling, telecommunications, OCS, ICT, track, etc.

A pre-commissioning phase will facilitate a period of Trial Operations over a designated section of the KV Line, and for which use of the Elevated Section is proposed. Being elevated few interruptions may be anticipated and, train operations are unlikely to adversely affect others to any great extent.

Trial Operations, which could extend over a 1-3 months period, are essential for reasons stated below:

- The RBTMS signaling system is new to Sri Lanka;
- The VOB systems are new to Sri Lanka;
- The train data radio system is new to Sri Lanka;
- CCTV-to-train and vice-versa systems are new to Sri Lanka;
- The OCS is new to Sri Lanka.

Completion of Trial Operations, including completion the Safety Case may permit Provisional Hand-over to SLR for all or part of the KV Line, and Final Commissioning. The Warranty Period, normally two years, but for some projects three years, would commence with the main contractor, together with their suppliers, acknowledging and accepting responsibility for system maintenance for the full duration of the Warranty Period, include supply of any necessary equipment in exchange for faulty equipment.

12.31 Systems Health and Performance

12.31.1 RAMS

RAMS performance requirements will be developed in accordance with the relevant standards during the Detail Design Stage, but will be appropriate to SIL4.

The suppliers will be required to demonstrate through theoretical, design, manufacture, delivery and construction at site, testing, commissioning and operations that RAMS performance levels are in full conformance with the technical requirements.

The requirements for preparation of a System Safety Case and appointment of an Independent Safety Assessment will be developed during the Detail Design Stage.

12.31.2 System Health Monitoring

System faults and non-critical failures affect the system performance and there is a need for the health of systems and components to be continuously monitored and recorded to the greatest extent possible. This includes the provision of Health Monitoring Systems for the following facilities:

- Central System and Equipment;
- Radio Transmitting Stations;
- Ground Controller and Field Controller;
- Vehicle-On-Board Systems;
- In-Track Balise, preferably a Vehicle-Borne System;
- Point Machines;
- Level Crossings;
- Power supply system.

All health monitoring systems should facilitate event recording and incorporate remote interrogation facilities.

12.31.3 Network Management System Terminal

A Network Management System (NMS) Terminal with full facilities will be provided at the OCC:

12.32 Degraded Operations

Degraded operation will be implemented in order to operate trains during period of a failure of the RBTMS, a sub system or equipment

There are several scenarios, under which degraded operations may be necessary, including those listed below:

- Failure of VOB systems or equipment;
- Failure of track-side systems or equipment;
- Data Communication Failure – partial or complete;
- Total System Failure.

12.32.1 VOB Systems or Equipment Failure

In a worst-case scenario of total failure of VOB systems, but with system power unaffected, then the driver would isolate the TCS systems, enter Isolation (IS) Mode, contact the dispatcher and agree the LMA (voice, text message) as prescribed in Block regulations, and proceed in IS Mode to the nearest EOA Marker Board. The driver will again contact dispatcher to agree further LMAs until arriving at the nearest crossing station, where the train may be parked in a loop platform pending repair or recovery. Repair may be accomplished in-situ by exchange of faulty equipment unit.

12.32.2 Track-Side Systems or Equipment Failure

In this scenario, issue of an LMA will not be possible, due for example, to loss of points detection. The driver would enter Staff Responsible (SR) Mode, contact the dispatcher and agree LMA (voice, text message) and proceed in SR Mode to the nearest EOA. The driver will again contact dispatcher to agree further LMAs until clear of the failure zone, where the driver will re-enter Full Supervision (FS) Mode and the train may proceed as normal to destination.

12.33 Operations & Maintenance (O&M)

12.33.1 Existing Maintenance Systems

Current maintenance practices on the KV Line generally follow legacy methods tried and tested over time. However, these traditional means trouble-shoot faults at site under operational conditions and, which will inevitably result in delays to train services until the fault has been identified and corrective action implemented. The KV Line is predominantly signaled in accordance with mechanical practices albeit some signals are in fact multi-aspect colour light signals. Existing telecommunications equipment generally comprises public (PSTN) telephones, et al, and tablet / token block system.

The maintenance regime will perforce undergo changes in organization, work practices and levels of skills, also types of skills in order to meet the challenges of modern computer-based signaling.

12.33.2 Maintenance Considerations

Modern maintenance practice recognises three maintenance regimes – preventive, predictive, reactive – together with four means of implementation – diagnostic tests, corrective action at site, equipment exchange and workshop repairs. Reactive maintenance responds to critical failures and carries a high risk of financial penalties consequential to resultant delays to train services.

Predictive maintenance is predominantly a desk-based function that will review historical failures to identify potential system weaknesses, equipment in need of special or extra attention, and equipment due for exchange or servicing.

Preventive maintenance comprises sets of routine tasks that are implement as part of a daily, weekly or monthly schedule.

Reactive maintenance refers to all actions undertaken in response to a system or equipment failure, an incident involving damage to equipment or some other cause where attendance of maintenance staff is necessary or desirable.

Proposals for future O&M have been discussed in *Chapter 7 Signaling and Train Management*.

12.34 References

Many of the sketches contained in this chapter have been prepared by telecommunications experts of the Joint Venture Study Team; a small number have been sourced from technical publications.

Where the latter has been the case, each instance has been cited and full details of the reference sources are listed in the following table.

Table 12-11 The List of Reference Sources

Reference		Source
APTA, 2012	Fig. 12-13, p.12-32 (qv Slide 11)	Witbeck, K., 2017, "Positive Train Control in the 220 MHz Band," APTA International ITS PMP-Stantec Consulting Services, USA, Best Practices Workshop, Transit Communications Systems, USA, 17 April 2017. https://www.apta.com/mc/its/previous/2012a/presentations/Presentations/Positive-Train-Control-in-the-220-MHz-Band-Karl-Witbeck.pdf, accessed:25.08.2018, 08:40 UTC +0:00
Arriva, 2011	Fig. 12-22, p.12-50 (qv Slide 6)	Leppard, P., 2011, "Cambrian Level 2: In service experience – a Train Operator‟s perspective," Arriva Train Wales, UK, IRSE ERTMS Seminar, 15 November 2011; http://www.irse.org/knowledge/publicdocuments/6_CPH%20ERTMS%20P%20Leppard.pdf, accessed: 31.05.2018, 13:09 +05:30 UTC
ATACS, 2014	Fig. 12-23, p.12-51 (qv Fig. 3, p.178);	Miyaguchi, L., Uchiyama, D., Inada, I., Baba, Y., & Hiura, N., 2014, "The radio-based train control system ATACS," Department of Electrical & Signal Network Systems, East Japan Railway Company, Japan, © WIT Transactions on The Built Environment, Vol. 155, 2014, www.witpress.com; http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.735.5364&rep=rep1&type=pdf, accessed: 27.05.2018, 15:39 +05:30 UTC

Reference		Source
JR East, 2008	Fig. 12-10, p.12-31 (q.v. Slide 5)	Hattori, T., 2008, "The Radio System for the New Train Control System ATACS," © East Japan Railway Company, Signalling System Management Centre, Japan, 2008; Website: https://uic.org/cdrom/2009/01_ERTMS-platform/docs/6-deliverables/3-workshops/6-16Oct2008/D1-hattori.pdf, accessed: 25.08.2018, 08:35 UTC +05:30;
IRJ, 2016	Fig. 12-24, p.12-53	Barrow, K. 2018, " Wireless level crossing control debuts in Japan," International Rail Journal, January 16, 2015, Paris, France; IRJ Website https://m.railjournal.com/index.php/signalling/wireless-level-crossing-control-debuts-in-japan.html, accessed: 29.06.2018, 17:54 UTC +5:30
IRSE, 2012	Fig. 12-12, p.12-32 (qv Fig. 1, p.3);	Moore, T., 2012, "Communications Based Signalling for the Australian Non-Urban Network – The Operations Benefits," Australian Rail Track Corporation, Aspect 2012 Seminar, London, UK, 11 September 2012; IRSE Knowledge Base, London, UK, http://www.irse.org/knowledge/publicdocuments/2.05%20Moore%20-%20Communications%20Based%20Signalling%20for%20Australian%20non-urban%20network.pdf, accessed:31.07.2018, 13:34 UTC +5:30
Prom-Electronica, 2007	Fig. 12-20, p.12-45 (qv still @)3:43)	Prom-Electronica, 2007, "The systems of the Research & Production Centre Prom-Electronica are used: […]," Research & Production Centre, Prom-Electronica, Ekaterinaberg, Russia; Still from Marketing Video @ 03 m 43 s.
UIC, 2011	Fig. 12-11, p.12-31 (qv §4, p.6)	ETSI, 2016, "ETSI TS 102 932-1 V1.1.1 (2011-11), Railways Telecommunications (RT); ER-GSM frequencies; Part 1: ER-GSM additional radio aspects," UIC, 650 Route des Lucioles, F-06921 Sophia Antipolis Cedex - FRANCE; https://www.etsi.org/deliver/etsi_ts/102900_102999/10293201/01.01.01_60/ts_10293201v010101p.pdf, accessed: 25.08.2018, 09:09 +05:30 UTC

CHAPTER

13

ICT Infrastructure Plan

Chapter 13 ICT Infrastructure Plan

Chapter Summary

Introduction and Background

The elements related to ICT (Information and Communication Technology) to be deployed as part of the Colombo Suburban Railway Project include Automatic Fare Collection (AFC), Passenger Information System (PIS) and Management Support systems. This constitutes a preliminary development plan for the ICT infrastructure of Sri Lanka Railways. A final in-depth plan will be developed during the detailed design stage of the project.

An analysis of the PPTA, conducted from an ICT perspective, allowed us to identify the following items to be addressed:

- Computerised Systems for Maintenance – although specified as a subsection of Signalling, a need for a global maintenance management system to be deployed is seen. This will address the management of maintenance operations for all the railway assets (from CTC to signalling and LC protection systems; all station buildings including station-installed equipment for the various support systems; and all rolling stock maintenance).
- The Passenger Information Display (PID) System, the Public Address (PA) System, and the Time Display, although specified as sub-sections of Telecommunications, should form part of a modern Passenger Information System (PIS).
- Ticketing and Fare Collection System, although specified as an Automated Fare Collection (AFC) system by Telecommunications, and being part of a separate on-going project that will provide a new AFC and Seat Reservation system must also be considered as a design constraint to the station buildings, and also for the respective communications network and electrical power supply.

Asset Management System (AMS)

One major finding from an initial assessment of SLR’s current capacities and needs in terms of IT, was the continuing reliance on manual, paper-based processes for maintenance management, and related activities, including procurement and the management of the spare parts stock. The large diversity of SLR’s rolling stock fleet alone makes this a daunting task, with more than 65,000 distinct part numbers being managed currently.

With the introduction of new rolling stock and all the new support systems on the suburban area, this complexity will increase beyond reason. Therefore, it is of prime importance to implement an computer-based Asset Management System (AMS), specially tailored for railroad operations, which will support the organization in all of these activities.

The functionalities necessary to achieve this include, asset tracking (continuous logging of each asset’s location, usage and incidents), incident management (recording, workflow, resolution), maintenance management (scheduling and recording of preventive and corrective maintenance activities, work management), and materials management (purchases, consumption, prediction of needs). Other specific high-level functions would include Warranty and Claims Management for newly acquired assets, Quality control and regulatory compliance (evaluation of the state of repair, risk assessment and asset-specific reporting (asset usage / demand / downtime / reliability / etc.).

Enterprise Resource Planning (ERP)

The next logical step on the ICT development plan for SLR is the deployment of an ERP system. As mentioned for asset management, the majority of the management information currently processed is handled on several loose spreadsheets, with plenty of manual data entry. Under these conditions, getting the required information to upper management is a lengthy and laborious process, with risk of inaccuracy arising from potential data entry mistakes.

This should be replaced by an ERP system, which would then provide accurate Profit & Loss information for all operational aspects, and empower management to make better-informed decisions for the future of the organization.

In order to do this in an efficient and error-free manner, the selected ERP platform must provide extensive data integration capabilities. Data should be imported automatically from at least the revenue and traffic data from AFC system, operations data from the train management system and maintenance data from the AMS. Other information, such as, ancillary revenue streams, Human Resources and payroll, etc., should be managed directly within the ERP system.

The ERP system should also generate a data output in a format suitable for integration into the government's departmental accounting platform. The full specification of the ERP system will be provided in a separate document, since its scope is far beyond the present Feasibility Study for the KV Line.

13.1 Introduction

This chapter describes the elements related to ICT (Information and Communication Technology) to be deployed as part of the Colombo Suburban Railway Project. We start with a brief analysis of the ICT scope of work and its relation with the present report. This is followed by the analysis of the three major blocks identified: Fare Collection, Passenger Information and Management Support systems. At this moment, this constitutes a preliminary development plan for the ICT infrastructure of Sri Lanka Railways. A final in-depth plan will be developed during the detailed design stage of the project.

13.1.1 Scope of work

The starting point for determining the scope of work to be addressed is the TOR (Terms of Reference) of our contract. Therein, on part B "Detailed Tasks of the Assignment", we find "Task 1. Technical Feasibility" from where the following items merit special attention in terms of ICT:

- Collect and review all available relevant studies, reports, materials, documents, and information including findings from the PPTA.
- Collect all necessary information of existing, ongoing and future planned development works of government and private sector in and around the project site and consult all relevant agencies/stakeholders. Take all findings into consideration in the study. Support the client in carrying out continuous coordination and consultations with all relevant stakeholders.
- Examine all existing infrastructure, operational facilities, rolling stock maintenance facilities, ICT Infrastructure, line capacity and business opportunities and make specific recommendations for their improvement.
- Evaluate existing ICT infrastructure and organisation's capacity and design an ICT Development plan for SLR

From the above, we conclude that the present Feasibility Study must include a follow-up on the recommendations from the PPTA, and further develop the analysis, seeking to address all the ICT systems needed to properly support the operation of SLR.

13.1.1.1. Relevant findings from the PPTA

An analysis of the PPTA, conducted from an ICT perspective, allowed us to identify the following items to be addressed:

- Section 7.1.13 Computerised Systems for Maintenance – although inserted in the PPTA as a subsection of the Signalling, we see the need for a global maintenance management system to be deployed. This will address the management of maintenance operations for all the railway assets (from CTC to signalling and LC protection systems; all station buildings including station-installed equipment for the various support systems; and all rolling stock maintenance).
- Sections 7.2.3.6 The Passenger Information Display (PID) System, 7.2.3.7 The Public Address (PA) System, and 7.2.3.8 Time Display – all the indicated items should form part of a modern Passenger Information System (PIS).
- Section 7.3 Ticketing and Fare Collection System – all stations must be equipped with an Automated Fare Collection (AFC) system. We were informed by the Project Director that a separate on-going project will provide a new AFC and Seat Reservation system, which will support the entire operation of SLR. The provision of the AFC system is, therefore, outside the

scope of the Colombo Suburban Railway Project. However, we must consider the presence and sizing of the AFC system as part of the design constraints to the station buildings, and also for the respective communications network and electrical power supply.

13.1.1.2. ICT systems needed to support the Operation

Further than the systems identified above, the scope of our work includes the evaluation of the SLR's existing ICT infrastructure and capabilities, to be matched against an assessment of the organization's needs in terms of ICT systems to ensure proper support of the operation and management. To this end, we received from the PD documents containing a prior analysis of SLR's needs for a Management Information System (MIS). We also had the opportunity of a full-day meeting with SLR, hosted by the Assistant Director of ICT, Mr. Prasad Jayawardena. During this meeting we analysed the current situation of SLR with regards to ICT infrastructure and capabilities, as well as the dependencies on the ICTA. We then went on to briefly visit the different divisions within SLR, to better understand the current organization and internal processes, and mapping out the needs in terms of ICT. The results of this analysis were then integrated into the present report.

On a second step, we need to access the additional needs brought about by the new operations plan for CSRP. A few items are already identified at this stage, but a more detailed specification will only be possible during the detailed design.

13.1.2 Insertion into the Present Report

At this point, it should be noted that a significant portion of the systems identified above are of a central nature, and therefore not exclusively directed to the operation of the Kelani Valley line. However, since the program timeline indicates a closure of the detailed design for the KV line well ahead of the remaining suburban lines, and we deem all of these systems as needed in time for the start of operations of the upgraded service, we opted to include all of the central systems on the present report. In terms of cost apportionment, this means we will consider here the basic cost of acquisition and deployment of all the systems considered, whilst on the FS for the other lines, to be produced at a later stage, we will consider the cost of increasing the capacity of those systems accordingly. This approach may need to be reviewed, in case of any negative decision to go ahead with the KV line project.

13.2 Automated Fare Collection System

As mentioned above, the implementation of the AFC system is considered outside of the scope of our project, since this is already being provided by a separate project. However, we do have to consider within the scope of our project to provide for the installation requirements of the AFC devices within the station buildings. This means that a thorough interface management between the two projects must be conducted, during both the Detailed Design and the Construction phases.

As part of the present FS, we include herein a preliminary analysis on the quantity of AFC devices which would be needed to cater for the foreseen demand on the KV line. Since we have not received any details about the design of the AFC system, this analysis is based on a few assumptions described below. These assumptions, together with the conclusions derived herein, should be cross-checked with the information from the AFC project, as soon as possible; and the results will be integrated into the detailed design of the stations to be modified or newly built under our project.

13.2.1 Demand Estimation for Ticketing

The starting point for our AFC demand estimation is the forecast included in the PPTA as figure 4-3, on page 4-9. This figure shows the forecasts for the daily, both directions, boarding and alighting at stations in 2025. We consider this to be the most relevant source for the design of the AFC system, for the following reasons:

- Ticket sales and validation equipment quantities must be related to the passengers boarding and alighting at each station.
- It is expectable that alternate channels (e.g. mobile ticketing) will be used by a growing share of passengers, year after year. Therefore, the need for fixed AFC equipment will probably be greater for system start-up than later on, hence we should focus on the year 2025 estimates.

The forecasts present in the PPTA, however, do not include the now planned new stations. For our preliminary analysis, we used a simple interpolation to assign a share of the forecast to these new stations. This analysis will be reviewed with the figures coming from our own demand estimation, for the final study.

Since these are daily forecasts, we must now derive the peak hour forecast for total boarding and alighting passengers at each station. We use the same ratio of 8.9% already indicated in the PPTA section 4.2.2.2, coming from the CoMTrans/Megapolis estimation. This total number is used to calculate the needed quantity of automatic gates, should that be the design option chosen for the AFC system.

In order to calculate the needed quantity of other AFC devices, we need to further refine this forecast, to estimate the peak hour passengers boarding at the station. This value is determinant for the quantity of ticket sales devices needed, as well as for free-standing ticket validators (to be used in case the option goes for an open AFC system). The geographical context of each station must be taken into account for this estimation:

- On stations outside the Colombo urban area, the peak hour boarding will be the morning rush hour, estimated as 80% of the total boarding and alighting figure.
- On stations inside the urban area, the peak hour boarding will be the afternoon rush hour. It is a well-known fact that the evening rush hour usually spreads over a larger period of time, and this results in a peak factor about 50% smaller than for the morning rush hour. This has been verified in many cities around the world, and a simple check using publicly-available affluence data from Google Maps® shows the same trend in Colombo. Therefore, we calculate the peak hour boarding on these stations as 40% of the total boarding and alighting.

For the purpose of this simple calculation, we considered the stations from Maradana to Nugegoda as inside the urban area, and from Nugegoda onwards outside of the urban area. To be on the safe side, we considered Nugegoda station as a mixed case, thus using a factor of 60% in the estimation.

The results of this demand estimation exercise for the AFC system are presented on the table below.

Table 13-1 Demand Estimation per Station for AFC System

Station	2025 daily forecast (PPTA)	Adjusted for new stations	Peak hour boarding + alighting	Boarding peak factor	Peak hour boarding
• Maradana	370,938	370,938	33,013	40%	13,205
• Baseline Road	26,448	26,448	2,354	40%	942
• Cotta Road	32,532	32,532	2,895	40%	1,158
• Narahenpita	29,870	29,870	2,658	40%	1,063
• Kirillapone	8,992	8,992	800	40%	320
• Nugegoda	76,560	76,560	6,814	60%	4,088
• Pangiriwatta	19,731	19,731	1,756	80%	1,405
• Udahamulla	29,614	29,614	2,636	80%	2,109
• Nawinna	12,744	12,744	1,134	80%	907
• Maharagama	27,397	21,918	1,951	80%	1,561
• New 2 (Dambahena)		10,189	907	80%	726
• Pannipitiya	13,358	10,686	951	80%	761
• Kottawa	21,233	21,233	1,890	80%	1,512
• Malapalla / Makumbura	30,479	24,383	2,170	80%	1,736
• New 4 (Makumbura North)		13,276	1,182	80%	946
• Homagama Hospital	22,623	18,098	1,611	80%	1,289
• Homagma	1,492	1,492	133	80%	106
• Panagoda	2,906	2,906	259	80%	207
• Godagama	18,510	18,510	1,647	80%	1,318
• Meegoda	24,038	24,038	2,139	80%	1,711
• Watareka	2,058	1,646	147	80%	118
• Liyanwara		7,903	703	80%	562
• Padukka	29,553	23,642	2,104	80%	1,683
• Arukwatte	11,449	11,449	1,019	80%	815
• Angampitiya	12,524	12,524	1,115	80%	892
• Ugalla	4,340	4,340	386	80%	309
• Pinnawala	3,843	3,843	342	80%	274
• Gammana	8,320	8,320	740	80%	592
• Morakelle	928	928	83	80%	66
• Waga	15,064	15,064	1,341	80%	1,073
• Kadugoda	14,752	14,752	1,313	80%	1,050
• Kosgama	35,273	35,273	3,139	80%	2,511
• Hingurala	17,755	17,755	1,580	80%	1,264
• Puwakpitiya	22,307	22,307	1,985	80%	1,588
• Avissawella	45,652	45,652	4,063	80%	3,250

13.2.2 AFC System Design Assumptions and Feasibility

In order to further calculate the quantities of AFC equipment needed per site, we need to establish a few assumptions on its design options, and also on the underlying fare policy to be adopted. A simple study, presented below, concludes that careful consideration must be given to these aspects, otherwise we could reach a situation where the deployment of the AFC system would not be feasible from a practical perspective, in terms of the needed space as well as operation costs.

For the sake of simplicity, we will focus our sensitivity analysis on the stations with the highest demand estimations above: Maradana, Nugegoda, Kosgama and Avisawella.

The critical factors to consider are:

- The performance of each individual AFC device;
- The ratio of ticket purchase to trips done.

On the present-day scenario, all ticket sales are done manually, using pre-printed paper tickets. Empirical data from SLR's commercial division points to around 5% of passengers holding season tickets, with the remaining 95% buying single trip tickets for each journey. This effectively adds up to a purchase-to-trip ratio of about 95%. Even with the quick operation achieved by the experienced ticket office staff, the end result can be witnessed with long queues forming at the ticket counters.

If we consider a similar scenario, but with the increased demand forecast, plus the introduction of a new AFC system (which will impose some delay on the sales process, especially during the learning curve of the staff), we would reach the following situation on the critical stations identified above:

Table 13-2 Ticket Counters needed for Current Fare Policy, Manual Sales Only

Station	Peak hour boarding	Purchase to trip ratio	Ticket Sales per hour	Ticket counter performance	Ticket counters needed
Maradana	13,205	95%	12,567	240 sales/h (typ)	55
Nugegoda	4,088	95%	3,891	240 sales/h (typ)	18
Kosgama	2,511	95%	2,390	240 sales/h (typ)	11
Avisawella	3,250	95%	3,093	240 sales/h (typ)	14

The number of ticket counters calculated above is clearly unreasonable, indicating that a different approach is needed. Some of the remedies that can be adopted are the following:

- Complement the ticket counters with self-service ticket vending machines (TVMs): this remedy has a limited effect. The self-service nature of the TVMs usually results in a lower performance figure, arising from the inexperience of some users and also from the internal mechanisms associated with payments. The typical performance for TVMs is thus around 120 sales per hour, or even lower, which means two TVMs are needed to replace each ticket counter. While this is still a positive balance in terms of space needed (a large array of TVMs can be installed side by side, lining up the walls of station halls, or even in clusters on the middle of said halls), this option brings with it tremendous increases in capital cost and O&M cost (TVMs normally need intensive maintenance to stay fully operative, and surveillance to deter vandalism and theft). Therefore, we would recommend the deployment of TVMs only on a few selected stations, such as the demand-critical ones identified above.
- Deployment of a Mobile Ticketing system: This remedy would effectively improve the situation, by providing an alternate mean for passengers to purchase their tickets, and thus reducing the need for fixed sales equipment. The share of passengers which would adopt the

mobile ticketing is limited by two factors, which are the market penetration of smartphones and the resistance to change by the end users. Latest statistic on the mobile internet usage (source: Hootsuite / we are social) indicates 6.15 million active users, accounting for 29% of the population; this ratio may be higher, if we consider the Colombo suburban area. But all factors considered, we would estimate that by the start of operations the mobile channel would divert about 20% of the demand. This figure will tend to grow progressively, which is why we do not expect there would be a need to increase the sizing of the AFC system to address the demand estimations for 2035 and beyond.

- Changes to the fare policy, creating incentives for regular passengers to buy season tickets: this is by far the most effective measure, and the only one which can bring down the AFC system quantities to a reasonable level. The adoption of an aggressive fare policy (e.g. making the price ratio between single tickets to season tickets in the 20x to 30x range, which effectively creates an interesting discount for regular users), coupled with the adoption of "sliding" season tickets (valid from first use, to prevent all passengers from having to renew on the same calendar day) is an approach successfully adopted by many mass transit agencies around the world. It targets specifically the daily commuters, which normally make up the vast majority of peak hour passengers. With the correct pricing and promotion, the season ticket should reach about 90% of the peak hour travellers, from which 2/3 could be monthly tickets and 1/3 weekly tickets. This would bring the purchase-to-trip ratio down to 16%, leading to a much more contained ticket sales subsystem.

Combining the two bottom remedies proposed above (mobile channel and fare policy), the combined purchase-to-trip ratio for the fixed sales becomes 13%, and we would reach the following scenario:

Table 13-3 Ticket Counters needed for Modified Fare Policy, Manual Sales Complemented by Mobile

Station	Peak hour boarding	Purchase to trip ratio	Ticket Sales per hour	Ticket counter performance	Ticket counters needed
Maradana	13,205	13%	1,727	240 sales/h (typ)	8
Nugegoda	4,088	13%	535	240 sales/h (typ)	3
Kosgama	2,511	13%	328	240 sales/h (typ)	2
Avisawella	3,250	13%	425	240 sales/h (typ)	2

In conclusion, we must consider some changes to the fare policy as imperative for the feasibility of the ticket sales subsystem needed to address the expected increase in passenger demand.

13.2.3 Detailed Design for the AFC System

The exact quantity and location of AFC devices must be determined during the detailed design stage, taking into account the implantation of each individual station. Some aspects to consider are the following:

- All local quantities should be calculated with n+1 redundancy, so that failure of any individual device will not affect regular operation.
- In case some stations are designed with more than one separate areas for passenger entrance, equipment quantities must be further adjusted, to ensure a minimum quantity assigned for each individual concourse.
- In case a closed AFC system is deployed (e.g. with automatic gates to control entrance and exit), special consideration must be given to public safety in case of emergency evacuation. This

should be reflected in some kind of emergency opening mechanism on all automatic gates, triggered centrally by the station master or the OCC. This would be in addition to any emergency exit doors, which will be included in the architectural design of the stations if the modelling of evacuation flows indicates such a need.

The outcome of this exercise must then be used, in conjunction with the information about the dimensions and installation requirements of AFC equipment, to finalize station design in terms of space allocated for these devices, as well as technical features needed for the installation (flooring, wiring and cable ducts, lighting, ventilation).

All of these aspects of the detailed design must be addressed by the interface management process between CSRP and AFC projects.

13.3 Passenger Information System

Considering that the major goal of the project is to bring more people to use the railway for their daily travels, we find that the provision of a comprehensive Passenger Information System (PIS) is of critical importance to the overall project success. Failing this component, first-time users may become frustrated with the difficulty in boarding the correct train, or they can feel insecure about when to alight; in both cases, the likely consequence is, they might go back to using other means of transport.

The Passenger Information System, described in this section, includes the provision of Passenger Information Displays (PID), and the Public Address (PA) system. The PIDs may also be used to display the current time. The entire PIS at stations and halts should be controlled from the OCC, automatically integrating information from the CTC system, whilst allowing override by station masters and OCC operators.

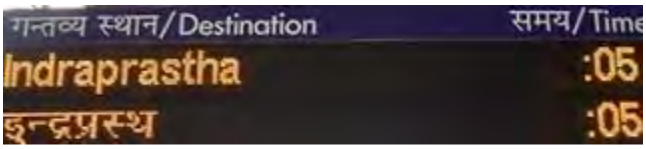
Another aspect to consider is the on-board PIS, including automated display and voice announcement of the next stop. However, since the design of the rolling stock is still in preliminary stage, the same applies to the specification of the on-board PIS within the present report.

13.3.1 PIS Equipment at Stations and Halts

All stations and halts will be equipped with a set of Passenger Information devices, as detailed below. platform displays will be present at all stations, positioned to provide information about the next train to service each individual platform. In complement, station hall displays will be installed in selected stations (primarily, on all stations which have more than one platform). Finally, each station will also have a PA system, providing vocal messages and alert sounds.

13.3.1.1. Platform Displays

As already mentioned, the main role of a platform display is to show clear information about the next train which is going to service each individual platform. This information should include the train's destination, departure time, and also what kind of train it is (regular, express, etc.). When idle, the platform display can also be used to show general messages, or for service announcements.



The platform display should be readable from the entire platform, when placed near the mid-point. In order to provide information to all passengers, it should display all messages in Sinhala, Tamil and English. In order to achieve these two goals, the selected approach is to use 3-line full-matrix LED displays, similar to the picture on the right. This type of technology offers high durability, low cost, and brings the added benefit that it can be made to any shape or size – thus making it possible to use the “banner” format, which is the most practical for the intended purpose.

13.3.1.2. Station Hall Displays

The purpose of the station hall display is to provide information to the passengers as they enter the station. The objective is to allow the passengers to know which platform they should go to, which can be particularly useful when certain architecture features are present (e.g. separate access paths, platforms on a different level than the station hall, viewing of the platform displays blocked by walls, etc.). In any case, since the detailed design is not known yet, for the present FS we assumed that one station hall display should be installed in all the stations with more than one platform. This number may need to be slightly adjusted during the detailed design: additional displays may be needed for stations with more than one entrance hall; some units may be cancelled from minor stations, especially when there is facilitated access between platforms.

The station hall display should be used to display a list of the next trains for the entire station, indicating the platform for each one. All information should be shown in the three languages. This means that a larger amount of information must be present on these displays, when compared to the platform displays; on the other hand, the reading distance can be smaller (up to 5 meters should suffice). To meet these requirements, we considered best to use full-HD LCD screens, such as the one depicted here. The full colour graphical capability of these displays makes them also usable for advertising, either alternating with the train information or splitting the screen are, in any case offering one more source of ancillary revenue to the SLR.

13.3.1.3. Station PA System

The entire KV line will be equipped with a typical long-line PA system, which consists of the following:

- A central PA control system, integrated into the PIS management suite, described below.
- One or more IP-addressable PA amplifier(s) per station. All sound streams will reach the amplifier(s) via the TCP/IP data network. It should be configured to accept connections from the PIS server, but also from a local console, to allow local announcements from the station staff. The amplifier provides a 100V audio line, to drive the PA speakers.
- A number of 100V PA Transformer/Speakers, to reproduce the PA sound. The exact number and location of the speakers must be determined during the detailed design stage.

Depending on the area of the station, either a single audio channel will be provided for the entire station, or different zones therein, covering both the entrance areas and the platforms. The audio system should be capable of playing automated announcements, coordinated with the trains arrival and departure, describing the train in a manner similar to the information displays. During idle times, the audio stream can also be used for general messages, or even background music. The audio volume should be adjusted automatically, depending on the time of the day and also on the level of ambient noise.

13.3.2 On-board PIS

Provision of some level of passenger information, on board the passenger cars, is equally important for the overall passenger experience. This is the role of the on-board Passenger Information System, which will be composed of passenger information displays and a sound system for voice announcements. At this preliminary stage, a detailed specification of this system is not prepared yet. We'll need to look into the internal arrangement of the passenger cars, to be reached during detailed design, in order to decide the adequate form factor for the on-board passenger information displays.

In any case, the on-board PIS should be driven by the Train Control System, in order to provide automatic display and announcement of the next station, upon approach. The audio system should also provide microphones to allow ad-hoc announcements to be done by the train crew.

13.3.3 PIS Management Suite

The entire Passenger Information System is managed from a centralized PIS management suite. This management suite will control the passenger information systems at the stations for the entire KV line. It will afterwards be expanded, to cover the entire CSRP operation. The same management suite should also provide the configuration front-end for the on-board PIS.

The management suite should provide the following functionalities:

- Configuration of text to be shown on PID, on all three languages

  - Train description for station PID.

  - Station name and related messages for on-board PID.

  - Generic messages to be displayed.

- Configuration of the voice announcements

  - Recording of voice snippets for train description, platform number, station names, etc.

  - Recording of entire generic messages.

  - Definition of background music playlists.

- Automated generation of text and voice announcements

  - Driven by CTC data

- OCC direct access

  - Override to allow a selected message to be sent directly to a specific station.

  - Voice console allowing direct announcement of ad-hoc messages on a selected station.

13.4 Asset Management System (AMS)

One of the results of our initial assessment of SLR's current capacities and needs in terms of IT, was that we were able to see that all of the maintenance management, and related activities, are still being managed with manual, paper-based processes. This includes the management of the spare parts stock and purchase. The large diversity of SLR's rolling stock makes this a daunting task already, with more than 65,000 distinct part numbers being managed currently.

With the introduction of new EMUs and all the new support systems on the suburban area, this complexity will increase beyond reason. Therefore, we consider it of prime importance to provide SLR with an Asset Management System, specially tailored for railroad operations, which will support the organization in all of these activities.

13.4.1 AMS High-level Functionalities

To achieve the purpose described above, the Asset Management System will provide several functionalities. Some of the most relevant are the following:

- Asset tracking (continuous logging of each asset's location, usage and incidents).
- Incident management (recording, workflow, resolution)
- Maintenance management (scheduling and recording of preventive and corrective maintenance activities, work management).
- Materials management (Purchases, consumption, prediction of needs).
- Warranty and Warranty Claim Management (especially for newly acquired assets).
- Quality control and regulatory compliance (evaluation of the state of repair, risk assessment).
- AM-specific reporting (asset usage / demand / downtime / reliability / etc.).

13.4.2 AMS Scope

All of the above is of critical importance for managing the rolling stock maintenance, which is the key reason to justify this investment. On the other hand, from the moment the AMS is available, it becomes best practice to use it on the management of all assets which may require any form of maintenance. This means that the full scope of the AMS should encompass all of the following:

- Rolling stock
- Track sections
- Track-side equipment (signalling, level crossings, telecom units)
- Station facilities (lighting, A/C, plumbing, etc.)
- Station equipment (ticketing, passenger information, misc. ITC)
- OCC facilities (lighting, ventilation, A/C, lifts, plumbing, fire detection/extinguishing, etc.)
- OCC systems (IT hardware, telecoms, video wall, etc.)
- Depot facilities
- Depot equipment (workshop machinery, misc. ITC)
- Other buildings and SLR properties

13.4.3 Other AMS Requirements

During the detailed design stage, we will prepare a separate bid document for the procurement of the Asset Management System, which will include the applicable requirements specification. At present, and given the preliminary stage of our work, a full specification of the requirements is undoable. Nevertheless, we can already identify some of the high-level requirements to consider:

- The selected AMS solution must have solid references on the railroad industry.
- It should provide multi-language support, including the two national languages and English, allowing each user to select his preferred language when interacting with the software.
- Access to the system should be intranet-based, supporting different form factors (standard workstations and portable devices such as tablets or mobile phones).
- The system should be customized, to implement the required partitioning, authorization workflows, etc. in concordance with SLR's organization structure.
- For the delivery of customization services, local consultants should be preferred (to avoid the language barrier when interviewing relevant stakeholders).
- The AMS must provide data interfaces to allow automatic import of operation data from the Train Control Centre system, as well as to allow automatic export of accounting data to be consumed by the ERP system.

13.4.4 AMS Roll-out Plan

The planned timeline of the Kelani Valley line modernization, within the CSRP, makes it a perfect target for a pilot project in terms of the Asset Management System. This means that the AMS should be implemented in time for the start of operations of the new EMU, and initially used with the reduced scope of the new assets acquired for the KV line. This approach will ease the learning curve for SLR staff, whilst also allowing for any imperfection on the systems' customization to be detected and corrected before its scope is enlarged. In this way, risk of impact on the on-going SLR operation is avoided.

As the system matures and the remaining CSRP advances, the scope will be increased to encompass all the assets on the Colombo Suburban Railway. It will be subject to decision of the SRL's management if and when this scope should increase to include the remaining network.

13.4.5 Justification for a Dedicated Asset Management System

At this point, we would like to include our reasons to recommend the implementation of a dedicated system to perform Asset Management. It should be said that we received a document from the PMU, stating the intention for the implementation of a Management Information System (MIS). Such a system would include separate modules to support the management of Operations, Rolling Stock Assets, Infrastructure Assets, Procurement and Materials, Railway Ticketing, Revenue Accounting, and Train Crew Rostering. It can be seen that part of the intended scope is now covered by the AMS described in the current section. The remaining modules will need to be implemented within an Enterprise Resource Planning (ERP) solution, which is described on the section below.

It would be possible to implement the entire scope, as described on the PMU's document, using exclusively an ERP system; and we are under the impression that this was the intention of the PMU. However, we have to advise against such approach, for a number of reasons detailed below:

- Generic ERP platforms, whilst fully customizable, are delivered as a "green field" platform in terms of customization. This means that all the work done to adapt the ERP for railway use, if any was done for other clients, normally will not be reused to the benefit of SLR. Instead, SLR would need to employ the services of an ERP consultant, whom will then take charge of understanding SLR's internal processes and map them out on the ERP platform. Even as this means the exact procedures of SLR would be followed, then again it doesn't contribute to the improvement of said procedures.

- The core functionalities in any ERP platform are the accounting-related primitives. As a result, it is expectable that extensive customization would be required to implement the required functionalities for the Asset Management part of the project. This would result in a costly, morose and high-risk implementation project, one that might leave the SLR without any usable solution within the intended timeframe and budget.
- With a higher degree of customization on the ERP solution, comes along a higher cost of maintenance for the software package. Extensive in-depth customization would mean that the SLR would have to keep employing a specialized ERP consultant to ensure the deployment of any upgrade or bug fix from the software manufacturer, as the consultant would need to check the compatibility of the new versions with the customizations previously done and perform any necessary adjustments. This would result in a much higher Total Cost of Ownership (TCO) for the ERP platform.
- On the other hand, using a dedicated AMS platform to address the specific needs associated to Asset Management (both rolling stock and infrastructure) and Materials Management means that the core functionalities of this platform are precisely the ones needed, and have been fine-tuned by the software manufacturer for this specific purpose. While some customization may still be needed, its scope should be reduced, thus allowing a reduction in project cost and duration.
- The ERP system will still be needed, to fulfil the remaining functionalities identified. However, since these functionalities will now be the ones closer to the core ERP, it is also expectable that the degree of customization needed will also be much smaller.
- In this way, the provision of two separate software packages is the best way to fulfil the needs of the SLR with the least cost, implementation time and risk, and TCO. It also allows different timelines to be followed, according to project constraints and organizational maturity.

13.5 Enterprise Resource Planning (ERP)

The next logical step on our ICT development plan for SLR is the deployment of an ERP system. As already mentioned for the maintenance part, we could see that most of the management information currently used by SLR is handled on several loose spreadsheets, with plenty of manual data entry. Under these conditions, getting the required information to upper management is a lengthy and laborious process, with risk of inaccuracy arising from potential data entry mistakes.

This should be replaced by an ERP system, which would then provide accurate P&L information for all operational aspects, and empower SLR's management to make informed decisions for the future of the organization.

In order to do this in an efficient and error-free manner, the selected ERP platform must provide extensive data integration capabilities. Data should be imported automatically from at least the following sources:

- Revenue and traffic data from AFC system;
- Operation data from CTC system;

- Maintenance data from Asset Management system.

Other information like ancillary revenue streams, HR & payroll, etc. should be managed directly within the ERP system.

The ERP system should also generate a data output in a format suitable for integration into the governmental accounting platform, to which SLR is obligated due to being a government department.

The full specification of the ERP system will be provided in a separate document, since its scope is far beyond the present Feasibility Study for the KV Line.

13.6 ICT Infrastructure

Under this section we describe the ICT equipment needed to support the new systems. This includes the central servers and related infrastructure, the workstations at OCC and administration offices, the station masters' workstations, the data entry devices for maintenance staff, the attendance control terminals for staff sign-on/sign-off, and the data communication network to support all of the above.

13.6.1 Central Servers and Computer Room

As a general approach, we consider that the provision of central servers should be the responsibility of the supplier for each independent system. It may not be the most cost-effective approach, but it is the only one that ensures full separation of responsibility in terms of warranties and maintenance.

The alternate approach would be to consider the direct acquisition of a high-availability server cluster, which would then host all the virtual machines needed to support each system. However, for this approach to be viable, it would require resident IT staff on SLR's side to ensure the management and maintenance of this cluster. Against this scenario, we have to consider that the organization nature of SLR, as a government department, is known to bring difficulties in attracting and retaining the specialized staff needed for this. Therefore, we see low viability in this alternate approach, and recommend the previous one explained above.

Under the proposed approach, it would still be upon project scope to provide adequate facilities for the installation of all the required hardware (servers, networking, storage, etc.). This should be in the form of a computer room, with multiple internal cages to allow physical separation of the systems under the responsibility of each supplier.

It should be noted that no safety-critical systems are to be deployed in this computer room area. Anything related to signalling, train control and level crossings will be placed on the CTCC secure equipment rooms.

The computer room described here will host the servers for the support systems: PIS, AMS, ERP, AFC, and station CCTV, among others which may be identified at a later stage. By analysing the importance of these systems in terms of business continuity, we recommend that the computer room facility should adhere to Tier-2 data centre requirements as per ANSI/TIA-942 standard. This means, among other things, that the following requirements must be considered:

- Building location must be outside any flood hazard area.
- Building structural system should be either steel or concrete.
- Floor with a minimum load bearing of 8.4 KPa.

- Vapor barriers should be provided for the walls and ceiling of the computer room.
- Raised floor with cable trays underneath should be installed.
- Dedicated entry lobby, physically separate from other building areas.
- Access controlled door, solid wood door on steel frame.
- Backup power generator with minimum fuel capacity for 24h operation, installed on vibration-insulated mounts.
- Floor drains in computer room for condensate drain water, humidifier flush water, and sprinkler discharge water.
- Air-conditioning with one redundant AC unit, including humidity control.
- Fire suppression equipment: fire detection system, fire sprinkler system, early warning smoke detection system, water leak detection system.
- Intrusion detection on all equipment rooms (computer room, generator room, telecom, etc.).

We believe the best location for this computer room would be the new SLR operations management building planned for the Maradana area. This matter will be analysed in further detail during the detailed design stage.

13.6.2 Workstations for OCC

Besides the CTC workstations, one additional generic workstation will be provided to train dispatchers and supervisors. This generic workstation is needed to allow interaction with the Passenger Information System (e.g. to send warning messages in case of service disruption), and also with the Asset Management System (to report any incident which requires attention from maintenance staff). At supervisor level, the same workstation can also be used to perform any administrative duties.

The exact size and location of the OCC workstations must be decided as part of the detailed design, taking into account the ergonomic design of the entire work positions addressed.

13.6.3 Administrative Workstations

With the deployment of management systems such as AMS and ERP, computer workstations must be provided to all the administrative staff how will work on the new systems. These computer workstations should be composed of a desktop computer, with keyboard, mouse and 24" monitor or similar, capable of running a browser to access the web-based management applications. Similar such workstations already exist in SLR's offices, which may be perfectly serviceable for the intended use. In any case, it should be the responsibility of the SLR's management team to decide on the renewal of such equipment or the acquisition of additional units, through the department's regular procurement process. Therefore, the acquisition of new administrative workstations was not considered within the budget of the present feasibility study.

13.6.4 Station Masters' Workstations

One workstation will be provided at the station master's office in each station. This workstation will be used to perform administrative duties, including the filing of reports pertaining to AMS and ERP systems' data input streams. The station's local PIS will also be configured to accept commands from this workstation, which will allow the station master to take control in case of necessity (e.g. to place service condition messages, in case of breakdown on the communications with the CTC). These workstations consist of a standard desktop computer, with keyboard, mouse and 24” monitor.

13.6.5 Data Entry Devices

Portable data entry devices will be provided for the use of maintenance staff. These devices will consist of industrial-grade tablet computers, protected from dust, water and impacts, equipped with Wi-Fi interface for connection into the network. The purpose of these devices is to allow maintenance staff to interact with the Asset Management System, to read their work orders and file the matching intervention reports. Similar devices will also be used during inspection activities, to record any issue detected.

13.6.6 Attendance Control Terminals

Attendance control terminals will be provided at depots and main stations, for the sign-on and sign-off of train crews. The detailed operations plan will be taken into account to decide which stations need to be equipped with these devices (i.e. those planned for crew relief).

13.6.7 Data Communication Network

All data communication needed for the systems described in this chapter will take place through TCP/IP connections. The telecommunication backbone will be used to route traffic from the stations and depots to the central servers. Each station will be equipped with a LAN switch, with the required number of ports to support all the local IT devices mentioned. On the depots, this will be complemented by Wi-Fi access points, to allow the use of the portable data entry devices. The exact number of access points need will be determined during the detailed design stage, taking into account the exact areas destined to maintenance operations pertaining to the KV line.

13.7 Staff Training

The successful introduction of all the new IT systems described on the present chapter will be dependent on the provision of adequate staff training for all the relevant user groups. A comprehensive training program must be put into place, through the creation of dedicated training courses targeted to each specific user group. In this way, each group will receive intensive training on the operations under their responsibility, without being overwhelmed with excess information regarding other systems.

In any case, the provision of training courses will be the responsibility of each individual system’s supplier. As such, this aspect shall be included in all the corresponding bid documents, to be prepared during the detailed design stage of our project. For the purpose of the present FS report, the cost of training is included in the estimated cost for each software package.

13.8 Conclusions and Recommendations

The primary ICT systems dedicated to operations are noted as either covered by relevant technical sections, or the subject of separate stand-alone projects.

However, asset management and maintenance activities are noted to have many common features and overlapping functions and requirements. Consequently, implementation of a network-wide, centrally managed AMS is recommended, which will encompass all the infrastruture and systems assets, including land and buildings.

The current enterprise and resources management methods and processes are noted as continuing to be paper-based and difficult to analyse. As a consequence, implementation of a new business-wide ERP system is recommended.

CHAPTER

14

Rolling Stocks

Chapter 14 Rolling Stocks

Chapter Summary

The following information is only basic requirements for EMU. The following values are not absolutely fixed and are adjustable within allowable tolerance scope.

(1) Size

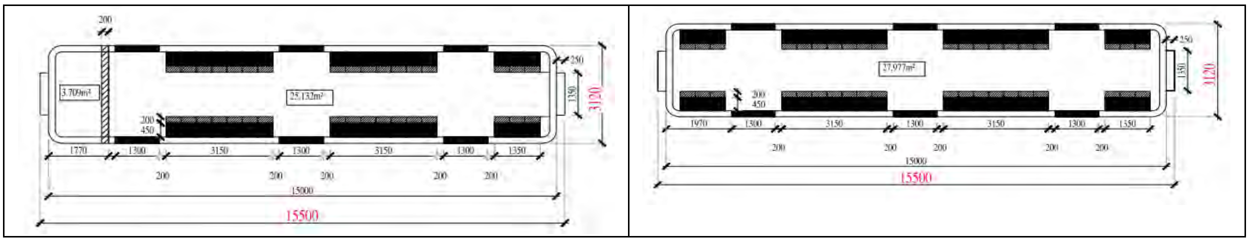
Category	Value	Remarks
Car length	Approximately 15,500mm	Including gangway or coupler
Car length	Approximately15,000mm	Excluding gangway or coupler
Trainset length	10-car trainset: approximately 155m 12-car trainset: approximately 186m	
Width	3,120mm or less	
Roof height	3,600mm or less	From Top of Rail
Floor height	Approximately1,150mm	From Top of Rail Comply with platform height

(2) Performances

Category	Value	Remark
Max. Velocity	More than 100km/h	
Acceleration	3.0km/h/s(0.83m/s2)or more	From 0km/h to 30km/h
Deceleration	Normal: 3.5 km/h/s(0.97 m/s2) or more	From 100 km/h to 0 km/h
	Emergency: 4.5 km/h/s (1.25 m/s2) or more	
Max. Jerk limit	0.8m/s3	
Speed control	VVVF	
Max. Gradient	20 ‰	
Min. Radius	120m	
Noise	80dB	Max. Velocity
Brake	Regenerative & Mechanical	

(3) Transportation capacity

Considering congestion ratio of 6 standing passengers per m2, available transportation capacity can be defined as follows.



Item	10-car/trainset (5+5)			12-car/trainset (6+6)		
Type	Persons	Unit	Total	Persons	Unit	Total
T_c	185	4	740	185	4	740

Item	10-car/trainset (5+5)			12-car/trainset (6+6)		
M or T	208	6	1,248	208	8	1,664
Total		10	1,988		12	2,404

- Maintenance Plan
  - Maintenance facility capacity is based on the 24 EMU trainsets including 4 EMU trainsets between Padukka and Avissawella which can be converted from DMU into EMU after the entire electrification is completed.

a. Light maintenance (24 Trainsets): Nearby Dematagoda

Classification	Design Criteria				Required Lines
	Type of Maintenance	Maintenance Cycle	Working Days	Working Allowance	
Light Maintenance	Examination Service	3 days	365 days	10%	2 Line
	Limited Inspection	3 months	230 days	10%	1 Line
	Temporary Repair	-	230 days	10%	1 Line
Cleaning	Daily Cleaning	3 days	365 days	10%	1 Line
	Monthly Cleaning	1 month	365 days	10%	1 Line
Total					6 Lines

b. Heavy maintenance(24 Trainsets)

Classification	Design Criteria				Required Lines
	Type of Maintenance	Maintenance Cycle	Working Days	Working Allowance	
Heavy Maintenance	Intermediate overhaul	3 years	230 days	20%	1 Trainset (12cars)
	Major overhaul	6 years	230 days	20%	
	Temporary Maintenance	-	230 days	20%	

c. DMU(S12)maintenance : At Avissawella

Section	Total (trainsets)	Main Line Parked (trainsets)	Storage Yard (trainsets)	Maintenance Facility (trainsets)	Remark
Light Maintenance	4	2	-	2	Avissawella
Heavy Maintenance	4	-	-	4	Ratmalana

Part A. Selection of Rolling Stocks

14.1 Introduction

The KV Line has the following unique conditions.

First, there are many sharp curves.

Second, various diesel trains can be operated considering intercity line.

Third, the service frequency is similar to that of metro line regardless of intercity line.

Thus, this report proposes the optimized solution. However, the following information describes only basic requirements. The specific values can be changeable in accordance with rolling stock supplier.

14.2 Definitions

14.2.1 EMU

The following shows definitions on each car. The following values are not absolutely fixed and can be adjustable within allowable tolerance scope.

(1) T_c : Trailer Car with Driver's Cab

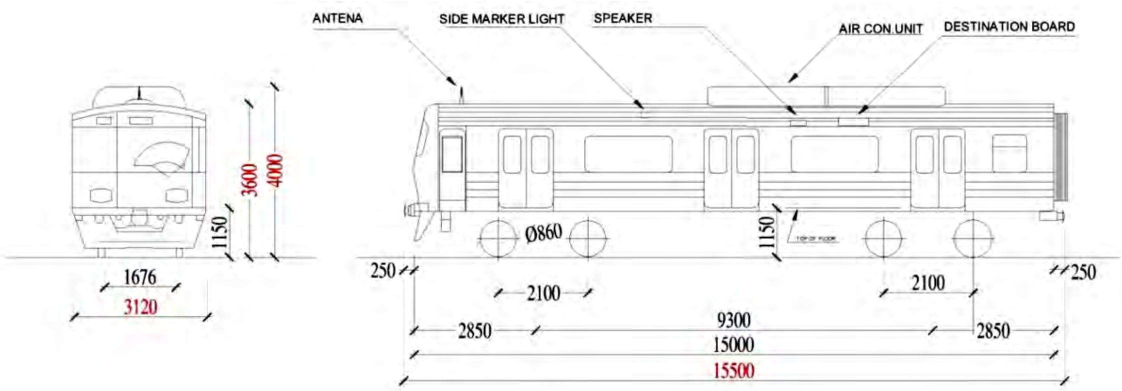


Figure 14-1 T_c

(2) M_1: Motor Car including pantograph

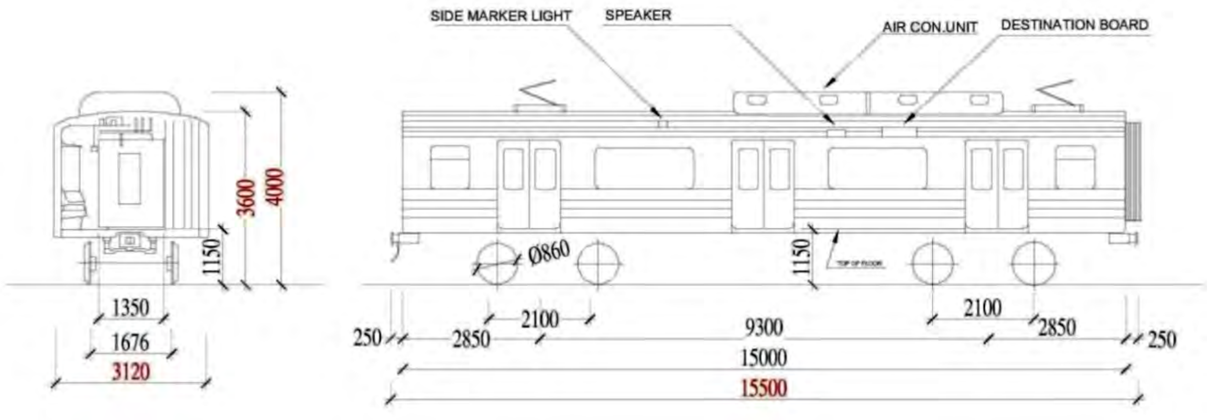


Figure 14-2 M_1

(3) M_2: Motor Car excluding pantograph

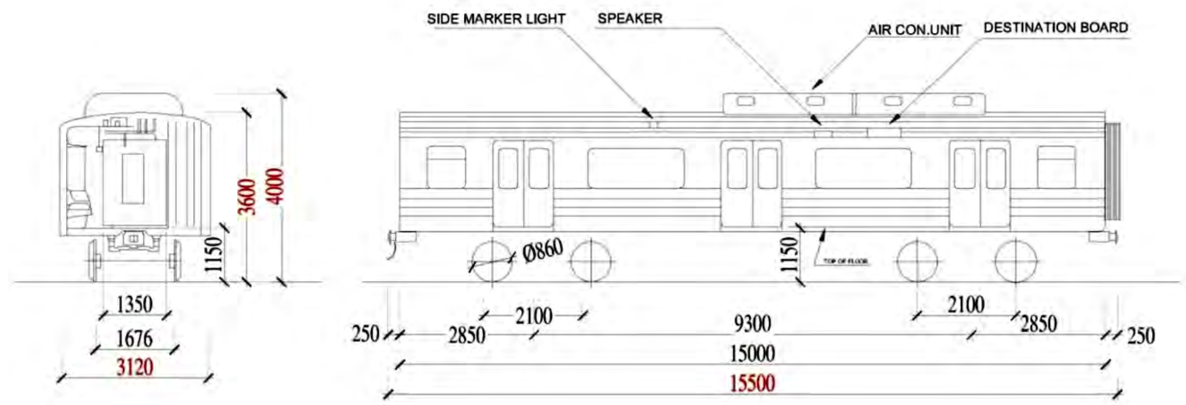


Figure 14-3 M_2

(4) T: Trailer Car excluding Driver's Cab

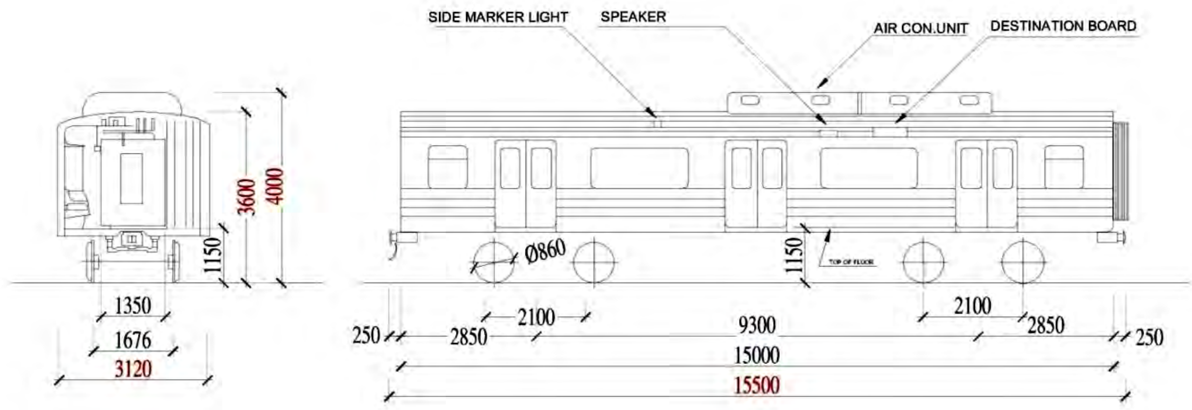


Figure 14-4 T

14.2.2 The existing rolling stocks in Sri Lanka Railways

The following shows definitions on various trains in operation in Sri Lanka railways.

Table 14-1 Definition on trains

Classification	Series	Remarks
DELO	M series	Diesel Electric Locomotives
DHLO	W series	Diesel Hydraulic Locomotives
DHMU	S1 ~ S8	Diesel Hydraulic Multiple Units
DEMU	S9 ~ S12	Diesel Electric Multiple Units
Railbus	T	Steel wheels
Shunter	G	Out of service
	T	Service only within depot
Narrow Gauge Locomotives	N and P	Out of service

14.3 Trains in operation for the KV Line.

The 4 kinds of trains are in operation now.

S12(DEMU)

S8(DHMU)

W3(DHLO)

Railbus

Figure 14-5 Trains in operation for KV Line

4 trainsets of S12 have been in commercial operations for the KV Line since 2012.

S8 trains have been in commercial operations for the KV Line since 1991. Therefore, they are expected to be transferred to other lines when the KV Line is fully electrified.

The poor performances of W3 prevent passenger from getting punctual services. Actually, W3 trains seldom operated in the KV Line.

Considering old life and poor performance of trains, only DMU 12 is expected to be operated eventually in the KV Line after electrification.

14.4 Major specifications of S12

Major specifications of S12 are shown below.

Table 14-2 Major specifications of S12

Classification	Dimension
Distance between Two Coupler Connecting Lines	16,383mm
Car body Width	2,895mm
Car body Height	3,818mm
Max Platform Height	900mm

14.5 Size of EMU

14.5.1 Vehicle gauge and width

Considering that the KV Line is intercity line, any trains can commute in the future between the KV Line and the other Lines in Sri Lanka railways. In addition, special trains for facilities maintenance and rescue operations can be required in the future.

In order to realize the concept, it is desirable to apply 3.2 m which is worldwide regarded as general width of vehicle gauge.

Therefore, width of EMU is 3.12 m considering that the 3.2 m is general width of vehicle gauge.

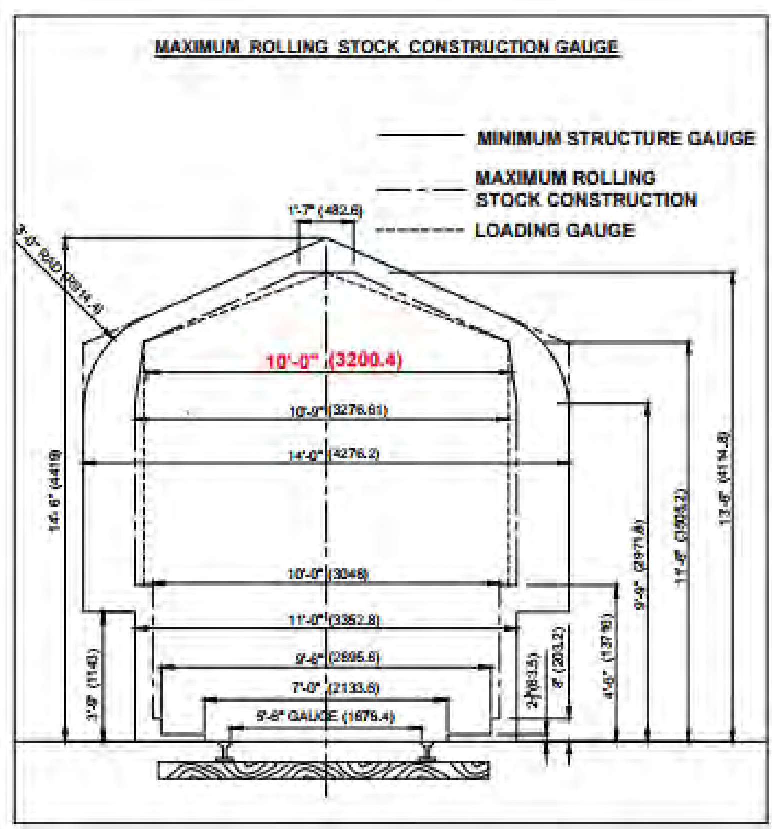


Figure 14-6 Vehicle gauge for Sri Lanka railway

14.5.2 Length

Major characteristic of the KV Line is sharply curved route. In particular, the gap between EMU and platform is one of critical factors to define the length of train.

An appropriate gap should be secured. If the gap is too narrow, trains can scratch the platform while entering the platforms. On the contrary, if the gap is too far, passengers including children and drunken people can fell their feet into the gaps.

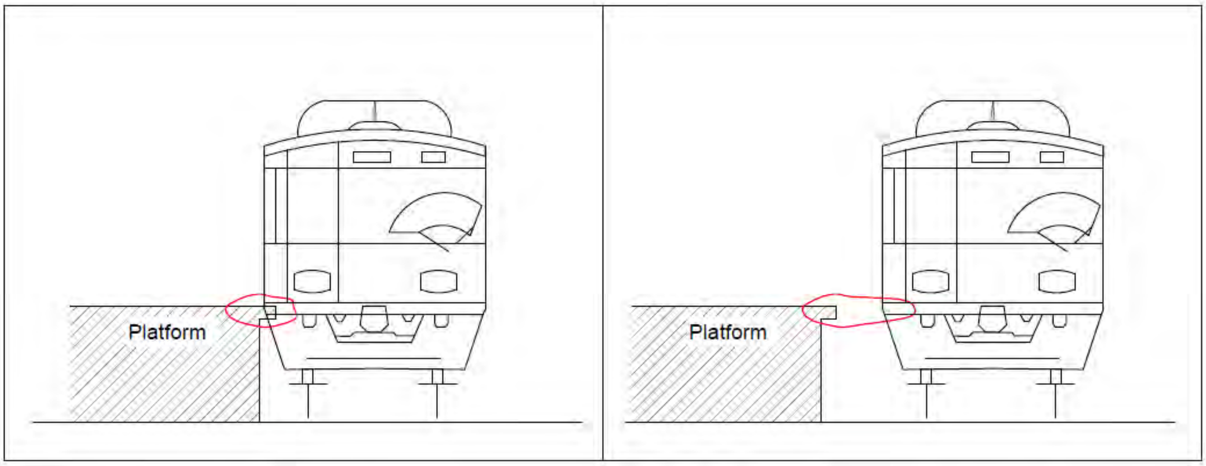


Figure 14-7 Gap between train and platform - 1

By the way, the longer the length of train is, the wider the gap is. Therefore, the car length of EMU is proposed as 15 m (15.5 m including couplers) as follows.

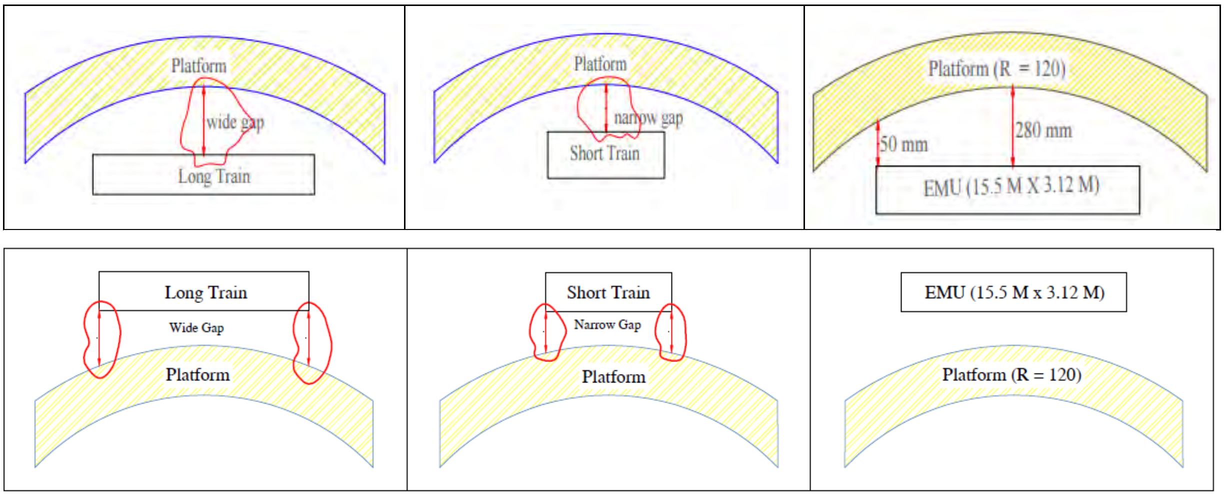


Figure 14-8 Gap between train and platform - 2

14.5.3 Floor Height

Since the height of diesel trains (especially locomotive's case) and platform is different each other, passengers should board and alight through steps or ladders. This makes dwelling time increase.

Thus, the height of EMU and platform will be almost same each other so that passengers can move between them promptly. This can also allow even wheelchair men to access easily.

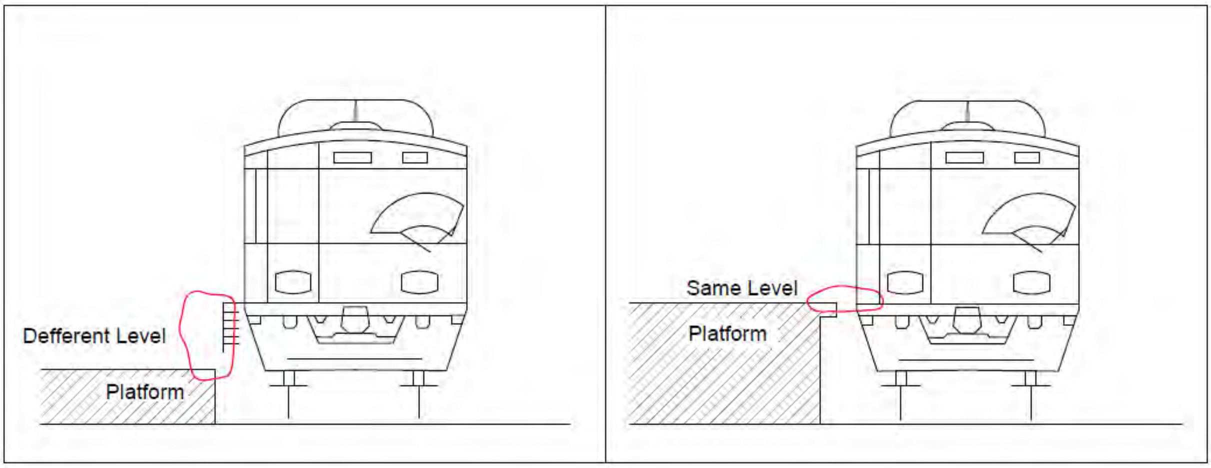


Figure 14-9 Height difference between train floor and platform

Interior steps in EMU are unnecessary because of the same level between train and platform. Only ladders are mounted in order to utilize in abnormal cases including emergency case or stabling yards.

14.6 Basic requirements for EMU

The following information is only basic requirements for EMU. The following values are not absolutely fixed and are adjustable within allowable tolerance scope.

14.6.1 Size

Table 14-3 Size of EMU

Category	Value	Remarks
Car length	Approximately 15,500mm	Including gangway or coupler
Car length	Approximately15,000mm	Excluding gangway or coupler
Trainset length	10-car trainset: approximately 155m 12-car trainset: approximately 186m	
Width	3,120mm or less	
Roof height	3,600mm or less	From Top of Rail
Floor height	Approximately1,150mm	From Top of Rail Comply with platform height

14.6.2 Performances

Table 14-4 Performances of EMU

Category	Value	Remark
Max. Velocity	More than 100 km/h	
Acceleration	3.0km/h/s(0.83m/s^2)or more	From 0km/h to 30km/h
Deceleration	Normal: 3.5km/h/s(0.97m/s^2) or more	From 100km/h to 0km/h
	Emergency: 4.5 km/h/s(1.25 m/s^2) or more	
Max. Jerk limit	0.8m/s^3	
Speed control	VVVF	
Max. Gradient	20 ‰	
Min. Radius	120m	
Noise	80dB	Max. Velocity
Brake	Regenerative & Mechanical	

14.6.3 Pantograph

Basic concepts on pantograph are described as follows. Considering energy saving and noisy, single arm type is proposed instead of double arm.

Force to push toward OCS is 70±10Nand pressure for air control is 490kPa ±98kPa(5kgf/cm2 ±1kgf/cm2). Since the width of pantographs is less than that of rolling stock, approximately 1.2m is recommendable.

Total numbers of pantographs per trainset are greater than or equal to 4(four). In particular, the distance between pantographs shall consider the length of electrical neutral section. In addition, each group of electrical devices under 4 pantographs should not be connected electrically so that electrical shortages should be avoided in the neutral section.

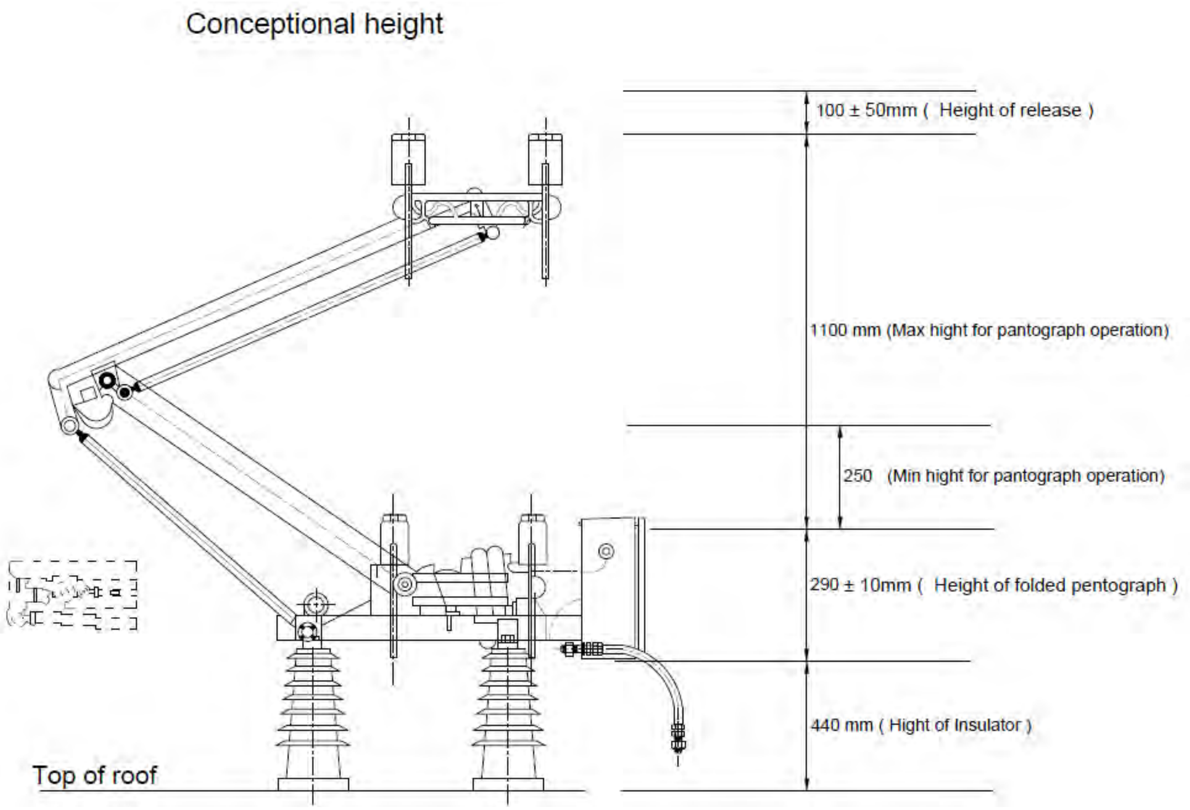


Figure 14-10 Conceptional pantograph dimensions

14.6.4 Aerodynamic Resistance

The following is aerodynamic resistance formula.

Table 14-5 Aerodynamic resistance formula

Category	Value
Underground	R = 1.867+0.0359V+0.000745V^2[kg/ton] R: Aerodynamic resistance V: Velocity
At-grade/Bridge	R = (1.65+0.024V)Wm + (0.78+0.0028V)Wt + (0.028+0.0078(n-1))V^2[kg] R: Aerodynamic resistance Wm: Total weight for M(ton) Wt: Total weight for T(ton) n: number of trainset formation

14.7 Trainset Formation of EMU

According to interface results from train operation, two types of trainset formation will be applied in the initial stage and the final stage.

Detailed arrangements of T_c , T, M_1, and M_2 are adjustable in accordance with Rolling stock suppliers' own specifications.

However, even if tractive motors are broken, the trainset formations of 5+5 and 6+6 should be able to start after pause 20‰slope section under the condition that every seat is occupied and congestion ratio of 6 standing passengers per m2.

14.7.1 Initial stage

The following coupled 5+5 car for 10-car/trainset will be operated.

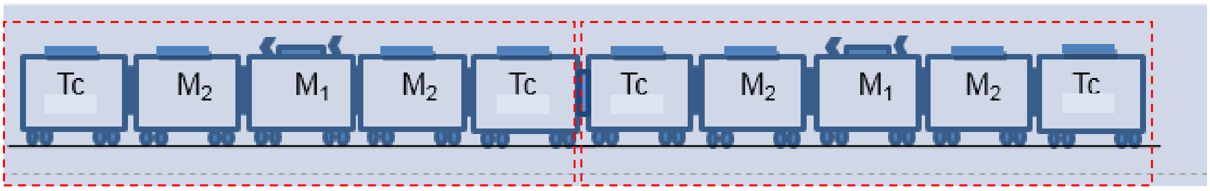


Figure 14-11 Coupled 5+5 car for 10-car/trainset

14.7.2 Final stage

The following coupled 6+6 car for 12-car/trainset will be operated.

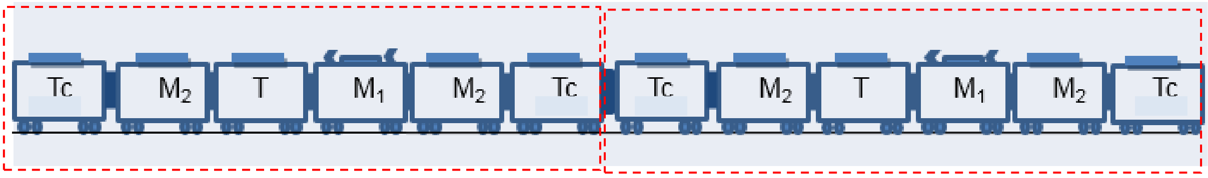


Figure 14-12 Coupled 6+6 car for 12-car/trainset

14.8 Seat layout and transportation capacity of EMU

14.8.1 Seat layout

There are 3 kinds seat layout.

Table 14-6 Seat layout

Classification	Type 1	Type 2	Type 3
Seat arrangement	Longitudinal	Traversal	Combination
Transportation capacity	Maximum	Minimum	Middle

Classification	Type 1	Type 2	Type 3
Time for boarding and alighting	Minimum	Maximum	Middle

Considering transportation capacity and service frequency, type 1 will be optimum. The seat layouts for T_c and the remaining M_1, M_2, T are follows.

- T_c

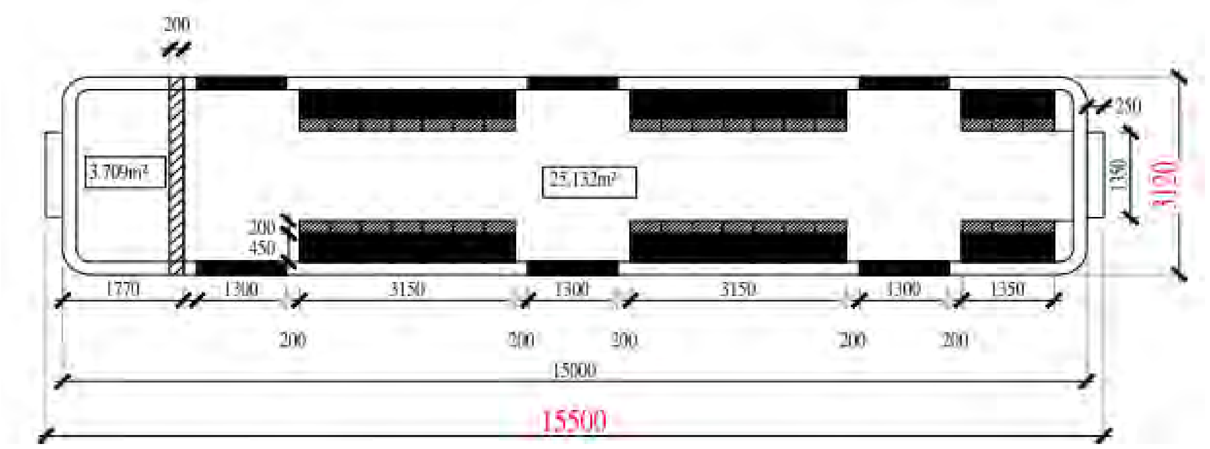


Figure 14-13 Seat layout for T_c

- M_1, M_2, T

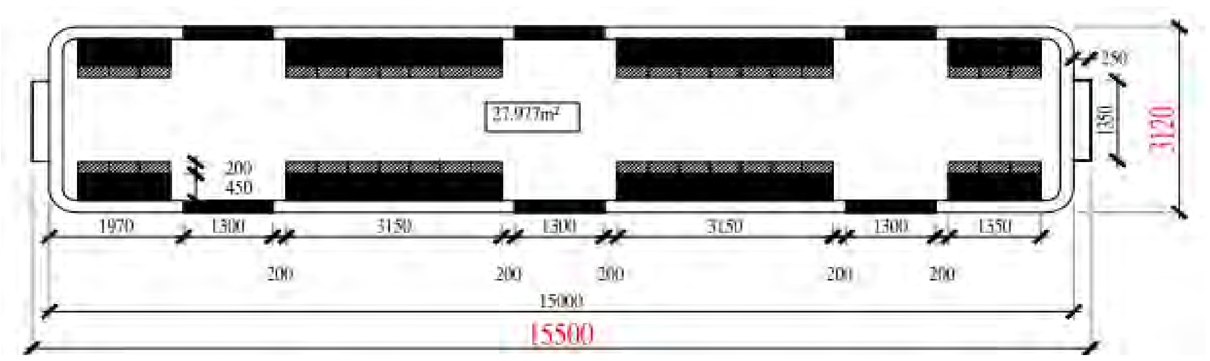


Figure 14-14 Seat layout for M1, M2, and T

Comprehensively considering 1) Travel time between stations, 2) Transportation capacity of rolling stock, and 3) maintenance facility in the depot, sanitary facility in the trainset is not taken into account.

14.8.2 Transportation capacity

Considering congestion ratio of 6 standing passengers per m^2, available transportation capacity can be defined as follows.

Table 14-7 Transportation capacity

Item	10-car/trainset (5+5)			12-car/trainset (6+6)		
Type	Persons	Unit	Total	Persons	Unit	Total
T_c	185	4	740	185	4	740
M or T	208	6	1,248	208	8	1,664
Total		10	1,988		12	2,404

14.9 Passenger door and HVAC System

Most of diesel trains are operated with their passenger door open. This Consultant suggests this problem originates from not only lack of safety concept but also too inferior cooling systems.

Hence, cooling system supported by HVAC(Heating, Ventilation, Air Conditioning) system will be adopted and EMU will be able to start from platforms only after automatically locking the entire doors. The HVAC system can passengers feel comfortable even if all doors and windows are locked.

Electric ceiling fans can be additionally installed so that the fans instead of air conditioners can be utilized for energy saving.

Figure 14-15 Air conditioner on the roof and ceiling fan

14.10 Interfaces

Following devices will be provided. The details will be described in the detailed design.

Table 14-8 Interfaces

Device	Interface partner	Remarks
On board signaling system	Signaling	Interface with TCMS
TRS(Train Radio System)	Telecommunication	Interface with TCMS
Passenger information system, CCTV, address system	ICT	Interface with TCMS
OCS	Electrification	Interface with TCMS

14.11 Transferring plan

Generally, trains are delivered to the depot by means of tow truck along land routes or locomotive along railway routes.

This Consultant suggests the optimized solution is locomotive delivery since EMU can be safely and economically transferred to the depot from the Colombo port through tracks that has been already installed.

Figure 14-16 Transferring plan

14.12 Regulations

In order to ensure quality and safety during design, production, test, and operation, the worldwide regulations of EN, UIC, IEC, etc. will be taken into account.

Part B. Maintenance Plan for Rolling Stocks

14.13 Introduction

- This proposes the most optimized depot locations considering train operation for KV Line.
- It is desirable to place depots in non-urban centers considering land costs, etc. In addition, it is recommended that depots stand nearby the terminal station to facilitate efficiently operation plan including train movements between main line and depot.
- The depot has various facilities for repair and maintenance which provides comfort and prevents accidents by maintaining perfect condition of train.
- Generally, the capacity for repair and maintenance facility should take into account future train operation plans that may change due to transport demand increase.

14.14 Plan on train operation for the KV Line

The following table shows the SLR's advice summary of train operation.

Table 14-9 Interface result summary of train operation

Train	Series	Section	Remarks
EMU	All stop	Maradana ~ Padukka	Note 1
EMU	Express	Maradana ~ Padukka	Note 2
DMU	All stop	Padukka~ Avissawella	Note 3

Note 1	EMU size is 3.12 m x 15 m (15.5 m including couplers). Compared to EMU, lower performance including acceleration, deceleration, etc. of DMU can cause EMU to fail in punctuality service. Different floor height between EMU and DMU requires additional ROW and/or construction cost.
Note 2	EMU Express services can be provided at certain key stations in accordance with side track plan through discussions with all of the related stakeholders.
Note 3	DMU S12 size is 2.89 m x 16.4 m including couplers EMU service is impossible since electrification is not taken into account.

14.15 Train Operation Plan and No. of Train Sets

Table 14-10 For Year 2025

Section	Length (km)	PPHPD*	Train Capacity (person)	Frequency of Train (min)	Commercial Speed(km/h)	No. of Rolling Stock
Maradana ~ Makumbura North	21.7	18,405	1,988(150%)	7.0	34.7	20 EMU Sets (17+3)
Makumbura North ~ Padukka	13.02	8,036		14		

Table 14-11 For Year 2035

Section	Length (km)	PPHPD*	Train Capacity (person)	Headway (min)	Commercial Speed(km/h)	No. of Rolling Stock
Maradana ~ Makumbura North	21.7	20,973	2,404(150%)	7.0	34.7	20 EMU Sets (17+3)
Makumbura North ~ Padukka	13.02	8,877		14		

* PPHPD – Passengers per Hour per Direction

- Maximum Passenger Ridership Section: Kirillapone station and Nugegoda Station
- Train units: 10-cars trainsets EMU (1,988 person / trainset), 12-cars trainsets EMU (2,404 person / trainsets).
- Spare Rolling stock at Maintenance and Emergency: 15%
- Padukka ~ Avissawella: The existing train(S12 DMU) will be operated under single line till electrification is completed.

* The Frequency of Train and No. of Rolling Stock can be adjusted according to the operation plan and the Structure Plan.

14.16 Train Parking Plan for KV Line

Table 14-12 Track layout with Parking Location

Rolling stock No.	Side track of Main Line	Depot
EMU: 20 trainsets	5 trainsets (Note 1)	15 trainsets
DMU:4 trainsets	4 trainsets (Note 2)	NA

- Padukka ~ Avissawella: The existing train (DMU) will Operate single line till the final phase
- Train capacity 994 person / trainsets (5cars), No. of Rolling Stock 4trainsets (DMU).
- Note 1: 5 trainsets at side tracks in the main line including Makumbura North and Padukka
- Note 2: Avissawella (2),Stabling shed (2)

14.17 Capacity Demand of Maintenance Facility for KV Line

- EMU

  This Consultant estimates maintenance facility capacity based on the 24 EMU trainsets including 4 EMU trainsets between Padukka and Avissawella which can be converted from DMU into EMU after the entire electrification is completed.

a. Light maintenance (24Trainsets)

Table 14-13 For Year 2035

Classification	Design Criteria				Required Lines
	Type of Maintenance	Maintenance Cycle	Working Days	Working Allowance	
Light Maintenance	Examination Service	3 days	365 days	10%	2 Line
	Limited Inspection	3 months	230 days	10%	1 Line
	Temporary Repair	-	230 days	10%	1 Line
Cleaning	Daily Cleaning	3 days	365 days	10%	1 Line
	Monthly Cleaning	1 month	365 days	10%	1 Line
Total					6 Lines

b. Heavy maintenance (24 Trainsets)

Table 14-14 For Year 2035

Classification	Design Criteria				Required Lines
	Type of Maintenance	Maintenance Cycle	Working Days	Working Allowance	
Heavy Maintenance	Intermediate overhaul	3 years	230 days	20%	1 Trainset (12cars)
	Major overhaul	6 years	230 days	20%	
	Temporary Maintenance	-	230 days	20%	

- DMU

Table 14-15 For Year 2035

Section	Total (trainsets)	Main Line Parked (trainsets)	Storage Yard (trainsets)	Maintenance Facility (trainsets)	Remark
Light Maintenance	4	2	-	2	Avissawella
Heavy Maintenance	4	-	-	4	Ratmalana

14.18 Plan of Depot

14.18.1 Background

- Location of light maintenance depot is nearby a start station or an end station of each line for smooth train operation.

- Topography and ground condition should be good.
- Location of the lands belongs to Sri Lankan Government or SLR if possible.

14.18.2 Light Maintenance Depot in View of Location

(1) Review of the 1st Attempt

All the existing diesel train services start at Colombo or Maradana. Light maintenance services for DMU will be continuously promoted in the existing depots till electrification.

Considering the above condition, location of the existing Dematagoda is an excellent candidate.

Major review results are described as follows.

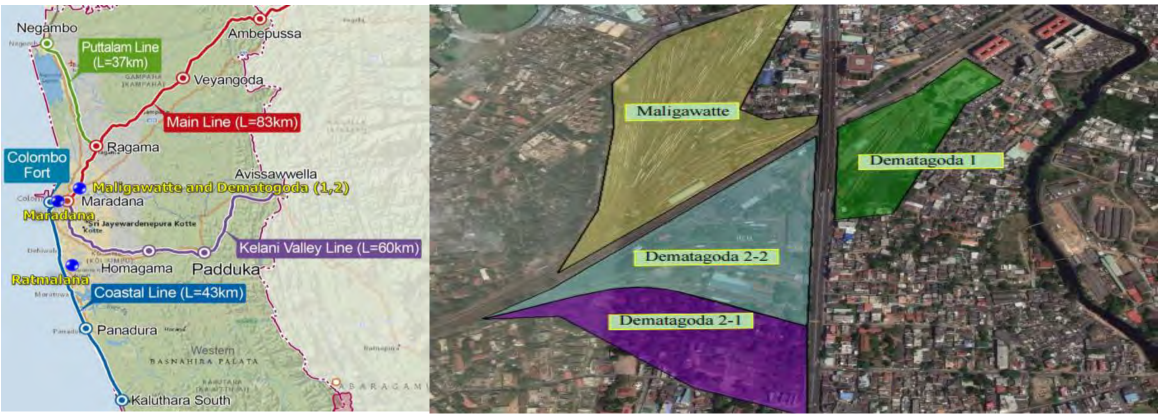


Figure 14-17 Existing light maintenance depot next to Maradana station

- Option1:Dematagoda 2-1
  - Location is nearby Maradana station. So, this place can provide smooth train operation.
  - Most of the buildings are not related to diesel train maintenance and lands belong to SLR.
  - Most of the existing facilities and residences need to be demolished because of inferior conditions. Resettlement plans should be established if the residences are demolished
  - Topography and ground condition is very good (existing Depot).

Empty zones	
	

Maintenance vehicle storage for track	Residence
	

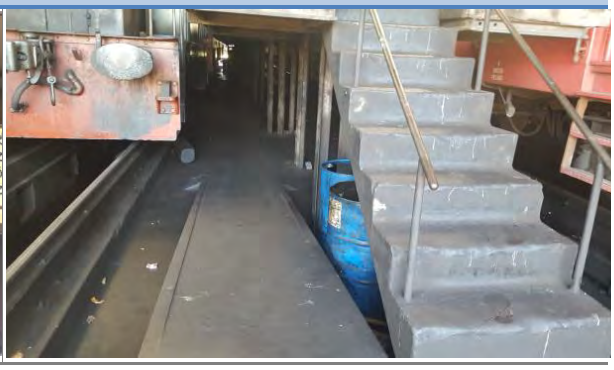
Figure 14-18 Existing conditions on Dematagoda 2-1

- Option 2:Dematagoda 1, Dematagoda 2-2 and Maligawatte
  - Most of the facilities and buildings are related to diesel train maintenance.
  - New DMU facility should be established if the existing facilities are demolished.

Stabling yard

Maintenance workshops (very poor condition in terms of safety and sanitation)

Shabby residences	Wheel truing facilities

Figure 14-19 Existing conditions on Dematagoda 1, 2-2 and Maligawatte

- Analysis Results of Option 1 and Option 2

  Option 1 absolutely superior to Option 2 in terms of all of conditions as described above.

  This Consultant will develop the Option 2 through discussions with all of the concerned stakeholders.

  However, if final decision on the above Option 1 or Option 2 fails during the detailed design stage, this Consultant will come up with other alternatives.

14.18.3 Stabling Shed for DME light maintenance

This Consultant suggests stabling shed for light maintenance of diesel trains at Avissawella.

The available capacity is only four trainsets of S12.

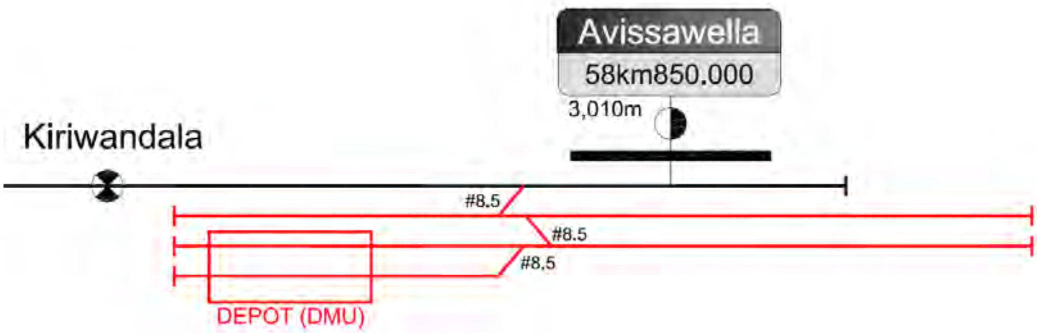


Figure 14-20 Simplified Track layout for stabling shed for DMU light maintenance

The stabling shed for S12 can be converted into EMU when the remaining section between Padukka and Avissawella is fully electrified.

14.18.4 Heavy Maintenance Workshop

All the existing diesel train services start at Colombo or Maradana. Heavy maintenance services for DMU will be continuously promoted in the existing workshop (Ratmalana) till electrification.

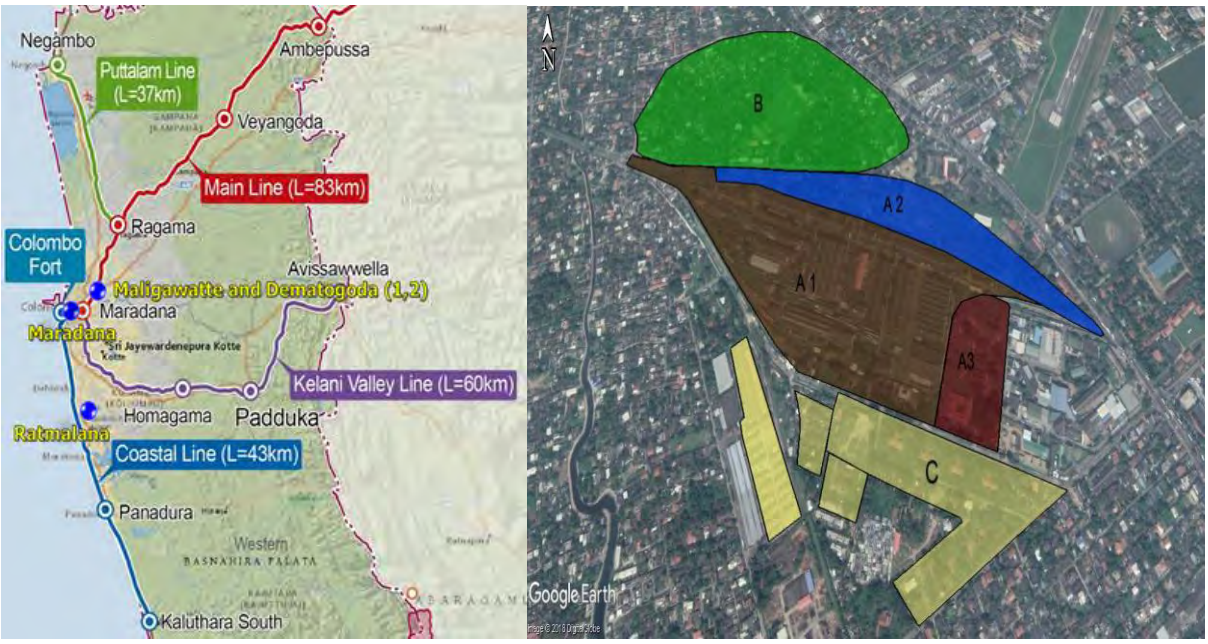


Figure 14-21 Zones of Ratmalana Workshop for DMU

- Option 1: Ratmalana A-1

  Existing heavy maintenance facilities and building should remain without demolition for DMU heavy maintenance.

Figure 14-22 Existing conditions on Ratmalana A-1

- Option 2: Ratmalana A-2

  The plan on installing new heavy maintenance facilities has been fixed, the fund provider has not been decided between Sri Lanka Government, SLR, ADB and Indian Government.

Figure 14-23 Existing conditions on Ratmalana A-2

- Option 3: Ratmalana B
  - Most of the buildings are not related to diesel train maintenance.
  - Most of the existing facilities can be demolished because of inferior conditions and some lodgings.

  But, resettlement plans should be established if the residences are demolished. The land length is not sufficient for installing workshop.

- Option4: Ratmalana C
  - Most of the buildings are not related to diesel train maintenance.
  - Most of the existing facilities can be demolished because of inferior conditions. But, the land width is not sufficient for installing workshop.

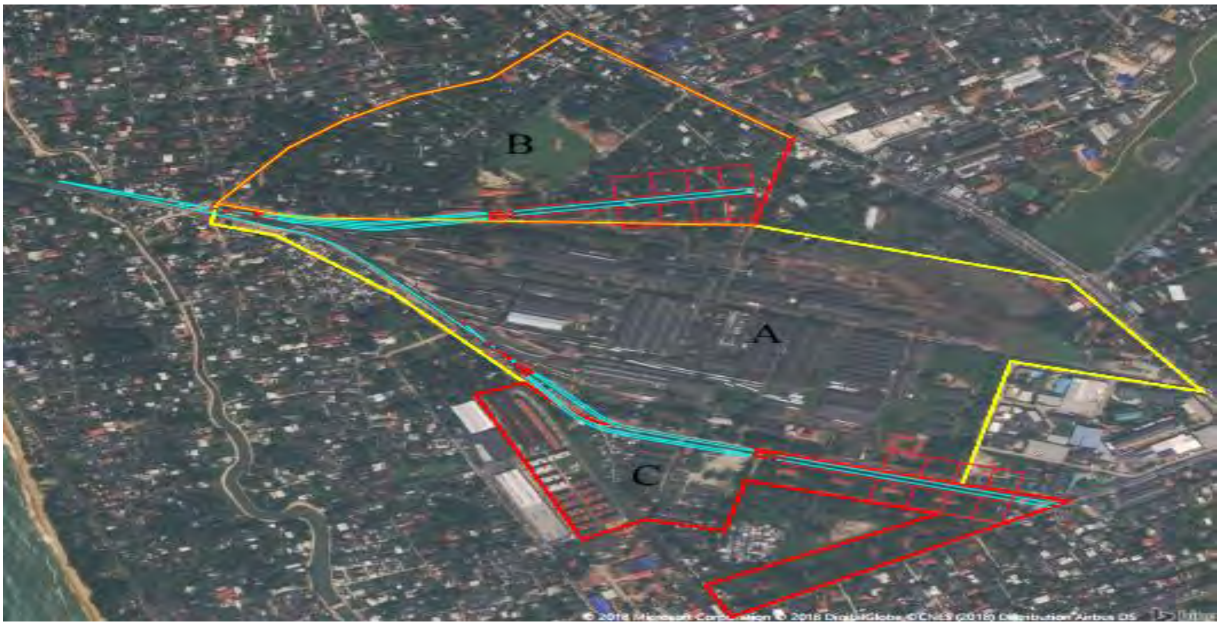


Figure 14-24 Conceptual depot layout in B and C

- Recommendation: The location of heavy maintenance depot will be determined later because it is necessary in 2028 and requires high cost for heavy maintenance facilities.

Therefore, EMU heavy maintenance depot for the total 4 suburban railways will be prudently reviewed through discussions with all the concerned stakeholders including PMU and SLR.

CHAPTER

15

Financial and Economic Analysis

Chapter 15 Financial & Economic Analysis

Chapter Summary

Financial analysis of the KV line shows that the investment cost of the project is estimated to be USD 1.42 billion. The construction cost of the project approximately consists of half of the investment cost (52.66%), whereas the rolling stock accounts for 18% of the investment cost. Modernization costs such as electrification, signaling & telecommunication also account for about 9.38% of the investment. Operating & Maintenance cost of the project consists of manpower cost, energy cost, and maintenance cost. Maintenance cost accounts for about 54% of the O&M cost while about 29% is attributable to energy cost. Manpower cost is relatively small with a 19% share of the total cost. O&M costs per passenger are in the range of LKR 3.80 to 4.35. Further O&M costs per passenger kilometer are fairly stable over the project period where the cost is between LKR 2.00 to 2.29. Accordingly setting prices higher than LKR 2.29 per passenger kilometer will ensure the recovery of O&M costs of the project.

Under the financial analysis, different alternative sources of funding are considered such as Asian Development Bank (ADB) loan, loans from local banks, foreign commercial loans and funds of Sri Lankan government along with the cost of funding (Weighted Average Cost of Capital-WACC). Eighty percent of the funding is received from an ADB loan and twenty percent of government funding results in a WACC of 3.04% excluding inflationary effects (Real WACC). Mixing with other sources in different proportions yields a WACC ranging from 2.77% to 4.25%. WACC of 3.04% is considered as the base case for evaluation where the effects of change in WACC are discussed under sensitivity analysis.

When evaluating further whether the project could recover its investment cost along with the cost of funding (WACC), it could be observed that project cash flows are not sufficient to fully recover the investment cost and cost of funding as evident by negative Financial Net Present Value (FNPV) of USD 981.92 million and negative Financial Internal Rate of Return (FIRR) of 3.84%. Even though the Project cash flows are not sufficient to fully recover the total investment and associated cost of funding, it could recover approximately 21.26% of the investment cost and related cost of funding. Accordingly, the project is able to recover certain components of investment costs such as rolling stock that accounts for 18.39% of the total investment (excluding price contingencies).

Despite the fact that the initial evaluation considers an economic life of 30 years in line with international practices, higher life spans of several assets such as bridges, flyovers, tracks, buildings, embankment, etc. are suggested by Sri Lankan standards for construction (based on Euro codes). When higher life spans are considered through a sensitivity analysis, 50 years' lifetime provides better financial indicators such as better FNPV and investment cost recovery. Accordingly, FNPV improves with 50 years of a lifetime but remains negative. Moreover, the investment recovery rate improves to 27.41% compared to the base case recovery rate of 21.26%. This recovery rate is sufficient to recover the aggregated investment cost and associated cost of funding pertaining to land acquisition and rolling stock costs (23.60% of the investment excluding price contingencies). Recovering the rest of the investment costs and paying the related cost of funding could not be made with project cash flows generated thus the government needs budgetary allocation from common public funds for the same which is the usual case with railway projects in many countries.

KV line requires a government subsidy of 290.27% from the operating & maintenance cost (at constant price) of each year to fully settle the investment cost and cost of funding. This total subsidy amounts to 150% of the cumulative revenue of the project. The current net cash flows of the project are sufficient to recover USD 289.08 million of the investment cost and related cost of funding without any subsidies. This amount is 21.26% of the total investment (excluding price contingencies) for a 30-year life span.

However, O&M costs and Replacement costs can easily be recovered with railway tickets and other income of the KV line. In many railways around the world, which focuses on passenger, transport alone cannot recover half of the OPEX. However, KV line is in a better position in recovering OPEX and replacement costs through ticket and other incomes.

Table 1 provides detailed Benefit-Cost Analysis in the base case of proposed KV Line project. The period considered in the evaluation is 30 years, which is the economic life cycle of the project. To calculate the Benefits and Costs of this project, assumptions were made in the above section.

Table 1: Economic Analysis - KV Line - Base Case (Constant Price)

(US $ Million)

Year	Years of Ope.	Cash Flow Statement											
		Direct Cost					Benefit Stream						Discounted Cash Flow
		Capital	O&M	Replace	Total	Discounted	VOC 179	VOT 179	Acc 179	Emm 179	Total	Discounted	
2018													
2019													
2020		70.80			70.80	59.76							-59.76
2021		429.59			429.59	333.58							-333.58
2022		429.59			429.59	306.90							-306.90
2023		429.59			429.59	282.35							-282.35
2024	1		18.27		18.27	11.05	420.02	110.36	17.39	29.58	577.35	349.10	338.05
2025	2		18.42		18.42	10.25	403.07	93.86	14.47	24.65	536.05	298.20	287.95
2026	3		18.57		18.57	9.50	386.23	77.08	11.41	19.28	494.00	252.82	243.32
2027	4		18.72		18.72	8.81	373.63	63.75	9.04	15.16	461.57	217.33	208.51
2028	5		18.87		18.87	8.17	364.82	53.18	7.17	11.95	437.11	189.35	181.17
2029	6		19.02		19.02	7.58	359.46	44.83	5.68	9.43	419.40	167.14	159.56
2030	7		19.19		19.19	7.03	357.32	38.28	4.48	7.41	407.49	149.40	142.37
2031	8		19.35		19.35	6.53	358.22	33.18	3.51	5.78	400.69	135.16	128.63
2032	9		19.51		19.51	6.06	362.08	29.27	2.70	4.45	398.49	123.66	117.60
2033	10		19.69	25.01	44.70	12.76	368.85	26.31	2.03	3.34	400.53	114.35	101.59
2034	11		19.86		19.86	5.22	378.56	24.15	1.46	2.41	406.58	106.79	101.57
2035	12		20.06		20.06	4.85	391.28	22.63	0.97	1.61	416.50	100.65	95.80
2036	13		20.06		20.06	4.46	391.28	22.63	0.97	1.61	416.50	92.59	88.13
2037	14		20.06		20.06	4.10	391.28	22.63	0.97	1.61	416.50	85.19	81.08
2038	15		20.06		20.06	3.78	391.28	22.63	0.97	1.61	416.50	78.37	74.60
2039	16		20.06		20.06	3.47	391.28	22.63	0.97	1.61	416.50	72.10	68.63
2040	17		20.06		20.06	3.20	391.28	22.63	0.97	1.61	416.50	66.33	63.14
2041	18		20.06		20.06	2.94	391.28	22.63	0.97	1.61	416.50	61.03	58.09
2042	19		20.06		20.06	2.70	391.28	22.63	0.97	1.61	416.50	56.15	53.44
2043	20		20.06	103.42	123.49	15.31	391.28	22.63	0.97	1.61	416.50	51.65	36.34
2044	21		20.06		20.06	2.29	391.28	22.63	0.97	1.61	416.50	47.52	45.23
2045	22		20.06		20.06	2.11	391.28	22.63	0.97	1.61	416.50	43.72	41.61
2046	23		20.06		20.06	1.94	391.28	22.63	0.97	1.61	416.50	40.22	38.28
2047	24		20.06		20.06	1.78	391.28	22.63	0.97	1.61	416.50	37.00	35.22
2048	25		20.06		20.06	1.64	391.28	22.63	0.97	1.61	416.50	34.04	32.40
2049	26		20.06		20.06	1.51	391.28	22.63	0.97	1.61	416.50	31.32	29.81
2050	27		20.06		20.06	1.39	391.28	22.63	0.97	1.61	416.50	28.81	27.43
2051	28		20.06		20.06	1.28	391.28	22.63	0.97	1.61	416.50	26.51	25.23
2052	29		20.06		20.06	1.17	391.28	22.63	0.97	1.61	416.50	24.39	23.21
2053	30		20.06	0.00	20.06	1.08	391.28	22.63	0.97	1.61	416.50	22.44	21.36
		1360	591	128	2079	1137	11567	1024	98	164	12853	3103	1967

EIRR	15.78%
ENPV	1967
B/C	2.73

All the gross benefits and costs were discounted by 9% discount rate and base case shows the feasible project results. Discounted NPV is the US $ million 1967 and EIRR is 15.78%. The benefit-cost ratio is 2.73 and all the project results have accepted value in the base case.

The sensitivity analysis is carried out to determine the economic consequences of:

(1) Not achieving the expected direct and indirect benefits,

(2) Increases in the capital and recurrent costs.

(3) Possible delays in project implementation

All the eight risk scenarios were presented for NPV, IRR, and B/C.

Table 2: Sensitivity Results of Economic Analysis

Case	Sc. ID	Scenario	Change	EIRR	NPV	B/C
Base case	A	Base case	0	15.78%	1,966.79	2.73
10% Demand Declined and Combined Cases	B	Demand Declined	10%	15.28%	1,887.47	2.66
	C	Cost Increase	10%	13.33%	1,773.81	2.42
	D	Benefit Declined	-10%	13.13%	1,585.07	2.39
	E	C+D	10%+(10%)	11.31%	1,471.41	2.18
	F	Project Delay	1 Year	15.28%	1,736.47	2.66
	G	C +D +F		11.31%	1,353.70	2.18
Separate Cases	H	Demand Declined	-15%	15.03%	1,847.93	2.63
	I	Demand Declined	-20%	14.77%	1,808.42	2.59

The overall Poverty Impact Ratio (PIR) value of the project is 73.25% and the minimum PIR value is 42.26 % and the maximum value is 86.81 %. This shows that there is a significant variance between the maximum and minimum values, which shows that some sections in the KV line development project heavily benefit the poor people living in Padukka to Avissawella while other sections have a moderate (neither high nor low) impact for the poor to improve their living standards. When there are industries like garments, timber, brick manufacturing, hospital, tea and rubber, the percentage of poor people using the 11.26% motorcycles and 58.92% public transports were reported to be higher percentages. This is the main reason for PIR value to be higher in railroad sections of KV line which have these industries located nearby the KV line.

The Project Impact Monitoring Matrix/Framework (PIMF) shows many of the baseline indicators will definitely improve in direct and indirect project impact areas due to the KV line development. Therefore, in order to improve these baseline indicators we can recommend the KV line development. After completion of the KV line railway project Sri Lanka is going to receive a state of art part elevated modern railway line with modern rolling stocks, new signaling system and information and an upgrade in communication technology with more travel time savings, vehicle operating costs reductions, emissions reduction with many environmental benefits and accident cost reductions for commuters and people living in and around this line.

Ticket price can be increased based on the five benchmark indices (consumer price index, wage rate index, energy index, labour productivity, and transport network capacity factor). Fair increase JICA-LRT: 2020 (1.2 times), 2025 (1.5 times) and 2035 (2.3 times). Model Output: 2020 (1.2 times), 2025 (1.5 times) and 2035 (1.5 times). Frights tariffs are no issue, but need heavy investment on freight carrying, handling and storing infrastructure with more commercial freedom to Railway and private sector participation. Five pillars (Policy area, Planning area, Implementation area, Monitoring aspect, and Regulation aspects) identified to build institutional arrangement for fare setting and periodic review. Key performance indicators for benchmarking are average fare, average tariffs, average passenger subsidy, operating ratio, labour share of revenue, employee productivity, operational sustainability, and working capital ratio.

Therefore, this KV line can be developed as a state-of-art model railway line to attract lost passengers back to railway and, it is better to explore the possibility of extension of this line to link it to the main line via For the Ratnapura, Balangoda, and Ambilipitiya to Kataragama cities there is a high value-added small freight transportation possibility and other commercial development such as hotels, housing schemes, trade, and distribution center's to generate more income to recover overall costs in the long run.

15.1 Introduction

This economic and financial feasibility report presents the main aspects of economic and financial analysis with many background chapters and a comprehensive appendix. This analysis is based on the following Terms of References (TORs):

- Prepare an economic and financial analysis of the proposed priority projects. The economic analysis should follow ADB's guidelines for the economic analysis of projects.
- Provide all analysis and calculations of costs and benefits of the project to the executing agency. Assess benefits of the proposed rail line, not only in financial terms or economical, but also in terms of safety, environmental impacts, time savings, savings of transportation and travel costs, poverty reduction, increase of life standard and enhancement of trade and commercial activities likely to be created as an outcome of the proposed projects.
- Calculate the Economic Internal Rate of Return (EIRR), NPV and C/B ratio for KV Railway Line project. Undertake sensitivity analysis on the risk factor basis for various scenarios such as changes to the capacity costs, operation and maintenance costs, traffic volume, and construction period, etc.
- Conduct willingness-to-pay and other relevant surveys. In consultation with SLR, propose appropriate fare. Calculate the Financial Internal Rate of Return (FIRR) on the same basis of EIRR calculation and FNPV and C/B Ratio.
- Estimate the required budget for appropriate operation and maintenance of each project. Assess financial sustainability by comparing the required budget with the current budget allocation, and make recommendations as appropriate.
- Prepare relevant chapters and appendixes of the feasibility study report on an economic and financial assessment.
- Develop a monitoring and evaluation framework in accordance with ADB's Guidelines for Preparing a Design and Monitoring Framework. Include in the framework appropriate indicators with baseline data and targets.
- Study existing railway fare structure and recommend a suitable formula for periodical revision of railway fares. Identify appropriate benchmark indicators for fare adjustments and institutional arrangements to carry out the periodic fare adjustments.

The structure of this report: Section 1 of this chapter introduces the Sri Lankan Railway and proposed KV Line development. Section 2 of this chapter presents other preliminaries such as establishing context etc. Section 3 deals with direct and indirect benefits identification and valuation techniques used for economic and financial analysis. Section 4 presents capital, operation and maintenance costs in a more detailed manner. Section 5 presents financial and financial sources analysis with various project life spans. Section 6 deals with a very comprehensive economic analysis covering sensitivity aspects. Section 7 presents very detailed benefits distribution and poverty impact analysis. Section 8 deals with the project impact monitoring framework. Section 9 presents railway fare structure and periodic fare adjustments with new admin structures to implement these tariff changes. The final section presents the summary and conclusions and after follows appendix, which includes Sri Lankan economic report and important data tables. A separate section is included for traffic studies in the main report therefore in the economic study a separate section for traffic is not included except for using traffic-forecasting data for economic analysis.

The below Section I of this report presents Overview of the Sri Lankan Railway, History of the Sri Lankan Railway, Current Situation and Progress of Sri Lanka Railway, Brief Description on KV Rail Line and Economic, commercial and demographic profiles in and around KV Rail Line.

15.1.1 Overview of the Sri Lanka Railway

Sri Lanka Railways (SLR) is a government department functioning under the Ministry of Transport. It is a major transport service provider and is the only rail transport organization in the country. SLR transports both passenger and freight. At its inception, the railway was carrying more freight than passengers. But today, it is passenger oriented. SLR‘s market share for passenger transport is about 6.0 % and about 0.7 % for goods transport. In Sri Lanka, the service provided by SLR in carrying the daily commuters to their workplaces is inevitable. Sri Lanka Railway operates approximately 396 trains which include 67 Long-Distance and 16 Inter-city trains and carries about 3.72 Million passengers daily. SLR owns and maintains 1561km of rail tracks, 72 locomotives, power sets 78, 565 carriages and the signaling network. At present, it has a workforce of 17,634. Sri Lanka Railways (SLR) functions under the General Manager of Railways (GMR). The General Manager reports to the Secretary of the Ministry of Transport. SLR has been divided into ten Sub Departments and three Units. Sub departments are managed by the Heads of the Sub-Departments who reports directly to the General Manager of Railways.

15.1.2 History of the Sri Lankan Railway

Rails were introduced in Sri Lanka in 1864 to transport coffee from plantations in the hill country district of Kandy to the port city of Colombo on its way to Europe and the world market. The coffee blight of 1871 destroyed many a fine plantation and tea replaced coffee. With the development of tea plantations in the 1880s, the joint stock companies swallowed up the former individual proprietorship of the coffee era. Under corporate ownership and management control by companies, the process of production of tea became more sophisticated and needed more and more railways built to the Kandyan highlands. To send tea to Colombo and to transport labour, machinery, manure, rice, and foodstuff, etc to Kandy, another 100 miles of railways were constructed in the tea planting districts to serve the expanding tea domain. To serve the coconut plantations flourishing in the west, South West and North West coastal areas of the country, and the wet inland rubber plantations below the tea belt, railway lines were built in the wake of these agricultural developments. Thereafter, the need for cheap and safe travel in order to open up the hinterland of the country led to the expansion of the railway. An extension of the Main Line to Kandy was made north to the ancient city of Anuradhapura, going further north to Kankesanturai and west to Talaimannar to connect the island with South India by ferry, to bring Indian labour for the tea and rubber plantations, and also import rice and other edibles not indigenously produced in sufficient quantities. Towards the east, there was little economic justification to lay a line to the dry zone in that direction, but it became strategically worthwhile to lay a line to the natural harbour of Trincomalee and also connect it to the provincial capital of Batticaloa. These lines were laid with light (21 kg) section rails, as was the narrow gauge section to serve the rubber plantations east of Colombo, known as the Kelani Valley Line. In upcountry, a similar branch line was laid from Nanu Oya on the Main Line through very difficult terrain to serve the tea plantations around Nuwara Eliya. Track alignment was defined in this section about 140 years ago when economic considerations were vastly different. The railways achieved modal superiority with speeds of 25 to 40 kmph in the hill country and 65 to 80 in the low country and civil engineering criteria was influenced by the economic need to minimize cuts and fills, permitting gradients to 2 to 3% and minimizing bridge lengths. As a result, the alignment here is winding with very sharp curves. In the early days of the railways, the bulk of the freight was carried to the port of Colombo and as the port expanded, rail lines were laid to serve every pier.

15.1.3 Current Situation and Progress of Sri Lanka Railway

The Sri Lanka Railway recorded a gradual improvement in its operational activities from 2016. Rail passenger km increased marginally due to low tariffs, increased road traffic, and expansion of the network to Northern Province. Goods km increased 7.6% from 2015 to 2016 due to commencement of the transportation of coal, oil, and cement. In the Railway infrastructure sector many developments were recorded such as replacement of numerous railway bridges during the year span of 2016-2017. The following Table 15-1 shows the performance of Sri Lanka Railway during 2013 to 2016.

Table 15-1 Salient Features of Sri Lanka Railway, 2013-16

Item	2013	2014	2015	2016	Growth (%)	
					2015	2016
Operated Km. (_000)	10924	11075	11797	12102	6.5	2.6
Passenger Km. (million)	6257	6842	7407	7413	8.3	0.1
Fright Ton Km. (_000)	133	130	130	140	-0.3	7.6
Total Revenue (Rs. Million)	5423	5909	6335	6623	7.2	4.6
Operating expenditure (Rs. Million)	10586	16943	14049	13396	-17.1	-4.6
Operating loss (Rs. Million)	5163	11034	7714	6773	-30.1	12.2

Source: Sri Lanka Railways, 2018

The following Table 15-2 to 15-6 shows the possible development in the Sri Lanka Railway for the next three year period.

Table 15-2 Increasing operating speed from 80 km/h to 100 km/h

Project	Project Area	Period	Remarks
Rehabilitation of Coastal Railway Line	159 km from Colombo to Marara	2 years	First phase is the construction of track from Galle to Matara (45 km) with a design speed of 100km/h has already been completed.
Rehabilitation of Northern Railway Line	170 km from Omanthai to Kankesanthurai	3 years	Track with a design speed of 120km/h will be constructed in two project from Omanthai to Pallai and Pallai to Kankesanthurai. Contract has been awarded to IRCON International - India
Rehabilitation of Talaimannar Railway Line	101 km from Medawachchiya to Talaimannar Pier	2 years	Track with a design speed of 120km/h will be constructed in two project from Medawachchiya to Madhu and Madhu to talaimannarPier . This includes construction of pier too. Contract has been awarded to IRCON International - India
Replacing of Steel Bridges	8 to 10 new steel bridges	2 years	8 to 10 old bridges will be replaced with new steel bridges with the financial assistance from Belgium

Source: Sri Lanka Railways, 2018

Table 15-3 Construction of new Railway Lines

Project	Project Area	Period	Remarks
Construction of Railway Line from Marara to Kataragama	First Phase – 35 km from Matara to Beliatta	3 years	Track with a design speed of 120km/h will be constructed in two project from Matara to Beliatta and from Beliatta to Kataragama.
Construction of Southern Railway Circle	79 km from Beliatta to Hambantota	3 years	Track with a design speed of 120km/h will be constructed from Beliatta to Hambantota through Suriyawewa. The project is in its design stage.
Construction of Railway Line from Kurunegala to Habarana	81 km from Kurunegala to Habarana		Track with a design speed of 120km/h will be constructed and the Feasibility Study has been completed.

Source: Sri Lanka Railways, 2018

Table 15-4 Increasing of Rolling Stock Fleet

Project	Project Area	Period	Remarks
Purchasing of Diesel Multiple Units from India	20 Diesel Multiple Units	2 years	Twenty Diesel Multiple Units will be purchased from India to be used in the Coastal Railway Line. The DMUs will be delivered in 2011.
Purchasing of Diesel Multiple Units from China	13 Diesel Multiple Units	2 years	Thirteen Diesel Multiple Units will be purchased from chaina to be used in the Coastal Railway Line. The DMUs will be delivered in 2012.
Purchasing of Locomotives from India	03 Locomotives	1 year	Two Locomotives will be received under Southern Line construction project. These Locos will initially be used for the track construction work.
Purchasing of Trains sets for Special Journeys from China	02 Train sets	2 years	Two train sets constructed with facilities for special journeys will be received from China in 2012
Purchasing of Tank wagons from Pakistan	24 Tank Wagons	1 years	Twenty four Tank Wagons will be purchased for Oil Transport from Pakistan
Purchasing of Locomotives from India	06 Locomotives	1 year	Two Locomotives will be received under Northern Line construction project. These Locos will initially be used for the track construction work.
Purchasing of Service Wagons from India	52 Service Wagons (BHO)	1 year	52 Service Wagons will be received under Northern Line construction project. These BHOs will initially be used for the track construction work.

Source: Sri Lanka Railways, 2018

Table 15-5 Rehabilitation of Signaling and Telecommunication

Project	Project Area	Period	Remarks
Rehabilitation of Signalling and Telecommunication System in the Northern and Talaimannar Lines	310 km from Anuradhapura to Kankesanthurai and Medawachchiya to Talaimannar Pier	3 years	The project includes installation of Colour Light Signaling and Telecommunication System with Optical Fiber backbone and Radio Telecommunication.
Replacing the Centralised Traffic Control System in the Coastal Line	35 km from Maradana to Wadduwa	1 year	The 25 year old CTC system in the Coastal Line from Maradana to Wadduwa will be replaced with a new system
Rehabilitation of Signalling and Telecommunication System in Main Line	72 km from Maradana to Rambukkana	2 years	The project includes replacing 50 year old Colour Light Signaling system including Centralized Traffic Controlling and installation of Telecommunication System with Optical Fiber backbone and Radio Telecommunication.

Source: Sri Lanka Railways, 2018

Table 15-6 Electrification

Project	Project Area	Period	Remarks
Electrification including Electric Multiple Units and Signalling	120 km from Veyangoda to Maradana, Ragama to Negambo and Maradana to Kaluthara	3 years	The project includes electrification and supply of 15 Electric Multiple Units.

Source: Sri Lanka Railways, 2018

Table 15-7 Information Technology

Project	Project Area	Period	Remarks
Electronic Payments	Electronic payment facility will be made available 06 payment types	01 year	Online payment facility for Seat Reservation, Reservation of Special Trains, and Payments for advertising, Filming, Goods Transportation and Tender Document Purchasing will be made available by developing applications. ICTA and SLR will sign a MoU for this implementation.
Mobile Seat Reservation	The existing M-Seat Reservation system in the main Line will be expanded to other lies	01 year	The Mobile Seat reservation system that was implemented for the Intercity trains between Colombo and Kandy will be expanded to other lines too. A MoU has been signed between SLR and Mobitel for this purpose.
SLR e-Pension System	Connecting SLR to the e-Pension System in the Pensions Department	02 years	The pilot project was started to connect SLR to the e-Pensions system. This reduce major delays in receiving the pension benefits by the SLR pensioners.
Train Tracking and Operating Information System	GPS/GSM based Train Tracking and Operating Information System for the entire railway system	02 years	The system will be installed at Maradana Train Control Center and train sets will be equipped with GPS/GSM/Speedometer Units. The system will enhance train controlling function while giving exact train operation information to public. This is done with the assistance from ICTA.

Source: Sri Lanka Railways, 2018

In spite of the introduction of some improvements and innovations as stated above, the quality of train services still remains sub-standard, requiring urgent attention in order to exploit unique opportunities in mass transit and transform the SLR into a financially viable institution. The shortage of trains and train compartments during peak hours, lower demand for train services during off-peak hours, lack of value-added services, including luxury and intercity train services, inability to ensure timely service delivery on a sustainable basis, a lack of emphasis on the usage of train services for goods transportation and inferior catering and sanitary facilities can be identified as key concerns. The availability of a reliable and comfortable train service could attract the general public towards mass transit. Therefore, upgrading and expanding the railway network through strategic Public-Private Partnerships to increase the capital infusion, including electrification of the railway, introducing faster and comfortable intercity services that could facilitate regular users as well as the increasing number of tourists who seek luxurious and relaxing ways to travel around the country, bringing modern technology to signaling and telecommunication systems to ensure a timely service delivery and promoting rail services as a cost effective alternative for goods transportation through a simple and efficient service are essential in improving the quality of railway services. Moreover, introducing market-oriented fare schemes while permitting concessionaries to the lowest fare segment would help improve the financial position of SLR and in overall serious thinking is necessary to re-engineer management style and structure in Railways to fit into modern age. Interesting fact is that in accordance with recent development in Colombo and Western Province such as Port-City and Meagapolis projects some development are happening in railway sector to smooth movements of passenger and goods between various urban and economic centers.

The following Figure 15-1 shows the overall railway network in Sri Lanka.

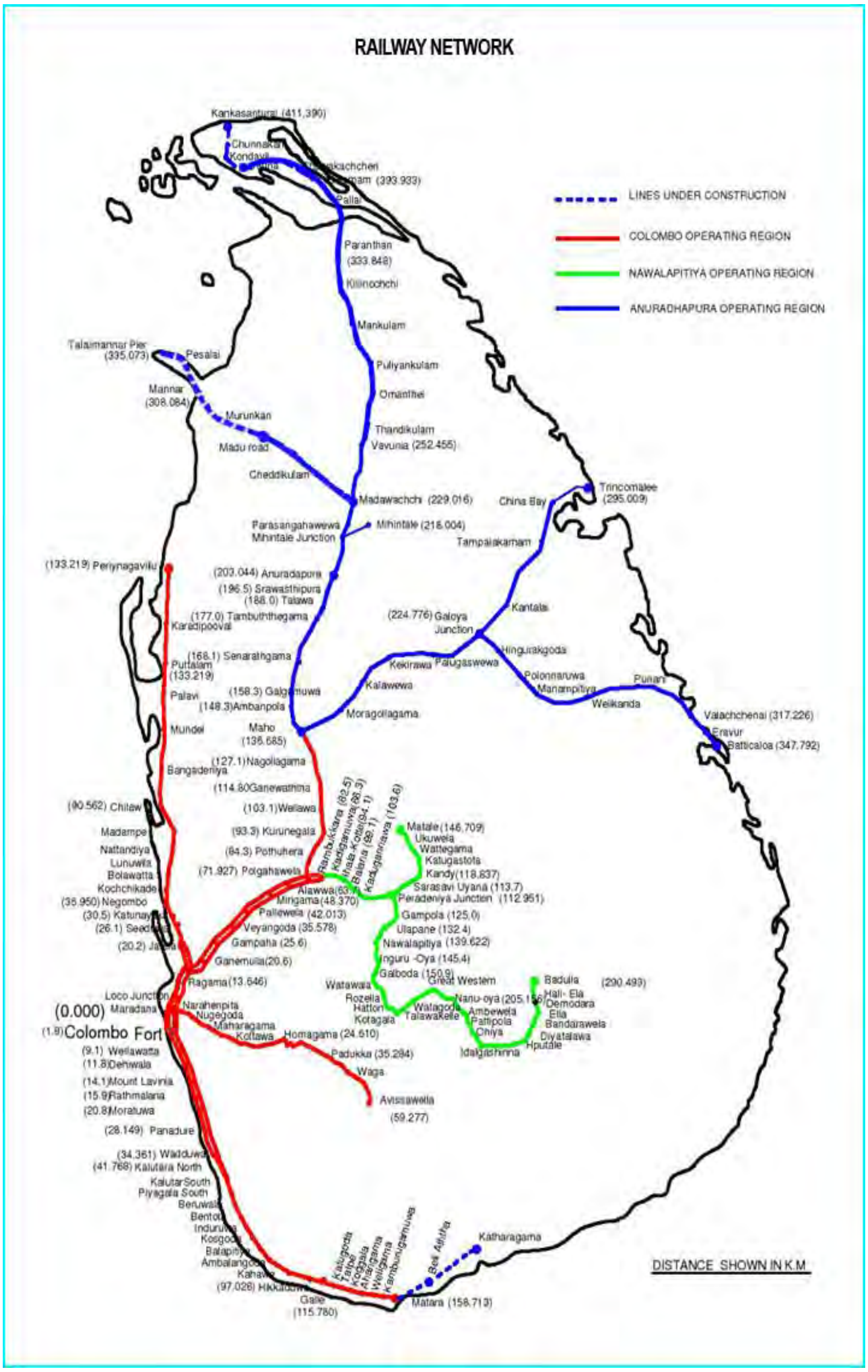


Figure 15-1 Overall Railway Network in Sri Lanka

The following Table 15-8 shows length of each railway line at 2016.

Table 15-8 Line-wise Track Lengths of Sri Lanka Railway at 2016

Railway Line Name	Lengths (km.)
Main Line	290.49
Matale Line	33.75
Puttalam Line	133.86
Puttalam Line – Airport Spur	2.0
Puttalam Line – Aruvakalu Spur	37.0
Northern Line Polghawela to Omanthi Omanthi to Killinochi Killinochi to Jaffna Jaffna to Kankasanthurai	 193.3 63.19 65.50 17.45
Talaimannar Line Medawachiya to Madu Madu to Talaimannar Pillar	 42.99 63.05
Batticaloa Line	211.10
Trincomalee Line	70.23
Coast Line	158.73
KalaniVally Line	59.27
Mihintale Line	15.0
Kolonnawa Spur	02
Habour Spur	02

Source: Sri Lanka Railway, 2018

15.1.4 Economic, Commercial and Demographic Situation in KV Railway Line

KelaniVelly (KV) railway route runs through Colombo district from Colombo fort to Avissawella. Avissawella is the final destination of the route, which is adjoining with the Ratnapura and Kegalle districts. Earlier this route existed up to Opanayaka city. The route runs through Kotte, Maharagama, Homagama, Padukka and Seethawaka (Avissawella) DS divisions. Kotta Road, Narahenpita, Kirullpane, Nugegoda, Maharagama, Pannipitiya, Kottawa, Malapalla, Homagama, Padukka, Kosgama and Avissawella are the main town areas where the train runs through. Among these major stations Nugegoda and Maharagama are urban locations and Homagama is a rapidly urbanizing area. Padukka, Kosgama and Avissawella are still considered as sub-urban areas with many potentials to develop as commercial and industrial centers. Therefore, the KV railway route connecting the urban, sub-urban and rural areas of Colombo leading to Rathnapura and Kegalle districts. Altogether 53 level crossings and 32 stations exist with a length of 60 km in Mardana and Avissawella.

The following Figure15-2 shows complete railway Line from Mardana to Avissawella.

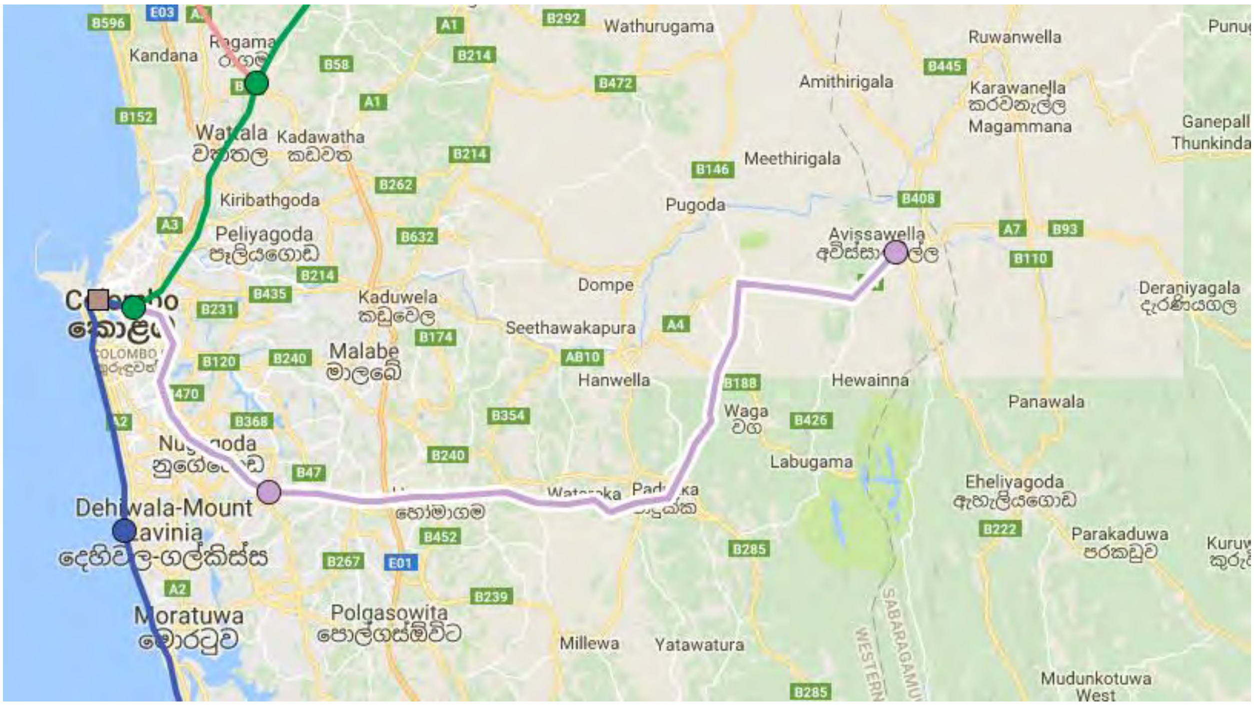


Figure 15-2 KV Railway Line Hinterland

Kotte DS division is covering 1700 Hec and hosting 110, 277 residents. The capital city of Sri Lanka is situated within the Kotte DS division. Hence this DS division has been one of the demanding residential destinations in Colombo district. There is no major agriculture production in Kotte, where Trade and commerce is the major economic activity. Nugegoda is the famous destination of the KelaniValley Rail route situated in Kotte DS divisions. Nugegoda is one of the major urbanized commercial towns in Kotte DS division. Nugegoda is hosting a famous destination for buying household items, tiles, garments, and private tuitions classes. Apart from that Nugegoda is a highly residential area, where a large number of people travel to Colombo for work. Since the Nugegoda railway station is located in the heart of the town with connecting public transports within close proximity, a large number of employees, consumers, and vendors travel by train on daily basis.

Maharagama DS division is hosting 200,703 residents within 3,800 Hec. Similar to Nugegoda, Maharagama is a famous residential area of Colombo district with high commercial attraction for garment products. Commercial and service sector is dominant in this area and there are a large number of wholesale and retail shops located to sell garments products coming from other parts of the country. There are large to small scale labor incentive garment factories in Maharagama which attract a large number of employees and customers to the town. Apart from that National Youth Centre and National Cancer hospital located in Maharagama DS division which attracts a large number of people to the city. Since Maharagama is a highly populated residential area, a large number of residents travel by train to the city of Colombo for their work places.

Homagama DS division is hosting 243,089 residents within 12,100 Hec land area. Owing to the diminishing nature of the lands in Kotte and Maharagama DS divisions large number of people attracted to Homagama DS division in recent years. Homagama DS division is the largest agriculture active DS division in Colombo district where 2939.3 Hec were cultivated in the year 2016, which is the highest extent in Colombo.

There are 116,287 residents living within 15000 Hec in Seethwaka DS division. There are 734.9 Hec of agriculture lands in the area cultivating paddy, food crops and industrial crops like rubber. Apart from the agriculture activities, Seethawaka DS division hosts the Seethavwaka Free Trade zone which is the largest industrial area within the division.

Padukka DS division is the least populated division along the Kelani Valley rail route with only 66,689 residents living in 11,000 Hec. Padukka DS division contains the second highest agriculture land extent in Colombo, where 1878.2 Hec has been used for farming. There are a number of garment factories, rubber, and furniture manufacturing factories in the area. When developed Kelani Valley railway route would be able to transport these products to Colombo city center and create new business opportunities for local industrial and agriculture products in Padukka DS division.

The following Table 15-9 shows micro, small, medium and large scale industries located in hinterlands of KV line.

Table 15-9 Small, Medium and Large Scale Industries in KV line Hinterland, 2013/14

DS Area	Micro	Small	Medium	Large
Colombo	23571	4055	686	274
Thimbirigasyaya	9067	2721	962	361
Kotte	4131	1062	292	82
Maharagama	9381	1176	193	36
Homagama	11340	976	178	33
Paddukka	2803	184	30	07
Sithawaka (Avissawella)	6419	516	66	33

Source: Census and Statistics Dept, Sri Lanka, Industry Census 2012/13.

The following Table 15-10 shows population data for year 2012 and 2016 in KV line hinterland.

Table 15-10 Population for 2012 and 2016 in KV Line Hinterland

DS Area	2012	2016	Growth rate
Colombo	323257	330301	2.17%
Thimbirigasyaya	238057	243245	2.17%
Kotte	107925	110277	2.17%
Maharagama	196423	200703	2.17%
Homagama	237905	243089	2.17%
Paddukka	65267	66689	2.17%
Sithawaka (Avissawella)	113807	116287	2.17%

Source: Population Census 2012 and District Statistical Hand Book 2017

The following Table 15-11 shows trade and service establishments in KV Line hinterland for year 2013/14.

Table 15-11 Trade and Service Establishments in KV Line Hinterland for year 2013/14

DS Area	Trade Establishments	Service Establishments
Colombo	56222	51128
Thimbirigasyaya	5246	6523
Kotte	2410	2455
Maharagama	4345	3958

DS Area	Trade Establishments	Service Establishments
Homagama	4655	4449
Paddukka	1182	1043
Sithawaka (Avissawella)	2693	2626

Source: Census and Statistics Dept, Sri Lanka, Non Agriculture Census, 2012/13

15.1.5 Justification of Economic and Financial Analysis on KV Railway Line Development

The KV Railway Line is a single track line with few passing loops in some places. The line is serving a highly populated area in and around Colombo Metropolitan area and Western Province and has a high ridership potential. Many studies (EGIS, 2017; Com Trans, 2014; MegaPolis, 2016) concluded that the single track layout does not provide the necessary capacity required to transport the estimated number of passengers and possibly freights. Even if all stations were equipped with passing loops, this would still not be enough. Many studies pointed out that KV Railway Line would need to be converted to double track to allow a greater number of service frequencies to attract h more passengers and freights. However, dueling of the tracks alone may not bring significant improvement in journey times. In addition, the laying of the double track will not bring a solution in regards of traffic road with numerous level crossings staying closed too long and the train speed will be limited due to sharp curves and the difficulties to rectify these curves at the level. Previous studies identify several constraints limiting the development of the KV Lines:

- The line is with single track with few passing loops, and there is no room for dueling the track due to high urbanization / encroachment next to the existing line;
- The line geometry is really winding with short radius curves limiting the maximum authorized speed and thus affecting the operating speed which average 25 kmph;
- Numerous level crossing with 17 level crossing on high to very high traffic roads;
- Station platform lengths are short and cannot accommodate long and more capacitive trains.
- Too many stations and too many level crossings.
- Heavy encroachments around KV Railway Line.

Therefore the natural speed of the railway is limited and many other benefits can be expected from the railway development that many may not realize. In this context, to develop the services on KV Railway Line with increased headways and reduced travel time, several options have been suggested by previous studies:

- Dueling of the tracks as much as possible.
- Improving the line geometry to ensure greater authorized speed at ground level.
- Eliminating as much as level crossing, too many stations and human encroachments around Rail Line.
- Introducing new technologies allowing higher speed with sharper curves.
- Increasing platform length and covert major stations as commercial centers.
- Link railway with many other economic and commercial activities/centers in and around KV Line. Especially this KV Line development can be linked with Sithawaka Industrial Zone, MegaPolis and other regional bodies‘ various development initiatives.

Therefore, it is better to conduct a deep scientific study to analyze an alternative for overall improvement of the KV Railway Line, studying layout improvement, and reducing rail - road conflicts by giving equal emphasis on the economic and financial feasibility of this development. Therefore this section of the feasibility report carries out the comprehensive economic and financial justification of the KV Railway Line development to check its real contribution to the national and private economy. This systematic process of identifying, quantifying, and comparing expected benefits and costs in economic and financial terms assists decision-makers to organize information about, and evaluate trade-offs among, alternative transportation investments to take the right decision on transport investment to utilize scarce public resources to the best alternative.

15.2 Establishing Context for Economic and Financial Feasibility Analysis

It is essential to place both, the general numerical frameworks as well as the financial and economic feasibility analysis results (FEFA) into a proper context of in reality interrelated and dynamic surroundings. This is achieved by identifying the development policy and planning as well as analytical perspectives in which the project analysis takes to plan. Only when interpreted in the context of such ―dynamic fields” become the numbers and their implications their real meaning.

The interrelated reference frameworks in the context of the KV Line feasibility study (FS) which are briefly discussed are:

- Previous analyses and their recommendations
- The project‘s relevance, justification and design
- The underlying general socio-economic framework conditions and those of the project‘s ―influence area”, and
- The capabilities of the transport modeling software that was engaged in estimating future demand, in this case future ridership on the KV Line.

The KV Line FS references in a strongly complimentary manner selected key planning and analytical documents. They are listed in Table 15-12 identifying by key categories their core characteristics. Key documents are colored in ―green” because of their scope and depth of analysis and recommendations. There is no need in the context of this FS to discuss in detail each and every aspect of these documents. However, they are referenced in particular for certain analytical aspects by using in a critical way their assumptions, findings and/or recommendations as plausibility control parameter for the present FS.

It suffices here to state that at transport/rail sector and project level the most important reference material originates from the 2014 Comprehensive Transport System Master Plan, the two Megapolis master plans and only to a certain extent the 2017 EGIS reports (though the pre-FS KV Line EGIS report covers only a segment of the KV Line that runs between Maradana to Avissawella Stations).

Table 15-12 Policy and Planning Studies Reviewed for this Feasibility Study

CRITERIA Document/Study	Year Issued	Analytical Level	Gist of Document	Relevance	Main Recommendations
1. Mahinda Chintana; Vision for a the future	2006	Policy document with vision	Sector-wise policy direction	Indirectly	10-years policy framework 2006 to 2016. The vision & objectives are sector-wise structured. The key phrase for transportation is "sustainable mobility".
2. Draft National Policy on Transport in Sri Lanka	2009	Draft poliicy for transport sector	Focus on transport sector	Indirectly (no final version yet)	Identifies strategies and policy objectives by transport mode. Defines key issues by mode. One key concern is the lack of coordinated efforts for inter-modal transportation is "sustainable mobility".
3. MEGAPOLIS Master Plan	2016	Policy Diretion for the Megapolis Region	Policy document	Directly	Comprehensive definition of vision, objectives and interventions for the whole region, covering key clusters of sectors and identifyng needed mega projects
4. MEGAPOLIS Western Region Transport Master Plan	2016	Policy document for transport sector	Sector-specific policy decoment	Directly	Comprehensive definition of objectives and investment interventions for the Megapolis transport sector development up to 2025
5. COMTrans Transport System - Technical Report 5	2013	Very detailed on demand modeling	Methodology Paper	Directly	This is a very comprehensive mthodology paper explaining the structure and use of the COMTrans demand modeling exercise
3. Sri Lanka Railway Master Plan	on-going	Development Project	Project document	Directly	ADB sponsored master plan for the railway sector with a planning horizon of 2040. Project covers hardware & software side of network development.
4. Colombo Sub-urban Railway Project PPTA	2017	Project level	Viability study	Directly	Technical and economic viability analysis of 2 lines of the railway network in the Colombo Metrpolitan Area and the Western Province. EGIS report
5. Kelani Valley Line - Alternatives study (Part of PPTA)	2017	Project level	pre- FS	Directly	The KV Line forms part of the 4 lines which are covered by this pre-FS. Modernization of this line is the key direction of analysis and recommendations. EGIS report
6. Intercity Rail Services (Part of PPTA)	2017	Project level	Analytical	Directly	Analyses intercity rail transport features and estimates impact of improved railway system taking into account demand, fares, improved service level. Horizon is 2035.
7. Economic Analysis Ticketing and Fare Collection Stsem (Part of PPTA)	2017	Project level	Analytical	Directly	Impact assessment of the introduction of a multi-modal ticketing system
8. Financial Management Assessment Part of PPTA)	2017	Project level	Analytical	Directly	Based on an assessment of financial manegment issues, establishes recommendations to address them and also includes a risk assessmen
9. Resettlement Plan for the Kelani Valley Line (UN-HABITAT report)	2017	Project level	Analytical & Planning	Directly	Very empirical resettlement plan for households and assets along the KV Line. However, one limitation is that it covers only the section between Maradana and Homogama
10. Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs	2014	Project level	Planning Master Planning Master	Directly	Very comprehensive transport sector analysis and sector planning with a planning horizon of 2035. Comprsies a number of short, medium and long term investments including intermodality and public transport
11. SLR Annual Performance Reports	Anually	Company level	Performance Evaluation	Directly	SLR reports yearly to Parliament on its perforance. The reports cover the whole railway network and provide empirical business performance statistics

Source: Feasibility Study Team.

15.2.1 Transport Sector Issues and Government Policy Objectives

The documentation identifies the following transport sector issues and Government policy objectives. The highest policy hierarchy level at national level is the ―Mahinda Chintana" policy that is geared at transforming Sri Lanka's economy and society. The ―Mahinda Chintana's" overall goals (MCGs) are directed:

- At raising the GDP growth rate over a long-term period in excess of 8 percent
- Increasing the country's per capita GNP to middle income country level (GNI 2018 base of between USD 3,956 to USD 12,235), and

- Reducing poverty and income disparities among geographic regions.

As regards to the transportation the policy‘s key dictum is ―sustainable mobility”. The MCG identifies as core issues: (i) the road mode, which is dominated by private motorized transportation, is the dominant mode; (ii) this leads to a significanly growing demand for energy imports; (iii) rail transport has only a very limited modal share; (iv) high petroleum prices result in the need for significant subsidies; and (v) there is only a limited role of public transport.

The vision for the transport sector is defined as an efficient and safe transport system at an affordable cost and responsive to the needs of social and economic development. Policies to achieve the objectives are identified as:

- The tariffs for transportation will be related to the cost of providing such services
- Subsidies shall not be granted by the Government to transport services providers and users except in very special cases
- Subsidies may be granted in order to reduce social cost, for example in the provision of urban or rural commuter service or for the transport of school children, and
- Government regulation of transport shall comprise safety and economic regulation.

These broad policy directions have a direct bearing in this feasibility study, for example on the rail fare level setting and fare adjustment mechanism dimensions.

The 2009 draft ―National Policy on Transport in Sri Lanka” formulates as a vision for the transport sector ―*To ensure a satisfactory access to and choice within a safe, reliable, efficient and integrated system of transport modes and services that satisfies the diverse public and corporate needs for mobility for both goods and people.*” The policy targets fourteen objectives and is tailored around principles. The most important objectives are, inter alia, adequate availability of transport infrastructure, the optimum utilization of existing resources, a minimum level of access, the reduction of social exclusion, safety and security and competitiveness among modes.

The two most relevant policy studies that guide the future development path for the Western Province in general, the Colombo Metropolitan Region (CMR) in particular and the project‘s ―influence area” are the recent ―Megapolis Master Plan” and the ―Megapolis Transport Master Plan”. A deeper appreciation of the gist, scope and depth of the two policy and planning documents is essential because of the strong and direct impact they have on:

- The project‘s design, justification and rationale (why is the project needed)
- The fundamental assumptions matrix (direct and ―silent” assumptions) that are employed in this feasibility study
- General numerical macro and socio-economic input data used in the STRADA model (the socio-economic projected frameworks)
- General numerical individual input parameter into the STRADA model for the demand/ridership estimations (for example existing and projected modal splits)
- The demand shaping factors that in turn generate the benefit streams which are assessed as against the project‘s cost streams indicating the project‘s overall economic viability (for example the shift from private motorized transport to the public transport system)
- The definition of 2018 ―base year” monetized unit values, such as for example for vehicle-operating-cost (VOC),vehicle-time-cost (VOT) and so on, and

- Identification of the type (sector and sub-sector), investment size, location relative to the project‘s influence are, and implementation timing of Megapolis public project investments that impact demand on the railway system, including the KV Line. These project form ―prerequisites" for the level of realisms of this FS demand/ridership and benefit streams estimations.

The above panoramic review of transport sector issues and policy responses by the Government of Sri Lanka shows that the subject project rationale is highly responsive to prevailing transport sector issues and Government policies. It will not only promote the use of public transport, but also enhance the potential role which rail-based passenger and goods transport can play in urban areas, in particular for commuter transportation.

The only somewhat ―difficult" and perhaps intrinsically contradictory policy field is the balance between the economic and social dimensions, i.e. finding the right answer to an adequate railway fare system and fare adjustment mechanism. This issue will be addressed more in depth in the relevant sub-chapter of this feasibility study. Another point to be discussed in this context is the question on how this project relates to the Government‘s ―Public Service Obligation (PSO)".

15.2.2 Sri Lanka's Motorization Growth Trend

Yet another key context dimension for the promotion of public transport is the country‘s motorization level and its long-term growth trend, because of the impacts on the environment (pollution) and other performance features (such as congestion levels, increases in VOC and VOT, parking problems and so on). Cost considerations and spatial limitations limit the possibilities for accommodating ever increasing motorization levels reflected in a certain ―motorization saturation" level. What are the characteristics, trends and potential future implications in the case of Sri Lanka? This section highlights these aspects for the proposed railway project. Reference is made in this context to an in-depth analysis made in 2014 under the umbrella of the comprehensive master plan for the CMR. This analysis uses the 2005 to 2012 period as reference period. These data are then complimented by characteristics indicated over the 2010 to 2015 period with a view to identify any trend changes in the structure of the motorized vehicle fleet and its growth. National and WP level characteristics are used as control parameter.

Table 15-13 summarizes the results for the long-term period and shorter 2010 to 2015 reference period. National level trends are utilized as plausibility control data for the Western Province, and Western Province data can be used as plausibility control data not only for the CMR, but also for the project‘s ―influence area".

The number and type of motorized vehicles in combination with average occupancy rates, existing and forecasted origin/destination (OD) patterns, operating cost and trip purpose highlights the potentials of modal shift away from private motorized vehicle use of various types toward public transport uses by public rail and/or public bus. Key characteristics are summarized as:

Table 15-13 Motorization Characteristics and Major Trends in Vehicle Stocks

Parameter	Unit	Stocks 2005	Stocks 2010	Stocks 2015	Stocks CAGR (%)	Growth trends (%) 2005 2010	Growth trends (%) 2010 2015
NATIONAL LEVEL							
1. Buses and coaches	"000"	40.2	41.5	52.7	2.74	0.64	5.22
2. Cars *)	"000"	397.2	486.9	865.4	8.10	4.16	12.19
3. Motor cycles	"000"	981.3	1,360.2	2,250.6	8.65	6.75	10.6
4. Goods Transport Vehicles	"000"	161.8	85.3	224.6	3.33	12.02	21.36
5. Land Vehicles	"000"	87.7	201.1	101.4	1.46	18.05	12.80
6. Three Wheelers	"000"	291.0	480.1	940.8	12.45	10.53	14.40
Total **)	"000"	**1,959.2**	**2,655.1**	**4,435.6**	8.51	6.27	10.81
WESTERN PROVINCE LEVEL							
1. Buses and coaches	"000"	20.2	21.2	25.2	2.24	0.97	3.52
2. Cars*)	"000"	292.5	335.2	463.6	4.71	2.76	6.93
3. Motor cycles	"000"	370.2	464.4	681.2	6.29	4.64	7.96
4. Goods Transport Vehicles	"000"	78.6	15.4	96.5	2.07	27.82	44.34
5. Land Vehicles	"000"	15.5	88.6	15.3	0.13	41.72	29.62
6. Three Wheelers	"000"	132.8	179.1	313.2	8.96	6.16	11.83
Total **)	"000"	**884.8**	**1,073.2**	**1,595.7**	6.07	3.94	8.26

otes: *) Includes dual purpose vehicles.
**) Excludes the vehicle "other" and "special purpose" vehices.
Sources: Technical support paper for the Comprehensive CMR Master Plan and data from Social & Economic Yearsbook 2017.

- The overall trend in motorization levels at national level for the period 2005 to 2015 is with about 8.5 percent well above the country's population growth rate and significantly above the average GDP growth for the period. The growth performance appears to be accelerating from about 6.3 percent (2005 to 2010) to about 10.8 percent for the period2010 to 2015
- The stock in motor cycles exceeds the stock of all other vehicles types by a wide margin, followed closely by cars and three wheelers which have significant importance for short to medium distance urban transportation. The CAGR for motor cycles over the reference period 2005 to 2015 exceeded with about 8.7 percent that of the total fleet (8.5 percent) closely followed by cars which grew at about 8.1 percent
- The highest absolute CAGR was with about 12.5 percent that for three wheelers, a typical short distance urban means of transport
- The growth trend at national level has accelerated for all vehicles types except land vehicles between 2010 to 2015 measured against the growth over the period 2005 to 2010
- If growth of the total motorized vehicle fleet continued in line with past trend, the country should have a total stock in 2018 of about 5.67 million motorized vehicles. However, official statistics for 2015 report the size of the motorized vehicle fleet to 6,302,141 and for 2016 6,334,942 vehicles of all vehicle types. The statistical per capita coverage ratio in 2015 was about 21 percent, or expressed differently every fifth Sri Lankan owned a private motorized vehicle

- The stock of motorized vehicles at Western Province level grew from about 884.8 thousand in 2005 to about 1.6 million in 2015 reflective of a CAGR of about 6.1 percent, i.e. below national average. The province‘s share in total national fleet size declined however from about 45 percent in 2005 to about 36 percent in 2015, which seems to be reflective of faster growing motorization trends in other provinces of the country
- As is the case at national level, the long-term trend CAGR over the period 205 to 2015 for three wheelers was highest at almost 9 percent, followed by motor cycles and cars
- As is the case at national level the growth performance accelerated from 2010 to 2015, except for land vehicles.

The above rather descriptive findings are a snapshot of past trends. It is instrumental to identify the most important implications for the country if the shift away from private motorized transportation to public rail or bus based transportation is significantly postponed or cannot for whatever reasons be realized. Selected key points are:

- Petroleum and petroleum-based products are traded in US dollars, which Sri Lanka has to earn mainly from her exports. However, the potential for rapid expansion of agricultural exports is quite limited due to limited land area availability and limitations to productivity improvements. For example, when the oil price was well above US$ 100/barrel the country had to allocate significant resources, in order to cover the oil/petroleum import bill. The base price for West-Texas-Intermediate (WTI) is again over 70 US$ and, for various reasons increasing. In short, Sri Lanka cannot afford an ever growing private motorized vehicle fleet
- The CMR is the country‘s largest urban agglomeration and densely urbanized. The urban road network cannot for physical and cost reasons be expanded easily. There is already severe congestion (though unevenly distributed) on the urban network, there is not enough parking space and there are basically no ―park & ride" facilities, and other effects, such as pollution, noise and so on, are on the rise.

These general notions are complimented by a ―what if" sketch, which is beyond the TOR for this FS, but which provides mental orientation points at the broader analytical level that uses a vehicle ownership indicator ―number of vehicles per 1,000 population" as main parameter to show what could happen, if:

- Past motorization trends are allowed to continue unabated at national and Western Region levels say up to the year 2055, and
- The Megapolis spatial structure and growth assumptions, in particular per capita income growth are realized as now planned (private vehicle ownership being quite responsive to per-capita income increases.

Table 15-14 shows the results of this mental exercise using the above identified analytical key indicator.

Table 15-14 —Wat if" Scenario Motorization Trends Continue Unabated to 2055

(Unit: as indicated)

Indicator	Unit	2025	2035	2045	2055	CAGR 2025 2055
At National Level						
1. Population Size*)	million	21.350	21.492	21.165	20.326	**-0.16**
2. Vehicle Stock **)	million	10,038	22,717	51,410	116,344	**8.51**
3. Implied Ownership Ratio	vehicles/ 1,000 people	**470**	**1,057**	**2,429**	**5,724**	

Source: Feasibility Study Team.

Notes: *) Data are from the UN-Population Division, Medium growth variant.
**) Assessed at 8.51% p.a. for the total fleet.

It can be rather categorically stated that such a development is completely undesirable. Selected key observations are:

- If past motorized vehicle stock at national level would continue growing at past growth performance the car ownership ratio would almost double only up to 2025, namely from an estimated 214 vehicles per 1,000 inhabitants in 2015 to about 470 vehicles per 1,000 inhabitants in 2025
- Under —cterus paribus" assumptions that ratio would increase between 2025 to 2035 to about 1,057 vehicles per 1,000 inhabitants by 2035, which is most likely clearly well above the country's –saturation ratio".

It is therefore suggested as a side output of this FS that the appropriate Government entities undertake as soon as possible an analytical scientific study of the likely future impacts and inter-relationships of potential future development trends in the level of motorization. The gist should, inter alia, look at:

- The empirical relationship between income growth and motorized vehicle ownership patterns
- The impacts of various policy interventions, such as import tariffs, tax levies on imprts and fuels, financing schemes and so on the pattern of motorized vehicle ownership
- The need for parking spaces and –park & ride" facilities under certain motorization patterns, and
- The impact of future possible motorization levels on the import bill for petroleum related products and the need to increase export earnings in order to earn the foreign exchange to pay for that energy import bill.

For, inter alia, all of these context reasons, the country has only the one choice of vigorously promoting public transport as a road to long-term sustainable transportation.

15.2.3 Transport Sector and Macro-economic Key Parameters

Table 15-15 summarizes selected transport sector relevant macro-economic key parameters. The eneral reference period is the eight years from 2010 to 2017. The direct and indirect impact on investment project realization and its potential consequences is summarized as:

Table 15-15 General Macro-economic Characteristics

(Unit: as indicated)

Parameter	Year / Unit	2010	2011	2012	2013	2014	2015	2016	2017	CAGR (%) 2010 to 2017
A. Gross Domestic Product (nominal (GDP)*)	Rs. billion	6,413.7	7,219.1	8,732.5	9,592.1	10,361.2	10,950.6	11,906.8	13,289.5	10.97
B. GDP (real 2010 constant prices)*)	Rs. billion	6,413.7	6,952.7	7,588.5	7,846.2	8,235.4	8,647.8	9,034.3	9,315.5	5.48
C. Population Size**)	Million	20.198	20.315	20.425	20.527	20.624	20.714	*20.819*	*20.924*	0.506
D. Per Capita Income (nominal)	Rs.	317,540	355,358	427,538	467,293	502,383	528,658	571,918	635,130	8.65
E.Per Capita Income (real 2010 prices)	2010 Rs.	317,540	342,246	371,531	382,238	399,313	417,487	433,944	445,206	3.83
F. Median Age	Years	22.8	24.2	25.8	27.6	28.9	30.4	32.2	32.3	n.a.
G. Labour Force***)	Million	8.108	7.926	7.798	8.034	8.049	8.214	8.311	8.567	0.79
H. Share in TOTPOP	%	40.14%	39.02%	38.18%	39.14%	39.03%	39.65%	39.92%	40.94%	n.a.
I. Population Size 15 to 64 years	Million	12.681	n.a.	n.a.	n.a.	n.a.	14.289	n.a.	n.a.	n.a.
J. Share of Working Age Population	%	62.78%	n.a.	n.a.	n.a.	n.a.	68.98%	n.a.	n.a.	n.a.
K. Participation Rate (****)(a)	%	48.10%	52.90%	47.20%	52.50%	53.70%	53.20%	53.80%	54.10%	n.a.
L. Gross Fixed Capital Formation (GFCF) (nominal terms)*****)	Rs. Billion	1,452.00	1,772.52	2,189.81	2,809.79	2,874.38	2,814.29	3,175.78	3,502.12	13.40
M. Share in Nominal GDP	%	22.64%	24.55%	25.08%	29.29%	27.74%	25.70%	26.67%	26.35%	n.a.

Source: *) Department of Census & Statistics, GDP Summary as of 2018-03-15.
**) Based on data tables of the UN Population Division. Population size for 2016 and 2017 based on growth rate between 2010-15.
***) Based on Table 54 of the Central Bank's Annual Report 2017.
****) Based on Table 7 of the Central Bank's Annual Report 2017.

Notes: a) Note that this rate is based on total household population aged 15 years and over.
n.a. = not applicable.

- Real GDP growth (2010 constant prices) over the reference period and at national level is recorded at about 5.5 percent hence, assuming roughly a 6 percent real GDP and/or gross-regional-domestic product as a minimum benchmark value for the projects broader influence area seems reasonable. Adjustments can be made in reflection of the influence area‘s GRDP structural composition and changes therein as well as other investment projects which will impact transport demand up to the project‘s planning horizon. The level of economic activity is one of the two most significant input parameter for transport demand modeling
- Nominal per capita income over the reference period grew by about 8.7 percent. This will influence the volume of private consumption expenditures that will be utilized for transportation and may have a profound impact on the composition of motorized transport (motorbikes, private vehicles and public transport modes). Table 15-16 summarizes private consumption expenditures for the reference period used for transportation. It is noteworthy that total consumption expenditures for transportation expanded by factor 3.3 faster than total private consumption expenditures (12.68 percent against 3.83 percent). On a per-capita basis expenditures for transportation expanded with a CAGR of about 8.8 percent over the reference period

- The absolute size of the recorded labor force did not increase significantly from about 8.1 million people in 2010 to about 8.6 million in 2017 reflecting a CAGR of only 0.79 percent, only slightly above the population growth rate. This raises the question for a deeper analysis of the sources of real GDP growth, the raising share of the working age population and the reported increase in the participation rate.

Table 15-16 Private Consumption Expenditures for Transportation

(Unit: current prices)

Parameter	Year / Unit	2010	2011	2012	2013	2014	2015	2016	2017	CAGR (%) 2010 to 2017
A. Total Private Consumption Expenditures*)	Rs. billion	3,651.6	4,568.4	5,274.5	6,483.7	6,981.9	7,376.2	7,601.4	8,262.8	3.83
B. Expenditures for Transportation*)	Rs. billion	774.7	963.6	1,240.8	1,353.7	1,548.5	1,363.3	1,423.0	1,786.6	12.68
C. Population Size**)	Million	20.198	20.315	20.425	20.527	20.624	20.714	*20.819*	*20.924*	0.506
D. Share of Transport in A)	%	21.22%	21.09%	23.53%	20.88%	22.18%	18.48%	18.72%	21.62%	n.a.
E.Per Capita Expenditure Transport	Rs.	38,357	47,435	60,750	65,948	75,081	65,816	68,350	85,386	8.76

Source: *) Central Bank Annual Reports 2017 and 2014.
**) Based on data tables of the UN Population Division. Population size for 2016 and 2017 based on growth rate between 2010-15.

Table 15-17 throws some highlights on the structural composition of GDP and changes therein. The recorded data indicate the following trends:

The Western Province" GRDP including the CMR account for over 40 percent of the country's GDP over the reference period of 2010 to 2015 although it must be noted that the relative position vis-à-vis the combined GRDP of all other provinces is slowly declining, and

The structural composition of GRDP itself depends heavily on the services sector with the industry sector slightly gaining in importance. The agricultural and services sectors both display a clear declining trend curve.

Though the above data are at national/provincial levels, they are used in plausibility tests in this feasibility study as control numbers or benchmarks for transport model input data as well as the forecasts for the project's generated transport demand generated in and by its influence area.

Table 15-17 GDP Structural Composition by Province 2010 to 2015

(Unit: percent)

Parameter	Year / Unit	2010	2011	2012	2013	2014	2015	2016	2017
WESTERN PROVINCE	%	**44.84%**	**44.23%**	**42.80%**	**42.21%**	**41.71%**	**41.23%**	**n.a.**	**n.a.**
Of which agriculture	%	3.02%	3.19%	2.87%	2.16%	2.04%	1.73%	**n.a.**	**n.a.**
Industry	%	31.95%	33.40%	35.01%	35.09%	33.81%	34.64%	**n.a.**	**n.a.**
Services	%	65.03%	63.42%	62.12%	55.94%	57.42%	56.51%	**n.a.**	**n.a.**
ALL OTHER PROVINCES	%	**55.16%**	**55.77%**	**57.20%**	**57.79%**	**58.29%**	**58.77%**	**n.a.**	**n.a.**
(combined)	%								
Of which agriculture	%	89.42%	88.36%	88.82%	88.11%	89.35%	91.13%	**n.a.**	**n.a.**
Industry	%	51.32%	50.59%	52.45%	49.20%	50.67%	49.94%	**n.a.**	**n.a.**
Services	%	49.51%	51.63%	53.75%	58.10%	57.77%	58.62%	**n.a.**	**n.a.**

Source: *) Central Bank, Economic and Social Indicators 2017, Table 4.11.

In the absence of a comprehensive transport sector analysis, this section will briefly introduce and discuss the relative position of the transport sector in the country‘s economy. Sri Lanka‘s transport sector comprises all transport modes, i.e. railways, bus, motorized (private and public vehicles, including motorbikes, taxis and three-wheelers) transport as well as non-motorized transportation (cycling and walking) and air and sea transportation. Inland waterway transportation (IWT) for freight has actually a long tradition in the country. However, there was only one study to investigate the technical and financial feasibility of a waterborne public transportation system on existing waterways in the CMR.

Table 15-18 summarizes the relative position of the transport sector in the country‘s GDP structure. The main features of the transport sectors (including port handling and warehousing are summarized as:

While the absolute size of the transport sector has expanded significantly over the reference period 2010 to 2017 with a CAGR of about 11.7 percent (roughly 0.7 percent points above the GDP CAGR), the sector‘s relative position has remained in the same order of magnitude at about 11.6 percent in 2010 and approximately 11.1 percent in 2017

The nominal values-based correlation factor between GDP and transport sector growth can be estimated at factor 1.063. This implies that for future years and assuming ―ceterus paribus" a 1 percent GDP growth rate is likely to result in a 1.063 growth rate in nominal terms of the transport sector, and

Expansion in the economic level measured by the growth rate should be supplemented by employment figures and their projected development.

Table 15-18 summarizes selected key characteristics of the road and rail-based transport sector (airways is excluded from the table) at national and provincial levels for the limited period 2010 to 2015.

Table 15-18 Relative Position of the Transport Sector in GDP

(Unit: as indicated)

Parameter	Year / Unit	2010	2011	2012	2013	2014	2015	2016	2017	CAGR (%) 2010 to 2017
A. Gross Domestic Product (GDP)	Rs. billion	6,413.7	7,219.1	8,732.5	9,592.1	10,361.2	10,950.6	11,906.8	13,289.5	10.97
B. Transport Sector*)	Rs. billion	682.1	782.1	958.5	1,162.8	1,288.1	1,302.3	1,425.9	1,476.4	11.66
C. Share in GDP (B/A)	%	10.64%	10.83%	10.98%	12.12%	12.43%	11.89%	11.98%	11.11%	n.a.
D. Correlation Factor (nominal values)	factor									1.06290
E. Real Gross Domestic Product **)	Rs. billion	n.a.	n.a.	n.a.	7,846.2	8,235.4	8,647.8	9,034.3	9,315.5	4.38
F. Transport Sector	Rs. billion	n.a.	n.a.	n.a.	849.5	885.5	931.5	956.9	991.7	3.95
G. Share in real GDP (F/E)	%	n.a.	n.a.	n.a.	10.83%	10.75%	10.77%	10.59%	10.65%	n.a.
H. Correlation Factor (real 2010 values)	factor									0.90183

Source: Central Bank Annual Reports of 2010, 2014 and 2017.

Notes: *) Includes port handling and warehousing.
**) The base year is 2010, adjusted from the previous base year of 2002. Data for 2010 to 2012 in constant 2010 prices are not available from the 2017 Annual Report.
n.a. = not applicable.

Some selected key reference data points are summarized as:

- The total length of class A and B roads at national level has more or less remained in the same order-of-magnitude of some 12,210 km (2015). The CAGR of the class A and B road network is recorded at only 0.32 percent over the reference period
- The increased number of buses operated measured as an average per day increased from 4,441 units in 2010 to about 5,270 units in 2015 reflecting a CAGR of about 3.5 percent. This in turn is reflective of an increasing demand for bus transportation which increased from about 11.8 million passenger-km in 2010 to about 15.2 million passenger-km in 2015. This is indicative of a CAGR of about 5.2 percent
- The demand for rail transport increased significantly from about 4.4 million passenger-km in 2010 to about 7.4 million passenger km in 2015, which is equivalent to a CAGR of about 11.2 percent for the country‘s total railway network. Noteworthy is the declining relevance of rail transportation for freight reflecting imports, exports and distributional freight transport among regions, provinces and production and consumption centers. Total performance declined from 163 million freight ton-km in 2010 to 130 million freight-ton km in 2015, equivalent to a negative CAGR of about minus 4.4 percent.

Table 15-19 Selected National Level Performance Characteristics of the Transport Sector

(Unit: as indicated)

Parameter	Year / Unit	2010	2011	2012	2013	2014	2015	2016	2017	CAGR (%) 2010 to 2017
A.Road Length*)	km	12,019	12,019	12,165	12,169	12,208	12,210	n.a.	n.a.	0.32
B. New Registration of Motor Vehices	unit	359,243	525,421	397,295	326,651	429,556	668,907	493,328	n.a.	5.43
of which:										
Buses & Coaches	unit	2,491	4,248	3,095	1,805	3,851	4,140	n.a.	n.a.	10.69
Buses & Coaches	%	0.69%	0.81%	0.78%	0.55%	0.90%	0.62%	n.a.	n.a.	n.a.
Cars	unit	23,072	57,886	31,546	28,380	38,780	105,628	n.a.	n.a.	35.56
Cars	%	6.42%	11.02%	7.94%	8.69%	9.03%	15.79%	n.a.	n.a.	n.a.
Motor Cycles	unit	204,811	253,331	192,284	169,280	272,885	370,889	n.a.	n.a.	12.61
Motor Cycles	%	57.01%	48.21%	48.40%	51.82%	63.53%	55.45%	n.a.	n.a.	n.a.
Goods Tran. Vehic.**)	unit	23,557	48,336	49,663	30,475	25,920	46,598	n.a.	n.a.	14.62
Goods Tran. Vehic.**)	%	6.56%	9.20%	12.50%	9.33%	6.03%	6.97%	n.a.	n.a.	n.a.
Land Vehicles	unit	19,664	23,194	21,892	13,038	9,082	12,105	n.a.	n.a.	-9.25
Land Vehicles	%	5.47%	4.41%	5.51%	3.99%	2.11%	1.81%	n.a.	n.a.	n.a.
Three Wheelers	unit	85,648	138,426	98,815	83,673	79,038	129,547	n.a.	n.a.	14.62
Three Wheelers	%	23.84%	26.35%	24.87%	25.62%	18.40%	19.37%	n.a.	n.a.	n.a.
Buses Operated Average per day)	units	4,441	4,364	4,314	4,373	4,226	5,270	n.a.	n.a.	3.48
Passenger km	million	11,815	11,907	11,909	12,201	12,717	15,210	n.a.	n.a.	5.18
Sri Lanka Railways										
Passenger km	million	4,353	4,574	5,039	6,257	6,842	7,407	n.a.	n.a.	11.22
Freight Ton km	million	163	154	142	133	130	130	n.a.	n.a.	-4.42

Source: Economic and Social Figures, 2016, table page 67.

Notes: *) Includes only class A and B roads.
**) Includes dual purpose vehicles.
n.a. = not applicable.

Table 15-19 summarizes selected key characteristics of the road and rail-based transport sector (airways is excluded from the table) at national and provincial levels for the limited period 2010 to 2015. As is the case with the other above data they are used for plausibility testing and as control indicators for the numerical frameworks applied in the project and its influence area. However, one caveat applies to the data in this table. There are only seven data points and no data for the years 2016 and 2017. Also, definitions of basic categories between the issues of 2014 and 2016 seem to have changed limiting cross-comparison and correlation with other numerical values. The appendix of this economic and financial feasibility report attach comprehensive economic report for Sri Lanka with latest macro-economic data.

15.2.4 Major Assumptions and Verification/Control Parameters for KV Line Feasibility

The most fundamental assumptions underlying the KV Line economic and financial feasibility study are that the Megapolis development direction with its sub-components will be realized comprehensively and timely. The major components are:

- Realization of the anticipated structure plan with its urban centers and area development schemes, including their spatial distribution
- Realization of the desired demographic trends
- Realization of the estimated GRDP growth and related employment, and
- Timely realization of the public investment projects, or project long-list of the Megapolis planning policy direction.

Figure 15-3 shows the structural hierarchy of urban centers and Figure 15-4 shows the past trend in urbanization.

Another important factor that influences development and key socio-economic characteristics in the project's ―influence area" and demand for transportation services of all modes will be the impacts caused by major private (for example in new supermarkets) and public sector investments, for example into roads, public buildings and so on. The 2014 comprehensive master plan transport study identified the broader impact area by the Sri Lankan urban hierarchy as summarized in Table 15-20.

Table 15-20 General Urbanization Impact Area by Urban Hierarchy

(Unit: radius in km)

Hierarchy	**First Order** National Urban Center	**Second Order** Regional Urban Center	**Third Order** Major Urban Center	**Fourth Order** Secondary Urban Center	**Fifthe Order** Divisional Urban Center
Radius of Impact Area	100- 350 km	50- 100 km	10- 50 km	5- 10 km	2- 5 km
Typical Population Size in Service Area	5,000,000 to 20,000,000	1,000,000 to 5,000,000	100,000 to 1,000,000	10,000 to 100,000	1,000 to 10,000

Sourse: Comprehensive Transport System Master Plan, Table 2.2.4, page 2-26.

Figure 15-3 Functional Hierarchy of Urban Centers

Figure 15-4 Urbanized Areas 1981, 1996 and 2012

Table 15-21 shows the planned public investment projects in Megapolis area.

Table 15-21 Planned Public Investment Projects in Megapolis Area

No	Project Name	Sector	Estimated Impact on Population	2018 2019 2020 2021 2022 2023 2024 2025 2026 2027	Potential Impact
1	17 large scale low cost houing projects in Maharagama, Homagama and Hanwella	Housing			Direct
2	MEGAPOLIS: Airport City (306 skm)	Infrastructure, Housing			Indirect
3	MEGAPOLIS: Logistics City (306 skm)	Logistics Residential			Indirect
4	MEGAPOLIS: Mirigama Industrial City (184 skm)	Manufacturing			Indirect
5	MEGAPOLIS:Plantatio City (330 skm)	Plantations			Direct
6	MEGAPOLIS: Forest City (1,050 skm)	Forestry			Indirect
7	MEGAPOLIS: Horana Industrial City (85 skm)	Manufacturing Housinng			Indirect Indirect
8	MEGAPOLIS: Science & Technology City (165 skm)	Industry			Direct
9	MEGAPOLIS: CBD & Inner Core Area (126 skm)	Mixed			Direct (freight)
10	MEGAPOLIS: Port City	Mixed			
11	Rehabilitation Talaimannar Railway Line (101 km)	Railways		2 years, exact dates to be determined	Indirect
12	Replacing of Steel Bridges (8 to 10)	Railways		2 years, exact dates to be determined	Indirect
13	New Line from Marara to Kataragama (35 km)	Railways		3 years, exact dates to be determined	Indirect
14	Southern Railway Circle (79 km)	Railways		3 years, exact dates to be determined	Indirect
15	Line from Kurunegala to Habarana (81 km)	Railways			Indirect
16	Replacing CTC Susyem in Coastal Line	Railways		1 year, exact dates to be determined	Indirect
17	Rehabilitation Signalling & Telcom (72 km from Maradana)	Railways		2 years, exact dates to be determined	Indirect
18	Electrification, 15 EMUs (120 km)	Railways		3 years, exact dates to be determined	Indirect
19	Electronic Payments	Railways		1 year, exact dates to be determined	Indirect
20	Mobile Seat Reservation	Railways		1 year, exact dates to be determined	Indirect
21	Train Tracking/Operating Information System	Railways		2 years, exact dates to be determined	Indirect
22	Construction of 7 Ligh Rail Transport Lines in CMR (65.1 km)	Railways		For Line 1 and 4 FS is on-going	Direct
23	Multimodal Transport Hub at Makumbura	Mutimodal Hub		on-going	Direct
24	Greater Colombo Wastewater Project	Water/Wastewater		on-going	Indirect
25	BEACH Norishment Project	Area Development			Indirect

Source: Feasibility Study Team.

Detailed information about private sector investments in or near the project‘s ―influence area" are presently not available. However, there are quite a number of planned public sector projects that will have in correlation with the size and type of the investments, the time needed for their realization, their relative position to the KV Line alignment, number and distance to stations on the line and user preferences have a direct or indirect impact on the future demand or ridership on the KV Line. The potential and/or possible impact should be verified by using the transport-analysis-zone (TAZ) approach as was done in the Megapolis planning study.

A quantitative impact assessment in terms of empirical evidence of all of these projects on demand on the KV Line and the overall railway network in the Western Region and beyond is for obvious reasons not easily possible, though important input parameter into the STRADA demand modeling software take them into account. This is complimented in this feasibility study with some major qualitative observations. Highlights of the more important impact project candidates are:

- The large scale low cost housing projects in Maharagama, Homagama and Hanwella. Impacts may be on the volume of ridership, changes in trip purpose for home-work home-education and home-shopping trip purposes. Other impacts may be in terms of revenue streams arising for SLR from the KV line
- The planned plantation city around Avissawella, which is the end-station of the KV Line. . Impacts may also be on the volume of ridership, changes in trip purpose for home-work home-education and home-shopping trip purposes. Given the gist of this project, there may also be a strong impact on freight transport for exports. Other impacts may be in terms of revenue streams arising for SLR from the KV line and the average travel distance
- The science and technology city as well as the development plans for the CBD and the inner core area will have a strong impact on the volume of ridership, trip purpose, revenue streams for SLR and the average travel distance on the KV Line,
- Other strong impacts on various dimension of the KV line must be deducted from the seven LRT projects and the multimodal transport hub at Makumbura, which is actually under construction.

Of high importance are the ―silent" and/or ―inherent" assumptions that went into project design. The most important and crucial assumptions are:

- That private motorized vehicle users can be attracted to use a modern and safe rail line. It is common knowledge that such objective is not easily achievable, since cars, motor bikes and so on are the most convenient point-to-point transport means
- That rail fare are competitive with transport cost of other transport modes
- That sufficient and adequate ―park & ride (P&R)" facilities are available
- That rail lines are properly maintained, in order to maintain a high quality level of service, and
- That the project‘s C/B ratio is within a reasonable range.

It follows from the intrinsic logic that the scope and depth of the assumptions that go into an analysis, planning and/or project design exercise pre-determine the scope and depth of the findings and recommendations. Hence, their validity can often not directly be compared as is the case for the three key input documents consulted for the present exercise. For example:

- The Megapolis general and transport master plans are the most recent and comprehensive planning documents, but they reflect many fundamental assumptions as regards phasing of structure plan related public investments into general infrastructure development which went as input parameter into the demand modeling exercise. If any of these public investments is for any reason scaled down, postponed or even cancelled this would have an impact on demand/ridership estimations
- The 2014 comprehensive transportation system master plan's results are not directly comparable with all results of the Megapolis study, mainly because the broader and more limited influence areas are not congruent
- The present KV Line FS isolates that line from the rest of the rail network, in particular the other three lines which will be considered at a later stage. Treating all four lines combined and on a consolidated basis and on a railway network wide basis will surely alter the results of demand/ridership estimation, and
- Last but not least, the Megapolis and EGIS reports have a quite short planning of less than 20 years, which is actually too short for a railway feasibility investigation.

This feasibility study uses therefore at various analytical steps plausibility testing values and/or benchmarks, in order to establish the probability or likelihood of a future numerical value to be within a reasonable range. Table 15-22 summarizes the plausibility criteria and their use in this feasibility study.

Table 15-22 Plausibility Criteria and Their Use

Plausibility Criteria Catalogue	**Plausibility Logic & Explanatory Value**
A. Socio-economic Framework Conditions A1. Absolute Population Size & Growth A2. Age Pyramid & Dependency Ratios A3. Average household (HH) sizes A4. Other Characteristics A5. Income Levels & Distributional Pattern A6. Vehicle Ownership Patterns A7. Transport Needs & Demand & Trip Rates A8. Characteristics of Trip Purposes A9. Average Travel Distances	PRINCIPLE: population size is one of the two main input parameter for any transport model. PLAUSIBILITY IMPLICATIONS: Any increase in demand exceeding "normal transport demand growth (past trend) can logically only originate from either (i) significantly increase population and/or (ii) transport demand sourced from other transport modes. Verifiers: absolute number of people; CAGR, changes in modal split. OTHER VERIFYERS: Shifts in O/Ds (new projects along the alignment, example: new residential housing blocks); changes in trip purpose; shifts in structure of transport means; changes in TAZ
B. Economic Structure & Dynamics B1. Past & Projected Growth Performance B2. Sector Characteristics/Structure B3. Employment/Unemployment B4. Labor Market Key Features/Indicators B5. Other Key Features & Indicators	PRINCIPLE: level of econommic activity is one of the two main input parameter for any transport model. PLAUSIBILITY IMPLICATIONS: Any increase in the level of economic activity typically measured by alternative GDP?GRDP growth scenarios results in different growth in transport demand. Scenarios should identify the sources of different growth per-formance, in particular required level of net investments. The plausibility and/or likelyhood of realization can be verified by using an "incremental-capital-output-ratio" (ICOR) test.
C. Policy Directions C1. Policy Direction, Objectives & Targets C2. Transport Policy Features C3. Institutional Frameworks C4. Legal Aspects & Frameworks	PLAUSIBILITY IMPLICATIONS: Transport demand cannot be judged without reference to a policy hierarchy and its objectives. For example, policy interventions geared at a shift from private to public transport demand will influence the modal split though not necessarily overall transport demand
D. Other Case-specific Dimensions	

Source: Feasibility Study Team

15.2.5 Demand Estimation Analysis

The demand or ridership analysis for the modernized KV Line is based on the STRADA software package which was developed by the ―Japan International Cooperation Agency (JICA" for transportation demand modeling. The software (version 3) comprises various modules which allow for the estimation of a number of direct and indirect transport parameter. The general flow diagram of STRADA‘s ―4 stages" modeling is presented in Figure 15-5.

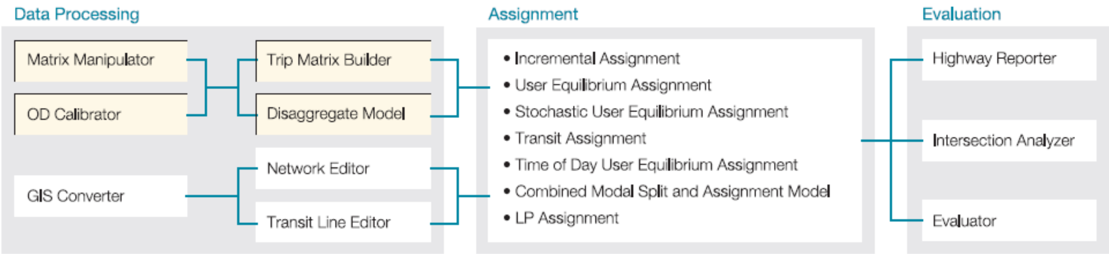


Figure 15-5 General Modeling Flow of STRADA Transport Modeling Software

There is no need to discuss in detail the pros & cons of the STRADA modeling software and its capabilities vis-à-vis other modeling software packages. It suffices to remember that all transport modeling software packages have their capabilities and limitations to such capabilities. This demand analysis part presents in another section of this feasibility report by transport demand forecaster.

15.3 Direct/Indirect Economic Benefits and Techniques Used for Evaluation

This section mainly discuss the Direct and Indirect Economic Benefits and Techniques Used for economic and financial evaluation of the KV line.

15.3.1 Direct Economic Benefits of KV Railway Line Development

Direct economic benefits mainly ascertain four aspects of benefits such as Vehicle Operation Costs Reduction, Travel Time Savings for Passengers and Freights, Accident Costs Reduction and Rail Road‘s Maintenance or Operation Costs Reduction and Savings in Greenhouse Gas Reduction. Direct benefits are usually quantifiable and can be expressed in monetary terms. It is therefore easier to establish these direct benefits accurately to a certain extent through some established methodologies.

15.3.1.1 Vehicle Operation Costs Reduction

Vehicle Operation Costs Reduction occurs in two ways: first for savings in road vehicle operating costs accrue as diversion occurs rail to roads due to this new development in rail roads with other infrastructure and railway itself get massive reduction of its operation costs. Generally rail provides more economically efficient service to public transport need in highly populated CMR in Sri Lanka. Therefore it is suspected that demand for rail passenger and freight transport is only constraint by the lack of capacity and the market is largely inelastic. Hence large percentage of diversion can expect in passenger and freight both by looking at distance. Any vehicle travelling over the existing roads will incur a cost due to its bad surface conditions, geometry and narrowness of roads and bridges and culverts, etc. This cost is a function of the distance travelled and the speed, plus surface condition, narrowness and geometry of the existing roads. Generally motorized vehicle performance predictions include speed (free flow and congested conditions) and consumptions. Predictions for vehicle operating costs include fuel, oil, tire and parts costs, crew and maintenance labor costs, capital depreciation, borrowing costs, and overhead costs. Same way this Vehicle Operation Costs Reduction occurs to railway substantially due to increase of operation conditions and other related railway infrastructure. Especially higher speed enable better assets utilization and contributes to lower unit operating costs. Double tracking increases capacity, reduces delays, and improve level of service and reliability. Through double tracking possibility is there to attract more frights to railways with introduction of priority freight trains.

15.3.1.2 Travel Time Savings for Passengers and Freights

Travel time savings are obtained when road improvements lead to an increase in trains' speeds, thus reducing the journey time of passengers and freight operators. A value of time per hour for each type of train is applied as a unit cost to journey times to produce passenger time costs. The value of time and its use in economic analysis remains a fairly contentious issue. On one hand it can be argued that all time saved will have a value to the individual, with the question as to whether or not a value can be placed on such savings being debatable. On the other hand, it can also be argued that only travel time saved on business has a tangible value and this releases additional productive time. In addition to this latter argument, it has also been argued by others that only a significant amount of time saved by an individual should be considered as a potential time saving. Nevertheless, one point is clear from all debates, time savings in relation to a trip purpose of "work", theoretically does have a monetary value. In the case of crew time it can also be readily appreciated that the accumulated savings in time brought about by investment in rail transport infrastructure may well result in additional vehicle trips being possible and, as such, clearly may have some impact on overall productivity and consequently has a monetary value.

15.3.1.3 Accident Costs Reduction

Accident cost savings occur when an improvement to a road with the provision of a better geometrically designed wider good condition road, and implementation of traffic discipline and rules with safety standards in developed roads results in a reduction in the number of accidents that occur. In the case of developed roads, it has been assumed that traffic will divert from the existing road to the developed better roads. But this accident part does not include for the benefits calculation due to lack of information on this area and even if we use this benefits it does not affect significantly for final results due to its low value. Furthermore, due to poor condition of existing roads, its maintenance and operation costs are higher for Authorities and after developing these poor roads these cost assume to be very much lower. This also can be counted as one of the main benefits of the roads development but due to lack of information this item also does not include for benefits calculation of this project.

15.3.1.4 Savings in Greenhouse Gas Reduction

Greenhouse gas (CHG) emission are an external costs to which is imposed on society and has been taken into account as an economic benefits. A reduction of CHG emission can come from various sources due to this rail road projects. These can be traffic diversion, improved operating efficiency in railway physical assets and other infrastructure.

15.3.2 Indirect Economic Benefits of KV Railway Line Development

Indirect benefits are difficult to measure and quantify on this rail project. Therefore this section mainly deals with growth of commercial, urban and rural centers and its various benefits under each rail sections‘ start and end nodes. Due to the non-availability of many regional rail-wise economic data to quantify indirect economic benefits, this feasibility study uses rail road start and end nodes as the main benefit generating places for the people in and around this KV Railway Line. Especially these start and end nodes connectivity will improve regional economic integration and spin off various urban agglomeration benefits due to the improvement of connectivity with high frequency and speed. This analysis looks at what type of regional economic benefits they made due to this connectivity improvement between economically important centers, cities and other nodes at start and end of each and every rail road. In addition to these nodes, economic implications of possible change of land use pattern are also discuss in this feasibility report.

There were 32 railway stations identified throughout this KV Line and most are upgraded and developed to suit with current requirements with state-of-art facilities. Each rail road segment has starting nodes and ending nodes. In order to ascertain the indirect benefits of the rail road segments these starting and ending nodes of were used. Google maps, photos, videos, physical visits and other narrations about the node towns have been used to get an insight on the socio-economic status. However they are not sufficient to decide whether the nodes are rural, urban or commercial in nature. Hence more acceptable and scientific categorization has been searched. In the Sri Lankan political administrative structure, the type of local authorities have been defined, based on the commercial, urban and rural nature of the governing area. According to this categorization, areas governed by the Pradeshiya Sabha were recognized as rural centers, the areas governed by the urban councils were recognized as urban centers and the areas governed by the Municipal Councils have been recognized as Commercialcenters1.

This categorization has been used to identify the starting and ending nodes of each rail road segment in KV line stations. The name of the nodes‘ town was cross checked for its governing local authority and based on the type of local authority, nodes were recognized as rural, urban and commercial centers. When any node was connected to an Expressway ADT high urban road, it can be assumed that highest indirect benefits can be generated out of that area. When any node was connected to Urban Center can be assumed that the next second highest indirect benefits can be generated out of that. When any node was connected to Rural Centre, it can be assumed that next third highest indirect benefits can be generated out of that. When any node was connected to just hinterland without any economically important nodes we can assume that not much indirect benefits is generated out of this connectivity improvement.

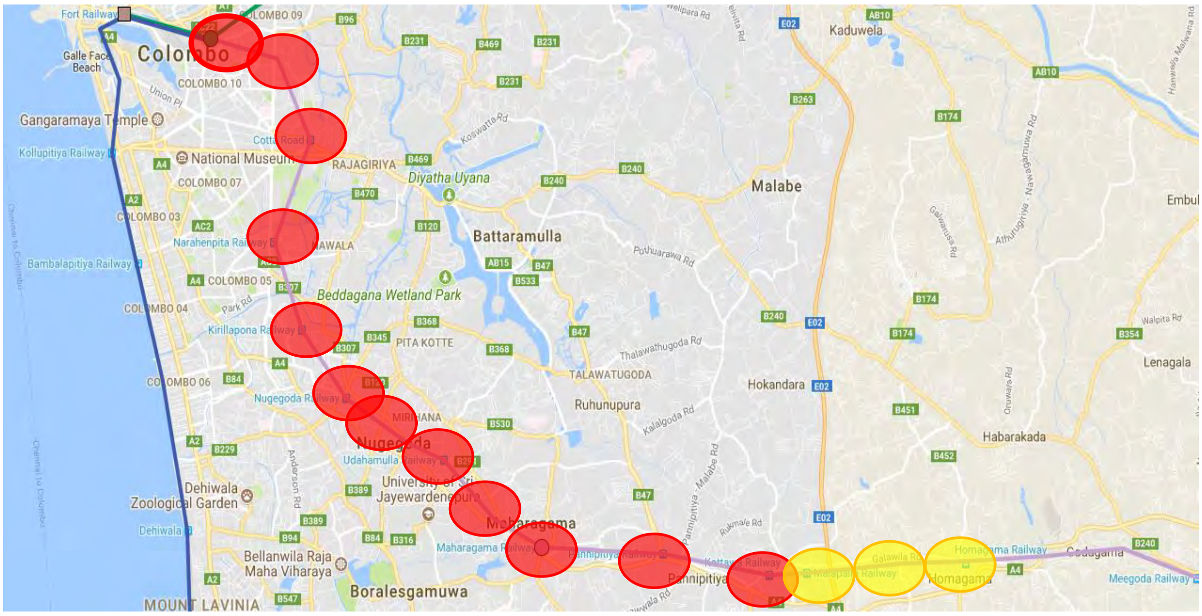
When selecting starting and ending nodes of the rail road segment between stations, it is essential to reduce the judgmental bias that may occur by focusing only on the starting and ending towns of the rail road. The impact of the railway line development would have much higher impact to the surrounding areas, population, business and industrial entities and urban and city development. Therefore the tracing of type of local authority that the start and end node towns belong to gives a much broader picture of the surrounding area of the KV Railway Line. Since the local authority boundaries are broader than the town area, it would give a much bigger picture about the impact area of the segments between stations. Municipal council areas are expected to have high population density and hence a large number of industrial and business entities provide products and services to the higher population. Urban council areas are also expected to be highly populated and have relatively active industrial, services and business operations. Rural areas are expected to be agriculture based less populated areas which have a relatively lesser number of industrial, services and business entities. Since the distances of the selected rail road segments are not very high, selecting local authority areas of the two ends would provide a holistic view to assess the indirect economic impact of the development of road segments. The following Table 15-23 and maps show this ending nodes of rail road segments between stations in KV Line in terms of Urban Centers, Commercial Centers and Rural Centers.

Table 15-23 Type of Nodes at Starting and Ending of Road Segment Maradana-Homagama

Station Name (from)	Station Name (to)	Daily Ridership in both Directions (2016)	Total length (KM)	Start Node	End Node
Maradana	Base Line Road	17000		Urban	Urban
Base Line Road	Cotta Road	17000		Urban	Urban
Cotta Road	Narahenpita	18000		Urban	Urban
Narahenpita	Kirillapone	23000		Urban	Urban
Kirillapone	Nugegoda	23000		Urban	Urban
Nugegoda	Pangiriwatta	24000		Urban	Urban
Pangiriwatta	Udahamulla	24000		Urban	Urban
Udahamulla	Navinna	23000		Urban	Urban
Navinna	Maharagama	23000		Urban	Urban
Maharagama	Pannipitiya	20000		Urban	Urban
Pannipitiya	Kottawa	17000		Urban	Urban
Kottawa	Malapalla	14000		Urban	Peri-Urban
Malapalla	Homagama Hospital	13000		Peri-Urban	Peri-Urban
Homagama Hospital	Homagama	13000		Peri-Urban	Peri-Urban

Source: Daily Ridership in both Directions obtained from COLOMBO SUBURBAN RAILWAY PROJECT, Kelani Valley Line Alternative Study – Report, EGIS Report 2017.

The start and end nodes of rail roads in the KV Line between Maradana and Homagama are presented in Figure 15-6.



If connected to Industrial and Commercial Center (Urban)

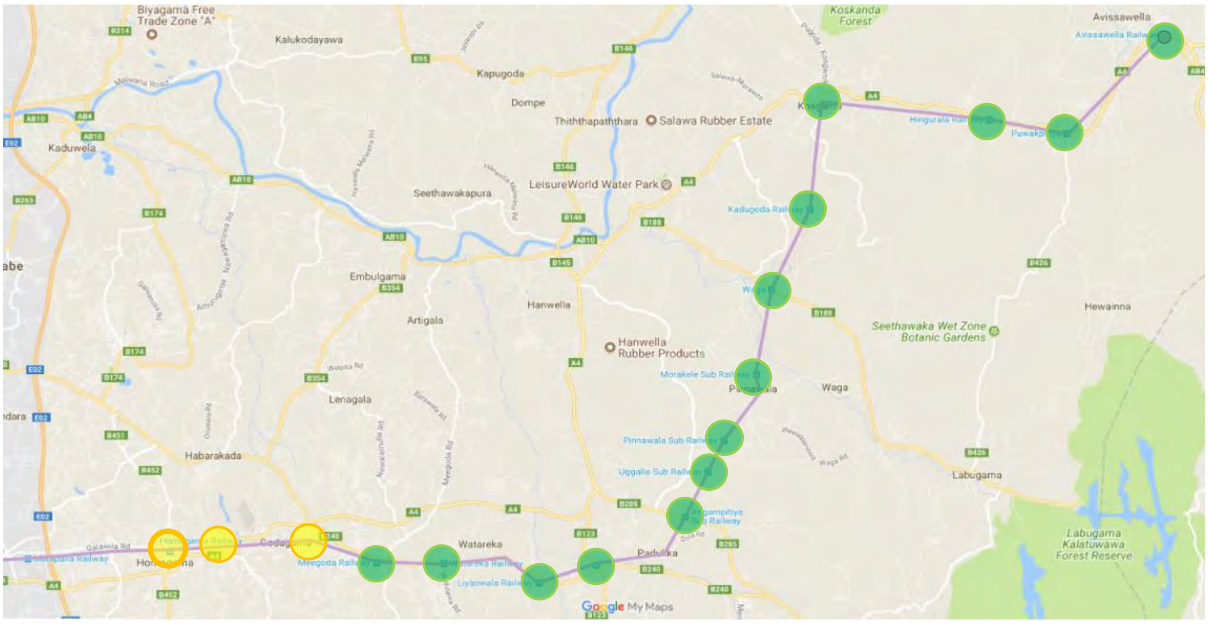
If connected to peri-Urban Center

Figure 15-6 Thestart and end nodes of rail roads in the KV Line stations between Maradana and Homagama.

Table 15-24 Type of Nodes at Starting and Ending of Road Segment Homagama-Awissawella

Station Name (from)	Station Name (to)	Daily Ridership in both Directions (2016)	Total length (KM)	Start Node	End Node
Homagama	Panagoda	11000		Peri-Urban	Peri-Urban
Panagoda	Godagama	10000		Peri-Urban	Rural
Godagama	Meegoda	9000		Rural	Rural
Meegoda	Wataraka	8000		Rural	Rural
Wataraka	Padukka	7000		Rural	Rural
Padukka	Arukwatta	3000		Rural	Rural
Arukwatta	Anganpitiya	3000		Rural	Rural
Anganpitiya	Ugalla	3000		Rural	Rural
Ugalla	Pinnawela	3000		Rural	Rural
Pinnawela	Gammana	3000		Rural	Rural
Gamamana	Morakelle	2000		Rural	Rural
Morakelle	Waga	2000		Rural	Rural
Wega	Katugoda	1000		Rural	Rural
Katugoda	Kosgama	1000		Rural	Rural
Kosgama	Hingurala	1000		Rural	Rural
Hingurala	Puwakpitiya	1000		Rural	Rural
Puwakpitiya	Avissawella	1000		Rural	Rural

Source: Daily Ridership in both Directions obtained from COLOMBO SUBURBAN RAILWAY PROJECT, Kelani Valley Line Alternative Study – Report, EGIS Report 2017.



If connected to peri-Urban Center

If connected to Rural Center

Figure15-7 The start and end nodes of rail roads in the KV Line stations between Homagama and Avissawella

After developing these rail road sections, exiting land use pattern will be changed in the respective project impact areas more towards more value added agricultural related activities. Furthermore, many unused lands will be developed and its productivity can go up in and around the rail road section as with emerging commercial and residential buildings. This in turn creates a good price for residential and commercial lands in and around these developed areas. Private sector companies can get many indirect benefits due to this KV Line development. These can create many changes in business transportation and supply chain strategies as well. Especially, improvements in the rail road network can flow on to influence the behavior of firms to further achieve productivity gains through reduction of cost of transporting goods and consequently there is potential for firms to reorganize their logistics operations to further improve productivity. Especially Seethawaka Industrial Zone get many benefits out of this KV Line development. Immediate cost reductions to carriers and freight operators, including gains to freight operators from reduced travel times and increased reliability. Reorganization-effect gains from improvements in logistics. Quantity of firms‘ outputs changes; quality of output does not change. Gains from additional re-organization effects such as improved products, new products, or some other change. Effects that are not considered as benefits according to the strict rules of cost-benefit analysis, but may still be of considerable interest to policy-makers. In overall, low density sprawl and a dispersed pattern of development have resulted in unorganized land use and inefficient public transport systems. Future growth will need to focus on compact town centers with increased residential density to halt the current inefficient uses of land and enable resources to be used in a more efficient and sustainable manner. Finally all these railway development in KV Line will bring many economic benefits to accelerate regional economic growth and to alleviate poverty in the hinterland by easing congestion in city areas.

15.3.3 Techniques Used for Economic and Financial Evaluation

Generally Economists assume that Economic Net Present Value (ENPV), Economic Internal Rate of Return (EIRR), Costs and Benefits (C/B) ratio well represent the economic feasibility of rail road investment. Therefore economic performance of this rail transport investment are assessed based on the ENPV, EIRR and C/B ratio.

- **Net Present Value (NPV) –** NPV measures the actual or real net economic benefits of the project. Actually the absolute net economic gains are calculated by subtracting the discounted costs from the discounted benefits. This NPV is preferable in a situation where projects are mutually exclusive. The formula and decision rule of NPV:

$$\text{NPV} = \sum_{n=0}^{N} \frac{(\text{B}_n - \text{C}_n)}{(i + r)^n}$$

Where, Bn = Project benefits in year n expressed in constant dollars

Cn = Project costs in year n expressed in constant dollars r = Discount rate

N = Number of years that costs and/or benefits are produced

Under this decision rule, a project is potentially worthwhile (or viable) if the NPV is greater than zero; i.e the total discounted value of benefits is greater than the total discounted costs. If projects are mutually exclusive, the project which yields the highest NPV would be chosen.

- **Internal Rate of Return (IRR) –** discount rate which reduces a future stream of costs and benefits to a net present value of zero; it was the EIRR that determined the selection of road sections based on overall economic feasibility of roads. For individual projects IRR is used mostly to evaluate the project economic feasibility. It measures the rate of return of benefits to costs. In algebraic terms the IRR is the value of r which solves the equation:

$$0 = \sum_{n=0}^{N} \frac{(B - C)_n}{(1 + r)^n}$$

Where, Bn = Project benefits in year n expressed in constant dollars/Rs.

Cn = Project costs in year n expressed in constant dollars r = real discount rate

N = Number of years that costs and/or benefits are produced

A project is potentially worthwhile if the IRR is greater than the test discount rate. If projects are mutually exclusive, this rule would suggest that the project with the highest IRR should be chosen.

- **Benefit and Cost Ratio (BCR) –** BCR is the ratio of the present value of benefits to the present value of costs and this measures the relative net gain of the proposed expenditure. Various verification can be obtained based on these costs and benefits. The formula and decision rule ofBCR:

$$BCR = \sum_{n=0}^{N} \frac{\frac{B_n}{(1+r)^n}}{\sum_{n=0}^{N} \frac{C_n}{(1+r)^n}}$$

A project is potentially worthwhile if the BCR is greater than 1; ie, the present value of benefits exceed the present value of costs. If projects are mutually exclusive, this rule would indicate thatthe project with the highest BCR should be chosen. The project with the higher BCR is expected to provide the greatest benefits per money invested and hence should receive priority in the allocation of funding and surely it will ensure the efficient allocation of scarce resources.

- **Financial Internal Rate of Return (FIRR)**

The Financial Internal Rate of Return (FIRR) is an indicator to measure the financial return on investment of an income generation project and is used to make the investment decision. The FIRR is obtained by equating the present value of investment costs (as cash out-flows) and the present value of net incomes (as cash in-flows) and thus finds out the break-even interest rate, i*.In general, the decision rule is as follows:

If FIRR > MARR (= WACC), then, accept the project.

If FIRR = MARR (= WACC), then, remain indifferent.

If FIRR < MARR (= WACC), then, reject the project.

- **Weighted Average Cost of Capital (WACC)**

The Weighted Average Cost of Capital (**WACC**) is the rate that a company (Railway in this case) is expected to pay on average to all its security holders to finance its assets. The WACC is commonly referred to as the firm‘s cost of capital. Importantly, it is dictated by the external market and not by management. The WACC represents the minimum return that a company must earn on an existing asset base to satisfy its creditors, owners, and other providers of capital, or they will invest elsewhere. Companies raise money from a number of sources: common stock, preferred stock, straight debt, convertible debt, exchangeable debt, warrants, options, pension liabilities, executive stock options, governmental subsidies, and so on. Different securities, which represent different sources of finance, are expected to generate different returns. The WACC is calculated taking into account the relative weights of each component of the capital structure. The more complex the company's capital structure, the more laborious it is to calculate the WACC.

15.4 Estimated Project Cost Streams

15.4.1 Basic Terminology and Definitions

Basic terminology and definitions applied in this feasibility study are provided below.

Domestic market prices; This refers to the actual market selling price, i.e. they contain all taxes and levies, such as value-added-tax, other taxes, import and stamp duties, etc. The following Table 15-25 presents latest taxes rates applied on goods and services in Sri Lanka.

Table 15-25 Tax Regime in Sri Lanka

Tax/Levy Item	Rate & Valuation Method
1. Value-Added-Tax	15% (general rate) 15% on imports (CIF+10%+duty+Surcharge+CESS+PAL+ excise)
2. Nation Building Tax	2% on CIF value
3. Import duty	Varies on goods
4. Ports & Airports Levy (PAL)	5% standard
5. Import Cess	1% to 45% on CIF
6. Social Responsibility (SRL)	1.5% on sum of duty+surcharge+excise

Source: Feasibility study Team based on MOF information.

Financial Prices & Economic prices; the methods of economic prices determination follows the ADB (2007, 2014) Guidelines for the Economic Analysis of Projects. It suffices here to state that the basic difference between financial and economic prices is that financial prices indicate the financial worth to the owners of the project‘s assets and economic prices represent the viewpoint of society as a whole. Financial prices are exiting market prices and mainly distorted due to government direct influences, taxes and subsides. Economic prices exclude all these government direct influences, taxes and subsides. Economic prices are efficiency or shadow prices mainly based on opportunity cost concept. Normally, financial prices are converted to economic prices by using the Standard Conversion Factor (SCF) and Shadow Exchange Rate Factor (SERF). The following Table 15-26 shows calculated SCF and SERF figures.

Table 15-26 Standard Conversion Factor (Unit: Million LKR)

	2012	2013	2014	2015	2016	2017
Import tax	328,164	328,164	348,315	359,210	493,923	554590
Import Duties	74,668	74,668	77,726	108,115	156,487	136501
VAT (Imports)	96,590	96,590	102,280	83,726	115,336	168395
Ports & Airports Development Levy	61,505	61,505	68,646	56,733	88,822	102400
Import Cess Levy	33,004	33,004	35,622	42,467	59,058	56574
Special Commodity Levy	46,704	46,704	47,952	52,275	55,825	71400
Nation Building Tax (Imports)	15,693	15,693	16,089	15,894	18,395	19320
Export tax	3,108	24,750	27,164	2,746	2,703	3010
Export Duties	21	21,663	24,080	33	31	30
Export Cess Levy	3,087	3,087	3,084	2,713	2,672	2980
3) Total Imports	2,440,899	2,323,128	2,535,163	2,572,467	2793016	3198580
4) Total Exports	1,245,531	1,344,054	1,453,176	1,431,431	1501092	1732006
SCF (3+4)/(3+1)+(4-2)	0.92	0.92	0.93	0.92	0.89	0.89
SERF = (1/SCF) =1>	1.08	1.08	1.07	1.08	1.12	1.12
Average SCF for the past six years	0.911					
Average SCRF for the past six years	1.093					

Source: Ministry of Finance Annual Report, Central Bank of Sri Lanka Statistics, 2012-2017.
The SCF, converting from financial prices to economic prices, has been calculated from the recent trade statistics of Sri Lanka.

Local cost (LC) and foreign cost (FC) components; Local cost comprises with the goods and services purchased locally for the project. Foreign cost includes the value capital items and other goods & services imported for the project.

Monetary units; US Dollar is used in many instances as there is significant foreign financing of the project. Local currency of Sri Lankan rupees also applied in few instances.

15.4.2 "Life Cycle" Approach and Analysis Horizon

The standard for the economic viability assessment of a railway line is usually 30 years. The intricacy with the KV Line assessment is that:

Demand/ridership forecast data are only available for two point estimations, namely 2025 and 2035. This is caused by the fact that the planning horizon for the Megapolis study is the year 2035. Critical input parameter for demand and benefit modeling, such as population growth, employment, Gross Regional Domestic Production (GRDP) growth and so on are only available up to that year. However, assuming typical durations for bid process, bid evaluation, signing of construction contract and test indicate that the KV Line may become commercially operational in mid-2023 leading to a computation cycle of only 12 years, i.e. less than 50% of the typical life cycle approach for a railway project

Hence, in order to calculate with a typical life cycle results for demand and benefit streams are capped in 2035 and by trend extrapolation extended to the years 2045 and 2053. This results in a computation cycle of 30 years

Finally it is estimated that the construction phase is four years from 2020-2023 and operational phase of the project is 30 years from 2024 to 2053.

As a consequence, rehabilitation and replacement investments for KV Line assets of all types must be taken into account in a total cost approach. Table 15-27 presents selected asset‘s life-spans for 30 year. Our main financial analysis carried-out for this 30 year life span.

Table 15-27 Life-spans for Railway Assets

Asset Type	Typical Life-span of Asset
1. Tracks & track beds	30
2. Bridges	30
3. Slab Tracks Stations	30
4. Civil works/stations	30
5. Signalling	10
6. Maintenace Sheds	30
7. DMUs/EMUs	30

Source: Feasibility Study Team.

But according to Euro standards sensitivity analysis carried out for 50 and 100 years as some railway assets have life span more than 30 years. The following Table 15-28 presents selected asset‘s life-spans for over 30 year.

Table 15-28 Life Span for Railway Assets Based on Euro Codes

Item	Life Time (Years)
1. Bridge & elevated construction	100
2. Flyover	100
3. Station Buildings	50
4. Embankment	50
5. Track and Track Bed	50
6. Electrification System	30
7. Signaling	20
8. Telecommunication System	10
9. Rolling Stocks	30

Source: Sri Lanka Standard - NA to SLS EN 1990 - 2018 (Gr), Sri Lanka National Annex (Informative) to Eurocode - Basis of Structural design, Sri Lanka Standards Institution.

15.4.3 Investment Cost

This section provides details on sub categories of investment cost attributable to the proposed KV line expansion project.

15.4.3.1 Cost Categories & Basis of Measurement

The viability assessment will comprise the following major cost stream categories as discussed below:

- **Pre-construction cost streams (PCS).** PCS includes cost for the PPTA feasibility study, the administrative overhead for the Ministry‘s ―project management unit (PMU)", cost that arise from utility relocation, pre-construction environmental protection measures etc. The cost items for this PPTA feasibility study, which are actually financed from the ADB‘s PPTA loan facility and the administrative overhead cost for the Ministry‘s ―Project Management Unit (PMU)" are treated as ―sunk cost". Utility shifting cost and Environmental mitigations costs are considered in the Investment cost.
- **Land Acquisition, Compensation and Resettlement Cost.** This cost is estimated based on a comprehensive site survey undertaken in 2017 by UN-HABITAT that covered Maradana to Homagama section of the KV Line comprising 24.440km length of the total KV Line length of about 58.400 km. An additional comprehensive site survey is underway that covers the remaining length of the KV Line according to the line Ministry. Land Prices have been adjusted upward from 2017 values based on Land Price Index (LPI) published by Central Bank of Sri Lanka which recorded an annual increase of 10.4% in December 2017.

Table 15-29 indicates reported land values around the KV Line for the year 2018 and for three types of land, namely residential, commercial and agricultural land. Land Acquisition. Compensation and Resettlement cost may vary from the estimated value due to inflation rate changes, compensation policy of the government etc.

Table 15-29 Land Values around KV Line at 2018 prices

(Unit: Rupees)

A r e a	Residential (Per perch)	Commercial (Per perch)	Agricultural (Per acre)
Colombo	2.8 million	40 million	
Maradana	2.0 million	35 million	
Kotte	1.5 million	30 million	
Maharagama	1.2 million	20 million	
Homagama	1.0 million	18 million	
Kottawa	1.1 million	1.8 million	
Hanwalla	0.6 million	1.2 million	
Panagoda	0.4 million	1.0 million	
Meegoda	0.2 million	4.5 million	
Padukka	0.15 million	4.2 million	1 million
Waga	0.1 million	3.8 million	0.7 million
Puwakpitiya	0.05 million	3.5 million	1.5 million
Avissawella	0.5 million	5 million	2.5 million

Source: Feasibility Study Team.

- **Construction Cost.** The construction cost covers three major cost sub-categories, namely track and civil works, buildings and civil works and flyovers or underpasses for the level crossings that are to be closed. Track and civil works differentiate between the rehabilitation of existing tracks on the single track line, new tracks on the elevated section, bridges, slab tracks at stations, siding, panels and fencing walls. Buildings/ Civil works cover the rehabilitation of old stations, new stations, the demolition of old stations, the control center building and depot construction.
- **Electrification Cost.** The electrification cost includes the total line, electrification at stations and the light maintenance depot at Dematagoda, as well as a common cost factor.
- **Signaling Cost.** Covers the cost for the total line, including signaling at the light maintenance depot in Dematagoda and the hard maintenance depot at Rathmalana.
- **Telecommunication Cost**. Covers the cost for the total line as well as costs related to the light maintenance depot at Dematagoda and the hard maintenance depot at Rathmalana.
- **Rolling stock**. Covers the total cost for all additional rolling stock to be purchased.
- **Other Cost Items**. Other cost items includes construction supervision cost of 4% from the sum of above cost items along with 5% physical contingencies and 5% price contingencies from the sum of above costs including supervision costs. These are the typical percentages applied in infrastructure projects in Sri Lanka.

Table 15-30 presents the cost estimation for the above cost categories.

15.4.3.2 Selected Characteristics of Cost Stream Structure

It is important to record here certain highlights of the cost stream structure and emphasize that the interpretation of the information provided needs to be done with great care for the reasons discussed below:

- **Caveat 1.** The KV Line forms an integral part of the country‘s overall railway network. Isolating the KV Line in the analysis thereby treating the line almost as a ―stand alone" line has its disadvantages. The clearest two examples are demand/ridership which may be very different, if the KV Line is treated as an integral part of the overall railway network. Secondly, as explained in the demand analysis, timely implementation of the Megapolis infrastructure and infrastructure related mega projects may again have a very significant impact on demand/ridership and therefore economic viability of the KV Line itself.

- **Caveat 2.** Investments into electrification of the KV Line are recorded from start of construction. However, electrification of the KV Line is likely going to be done in harmony with the electrification of other railway lines and/or the whole railway network, which would imply pushing such investments done the time line. The cost stream for electrification is at present estimated at million US$ 30.12

- **Caveat 3.** The share of rolling stock related investment cost is after the elevated construction the second most costly cost component accounting for million US$ 250. An in-depth operational plan that is closely correlated with demand/ridership and its expansion over time may reduce the initial investment cost into rolling stock and phase the purchase better over time

- **Caveat 4.** The demand analysis suggests that much of the incremental ridership will shift from motor bike and private cars to the public transport on the KV Line. However, that can only happen, if there are sufficient ―park & ride" facilities available at stations and along the line‗s alignment

- **Caveat 5.** Land acquisition and compensation cost may vary with the changes in government compensation policies as well as inflationary rate changes.

Table 15-30 Preliminary Detailed Cost Estimation KV Line By Section and Cost Category (CAPEX)

No	Description	Maradana to Homagama	Homagama to Padukka	Padukka to Avissawella	Cost US$	%	Local Cost US$	Foreign Cost US$
1	**Construction costs**							
1.1	Demolition Cost							
	a) Buildings	642,950.55	96,970.73	21,389.63	761,310.91	0.05	761,310.91	
	b) Existing Railway Lines	1,083.69	464.56	1,041.05	2,589.30	0.00	2,589.30	
	c) Culvert & Bridges	159,676.86	34,727.73	298,860.49	493,265.08	0.03	493,265.08	
1.2	Elevated construction	420,507,543.46			420,507,543.46	29.52	126,152,263	294,355,280.42
1.3	Bridge construction		1,021,299.58	2,683,841.34	3,705,140.92	0.26	1,111,542.28	2,593,598.64
1.4	Flyover Construction	6,079,191.79	6,079,191.79		12,158,383.58	0.85		
1.5	Station Construction							
	a) Earth work & others	5,049,437.61	4,328,090.15	582,192.27	9,959,720.03	0.70		
	b) Station Building	18,003,770.95	4,491,201.05	5,777,094.97	28,272,066.97	1.98		
	c) Platform Construction	14,868,941.85	5,045,046.15	6,226,758.89	26,140,746.89	1.84	7,842,224.07	18,298,522.82
1.6	Embankment							
	a) Earth work	22,529,533.88	34,602,728.07	43,679,240.23	100,811,502.18	7.08	80,649,201.74	20,162,300.44
	b) Drainage Work	1,709,120.15	2,071,906.03	2,707,381.33	6,488,407.52	0.46	5,190,726.01	1,297,681.50
	c) Culvert Construction	3,985,211.53	1,992,605.77	4,440,664.28	10,418,481.57	0.73	8,334,785.26	2,083,696.31
	d) Light maintenance depot-Dematagoda				72,965,611.00	5.12	21,889,683.30	51,075,927.70
	e) Fence Construction	87,267.91	494,090.28	2,032,187.88	2,613,546.07	0.18	784,063.82	1,829,482.25
	f) Sound Barrier Construction	2,712,415.64	2,896,109.50	3,293,005.47	8,901,530.61	0.62	2,670,459.18	6,231,071.43
1.7	Track Construction	22,359,335.11	11,088,393.33	12,382,567.32	45,830,295.76	3.22	13,749,088.73	32,081,207.03
2	**Resettlement costs**	65,964,814.81	4,839,629.63		70,804,444.44	4.97	70,804,444.44	
3	**Electrification costs**							
3.1	Total Line	8,823,600.00	3,837,600.00	626,400.00	13,287,600.00	0.93	664,380.00	12,623,220.00
3.2	Station	2,510,000.00	850,000.00	1,570,000.00	4,930,000.00	0.35	1,479,000.00	3,451,000.00
3.3	Light maintenance depot-Dematagoda				900,000.00	0.06	270,000.00	630,000.00
3.4	Common Cost				11,000,000.00	0.77	3,300,000.00	7,700,000.00

Table 15-31 Preliminary Detailed Cost Estimation KV Line By Section and Cost Category

No	Description	Maradana to Homagama	Homagama to Padukka	Padukka to Avissawella	Cost US$	%	Local Cost US$	Foreign Cost US$
4	**Signalling costs**							
	a) For Signalling costs	44,125,360.00	15,558,680.00	13,092,000.00	72,776,040.00	5.11	14,555,208.00	58,220,832.00
	b) Light maintenance depot-Dematagoda				5,638,000.00	0.40	1,127,600.00	4,510,400.00
5	**Telecommunication**							
	a) For Lines	11,321,000.00	6,337,800.00	6,300,100.00	23,958,900.00	1.68	7,187,670.00	16,771,230.00
	b) Light maintenance depot-Arukwathpura				1,049,700.00	0.07	314,910.00	734,790.00
6	**Rolling stock costs**				250,000,000.00	17.55	12,500,000.00	237,500,000.00
7	**Utility shifting costs**	339,293.56	323,171.50	1,096,096.26	1,758,561.32	0.12	1,670,633.25	87,928.07
8	**Environment mitigation costs**	29,929,857.72	4,720,594.76	5,247,648.96	39,898,101.45	2.73	39,898,101.45	
	Sub Total-1	681,109,629.07	110,759,242.61	111,617,308.38	1,245,039,491.05	87.41	437,528,203.03	807,511,288.02
9	**Construction Supervision costs (4%)**				49,801,579.64	3.50	9,960,315.93	39,841,263.71
	Sub Total -2				1,294,841,070.69	90.91	447,488,518.96	847,352,551.73
10	**Physical contingencies (5%)**				64,742,053.53	4.55	22,374,425.95	42,367,627.59
11	**Price contingencies (5%)**				64,742,053.53	4.55	22,374,425.9	42,367,627.59
	Total Cost				**1,424,325,177.76**	**100.00**	492,237,370.85	932,087,806.90
	1US$ = Rs. 179.00							

Table 15-32 summarizes the distribution of cost streams over major cost categories.

Table 15-32 Investment Cost Streams and Structure

Cost item	Cost (USD)	%	Local Cost (USD)	Foreign Cost-FC (USD)	FC %
Construction costs;					
Demolition costs	1,257,165	0.09	1,257,165	-	-
Elevated Construction	420,507,543	29.52	126,152,263	294,355,280	
Bridge Construction	3,705,141	0.26	1,111,542	2,593,599	70
Flyover Construction	12,158,384	0.85	3,647,515	8,510,869	70
Station Construction	64,372,534	4.52	19,311,760	45,060,774	70
Embankment	202,199,079	14.20	119,518,919	82,680,160	41
Track Construction	45,830,296	3.22	13,749,089	32,081,207	70
Sub total	**750,030,142**	**52.66**	**284,748,254**	**465,281,888**	**62**
Land acquisition and resettlement costs	70,804,444	4.97	70,804,444	-	-
Electrification costs	30,117,600	2.11	5,713,380	24,404,220	81
Signaling costs	78,414,040	5.51	15,682,808	62,731,232	80
Telecommunication	25,008,600	1.76	7,502,580	17,506,020	70
Rolling stock costs	250,000,000	17.55	12,500,000	237,500,000	95
Utility shifting costs	1,758,561	0.12	1,670,633	87,928	5
Environment mitigation costs	38,906,103	2.73	38,906,103	-	-
Sub total	**1,245,039,491**	**87.41**	**437,528,203**	**807,511,288**	**65**
Construction Supervision Costs (4%)	49,801,580	3.50	9,960,316	39,841,264	80
Sub total	**1,294,841,071**	**90.91**	**447,488,519**	**847,352,552**	**65**
Physical contingencies (5%)	64,742,054	4.55	22,374,426	42,367,628	65
Price contingencies (5%)	64,742,054	4.55	22,374,426	42,367,628	65
Total	**1,424,325,178**	**100.00**	**492,237,371**	**932,087,807**	**65**

Source: Feasibility study team

Construction cost of the project is 53% out of which 30% is attributable to the elevated construction. Embankment costs is also significant at the level of 14%. Construction cost mainly consists of a foreign cost component that accounts for 62%. The next major cost is attributable to acquisition of rolling stocks amounting to 18% of the total cost.

Modernization cost items, such as for electrification, signaling and telecommunications together account for 9 % of the total investment cost.

Foreign cost component of the total investment cost is 65%. This is mainly due to the fact that Sri Lanka imports steel, cement and equipment, since those cannot be sourced locally in the needed quantities or are not available from domestic producers.

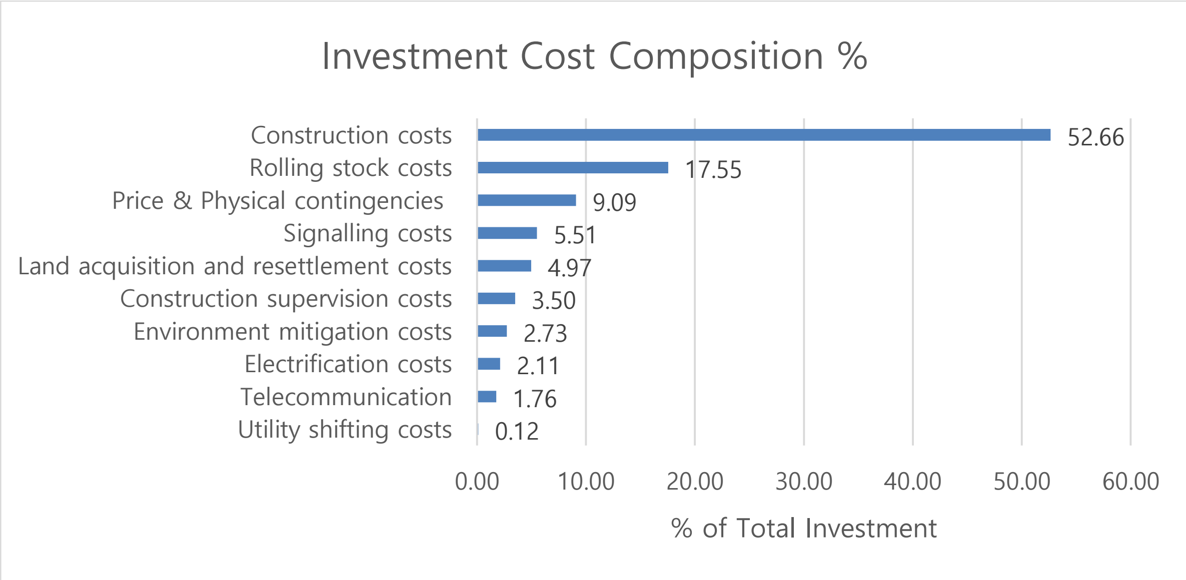


Figure 15-8 Investment Cost breakup

The above diagram illustrates the investment cost composition from the highest to the lowest. Construction cost approximates to half of the investment cost while the rolling stock cost ranked the second at a level of 18%.

15.4.4 Operation and Maintenance Costs

Operating & Maintenance (O&M) costs primarily consist of energy costs, manpower cost and maintenance cost, including spare parts and consumables. The O&M cost estimation has taken into the account of several factors such as electrification of the KV Line, incremental personnel needed for train operations, incremental personnel needed for routine and periodic maintenance of the track network and the number of trains, and spare parts.

The following operating capacity in terms of rolling stock have been estimated to handle the increased traffic along the KV line. In general, it plans to run 42 trains on KV Line each way is as follows.

(4) 15 EMU trains of 10 cars consist with carrying capacity of 1988 passengers in 2024 between Maradana & Makumbura North.

(5) 5EMU trains of 10 cars consist with carrying capacity of 1988 passengers in 2024 between Makumbura North & Padukka.

(6) 4 DMU trains of 5 cars consist with carrying capacity of 750 passengers in 2024 between Padukka &Avissawella.

Table 15-33 Operating capacity

Route	Train Type	No of cars per Train	No of Trains	Passenger Capacity per train
Maradana- Makumbura North	EMU	10	15	1988
Makumbura North-Padukka	EMU	10	5	1988
Padukka-Avissawella	DMU	5	4	750

Source: Feasibility study team

Composition of EMU trains is expected to increase up to 12 cars per train in 2035 with a passenger capacity of 2404 passengers. Peak hours are between 06.30 hrs to 09.30 hrs from the Avissawella end while from 16.30hrs to 19.30hrs from the Colombo end.

15.4.4.1 Energy Costs

Energy cost primarily comprises of the electricity cost where the annual consumption level has been estimated in Kwh as given below. Tariff rate between LKR 22.0-27.4 per Kwh is applied to arrive at an annual energy cost. In addition to the electricity cost, the fuel cost has been estimated for the DMUs run between Padukka and Awissawella. The fuel price has been estimated based on the forecasted fuel prices by USA Energy Information Administration department. Total energy Cost is then converted to USD at a rate of LKR 179.00 per USD.

Table 15-34 Energy Costs

Year	Electricity		Fuel		Total Energy Cost (USD)	Total Energy Cost (USD million)
	Electricity Consumption (kWh)	Energy Cost (LKR)	Fuel Consumption (Liters)	Fuel Cost (LKR)		
2024	36,958,776	813,093,072	668,116	125,959,748	5,246,105	5.25
2025	37,697,951	844,434,102	689,210	131,760,941	5,453,604	5.45
2026	38,451,911	880,548,762	710,304	138,598,288	5,693,559	5.69
2027	39,220,949	913,848,112	732,044	144,786,247	5,914,158	5.91
2028	40,005,368	952,127,758	754,449	151,996,262	6,168,291	6.17
2029	40,805,475	991,573,043	777,540	159,244,930	6,429,151	6.43
2030	41,621,584	1,032,215,283	801,337	165,936,935	6,693,588	6.69
2031	42,454,016	1,074,086,605	825,863	174,784,300	6,976,932	6.98
2032	43,303,096	1,117,219,877	851,140	181,976,430	7,258,080	7.26
2033	44,169,159	1,161,648,882	877,190	190,153,931	7,551,971	7.55
2034	45,052,542	1,207,408,126	904,037	199,137,931	7,857,799	7.86
2035	45,953,593	1,259,128,448	960,223	213,927,724	8,229,364	8.23
2036-2053	45,953,593	1,259,128,448	960,223	213,927,724	8,229,364	8.23

Source: Feasibility study team

15.4.4.2 Manpower Cost

Staff requirement for train operation, maintenance staff at depots and other overhead staff has been estimated as per the given table. Accordingly, it could be noted that 10 persons are required per route km in 2024 (576/58.4 km). The average cost per person has been estimated based on 2017 actual cost adjusted for salary increase. No of persons are then multiplied with the average annual salary to arrive at the total cost.

Table 15-35 Manpower Cost

Year	Man Power Requirement	Unit Cost (USD)	Total Cost (USD)
2024	576	4,387	2,527,011
2025	588	4,593	2,700,900
2026	600	4,809	2,885,554

Year	Man Power Requirement	Unit Cost (USD)	Total Cost (USD)
2027	612	5,035	3,081,598
2028	624	5,272	3,289,697
2029	636	5,520	3,510,549
2030	649	5,779	3,750,674
2031	662	6,051	4,005,616
2032	675	6,335	4,276,237
2033	689	6,633	4,570,081
2034	703	6,945	4,882,100
2035	717	7,271	5,213,354
2036-2053	717	7,271	5,213,354

Source: Feasibility study team

15.4.4.3 Maintenance Cost

Maintenance costs comprise consumables, spare parts, etc. for rolling stock maintenance, track maintenance and maintenance of machines and equipment. Annual costs have been estimated as 0.8% of the investment (CAPEX) of the project. This percentage is determined based on the similar projects carried in India. CAPEX of the project has been escalated by 1.5% annually so that the maintenance cost is also increased accordingly.

Table 15-36 Maintenance Cost

Year	CAPEX (billion USD)	Maintenance Cost (million USD)
2024	1.42	11.39
2025	1.45	11.57
2026	1.47	11.74
2027	1.49	11.92
2028	1.51	12.09
2029	1.53	12.28
2030	1.56	12.46
2031	1.58	12.65
2032	1.60	12.84
2033	1.63	13.03
2034	1.65	13.22
2035	1.68	13.42
2036-53	1.68	13.42

Source: Feasibility study team

15.4.4.4 Total Operating & Maintenance Costs

Total O&M costs comprising of Manpower cost, energy consumption cost and maintenance cost are summarized in the table below. However, these costs do not include depreciation of assets.

Table 15-37 Total O&M cost

Year	Man power Cost (million USD)	Maintenance Cost (million USD)	Energy Consumption Cost (million USD)	Total Cost (million USD)
2024	2.53	11.39	5.25	19.17
2025	2.70	11.57	5.45	19.72
2026	2.89	11.74	5.69	20.32
2027	3.08	11.92	5.91	20.91
2028	3.29	12.09	6.17	21.55
2029	3.51	12.28	6.43	22.21
2030	3.75	12.46	6.69	22.90
2031	4.01	12.65	6.98	23.63
2032	4.28	12.84	7.26	24.37
2033	4.57	13.03	7.55	25.15
2034	4.88	13.22	7.86	25.96
2035	5.21	13.42	8.23	26.86
2036-53	5.21	13.42	8.23	26.86

Source: Feasibility study team

Figure 15-9 illustrates that the major part of the O&M cost consists of maintenance cost. This is followed by the energy consumption cost. Least portion is applicable to the man power cost.

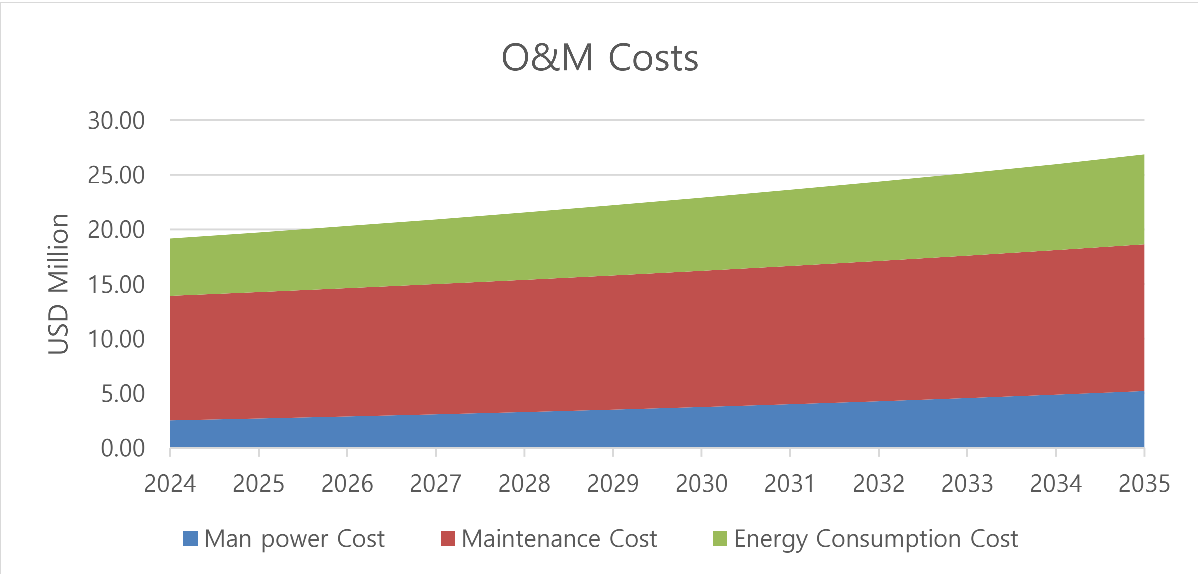


Figure 15-9 Total O&M Cost Composition

15.4.4.5 Operating & Maintenance Costs per Passenger

O&M costs are divided by the annual passenger volume to arrive at the cost per passenger and presented below. This cost is converted to LKR based on the exchange rate at LKR179 per USD. It could be observed O&M costs per passenger is in the range of LKR 3.80 to 4.35.

Table 15-38 O&M Cost per Passenger

Year	Passengers (in Million)	Man Power/ Passenger (USD)	Main/Passenger (USD)	Energy/Passenger (USD)	O&M/Passenger (USD)	O&M/Passenger (LKR)
2024	903.97	0.0028	0.0126	0.006	0.0212	3.80
2025	925.81	0.0029	0.0125	0.006	0.0213	3.81
2026	941.65	0.0031	0.0125	0.006	0.0216	3.86
2027	957.89	0.0032	0.0124	0.006	0.0218	3.91
2028	974.56	0.0034	0.0124	0.006	0.0221	3.96
2029	991.65	0.0035	0.0124	0.006	0.0224	4.01
2030	1009.20	0.0037	0.0123	0.007	0.0227	4.06
2031	1027.21	0.0039	0.0123	0.007	0.0230	4.12
2032	1045.70	0.0041	0.0123	0.007	0.0233	4.17
2033	1064.68	0.0043	0.0122	0.007	0.0236	4.23
2034	1084.18	0.0045	0.0122	0.007	0.0239	4.29
2035	1104.21	0.0047	0.0122	0.007	0.0243	4.35

Source: Feasibility study team

Figure 15-10 provides the O&M costs per passenger in LKR. Accordingly it could be noted that O&M costs gradually rises over the period.

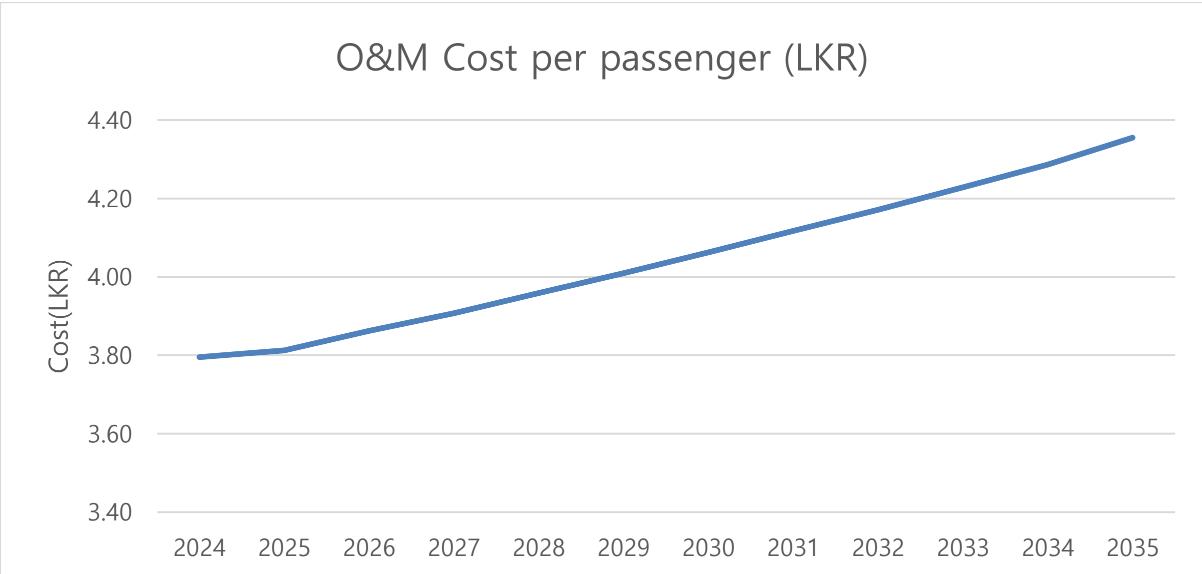


Figure 15-10 O&M Costs per Passenger

15.4.4.6 Operating & Maintenance Costs per Passenger Kilometer

The following table provides the O&M costs per passenger Km and the cost is between LKR 2.00 to 2.29 over the period.

Table 15-39 O&M Cost per Passenger Kilometer

Year	Passenger Km (in Million)	Man Power/ Passenger Km(USD)	Maintenance/ Passenger Km (USD)	Energy/Passenger Km (USD)	O&M/Passenger Km (USD)	O&M/Passenger Km (LKR)
2024	1,718	0.0015	0.0066	0.0031	0.0112	2.00
2025	1,759	0.0015	0.0066	0.0031	0.0112	2.01
2026	1,789	0.0016	0.0066	0.0032	0.0114	2.03
2027	1,820	0.0017	0.0065	0.0032	0.0115	2.06
2028	1,852	0.0018	0.0065	0.0033	0.0116	2.08
2029	1,884	0.0019	0.0065	0.0034	0.0118	2.11
2030	1,917	0.0020	0.0065	0.0035	0.0119	2.14
2031	1,952	0.0021	0.0065	0.0036	0.0121	2.17
2032	1,987	0.0022	0.0065	0.0037	0.0123	2.20
2033	2,023	0.0023	0.0064	0.0037	0.0124	2.23
2034	2,060	0.0024	0.0064	0.0038	0.0126	2.26
2035	2,098	0.0025	0.0064	0.0039	0.0128	2.29

Source: Feasibility study team

According to Figure 15-11, it could be noted that O& M cost per passenger Km is gradually rising over the period. However the rate of change is as low as 1% approximately.

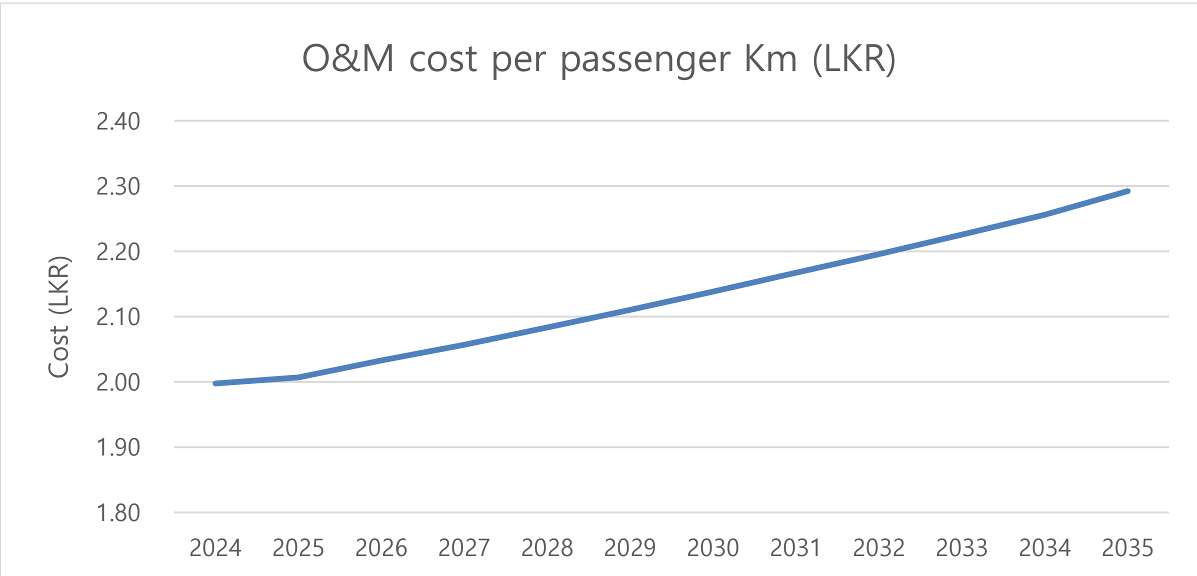


Figure 15-11 O&M Costs per Passenger Kilometer

15.5 Financial Analysis

15.5.1 Introduction

Department of Sri Lanka Railway operates the railway service across the country through a network of about 1460.91 kms. The railway network includes 10 lines that connect the commercial capital of the country, the Colombo city. This section evaluates the development project of the Kelani Valley (KV) line which connects Colombo with the east of the western province. Currently, the KV line is a single track line for 58.4kms and it is expected to carry out electrification with the additional track under the scope of this project.

The construction phase of the project is estimated to be four years starting from 2020. This includes acquisition of lands, construction of tracks and other structures, acquisition of rolling stock, etc. Tracks, permanent structures, and rolling stocks usually have an economic life of 30 years in par with international standards as a result operation phase is considered to be 30 years. However according to Sri Lankan standards (based on Euro codes) certain assets such as bridges, flyovers, buildings, embankment, etc. have a useful life of 50 years or greater as a result sensitivity analysis considers longer life spans.

The financial evaluation has considered the with-project scenario. The project converts the existing operation significantly through electrification of the major part of the line and double tracks. When considering the magnitude of conversion, the without-project scenario generates insignificant cash flows. This is evident by an insignificant number of traffic generated by the STRADA model for the without-project scenario. Accordingly, when looking at the substance, the project needs to be considered as a new project for evaluation purpose rather than an expansion project with incremental benefits.

15.5.2 Investment Plan

KV line development project requires an investment of USD 1.42 billion. Land acquisition and resettlement costs estimated to be 5% of the investment. Construction costs of tracks and other permanent structures account for 53% and 18% of investment is attributable to rolling stocks. Details are provided in Table 15-40.

Table 15-40 Investment Plan

Cost item	Cost (USD)	Cost (USD)	%	% excluding price contingencies
Construction costs;				
Demolition costs	1,257,165			
Bridge Construction	420,507,543			
Flyover Construction	3,705,141			
Station Construction	12,158,384			
Embankment	202,199,079			
Track Construction	45,830,296	750,030,142	52.66	55.17
Land acquisition and resettlement costs		70,804,444	4.97	5.21
Electrification costs		30,117,600	2.11	2.22
Signaling costs		78,414,040	5.51	5.77

Cost item	Cost (USD)	Cost (USD)	%	% excluding price contingencies
Telecommunication		25,008,600	1.76	1.84
Rolling stock costs		250,000,000	17.55	18.39
Utility shifting costs		1,758,561	0.12	0.13
Environment mitigation costs		38,906,103	2.73	2.86
Sub total		1,245,039,491	87.41	91.58
Feasibility, Design & Supervision (8%)		49,801,580	3.50	3.66
Sub total		1,294,841,071	90.91	95.24
Physical contingencies (5%)		64,742,054	4.55	4.76
Price contingencies (5%)		64,742,054	4.55	-
Total		1,424,325,178	100.00	100.00

Source: Estimated data

15.5.3 Sources of Finance

The project requires an investment of USD 1,424.33 billion as illustrated under Table 15-40. Different funding sources for the project could be identified such as Asian Development Bank (ADB) loan, foreign commercial basis loans, local bank commercial loans and funds of Government of Sri Lanka (GOSL). Alternative mixing of these funding sources along with the respective cost of funding (Weighted Average Cost of Capital-WACC) is analyzed in the forthcoming paragraphs.

As the base case scenario, it is estimated that 80% of the investment will be funded through an ADB loan while the balance is funded by the Government of Sri Lanka. The weighted average cost of funding is estimated following the approach suggested in ADB Financial Management guidelines and provided in Table 15-41.

Table 15-41 Weighted Average Cost of Capital

No.	Indicator	Unit	ADB Loan	Foreign Loan	Local Bank	GOSL Funds	Total
			80%	0%	0%	20%	
1	Amount	US $ mn	1,139.46	0.00	0.00	284.87	1,424.33
2	Weighting	%	80.00	0.00	0.00	20.00	100.00
3	Nominal Cost	%	3.61	0.00	0.00	11.90	
4	Tax rate	%	0.00	0.00	0.00	0.00	
5	Tax Adjusted Nominal Cost	%	3.61	0.00	0.00	11.90	
6	Inflation Rate	%	1.50	0.00	0.00	4.70	
7	Real Cost	%	2.08	0.00	0.00	6.88	
8	Weighted Component of WACC	%	1.67	0.00	0.00	1.38	3.04

Nominal interest for ADB loan is estimated based on indicative lending rates for LIBOR based loans of Asian Development Bank published on 15/03/2019. Accordingly, fixed swap rate for 30-year loan has been considered. The interest rate for GOSL funds is estimated based on Treasury bond rate for 15-year bond (issued on 15/10/2018) as there were no other longer-term bonds recently issued matching the project duration. International Inflation Rate is extracted from the ADB sources while the Sri Lankan inflation rate is based on the inflation rate (GDP deflator) estimated by the Department of Census and Statistics. Calculated WACC represents the real cost of funding the investment excluding inflationary effects. Sri Lanka Railway is a government department thus it is not liable for income tax. Accordingly, the tax rate is considered to be zero.

Table 15-42 Alternative sources of funding and WACC

Scenario	Description	ADB Loan	Foreign Loan	Local Bank	GOSL Funds	WACC (Real) %
Base Case	Weight %	80	-	-	20	3.04
	Nominal cost %	3.61	-	-	11.90	
Alternative 1	Weight %	30	50	10	10	4.25
	Nominal cost %	3.61	6.00	12.27	11.90	
Alternative 2	Weight %	30	60	-	10	3.97
	Nominal cost %	3.61	6.00	0.00	11.90	
Alternative 3	Weight %	60	30	0	10	2.77
	Nominal cost %	3.61	6.00	0.00	11.90	

Several alternative funding scenarios are analyzed and presented in the Table 15-42. WACC under each alternative is provided in real terms following the detailed approach as illustrated in table 15-41. Alternative one considers a scenario where 30% of funding from ADB loan, 50% from foreign loan, 10% local bank loan and 10% government funds. This mix of funding result a real WACC of 4.25%. When the foreign loan composition is increased to 60% by removing local banks, WACC decreases to 3.97%. Moreover the increasing the ADB loan up to 60% and decreasing the foreign loan up to 30% along with 10% government funds result a WACC of 2.77%

Further analysis considers the base case scenario WACC of 3.04%. This WACC is between the lowest and highest values derived under different alternatives thus represents a modest level. However sensitivity analysis section deals with the changes in WACC under different alternatives.

15.5.4 Financial Analysis Related Various Measurements

This section of the report provides revenue & cost details of the project, project cash flows and project financial viability analysis through different measurements.

15.5.4.1 Traffic Demand Forecast & Revenue

Daily passenger traffic between the stations are estimated based on a comprehensive transport model (STRADA model). Results of the model for the years 2025 and 2035 provided in the Table 15-43 below. This table also includes peak hour traffic for the same years. Annual forecasting is made on the basis of operating for 365 days. Average cumulative annual growth rate of passengers for all the stations estimated to be 2.68%.

Table 15-43 Daily Passenger Traffic

Station Name	Station Name	Daily Passenger Volume		Peak Hour Passenger Volume Per Direction (PPHPD)	
From	To	Year 2025	Year 2035	Year 2025	Year 2035
Maradana	Baseline	133,771	168,893	13,912	17,565
Baseline	Kotte Road	132,807	160,817	13,812	16,725
Kotte Road	Narahenpita	144,468	170,352	15,025	17,717
Narahenpita	Kirulapone	169,559	194,403	17,634	20,218
Kirulapone	Nugegoda	176,969	201,662	18,405	20,973
Nugegoda	Pangiriwatta	173,328	197,899	18,026	20,581
Pangiriwatta	Udahamulla	156,471	180,373	16,273	18,759
Udahamulla	Navinna	140,155	166,655	14,576	17,332
Navinna	Maharagama	131,353	160,494	13,661	16,691
Maharagama	New1-Dambahena	102,406	133,684	10,650	13,903
New 1-Dambahena	Pannipitiya	100,224	134,653	10,423	14,004
Pannipitiya	Kottawa	100,224	134,653	10,423	14,004
Kottawa	Malapalla	88,547	127,291	9,209	13,238
Malapalla	Makumbura	85,306	96,574	8,872	10,044
Makumbura	Homagama Hospital	77,267	85,359	8,036	8,877
Homagama Hospital	Homagama	68,704	72,049	7,145	7,493
Homagama	Panagoda	54,888	55,077	5,708	5,728
Panagoda	Godagama	53,683	53,965	5,583	5,612
Godagama	Meegoda	48,727	48,378	5,068	5,031
Meegoda	Watareka	37,529	36,477	3,903	3,794
Watareka	Padukka	35,781	34,564	3,721	3,595
Padukka	Arukwathupura	31,122	30,014	3,237	3,121
Arukwathupura	Angampitiya	29,750	29,617	3,094	3,080
Angampitiya	Uggalla	29,036	30,596	3,020	3,182
Uggalla	Pinnawala	30,444	32,690	3,166	3,400
Pinnawala	Gammana	31,868	34,925	3,314	3,632
Gammana	Morakele	26,509	30,289	2,757	3,150
Morakele	Waga	26,823	30,644	2,790	3,187
Waga	Kadugoda	24,235	30,695	2,520	3,192
Kandugoda	Kosgama	23,728	32,402	2,468	3,370
Kosgama	Hingurala	19,906	38,900	2,070	4,046
Hingurala	Puwakpitiya	25,744	46,401	2,677	4,826
Puwakpitiya	Avissawella	25,132	43,787	2,614	4,554
Total		2,536,464	3,025,232	263,792	314,624

Source: Chapter 3 of DFSR -Traffic Studies and Ridership for Demand Forecast, Figure 3.5

Revenue of the KV line stems from passenger revenue as well as other revenue such as transporting freight.

Table 15-44 RevenueForecast

Year	Passenger Revenue (Million USD)	Mail & Parcels Revenue (Million USD)	Other Revenue (Million USD)	Total (Million USD)
2024	24.66	0.75	2.57	27.98
2025	25.25	0.77	2.63	28.65
2026	25.71	0.78	2.68	29.17
2027	26.19	0.79	2.73	29.71
2028	26.68	0.81	2.78	30.27
2029	27.18	0.82	2.83	30.84
2030	27.70	0.84	2.89	31.43
2031	28.24	0.86	2.94	32.03
2032	28.79	0.87	3.00	32.66
2033	29.36	0.89	3.06	33.31
2034	29.94	0.91	3.12	33.97
2035	30.55	0.93	3.18	34.66
2036	31.17	0.95	3.25	35.37
2037	31.82	0.97	3.32	36.10
2038	32.48	0.99	3.39	36.85
2039	33.17	1.01	3.46	37.63
2040	33.88	1.03	3.53	38.44
2041	34.62	1.05	3.61	39.27
2042	35.38	1.07	3.69	40.14
2043	36.16	1.10	3.77	41.03
2044	36.98	1.12	3.85	41.95
2045	37.82	1.15	3.94	42.91
2046	38.69	1.17	4.03	43.90
2047	39.60	1.20	4.13	44.93
2048	40.54	1.23	4.22	45.99
2049	41.51	1.26	4.33	47.10
2050	42.52	1.29	4.43	48.24
2051	43.57	1.32	4.54	49.43
2052	44.65	1.35	4.65	50.66
2053	45.78	1.39	4.77	51.94

Source: Estimated data

Passenger revenue is estimated based on expected traffic as illustrated in table 15-43 above. Revenue forecast for the KV line is provided in the Table 15-44. Distance based price is first computed which is then multiplied with passenger traffic between each station to arrive at the passenger revenue. KV line usually carries fare class 3 passengers and average fare per passenger-km was Rs. 1.30 in 2018. It is expected to charge 2.3 times of the current price when the operation phase of the project initiates in 2024 i.e Rs. 2.99 per passenger-km.

Revenue for the 30 years of operation is computed based on the price in 2024 i.e Rs. 2.99 per passenger-km. This fixed price is applied due to the fact that STRADA model suggests stable price having considered competitive factors to the railway transport during the project life. This revenue computed can also be regarded as the real cash flow since fixed price is applied for the entire operation phase.

It could be observed that the passenger revenue is usually higher with an account of 82% from the total revenue during last five years according to financial statistics of Sri Lanka Railway. Freight revenue accounts for 7% of the total revenue, Mail & parcels is 2% while other revenue sources accounted for 9% of the revenue. Since major part of proposed KV line is elevated, it is not expected carry freight other than mail & parcels. Accordingly the Mail & parcels revenue and other revenue of KV line are estimated considering those percentages.

15.5.4.2 Operating & Maintenance Costs

Operating & Maintenance (O&M) costs primarily consist of man power cost, maintenance cost and energy consumption cost. These costs are estimated on the basis of operating 24 trains as illustrated below Table 15-45.

Table 15-45 Operating Capacity

Route	Train Type	No of cars per Train	No of Trains	Passenger Capacity per train
Maradana- Makumbura North	EMU	10	15	1988
Makumbura North -Padukka	EMU	10	5	1988
Padukka-Avissawella	DMU	5	4	750

Source: Estimated data

Estimated O&M costs per annum are between USD 19.17mn-USD 26.86 mn during the operation phase of the project as provided in the Table 15-46. This cost does not include depreciation thus it can be regarded as a cash outflow.

Table 15-46 Operating & Maintenance costs

Year	Man power Cost (million USD)	Maintenance Cost (million USD)	Energy Consumption Cost (million USD)	Total Cost (million USD)
2024	2.53	11.39	5.25	19.17
2025	2.70	11.57	5.45	19.72
2026	2.89	11.74	5.69	20.32
2027	3.08	11.92	5.91	20.91
2028	3.29	12.09	6.17	21.55
2029	3.51	12.28	6.43	22.21
2030	3.75	12.46	6.69	22.90
2031	4.01	12.65	6.98	23.63
2032	4.28	12.84	7.26	24.37
2033	4.57	13.03	7.55	25.15
2034	4.88	13.22	7.86	25.96
2035	5.21	13.42	8.23	26.86
2035-2053	5.21	13.42	8.23	26.86

Source: Estimated data

O&M costs have been converted to constant price in 2020 in order to find the real cash out flow without inflationary effects. These are provided in Table 15-47. Manpower requirement is multiplied by the annual average salary of USD 3651 in 2020. This salary is derived through adjusting the actual salary reported for 2017. Maintenance cost has been originally estimated as 0.8% of the total investment where the total investment has been inflated by 1.5% every year. Real cash flow pertaining to the maintenance cost is calculated by removing 1.5% inflation thus represents 0.8% of original investment.

Table 15-47 Operating & Maintenance costs @ 2020 constant price

Year	Man power Cost (million USD)	Maintenance Cost (million USD)	Energy Consumption Cost (million USD)	Total Cost (million USD)
2024	2.10	11.39	4.78	18.27
2025	2.15	11.39	4.88	18.42
2026	2.19	11.39	4.98	18.57
2027	2.23	11.39	5.09	18.72
2028	2.28	11.39	5.20	18.87
2029	2.32	11.39	5.31	19.02
2030	2.37	11.39	5.42	19.19
2031	2.42	11.39	5.54	19.35
2032	2.46	11.39	5.66	19.51
2033	2.52	11.39	5.78	19.69
2034	2.57	11.39	5.90	19.86
2035	2.62	11.39	6.05	20.06
2036-53	2.62	11.39	6.05	20.06

Source: Estimated data

Real cash outflow pertaining to the O&M costs lie between USD 18.27 mn to 20.06 mn.

15.5.4.3 Replacement Costs

Most of the assets of the project provides benefits for an economic useful life of 30 years. However the Telecommunication system has a shorter life time of 10 years thus needs replacement in two occasions during the project life. Further the signaling system has a useful life of 20 years accordingly it requires replacement in one occasion. Details are presented in Table 15-48.

Table 15-48 Replacement cost

#	Item	Life Time (Years)	Cost (US $)	Replacement Cost (US $)	
				2033	2043
1	Signaling	20	78,414,040		78,414,040
2	Telecommunication System	10	25,008,600	25,008,600	25,008,600
	Total		103,422,640	25,008,600	103,422,640

Source: Estimated data

Replacements costs are estimated at base year price. Accordingly they reflect the real cash flows without any inflationary effects.

15.5.5 Financial Viability

This section evaluates the financial viability of the project through different financial indicators such as operating self-sufficiency, Financial Net Present Value (FNPV), Financial Internal Rate of Return (FIRR) and Payback period of the project.

15.5.5.1 Operating Self-Sufficiency

Operating costs (at current prices) of the project are compared against the expected revenue in order to find the operating cost recovery rate and presented below Table 15-49.

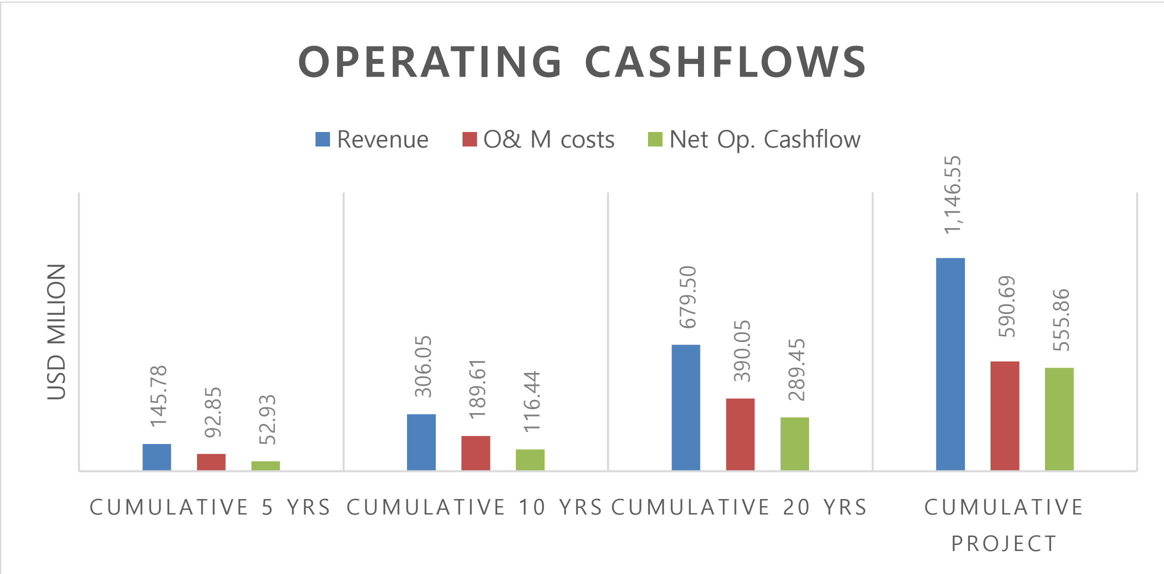
Table 15-49 Operating cost recovery

Year	Revenue	O&M Cost	O&M %
2024	27.98	19.17	146
2025	28.65	19.72	145
2026	29.17	20.32	144
2027	29.71	20.91	142
2028	30.27	21.55	140
2029	30.84	22.21	139
2030	31.43	22.90	137
2031	32.03	23.63	136
2032	32.66	24.37	134
2033	33.31	25.15	132
2034	33.97	25.96	131
2035	34.66	26.86	129
2036-53	42.88	26.86	160

Source: Estimated data

It could be observed that operating cost recovery rate is above 100% during the operation phase of the project. This reflects the fact that the operating costs of the project could be fully recovered from the revenue generated. Accordingly there is no need of government subsidies for operating costs. Revenue beyond 2035 represents the average revenue where as it is assumed the same O&M cost in 2035 sustain in the rest of the project life.

Figure 15-12 shows the real operating cash inflows and outflows without inflationary effects. Accordingly it could be noted that cash inflows are sufficient to meet the operating cash outflows over different time intervals during the operation phase.



Source: Estimated data

Figure 15-12 Operating Cash flows (at constant prices)

According to the table below it could be noted that revenue is above the O&M costs over the project lifetime. As a result cost recovery rates are above 100%. Accordingly the government subsidies are not required to cover the operating & maintenance costs of the project.

Table 15-50 Operating & replacement Cost recovery (at constant prices)

Description	Cumulative 5 yrs	Cumulative 10 yrs	Cumulative 20 yrs	Cumulative Project-30 yrs
Revenue (USD million)	145.78	306.05	679.50	1,146.55
O& M costs (USD million)	92.85	189.61	390.05	590.69
Net Op. Cashflow (USD million)	52.93	116.44	289.45	555.86
Operating Cost Recovery	157%	161%	174%	194%
Replacement Cost (USD million)		25.01	128.43	128.43
Replacement cost recovery		466%	225%	433%

Replacement of some capital assets such as Signaling system and Telecommunication system are required during the project life. Replacements costs occurred during first 10 years and beyond could be fully funded through net operational cash flows as the replacement costs recovery rates are above 100% as a percentage of net operating cash flow.

15.5.5.2 Financial Net Present Value (FNPV) and Financial Internal Rate of Return (FIRR)

Net Cash flows of the project are provided in the Table 15-51 below. All the cash flows are at constant prices excluding inflationary effects.

Investment cost of the project amounting to USD 1359.58 million is arrived at excluding the price contingencies of USD 64.74 million as illustrated in table 15-40. Land acquisition and resettlement cost of USD 70.8mn is expected to incur during the first year. Rest of the investment cost is assumed to be evenly incurred over the next three years of the construction phase. Residual value of the project is derived by considering the non-depreciated value of the assets at the end of the project. This basically consists of signaling infrastructure which has been replaced in twenty years but has a remaining life of 10 years when the project ends in 30th year. Further the cost of lands have been added to the same when deriving the residual value.

Table 15-51 Project Cash flows

Year	Cost				Revenues				Residual Value	Net Cashflow	Discounted Cash Flow
	Capital	O&M	Replace	Total	Passengers	Mail & Parcels	Other	Total			
2020	- 70.80			- 70.80						- 70.80	-68.71
2021	- 429.59			- 429.59						- 429.59	-404.61
2022	- 429.59			- 429.59						- 429.59	-392.67
2023	- 429.59			- 429.59						- 429.59	-381.08
2024		-18.27		- 18.27	24.66	0.75	2.57	27.98		9.70	8.35
2025		-18.42		- 18.42	25.25	0.77	2.63	28.65		10.23	8.55
2026		-18.57		- 18.57	25.71	0.78	2.68	29.17		10.61	8.60
2027		-18.72		- 18.72	26.19	0.79	2.73	29.71		11.00	8.65
2028		-18.87		- 18.87	26.68	0.81	2.78	30.27		11.40	8.70
2029		-19.02		- 19.02	27.18	0.82	2.83	30.84		11.81	8.76
2030		-19.19		- 19.19	27.70	0.84	2.89	31.43		12.24	8.81
2031		-19.35		- 19.35	28.24	0.86	2.94	32.03		12.69	8.86
2032		-19.51		- 19.51	28.79	0.87	3.00	32.66		13.15	8.91
2033		-19.69	-25.01	- 44.70	29.36	0.89	3.06	33.31		- 11.39	-7.49
2034		-19.86		- 19.86	29.94	0.91	3.12	33.97		14.11	9.00
2035		-20.06		- 20.06	30.55	0.93	3.18	34.66		14.59	9.04
2036		-20.06		- 20.06	31.17	0.95	3.25	35.37		15.30	9.20
2037		-20.06		- 20.06	31.82	0.97	3.32	36.10		16.03	9.35
2038		-20.06		- 20.06	32.48	0.99	3.39	36.85		16.79	9.50
2039		-20.06		- 20.06	33.17	1.01	3.46	37.63		17.57	9.65
2040		-20.06		- 20.06	33.88	1.03	3.53	38.44		18.38	9.80
2041		-20.06		- 20.06	34.62	1.05	3.61	39.27		19.21	9.94
2042		-20.06		- 20.06	35.38	1.07	3.69	40.14		20.07	10.08
2043		-20.06	-103.42	- 123.49	36.16	1.10	3.77	41.03		- 82.46	-40.18
2044		-20.06		- 20.06	36.98	1.12	3.85	41.95		21.89	10.35
2045		-20.06		- 20.06	37.82	1.15	3.94	42.91		22.85	10.48
2046		-20.06		- 20.06	38.69	1.17	4.03	43.90		23.84	10.62
2047		-20.06		- 20.06	39.60	1.20	4.13	44.93		24.86	10.75
2048		-20.06		- 20.06	40.54	1.23	4.22	45.99		25.93	10.88
2049		-20.06		- 20.06	41.51	1.26	4.33	47.10		27.03	11.00
2050		-20.06		- 20.06	42.52	1.29	4.43	48.24		28.18	11.13
2051		-20.06		- 20.06	43.57	1.32	4.54	49.43		29.36	11.26
2052		-20.06		- 20.06	44.65	1.35	4.65	50.66		30.60	11.39
2053		-20.06		- 20.06	45.78	1.39	4.77	51.94	110.01	141.89	51.24
Total	**- 1,359.58**	**- 590.69**	**- 128.43**	**- 2,078.71**	**1,010.57**	**30.66**	**105.32**	**1,146.55**	**110.01**	**- 822.14**	**- 981.92**
										FNPV	**-981.92**
										FIRR	**-3.84%**
										MIRR	**1.2%**

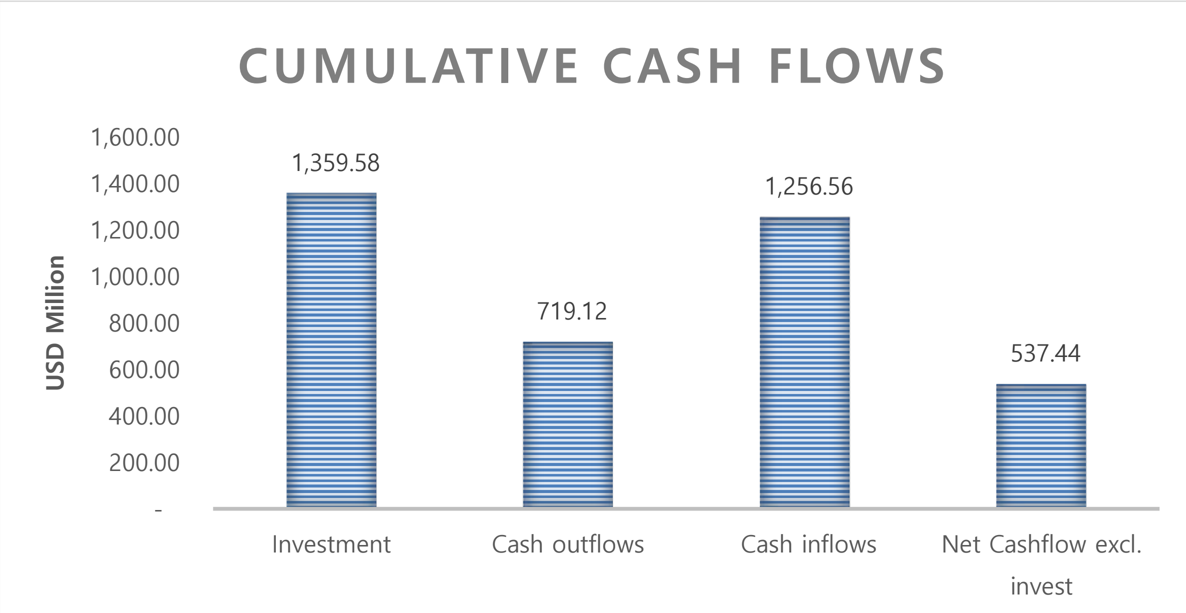
Real net cash flows of the project is discounted at real WACC rate of 3.04% to arrive at Financial Net Present Value (FNPV). Calculation of real WACC rate is discussed under section 15.5.3 of this report. Financially viable projects usually generates a FNPV value of zero or above. However FNPV calculated for the project stood at negative USD 981.92 million. This shows that the project does not generate sufficient cash flows to cover its investment and cost of funding. Thus the investors of the project neither earn expected return nor fully recover the investment provided through debt or other means.

Financial Internal Rate of Return (FIRR) of a project shows the investment return generated from a project. FIRR should be higher than the cost of funding (WACC) in order to be financially viable.

However Financial Internal Rate of Return (FIRR) of the project is negative 3.84%. Accordingly the project does not generate a sufficient investment return to cover its cost of funding of 3.04%.

15.5.5.3 Project Payback Period

Project payback period measures how long it takes to recover the investment made in a project. Generally projects with earlier payback period are preferred. When analyzing the cash flows of the project it could be observed that cumulative net cash flows of the project excluding the investment is USD 537.44 million. However this amount is not sufficient to recover the investment of USD 1359.58 (excl. price contingencies) as illustrated in the Figure 15-13 below. Accordingly the project could not recover its investment during the life time of the project.



Source: Estimated data

Figure 15-13 Cumulative Cash flows

15.5.6 Recovery of Investment Cost and Cost of Funding

As discussed in section 15.5.5.1, operational self-sufficiency, the project is operationally viable as it could recover O&M costs from operational revenue. The project results annual financial cost of 3.04% (WACC) as interest payments on loan and opportunity cost of government funds. Further the project requires to recover the investment in order to pay off the loans.

Significant Negative FNPV of the project indicates that neither the financing cost nor the investment could be fully recovered from the project cash flows. If increasing revenue is considered as an option it needs to increase annual revenue by 156% for FNPV to be zero. This means that number of passengers & parcels transported and other sources should be improved. Alternatively it could be considered government subsidies for recovering the financing cost and investment. Table 15-52 provides the amount of subsidies required in order to pay the cost of funding and recovering the investment. Investment cost recovery is needed in order to settle the funds obtained from various parties through debt or other means.

Table 15-52 Subsidies for cost of funding and investment cost recovery

Year	Cost				Revenues					Net Cashflow	Discounted Cash Flow
	Capital	O&M	Replace	Total	Passengers	Freight	Other	Subsidy	Total		
2020	-70.80	0.00	0.00	-70.80	0.00	0.00			0.00	-70.80	-68.71
2021	-429.59	0.00		-429.59	0.00	0.00			0.00	-429.59	-404.61
2022	-429.59	0.00		-429.59	0.00	0.00			0.00	-429.59	-392.67
2023	-429.59	0.00		-429.59	0.00	0.00			0.00	-429.59	-381.08
2024		-18.27		-18.27	24.66	0.75	2.57	53.04	81.02	62.74	54.02
2025		-18.42		-18.42	25.25	0.77	2.63	53.47	82.12	63.70	53.22
2026		-18.57		-18.57	25.71	0.78	2.68	53.90	83.07	64.50	52.30
2027		-18.72		-18.72	26.19	0.79	2.73	54.33	84.05	65.33	51.41
2028		-18.87		-18.87	26.68	0.81	2.78	54.77	85.04	66.17	50.54
2029		-19.02		-19.02	27.18	0.82	2.83	55.22	86.06	67.04	49.69
2030		-19.19		-19.19	27.70	0.84	2.89	55.69	87.12	67.93	48.86
2031		-19.35		-19.35	28.24	0.86	2.94	56.16	88.20	68.85	48.06
2032		-19.51		-19.51	28.79	0.87	3.00	56.65	89.31	69.79	47.28
2033		-19.69	-25.01	-44.70	29.36	0.89	3.06	57.15	90.45	45.76	30.08
2034		-19.86		-19.86	29.94	0.91	3.12	57.65	91.62	71.76	45.79
2035		-20.06		-20.06	30.55	0.93	3.18	58.24	92.90	72.83	45.10
2036		-20.06		-20.06	31.17	0.95	3.25	58.24	93.61	73.54	44.20
2037		-20.06		-20.06	31.82	0.97	3.32	58.24	94.34	74.27	43.32
2038		-20.06		-20.06	32.48	0.99	3.39	58.24	95.09	75.03	42.47
2039		-20.06		-20.06	33.17	1.01	3.46	58.24	95.87	75.81	41.64
2040		-20.06		-20.06	33.88	1.03	3.53	58.24	96.68	76.62	40.84
2041		-20.06		-20.06	34.62	1.05	3.61	58.24	97.51	77.45	40.07
2042		-20.06		-20.06	35.38	1.07	3.69	58.24	98.38	78.31	39.32
2043		-20.06	-103.42	-123.49	36.16	1.10	3.77	58.24	99.27	-24.22	-11.80
2044		-20.06		-20.06	36.98	1.12	3.85	58.24	100.19	80.13	37.89
2045		-20.06		-20.06	37.82	1.15	3.94	58.24	101.15	81.09	37.21
2046		-20.06		-20.06	38.69	1.17	4.03	58.24	102.14	82.08	36.56
2047		-20.06		-20.06	39.60	1.20	4.13	58.24	103.17	83.10	35.92
2048		-20.06		-20.06	40.54	1.23	4.22	58.24	104.23	84.17	35.31
2049		-20.06		-20.06	41.51	1.26	4.33	58.24	105.34	85.27	34.72
2050		-20.06		-20.06	42.52	1.29	4.43	58.24	106.48	86.42	34.14
2051		-20.06		-20.06	43.57	1.32	4.54	58.24	107.67	87.60	33.59
2052		-20.06		-20.06	44.65	1.35	4.65	58.24	108.90	88.84	33.06
2053		-20.06		-20.06	45.78	1.39	4.77	58.24	110.18	200.13	72.28
Total	**-1359.58**	**-590.69**	**-128.43**	**-2078.71**	**1010.57**	**30.66**	**105.32**	**1714.60**	**2861.15**	**892.46**	**0.00**
										FNPV	**0.00**
		-				-				**FIRR**	**3.04%**

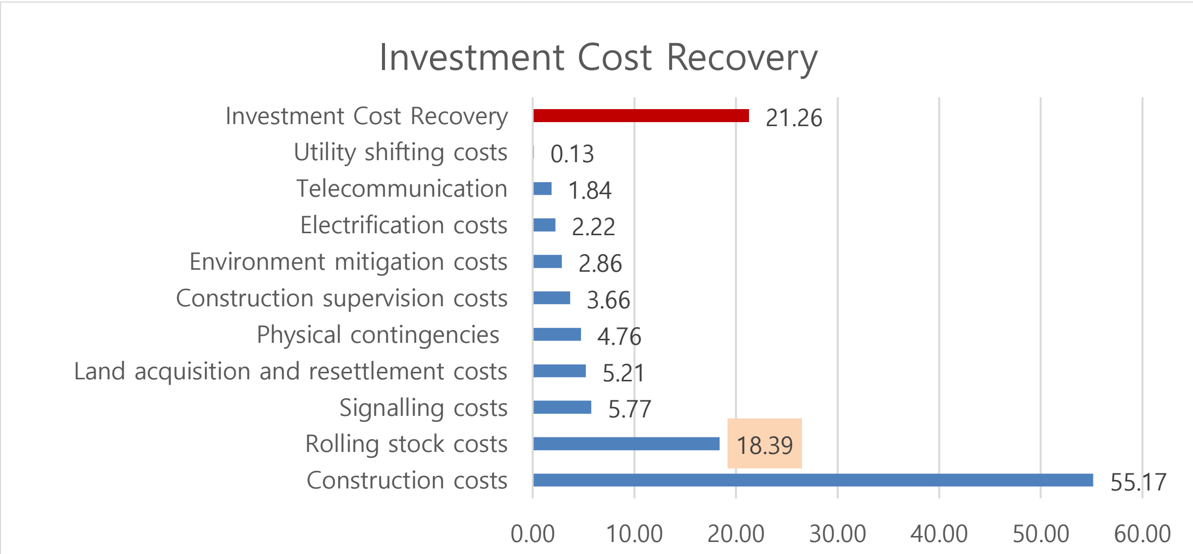
As per the Table 15-52 given above it requires a government subsidy of 290.27% from the operating & maintenance cost (at constant price) of each year to fully settle the investment cost and cost of funding. The total subsidy of the project amounts to 150% of the cumulative revenue of the project. When the investment excluding the government funding is considered (ADB loan), it requires a subsidy of 216.54% of annual O&M costs for recovering investment and related cost of funding. Net cash flows of the project is sufficient enough to recover USD 289.08 million of investment cost and related cost of funding without any subsidies. This amount is 21.26% of the total investment (excluding price contingencies).

Table 15-53 Subsidies for cost of funding and investment costs recovery (sensitivity)

Scenario	Investment Cost USD million	As a % of total investment (excl. price contingencies)	Subsidies (As a % of annual O&M costs)
Total investment excl. price contingencies	1359.58	100%	290.27 %
Investment excl. government funding of 20% (ADB Loan)	1161.00	80%	216.54%
Break even investment (Investment recovered without subsidies)	289.08	21.26%	0%
Investment in Rolling Stock	250.00	20.67%	0%

Source: Estimated data

When the investment for rolling stock is compared with the break-even investment recovery of 21.26%, it can be concluded that rolling stock cost could be easily recovered from the project cash flows as shown in Figure 15-14.



Source: Estimated data

Figure 15-14 Investment cost vs Investment recovery rate

Moreover the Figure 15-14 compares the investment cost recovery rate with different components of the investment cost (excluding price contingencies). Accordingly it could be observed that investment cost recovery rate is higher than the aggregate investment requirement for land acquisition and modernization costs of Electrification, telecommunication & signaling.

15.5.7 Sensitivity Analysis

Sensitivity analysis provides the impact on the key decision indicators of the project upon variability of several inputs. The following sections discusses the variability of WACC, variability of operating and investment cash flows and variability of project life.

15.5.7.1 Variability of WACC

The following Table 15-54 evaluates the impact to FNPV, FIRR and investment recovery percentage under alternative cost of funding (WACC). WACC under alternative 01 is 4.25% and corresponding FNPV becomes further negative from the base case figures. Investment recovery percentage drops to 17.10% from the base case level of 21.26% at this higher level of WACC. However the investment recovery percentage is higher than the required investment on land acquisition and resettlement.

Table 15-54 Alternative sources of funding vs Investment recovery

Scenario	Sources of Funding				WACC (Real) %	FNPV	FIRR	% of Investment Recovery	% of Investment in Land
	ADB Loan %	Foreign Loan %	Local Bank %	GOSL Funds %					
Base Case	80	0	0	20	3.04	-981.92	-3.84%	21.26%	5.21%
Alternative 1	30	50	10	10	4.25	-999.74	-3.84%	17.10%	5.21%
Alternative 2	30	60	0	10	3.97	-997.07	-3.84%	17.96%	5.21%
Alternative 3	60	30	0	10	2.77	-975.41	-3.84%	22.37%	5.21%

Source: Estimated data

Resulting WACC under alternative 2 is 3.97% and investment recovery of the project is 17.96% for the same WACC. Accordingly the project could fully recover its investment in land acquisition and resettlement cost. The lowest WACC could be observed under alternative 3. However the project metrics of FNPV and FIRR are still negative. Investment recovery rates improves up to 22.37% at this lower level of WACC.

15.5.7.2 Variability of Operating & Investment Cash flows

The following Table 15-55 compares the base case with different scenarios such as when investment costs increases by 10%, when O&M costs increases by 10% and when revenue drops by 10%.

Table 15-55 Sensitivity of investment, O&M costs and Revenue

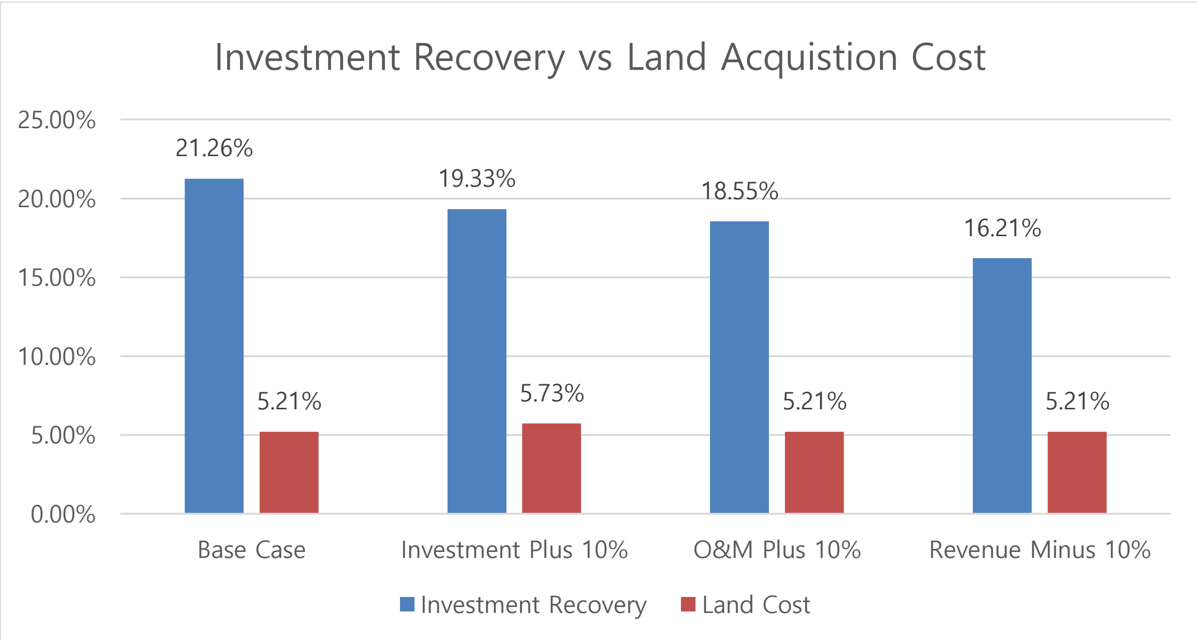
Item	Base Factor	New Factor	Change %	Excluding Subsidy		Subsidy as a % of O&M costs to recover investment and cost of funding			Investment Recovery with no subsidies	% of Investment in Land
				FNPV	FIRR	Total invetment	Only ADB loan	20% Investment		
Base Case				-981.92	-3.84%	290.27%	216.54%	0.00%	21.26%	5.21%
Investment Plus 10%	1,359.58	1,495.54	10%	-1106.63	-4.21%	327.14%	246.03%	2.72%	19.33%	5.73%
O&M Plus 10%	590.69	649.76	10%	-1015.75	-4.19%	272.97%	205.94%	4.86%	18.55%	5.21%
Revenue Minus 10%	1,146.55	1,031.90	-10%	-1044.97	-4.58%	308.91%	235.18%	13.98%	16.21%	5.21%

Source: Estimated data

When the investment cost increases by 10%, FNPV and FIRR further becomes negative. Government needs to subsidize 327.14% of annual O&M costs in order to fully recover the investment and associated cost of funding. However if only ADB funds are recovered (80% of investment), It needs 246.03% of annual O&M costs as subsidies. Recovering 20% investment and related cost of funding requires only 2.72% of annual O&M costs as subsidies. If the government does not provide any subsidy, the project could recover only 19.33% of the investment. However this is higher than the 5.73% of investment (with proportionate increase of 10%) required for land acquisition and resettlement.

When the O&M cost increases by 10%, FNPV and FIRR further reduces from the base level. Recovery of total investment costs and associated cost funding needs 272.97% of O&M costs as subsidies. Though this percentage is lower than the base case scenario, it needs to understand that it is due to increased O&M costs resulting increased subsidies when subsidies are tied with O&M costs. If the government does not provide any subsidy, the project could recover only 18.55% of the investment however it is again sufficient to recover 5.21% investment in lands.

When the revenue drops by 10% from the base case scenario, Investment recovery of the project is estimated to be 16.21%. Government needs to subsidize 13.98% of O&M costs to recover 20% of investments and associated cost of funding. Figure 15-15 compares investment recovery rate under each scenario with the land acquisition cost.



Source: Estimated data

Figure 15-15 Sensitivity of Investment Recovery rate

According to Figure 15-15, it could be observed that investment recovery rate of the project under different scenarios are always higher than the land acquisition cost.

15.5.7.3 Variability of Project Life

The base case scenario considers the project life time of 30 years based on international practices of railway project assessment. However According to Sri Lankan standards (based on Euro codes) certain assets have a longer life span above 30 years as provided below Table 15-56.

Table 15-56 Assets Life time as per Sri Lankan Standards (Based on Euro codes)

#	Item	Life Time (Years)
1	Elevated Construction	100
2	Bridge	100
3	Flyover	100
4	Station Buildings	50

#	Item	Life Time (Years)
5	Embankment	50
6	Track and Track Bed	50
7	Electrification System	30
8	Signaling	20
9	Tele Communication System	10
10	Rolling Stocks	30

Source: Sri Lanka Standard - NA to SLS EN 1990 - 2018 (Gr), Sri Lanka Standards Institutions

Accordingly three scenarios have been identified; 50 years, 75years and 100 years life time for sensitivity analysis. Replacement cost schedule and residual value for 50 years life time is provided below table 15-57. Replacement costs represent the base price and residual value is based on undepreciated value at the end of the project.

Table 15-57 Replacement Cost Schedule and Residual Value for 50 Years Life

#	Item	Life Time (Years)	Cost (US $)	Replacement Cost (US $)				Residual Value
				2033	2043	2053	2063	As at 2073
1	Elevated Construction	100	420,507,543					210,253,772
2	Bridge	100	3,705,141					1,852,570
3	Flyover	100	12,158,384					6,079,192
4	Station Buildings	50	64,372,534					0
5	Embankment	50	202,199,079					0
6	Track and Track Bed	50	45,830,296					0
7	Electrification System	30	30,117,600			30,117,600		10,039,200
8	Signaling	20	78,414,040		78,414,040		78,414,040	39,207,020
9	Telecommunication System	10	25,008,600	25,008,600	25,008,600	25,008,600	25,008,600	0
10	Rolling Stocks	30	250,000,000			250,000,000		83,333,333
11	Land	N/A	70,804,444					70,804,444
	Total		**1,203,117,661**	**25,008,600**	**103,422,640**	**305,126,200**	**103,422,640**	**421,569,532**

Source: Estimated data

Annual revenue and operation cost cash flows are assumed to be constant beyond 2053. Similar calculations and assumptions have been made for 75 years and 100 years lifetime. Accordingly FNPV, FIRR, subsidy rates and investment recovery rates are presented for these different life spans in the Table 15-58.

Table 15-58 Sensitivity of project life time

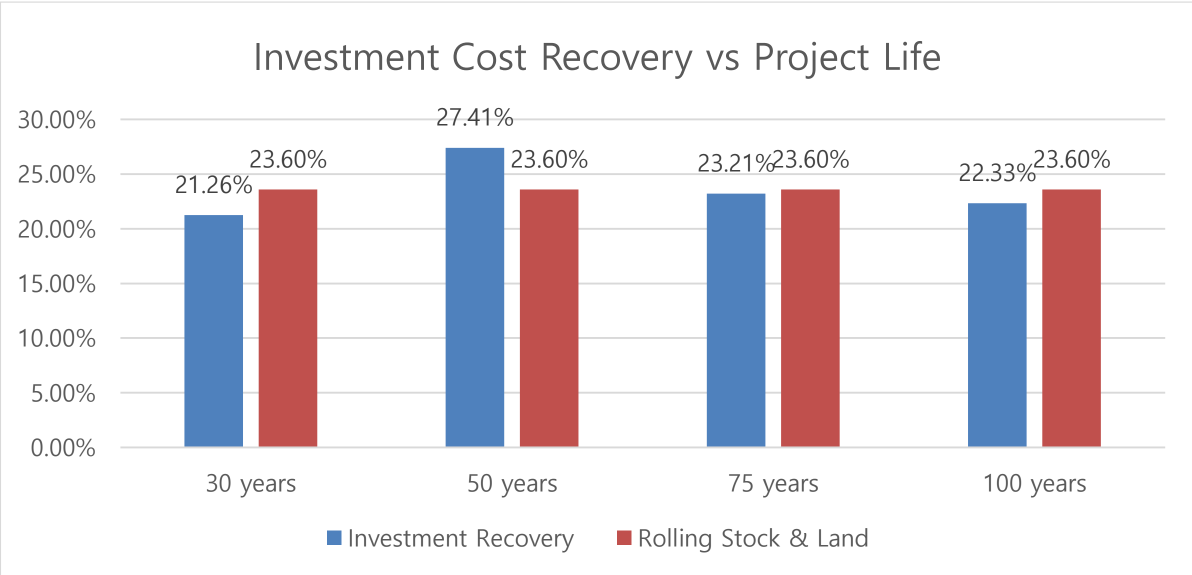
Project Life	Excluding Subsidy		Subsidy as a % of O&M costs to recover investment and cost of funding			Investment Recovery with no subsidies	% of Investment in rolling stock
	FNPV	FIRR	Total Investment	Only ADB loan	20% Investment		
30 (base case)	-981.92	-3.84%	290.27%	216.54%	0.00%	21.26%	18.39%
50	-905.25	-0.57%	203.12%	147.15%	0.00%	27.41%	18.39%
75	-957.63	-0.20%	186.06%	137.60%	0.00%	23.21%	18.39%
100	-968.66	-0.01%	176.99%	131.42%	0.00%	22.33%	18.39%

Source: Estimated data

FNPV improves but still negative for 50 years project life compared to the base case of 30 years. Investment recovery rate of the project increases up to 27.41% compared with the base case recovery rate of 21.26%. Investment in rolling stock comprises of 18.39% from the total investment (excluding price contingencies). Thus the investment recovery rate of 27.41% is well above the investment requirement for rolling stocks. Accordingly if the project is operated for 50 years, the project could recover the investment and related cost of funding attributable to rolling stocks.

When Project life span of 75 years is considered, it reduces the negative FNPV from the base case scenario. Further the corresponding investment recovery rate of 23.21% is higher than the base case scenario.

When the project is operated for 100 years, negative FNPV further reduces compared to the base case scenario but higher than other scenarios. Moreover the investment recovery rate is at 22.33% for 100 years duration.



Source: Estimated data

Figure 15-16 Investment Cost recovery

The above Figure 15-16 shows the investment cost recovery rate and investment costs components of rolling stock and land acquisition costs over different life spans. Accordingly the aggregate rolling stock and land acquisition cost is 23.60% from the total investment. It could be observed that investment cost recovery rate is higher than rolling stock and land acquisition costs for 50 years project life. Moreover the investment recovery rate is at the highest when the project is operated for 50 years. The above analysis suggests that the 50 years project life span as the best scenario. Accordingly the better financial results could be achieved if the project runs for 50 years.

15.5.8 Conclusion

This financial analysis evaluates the financial viability of the project of electrification and expanding KV line from a single track to double track with an elevation of Maradana to Malapalla section and many other developments. The project requires an investment of USD 1424.33 million and it is expected to generate wide economic, environmental and social benefits. Financial viability is assessed to identify whether the railway project could generate sufficient cash flows to cover its operating costs, investment costs and costs of funding of the investment.

KV line project has sufficient operating cash flows to meet up its operating expenses thus the project is operationally self-sufficient. Accordingly, the project does not require government subsidies for meeting operating costs. Moreover, its operating cash flows are sufficient to meet up the replacement costs of certain capital assets that needs replacing during the project life of 30 years.

When evaluating further whether the project could recover its investment cost along with the cost of funding, it could be observed that the project cash flows are not sufficient to fully recover the investment cost and associated cost of funding as evident by negative FNPV and FIRR. The investment recovery rate of the project is 21.26% thus the project is able to recover certain components of investment cost. For example, the investment required for rolling stocks.

Sri Lankan standards on construction (based on Euro codes) suggests higher life spans of several elements such as bridges, flyovers, tracks, buildings, embankment, etc. compared to the initial evaluation period of 30 years. When higher life spans are considered 50 years' lifetime provides better financial results such as higher FNPV and investment cost recovery. Accordingly, FNPV improves with 50 years of lifetime but still remains negative. Further, the investment recovery rate improves to 27.41% for 50 years duration. This recovery rate is sufficient enough to recover the investment and associated cost of funding pertaining to land acquisition and rolling stock costs which accounts for 23.60% of the total investment (excluding price contingencies). Recovering the rest of the investment costs and paying the related cost of funding could not be made with project cash flows generated thus the government needs budgetary allocation from common public funds for the same which is the usual case with railway transport facility projects in many countries.

Especially, this KV line is developed as a passenger line, therefore, it is harder to recover both CAPEX and OPEX together within a project life period. But KV line income generating capability is in a very commendable position because hardly any passenger railway lines recover part of OPEX. But this line not only fully recovers its OPEX it also recovers part of the CAPEX also within the project life period. However in the long-run with a possible extension of KV line via Rathnapura, Balangoda and Ambilipitiya to main line, this could be one of the profit-generating model railways in Sri Lanka with more passenger and freight attractions.

15.6 Economic Analysis

15.6.1 Concept Approach and Basic Assumptions

This economic analysis work followed Asian Development Bank's (ADB) Guidelines for Economic Analysis of projects-2017. A well-conducted economic analysis should show that:

(7) A project is in line with the development context of a borrowing country and ADB's country partnership strategy (CPS).

(8) There is strong rationale for the public sector and ADB to finance the project

(9) The selected project represents the most efficient or least-cost option among all the feasible alternatives for achieving the intended project benefits.

(10) When benefit can be valued, it will generate a positive economic net present value (ENPV) using the minimum required economic internal rate of return (EIRR) as the discount rate.

The following assumptions were employed in the benefit cost analysis:

(1) Costs are based on the estimated capital and operation and maintenance costs.

(2) Used 2020 constant price to calculate O&M cost (Details are given in financial analysis section)

(3) Benefits are based on STRADA transport model output and used 2020 constant prices.

(4) The Benefit Cost analysis has been carried out using IRR, NPV, B/C and sensitivity analysis and used 9% discount rate.

(5) Period of analysis is 30 years.

15.6.2 Conversion Factors

The methods of economic prices determination follow the ADB Guidelines for the Economic Analysis of Projects. It suffices here to state that the basic difference between financial and economic prices is that financial prices indicate the financial worth to the owners of the project‘s assets and economic prices represent the viewpoint of society as a whole. Financial prices are exiting market prices and mainly distorted due to government direct influences, taxes and subsides. Economic prices exclude all these government direct influences, taxes and subside.

Normally, financial prices are converted to economic prices by using the Standard Conversion Factor (SCF). Generally, SCF calculated by border price divided by domestic price as a ratio. For this analysis, the average conversion factor was calculated based on the last 6 year averages as 0.91. Detailed SCF calculation method is given in Table 15-59.

Table 15-59 Standard Conversion Factor

(US $ Million)

Trade Information	2012	2013	2014	2015	2016	2017
1) Import tax	2063.92	2063.92	2190.66	2259.18	3106.43	3487.99
Import Duties	469.61	469.61	488.84	679.97	984.19	858.50
VAT (Imports)	607.48	607.48	643.27	526.58	725.38	1059.09
Ports & Airports Dev. Levy	386.82	386.82	431.74	356.81	558.63	644.03
Import Cess Levy	207.57	207.57	224.04	267.09	371.43	355.81
Special Commodity Levy	293.74	293.74	301.58	328.77	351.10	449.06
Nation Building Tax (Imports)	98.70	98.70	101.19	99.96	115.69	121.51
2) Export tax	19.55	155.66	170.84	17.27	17.00	18.93
Export Duties	0.13	136.25	151.45	0.21	0.19	0.19
Export Cess Levy	19.42	19.42	19.40	17.06	16.81	18.74
3) Total Imports	15351.57	14610.87	15944.42	16179.04	17566.14	20116.86
4) Total Exports	7833.53	8453.17	9139.47	9002.71	9440.83	10893.12
SCF	0.919	0.924	0.925	0.918	0.897	0.899
Average SCF for the six years	0.91					

Source: Ministry of Finance Annual Reports, Central Bank of Sri Lanka Statistics, 2012-2017

The SCF, converting from financial prices to economic prices, has been calculated from the recent trade statistics of Sri Lanka.

15.6.3 Purpose of the Economic Analysis of KV Line

The main purpose of project economic analysis is to help design and select projects that contribute to the welfare of a country. Economic analysis of an investment project is the procedure for assessing the opportunity of a project by considering the benefits compared to the costs. Finally, both elements being considered at economic prices. The main role of economic analysis is to design and select the projects that contribute to the welfare of a region or a country. The economic analysis is most useful when used early in the project cycle, to identify negative or positive yield for decision making purpose. Economic analysis differs from financial analysis, which evaluates a project only from the point of view of the owner of the investment. However, Economic analysis includes all social and environmental costs which were not taken into account by financial analysis and focused on national development perspective.

15.6.3.1 Project Economic Life and Technical Life

1) Project Economic Life

The standard for the economic viability assessment of a railway line is 30 years. Some of railway assets will not be fully depreciated at the end of the project period, but not included for this analysis, based on ADB guideline on Economic Analysis of the Projects. However, all replacement values were included for economic analysis and therefore, BCA has been considered 30 years project Economic Life Approach.

2) Project Technical Life

Total construction period will be run from 2020 to 2023 for four year period. After completion of all construction works of KV Line, commercial operation will be commence on 2024 and total operational period will be 30 years from 2024 to 2053. Hence, in order to calculate with a typical life cycle results for demand and benefit streams are capped in 2053. As a consequence, replacement investments for KV Line assets of all types must be taken into account in a total cost approach.

3) Project Economic Life vs. Technical Life

Many railroad assets are designed for very long-term use, such as major structures (Ex. bridges). Therefore, expected technical life of such resources would exceed the economic life and these differences were carefully analyzed by Economic and Financial Team, when accounting replacement cost for them in BCA. Therefore, to include replacement cost to BCA model, this analysis has been considered Economic Life of such assets and computed accordingly.

Hence, above replacement cost is represent the additional future capital costs to spend in order to continue to provide the service improvements and used BCA model as discounted value. Table 15-60 presents the assets and life spans under the technical and economic lenses.

Table 15-60 Economic Life vs. Technical Life - KV Line Assets

Item	Economic Life (Years)	Technical Life (Years)*	Economic Minus Technical (years)
1. Bridge	30	100	70
2. Flyover	30	100	70
3. Station Buildings	30	50	20
4. Embankment	30	50	20
5. Track and Track Bed	30	50	20
6. AFC	10	10	0

Item	Economic Life (Years)	Technical Life (Years)*	Economic Minus Technical (years)
7. Electrification System	30	30	0
8. Signaling	20	20	0
9. Tele Communication System	10	10	0
10. Rolling Stocks	30	30	0

Source: *National Annex (Informative) - SLS EN 1990: 2018.

(6) Eurocode–Basis of Structural Design (pp 2-3) Published by Council of the Sri Lanka Standard Institution on 2018-02-23.

The ADB Guideline on Economic Analysis of Projects – 2017, highlights the project operating life. If the project economic life is shorter than the technical life, the economic life should be used. The economic life is defined as the number of years before the annual economic cost of operations begins to exceed annual economic benefits. Therefore this analysis used 30 years of economic life as estimated.

According to the above table, some projects assets have remaining service life after replacement (Ex. Signaling). However, remaining service periods were not computed for the BCA.

Example 1: Railway Signaling Case

Above asset number 8, assumed to require replace in every 20 years.

If the analysis period is 30 years, the BCA would have assumed the cost of replacing the asset at year 20, and not taken remaining 10 years of service life for BCA.

A simple approach to estimating the replacement cost of an asset is to assume that its residual value multiplied by life time. Estimated replacement cost included the BCA with particular discount values.

Example 2: Railway Bridge Replacement Case

Replacement period under economic life is 30 years and technical life is 100 years. Due to considering Economic Life Approach for this calculation, bridge replacement cost is coming under the BCA model.

Table 15-61 presents the replacement cost and life spans under each technical and economic calculation.

Table 15-61 Residual Values of Economic and Technical Life

Item	Initial Replacement Cost (US $)	Economic Life *(Years)	Residual Value (US $ Mn.)	Technical Life** (Years)	Residual Value (US $ Mn.)
1. Bridge	3,705,140.92	30	0.12	100	0.04
2. Flyover -(Underpass)	12,158,383.58	30	0.41	100	0.12
3. Station Buildings	64,372,533.89	30	2.15	50	1.29
4. Embankment	202,199,078.95	30	6.74	50	4.04
5. Track and Track Bed	45,830,295.76	30	1.53	50	0.92
6. AFC	0.00	10	0.00	10	0.00
7. Electrification System	30,117,600.00	30	2.10	30	2.10
8. Signaling	78,414,040.00	20	3.92	20	3.92
9. Tele Communication System	25,008,600.00	10	2.50	10	2.50
10. Rolling Stocks	250,000,000.00	30	10.00	30	10.00

Source: *Economic Life Assumed by International Consultant and used average values.
**Technical Life - National Annex (Informative) - SLS EN 1990: 2018. Eurocode –Basis of Structural Design (pp 2-3) Published by Council of the Sri Lanka Standard Institution on 2018-02-23.

According to the argument on Economic Life vs Technical Life case, following conclusions were made:

(1) The project Economic Life will be assumed on BCA model

(2) Technical life of a railway project is usually long with sound maintenance program, but not taken in to the economic analysis.

15.6.3.2 Project Cost in Economic Perspectives

The project cost consists of three main components as investment costs, O&M costs and depreciation costs. These costs have been estimated and included in the benefit cost analysis at constant prices. The initial project investment costs were estimated for entire KV line and included as construction costs, land acquisition and resettlement costs, electrification costs, signaling costs, telecommunication, rolling stock costs, construction supervision costs and etc. The yearly costs for operation and maintenance for KV line have been estimated and included as: man power costs, maintenance costs and energy costs. Following Table 15-62 shows the summary of project cost,

Table 15-62 Summary of Project Cost

Item		Total (US $)
A	Construction costs	750,030,141.84
B	Automatic Fair Collection (Removed)	0.00
C	Re-settlement costs	70,804,444.44
D	Electrification costs	30,117,600.00
E	Signaling costs	78,414,040.00
F	Telecommunication	25,008,600.00
G	Rolling stock costs	250,000,000.00
H	Utility shifting costs	1,758,561.32
I	Environment mitigation costs	38,906,103.45
	Sub Total-1	1,245,039,491.05
J	Construction Supervision Cost (4%)	49,801,579.64
	Sub Total -2	49,801,579.64
	Sub Total - 3 (Total Base Cost)	1,294,841,070.69

Source: Final Cost Estimate

The life of the proposed railway project is much longer than the analysis period used in the benefit cost analysis. The analysis period is limited to 30 years, however life time of railway resources are higher than this. The Sri Lanka Standard Institution published ―National Annex (Informative) to SLS EN 1990: 2018, Eurocode –Basis of Structural Design". This ―National Annex" was approved by the Council of the Sri Lanka Standard Institution on 2018-02-23 and prepared in association with European Committee for Standardization and British Standard Institution. Therefore, life span of railway resources were calculated based on ―National Annex (Informative) to SLS EN 1990: 2018, Eurocode –Basis of Structural Design". Based on above Sri Lanka standard, depreciation values were included to the benefit cost analysis.

1) Contingency Allowances on Engineering and Economic Lenses

Detailed engineering cost estimate has been provided two types of contingency values as price and physical. The ADB Guideline for the Economic Analysis of Project – 2017 has been given consideration of contingencies. The guideline clearly says:" Physical contingencies represent the monetary value of additional real resources that may be required beyond the base cost to complete the project, and should be treated as part of the economic cost". Hence, for project economic analysis, it is appropriate to include the physical contingency allowance, but not the price contingency. Based on ADB guideline, this BCA used physical contingencies and excluded price contingencies and given in Table 15-63.

Table 15-63 Project Cost with Physical Contingencies

	Item	Total (US $)
A	Implementation Cost	1,245,039,491.05
	Sub Total-1	**1,245,039,491.05**
B	Construction Supervision Cost	49,801,579.64
	Sub Total -2	**49,801,579.64**
	Sub Total - 3 (Total Base Cost)	**1,294,841,070.69**
C	Physical Contingencies (5%)	64,742,053.53
	Sub Total -4	**64,742,053.53**
	Sub Total - 5	**1,359,583,124.22**

Source: Final Cost Estimate

2) Depreciation

Depreciation is not considered in economic analysis to avoid double counting of capital costs. Replacement expenditure is included as needed during the project's economic life.

3) Interest Charges

Interest charges accrued during project construction are similarly not included in capital cost in project economic analysis.

4) Inflation

In economic analysis, project benefits and costs are measured in constant prices of a base year and effect of general inflation is eliminated, however adjusted for the effect of general inflation. All the project inputs and outputs were followed by price adjustments equally. Using constant prices ensures that the future costs and benefits of a project are comparable to those incurred at the time the decision to invest in the project is made. Based on this principle, 2020 constant prices were applied for both cost and benefits stream. Project construction works will commenced on 2020 and total construction period is 4 years and by 2024, project operations will commence. The total base cost of the project is US $ 1.38 billion which is eliminated general inflation. Total project cost is US $ 1.45 billion including physical contingencies, but eliminated price contingencies, according to ADB Guidelines on Project Economic Analysis. Table 15-62 and Table 15-63 respectively presented above two cost calculations in details.

Table 15-64 shows the constant price projections for project benefit stream. For this Economic Analysis, all the non-traded project benefits were generated by STRADA transport model and calculate with constant prices on 2020. As per the recommendation of ADB Economic Analysis Guidelines, consumer price index (2013=100) has been used and computed constant prices.

Table 15-64 Consumer Price Index

Year	CPI (2013 = 100)	CPI Change %
2014	105.1	5.1
2015	107.4	2.2
2016	111.7	4.0
2017	119.0	6.5
2018	123.2	3.5
2019	127.6	3.5
2020	132.1	3.5
2021	136.8	3.5
2022	141.6	3.5
2023	146.6	3.5
2024	151.8	3.5

Source: Department of Census and Statistics (2014 to 2017)
From 2018 - 2024 Consultant's Estimates.

15.6.3.3 Benefit Estimation on Demand Analysis

The demand analysis is a key of the project development cycle and challenging task for achieving overall quantitative results. According to the ADB Economic Analysis Guidelines, sound demand analysis is an essential component to the project benefit estimation. Detailed financial benefit estimation based on demand analysis is given in financial analysis section. For the economic feasibility analysis, KV Line project has been used transport sector specific STRDA transport model approach to estimate economic benefits. Final economic benefits of overall transport demand analysis are presented in Table 15-70 as with project system cost savings. Large number of variables were used to overall transport demand estimation of KV Line and some of key variables are presented in following Table 15-65.

Table 15-65 Key Demand Analysis Variables

S / N	Variable	Unit
1	Motorized Trips per Day	Million
2	Public Transport Share	Trips
3	Private Transport Share	Trips
4	Vehicle Km Travelled	Km.
5	Passenger Km Travelled	No.
6	Average Trip Distance	Km.

S / N	Variable	Unit
7	Passenger Hours Travelled	hrs.
8	Average Travel Speed	Km/h

Source: STRADA Model

15.6.3.4 Calculation of Annual Sectional Passenger Volume

The KV line project investment is nearly US $ 1.424 billion (including price contingencies) and therefore, projects have long gestation periods. Hence, prior to take the investment decision adequately estimated future demand function is required. This section discussed only KV Line passenger demand on with project scenario. Mainly assumed KV Line demand function consists of traffic volume, supply characteristics and capacity enhancement, new technology, service quality improvement and socio economic activities. This demand analysis is mainly based on Key Performance Indicators (KPI) provided by STRADA transport model. Following table shows the summary of daily sectional volume of passengers between stations.

The Table 15-66 shows the daily sectional passenger volume, based on field studies. The economic life of the project is 30 years and annual passenger demand was calculated on 2024 onwards.

Table 15-66 Sectional Demand Growth Rate

S/N	Station Name	Station Name	GR	S/N	Station Name	Station Name	GR
1	Maradana	Baseline	0.02359	18	Panagoda	Godagama	0.00052
2	Baseline	Kotte Road	0.01932	19	Godagama	Meegoda	-0.00072
3	Kotte Road	Narahenpita	0.01662	20	Meegoda	Watareka	-0.00284
4	Narahenpita	Kirulapone	0.01377	21	Watareka	Padukka	-0.00345
5	Kirulapone	Nugegoda	0.01315	22	Padukka	Arukwathupura	-0.00362
6	Nugegoda	Pangiriwatta	0.01335	23	Arukwathupura	Angampitiya	-0.00045
7	Pangiriwatta	Udahamulla	0.01432	24	Angampitiya	Uggalla	0.00525
8	Udahamulla	Navinna	0.01747	25	Uggalla	Pinnawala	0.00714
9	Navinna	Maharagama	0.02024	26	Pinnawala	Gammana	0.00920
10	Maharagama	New1-Dambahena	0.02701	27	Gammana	Morakele	0.01342
11	New 1- Dambahena	Pannipitiya	0.02997	28	Morakele	Waga	0.01341
12	Pannipitiya	Kottawa	0.02997	29	Waga	Kadugoda	0.02391
13	Kottawa	Malapalla	0.03696	30	Kandugoda	Kosgama	0.03165
14	Malapalla	Makumbura	0.01248	31	Kosgama	Hingurala	0.06929
15	Makumbura	Homagama Hospital	0.01001	32	Hingurala	Puwakpitiya	0.06068
16	Homagama Hospital	Homagama	0.00477	33	Puwakpitiya	Avissawella	0.05709
17	Homagama	Panagoda	0.00034				

Source: Chapter 3 of DFSR -2025 and 2035 Daily Passenger Volume based annual calculation

Following Table 15-67 shows the summary of daily sectional volume of passengers between stations. Passenger demand sectional growth rate calculation was based daily passenger volume of project scenario 1 year 2025 and project scenario 1 year 2035, but not considered peak hour demand data.

Table 15-67 Summary of Daily Sectional Volumes Between Stations

Station Name	Station Name	Daily Passenger Volume MG		Peak Hour Passenger Volume Per Direction (PPHPD)	
		Medium Growth Sc (MG_2025_SC1)	Medium Growth Sc (MG_2035_SC1)	Year 2025 Medium Growth Sc (MG_2025_SC1)	Year 2035 Medium Growth Sc (MG_2035_SC1)
Maradana	Baseline	133771	168893	13912	17565
Baseline	Kotte Road	132807	160817	13812	16725
Kotte Road	Narahenpita	144468	170352	15025	17717
Narahenpita	Kirulapone	169559	194403	17634	20218
Kirulapone	Nugegoda	176969	201662	18405	20973
Nugegoda	Pangiriwatta	173328	197899	18026	20581
Pangiriwatta	Udahamulla	156471	180373	16273	18759
Udahamulla	Navinna	140155	166655	14576	17332
Navinna	Maharagama	131353	160494	13661	16691
Maharagama	New1-Dambahen	102406	133684	10650	13903
New 1- Dambahena	Pannipitiya	100224	134653	10423	14004
Pannipitiya	Kottawa	100224	134653	10423	14004
Kottawa	Malapalla	88547	127291	9209	13238
Malapalla	Makumbura	85306	96574	8872	10044
Makumbura	Homagama Hosp	77267	85359	8036	8877
Homagama Hospital	Homagama	68704	72049	7145	7493
Homagama	Panagoda	54888	55077	5708	5728

Source: New Calculation - Chapter 3 of DFSR -Traffic Studies and Ridership for Demand Forecast.

Table 15-67 Summary of Daily Sectional Volumes Between Stations

Station Name	Station Name	Daily Passenger Volume MG		Peak Hour Passenger Volume Per Direction (PPHPD)	
		Medium Growth Sc (MG_2025_SC1)	Medium Growth Sc (MG_2035_SC1)	Year 2025 Medium Growth Sc (MG_2025_SC1)	Year 2035 Medium Growth Sc (MG_2035_SC1)
Panagoda	Godagama	53683	53965	5583	5612
Godagama	Meegoda	48727	48378	5068	5031
Meegoda	Watareka	37529	36477	3903	3794
Watareka	Padukka	35781	34564	3721	3595
Padukka	Arukwathupura	31122	30014	3237	3121
Arukwathupura	Angampitiya	29750	29617	3094	3080
Angampitiya	Uggalla	29036	30596	3020	3182
Uggalla	Pinnawala	30444	32690	3166	3400
Pinnawala	Gammana	31868	34925	3314	3632
Gammana	Morakele	26509	30289	2757	3150
Morakele	Waga	26823	30644	2790	3187
Waga	Kadugoda	24235	30695	2520	3192
Kandugoda	Kosgama	23728	32402	2468	3370
Kosgama	Hingurala	19906	38900	2070	4046
Hingurala	Puwakpitiya	25744	46401	2677	4826
Puwakpitiya	Avissawella	25132	43787	2614	4554

Source: New Calculation -Chapter 3 of DFSR -Traffic Studies and Ridership for Demand Forecast

To calculate the annual sectional passenger volume, Economic and Financial Team has been used daily passenger volume in 2025 and 2035 and compound annual growth rates. This demand analysis shows the demand trend for next 30 years from 2024 for KV Line under with project scenario.

This demand analysis is anticipating 926 million passengers to travel in 2035, it is nearly 1.19 times of 2025 passenger volume and it is 776 million. This demand prediction is based on compound annual growth rates and summary of demand analysis is given in following Table 15-68.

Table 15-68 Annual Passenger Volume

S/I	Year	Volume	S/I	Year	Volume
1	2024	757,850,369	16	2039	997,697,177
2	2025	776,157,984	17	2040	1,016,982,734
3	2026	789,437,229	18	2041	1,036,824,320
4	2027	803,056,196	19	2042	1,057,243,309
5	2028	817,026,318	20	2043	1,078,262,104
6	2029	831,359,525	21	2044	1,099,904,195
7	2030	846,068,269	22	2045	1,122,194,226
8	2031	861,165,551	23	2046	1,145,158,051
9	2032	876,664,952	24	2047	1,168,822,808
10	2033	892,580,660	25	2048	1,193,216,989
11	2034	908,927,505	26	2049	1,218,370,518
12	2035	925,720,992	27	2050	1,244,314,830
13	2036	942,977,338	28	2051	1,271,082,960
14	2037	960,713,508	29	2052	1,298,709,634
15	2038	978,947,258	30	2053	1,327,231,365

Source: STRADA Model output

15.6.3.5 KV Line Demand Ridership

Demand/ridership forecast data are initially estimated by STRADA model, available only for two point estimations, namely 2025 and 2035 and compound annual growth rate was used to calculate 30 years transport demand for KV Line.

Table 15-69 Passenger Km. Travel Percentage

Mode	2025 PC vs BC	2035 PC vs BC	2035PC vs 2025 PC
Bus	1.45	-5.98	-4.55
Rail	41.72	28.71	33.35

Source: KV Line STRADA Model Output

To estimate the future economic benefits of KV line, this analysis have been used future travel demand in association with STRADA model. Following table shows the 2025 and 2035 demand growth percentages for public transport system with KV line project intervention. Table 15-69 present the 2025 and 2035 public transport demand estimation. With reference to above table, KV line will attract 41.72% of additional transport demand by 2025 and 28.71% by 2035. Due to this future demand attraction in association with service efficiency, KV line will operate with new fare structure on growth rail transport demand. With comparison of 2025 base case of KV line, rail passenger transport demand will increase by 41.72% and by 2035 it will grow by 28.71%. According to STRADA demand analysis, project cases of 2025 vs. 2035 of KV line, it will grow by 33.35%. On the other hand, daily rail passenger Km. of KV line will grow 25,500,873 to 34,005,570 from 2025 to 2035. To cater the growing rail transport demand, government of Sri Lanka has been plan to improve four rail transport lines and KV line was identified as the first priority among other four lines, which connect the city center and the sub urban areas. The KV line passing urban centers are Maradana, Nugegoda, Maharagama, Kottawa, Homagama, Padukka, Kosgama and Avissawella. The economic analysis on KV line is aiming to ensure that the resources are allocated efficiently, and that investment brings benefits to the country and raises the welfare of its citizens.

15.6.3.6 Project Benefit Stream

According to the ADB Economic Analysis guidelines, benefits for normal traffic are non-incremental and can be valued in cost savings measured at economic prices. Therefore, the entire project benefit stream is falling under the non-incremental category and applied the same principle for this analysis. Therefore, direct benefits stream comprise mainly vehicle operating cost savings, travel time savings, reductions in accident costs and reduction in emission costs. These benefits were estimated for 2 main groups namely public and private transport users. Main public transport modes are bus and rail transport and other main private transport modes included: cars, motorcycles, three-wheelers, trucks, etc.

The cost of accidents was calculated based on Rs. per Km. basis and economic prices were used in STRADA model to generate total accident cost saving. Emission cost is one of the critical transport related cost component in national perspective and calculated based on the cost of air emission on Rs. per Km. basis. Saving of the vehicle operating cost was calculated by STRADA model in association with vehicle category and Rs. per Km. basis and value of time were estimated on Rs. per hourly basis under the economic prices. The estimated entire benefits are coming under the potential non-incremental benefit category in national economic perspective and final estimated _with project‘ system cost saving benefits are given in the following table. Table 15-70 presents US $ 525 million in 2025 and US $ 405 million in 2035 _with project‘ scenario.

Table 15-70 Project Benefits

(US $ Million)

Project Year	Scenario Name	Scenario	VOC	VOT	ACC Cost	EMM Cost	Total System Cost	With Project System Cost Saving Benefit
2025	SC 12	2025 BC	3,031.73	885.93	124.48	218.58	4,260.72	
2025	SC 10	2025 PC	2,636.18	795.68	110.02	193.95	3,735.83	524.89
2035	SC 11	2035 BC	3,714.24	1,076.81	143.47	252.56	5,187.07	
2035	SC 5	2035 PC	3,329.86	1,058.81	142.50	250.96	4,782.13	404.94

Source: STRADA Model Output

15.6.3.7 With and Without Project Benefits

With and without project benefits were estimated by STRADA model and given in the following table in 2025 and 2035 base cases and project cases. Project scenario 10 and 5 represents the _with‘ project benefits. System costs significantly decline in 2025 and 2035 project cases, with the comparison of 2025 and 2035 base cases. Table 15-70 shows the _with‘ project system cost saving benefits in 2025 and 2035. All the project benefits were adjusted with SCF to reflect their economic values and included BCA to estimate final results. Summary of the, with and without project benefits are illustrated in Table 15-71.

Table 15-71 with and without Project Benefits

(US $ Million)

Project Year	Scenario Name	Scenario	VOC	VOT	ACC Cost	EMM Cost	Total System Cost
2025	SC 12	2025 BC	3,031.73	885.93	124.48	218.58	4,260.72
2025	SC 10	2025 PC	2,636.18	795.68	110.02	193.95	3,735.83
2035	SC 11	2035 BC	3,714.24	1,076.81	143.47	252.56	5,187.07
2035	SC 5	2035 PC	3,329.86	1,058.81	142.50	250.96	4,782.13

Source: STRADA Model Output

The benefits of the KV Line project will primarily be concerned with transport system benefits, includes changes in the cost of travel for passengers and agencies. In this analysis, major economic benefits are measured in terms of the VOC, VOT and Accident cost saving and minimized emission costs. The Table 15-70 and Table 15-71 illustrates the, With and Without project scenario benefits and compared accordingly. Following section shows what will happen in the absence of the project.

15.6.3.8 Absence of the Project

1) VOC Savings Benefit

Vehicle operating cost savings for with and without scenario is outlined in following Table 15-72.

Table 15-72 VOC Savings Benefits

(US $ Million)

Project Year	Scenario Name	Scenario	VOC	VOC Savings	% Change
2025	SC 12	2025 BC	3,031.73	0	0
2025	SC 10	2025 PC	2,636.18	395.55	13.04
2035	SC 11	2035 BC	3,714.24	0	0
2035	SC 5	2035 PC	3,329.86	384.38	10.35

Source: STRADA Model Output

Without project VOC saving benefits is 0% and with project VOC saving benefit increased up to 13.04% in 2025 Scenario 10. In 2035 without project VOC saving benefits is 0% and with project VOC saving benefit is 10.35%.

2) VOT Savings Benefit

The travel time savings associated with safe, faster and less congestion as a result of project intervention and results are outlined in following Table 15-73.

Table 15-73 VOT Savings Benefits

(US $ Million)

Project Year	Scenario Name	Scenario	VOT	VOT Savings	% Change
2025	SC 12	2025 BC	885.93	0	0
2025	SC 10	2025 PC	795.68	90.25	10.18
2035	SC 11	2035 BC	1,076.81	0	0
2035	SC 5	2035 PC	1,058.81	18.00	1.67

Source: STRADA Model Output

Without project VOT savings benefits is 0 and with project VOT savings benefit increased up to 10.18 in 2025 project scenario. In 2035, base case scenario savings benefits is 0% and project case scenario VOT savings benefit is 1.67%.

3) Accident Cost Savings Benefit

The accident cost savings associated project benefits are outlined in following Table 15-74. In base case scenario, accident cost savings benefits is 0 and project scenario accident cost savings benefit increased up to 14.46 in 2025. In 2035, base case scenario accident cost savings benefits is 0% and project case scenario accident cost savings benefit is 0.67%.

Table 15-74 Accident Cost Savings Benefit

(US $ Million)

Project Year	Scenario Name	Scenario	Acc	Acc Savings	% Change
2025	SC 12	2025 BC	124.48	0	0
2025	SC 10	2025 PC	110.02	14.46	11.61
2035	SC 11	2035 BC	143.47	0	0
2035	SC 5	2035 PC	142.50	0.97	0.67

Source: STRADA Model Output

4) Emission Cost Reduction Benefit

The emission cost reduction associated project benefits are outlined in following Table 15-75.

Table 15-75 Emission Cost Reduction Benefit

(US $ Million)

Project Year	Scenario Name	Scenario	Emm	Emm Reduction	% Change
2025	SC 12	2025 BC	218.58	0	0
2025	SC 10	2025 PC	193.95	24.63	11.27
2035	SC 11	2035 BC	252.56	0	0
2035	SC 5	2035 PC	250.96	1.60	0.63

Source: STRADA Model Output

In base case scenario emission cost reduction benefits is 0 and project scenario emission cost savings benefit increased up to 24.63 in 2025. In 2035, base case scenario emission cost reduction benefits is 0% and project case scenario emission cost savings benefit is 0.63%.

5) Total Benefits

The STRADA traffic model is used to generate a number of outputs for use in the benefit computation. The model outputs include VOC, VOT, Accident Cost and Emission Cost for the base case and project case. Based on each output, with and without benefit comparisons are given in above tables. Total benefits across base case and project case results for KV Line traffic modelling are shown in Table 15-76.

Table 15-76 Total Benefits – System Cost saving Benefits

(US $ Million)

Project Year	Scenario Name	Scenario	System Cost	System Cost Savings	% Change
2025	SC 12	2025 BC	4,260.72	0	0
2025	SC 10	2025 PC	3,735.83	524.89	12.32
2035	SC 11	2035 BC	5,187.07	0	0
2035	SC 5	2035 PC	4,782.13	404.94	7.81

Source: STRADA Model Output

In base case scenario, total system cost saving benefit is 0% and project scenario system cost savings benefit increased up to 12.32% in 2025. In 2035, base case scenario system cost saving benefits is 0% and project case scenario system cost savings benefit is 7.81%.

15.6.3.9 Calculation of Project Benefits at Constant Price

The KV Line is aim to improve service quality and develop network infrastructure facilities. Due to this intervention, anticipated key benefits are non-incremental as reduction in VOC, reduction in VOT, reduction in accident costs and minimize CO2 emission. Above key benefits are consists of reductions in user costs, diversion of traffic from roads to rail, lower congestion of road network due to project intervention, increase fuel use efficiency etc. The ADB Guideline shows the non-incremental benefit calculation procedures, mainly focused on domestic resource cost savings amount at economic prices. The Table 15-77 shows the pricing procedure applied for the economic analysis.

Table 15-77 Economic Price Adjustment – Accident Cost

(LKR\Km)

Acc	Financial	Economic	2020 Econ Price*	2024 Econ Price
All	1.41	1.29	1.62	1.86

Sources:

1. STRADA Model Output
2. SL Trade statistics used to calculate SCF – Min. of Finance Annual Reports, CBSL Statistics 2012-2017.
3. Comtrans Project base data
4. 2014 – 2017 CPIs from Department of Census and Statistics

Financial price for the accident cost per Km. is LKR 1.41 and its economic price is LKR 1.29 under the SCF. The SCF was generated through Sri Lanka trade statistics and followed ADB recommended standard method. The Department of Census and Statistics provided details of CPI and estimated up to year 2024 to generate constant price. Based on all data sources, 2020 economic price of accident cost per Km. is calculated as LKR 1.62 and used for entire project economic life. Project construction will commence on 2020 and hence, used 2020 constant price for BCA model. Main purpose of the use of constant price is to ensure that the future costs and benefits of a project are comparable to decision making time of investment. The Table 15-78 shows the economic prices of emission costs.

Table 15-78 Economic Price Adjustment – Emission Cost

(LKR\Km)

Emm	Financial	Economic	2020 Econ Price*	2024 Econ Price
Car	2.18	1.98	2.49	2.86
MC	2.47	2.25	2.83	3.25
3W	2.47	2.25	2.83	3.25
Bus	3.01	2.74	3.44	3.96
Trucks	3.01	2.74	3.44	3.96

Source:

1. STRADA Model Output
2. SL Trade statistics used to calculate SCF – Min. Of Finance Annual Reports, CBSL Statistics 2012-2017.
3. Comtrans Project base data
4. 2014 – 2017 CPIs from Department of Census and Statistics

Above table shows the financial and economic prices of each vehicle category and 2020 economic prices. Above 2020 constant prices were applied to STRADA model to estimate vehicle emission cost saving benefits.

15.6.3.10 Benefit Cost Analysis

The KV line benefit cost analysis has been used discounted cash flow technique on the basis of 9% discount rate and project benefits and costs are measured in constant prices of a base year. All the constant prices were adjusted for the effect of general inflation. This section of the report presents the benefit cost analysis and sensitive analysis included to assess the robustness of results and comparisons.

1) Detailed Project Benefits and Costs

This section presents the detailed project benefits –cost analysis. For this this analysis, Economic and Financial Team used 2020 constant prices. Construction will commence on 2020 and extend up to 2023. Total operation period of the project is 30 years from 2024 to 2053.

The Table 15-79 illustrates the detailed cost and benefits. Total capital cost is US $ 1360 and total O&M cost for project period is US $ million 591. Average annual O&M cost is US $ million 19.69 and total replacement cost is US $ million 128 for 30 years period. There are two events of replacement cost in every 10 years as US $ million 25 in 2033 and US $ 103 million in 2043 and no any replacement cost in 2053.

This project will be completed by 2023 and fully operated by year 2024. Therefore, benefits by the project will be received starting from the year 2024. Four types of economic benefits derived by STRADA model and detailed discussed in previous sections. Mainly four types of benefits we discussed and its total gross values is US $ million 12508. Mainly this value comprise of US $ million 11355 of VOC savings, US $ 891 million of VOT savings, US $ 98 of accident cost savings and US $ million 164 of emission cost savings.

Table 15-79 Project Cost and Benefits Stream (Constant)
US $ Million)

Year	Years of Ope.	Cash inflow / Cash Outflow								
		Direct Cost				Direct Benefit Stream				
		Capital 1.00	O&M 1.00	Replace	Total Cost	VOC 179	VOT 179	Acc 179	Emm 179	Total Benefits
2018										
2019										
2020		70.80			70.80					0.00
2021		429.59			429.59					0.00
2022		429.59			429.59					0.00
2023		429.59			429.59					0.00
2024	1		18.27		18.27	412.48	106.88	17.38	29.56	566.30
2025	2		18.42		18.42	395.55	90.25	14.46	24.63	524.89
2026	3		18.57		18.57	378.73	73.35	11.40	19.26	482.75
2027	4		18.72		18.72	366.17	59.89	9.03	15.14	450.23
2028	5		18.87		18.87	357.40	49.21	7.16	11.94	425.70
2029	6		19.02		19.02	352.10	40.75	5.67	9.41	407.93
2030	7		19.19		19.19	350.02	34.10	4.47	7.39	395.98
2031	8		19.35		19.35	350.99	28.90	3.50	5.76	389.15
2032	9		19.51		19.51	354.92	24.89	2.69	4.43	386.93
2033	10		19.69	25.01	44.70	361.77	21.85	2.02	3.32	388.96
2034	11		19.86		19.86	371.57	19.60	1.45	2.39	395.00
2035	12		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2036	13		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2037	14		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2038	15		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2039	16		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2040	17		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2041	18		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2042	19		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2043	20		20.06	103.42	123.49	384.38	17.99	0.97	1.60	404.94
2044	21		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2045	22		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2046	23		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2047	24		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2048	25		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2049	26		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2050	27		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2051	28		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2052	29		20.06		20.06	384.38	17.99	0.97	1.60	404.94
2053	30		20.06	0.00	20.06	384.38	17.99	0.97	1.60	404.94
		1359.58	590.69	128.43	2078.71	11354.96	891.51	97.60	163.57	12507.64

Source: Finalized Capital and O&M cost estimate and STRADA model output.

Table 15-80 provides detailed Benefit Cost Analysis in base case of proposed KV Line project. The period considered in the evaluation is 30 years, which is the economic life cycle of the project. To calculate the Benefits and Costs of this project, assumptions were made in above section.

Table 15-80 Economic Analysis - KV Line - Base Case (Constant Price)

(US $ Million)

Year	Years of Ope.	Cash Flow Statement											
		Direct Cost					Benefit Stream						Discounted Cash Flow
		Capital	O&M	Replace	Total	Discounted	VOC 179	VOT 179	Acc 179	Emm 179	Total	Discounted	
2018													
2019													
2020		70.80			70.80	59.76							-59.76
2021		429.59			429.59	333.58							-333.58
2022		429.59			429.59	306.90							-306.90
2023		429.59			429.59	282.35							-282.35
2024	1		18.27		18.27	11.05	420.02	110.36	17.39	29.58	577.35	349.10	338.05
2025	2		18.42		18.42	10.25	403.07	93.86	14.47	24.65	536.05	298.20	287.95
2026	3		18.57		18.57	9.50	386.23	77.08	11.41	19.28	494.00	252.82	243.32
2027	4		18.72		18.72	8.81	373.63	63.75	9.04	15.16	461.57	217.33	208.51
2028	5		18.87		18.87	8.17	364.82	53.18	7.17	11.95	437.11	189.35	181.17
2029	6		19.02		19.02	7.58	359.46	44.83	5.68	9.43	419.40	167.14	159.56
2030	7		19.19		19.19	7.03	357.32	38.28	4.48	7.41	407.49	149.40	142.37
2031	8		19.35		19.35	6.53	358.22	33.18	3.51	5.78	400.69	135.16	128.63
2032	9		19.51		19.51	6.06	362.08	29.27	2.70	4.45	398.49	123.66	117.60
2033	10		19.69	25.01	44.70	12.76	368.85	26.31	2.03	3.34	400.53	114.35	101.59
2034	11		19.86		19.86	5.22	378.56	24.15	1.46	2.41	406.58	106.79	101.57
2035	12		20.06		20.06	4.85	391.28	22.63	0.97	1.61	416.50	100.65	95.80
2036	13		20.06		20.06	4.46	391.28	22.63	0.97	1.61	416.50	92.59	88.13
2037	14		20.06		20.06	4.10	391.28	22.63	0.97	1.61	416.50	85.19	81.08
2038	15		20.06		20.06	3.78	391.28	22.63	0.97	1.61	416.50	78.37	74.60
2039	16		20.06		20.06	3.47	391.28	22.63	0.97	1.61	416.50	72.10	68.63
2040	17		20.06		20.06	3.20	391.28	22.63	0.97	1.61	416.50	66.33	63.14
2041	18		20.06		20.06	2.94	391.28	22.63	0.97	1.61	416.50	61.03	58.09
2042	19		20.06		20.06	2.70	391.28	22.63	0.97	1.61	416.50	56.15	53.44
2043	20		20.06	103.42	123.49	15.31	391.28	22.63	0.97	1.61	416.50	51.65	36.34
2044	21		20.06		20.06	2.29	391.28	22.63	0.97	1.61	416.50	47.52	45.23
2045	22		20.06		20.06	2.11	391.28	22.63	0.97	1.61	416.50	43.72	41.61
2046	23		20.06		20.06	1.94	391.28	22.63	0.97	1.61	416.50	40.22	38.28
2047	24		20.06		20.06	1.78	391.28	22.63	0.97	1.61	416.50	37.00	35.22
2048	25		20.06		20.06	1.64	391.28	22.63	0.97	1.61	416.50	34.04	32.40
2049	26		20.06		20.06	1.51	391.28	22.63	0.97	1.61	416.50	31.32	29.81
2050	27		20.06		20.06	1.39	391.28	22.63	0.97	1.61	416.50	28.81	27.43
2051	28		20.06		20.06	1.28	391.28	22.63	0.97	1.61	416.50	26.51	25.23
2052	29		20.06		20.06	1.17	391.28	22.63	0.97	1.61	416.50	24.39	23.21
2053	30		20.06	0.00	20.06	1.08	391.28	22.63	0.97	1.61	416.50	22.44	21.36
		1360	591	128	2079	1137	11567	1024	98	164	12853	3103	1967

EIRR	15.78%
ENPV	1967
B/C	2.73

Source: Finalized Capital and O&M cost estimate and STRADA model output.

15.6.4 Sensitivity Analysis

The, sensitivity analysis is carried out to determine the economic consequences of:

(1) Not achieving the expected direct and indirect benefits,

(2) Increases in capital and recurrent costs.

(3) Possible delays in project implementation

The following are the considerations for sensitivity analysis;

(1) Cost increase by 10%

(2) Benefit decrease by 10%

(3) Cost increase by 10% and benefit decrease by 10% together

(4) Project implementation delay by one year

(5) Rail demand decreased by 10% and combined with above 4 cases

(6) Occurrence of all the above 5 scenarios combined together. (worst case scenario)

(7) Rail demand decreased by 15% as a separate case

(8) Rail demand decreased by 20% as a separate case

The above Table 15-80 illustrate that base case results. All the gross benefits and costs were discounted by 9% discount rate and base case shows the feasible project results. Discounted NPV is US $ million 1967 and EIRR is 15.78%. Benefit Cost ratio is 2.73 and all the project results have accepted value in base case. This economic analysis was further strengthen by carrying out above 1-6 commonly occurring sensitivity factors to determine the viability of the KV Line project. Further 2 additional sensitive factors were considered as 15% and 20% rail demand decreases.

All the eight risk scenarios were presented for NPV, IRR, and B/C. All Financial Values were converted to the Economic Values, through SCF and results are given in following Table 15-81. All these sensitivity calculation tables are attached to the Appendix D of this report.

Table 15-81 Sensitivity Results

Case	Sc. ID	Scenario	Change	EIRR	NPV	B/C
Base case	A	Base case	0	15.78%	1,966.79	2.73
10% Demand Declined and Combined Cases	B	Demand Declined	10%	15.28%	1,887.47	2.66
	C	Cost Increase	10%	13.33%	1,773.81	2.42
	D	Benefit Declined	-10%	13.13%	1,585.07	2.39
	E	C+D	10%+(10%)	11.31%	1,471.41	2.18
	F	Project Delay	1 Year	15.28%	1,736.47	2.66
	G	C +D +F		11.31%	1,353.70	2.18
Separate Cases	H	Demand Declined	-15%	15.03%	1,847.93	2.63
	I	Demand Declined	-20%	14.77%	1,808.42	2.59

Source: Consultants Estimates with Final Project Cost and STRADA Transport Model

15.6.5 Conclusion

Table 15-81 illustrates that even during the occurrence of the worse sensitive scenarios, still the project will generate an EIRR of 11.31% in economic terms and the generated NPV value is USD million 1353. In terms of economic analysis, the above results demonstrate the economic viability of KV Line project. Highest EIRR recorded in base case as 15.78% with the highest NPV wiliest worse case reported 11.31% EIRR, with all worse cases happened in one time.

The economic analysis carried out concludes;

When considering the occurrence of potential sensitivity factors, it brings about more positive results, where during the worst case scenario, yields EIRR of 11.31 % in economic terms.

Further, KV Line project generates more economic benefits in the future, such as VOC and VOT savings, Accident cost savings and reduction of emission costs are national benefits. Opening up of other indirect economic opportunities are not taken into economic analysis, but it is larger than the above-given benefits. Therefore, considering future economic development benefits, this analysis will provide even a higher EIRR and thus it can be concluded that the proposed KV Line intervention is economically feasible.

15.7 Distribution and Poverty Impact Analysis

15.7.1 Introduction

This section presents three aspects of Poverty Impact Assessments.

- Beneficiary analysis – the identification of the project beneficiaries and the number of poor among those beneficiaries.
- Distribution analysis – the estimation of the allocation of benefits between the poor, the non-poor, and the government, to calculate the Poverty Impact Ratio (PIR).
- Potential complementary action - an identification of measures that can be taken to increase the number of poor beneficiaries or the proportion of benefits accruing to the poor.

The approach and method used for this analysis is based on ―The Handbook for Integrating Poverty Impact Assessment in the Economic Analysis of Projects" by ADB Economics Development Resource Centre (2001) and its subsequent updates such as ―Assessing the ―Use of Project Distribution and Poverty Impact Analysis" by Economics and Research Depart of ADB (2005) and ―Handbook on Poverty and Social Analysis -A Working Document" etc. Generally, the calculation of Poverty Impact ratio is very complex because many financial data have to convert to economic data to remove distortions and to value country‘s real factor endowment impact. Another part of the problem is in the interpretation of the PIR, which is calculated by means of a distribution analysis. Initially, the PIR was interpreted as the percentage of a proposed project‘s economic net present value that is forecast to accrue to the poor. Then a number of proposed projects‘ distribution analysis resulted in estimated PIR‘s percentages that were greater than one. How can the percentage of a project‘s net economic benefits exceed one? The answer is straightforward: when almost the entire project‘s economic benefits accrue to the poor, and the non-poor pay for the project as a transfer from their wealth. ADB analysts used to consider a percentage of PIR greater than one as a positive indicator of a project‘s pro-poor impacts. Another source of confusion is that the PIR is a measure of the poor‘s share in the project‘s economic gains; as such it should be compared to the poor‘s share in regional or national GDP. Earlier, many were comparing the PIR to the headcount incidence of poverty in the project area or the country. The largest remaining problem is that the analyses require a sizeable project-specific data base to prepare scientifically defensible estimates. The budget and time allowed to prepare these analyses at present are not sufficient to complete them in a scientifically defensible manner. Therefore an insightful distribution analysis mainly relies on secondary data, small surveys, other rapid-appraisal techniques, and participant- observer techniques that must be done by the experienced professional responsible for the work.

In general, PIR is calculated by means of distribution analysis. Distribution analysis looks at how a proposed KV Line development will affect different stakeholders those groups who will benefit from the project and those who will lose and not getting anything out of this. Primarily, the PIR was interpreted as the percentage of a proposed rail road project‘s economic net present value that is forecast to accrue to the poor. The number of proposed railroad projects‘ distribution analyses resulted in an estimated percentage of PIR‘s that were greater than one. When almost the entire road project‘s economic benefits accrue to the poor, and the non-poor pay for the project as a transfer from their wealth. PIR is a measure of the poor‘s share in the project‘s economic gains. The PIR, or the estimated percentage of rail road project‘s economic net present value (ENPV) that will accrue to the poor, is often incorrectly compared to the percentage of poor beneficiaries. So, for example, when the PIR = 0.5, or that 50 percent of the project‘s ENPV is estimated to ensue to the poor.

Method to calculate the Poverty Impact Ratio (PIR): **PIR = (ENPVpoor)/(ENPVtotal)**

15.7.2 Poverty Definition in Sri Lanka

Sri Lanka uses Official Poverty Line (OPL) which was established by the Department of Census and Statistics (DCS) to measure poverty. The value of OPL is based on Household Income and Expenditure Survey (HIES) data. OPL, which was established in 2016, was Rs. 1,423 (real total expenditure per person per month) this is updated for the inflation of prices through the Colombo Consumer Price Index (CCPI) calculated monthly by the DCS. According to the average price index values adjusted for HIES survey months, DCS publishes Head count index for each survey periods. The current value of OPL is Rs.14.473 per person per month for 2016/2017.

But various government and International financial institutions calculated various poverty lines time to time for their studies. However the most accepted ones are Census and Statistics Dept. Food Energy Intake method, no. of Samurdhi welfare assistance recipients and Head Count Ratio or Index (HCR). HCR presents the total number of persons living under the poverty line as a percentage of the total population. HCR is common indicator used to measure poverty. But it does not take into account the depth and the severity of poverty among the poor. But for better targeting for reduction of poverty it is important to consider the depth and the inequality among the poor. Squared Poverty Gap Index (SPGI) measures the poverty by taking into account the degree of inequality among the poor themselves where keeping more weight to the poorer individual falls well below the poverty line. In other words, when calculating SPGI by squaring the Poverty Gap then gives a greater weight to the poorest individual since there Poverty Gap will be large.

But many other income and non-income related poverty indicators such as Poverty shortfall is more informative than the HCR as it describes the depth of poverty in terms of funds required to get the consumption expenditure increased to get rid of poverty. Poverty shortfall is the amount of expenditure or income needed for those who are poor to bring their expenditure or income up to the value of poverty line to get rid of poverty. Poverty gap is the mean shortfall from the poverty line (counting the non-poor as having zero shortfall), expressed relative to the poverty line. This measure reflects the depth of poverty as well as its incidence. This information is more precious to target the transfers to poor for poverty reduction.

Gini coefficient and Quintile ratio are the most popular inequity indicators to measure poverty. In general, poverty headcount index is a common indicator used to measure poverty. But it does not take into account the depth and the severity of poverty among the poor. But for better targeting for reduction of poverty it is important to consider the depth and the inequality among the poor. Squared Poverty Gap Index (SPGI) measure poverty taking into account the degree of inequality among the poor themselves where keeping more weight to the poorer individual falls well below the poverty line. In other words, when calculating SPGI by squaring the Poverty Gap then gives a greater weight to the poorest individual since there Poverty Gap will be large. Household Income and Expenditure Survey collects the social protection information of 12 social protection programs launched by the government mainly under the social assistance and social insurance. Most of these programs also can be considered as measures of poverty by correlating with other variables.

Normally, poverty status in Sri Lanka is determined by various indicators by looking at data availability:

(1) Comparing the monthly real per capita expenditure to set official poverty line. If the per capita monthly real expenditure is less than the value of the official poverty line, then that individual is considered to be in poverty.

(2) No of Samurdhi beneficiaries and their % in total families.

15.7.3 Regional Variation of Poverty

The percentage of the poor household in each district in Sri Lanka shows Table 15-82 with per head count index, number of poor population and the contribution to total poverty in 2016 Household Income and Expenditure Survey. In general, Sri Lanka‘s headcount poverty index 4.1% and number of poor population around 843913 in 2016 and 82% of that live in Rural areas and 10% Estate and rest (8%) live in Urban areas. In Province-wise poverty based on head count index is very high in Northern, Eastern, Sabaragamuwa and Uva and lowest in Western, North Western and Southern Provinces.

As shown in Table 15-82 the poverty head count index, the number of poor population and contribution to total poverty by sector – 2016. Poverty head count Index is the percentage of population below the poverty line and it is widely used to measure poverty in Sri Lanka. Poverty headcount index is 4.1 percent in 2016 (percentage of population below the poverty line) at national level. This railway Line located in Colombo District and it has Urban, Rural and Estate features.

Table 15-82 Poverty head count index, number of the poor population and contribution to total poverty by sector – 2016

District	Poverty head count Index (%)	No of poor population	Contribution to total poverty (%)
Colombo	0.9	19,796	2.3
Gampaha	2.0	45,827	5.4
Kaluthara	2.9	35,719	4.2
Kandy	5.5	76,429	9.1
Matale	3.9	19,357	2.3
NuwaraEliya	6.3	46,257	5.5
Galle	2.9	30,775	3.6
Matara	4.4	36,544	4.3
Hambanthota	1.2	7,450	0.9
Jaffna	7.7	46,052	5.5
Mannar	1.0	1,005	0.1
Vavunia	2.0	3,526	0.4
Mullaitivu	12.7	12,003	1.4
Killinochchi	18.2	21,249	2.5
Batticaloa	11.3	60,912	7.2
Ampara	2.6	17,431	2.1
Trincomalee	10.0	39,718	4.7
Kurunegala	2.9	47,930	5.7

District	Poverty head count Index (%)	No of poor population	Contribution to total poverty (%)
Puttalam	2.1	16,708	2.0
Anuradhapura	3.8	33,140	3.9
Polonnaruwa	2.2	9,051	1.1
Badulla	6.8	56,698	6.7
Moneragala	5.8	27,187	3.2
Ratnapura	6.5	72,715	8.6
Kegalle	7.1	60,435	7.2

Source: Census and Statistics Dept., House Hold Income and Expenditure Survey, 2016.

The poverty line is an absolute poverty definition, derived from the cost of basic needs, comprising food and non-food items. Therefore the poverty line needs to be adjusted for changes in prices over time. At the time of the official poverty line was established the percentage of households below the equivalent level of expenditure in earlier years was calculated. These did not show much change, suggesting that the proportion of the poor is fairly stable, and the continued economic growth will lead to improvement, the present levels can be used as a general guide for the future. Therefore with this railway development poverty level can be decreased due to many benefits generated out of this development. Especially Urban poor areas and from Homagama to Avissawella many poor households are located in and around this KV Line.

In Sri Lanka many regional variations can be seen in poverty indicators but a more equal nature can be found in more developed areas. However this KV Line rail road project covers only Colombo district Maradana to Avissawella and most of the low income settlers can be seen in tail end of Avissawella from Homagama. Table 15-83 shows mean and median household income in Colombo district and national average in Sri Lanka.

Table 15-83 Mean and Median Households Income, 2012/13

District	Mean HH Income (Expenditure)	Median HH Income (Expenditure)	Gini coefficient for Mean HH Income
Colombo	104,581 (90,670)	70,000 (64,981)	0.46
Sri Lanka	62,237 (54,999)	43,511 (40,186)	0.45

Source: Dept. Census and Statistics, 2016/17

As shown in Table 15-83, mean household income is the value obtained by dividing the total aggregated household income by the total number of households in a domain or in an area. Median income is the income value at which the income distribution is divided into two equal size groups. This middle point or the median is important as always the income of one half of the population falls either above or below that value and the median household income is a better indicator than the mean (average) household income as the median is not dramatically affected by extreme or unusually high or low values. In Table 15-84 within brackets, mean household expenditure is shown. Furthermore, the last column of this Table 15-84 shows Gini coefficient for Per-Capita HH Income in project district. Gini coefficient (Gini) is one of the widely used indicators to measure the depth of inequality of an income distribution. The Gini is based on the Lorenz curve which plots cumulative proportions of the total income of the population in y axis and cumulatively share of the population from the lowest to highest income in x axis. The Gini can take values between zero and one and the line drawn at 45 degrees or the diagonal of the Lorenz curve represents a distribution with zero Gini value which indicates perfectly equal or zero level of inequality of the distribution. This shows that Colombo district has similar value to national average value but it can be further dropped due to this KV Line development.

Table 15-84 Per-capita Mean and Median Households Income, 2016/17

District	Per-Capita Mean HH Income (Expenditure)	Per-capita Median HH Income	Gini coefficient for Per-Capita HH Income
Colombo	26,242 (22,752)	16.677 (16,052)	0.44
Sri Lanka	16,377 (14,473)	11,307 (10,429)	0.46

Source: Dept. Census and Statistics, 2016/17

Household per capita income is frequently used as a better indicator to understand and compare the country‘s standard of living over time. However the per-capita income varies, in reverse to the household income with the household size. Lower household size shows the higher per-capita income. Per capita income in a domain is calculated by dividing the estimated total household income by the estimated number of household population in the domain and is also used to measure and compare the wealth status of domains. Both these per-capita median and median HH incomes can increase due to this Railway Line development and Gini Coefficient can be reduced over the years with reduction of poverty and lessening income gaps between poor and high income groups. Table 15-85 shows percentage share of income received by poorest to richest households in Colombo district and national situation, 2016/17.

Table 15-85 Percentage share of income received by poorest to richest households by sector, province and district, 2016/17

District	Poorest 20% (%)	Middle 60% (%)	Richest 20% (%)	Poorest 40% (%)
Colombo	5.4	42.2	52.3	14.8
Sri Lanka	4.8	44.4	50.8	14.4

Source: Dept. Census and Statistics, 2016/17

This situation can be improved especially poor groups income can increased due to this Railway Development in Colombo district. Table 15-86 shows percentage expenditure on transport out of non-food expenditure, 2016/17.

Table 15-86 Percentage Expenditure on Transport out of non-food expenditure, 2016/17

District	Transport (%)
Colombo	14.7
Sri Lanka	12.4

Source: Dept. Census and Statistics, 2016/17

This percentage expenditure on transport out of non-food expenditure can be reduced with this Railway development. To determine the benefits received by poor from this KV Line project, mainly data is necessary in the aspect of transport expenditure that incurred out of their income and type of transport mode they used and the vehicle ownership of low income groups. Normally these data are obtained from the Consumer and Finance Surveys and House Hold Income and Expenditure Survey of Statistical Authorities.

Table 15-87 Vehicle Ownership in Project Impact DS Divisions up to 2017

DSD	Car	3W	MC	MPV	Lorry	Single cab	Commercial	Other	Total
Maharagama	1727	550	2694	375	209	126	68	85	5834
SJPK	1317	452	1975	376	234	36	370	133	4893
Thimbirigasyaya	114	30	32	30	1	5	14	15	241
Homagama	1480	723	4522	436	299	241	78	160	7939
Colombo	203440	146441	371954	2927	44675	18244	70279	22377	880337
Padukka	293	186	1385	129	136	165	70	72	2436
Seethawaka	230	251	1015	111	95	81	41	46	1870

Source: Motor Traffic Department of Sri Lanka, 2017.

Note: Others includes Three Wheeler Cars, Ambulances, Commercial vehicles, Forklifts, Large and Small Land Vehicles, Lorry Trailer/ Bowser, invalid Carriage, Motor Hearse, Motor Tricycle Vans, Non Agricultural Land Vehicles, Prime Movers, and Special Purpose Vehicles.

As shown in Table 15-87, the highest number of registered vehicle categories are motor cycles, three wheels and private cars. In general Three Wheels and Motor Cycles are considered as poor and low income groups‘ main mode of transport. However, 2015 data showed that 50% trips are made by using private transport rather than public and each and every year public transport dropped around 2 to 3 percent annually due to very many factors. In overall, the current real poverty situation in project impact areas are presented in Table 15-88 with Samudhi benefits recipients‘ data.

Table 15-88 Samurdhi Benefits Recipients Data on KV Line Hinterland for 2015

DS Divisions	Total Families	No of Samurdhi Benefits Recipients Families	No of Samurdhi Benefits Recipients Families (%)
Colombo	67568	6228	9.21
Thimbirigasyaya	56601	2661	4.70
Kotte	27647	1903	6.88
Maharagama	50614	3338	6.59
Homagama	61196	3958	6.49
Paddukka	16929	2879	17.0
Sithawaka (Avissawella)	28775	5143	17.87

Source: Samurdhi Commissioner General Dept. 2017

15.7.4 Project Benefits and Distribution

15.7.4.1 Vehicle Operating Costs Savings

The direct beneficiaries of rail road development are the rail authorities and private vehicle owners. Especially due to this railway development, railway locomotives, railroad cars, coaches, and wagons repair costs will go down. And on the other hand due to this improvements in railway, new passengers attract and their vehicle stay at home and therefore VOC reduction can come from that front as well. In general railway mainly used by low and middle income earners and among the government servants it is popular mode of transport due to low costs. Therefore the poor get more benefits because most of them are using railway transport due to very many reasons.

15.7.4.2 Value of Time Savings

Time savings benefits mainly gives to the all railway users (existing and newly attracted ones) and in general assumption is that railway is mainly used by low income poor and lower paid public sector employees low income groups and poor can benefit immensely because they can use the saved time to engage in more income generating activities. Women also can get engaged in many other income generating activities due to this travel time savings with railway development.

15.7.4.3 Reduced Rail/Road Accidents

Due to this development in KV Line, many accidents in level crossings may be reduced (elevated from Maradana to Kottawa) and it has many implications for poor commuters. Due to model shift from private road vehicles to Railways another round of accidents reduction and due to improvements in Railway rolling stocks, lines and other infrastructure improvements many accidents can be decreased. All these accidents reduction can give many economic and social benefits to poors‘ in and around KV Line.

15.7.4.4 Reduced Environmental Pollution

Environment pollution reduction benefits mainly come from the electrification and other improvements in whole KV Line system to modern state-of-art levels. It has uncountable economic and social benefits to people in and around KV Line.

15.7.5 Calculation of PIR

The approach and method used to calculate the PIR is described in ―Handbook for Integrating Poverty Impact Assessment in the Economic Analysis of Projects" published by the Economics and Development Resource Center of the ADB. The method is more complex than just taking the benefits identified in the economic appraisal of the proposed road improvements. Gains and losses due to financial arrangement of the project and from the distortions or externalities that are captured in an economic analysis must also be taken into account. The NPV of a project, which measures its full contribution to national welfare, will be the sum of its financial effects and its external economic effects. The steps involved in calculating the PIR is described below.

(1) Based on the expected financing arrangements, the annual financial data of the project showing inflows (revenue and loan receipts) and outflows (investment, operating costs, and loan interest and principal repayments) is taken.

(2) Annual inflows and outflows are discounted to derive the present values for each category; financial net present value (NPV), gains to the government from tax payments, and losses to lenders.

(3) For each project input/output category, the economic value to be used is identified. The ratio between this economic value and the financial value for actual transaction is the conversion factor (CF) for the concerned item.

(4) Express all project items in economic terms by applying CFs to revalue the financial data from the first step.

(5) Allocate difference between financial and economic values to particular groups. These plus the changes for project owners and others at step 2, give the net benefit created by the project. The net benefits to different groups‘ sums up to economic NPV of the project, since this measures the total net benefits of the project.

(6) For each group affected by the project, the proportion of net benefits that will go to those defined as poor need to be estimated. For the government what is required is an estimate of the proportion of expenditure diverted from other users by the project under consideration would have otherwise benefited the poor.

(7) Finally, all benefits going to the poor are totaled and divided by the total net benefits (economic NPV) to produce the poverty impact ratio (PIR).

Table 15-89 Inputs Parameter Values (National)

Inputs Parameters	Value
Standard Conversion Factor	0.91
Poor's share of passenger car usage	15.01%
Poor's share of motor cycle usage	11.26%
Poor's share of three wheeler usage	5.75%
Poor's share of public transport usage (assume this is applicable to railway also)	58.92%
Poor's share of truck users	4.29%
Poor's share of government expenditure	26.75%

Source: Field Survey, Annual Report of Ministry of Finance, 2014 -2016 and Model Output Data

Table 15-90 Poverty Impact Ratio for KV Line

KV Line	Fin. Net Present Value at 9%	Econ. Net Present Value at 9%	Economic Minus Financial Value	Government /Economy	Stakeholders	Distribution of Project Effects								
						Bus	Rail	RTS	Water	Cars	MC	3W	Truck	Total
		0.914				**40.91%**	**18.01%**	**4.73%**	**0.05%**	**15.01%**	**11.26%**	**5.75%**	**4.29%**	**100%**
Inflow:														
VOC Savings		2386.47	2,386.47			50.30	-109.15	-16.05	0.02	1,445.30	234.32	90.25	916.51	2,386.47
VOT Savings		276.60	276.60			41.40	-87.34	-4.61	0.36	187.69	148.84	2.13	14.21	276.60
Accident Cost Savings		37.41	37.41			0.91	-0.13	-0.02	0.00	19.52	17.48	-0.39	3.57	37.41
Env.Cost Savings (CO_2 Emission)		62.98	62.98			1.93	-0.27	-0.04	0.00	30.01	30.53	-0.81	7.58	62.98
Total System Cost Saving		2763.46	2,763.46		2,763.46	94.53	-196.89	-20.71	0.38	1,682.53	431.18	91.17	941.86	2,763.46
Outflow	-1424.33													
Project Effect	-1009.03	2763.46	3,772.49	1,009.03										3,772.49
Net Financial Effect	-1009.03													(1,009.03)
Net Economic Effect		2763.46		-										2,763.46
Accruing to Poor				1,009.03	2,763.46									3,772.49
Share Net Benefits to Poor (%)				26.75	73.25	0.409	0.180	0.047	0.00	0.150	0.113	0.057	0.043	
Share Net Benefits to Poor (Amount)				1,009.03	2,763.46	1,130.65	497.60	130.62	1.45	414.74	311.12	158.79	118.48	2,763.46
PIR					0.7325									

Source: Output Data- Transport Model and Tentative Cost Estimates for KV Line

Table 15-91 Poverty Impact Ratio for KV Line Passing DS Divisions

DS Division	KV Line Passing Km	Poverty Impact Ratio (%)	Rank
Colombo	1.82	82.30	3
Thimbirigasyaya	5.44	42.26	7
SJPK (Kotte)	4.2	68.67	5
Maharagama	4.91	67.17	6
Homagama	8.09	79.66	4
Paddukka	10.62	86.81	1
Sithawaka (Avissawella)	23.9	85.85	2

Source: Estimated Based on Table 15-90.

15.7.6 Conclusion

The analyzed data were used to calculate the PIR for all DS divisions in KV rail line sections individually and finally used to calculate the overall PIR (0.7325) for the whole KV Line project. Overall PIR calculation for the KV Line is given in Table 15-90 and attached in the appendix as well. We could examine higher PIR values for railroad sections which are mainly used by the poor people of that area. When there are industries like garments, timber, brick manufacturing, hospital, tea and rubber, the percentage of poor people using the 11.26% motorcycles and 58.92% public transports were reported to be higher percentages. This is the main reason for PIR value to be higher in rail road sections of KV line which have these industries located nearby the KV line. Roads which are mainly used by personal vehicles have a higher percentage. The overall PIR value of the project is 73.25% and the minimum PIR value is 42.26 % and the maximum value is 86.81 %. This shows that there is a significant variance between the maximum and minimum values, which shows that some sections in KV line development project are heavily benefiting the poor people living at Padukka to Avissawella while other sections do have moderate (neither high nor low) impact for the poor to improve their living standards.

15.8 Project Impact Monitoring Framework (PIMF)

Project Impact Monitoring Framework (PIMF) is a results-based approach to project planning, performance monitoring, and evaluation of results. During the design phase, PIMF emphasizes to builds on a cause-effect to ensure a consequential relationship between inputs, activities, outputs, outcome, and impact; and determines a set of measurable process and result indicators with performance targets.

15.8.1 Introduction

The main objectives of the development of this KV Railway Line is to

- Resolve of traffic congestion by expanding railway share in passenger and goods transport in Colombo Metropolitan Region,
- Promote suburban economy and provide better commuter service through improvement of suburban railway,
- Introduce new systems and modernize maintenance facilities to provide improved railway services in association with other modes of transportation and promote regional economy.
- Improve public transport by planning a practical complex transport system.

Since this project is designed as result-focus project which expects to improve the selected base line impact and output indicators by improving project quality at entry and strengthening project management. In accordance with these objectives the following PIMF develop to identify impact, outcome and output with measurable indicators.

15.8.2 Definitions

15.8.2.1 Impact

A project‘s impact describes the anticipated beneficial consequences of achieving the outcome on sector/s performance three to five years after project completion. The impact links a project with the relevant sector or thematic results framework in the country partnership strategy. In general, the impact statement phrased as an end situation of the project, reflecting a direct means-end relationship with the project‘s outcome.

15.8.2.2 Outcome

A project output describes as what the project aims to achieve using the provided outputs by the end of project implementation. The outcome statement determines the nature and scope of the outputs that will be sufficient to achieve the outcome. In general, outcome statement explains an end situation, describing institutional or organizational performance change, or behavioral change of beneficiaries, which is necessary but not sufficient to achieve the impact.

15.8.2.3 Outputs

Outputs are the physical and/or tangible goods and/or services delivered by the project and describe the scope of the project. The outputs are necessary to achieve the outcome with a clearly identified means-end relationship. Outputs are phrased as an end situation, not an action. The outputs would be achievable during the life of the project within the available resources.

15.8.2.4 Performance indicators

Performance Indicators are quantifiable with a target values of impact, outcome and output that identify how much will be achieved in a specific timeframe. A baseline value is presented for each indicator, and for some numeric output indicators the baseline may be zero, since the baseline data has not been captured since the indicator is generated through the project.

15.8.3 Methodology

Project Impact Monitoring Framework (PIMF) has been worked out with indicators for monitoring of impact, outcome and output through a consultation process. This PIMF has attempted to define the selected indicators, measuring units for each parameter that need to be measured/surveyed, sources of data, frequency of measuring/ updating parameters. In addition, it has given baseline situations for an adequate number of indicators and reference sources

Baseline information / data collection was conducted during the initial study period in late 2017, and the benchmark for the present study was established. Accordingly, a sample household surveys on KV line was carried out to generate firsthand data and information from the relevant stakeholders. The consultant involved in collecting primary and secondary baseline data and information during the period from December 2017 to May 2018, which provided the basis for this PIMF report.

Accordingly, the methodology followed for collecting of data / information on PIMF is summarized in Table 15-92 below:

Table 15-92 Methodology followed for collecting data/information on PPMS

Type of data / information	Methodology	Sources of data / information
Primary / First hand data	Social and Environmental feasibility studies conduct Questionnaire-based Field survey on a representative sample of roads & households.	Sample Households located in impacted DS divisions
Secondary data	Conduct a: Literature review on project-related documents, and Review of District & Divisional level resource documents	-Project feasibility reports, -Progress reports of PMU office -DSD-wise resource profiles, maintained by DPUs of relevant District & Divisional Secretariats
Project-level information	Conduct discussions with project implementing officials	-PMU and Project engineers, -Other district level development practitioners
General Information	Make observations on relevant aspects at sites while attending to field-survey and scrutinize other sources	On site investigations and feasibility reports & progress reports available at the Project Office

15.8.4 Impact of KV Line Development

The main impact of this railroads development is expansion of economic opportunities leading to higher incomes in project impact areas in Western and Sabaragamuwa Provinces through efficient transportation system and later it creates overall spillover benefits to whole of Sri Lankan economy to reach its next level of growth by reducing disparities between center and periphery. This impact can be measured through performance targets and indicators such as increased number of businesses and industries, increase of employment opportunities, higher lesser private vehicle ownership, higher land values and reduction of accident rates in crossing and travel time reduction by facilitating efficient movement of passengers and freights, improvements of environment, etc. The data sources and reporting mechanism for this impact can be multiple sources such as with and without project road surveys, statistics of Industry and Trade Ministries, Central Environmental Authority and various other national and regional level measurable indicators. The main positive assumptions/risks associated with this project impact are existence of complementary external assistance and government commitment to continue the development of other rail road networks, and infrastructure in the project impact areas and other parts of the country.

15.8.5 Outcome of KV Line Development

The outcome is the improved efficiency of the railway connectivity and an overall improvement of the national rail network. Due to this improved efficiency in links roads, traffic volumes will increase; vehicle maintenance costs and the travel time will be reduced, and bus fares and freight rates will remain somewhat stable or possibly can be reduced due to oil prices decreases. Furthermore, this improved efficiency could assist in the determination of a mechanism to generate rail road maintenance funds and to generate many measurable indicators to use as key performance for the railway sector. Feasibility studies and detailed design studies; the Sri Lanka Railway project performance monitoring system; before and after construction surveys of consultants and other authorities; Ministry of Transport; Police Traffic data; Railway Maintenance Dept‘s, and Ministry of Finance and Planning, will constitute the data sources and reporting mechanisms for this outcome. The main positive assumptions/risk associated with this outcome are: Railway reforms continued with the aim of lesser burden to government finance; timely maintenance of railroad infrastructure; maybe Rail Road Maintenance Trust Fund (RMTF) in place in due course; and maintenance is carried out in an efficient fashion by linking many city centers with railways by linking underdeveloped Sabaragamuwa area with the Western Province growth center.

15.8.6 Outputs of KV Line Development

The Project‘s main outputs would strengthen railway road network and railway related institutions and an improved national railway network by connecting inter and multi-model transport for speedy hassle free movements of passenger and freights. Especially the establishment of a robust rail network will finally contribute to the stronger integration of the national economy into the global value chain by improving the capacity and operating speed of the railway by modernizing and upgrading track, signaling and telecommunication infrastructure and potentially electrifying the suburban railway lines. This project will brings more outputs such as support for procurement of fast and modern commuter trains and modernization of rolling stocks maintenance facilities, construct and upgrade railway tracks, install new signaling systems, upgrade railway stations, to provide improved inter-model connectivity with other modes of public transport and through park-and-ride facilities at selected stations. In overall this project will increase capacity and attractiveness of the railway system, thus increasing its market share in passenger and freight segments by reducing road congestion by promoting model shifts. As this project designed on modular basis it allows future expansion in whole Sri Lankan railway network. Finally the outputs will promote sustainable economic growth leading to poverty reduction by lowering the cost of transport; relieving traffic congestion; and, by improving access to all communities and institutions. Performance targets and indicators for strengthened railway sector institutions will be an improvement of Sri Lankan Railway productivity and capability in updating investment plans and issuing annual maintenance plans; and reduction of staff/km ratio. The data sources and reporting mechanisms for outputs are: SLR‘s project performance management system; SLR‘s Planning Department; SLR‘s Finance and Administration Department; Supervision consultant‘s progress reports; ADB‘s review missions; and, before and after construction surveys and National level data authorities such as Census and Statistics Department, Central Bank of Sri Lanka, etc. The main positive assumptions/risk associated with this outputs are government‘s commitment to the in the re-engineering and reorganization of SLR; timely completion of environmental clearance, human resettlements and utility relocation; and, successful implementation, continuity and replication of performance-based maintenance. The risks associated with these outputs are slow and problematic land acquisition with compensation and resettlement processes. Especially, modernization and re-structuring of railway administrative structure to suit with modern efficient organization can be a huge challenge.

Table 15-93 illustrate the PMF impact, outcome and output indicators, their definitions, data sources, Baseline values, frequency of the progress monitoring and expected values at the end of the project.

Table 15-93 Project Monitoring and Design Framework (PMF) for KV Line Development Project

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
1. Impact							
Economic Level: 1.1 Increased proportion of Western and Sabaragamuwa Province GDP to National GDP	At current factor cost prices, GDP SP/GDP SL as %	Central Bank of Sri Lanka (CBSL), Annual Reports and Census and Statistics Dept. (CSD) National Account Section.	Annually	Proportions of GDP in 2016 Western- -39.7 Please refer the Table 1.1	2022	-	-
1.2 Increased growth rate of Western Province GDP relative to National GDP	GDP growth rate %	Central Bank of Sri Lanka, Annual Report and Census and Statistics Dept. (CSD) National Account Section.	Annually	2017 4.7% Please refer the Table 1.2	2022	-	-
1.3 Reduced unemployment rate for men and women in Western Province relative to National rate	% of unemployed out of labour force in terms of gender, age, education, etc.	CSD labour force survey reports, DS offices, field surveys	Annually	2017 Gender Male→2.7 Female→6.5 Age 15—24 →18.5 25—29→ 8.0 Over 30→ 1.6 Please refer the Table 1.3	2022	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
1.4 Reduced relative poverty in Western Province in comparison with the national level	• Poverty headcount index, poverty gap index and squared poverty gap index (% of population below the poverty line for Western and Southern Provinces as % of average for SriLanka) • Mean household income for Western and Southern Provinces as % of Sri Lankaaverage • Gini coefficient for Western and Southern Provinces as % of Sri Lanka average • Other inequality measures such as share of poorest 20% in total consumption, daily average dietary energy consumption per person in poorgroup. • Number of Samurdhi benefitsrecipients.	CSD household income and expenditure surveys. Central Bank Consumer Survey Finance reports Samurdhi Commissioner General Office, DS Office	Years on surveys conducted (Once in every five years) Annually	Poverty headcountindex 1.4%, poverty gap index 0.3% squared poverty gap index 0.2% for 2012/13. Mean household income Rs. 77,723 for 2012/13. Gini coefficient 0.48 for 2012/13. share of poorest 20% in total consumption 5% for 2012/13. Daily average dietary energy consumption per person in poor group 1,077 kcal for 2012/13.	2022 2022	-	- -

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
Land Value:							
1.5 Increased market	Price per perch and acre	Field survey on real	At baseline and	2018- 0.96 Million per perch	2022	-	-
value of land in divisional secretary's areason either side of the KV rail line		estate agents, land brokers, Property and land sections in News Papers, land and real estates related web sites(www.ikman.lk, …), DS offices around project roads	project completion	Colombo- 2.8Mln Maradana- 1.8 Mln Kotte- 1.5Mln Maharagama- 1.2Mln Homagama- 1.0 Mln Sithawaka- 0.6 Mln Kottawa – 1.1 Mn Meegoda-0.2 Mln Padukka-0.15 Mln Waga- 0.1 Mln Puwakpitiya-0.05 Mln Avissawella-0.5 Mln			
Tourism:							
1.6 Increased tourist hotel room occupancy rate in the hinterlands of KV Line. Newly built rooms/hotels/resorts in the hinterland.	Room occupancy rate (%) as specified by Sri Lanka Tourism Development Authority (SLTDA) and Newly built number of rooms/hotels/resorts in Southern coast.	Statistical Report of Sri Lanka Tourism Development Authority (SLTDA)	Annually	2017 (Room occupancy rate (%) as specified by Sri Lanka Tourism Development Authority (SLTDA) 74.3% Number of rooms increases in Southern coast 2015/2016 1650 with 24.1% growth)	2022	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
Agriculture:							
1.7 Increased producer prices for agricultural produce in the surrounding areas of the links roads with KV Line.	Rs.per kg in tea, rubber, coconuts, paddy, cinnamon, pepper and fisheries	Sri Lanka Tea Board/Hector Kobbekaduwa Agrarian Research & Training Institute, Plantation Ministry, Fisheries corporation	Annually	2016 SLRs per KG Tea – 473.15 Rubber-294.33 Coconuts- 45.82 Paddy-30.88 Cinnamon-1670 Pepper- 1329 Fisheries- Tuna- 750	2022	-	-
Environment:							
1.8 Environmental noise at permissible level	Background noise levels Assume 10dB less than the regulated level of noise Area, day value, night value • Low Noise (any Pradeshiya Sabha area) ,45, 35 • Medium Noise (any Municipal Council or Urban Council area), 53, 40 • High Noise ,60, 50 Silent Zone (100m from restricted places),40, 35	Environment Feasibility study, Field survey/Central Environmental Authority (CEA) specification standards/Field tests	Baseline and project completion	2018 (Background noise level measurements carried-out in selected location in projects rail roads.)	2022 (Within Central Environmental Authority (CEA) specification for noise level)	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
1.9 Ambient air quality at permissible level	Presence of NO2, SO2,CO…. *Component, recorded value, regulated value* • Carbon monoxide,2.86,26 • Sulfur dioxide, 0.104,0.08 • Nitrogendioxide, 0.102,0.13 • particulate matter from 2.5 - 10 micrometer (PM10), 146 microgrammes / m3, 100	Environment Feasibility study, Field survey/Central Environmental Authority (CEA) specification standards/Field tests	Baseline and project completion	2018 (Background noise level measurements carried-out in selected location in projects rail roads.)	2022 (Within Central Environmental Authority (CEA) specification for ambient air quality level)	-	-
1.10 Surfaceandground water quality at permissiblelevel	Water quality parameters: Component, regulated value • TSS,50mg/l • particle size,less than 850 micro meter • BOD5,30mg/l • oil and greases, 10mg/l • lead, 0.1mg/l • COD, 250mg/l • pH, 6-8.5 • sulfides, 2mg/l	Environment Feasibility study, Field survey/Central Environmental Authority (CEA) specification standards/Field tests	Baseline and project completion	2018 (Surface water quality measurements were carried-out on selected surface water bodies and ground water quality along the selected locations along the trace)	2022 (Within Central Environmental Authority (CEA) specification for surface water & ground water quality in 2018)	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
2.Outcome							
Improvement of transport efficiency							
2.1 Reduced travel time between Maradana and Avissawella.	Hours/Minutes	SLR	Baseline and project completion	2018 (23.5 kmph)	2022 (70 kmph)	-	-
2.2 2.2.1 Increased traffic volume in railway. 2.2.2 Traffic reduction in adjacent roads	No. of Rail frequencies and ADT per day ADT in Roads	SLR, Road Development Authority (RDA) Planning Division, SL Annual Reports	Baseline and project completion	2018	2022	-	-
2.3 Reduced fatal and other accident rates in rail track and crossing line roads	No. of accidents per month/Year	SLR, RDA (Planning division), SLR and Regional Police stations	Monthly/Yearly	2017	2022	-	-
2.4 Reduce rail road curvature. 2.4.2 Reduction of rail and road exposure index	Radius of the curve Rail and road exposure index	Feasibility studies SLR, Field surveys Feasibility studies SLR, Field surveys	Baseline and project completion Baseline and project completion	2018 (42% of the alignments is on sharp curves with radius<150 mrts) 2018 (Total No. of trains crossing per day (28)/AADT in crossing Lines)	2022 2022	-	-
2.5 Increased motoring speed/reduce journey time/more frequencies.	Average comfortable vehicle speed in project roads, km/ ph, Journey time, frequencies	SLR, Feasibility studies and surveys	Annually	2018 (23.5 kmph, 2.5 hours travel time, 4 frequencies)	2022 (70 kmph)	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
2.6 Reduce VOCs	Net vehicle operating costs per vehicle km	SLR, Feasibility studies, RDA and surveys	Annually	2017	2022	-	-
2.7 Reduce costs of transport	Rail tariffs per freight and passenger km	Feasibility studies, SLR and surveys	Annually	2018	2022	-	-
Socio-Economic indicator improvements							
2.8 Proportionate decreased private vehicle ownerships	Average vehicle ownership in project impact areas	Motor Traffic Dept., Divisional Sectaries (DS) offices	Annually	2017 (Please Table 2.8)	2022	-	-
2.9 Industrial enterprises will continually increase along in KV Line, adjacent roads and project impact areas.	Number of Small, Medium and Large scale industries.	CSD and DS offices. Ministry of Industries.	Annually/Decade	2013/14 Small - 71126 Medium - 10405 Large – 2414 Please Refer Table 2.9	2023/24	-	-
2.10 Increase in number of commercial, trade and service establishments within the Divisional Secretary's areas located on either side of the KV Line, adjacent roads and project impact areas.	Number of commercial, trade and service establishments	CSD and DS offices. Company registrar Office.	Annually/Decade	2013/14 Trade- 25.6% Service – 33.8% Please refer Table 2.10	2023/24 -	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
2.11 Improved socioeconomic conditions of Households in the sample areas surveyed for baseline especially on access to health, education and social services.	Number of health facilities, schools, social service centers	Health Ministry, Education Ministry, Other Line Ministries	Annually	2017 (Refer Table 2.11)	2022	-	-
2.12 Improved standard of living of Affected Persons (APs) in resettlement sites	% of House Holds (HH) of re-setters with better housing facilities, pipe water supply and electricity supply	Project Management Unit (PMU)	Annually	2017	2022	-	-
2.13 Improved levels of livelihoods of APs in resettlement	Average monthly income (Rs.)	PMU	Annually	2017	2022	-	-
2.14 Increased mobility for residents in the broader influence area	Increased ridership on the lines	Annual reports from MT&CA, reports to parliament from SLR	Annually	2017	2022	-	-
3.Outputs							
3.1 Rehabilitation and improvement of 60km Line, stations and other infrastructure.	Rail tract km and number of bridges/culverts	PMU	Once	2018	2022 (Total Km.60)	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
3.2 Basic rail road safety equipment in place by removing roadway obstacles such as unnecessary level crossings and small stations.	Number	SLR, PMU/Police Traffic Division	Once	2018	2022	-	-
3.3 Reduction in maintenance cost and reduction of SLR staff staff/km	Cost/km, staff/km	SLR, PMU	Annually	2018	2022	-	-
3.6 Resettlement of Affected Households completed	%	PMU	Annually	2018	2022	-	-
3.7 Payment of compensations to APs completed	%	PMU	Annually	2018	2022	-	-
3.8 Income Restoration Program (IRP) for APs completed	Number	PMU	Annually	2018	2022	-	-
3.9 Public awareness campaign on new rail stations and crossing discipline/safety	Awareness methods (Brochures, road shows, sign boards, etc.)	SLR/RDA/Police	Annually	2018	2022	-	-

Type & Name of Indicator (1)	Definition and Units (2)	Data Source(s) (3)	Frequency of Measurement (4)	Baseline Measurement(5)	Target Value / date (6)	Performance status [as of (date)..] (7)	Observations / Remarks (8)
4. Overall Project Performance	% of beneficiaries satisfied with the project performance after completion	Field surveys and line Ministry data sources. Without project and with project photos.	At completion and annually afterwards. Rail Road photos with features and stations, bridges and culverts before and after completion of project.	- 2018	2022 (60km KV Line, stations, level crossings and bridges and culverts. Modern rolling stocks, signaling systems and ICT infrastructure)	-	-

15.8.7 Supportive Data for PIMF

Table 15-94 At current factor cost prices, GDP SP/GDP SL as %

Baseline 2016		
	GDP	Proportion
National	Rs.11,839 billion	100%
Western Province	Rs.4,697 billion	39.7%
Sabaragamuwa	Rs.892 billion	7.5%

Source: Economic and Social Statistical Data report 2017 Central Bank of Sri Lanka

Table 15-95 GDP growth rate %

Baseline 2016			
	2015	2016	
	GDP Proportion	GDPProportion	Growth
National	Rs.10,952 billion	100%	4.7%
Western Province	Rs.4,365 billion	39.9%	7.6%
Sabaragamuwa	Rs.825 billion	7.5%	8.2%

Source: Economic and Social Statistical Data report 2017 Central Bank of Sri Lanka

Table 15-96 Unemployment Rate

Baseline 2017		
	Male	Male
Age -Total	2.7	2.7
15-24	17.1	17.1
25-29	5.1	5.1
30-39	0.9	0.9
Over 40	0.5	0.5
Education- Total	2.7	2.7
Grade 5 and below	0.3	0.3
Grade 10 and below	2.7	2.7
GCE O/L	4.1	4.1
GCE A/L or above	4.7	4.7

http://www.statistics.gov.lk/samplesurvey/LFS_Q1_Bulletin_WEB_2017_final.pdf

Table 15-97 Poverty Measurements

Baseline 2017	
Poverty headcount index	1.4%
poverty gap index 0.3%	0.3%
squared poverty gap index	0.2%
Mean household income	Rs.77723
Gini coefficient 0.48 for 2012/13.	0.48
share of poorest 20% in total consumption 5% for 2012/13.	5%
Daily average dietary energy consumption per person in poor group	1,077kcal
Number of Samurdhi benefits recipients.	

Source: Census and Statistics of Sri Lanka 2016/2017

Table 15-98 Land Value

Baseline 2018			
	Residential	Commercial	Agricultural
Price per perch	0.96 Million per perch		
Colombo	2.8 Million	40 Millon	
Maradana	2.0 Million	35 Million	
Kotte	1.5 Million	30 Million	
Maharagama	1.2 Million	20 Million	
Homagama	1.0 Million	18 Million	
Kottawa	1.1 Million	1.8 Million	
Hanwalla	0.6 Million	1.2 Million	
Panagoda	0.4 Million	1.0 million	
Meegoda	0.2 Million	4.5 Million	
Padukka	0.15 Million	4.2 Million	1 Million per acre
Waga	0.1 Million	3.8 Million	0.7 Million per acre
Puwakpitiya	0.05 Million	3.5 Million	1.5 Million per acre
Avissawella	0.5 Million	5 Million	2.5 Mln per acre

Residential – https://ikman.lk/en/ad/75p-residential-land-for-sale-in-kotte-for-sale-colombo
Commercial – https://ikman.lk/en/ad/9-bed-hotel-for-sale-in-pita-kotte-for-sale-colombo
Agriculture-https://ikman.lk/en/ad/rubber-cum-tea-land-awissawella-for-sale colombo-1
https://ikman.lk/en/ad/tapping-rubber-state-in-hanwella-waga-for-sale-colombo

Table 15-99 Tourism

Baseline 2017	
2017 (Room occupancy rate (%) as specified by Sri Lanka Tourism Development Authority (SLTDA) 74.3%	74.3%
Number of rooms increases in Southern coast 2015/2016	1650 with 24.1% growth

Source: Sri Lanka Tourism Board 2016/2017

Table 15-100 Agriculture

Price per kg	Baseline 2016(Rs.)
Tea	473.15
Rubber	294.33
Coconuts	45.82
Paddy	30.88
Cinnamon	1670
Pepper	1329
Fisheries (Tuna)	750

Source: Central Bank of Sri Lanka 2016/2017

Socio-Economic indicator improvements

Table 15-101 Average vehicle ownership in road impact areas - 2015

	Motor Cars	Motor Bicycles	Three Wheelers	Private Bus	Dual Purpose Vehicles	Motor Lorry	Land Vehicles	Other
Colombo	99897	111536	71026	11458	41321	42108	7512	5348
Homagama	1158	6028	3047	398	904	807	157	9
Seethawaka	11208	15421	7845	701	5087	3015	412	34
Padukka	7541	8741	4758	362	2974	1124	187	5
Maharagama	6874	12178	5108	608	3741	3021	508	5
Kotte	8347	18056	8896	912	5041	3471	571	14

Source: District Statistical Hand book 2017

Table 15-102 Small, Medium and Large-Scale Industries in KV line Hinterland, 2013/14

DS Area	Micro	Small	Medium	Large
Colombo	23571	4055	686	274
Thimbirigasyaya	9067	2721	962	361
Kotte	4131	1062	292	82
Maharagama	9381	1176	193	36
Homagama	11340	976	178	33
Paddukka	2803	184	30	07
Sithawaka (Avissawella)	6419	516	66	33

Source: Census and Statistics Dept, Sri Lanka, Industry Census 2012/13.

Table 15-103 Trade and Service Establishments in KV Line Hinterland for year 2013/14

Baseline 2017		
DS Area	Trade Establishments	Service Establishments
Colombo	56222	51128
Thimbirigasyaya	5246	6523
Kotte	2410	2455
Maharagama	4345	3958
Homagama	4655	4449
Paddukka	1182	1043
Sithawaka (Avissawella)	2693	2626

Source: Census and Statistics Dept, Sri Lanka, Non Agriculture Census, 2012/13

Table 15-104 Social Services by impacted DS Divisions

Baseline 2017			
DS Area	Schools	Hospital Beds	Cultural centres
Colombo	69	58	ND
Homagama	38	526	1
Seethawaka	37	594	1
Padukka	23	72	1
Maharagama	22	-	1
Kotte	18	-	1

Source: District Statistical Hand book 2017

15.8.8 Base Line Photos of KV Line


STOP


MALAPALLA


HONAGAMA


PADUKKA




15
KMPH



STOP
7
STOP
4


STOP


15
KMPH
STOP

15.9 Railway Fare Structure and Periodic Fare Adjustments

This section presents an analysis of existing railway fare structure, recommend a suitable formula for periodical revision of railway fares, and identify appropriate benchmark indicators for fare adjustments and brief institutional arrangements to carry out the periodic fare adjustments for Sri Lanka Railways.

15.9.1 Prevailing Relative Position of Railway Fares

Sri Lanka Railways (SLR) was established by the British administration, mainly for transportation of agricultural products to the Colombo harbor. After independence in 1948, the transportation pattern changed with the socio-economic changes of the country. Accordingly, the scope of SLR has been completely changed as daily passenger transporter from the cargo transporter. Passenger trains are not as profitable as freight trains in any country. Many countries even OPEX cannot recover from passenger transportation and most cases it is government subsidy based business due to the public good nature of the railway. However, the financial position of the SLR moderately improved during 2016. The total revenue of the SLR increased by 4.6 per cent to Rs. 6.6 billion, while current expenditure decreased by 4.6 per cent to Rs. 13.4 billion, benefitting from low oil prices. The increase in revenue and the reduction in expenditure resulted in reducing operating losses of the SLR to Rs. 6.8 billion in 2016 from a loss of Rs. 7.7 billion in 2015. Capital expenditure of the SLR also witnessed a decline of 48.4 per cent to Rs. 15.7 billion in 2016 from Rs. 30.4 billion in the previous year, mainly due to the completion of the expansion of railway services in the Northern Province. In the meantime, the government decided to keep the rail tariff unchanged in 2016. In spite of the introduction of some improvements and innovations, the quality of train services still remains sub-standard, requiring urgent attention in order to exploit unique opportunities in mass transit and transform the SLR into a financially viable institution. The shortage of trains and train compartments during peak hours, lower demand for train services during off-peak hours, lack of value added services, including luxury and intercity train services, inability to ensure timely service delivery on a sustainable basis, a lack of emphasis on the usage of train services for goods transportation and inferior catering and sanitary facilities can be identified as key concerns. The availability of a reliable and a comfortable train service could attract the general public towards mass transit. Therefore, upgrading and expanding the railway network through strategic PPPs to increase the capital infusion, including electrification of the railway, introducing faster and comfortable intercity services that could facilitate regular users as well as the increasing number of tourists who seek luxurious and relaxing ways to travel around the country, bringing modern technology to signaling and telecommunication systems to ensure a timely service delivery and promoting rail services as a cost effective alternative for goods transportation through a simple and efficient service are essential in improving the quality of railway services. Moreover, introducing market oriented fare schemes while permitting concessionaries to the lowest fare segment would help improve the financial position of SLR.

During the past several decades, SLR revenue has never reached even the operating cost recovery level. Therefore, Sri Lanka Railway has been running at a loss all the time. As per data available from 2011 to 2017, annual average operational loss is nearly Rs. 6422 million per year, while highest operational loss is Rs. 7714 million in 2015. The Table 15-105 highlights the operational loses.

Table 15-105 Operational Loses from 2012 -2017 in Rs. Millions

Description	2012	2013	2014	2015	2016	2017
Total Revenue	4851.87	5423.29	5909.30	6334.20	6462.56	6477.09
Recurrent Expenditure	8647.65	10586.48	16943.26	14048.77	13396.29	14080.66
P & L after Present Scenario	-3795.78	-5163.19	-11033.96	-7714.57	-6933.73	-7603.57

Source: Annual Performance Reports of SLR -2013, 2015 and 2017.

According to the information from Central Bank's "Annual Report 2017", Rail transportation recorded a modest growth in passenger transportation activities in 2017. Rail passenger Kilometrage increased by 1.1 per cent from 7.4 billion Km. in 2016 to 7.5 billion km in 2017. However, an average Sri Lanka Railway passenger pays very less amount per Km. and this is the main reason behind the operational loses. Majority of passengers are prefer to use SLR due to existing heavy road traffic situation in peak hours. Hence, entire railway passengers are suffering due to high rail transport demand and over-crowding, but not increased facilities and services according to the demand.

The lack of timely investment in fleet and rolling stock replacement and lack of technology usage by the SLR have resulted in over-crowding of trains and delays, reducing the reliability of the railway transport system. Further, disrupt the smooth functioning of the service due to technical issues and low passenger fares and goods transport tariffs worsen the financial viability of the SLR, and thereby reduce the available funds for future investment. Therefore, the SLR needs to focus on fare restructuring policy to improve passenger services, as an efficient transport mode that is complementary to road transportation.

The SLR fare can be formulated according to the consumer demand. Main consumer of SLR is mainly passengers and passenger fare is almost subsidized. The major rail markets in Sri Lanka are:

- Passengers
- Tourists
- Petroleum
- Livestock
- Cement and coal
- Fertilizer, raw materials and general freight

According to above market segments, SLR passenger fare reformulation process should be based on following principles:

- Cost based
- Competition based
- Value based

The travel cost is the key factor affecting travel demand. An increased price for a particular type of travel tends to reduce its consumption and sometimes causes shift to alternatives. The Table 15-106 shows factors that can affect passengers travel demand and price settings:

Table 15-106 Factors Affecting Passenger Transport Demand and Price Settings

Demographic	Commercial	Transport Options	Land Use	Demand Management	Prices
Number of people	Number of jobs	Public transport	Density	Road use priorritization	Fuel prices and Taxes
Employment rate	Number of business activities	Private transport	Walkability	Pricing reforms	Vehicle taxes and fee
Wealth and income	Tourist activities	Cycling	Connectivity	Parking management	Road tolls
Age and life style		Walking	Roadway design	User information	Parking fees
Preferances					Vehicle insurances
					Public transport fares

Source: Consultants Analysis

Based on Table 15-106: general passenger travel demand function can be derived as below:

Dt = F (Cm, Dm, LU, Pr, TO DM)

Where;

Cm - Commercial factors

Dm - Demographic factors

DM - Demand management

Dt - Passenger travel demand

LU - Land use factors

Pr - Price

TO - Transport options

People‘s travel decisions are limited by their ability to pay for trips. In addition, their preference, income, other competitive transport prices and service quality also affected. Rail passenger transport price setting can be divided in to two broad categories as:

- Passenger based price setting approach, mainly focused on social welfare
- Revenue based price setting approach, mainly considered cost recovery plus profits.

Currently, SLR is running under the government subsidy to cater growing transport demand. The SLR is not be able to meet its own O&M costs from the revenues that it generates. However, SLR is still delivering greatest social and economic benefits to the national economy via state subsidy. Due to huge benefit scheme of SLR, our price setting exercise was focused on mixed approach of above.

15.9.2 Impacts of Different Fare Levels

The SLR fare in Sri Lanka was increased last in 2012. Since then the price of the fuel has increased by two and half. The prices of the electricity and the water are also increased by two and half times up to now. The salaries have doubled. The passenger pays only 50 rupees per 100 kilometres on average and fare of the SLR is extremely low. The amount of revenue is not sufficient to meet the fuel bill even.

In the current pricing system, a normal passenger has to pay only 90 cents per kilometer to travel by train. That means on average the revenue generated per passenger kilometer is 98 cents. When considering the above information it is very clear that the SLR has no any accurate costing system to do the pricing in a proper and profitable way. The current fares have no relationship with the cost of the railway. Hence, a proper costing system should be introduced to overcome this situation. The table 15-107 shows the unit price per Km. in different railway lines:

Table 15-107 Unit Price per Km.

Line	Fare (Rs./Km.)		
	1st Class	2nd Class	3rd Class
MainLine	3.31	1.79	0.97
Puttlam Line	3.27	1.78	0.95
Northern Line	2.85	1.56	0.85
KV Line	4.09	2.14	1.16
Coast Line	3.45	1.85	0.99
Mean Value	3.39	1.82	0.98

Source: Sri Lanka Railway Department

Sri Lanka Railway manages a 1,449 km length of rail network with 323 stations that covers most part of the country. The main railway lines radiate from Colombo and branch off at regular intervals. However, except for 126 km. double-track lines around Colombo, rest of the network is single-track line. The depleted assets base, obsolete signal and communication system and aging rolling stock fleet severely constrain delivering quality service to the passengers. This situation has further increased by the inappropriate organization and management systems practiced by the SLR throughout decades which are not taken any positive step to meet present transport demand.

The National Transport Policy envisages making rail transport an attractive and efficient mode of public transport. It is expected to increase the modal share of passenger transport from 6% to 10% and freight sectors of Railway from 2% to 5% by 2016. However, still SLR is operating under state funds and not taken following initiatives to compete with road transport sector.

- SLR not initiated to take favorable steps to exploit consumer surplus by differentiating prices plus value added service by utilizing existing capacity and resources.
- To formulate a railway fare policy on the line of the bus fare policy for future fare revisions.
- During last decade, SLR has not formulate a railway fare policy parallel to bus fare policy and passenger concessionary tariff structure also not rationalized to ensure cost effectiveness.
- Railway freight tariffs were also not re-formulated with competitive market signals and no any future plans or pricing formulae to attract freight transport from road to rail.
- Current SLR services are at below marginal cost and prices are not related to marginal costs. Costs are not properly identified or measured.

15.9.3 Sri Lanka Railway Market Structure

The most common market structure for the SLR is single state-owned public enterprise called natural monopoly business. Both infrastructure and the rail services owned by SLR and restricted to the market entry. It had been widely assumed that public monopolies required price and service regulation to protect the public interest. However, SLR‘s annual operational cost is increasing rather than its annual revenue and following main reasons were identified with revenue analysis and given in Table 15-105.

- Imposed unsustainable fare, service conditions and subsidy schemes.
- Excessive operating costs due to operational inefficiency. Not bearing track and infrastructure costs with other stakeholders. (Not competing with road transport operators).

- Private sector entry to the rail sector is restricted, fares and freight charges are usually controlled by government and no independent decision making. This has led to the "padding out" of costs by excessive capitalization.
- Strict entry regulation limits the possibility of providing innovative forms of lower cost rail transport which meets the transport demands of the poorer groups or higher quality alternatives meeting the needs of those willingness to pay.

15.9.4 Creating Competition in the Sri Lankan Railway Industry

Economic principles suggest that the price of products should be set at some measure of marginal cost. Many countries are therefore seeking economic reforms aimed at creating a competitive market-based rail transport industry. Competition is the most important mechanism for maximising consumer benefits, and for limiting monopoly power. Competitive market may offer better quality of services for value for money to attract customers. In general, the goal of competition policy is to promote, protect and preserve competition as the most appropriate means of ensuring the efficient allocation of resources.

The structure and level of rail fares in Sri Lanka is determined by a Ministry of Transport, but not involved market forces. Rail fare is not implemented in association with current bus fare policy, because rail transport fare policy implemented due to on state /political interest. Further, value for money in the rail industry is not assessed and addressed to determine the incremental changes to service. Therefore, rail fare is not implemented on competitive basis. However, competitive fare policy will be incentive to increase revenue and service quality.

In undertaking this analysis for SLR, Consultants have used the best data sources available. Briefly this analysis revealed that particular shortcomings of current fare structure, already highlighted in above sections. This analysis provided number of alternatives, but not recommended any fare setting formula, but recommended number of fare setting policy options for future sustainable operations.

15.9.5 Fare Option Analysis

The ultimate aim of this analysis is to develop most important fare options regarding how best to change the existing level and structure of rail fares. The Table 15-107 shows the average train passenger fare in each railway line. Majority of passengers are travelling on fare class 3 and national average is approximately Rs. 0.98 per Km. With comparison of fare class 3, first and second fare classes averages are higher than 345% and 185% times respectively. Table 15-108 shows the current fare setting formulae.

Current SLR fare calculation is based on three fare class and distances. Base distance of fare class 1 and fare class 2 are similar and fare class 3 base distance is 10 Km. and different with 1 and 2. Table 15-108 illustrated the current fare classes, base fare and distances in Km.

Table 15-108 Current Fare Calculation

Fare Class 1			Fare Class 2			Fare Class 3		
Km.	Fare	Calculation	Km.	Fare	Calculation	Km.	Fare	Calculation
1 - 14	40	Base fare	1 - 14	20	Base fare	1 - 10	10	Base fare
15 - 20	60	1.5 time of Base fare	15 - 17	30	1.5 time of Base fare	11 - 15	15	1.5 time of Base fare
21 - 25	80	2 times of base fare	18 - 23	40	2 times of base fare	16 - 20	20	2 times of base fare
26 - 31	100	2.5 times of base fare	24 - 29	50	2.5 times of base fare	21 - 29	25	2.5 times of base fare
32 - 37	120	3 times of base fare	30 - 34	60	3 times of base fare	30 - 33	30	3 times of base fare

Source: Sri Lanka Railway Department

Above SLR fares structure is a key element in the railway system and following alternative fare options were proposed in association with recent feasibility studies and findings and mainly our approach was based on the revenue maximization.

- Cost based Inflation pricing model
- Future demand based pricing model
- JICA – LRT pricing model
- Competitive pricing model
- Value based pricing model – (This section will discussed with comments)

15.9.6 Detailed Fare Option Analysis

15.9.6.1 Cost Plus Inflation Pricing Model

Table 15-109 shows the main ticket types in the current fare structure in 2012. The proposed fare projection was based on transport sector inflation rate (3.15%) for 3 scenarios. The Colombo Consumer Price Index (CCPI 2013=100), which is compiled by the Department of Census and Statistics and granted 10.6 weighted average for transport expenditure. In 2018 January to May, transport sector inflation was recorded from 4.1% to 4.4%. However, this analysis was considered annual average transport sector inflation as 3.15% and applied for the fare calculation. Mainly rail passenger transport is highly bounded with personal disposable income and therefore, fare setting calculation was avoided high level inflation rates and focused on social welfare lenses whilst considering to recover full or part of O&M cost. Table 15-109 highlights the fare calculation output under Cost plus inflation pricing model.

Table 15-109 Cost Plus Inflation based Fare Calculation (Rs.)

Km.	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
1-10	40	51	60	82	20	26	30	41	10	13	15	20
11-15	40	51	60	82	20	26	30	41	15	19	22	31
16 - 20	60	77	90	122	30	38	45	61	20	26	30	41
21 - 25	80	103	120	163	40	51	60	82	25	32	37	51
26 -30	100	128	150	204	50	64	75	102	30	38	45	61
31 - 40	120	154	180	245	60	77	90	122	35	45	52	71
41 - 45	140	179	210	286	80	103	120	163	40	51	60	82
46 - 50	160	205	239	327	100	128	150	204	45	58	67	92
51 - 60	180	231	269	367	120	154	180	245	50	64	75	102
61 - 65	200	256	299	408	140	179	210	286	55	70	82	112
66 - 70	240	308	359	490	160	205	239	327	60	77	90	122
71 - 75	260	333	389	531	180	231	269	367	65	83	97	133
76 - 80	280	359	419	571	200	256	299	408	70	90	105	143
81 - 90	300	384	449	612	220	282	329	449	75	96	112	153
91 - 95	320	410	479	653	240	308	359	490	80	103	120	163
96 - 100	340	436	509	694	260	333	389	531	85	109	127	173

Source: 1. Source: Sri Lanka Railway Department and Department of Census and Statistics

According to CCPI, Cost plus Inflation based fare calculation and proposed fare structure of SLR, alternative fare ratio is given in Table 15-110. Following results were directly applied with SLR revenue and O&M cost stream to review cost recovery possibilities under proposed three scenarios of 2020, 2025 and 2035.

Table 15-110 Fare Calculation

Year	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
Ratio	1.0	1.3	1.5	2.0	1.0	1.3	1.5	2.0	1.0	1.3	1.5	2.0
Calculation	Base fare	BF xTransport inflation			Base fare	BF x Transport inflation			Base fare	BF x transport inflation		

Source: Department of Census and Statistics

Based on 2012 – 2017, SLR revenues, O&M costs and capital expenditure, operation loses / profits were analyzed before and after fare setting. In 2012, Rs. 3796 million was reported as operational loss. Highest operational loss was reported in 2014 due to increase of fuel prices as Rs. 8921 million.

After setting fares under three scenarios (1.2, 1.5 and 2.0) operational loses are declining and with comparison of current operational loses, scenario three is reporting lowest amount for 2012-2017 under the fare hike of 2 times in association with current fares. From year 2018 to 2035, new additional O&M cost also included under the KV line. Therefore, 2018 Annual O&M costs is more than 2 times of 2017 O&M cost. Accordingly, 2020, 2025 and 2035 revenues, O&M costs and operational loses also calculated. Table 15-111 shows the current and forecasted cost and revenues.

Table 15-111 Cost Plus Inflation based Revenue and O&M Analysis - Fare class 3 (Rs. Million)

Year	Revenue	O&M	Op. Loss or Profits	Scenario 1 - 1.3		Scenario 2 - 1.5		Scenario 3 - 2	
				Revenue	Op.Loses or Profits	Revenue	Op.Loses or Profits	Revenue	Op.Loses / Profits
2012	4851.87	8647.65	-3795.78	6307.43	-2340	7277.81	-1370	9703.74	1056
2013	5423.29	10586.47	-5163.18	7050.28	-3536	8134.94	-2452	10846.58	260
2014	5909.30	14830.10	-8920.80	7682.09	-7148	8863.95	-5966	11818.60	-3012
2015	6334.20	14048.77	-7714.57	8234.46	-5814	9501.30	-4547	12668.40	-1380
2016	6462.56	13396.29	-6933.73	8401.33	-4995	9693.84	-3702	12925.12	-471
2017	6477.09	14080.66	-7603.57	8420.22	-5660	9715.64	-4365	12954.18	-1126
2018	6684.36	19116.92	-12432.56	8689.66	-10427	10026.54	-9090	13368.71	-5748
2020	7119.00	20061.80	-12942.80	9254.70	-10807	10678.50	-9383	14238.00	-5824
2025	8333.31	24845.92	-16512.61	10833.30	-14013	12499.96	-12346	16666.62	-8179
2035	11418.64	37162.67	-25744.03	14844.24	-22318	17127.96	-20035	22837.29	-14325

Source: 1. SLR Annual Performance Reports 2013, 2015 and 2017

2. Department of Census and Statistics

Note:1. KV line O&M cost and capital cost included

2. From 2018 - 2024 O&M category 1 - based on cost estimate

3. From 2025 - 2034 O&M category 2 - based on cost estimate

4. From 2035 O&M category 3 - based on cost estimate

5. Capital cost distributed from2020 to 2024 - based on cost estimate

6. Above revenue and O&M analysis considered only fare class 3.

7. Sc. 1 – 2020 = 1.3, Sc. 2 – 2025 = 1.5, Sc.3 – 2035 = 2.0 calculated with fare class 3.

In association with Table 15-111, Table 15-112 illustrated the operational loses or profits as a percentage of revenue under 3 fare hike scenarios (1.3, 1.5 and 2.0), Based on following table, decision makers will be able to select most appropriate fare option on social, political and economic lenses.

Table 15-112 Op. Loses /Profits as a Percentage of Revenue

Year	Present Sc.	SC 1- 1.3	SC 2- 1.5	SC 3- 2.0
2012	-78.23	-37.10	-0.19	0.11
2013	-95.20	-50.16	-0.30	0.02
2014	-150.96	-93.05	-0.67	-0.25
2015	-121.79	-70.61	-0.48	-0.11
2016	-107.29	-59.45	-0.38	-0.04
2017	-117.39	-67.22	-0.45	-0.09
2018	-185.99	-120.00	-0.91	-0.43
2020	-181.81	-116.77	-0.88	-0.41
2025	-198.15	-129.35	-0.99	-0.49
2035	-225.46	-150.35	-1.17	-0.63

Source: Economic and Financial Team

15.9.6.2 Future Demand Based Pricing Model

Sri Lanka Transport Sector Policy Note published by the World Bank (WB) highlighted important future transport demand trend. Mainly, WB estimated bus transport share will reduced by 55% to 20% by 2031 and railway traffic is expected to increase from 5.4 to 9.7 million passenger km. by 2031.

In economic theory, effective pricing requires to allocate scarce resources for the largest returns. Currently SLR pricing formula is based on political interest, social welfare and therefore, market mechanism is not functioning properly. Main reason for the O&M cost is far below the total revenue is lack of demand based pricing mechanism in passenger tickets of SLR.

Future demand based pricing is a pricing method based on the customer‘s demand and the perceived value of the product or services. This pricing model assumes that future demand pressure on public transport sector with rapid population growth and increased economic opportunities. The future demand based pricing model is based on three project scenarios as 2020, 2025 and 2035. Transport demand model has been provided three alternative ratios to fare setting, whilst considering forth coming other public transport alternatives also. Therefore, this analysis was used 2 ratios as 1.2 and 1.5 for 2020 and 2025 respectively. However, for 2035, transport demand analysis has been used 2025 ratio, because different public transport alternatives.

Table 15-113 illustrates the fare calculation output under future demand based pricing model.

Table 15-113 Future Demand based Fare Calculation (Rs.)

Km.	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
1-10	40	48	60	60	20	24	30	30	10	12	15	15
11-15	40	48	60	60	20	24	30	30	15	18	23	23
16 - 20	60	72	90	90	30	36	45	45	20	24	30	30
21 - 25	80	96	120	120	40	48	60	60	25	30	38	38
26 -30	100	120	150	150	50	60	75	75	30	36	45	45
31 - 40	120	144	180	180	60	72	90	90	35	42	53	53
41 - 45	140	168	210	210	80	96	120	120	40	48	60	60
46 - 50	160	192	240	240	100	120	150	150	45	54	68	68
51 - 60	180	216	270	270	120	144	180	180	50	60	75	75
61 - 65	200	240	300	300	140	168	210	210	55	66	83	83
66 - 70	240	288	360	360	160	192	240	240	60	72	90	90
71 - 75	260	312	390	390	180	216	270	270	65	78	98	98
76 - 80	280	336	420	420	200	240	300	300	70	84	105	105
81 - 90	300	360	450	450	220	264	330	330	75	90	113	113
91 - 95	320	384	480	480	240	288	360	360	80	96	120	120
96 - 100	340	408	510	510	260	312	390	390	85	102	128	128

Source: Sri Lanka Railway Department and ComTrans Report

The Table 15-114 shows developed alterative fare ratio for further revenue analysis and described in Table 15-115. To decide most appropriate fare levels, O&M cost recovery levels are also important.

Table 15-114 Fare Calculation

Year	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
Ratio	1.00	1.20	1.50	1.50	1.00	1.20	1.50	1.50	1.00	1.20	1.50	1.50
Calculation	BF	BF x 1.2	BF x 1.5	BF x 1.5	BF	BF x 1.2	BF x 1.5	BF x 1.5	BF	BF x 1.2	BF x 1.5	BF x 1.5

Source: Sri Lanka Railway Department and ComTrans Study Report

The Table 15-114 have been illustrated 3 fare scenarios, but 2 and 3 are almost same ratio (1.2, 1.5 and 1.5). Based on above table following cost recovery analysis have been developed.

Table 15-115 Future Demand based Revenue and O&M Analysis - Fare class 3 (Rs. Million)

Year	Revenue	O&M	Op. Loss or Profits	Sc. 1 - 1.2		Sc. 2 - 1.5		Sc. 3 - 1.5	
				Revenue	Op.Loss or Profits	Revenue	Op.Loss or Profits	Revenue	Op.Loss or Profits
2012	4851.87	8647.65	-3795.78	5822.24	-2825.41	7277.81	-1369.85	7277.81	-1369.85
2013	5423.29	10586.47	-5163.18	6507.95	-4078.52	8134.94	-2451.54	8134.94	-2451.54
2014	5909.30	14830.10	-8920.8	7091.16	-7738.94	8863.95	-5966.15	8863.95	-5966.15
2015	6334.20	14048.77	-7714.57	7601.04	-6447.73	9501.30	-4547.47	9501.30	-4547.47
2016	6462.56	13396.29	-6933.73	7755.07	-5641.22	9693.84	-3702.45	9693.84	-3702.45
2017	6477.09	14080.66	-7603.57	7772.51	-6308.15	9715.64	-4365.03	9715.64	-4365.03
2018	6684.36	19116.92	-12432.56	8021.23	-11095.69	10026.54	-9090.39	10026.54	-9090.39
2020	7119.00	20061.80	-12942.80	8542.80	-11519.00	10678.50	-9383.30	10678.50	-9383.30
2025	8333.31	24845.92	-16512.61	9999.97	-14845.95	12499.96	-12345.96	12499.96	-12345.96
2035	11418.64	37162.67	-25744.03	13702.37	-23460.30	17127.96	-20034.71	17127.96	-20034.71

Source: 1. SLR Annual Performance Reports 2013, 2015 and 2017 and ComTrans Study Report

Note:
1. KV line O&M cost and capital cost included
2. From 2018 - 2024 O&M category 1 - based on cost estimate
3. From 2025 - 2034 O&M category 2 - based on cost estimate
4. From 2035 O&M category 3 - based on cost estimate
5. Capital cost distributed from2020 to 2024 - based on cost estimate

6. Above revenue and O&M analysis considered only fare class 3.
7. Sc. 1 – 2020 = 1.2, Sc. 2 – 2025 = 1.5, Sc.3 – 2035 = 1.5 calculated with fare class 3.

Table 15-116 shows the operational loses or profits as a percentage of annual revenues under 3 fare hike scenarios (1.3, 1.5 and 2.0), Based on following table, decision makers will be able to select most appropriate fare option on social, political and economic lenses.

Table 15-116 Operational Loses /Profits as a Percentage of Revenue

Year	Present Sc.	SC 1- 1.3	SC 2- 1.5	SC 3- 2.0
2012	-78.23	-48.53	-18.82	-18.82
2013	-95.20	-62.67	-30.14	-30.14
2014	-150.96	-109.14	-67.31	-67.31
2015	-121.79	-84.83	-47.86	-47.86
2016	-107.29	-72.74	-38.19	-38.19
2017	-117.39	-81.16	-44.93	-44.93
2018	-185.99	-138.33	-90.66	-90.66
2020	-181.81	-134.84	-87.87	-87.87
2025	-198.15	-148.46	-98.77	-98.77
2035	-225.46	-171.21	-116.97	-116.97

Source: Economic and Financial Team

15.9.6.3 JICA – LRT Pricing Model

JICA – LRT project PPTA team examined fares of existing bus services. This model examined three options as: Normal Fare x 1.2 for 2020, Normal Fare × 1.5 for 2025 and Normal Fare × 2.3 for 2035.

JICA funded CoMTrans Urban Transport Master Plan Final Report has been illustrated the rapid economic growth pattern during next decade or so. Due to rapid urbanisation and economic growth in the Western Province, job opportunities and educational facilities would be expanded. This would attract a large number of people towards the Western Province and people‘s willingness to pay for the improved and qualitative public transport facility also will also be increased. According to the ComTrans study report, estimated and forecasted employment rates and employed population are given in the following Table 15-117.

Table 15-117 Employed Population Projection

Colombo District	2020	2025	2030	2035
Total Population	2476100	2624400	2795900	2979700
Employed Popuation	923100	980300	1047100	1119000
Employed Popuation %	37.28	37.35	37.45	37.55

Source: CoMTrans Urban Transport Master Plan Final Report

Mainly above three fare settings were looked on very important lenses: political view, social view and revenue view. Therefore, this fare setting exercise also used JICA-LRT options to calculate train fares in same scenarios and details are given in Table 15-118.

Table 15-118 Political, Social and Revenue based Fare Calculation (Rs.)

Km.	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
1-10	40	48	60	92	20	24	30	46	10	12	15	23
11-15	40	48	60	92	20	24	30	46	15	18	23	35
16 - 20	60	72	90	138	30	36	45	69	20	24	30	46
21 - 25	80	96	120	184	40	48	60	92	25	30	38	58
26 -30	100	120	150	230	50	60	75	115	30	36	45	69
31 - 40	120	144	180	276	60	72	90	138	35	42	53	81
41 - 45	140	168	210	322	80	96	120	184	40	48	60	92
46 - 50	160	192	240	368	100	120	150	230	45	54	68	104
51 - 60	180	216	270	414	120	144	180	276	50	60	75	115
61 - 65	200	240	300	460	140	168	210	322	55	66	83	127
66 - 70	240	288	360	552	160	192	240	368	60	72	90	138
71 - 75	260	312	390	598	180	216	270	414	65	78	98	150
76 - 80	280	336	420	644	200	240	300	460	70	84	105	161
81 - 90	300	360	450	690	220	264	330	506	75	90	113	173
91 - 95	320	384	480	736	240	288	360	552	80	96	120	184
96 - 100	340	408	510	782	260	312	390	598	85	102	128	196

Source: Sri Lanka Railway Department and JICA – LRT study report

In association with JICA – LRT study report, this study examined 3 fare ratios under the 2020, 2025 and 2035 scenarios and Table 15-119 presented the applicable ratios and method.

Table 15-119 Fare Calculation

Year	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
Ratio	1.00	1.20	1.50	2.30	1.00	1.20	1.50	2.30	1.00	1.20	1.50	2.30
Calculation	BF	BF x 1.2	BF x 1.5	BF x 2.3	BF	BF x 1.2	BF x 1.5	BF x 2.3	BF	BF x 1.2	BF x 1.5	BF x 2.3

Source: JICA –LRT study report

Based on Table 15-118 and 15-119, following table calculated three alternative revenue options to cover full or part of O&M costs.

Table 15-120 Political, Social and Revenue based Analysis - Fare class 3 (Rs. Million)

Year	Revenue	O&M	Op. Loss or Profit	Sc 1 - 1.2		Sc 2 - 1.5		Sc 3 - 2.3	
				Revenue	Op.Loses or Profits	Revenue	Op.Loses or Profits	Revenue	Op.Loses or Profits
2012	4851.87	8647.65	-3795.78	5822.24	-2825.41	7277.805	-1369.845	11159.30	2511.65
2013	5423.29	10586.47	-5163.18	6507.95	-4078.52	8134.935	-2451.535	12473.57	1887.10
2014	5909.30	14830.10	-8920.8	7091.16	-7738.94	8863.95	-5966.15	13591.39	-1238.71
2015	6334.20	14048.77	-7714.57	7601.04	-6447.73	9501.3	-4547.47	14568.66	519.89
2016	6462.56	13396.29	-6933.73	7755.07	-5641.22	9693.84	-3702.45	14863.89	1467.60
2017	6477.09	14080.66	-7603.57	7772.51	-6308.15	9715.635	-4365.03	14897.31	816.65
2018	6684.36	19116.92	-12432.56	8021.23	-11095.69	10026.5353	-9090.39	15374.02	-3742.90
2020	7119.00	20061.80	-12942.80	8542.80	-11519.00	10678.5008	-9383.30	16373.70	-3688.10
2025	8333.31	24845.92	-16512.61	9999.97	-14845.95	12499.9642	-12345.96	19166.61	-5679.31
2035	11418.64	37162.67	-25744.03	13702.37	-23460.30	17127.964	-20034.71	26262.88	-10899.79

Source: 1. SLR Annual Performance Reports 2013, 2015 and 2017 and JICA – LRT Study Report

Note:
1. KV line O&M cost and capital cost included
2. From 2018 - 2024 O&M category 1 - based on cost estimate
3. From 2025 - 2034 O&M category 2 - based on cost estimate
4. From 2035 O&M category 3 - based on cost estimate

5. Capital cost distributed from2020 to 2024 - based on cost estimate
6. Above revenue and O&M analysis considered only fare class 3.
7. Sc. 1 – 2020 = 1.2, Sc. 2 – 2025 = 1.5, Sc.3 – 2035 = 2.3 calculated with fare class 3.

For easy reference to full or part of O&M cost recovery alternatives, Table 15-121 has been given annual percentage values. With comparison of three scenarios, Sc. 3 is the most feasible cost recovery approach with 2.3 time fare hike ratio.

Table 15-121 Operational Loses /Profits as a Percentage of Revenue

Year	Present Sc.	SC 1- 1.2	SC 2- 1.5	SC 3- 2.3
2012	-78.23	-48.53	-18.82	22.51
2013	-95.20	-62.67	-30.14	15.13
2014	-150.96	-109.14	-67.31	-9.11
2015	-121.79	-84.83	-47.86	3.57
2016	-107.29	-72.74	-38.19	9.87
2017	-117.39	-81.16	-44.93	5.48
2018	-185.99	-138.33	-90.66	-24.35
2020	-181.81	-134.84	-87.87	-22.52
2025	-198.15	-148.46	-98.77	-29.63
2035	-225.46	-171.21	-116.97	-41.50

Source: Economic and Financial Team

15.9.6.4 Competition Based Pricing Model

Competition-based pricing is a pricing method that makes use of competitors' prices for the same or similar product or services as basis in setting a price. Mainly this fare calculation was examined existing bus services fare in Sri Lanka. There are three classes, according the National Transport Commission. Fare of luxury buses is two times of normal bus fare, semi-luxury buses is 1.5 times of normal bus fare. This competitive based price setting was used recent bus fare calculation ratio to this study and below Table 15-122 given competitive based prices in each fare class. Table 15-123 shows the applicable ratios and method.

Table 15-122 Competition based Fare Calculation (Rs.)

Km.	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
1-10	40	58	68	93	20	29	34	46	10	14	17	23
11-15	40	58	68	93	20	29	34	46	15	22	25	35
16 - 20	60	87	102	139	30	43	51	70	20	29	34	46
21 - 25	80	116	136	186	40	58	68	93	25	36	42	58
26 -30	100	145	169	232	50	72	85	116	30	43	51	70
31 - 40	120	174	203	279	60	87	102	139	35	51	59	81
41 - 45	140	203	237	325	80	116	136	186	40	58	68	93
46 - 50	160	232	271	371	100	145	169	232	45	65	76	104
51 - 60	180	261	305	418	120	174	203	279	50	72	85	116
61 - 65	200	289	339	464	140	203	237	325	55	80	93	128
66 - 70	240	347	407	557	160	232	271	371	60	87	102	139
71 - 75	260	376	441	604	180	261	305	418	65	94	110	151
76 - 80	280	405	474	650	200	289	339	464	70	101	119	163
81 - 90	300	434	508	696	220	318	373	511	75	109	127	174
91 - 95	320	463	542	743	240	347	407	557	80	116	136	186
96 - 100	340	492	576	789	260	376	441	604	85	123	144	197

Source: Sri Lanka Railway Department and department of Census and Statistics

The Table 15-123 have been developed three alterative fare ratios under 3 fare classes for three scenarios as 2020, 2025 and 2035 respectively. Bench mark of this fare calculation directly used to analysis O&M cost recovery options in Table 15-124.

Table 15-123 Fare Calculation

Year	Fare Class 1				Fare Class 2				Fare Class 3			
	2012	2020	2025	2035	2012	2020	2025	2035	2012	2020	2025	2035
Ratio	1.00	1.45	1.69	2.32	1.00	1.45	1.69	2.32	1.00	1.45	1.69	2.32
Calculation	BF	BF x increase % x I			BF	BF x increase % x I			BF	BF x increase % x I		

Source: National Transport Commission of Sri Lanka
I - Inflation

One of key objective of the fare setting is to maximize SLR revenue stream, at least to recover full or part of the O&M cost. Railway passenger fare setting is very sensitive task and need to examine existing political interest, social factors and economic conditions. Therefore, entire fare setting exercise was avoided more extreme conditions and cases. The Table 15-124 illustrated the annual revenues under each fare setting scenario.

Table 15-124 Competition based Revenue and O&M Analysis - Fare class 3 (Rs. Million)

Year	Revenue	O&M	Op. Loss or Profits	Sc 1 - 1.45		Sc 2 - 1.69		Sc 3 - 2.32	
				Revenue	Op.Loses/ Profits	Revenue	Op.Loses or Profits	Revenue	Op.Loses or Profits
2012	4851.87	8647.65	-3795.78	7035.21	-1612.44	8199.66	-447.99	11256.34	2608.69
2013	5423.29	10586.47	-5163.18	7863.77	-2722.70	9165.36	-1421.11	12582.03	1995.56
2014	5909.30	14830.10	-8920.8	8568.49	-6261.62	9986.72	-4843.38	13709.58	-1120.52
2015	6334.20	14048.77	-7714.57	9184.59	-4864.18	10704.80	-3343.97	14695.34	646.57
2016	6462.56	13396.29	-6933.73	9370.71	-4025.58	10921.73	-2474.56	14993.14	1596.85
2017	6477.09	13396.29	-6919.2	9391.78	-4004.51	10946.28	-2450.01	15026.85	1630.56
2018	6684.36	19116.92	-12432.56	9692.32	-9424.60	11296.56	-7820.36	15507.71	-3609.21
2020	7119.00	20061.80	-12942.80	10322.55	-9739.25	12031.11	-8030.69	16516.08	-3545.72
2025	8333.31	24845.92	-16512.61	12083.30	-12762.62	14083.29	-10762.63	19333.28	-5512.64
2035	11418.64	37162.67	-25744.03	16557.03	-20605.64	19297.51	-17865.17	26491.25	-10671.42

Source: 1. SLR Annual Performance Reports 2013, 2015 and 2017

Note:
1. KV line O&M cost and capital cost included
2. From 2018 - 2024 O&M category 1 - based on cost estimate
3. From 2025 - 2034 O&M category 2 - based on cost estimate
4. From 2035 O&M category 3 - based on cost estimate
5. Capital cost distributed from2020 to 2024 - based on cost estimate
6. Above revenue and O&M analysis considered only fare class 3.
7. Sc. 1 – 2020 = 1.45, Sc. 2 – 2025 = 1.69, Sc.3 – 2035 = 2.32 calculated with fare class 3.

Table 15-125 highlighted level of O&M cost recoveries under each fare setting scenario. SC. 3 O&M cost recovery is higher than the SC. 1, SC. 2 and possible to recover major portion of O&M cost.

Table 15-125 Operational Loses/Profits as a Percentage of Revenue

Year	Present Sc.	SC 1- 1.45	SC 2- 1.69	SC 3- 2.32
2012	-78.23	-22.92	-5.46	23.18
2013	-95.20	-34.62	-15.51	15.86
2014	-150.96	-73.08	-48.50	-8.17
2015	-121.79	-52.96	-31.24	4.40
2016	-107.29	-42.96	-22.66	10.65
2017	-106.83	-42.64	-22.38	10.85
2018	-185.99	-97.24	-69.23	-23.27
2020	-181.81	-94.35	-66.75	-21.47
2025	-198.15	-105.62	-76.42	-28.51
2035	-225.46	-124.45	-92.58	-40.28

Source: Economic and Financial Team

15.9.7 Evaluation of Cases

The following four cases were evaluated under 3 scenarios and recommended fare setting are given in following Table 15-126.

Table 15-126 Evaluation of Cases

Item	Case 1 2020	Case 2 2025	Case 3 2035
Future Demand	1.2 times of normal fare	1.5 times of nornal fare	1.5 times of normal fare
JICA - LRT Proposal	1.2 times of normal fare	1.5 times of normal fare	2.3 times of normal fare
Base Bus Fare	1.45 times of normal fare	1.69 times of normal fare	2.32 times of normal fare
Inflation Based	1.3 times of normal fare	1.5 times of normal fare	2 times of normal fare

Table 15-126 represents the different price setting options under previous 3 studies as: future demand based under the STRADA model, JICA –LRT study and recently implemented bus transport pricing. In addition, this study examined cost plus inflation model, in association with transport sector annual average inflation rates (CCPI 2013 =100). In 2018 May, transport sector inflation rate was recorded as 4.3%. However, last five years annual inflation rates also examined against this figure and finally study team decided to use average transport sector inflation rate as 3.15% to avoid some extreme conditions, whilst considering political interest, social welfare and economic conditions.

According to above three evaluation cases, study team decided to examine impact level to the SLR O&M cost under ―with and without" project scenarios and details are given under each section. The Table 15-127 sumarises operational loses or profits as a percentage of revenue under ―with and without" project scenarios. Majority of SLR passengers are travelling on fare class 3 and particular fare ratios were applied to fare class 3 to analyze revenue and O&M costs.

Table 15-127 Comparison of Four Scenarios on O&M Recoveries

Year	Cost Plus Inflation Pricing Model				Future Demand Based Pricing Model			JICA – LRT Pricing Model			Competition Based Pricing Model		
	Present Sc.	SC 1- 1.3	SC 2- 1.5	SC 3- 2.0	SC 1- 1.3	SC 2- 1.5	SC 3- 2.0	SC 1- 1.2	SC 2- 1.5	SC 3- 2.3	SC 1- 1.45	SC 2- 1.69	SC 3- 2.32
2012	-78.23	-37.10	-0.19	0.11	-48.53	-18.82	-18.82	-48.53	-18.82	22.51	-22.92	-5.46	23.18
2013	-95.20	-50.16	-0.30	0.02	-62.67	-30.14	-30.14	-62.67	-30.14	15.13	-34.62	-15.51	15.86
2014	-150.96	-93.05	-0.67	-0.25	-109.14	-67.31	-67.31	-109.14	-67.31	-9.11	-73.08	-48.50	-8.17
2015	-121.79	-70.61	-0.48	-0.11	-84.83	-47.86	-47.86	-84.83	-47.86	3.57	-52.96	-31.24	4.40
2016	-107.29	-59.45	-0.38	-0.04	-72.74	-38.19	-38.19	-72.74	-38.19	9.87	-42.96	-22.66	10.65
2017	-117.39	-67.22	-0.45	-0.09	-81.16	-44.93	-44.93	-81.16	-44.93	5.48	-42.64	-22.38	10.85
2018	-185.99	-120.00	-0.91	-0.43	-138.33	-90.66	-90.66	-138.33	-90.66	-24.35	-97.24	-69.23	-23.27
2020	-181.81	-116.77	-0.88	-0.41	-134.84	-87.87	-87.87	-134.84	-87.87	-22.52	-94.35	-66.75	-21.47
2025	-198.15	-129.35	-0.99	-0.49	-148.46	-98.77	-98.77	-148.46	-98.77	-29.63	-105.62	-76.42	-28.51
2035	-225.46	-150.35	-1.17	-0.63	-171.21	-116.97	-116.97	-171.21	-116.97	-41.50	-124.45	-92.58	-40.28

Source: Study team calculation

The SLR has never at any point in recent history managed to recover its costs from revenues. At least SLR was unable to recover O&M cost during its recent history. The costs of railway investment are usually ―sunk” since they cannot be avoided or reversed once the investment has been delivered. Because railway assets usually have few alternative uses, particularly in the case of infrastructure and nature of entry barriers to the industry due to state monopoly. Therefore, SLR is operating under state subsidy to provide benefits to other economic sectors. The Table 15-126 highlights the O&M recoveries during 2012 to 2017 under the present scenario (Present Sc.). Designed O&M recovery scenarios are given in vertically from 2018, 2020, 2025 and 2035 and horizontally from 2012 to 2017 and 2018, 2020, 2025 and 2035 within the framework of SC 1 to SC 3. All vertical and horizontal scenario revenues are less than the O&M costs ―without” and ―with” KV line investment. Table 15-128 illustrated the O&M cost recovery percentages under each scenario and required state subsidy level to recover full O&M costs.

Table 15-128 O&M Cost Recovery Percentage and Required Subsidy Percentage

Pricing Model	O&M Cost Recovery %			State Funds Required %		
	SC 1	SC 2	SC 3	SC 1	SC 2	SC 3
Cost plus inflation pricing	10.59	99.36	99.77	89.41	0.64	0.23
Competitive pricing	30.92	54.93	94.32	69.08	45.07	5.68
JICA - LRT pricing	-5.19	35.85	92.94	105.19	64.15	7.06
Future demand based pricing	-5.19	35.85	35.85	105.19	64.15	64.15

Source: Study team calculation

15.9.7.1 Selection of Best Option

With detailed analysis of four pricing models and three scenarios, results are given in Table 15-127. Above table illustrates the relationship between pricing models and cost recovery possibilities. According to above table, SC 3 of cost plus inflation pricing model can be recover 99.77% of O&M cost by 2035 and 0.23% of state subsidy required to recover O&M cost under the given fare level in 2035. Second best option is SC 3 of competitive pricing model and third best option is SC 3 of JICA – LRT pricing model. However, government required to provide 5.68% and 7.06% subsidies to recover full O&M cost respectively.

15.9.7.2 Rail industry subsidies in other countries

The Directorate General for Mobility and Transport of the European Commission, recently discussed the level of rail passenger transport subsidies of their member countries through ―Study on the Cost and Contribution of the Rail Sector” Final Report of September 2015. This report highlighted the level of passenger transport subsidies and mainly included Belgium, Bulgaria, Denmark, Germany, Spain, France, The Netherlands and Finland out of 28 European Countries. Except few countries in the world, majority of them are subsidizing rail for rail industry.

15.9.8 Railway Fare Setting and Development of New Formula

According to pure economic theory, to maximize overall economic welfare for the whole community, the most economically efficient pricing approach would be for prices to equal the marginal social costs of railway services. As a practical matter, no railway in the world does this for the following reasons.

- In economic theory, the concept of ‗margin' is a very small unit of output, such as a single passenger seat-km. or wagon-km. of freight.
- Railway costs that are variable, particularly in the short term, are less than total costs, so that pure marginal cost pricing will lead to financial losses. Even long-run marginal cost pricing is insufficient to recover all railway running costs, when all fixed common and joint costs are included.
- In virtually all countries, railways' main transport competitors do not include external costs in their prices. This negates the assumption underlying the economic theory—to charge social costs only in the rail sector would create perverse outcomes.

In practice, there is no prescribed or standard form of market-based pricing for railways. Good railway managements adapt pricing practices to their markets, customers, institutional arrangements, pricing regulations, and the social and economic norms in which they operate. (Railway Reform: A Toolkit for Improving Rail Sector Performance. World Bank 2017)

15.9.8.1 International cases on railway fare setting

Prior to develop the fare setting formula, study team reviewed and analyzed different fare setting methodologies in different countries used to fare adjustment. Some of international literature and news articles were useful to understand the fare setting exercise, its impacts to ridership and few of extracted findings are highlighted below;

- Hong Kong: The fares of MTR have increased under the fare adjustment mechanism annually since 2010, with a cumulative increase of 25.2% until 2016. This was broadly in line with the consumer price index changes over the same period, according to a Hong Kong government reports. (The Hindu Business Line).
- Singapore: Public Transport Council decides the fare adjustment, after the transport operators seek a fare change based on the principle of balancing the twin objectives of ―keeping our public transport fares affordable and ensuring long term viability". Taking into account household incomes, Singapore devises mechanisms to meet its principle of keeping fares affordable for lower-income households. (The Hindu Business Line).
- Australia: Following the 2009 election, a five year fare strategy was launched to build the public transport network and increase fare box cost recovery from 25% to 30%. Individual go card fares were planned to rise by 16% to 21%, and paper tickets by 13% to 42%. This was in contrast to previous fare increases which had been in line with CPI, roughly 4% at that time. (Ticket to Ride – Australia 2016)

- Malaysia: The Public Transport Commission of Malaysia announced an increase in public transport fares and it would lead to an improvement in the quality of service. The fare increase took into consideration various factors, including operational costs, maintenance costs and salaries. (Malay Mail – 17 April 2015)
- Egypt: Greater Cairo Transport Regulatory Authority in Egypt works under the umbrella of the Ministry of Transport. The Greater Cairo Region has a metro service which is the best mode of transport for big metropolis but its construction costs are really high and this is letting slow its development. After various months of speculated talk of ticket increases, the surge in prices was confirmed to come into effect. The first nine stops will cost EGP 3 while an additional EGP 2 will be added for seven more stations (totaling to EGP 5). A full line of stations, from start to finish, will cost a maximum fare of EGP 7. (Egyptian Street. 11 May 2018).
- India: The Terms and Conditions for pricing formula as per Indian Government Order 30-09-2000: Whenever, there is decrease in the diesel price and relevant prices, the fare shall also be decreased. Fare increase on account of diesel or relevant prices hike. The additional revenue realization on account of revised fares shall not exceed the total increased costs. (Bangalore Metropolitan Transport Commission, December 2013).

After 2012, SLR was unable to implement new rail fare structure and in 2018, five member committees presented a new rai fare adjustment report to political authority. This document is still not published and not taken any action to implement new proposal. The Table 15-129 illustrated the CPI based public transport fare adjustment procedures of five countries and presented as fare setting international bench mark.

Table 15-129 Fare Setting International Benchmark

Country	Fare Setting	Discription
India	CPI Based	Paralel to CPI fluctuation
Malysia	CPI Based	Paralel to CPI fluctuation
Singapore	CPI Based	Max 0.5 Weighted Avg granted to CPI (Annually)
Hongkong	CPI Based	4.2% Annual (for 6 years = 25.2%)
Austrelia	CPI Based	Last fare hike is 4% with CPI

Source: The Hindu Business Line, Ticket to Ride – Australia, Malay Mail, Bangalore – MTC.

15.9.8.2 National Competitive Transport Operating Cost and Fare Setting Benchmark

The National Transport Commission (NTC) is entrusted to implement the National Fare Policy which was approved by the Cabinet in 2002. Accordingly, NTC is authorized to revise annual bus fares in relation to 12 components of operating cost index which is formulated in terms of National Bus Fare Policy. However, Annual Bus fare revision was not done in 2014 due to non-change of fuel prices as at scheduled date for bus fare revisions. (Source: National Transport Statistics 2016 | Volume V). Following Table 15-130 shows the operating cost index

Table 15-130 Bus Operating Cost Index (Rs. / Km.)

Cost Component	2009	2010	2011	2012	2013	2014	2015	2016	2018	Annual Average)
Total Cost	70.92	71.29	76.29	91.57	97.99	98.07	89.99	95.12		
Cost Increase Rs.	3.53	0.37	5.37	15.28	6.42	0.08	-8.01	5.15		
Cost increase %	5.30	0.53	7.57	20.03	7.01	0.08	-8.17	5.73		
Actual Increase %	5.30	NR	7.60	20.00	7.00	NR	-8.20	6.00	12.50	5.02

Source: National Transport Statistics 2016, Volume V

NR – Nor Revised

According to Table 15-130, annual average increase of bus operating cost is Rs. 5.02 per Km. the Table 15-131 given historical annual fare revision details.

Table 15-131 Annual Fare Revision of Bus

Year	Fare Rivision %
2009	5.3
2010	Not Given
2011	7.6
2012	20
2013	7
2014	Not Given
2015	-8.2
2016	6
2017	Not Given
2018	12.5
Annual Average	5.02

Source: National Transport Statistics2016, Volume V

With comparison of Table 15-130 and Table 15-131, annual operating costs were increased and amount is equal to annual bus fare increase. Finally, above fare setting formula is based on CPI in association with current market prices and applicable to bus transport industry. Therefore, this competitive benchmark fare formula can be applied to rail passenger fare revision with some modifications.

15.9.8.3 Fare Setting Initiatives for New Rail Project as Benchmark

Urban Transport System Development Project for Colombo Metropolitan Region has taken and initial steps to develop fare setting formula. Some of assumptions were used to develop the formula and used 2012 fare structure also. Fare changing rate is set with consideration of future development plans of the railway. In addition JICA – LRT project recommended fare settings under 3 scenarios and mainly based on demand and base fare. Another fare setting approach can be discussed in association with bus fare setting policy.

The Table 15-132 discussed the four fare setting approaches and following four alternative approaches can be considers as bench mark of rail fair setting in Sri Lanka.

Table 15-132 Fare Setting Alternatives

Item	Case 1 2020	Case 2 2025	Case 3 2035
Future Demand	1.2 times of normal fare	1.5 times of nornal fare	1.5 times of normal fare
JICA - LRT Proposal	1.2 times of normal fare	1.5 times of normal fare	2.3 times of normal fare
Base Bus Fare	1.45 times of normal fare	1.69 times of normal fare	2.32 times of normal fare
Inflation Based	1.3 times of normal fare	1.5 times of normal fare	2 times of normal fare

Source: JICA – LRT Study, ComTransStudy and recent bus fare hike.

15.9.9 Components of Rail Fare Setting Formulae for Sri Lanka Railway

15.9.9.1 Sri Lanka Railway

As per the section 6 of the SLR Act (Act No. 60 of 1993), explains the Powers and duties of the Railways Authority, which highlights the enforcement of appropriate tariff, rates and fares for railway transportation as below:

> ―To fix tariffs, rates and procedures for the carriage by it of goods and persons by rail in such manner as may be appropriate to ensure the competitiveness of the services provided by it with the services provided by other modes of transport;

According to the provisions of the section 6, it is necessary to maintain the competitiveness of railway pricing compared to other modes of transportation. Accordingly, proposed fare setting formula is based on competitiveness, cost recovery and following section describes the procedures.

15.9.9.2 Selection of Benchmark Indices

Five benchmark indices were selected to fare setting exercise as measurement tools. All the selected benchmark indicators are compatible with ultimate target of fare setting and timely available under the reliable official sources given in following Table 15-133.

Table 15-133 Benchmark Indices

Index	Source	Base Year
Consumer Price Index	Dept. Census & Statistics	2013
Wage Rate Index	Central Bank of Sri Lanka	2012
Energy Index	Dept. Census & Statistics	2013
Labour Productivity ($W = MP_L$ x P)	Central Bank of Sri Lanka	2010
Transport Network Capacity Factor (Bus + Train)	Central Bank of Sri Lanka	Annual

Source: Department of Census and Statistics, Central Bank of Sri Lanka and Ceylon Petroleum Corporation.

15.9.9.3 Consumer Price index (CPI)

According to the Department of Census and Statistics of Sri Lanka, ―CPI is an indicator to measure the changes in the general level of consumer prices and used as one of the key indicators of inflation. CPI is also used for socio-economic analysis and policy purposes. CPI is more comprehensive indicator in the overall inflation in a country. The year 2013 is the base period for CPI (2013 = 100) and covers all island and 11 main categories. The Table 15-134 shows the CPI behavior from 2014 to 2018.

Table 15-134 CPI Behavior from 2014 to 2018

Year	CCPI (2013 = 100)	CPI Change %
2014	105.1	
2015	107.4	2.2
2016	111.7	4.0
2017	119.0	6.5
2018*	122.1	2.6

Source: Department of Census and Statistics
* Estimated with 2018 January –May

15.9.9.4 Wage Rate Index

Wage rate index developed and calculated by Central Bank of Sri Lanka. Wage rate index is an indicator to measure the changes in the nominal wage levels on annual basis and it is directly link with the national inflation levels. The year 2012 is the base period for wage rate index (2012 = 100). Wage rate index indicates the signs of wage pressure in the economy. The Table 15-135 shows the behavior of wage rate index from 2016 to 2018.

Table 15-135 Wage Rate Index Behavior from 2016 to 2018

Year	WI National	WI Change %
2015		
2016	148.8	
2017	155.3	4.4
2018	160.6	3.4

Source: Central Bank of Sri Lanka
2018 values estimated with January –May

15.9.9.5 Energy Index

Energy index measure the changes in the energy price levels on annual and monthly basis. Energy index is calculated by Department of Census and Statistics in association with CPI. Weighted average is for the Energy index is 32% and represent highest portion. Base year for the index is 2013. (2013 = 100). The Table 15-136 shows the behavior of Energy Index.

Table 15-136 Energy Index Behavior from 2014 to 2018

Year	Energy Index	Index Change %
2014	108.9	
2015	110.3	1.3
2016	110.1	-0.2
2017	110.2	0.1
2018	110.8	0.5

Source: Department of Census and statistics.
2018 values estimated with January –May.

15.9.9.6 Labour Productivity

Labour productivity measures the marginal productivity of labour (MPL) in terms of wage in 2010 prices. Labour productivity can measure as: W = MPL × P = Rs/Hour. This indicator was specially applied for the fare setting of SLR, because SLRs‘ MPL is smaller than other operators. Labour productivity data extracted from Annual reports of Central Bank. The Table 15-137 shows the behavior of labour productivity during past few years.

Table 15-137 Labour Productivity Behavior from 2014 to 2017

Year	Labour Productivity (Rs./hour)	%
2014	410.2	
2015	462.09	12.6
2016	463.56	0.3
2017	458.29	-1.1

Source: Central Bank of Sri Lanka (2018 data is not available)

15.9.9.7 Transport Network Capacity Factor (TNCF)

The TNCF was extracted through literature review and very recently introduced to the market by Singapore government. Main objective of the incorporate TNCF is maximize the fare setting rate to minimize the operation losses. (Extracted from Singapore Transport Authority).

Applicable data to the TNCF is available on annual basis under the Central Bank annual reports. The TNCF can be calculated as: percentage change in operated train Km. divided by percentage change in train passenger Km. multiplied by 0.5. Same procedure should be applied to bus transport and final formula will be:

TNCF = 0.5 × ΔOPT (Km)/ Δ PKm. T + 0.5 × Δ OPB (Km.) / Δ PKm. B

Where;

TNCF	- Transport Network Capacity Factor
OPT	- Operated Trains (Km.)
PKm. T	- Passenger Km for Train
OPB	- Operated Bus (Km.)
PKm. B	- Passenger Km. for Bus
0.5	- Equal Weighted Averages granted for Bus and Train as public transport mode (Weighted average can be change according to the requirement)

Following Table 15-138 shows the CBSL data for 2 years period.

Table 15-138 Transport Network Capacity Factor (TNCF) – Sri Lanka Data

Operator	Description	2016	2017
SLTB	Operated Km. (Million)	560.12	448.10
	Passenger Km. (Million)	16100.00	15800.00
Private	Operated Km. (Million)	1000.00	979.00
	Passenger Km. (Million)	50800.00	49580.00
Total	Operated Km. (Million)	1560.12	1427.10
	Passenger Km. (Million)	66900.00	65380.00
Train	Operated Km.	11921000.00	11679000.00
	Passenger Km.	7413000000.00	7945000000.00

Source: Central Bank of Sri Lanka – 2017 Annual Report

Application of CBSL 2016 and 2017 data and obtained following values.

Table 15-139 TNCF Calculation Procedure

Operator	Transport Sector Indicator	2016	2017	Δ = (2017 -2016)	ΔOPB and ΔOPT (Km.)	Δ PKm. T and Δ PKm. B
SLTB	Operated Km. (Million)	560.12	448.10	-112.02		
	Passenger Km. (Million)	16100	15800	-300.00		
Private	Operated Km. (Million)	1000	979	-21.00		
	Passenger Km. (Million)	50800	49580	-1220.00		
Bus Total	**Operated Km. (Million)**	**1560.12**	**1427.10**	-133.02	-133.02	
	Passenger Km. (Million)	**66900**	**65380**	-1520.00		-1520
Train Total	Operated Km.	11921000	11679000	-242000.00	-242000.00	
	Passenger Km.	7413000000	7945000000	532000000.00		532000000

Source: Central Bank of Sri Lanka – 2017 Annual Report

Finally following TNCF value obtained from the formula as below:

TNCF = 0.5×ΔOPT (Km)/ Δ PKm. T + 0.5 × Δ OPB (Km.) / Δ PKm. B

TNCF = 0.043529 - Total Transport Network Capacity Factor.

15.9.9.8 Calculation of Benchmark Indices

To calculate the benchmark indices, following weighted averages were granted, according to the importance of each index. However total index values should not exceed 1, equal to 100.

CPI +0.5 (CPI represents overall national economy and price levels)

WI +0.4 (WI represents the change in nominal wage levels)

EI +0.1 (EI represents the change in fuel prices)

MPL - 0.1 (Represent Marginal Productivity of Labour in national economy - Adjustable factor)

TNCF (+ or -) (TNCF can be change)

The Table 15-140 shows the benchmark indices values.

Table 15-140 Benchmark Indices and Values

Year	CPI (2013 =100)	Δ%	WI - National (2012 = 100)	Δ%	EI (2013 = 100)	Δ%	Productivity (W = MPL x P)= Rs/Hour (2010 = 100)	Δ%	TNCF
2014	105.1				108.9		410.2		
2015	107.4	2.2			110.3	1.3	462.09	12.6	
2016	111.7	4.0	148.8		110.1	-0.2	463.56	0.3	
2017	119.0	6.5	155.3	4.4	110.2	0.1	458.29	-1.1	0.0435
2018	122.1	2.6	160.6	3.4	110.8	0.5	460.92	0.6	

Note: 2018 (W = MPL × P = 460.92) Estimated with 2 year averages

TNCF - Transport Network Capacity Factor

Therefore, 2017 benchmark indices value were calculated as below:

2017 Benchmark Indices Value = 0.5 ΔCPI % +0.4 Δ WI (N)% + 0.1 ΔEI% - 0.1% Δ MPL% + TNCF

2017 Benchmark Indices Value = 5.18%

According to the benchmark value, 2017 SLR fare should be increase with 5.18%. (Approximately 5%)

Final Calculation = BF + (BF × 5.18%)

Ex: BF = Rs. 10,

2017 Fare hike = 5.18% or 0.0518

2017 Fare = Rs. 10.50

15.9.9.9 Fare Calculation Formula to Periodic Revision of SLR Passenger Fare

Based on benchmark indices values, annual SLR fare calculation formula is given in following table.

Table 15-141 Annual Fare Calculation Formula

Year	Fare Calculation Formulae
2017	2012 BF +(2012 BF x 2017 IV)
2018	2017 BF + (2017 BF x 2018 IV)
2019	2018 BF + (2018 BF x 2019 IV)
2020	2019 BF + (2019 BF x 2020 IV)
2021	2020 BF + (2020 BF x 2021 IV)
2022	2021 BF + (2021 BF x 2022 IV)
2023	2022 BF + (2022 BF x 2023 IV)
2024	2023 BF + (2023 BF x 2024 IV)
2025	2024 BF + (2024 BF x 2025 IV)

Source: Economic and Financial Team in association with national benchmark indices
IV = Indices Value

With reference to fare calculation formula given in above table, following example was generated with constant indices value assumption. However, indices values are subjected to change on year by year with change on annual CPI change, Annual wage rates, Annual fuel prices etc.

Table 15-142 Annual Fare Calculation Example

Year	Base Fare (Rs.)	Indices Value*	Annual Fare (Rs.)	Adjusted Annual Fare (Rs.)
2012	10.00	0.0000	10.00	10.00
2017	10.00	0.0518	10.52	10.50
2018	10.52	0.0518	11.06	11.00
2019	11.06	0.0518	11.64	11.50
2020	11.64	0.0518	12.24	12.00
2021	12.24	0.0518	12.87	12.50
2022	12.87	0.0518	13.54	13.50
2023	13.54	0.0518	14.24	14.00
2024	14.24	0.0518	14.98	14.50
2025	14.98	0.0518	15.75	15.50

* Indices values are subjected to change on year by year.
(0.518 is assumed value for 2017 and used for 2018 to 2025 period)

15.9.9.10 Fare Setting for Goods and Freight

Sri Lanka has fast growing goods and freight transportation market and private sector has a leading role. However, due to the lack of competition, SLR is gradually losing its place. During last decade SLR was unable to fulfill required infrastructure investments to attract goods and freight transportation to SLR. Following table shows the current revenue and cost for freight transportation.

Table 15-143 Freight Revenue vs. Cost

Mode of Transport	Revenue	Cost
Rail	3.75	0.80
Container	6.20	3.00
Lorry	9.00	4.80

Source: 1. Daily Mirror 08-10-2014
2. SLR Administration Report 2016

Note: 1. SLR freight rates revised on 01. November 2007
2. Revenue / Cost per Ton per Km.

According to the above table, SLR has the highest competitive advantages, but not an extracted market share due to lack of competition and lack of organizational arrangements. Cost per SLR freight Km. is Rs. 0.80 and revenue is 3.25 or 4 times higher than the cost. On the other hand net revenue is Rs. 2.45 per Km.

This section briefly describes the proposed fare structure for parcel and bulk transportation for SLR.

15.9.9.11 Fare Setting for Goods and Parcels

The Table 15-144 highlights the current fare rates for parcels.

Table 15-144 Railway Parcel Rates (Rs./Kg.)

Distance	Weight	Charge	Charges for Addl. 10 Kg.
0-25	50	50	15
25-40	45	50	16
25-40	50	53	**16**
40-55	40	50	17
100-115	25	50	21

Source: Sri Lanka Railway Department
Note: Selected only few cases for analytical purpose

The Table 15-145 shows the revised fare for parcels, through new fare setting formula and this table represents few true cases as examples.

Fare Setting formulae:- 0.5 ΔCPI % +0.4 Δ WI (N)% + 0.1 ΔEI% - 0.1% Δ MPL% + TNCF

Indices values are subjected to change on annual basis, because CPI, energy prices, wage rates and other variables also can be change. For this calculation, 2017 indices value applied for 2018 to 2020. According to new fare setting formula, 2018 parcel rate is increased by 6%, 2019 = 10% and 2020 =16% parallel to 2017 price. However, annual proposed incremental value is 5.3 %.

Table 15-145 Revised Parcel Rates (Rs./ Kg.) with New Formula

Distance (Km.)	Weight (Kg.)	Current Fare (Rs.)	Indices Value*	Rivised Fare (Rs.)		
				2018	2019	2020
0-25	50.00	50.00	0.0518	53	55	58
25-40	45.00	50.00	0.0518	53	55	58
25-40	50.00	53.00	0.0518	56	59	62
40-55	40.00	50.00	0.0518	53	55	58
100-115	25.00	50.00	0.0518	53	55	58

Source: Current rates extracted from SLR website

15.9.9.12 Fare Setting for Bulk Transportation

The Table 15-146 illustrated the current bulk fare structure for low and up country. There are two class and two different rates.

Table 15-146 Railway Bulk Charges (Rs./ Km.)

Class	Below Rambukkana*	Above Rambukkana**
Class 1	3.75	5.25
Class 2	4.50	6.00

Source: Current rates extracted from SLR website

Table 15-147 and Table 15-148 presented proposed new structure for low lying are and up country respectively.

Table 15-147 Revised Bulk Charges (Rs./ Km.) with New Formula - Low Lying Area

Class	Current Fare (Rs./Km.)	Indices Value*	Revised Fare (Rs./Km.)		
	Below Rambukkana*		2018	2019	2020
Class 1	3.75	0.0518	3.94	4.15	4.35
Class 2	4.50	0.0518	4.69	4.90	5.10

Source: Current rates extracted from SLR website

The new fare setting formulae represents new fare rates as 5% increase in 2018, 10.6% increase in 2019 and 16% increase in 2020 parallel to 2017 price. Annual incremental value is 5.3%.

Table 15-148 Revised Bulk Charges (Rs. / Km.) with New Formula – Up Country

Class	Current Fare (Rs./Km.)	Indices Value*	Revised Fare (Rs./Km.)		
	Above Rambukkana*		2018	2019	2020
Class 1	5.25	0.0518	5.44	5.65	5.85
Class 2	6.00	0.0518	6.19	6.40	6.60

Source: Current rates extracted from SLR website

15.9.9.13 Fare Setting for Petroleum Product Transportation

Mainly SLR is transporting petroleum products to all destinations. There are two petroleum products as: Aviation Sprits (Limited destinations) and other petroleum products including Petrol, Diesel, Gasoline and other oils. There are two fare categories as above low lying areas and up country, as well as there are discriminated fare rates on product basis. The Table 15-149 describes the current fare rates under each category and product basis. Table 15-150 to 15-152 shows current fare setting for other petroleum products.

Table 15-149 Railway Charges for Petroleum Products (Rs./ Km.)

Product	Below Rambukkana*	Above Rambukkana**
Aviation Sprit	6.00	
Other Petrolium Products	4.50	5.25

Source: Current rates extracted from SLR website

Table 15-150 Revised Charges for Petrolium Products (Rs./ Km.) with New Formula – Low Lying Area

Product	Current Fare (Rs./Km.)	Indices Value*	Revised Fare (Rs./Km.)		
	Below Rambukkana*		2018	2019	2020
Aviation Sprit	6.00	0.0518	6.19	6.40	6.60
Other Petrolium Products	4.50	0.0518	4.69	4.90	5.10

Source: Current rates extracted from SLR website

Table 15-151 Revised Charges for Petroleum Products (Rs./Km.) with New Formula–Low Lying Area

Product	Current Fare (Rs./Km.)	Indices Value*	Revised Fare (Rs./Km.)		
	Below Rambukkana*		2018	2019	2020
Aviation Sprit	6.00	0.0518	6.19	6.40	6.60

Table 15-152 Revised Charges for Petroleum Products (Rs./Km.) with New Formula–Low Lying Area

Product	Current Fare (Rs./Km.)	Indices Value*	Revised Fare (Rs./Km.)		
	Below Rambukkana*		2018	2019	2020
Other Petrolium Products	5.25	0.0518	5.44	5.65	5.85

Source: Current rates extracted from SLR website

15.9.10 Key Performance Indicators

This section briefly discussed the key performance indicators for SLR.

Benchmarking is the process of comparing performance of one entity to the performance of other entities to identify best practices and opportunities for improvement. (World Bank 2017). Mainly development of key performance indicators were based on revenue maximization of SLR.

Table 15-153 Key Performance Indicators

Key Performance Indicator	Calculation
Average Fare	1. Passenger Revenue/Passenger-km.
Average Tariff	2. Freight Revenue/Ton-Km.
Average Passenger Subsidy	3. Passenger Subsidy/Passenger-Km.
Operating Ratio	4. Operating Costs/Operating Revenue
Labor Share of Revenue	5. Total Wages/Total Revenue
Employee Productivity	6. (Passenger-Km. + Ton-Km,)/ Employee
Operational Sustainability	7. (Operating Expenses— Depreciation)/Revenue
Working Capital Ratio	8. (Operating Expenses— Depreciation)/Revenue

15.9.11 Proposed Institutional Arrangements to Periodic Fare Adjustments

To prepare an institutional arrangement, Economic and Financial Team has been reviewed recent project documents including JICA – LRT final report, ComTrans final report and JICA funded ―Preparatory survey for new integrated urban public transport system introduction project – Final Report" and existing SLR institutional arrangements. Furthermore, Economic and Financial Team reviewed institutional arrangements of other external organizations, including National Water Supply and Drainage Board, Ceylon Electricity Board, Ceylon Petroleum Corporation, Public Utility Commission of Sri Lanka, National Transport Commission etc. on fare adjustment subject. In addition, the team reviewed future transport sector development projects and stakeholders, Public Private Partnership possibilities and existing transport administrative structure. Mainly Economic and Financial Team identified applicable five pillars to institutional arrangement for fare setting and periodic review.

- Policy area
- Planning area
- Implementation area
- Monitoring aspect
- Regulation aspects

According to above details, there are defined responsibilities and delegated authority among stakeholder agencies. Hence, preparation of institutional arrangements to periodic fare review and adjustment is not a single or isolated task. Therefore, Economic and Financial Team has been decided to prepare separate comprehensive report on this subject as this is beyond KV Line feasibility study.

15.9.12 Conclusion

This analysis is based on existing cost data of KV Line, revenue and cost data of SLR and findings of other feasibility studies. Fare setting for above subgroups are time taking exercise and need to study industry competitors, dominant price leaders, market share and competitive prices and industry, entry barriers, etc. All the ―with project" O&M costs, revenues and fares will be subjected to change in the future with new estimates and decisions. Finally, SLR fare setting must be focused on political interest, social factors, economic conditions and transport sector other variables rather costs alone. In most cases, change had been slow, due in part to confusion about which functions should be managed by the Ministry and which by the SLR. It is recommended to remove restrictions on competing modes, tax them appropriately and limit subsidies to railways to uplift cost recovery mode by giving more flexibility to take commercial decisions. Develop capacities in existing railway staff and bring in new management and marketing skills more appropriate to commercial operations. Ensure that investment projects aim to serve the customer or operating needs so as not to become white elephants. A periodic review of performance of all sectors and staff is also required. Government should allow SLR to start projects which gives process of managerial and structural transformation. Hence, structural transformation and new institutional arrangement are required for commercial operations as a commercial establishment. The following section outlines the techniques for railway restructuring:

- A Strategic Plan that relates the restructured railway enterprise to the broader political, social, and economic context within which it will function and addresses major public policy options;

- A Contract Plan that defines specific commitments and obligations flowing from the Strategic Plan that government and the railway enterprise formally accept as their respective responsibilities;
- A railway Management Plan that establishes an organizational structure, functional responsibilities, and performance measures for effective internal management control, in light of the requirements imposed by the decision to operate as a commercial enterprise;
- An "Enabling Actions" Plan to list necessary legislative, legal, and administrative changes to carry out planned restructuring. ―Optins for Reshaping the Railway" addressed issues involved in breaking up the historically monolithic railway institution, for example by creating tenant operators that paid for access, or even for infrastructure separation—an independent infrastructure agency and all operators pay for access.

Finally, the SLR need to open the transport market to competition, both in and eventually for provision of rail services and railways into a mold of separated infrastructure with competition in freight and long-haul passenger markets and competition for suburban and regional passenger markets. In addition, SLR necessary to open and expand private sector role in railway services based on public-private partnerships.

15.10 Summary, Conclusions and Policy Recommendations

This section presents the summary, conclusions and possible policy recommendations for the KV Line development from Maradana to Avissawella.

15.10.1 Summary

Section 1 of this chapter introduces Sri Lankan Railway and provides justifications for the development of KV Line from Maradana to Avissawella as a modern state-of-art railway line with many infrastructure developments with an elevated option for Maradana to Mapalla at Kottawa. First, this section dealt with an overview, history, the current poor condition, and the future prospects for the Sri Lankan Railway. Secondly, this section presents economic, commercial and demographic profiles of KV Railway Line with the justification of Line Development as an alternative solution to burning transport issues in the Colombo city.

Section 2 of this chapter presents other preliminaries such as establishing context for KV Line Economic and Financial Feasibility Analysis. First, it deals with transport sector issues and the Government policy objectives. Secondly and thirdly, it presents Sri Lanka‘s motorization growth trend, the relationships between the transport sector and macro-economic key parameters. Fourth, it presents major assumptions and verification/control parameters necessary for analysis. Finally, a brief is presented on demand estimation analysis.

Section 3 of this chapter presents the direct/indirect benefit identifications and valuation techniques used for economic and financial analysis. Initially, it identifies direct economic benefits under various headings such as vehicle operation costs reduction, travel timesaving‘s for passengers and freights, reduced rail/road accidents and reduced environmental pollution. Next, it discusses in depth many indirect economic benefits. Finally, the main techniques used for the economic and financial evaluation of the project are presented.

Section 4 of this chapter deeply analyzes capital, operation, and maintenance costs in a more detailed manner. Firstly this chapter presents basic terminology, definitions, and life cycle approach and analysis horizons. Secondly, capital, operation, and maintenance costs are deeply discussed as separate items. Finally, operating & maintenance costs presented per passenger and kilometer.

Section 5 of Chapter 15 presents financial and sources of fund analysis with various project life spans of 30, 50, 75 and 100 years. First, it presents a brief on an investment plan and sources of funds analysis. Secondly, it deals with various measurements related to financial analysis. Thirdly, the traffic demand forecast & revenue, operating & maintenance, and replacement costs are presented. The fourth section of this chapter presents the financial viability aspect under the operating self-sufficiency, financial net present value and financial internal rate of return and payback period. Finally, it deals with the recovery of investment cost and cost of funding and comprehensive financial sensitivity analysis with changing various key financial indicators.

Section 6 of this chapter deals with very comprehensive economic analysis covering sensitivity aspects. The first part of this section, presented the concept, approach, and basic assumptions. The second part presented conversion factors and EIRR, ENPV and C/B Ratio calculations. The third section of this chapter deals with sensitivity analysis. Finally, some concluding remarks are presented.

Section 7 of Chapter 15 presents a very detailed benefits distribution and poverty impact analysis. The first part of this section presents poverty-related various definitions, regional variation of poverty, etc with special emphasis on KV line‘s direct and indirect impact area. Second, this section presented project benefits and distribution under the headings of various benefits. Finally, Poverty Impact Ratio calculations by DS wise and concluding remakes presented.

Section 8 of Chapter 15 developed a very detailed Project Impact Monitoring Framework with many baseline performance indicators. After a brief introduction to PIMF, it dealt with various definitional issues of project impact, outcome and outputs with real contributions of KV line development under these three headings. Finally, this section presents supportive data and baseline photos of KV line to show the current pathetic situation.

Section 9 of this chapter presents the railway fare structure and periodic fare adjustments with new admin structures to implement these tariff changes

The final section of this chapter presents the summary and conclusions and after followed appendix which included Sri Lankan economic report and important data tables.

15.10.2 Conclusions

Investment cost of the project is estimated to be USD 1.42 billion. The construction cost of the project approximately consists of half of the investment cost (52.66%), whereas the rolling stock accounts for 18% of the investment cost and elevation 30%. Modernization costs such as electrification, signaling & telecommunication also account for about 9.38% of the investment. Operating & Maintenance cost of the project consists of manpower cost, energy cost, and maintenance cost. Maintenance cost accounts for about 54% of the O&M cost while about 29% is attributable to energy cost. Manpower cost is relatively small with a 19% share of the total cost. O&M costs per passenger are in the range of LKR 3.80 to 4.35. Further O&M costs per passenger kilometer are fairly stable over the project period where the cost is between LKR 2.00 to 2.29. Accordingly setting prices higher than LKR 2.29 per passenger kilometer will ensure the recovery of O&M costs of the project. Overall at the feasibility stage, these costs subject to + or – 10% or more error margin and after detailed design are overall these costs figures are re-verified.

Under the financial analysis, different alternative sources of funding are considered such as Asian Development Bank (ADB) loan, loans from local banks, foreign commercial loans and funds of Sri Lankan government along with the cost of funding (Weighted Average Cost of Capital-WACC). Eighty percent funding from ADB loan and twenty percent government funding result a WACC of 3.04% excluding inflationary effects (Real WACC). Mixing with other sources in different proportions yields a WACC ranging from 2,77% to 4.25%. WACC of 3.04% is considered as the base case for evaluation where the effects of change in WACC are discussed under sensitivity analysis.

When evaluating further whether the project could recover its investment cost along with the cost of funding (WACC), it could be observed that project cash flows are not sufficient to fully recover the investment cost and cost of funding as evident by negative Financial Net Present Value (FNPV) of USD 981.92 million and negative Financial Internal Rate of Return (FIRR) of 3.84%. Even though the Project cash flows are not sufficient to fully recover the total investment and associated cost of funding, it could recover approximately 21.26% of the investment cost and related cost of funding. Accordingly, the project is able to recover certain components of investment costs such as rolling stock that accounts for 18.39% of the total investment (excluding price contingencies).

Despite the fact that the initial evaluation considers an economic life of 30 years in line with international practices, higher life spans of several assets such as bridges, flyovers, tracks, buildings, embankment, etc. are suggested by Sri Lankan standards for construction (based on Euro codes). When higher life spans are considered through a sensitivity analysis, 50 years‘ lifetime provides better financial indicators such as better FNPV and investment cost recovery. Accordingly, FNPV improves with 50 years of a lifetime but remains negative. Moreover, the investment recovery rate improves to 27.41% compared to the base case recovery rate of 21.26%. This recovery rate is sufficient to recover the aggregated investment cost and associated cost of funding pertaining to land acquisition and rolling stock costs (23.60% of the investment excluding price contingencies). Recovering the rest of the investment costs and paying the related cost of funding could not be made with project cash flows generated thus the government needs budgetary allocation from common public funds for the same which is the usual case with railway projects in many countries.

KV line requires a government subsidy of 290.27% from the operating & maintenance cost (at constant price) of each year to fully settle the investment cost and cost of funding. This total subsidy amounts to 150% of the cumulative revenue of the project. The current net cash flows of the project are sufficient to recover USD 289.08 million of investment cost and related cost of funding without any subsidies. This amount is 21.26% of the total investment (excluding price contingencies) for a 30-year life span.

However, O&M costs and Replacement costs can easily be recovered with railway tickets and other income of the KV line. In many railways around the world, which focuses on passenger, transport alone cannot recover half of the OPEX. However, KV line is in a better position in recovering OPEX and replacement costs through ticket and other income.

Economic analysis shows that ENPV as USD Million 1863, base EIRR as 14.28% and cost-Benefits ratio as 2.50. All these are within acceptable limits and sensitivity analysis showed all these indicators are above to acceptable levels even in worse cases, therefore, it proved this project is economically viable.

The overall PIR value of the project is 71.96%, the minimum PIR value is 46.89%, and the maximum value is 94.71 %. This shows that there is a significant variance between the maximum and minimum values, which shows that some sections in KV line development project are heavily benefiting the poor people while other sections do have a moderate impact for the poor. In general, the development of the KV line may assist to reduce poverty in DS beyond Padukka to Avissawella end.

Project Impact Monitoring Matrix/Framework shows many of the baseline indicators under the headings of project inputs, outcome and outputs will be definitely improved in direct and indirect project impact areas due to KV line development.

Ticket price can be increased based on the five benchmark indices (consumer price index, wage rate index, energy index, labor productivity, and transport network capacity factor). Fair increase JICA-LRT: 2020 (1.2 times), 2025 (1.5 times) and 2035 (2.3 times). Model Output: 2020 (1.2 times), 2025 (1.5 times) and 2035 (1.5 times). Frights tariffs are no issue, but need heavy investment on freight carrying, handling and storing infrastructure with more commercial freedom to Railway and private sector participation. Five pillars (Policy area, Planning area, Implementation area, Monitoring aspect, and Regulation aspects) identified to build institutional arrangement for fare setting and periodic review. Key performance indicators for benchmarking are average fare, average tariffs, average passenger subsidy, operating ratio, labor share of revenue, employee productivity, operational sustainability, and working capital ratio.

15.10.3 Possible Recommendations

(1) The project needs attention on costs minimization strategies with suitable costs minimizing value engineering designs during detailed design, BOQ and tender stages. Especially, competitive bidding will help to reduce costs further. The 50-year life span of the project seems ideal for financial analysis rather than the 30-year suggested by looking at the main financial indicators discussed in financial analysis sections and Sri Lankan standards based on Euro codes. Therefore, it is recommended to consider 50 years as project life span rather 30 years if possible.

(2) In economic terms, KV line development generates sound economic benefits for the national economy. Therefore, economically the project is feasible by looking at indicators of EIRR, ENPV and C/B ratio. Even sensitivity, switching and risks analysis show that KV line development generates sound economic benefits and it is a moderately robust project with changes of demand, costs, construction period and other key benefits variables.

(3) Only in very few countries, the railway is recovering part of OPEX if they focused only on passenger transportation. In general, many Railways around the world are earning through freights rather than passengers. As this KV Line focuses mainly on passenger transportation, government subsidy is the only way to recover both CAPEX and OPEX because often ticket price increases have many political and social implications. However, in KV line O&M costs and replacement costs easily can be recovered with railway ticket and other incomes. Nevertheless, problems come with huge capital costs (CAPEX).

(4) But in the long run, part or full of the CAPEX recovery is possible if the Railway Authority gets a new flexible administrative system with more commercial freedom to managers and more private sector participation for various railway commercial activities.

(5) KV line development has some implications for poverty reduction in many DS divisions in and around the KV line as shown by the Poverty Impact Ratios. Therefore, the development of the KV line may assist to reduce poverty in DS beyond Padukka to Avissawella end.

(6) As shown in the Project Impact Monitoring Matrix/Framework, many of the baseline indicators will definitely improve in direct and indirect project impact areas due to KV line development. Therefore, in order to improve these baseline indicators, we can recommend KV line development.

(7) First this KV line can be developed as a state-of-art model line to attract lost passengers back to railway and, it is better to explore possibility of this line extension to link it to the main line via Ratnapura, Balangoda, and Ambilipitiya to Kataragama city with freight transportation possibility and other commercial development such as hotels, housing schemes, trade, and distribution center‘s to generate more income to recover overall costs in the long run.

Appendices

Appendix A
Geotechnical Studies:
The Outcome of the Visual Observation

Table A-1 The Outcome of the Visual Observation

From	To	General Condition	Special Geological Conditions
Maradana	Baseline	Extremely Congested.	Manmade ground
Baseline	Kotta Road	Highly congested but can find locations for testing along the rail line for testing	Manmade ground
Kotta Road	Narahenpita	This section falls mainly within the Golf Ground.	Manmade ground
Narahenpita	Kirillapana	Highly congested up to Kirulapana canal and medium congested from Canal to Kirulapana station.	Manmade ground and some lateritic residual soils can be observed. A shear zone falls in this area.
Kirulapana	Nugegoda	Medium congested.	Manmade ground and some lateritic residual soils can be observed.
Nugegoda	Pangiriwatta	Slightly congested.	Rock outcrops and lateritic residual soils can be observed.
Pangiriwatta	Udahamulla	Slightly congested	Manmade ground and lateritic residual soils can be observed.
Udahamulla	Nawinna	Slightly congested. Nearly 1km stretch is Highly congested near Nawinna Station	Manmade ground and lateritic residual soils can be observed.
Nawinna	Maharagama	Medium congested.	Manmade ground and lateritic residual soils can be observed.
Maharagama	Pannipitiya	Slightly congested.	Manmade ground and lateritic residual soils can be observed. A shear zone falls in this area.
Pannipitiya	Kottawa	Slightly congested	Manmade ground and lateritic residual soils can be observed. A shear zone falls in this area.
Kottawa	Malapalla	Slightly congested	Manmade ground and lateritic residual soils can be observed.
Malapalla	Homagama Hospital	Most of the area falls in paddy fields.	Flat bottom valleys can be observed.
Homagama Hospital	Homagama	Accessible for testing	Rock outcrops and Lateritic residual soils can be observed.
Homagama	Panagoda	Firm ground condition	Lateritic residual soils can be observed.
Panagoda	Godagama	Most of the area falls in paddy fields.	Flat bottom valleys and firm grounds contain Lateritic residual soils can be observed in the area. Oruwala anti form traverses in this area.
Godagama	Meegoda	Firm grounds and paddy fields.	Flat bottom valleys and firm grounds contain Lateritic residual soils can be observed in the area. Nawagama Synform traverses in this area.
Meegoda	Wataraka	Firm grounds and paddy fields.	Flat bottom valleys and firm grounds contain Lateritic residual soils can be observed in the area.
Wataraka	Liyanwala	Firm grounds and paddy fields.	Flat bottom valleys and firm grounds contain Lateritic residual soils can be observed in the area.
Liyanwala	Padukka	Firm grounds and paddy fields.	Flat bottom valleys and firm grounds contain Lateritic residual soils can be observed in the area. Hanwella Antiform traverses in this area.

Appendix B
Geotechnical Studies:
Borehole Profiles

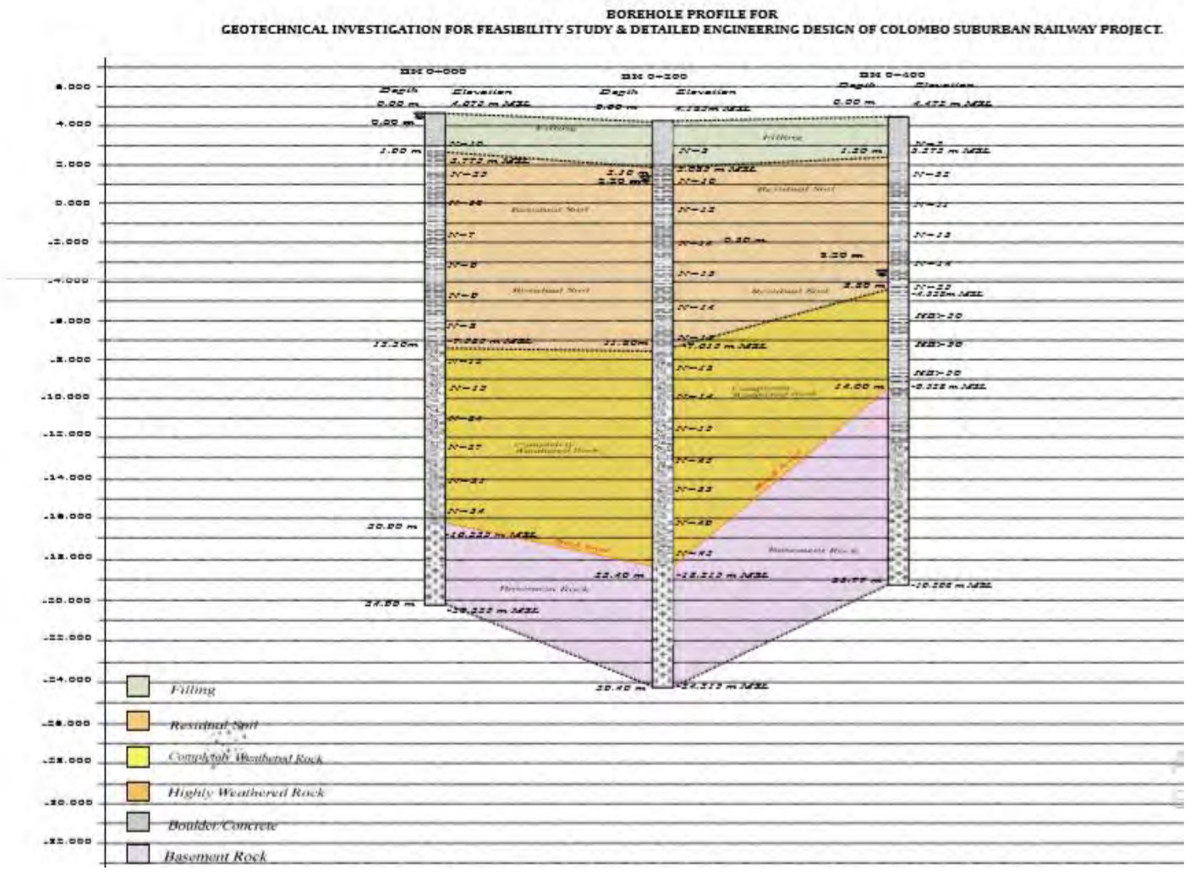


Figure B-1 Borehole Profile-1

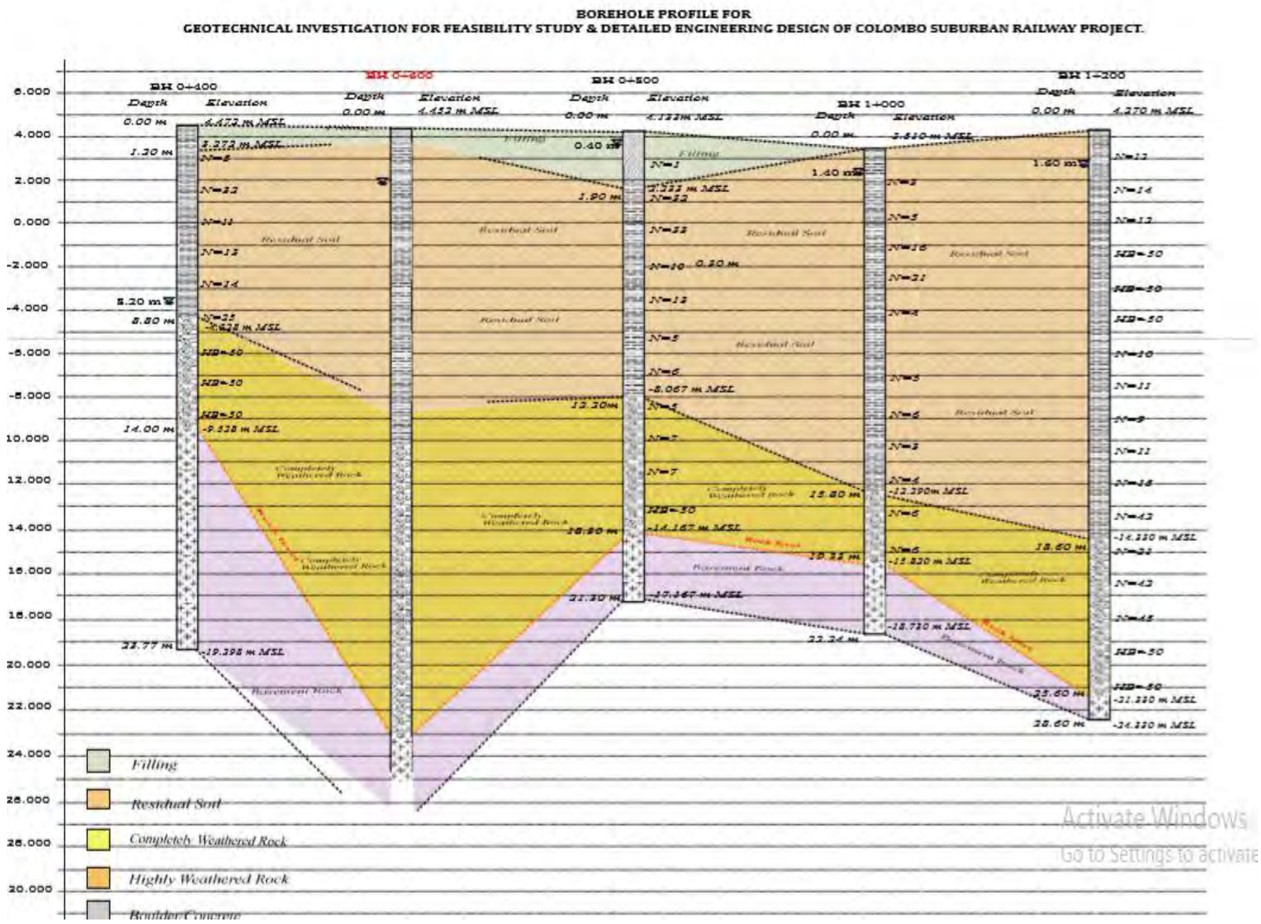


Figure B-2 Borehole Profile-2

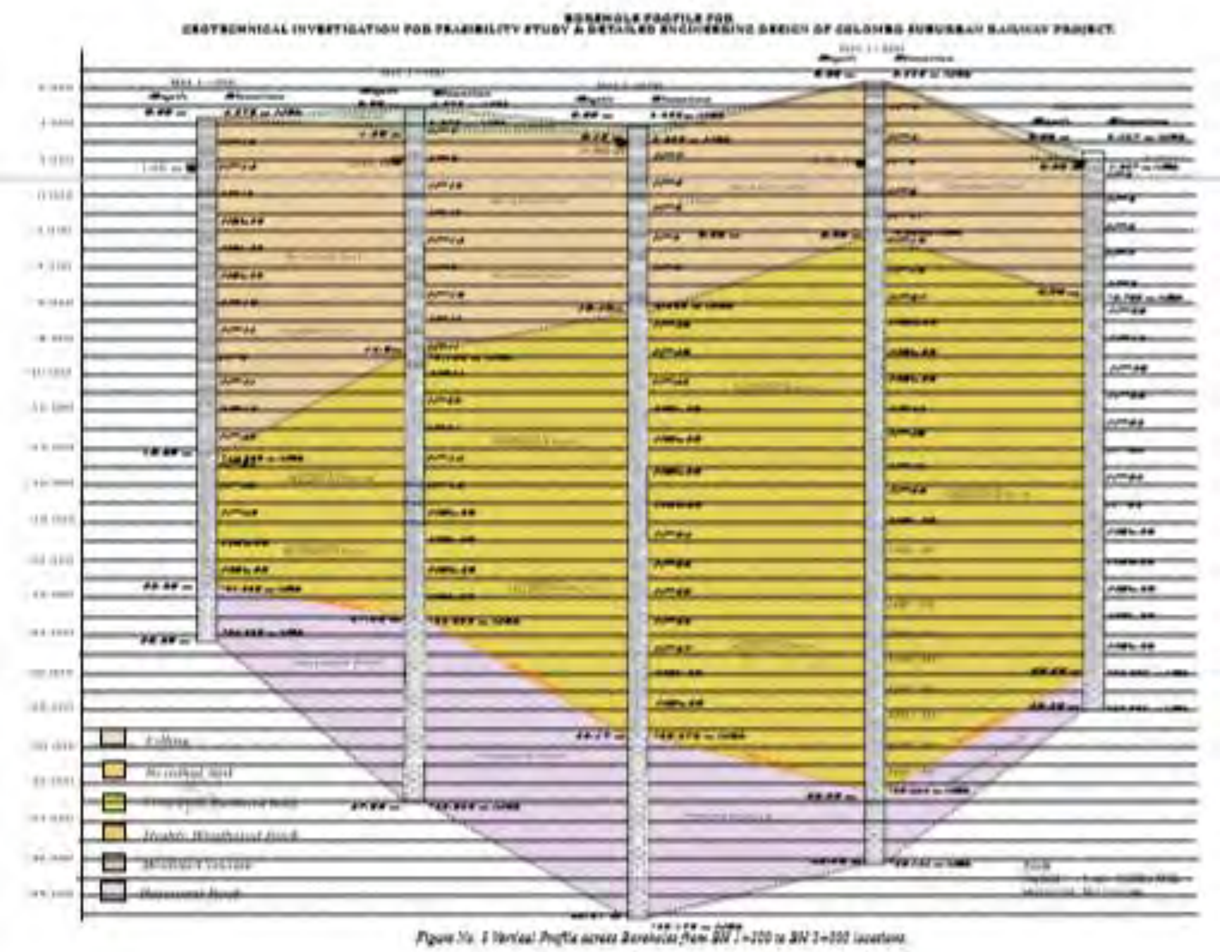


Figure B-3 Borehole Profile-3

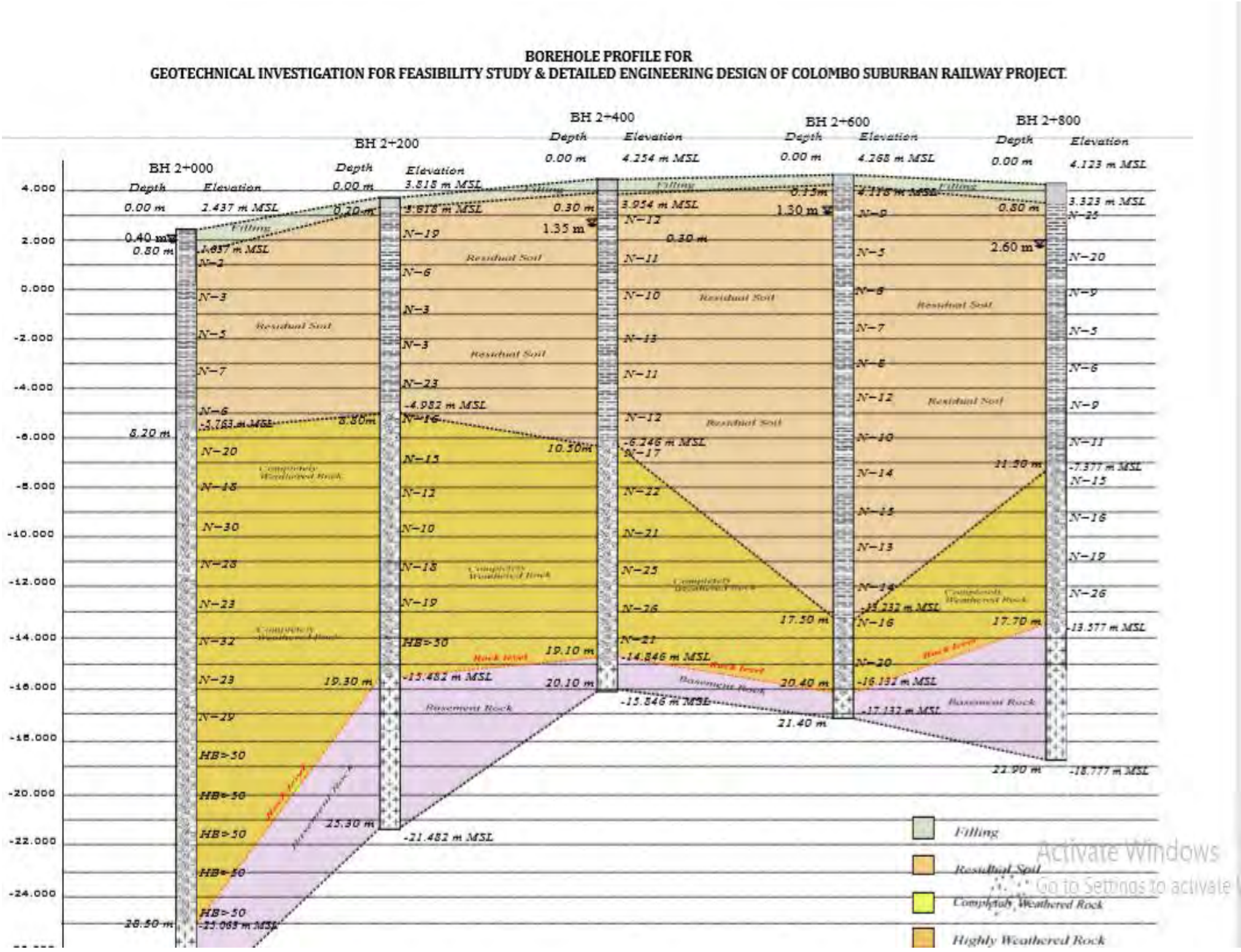


Figure B-4 Borehole Profile-4

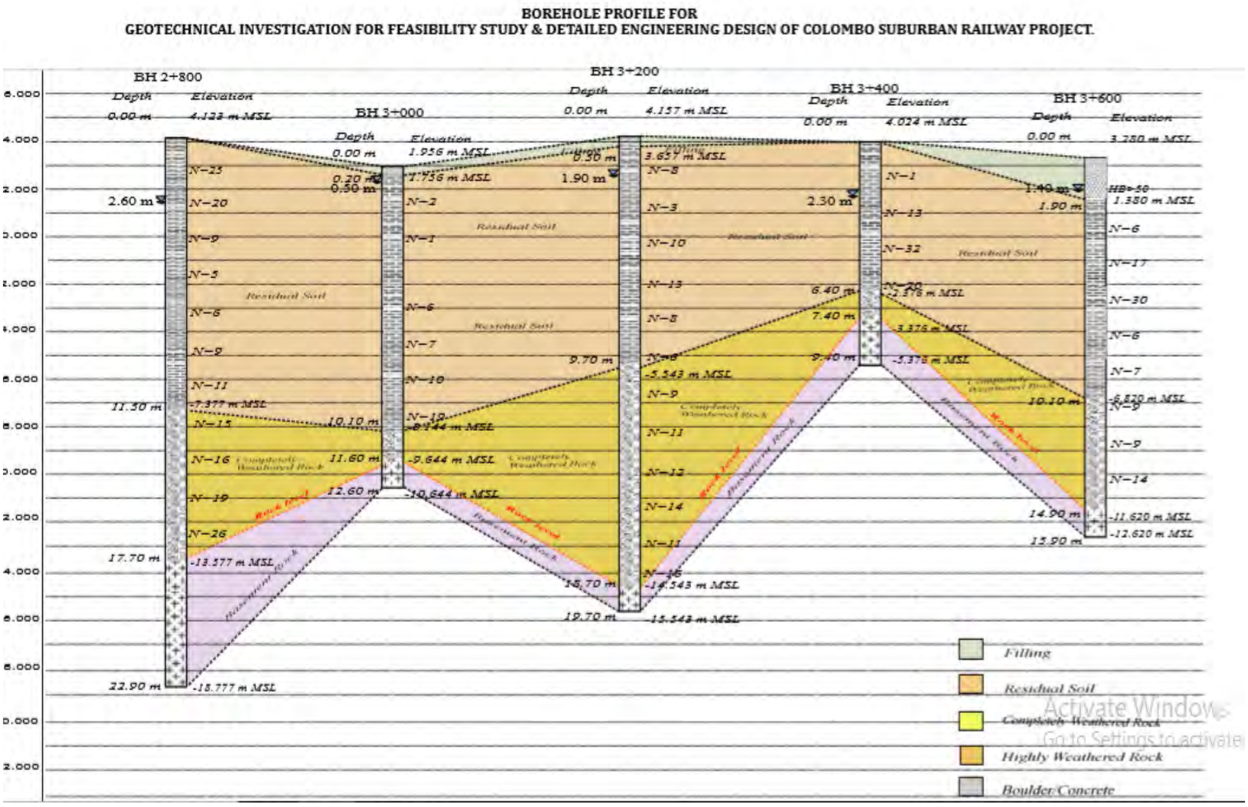


Figure B-5 Borehole Profile-5

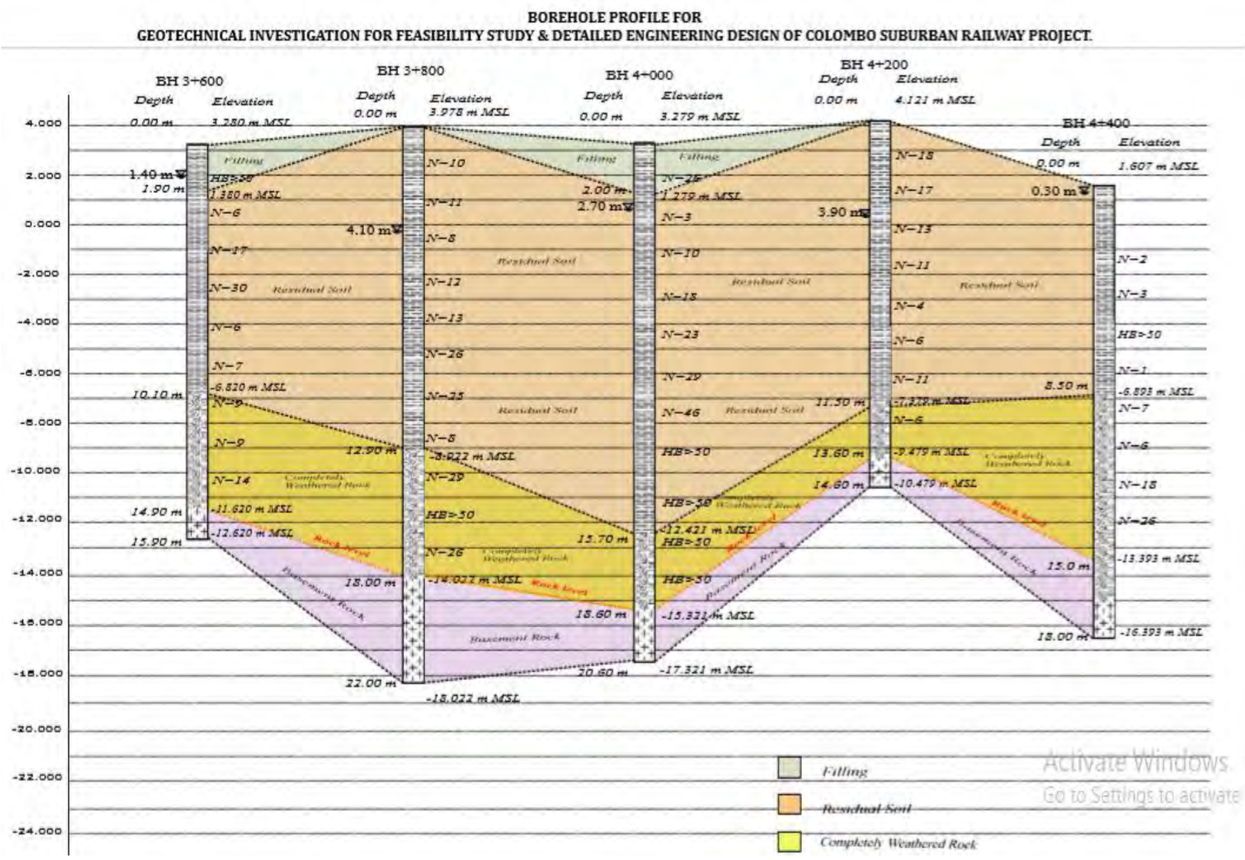


Figure B-6 Borehole Profile-6

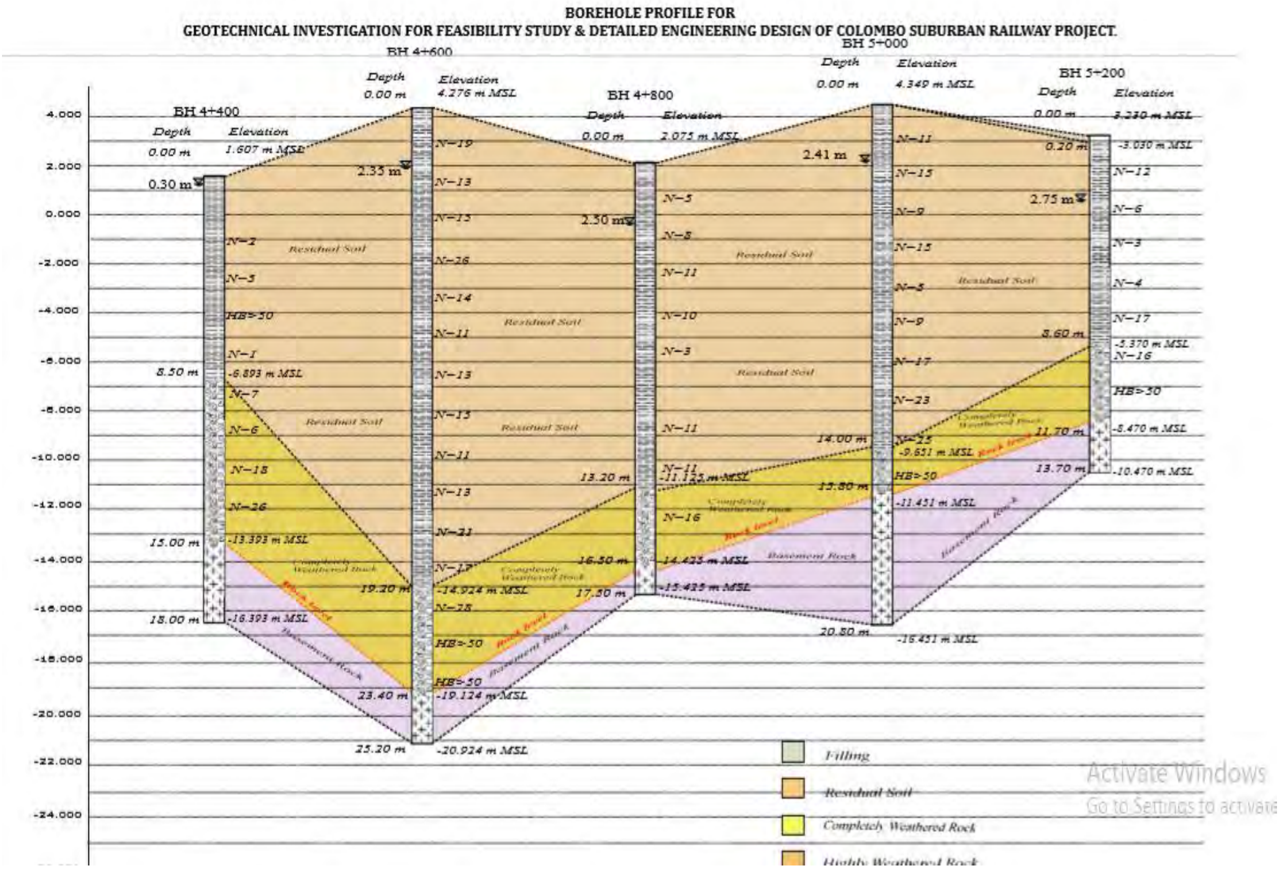


Figure B-7 Borehole Profile-7

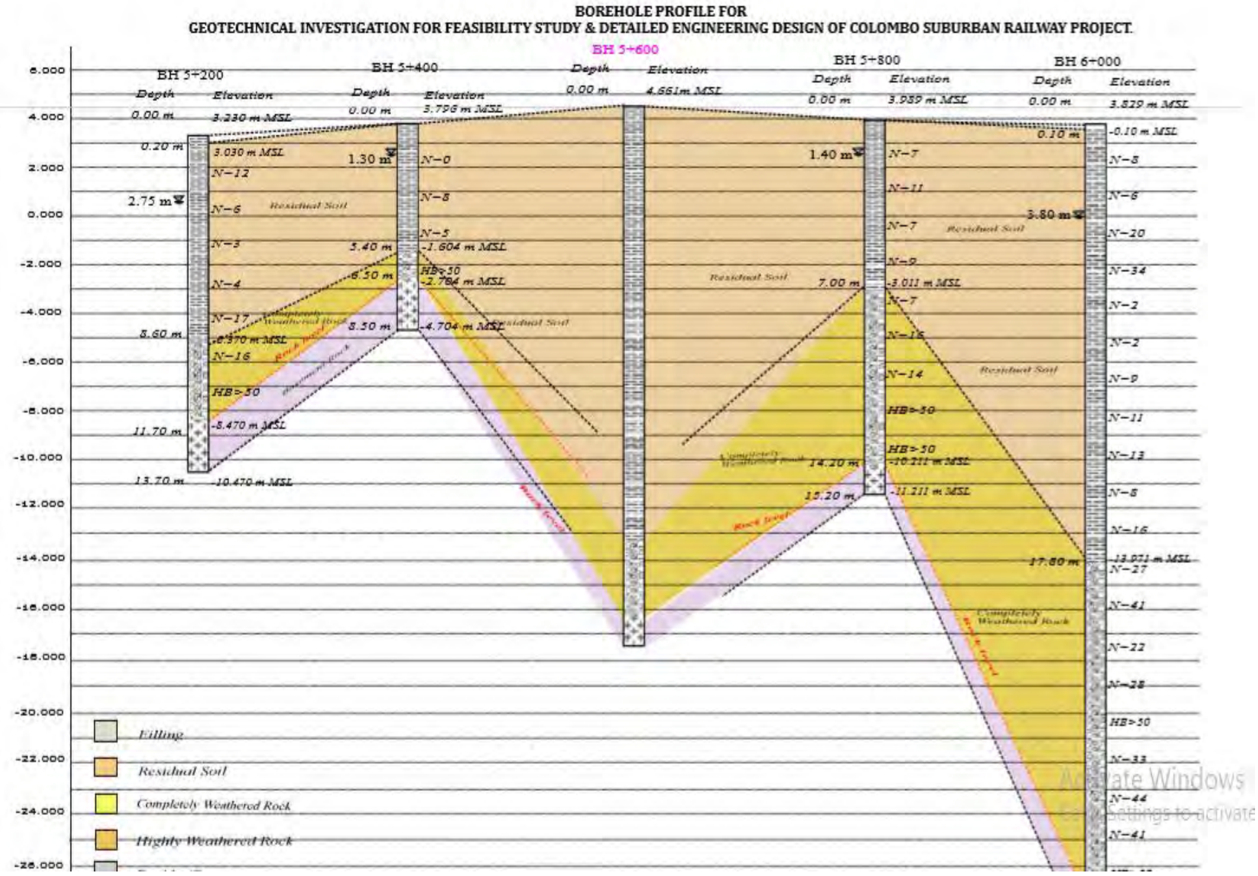


Figure B-8 Borehole Profile-8

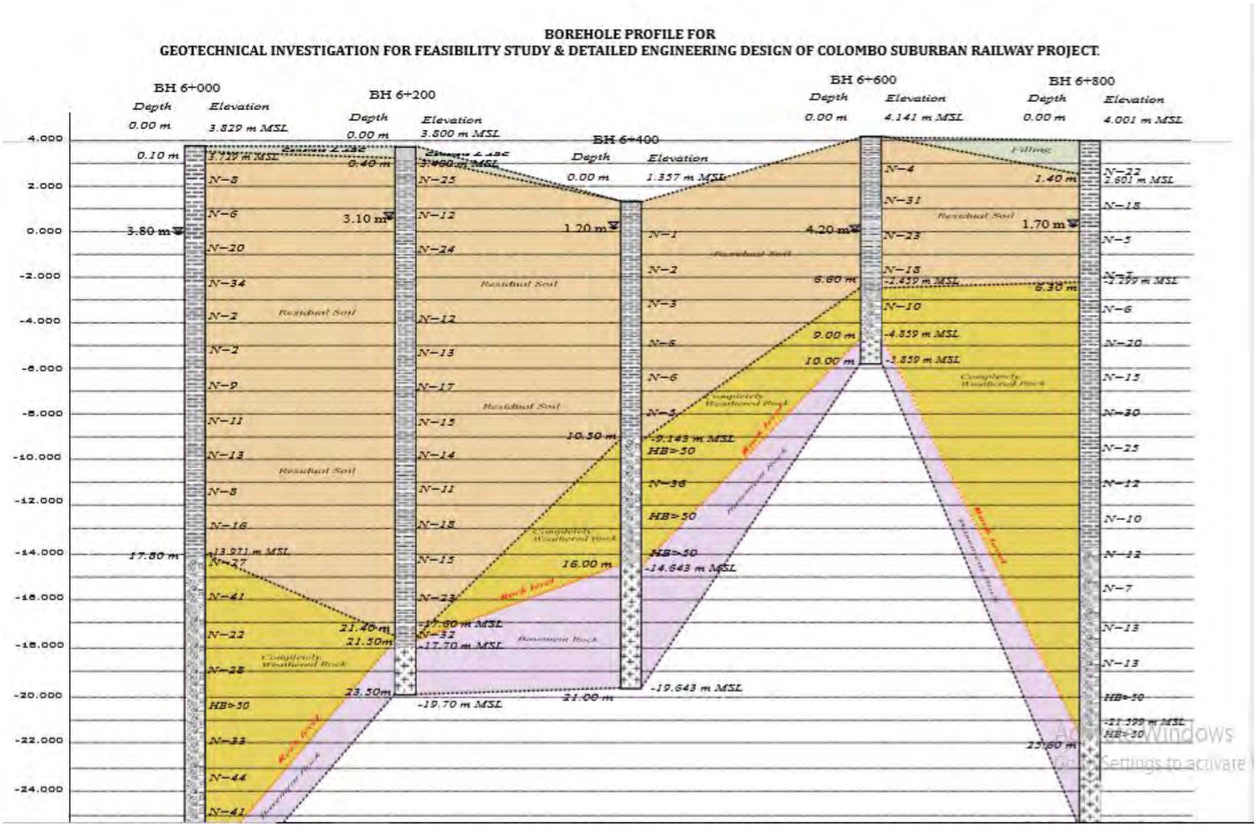


Figure B-9 Borehole Profile-9

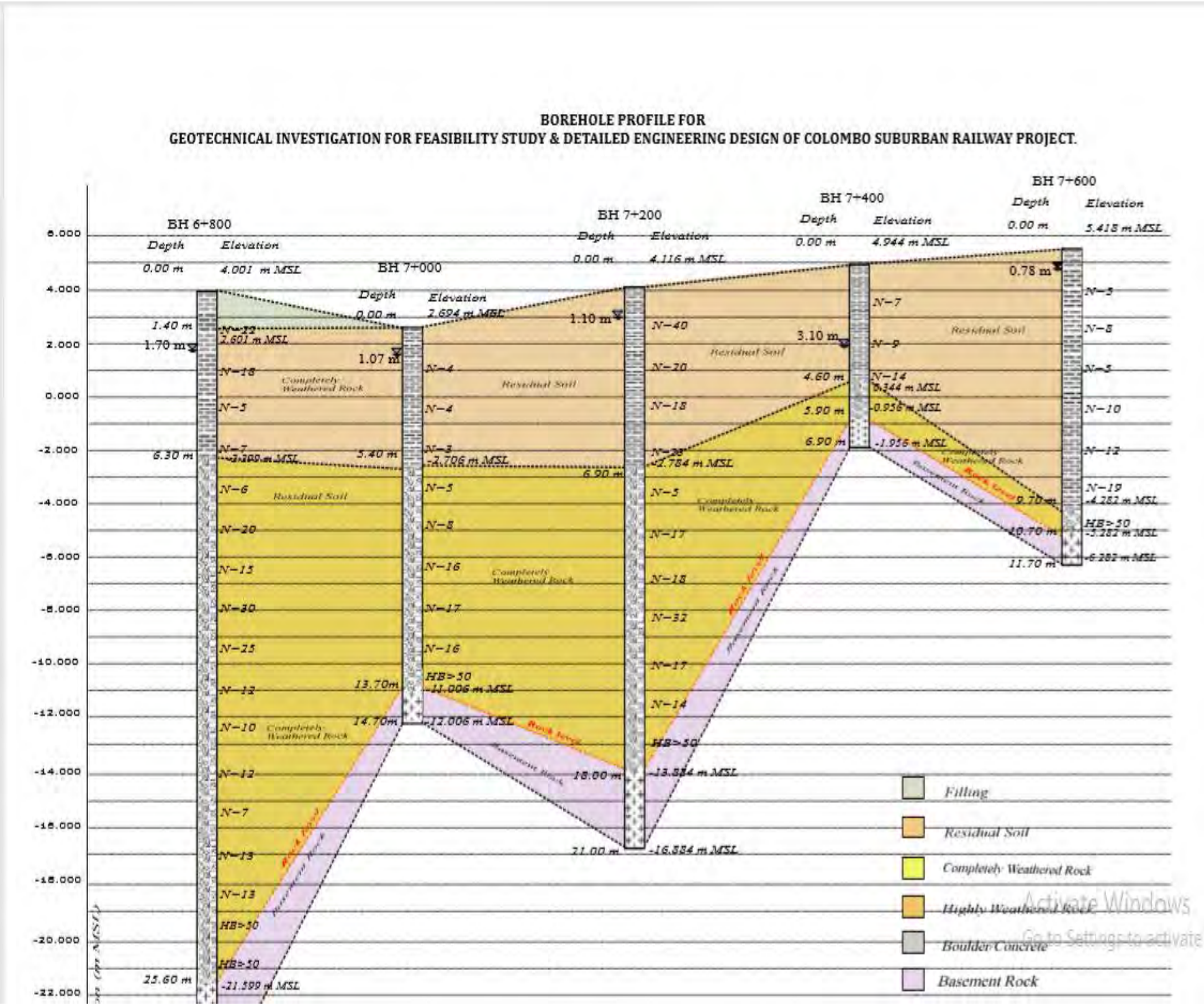


Figure B-10 Borehole Profile-10

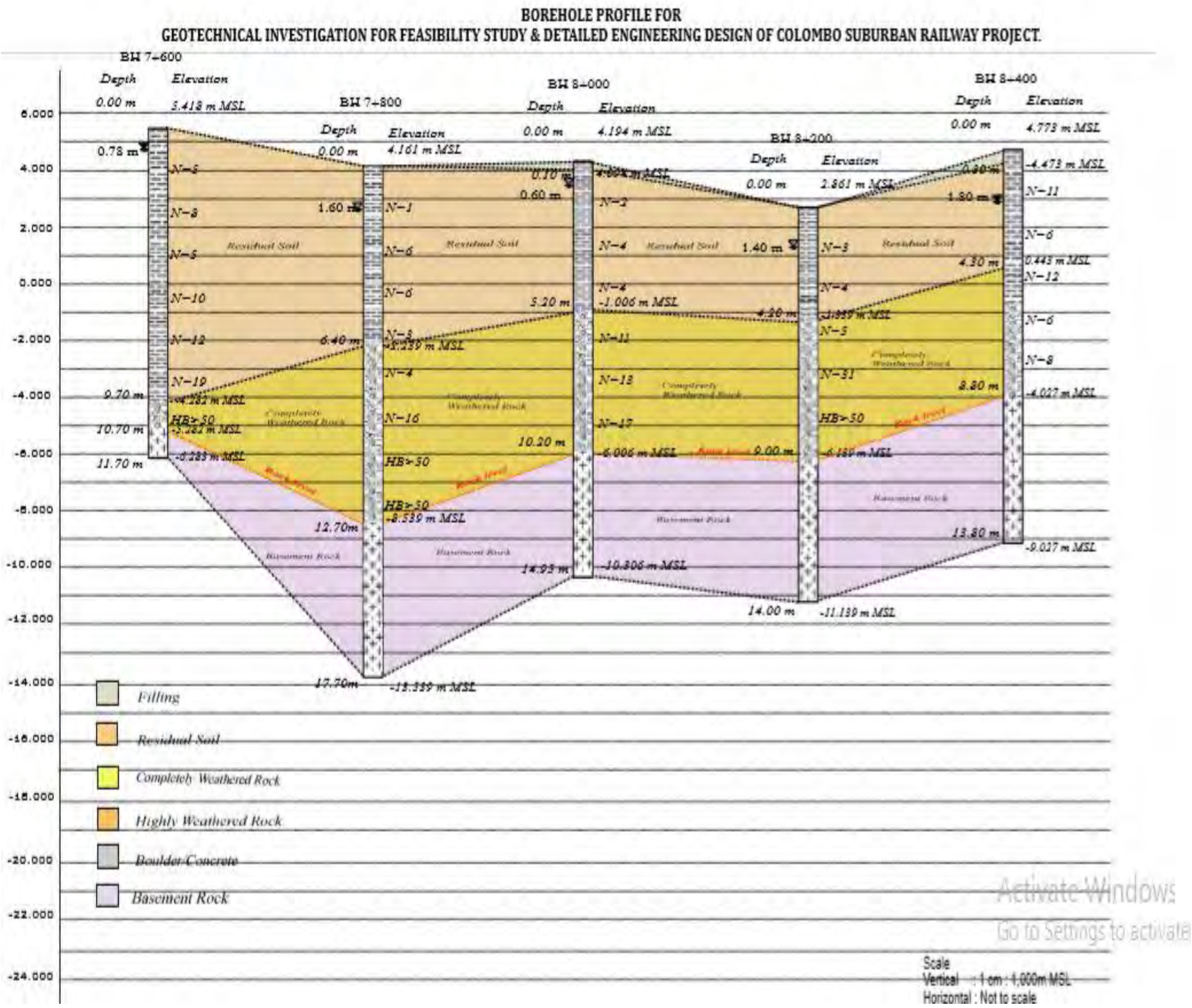


Figure B-11 Borehole Profile-11

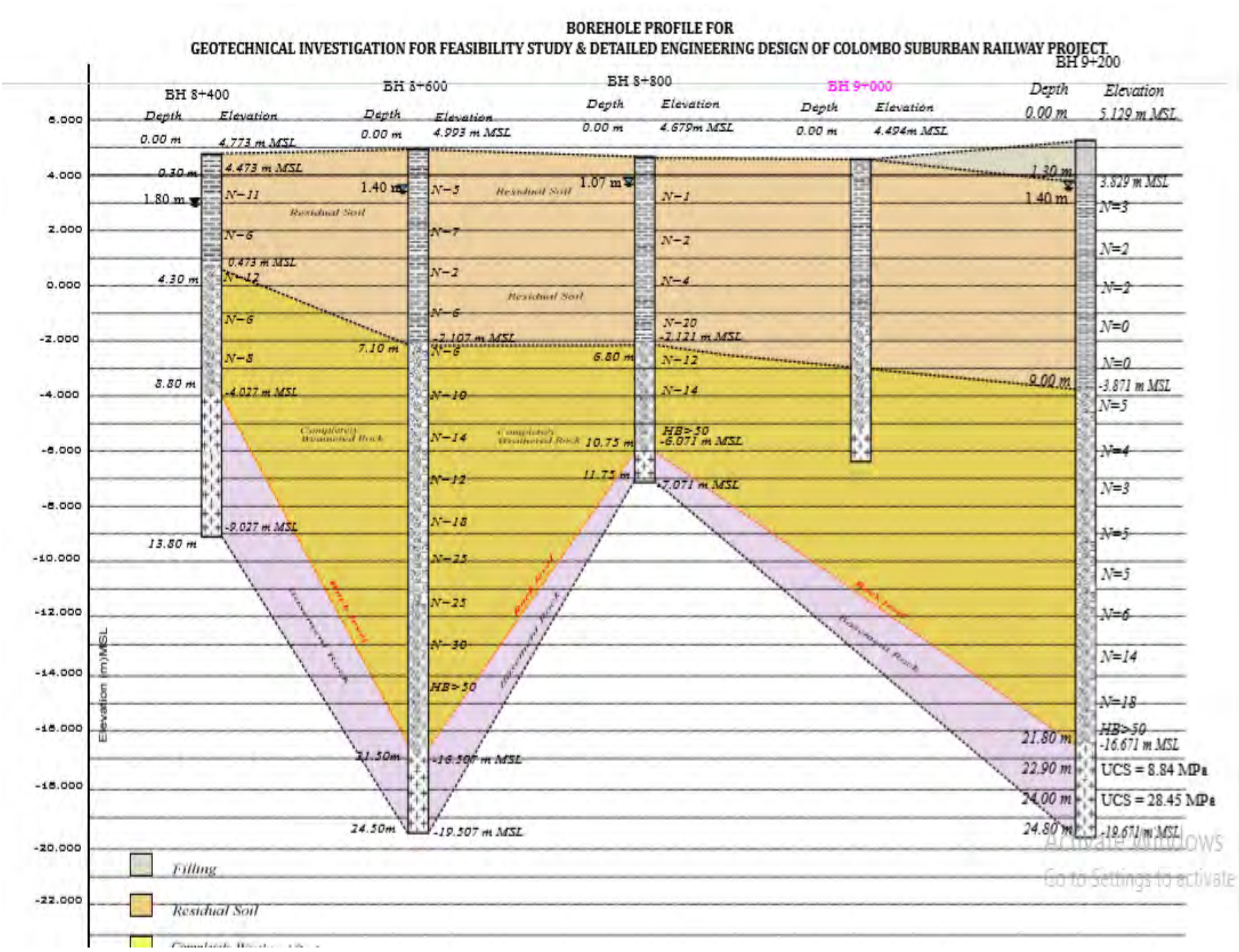


Figure B-12 Borehole Profile-12

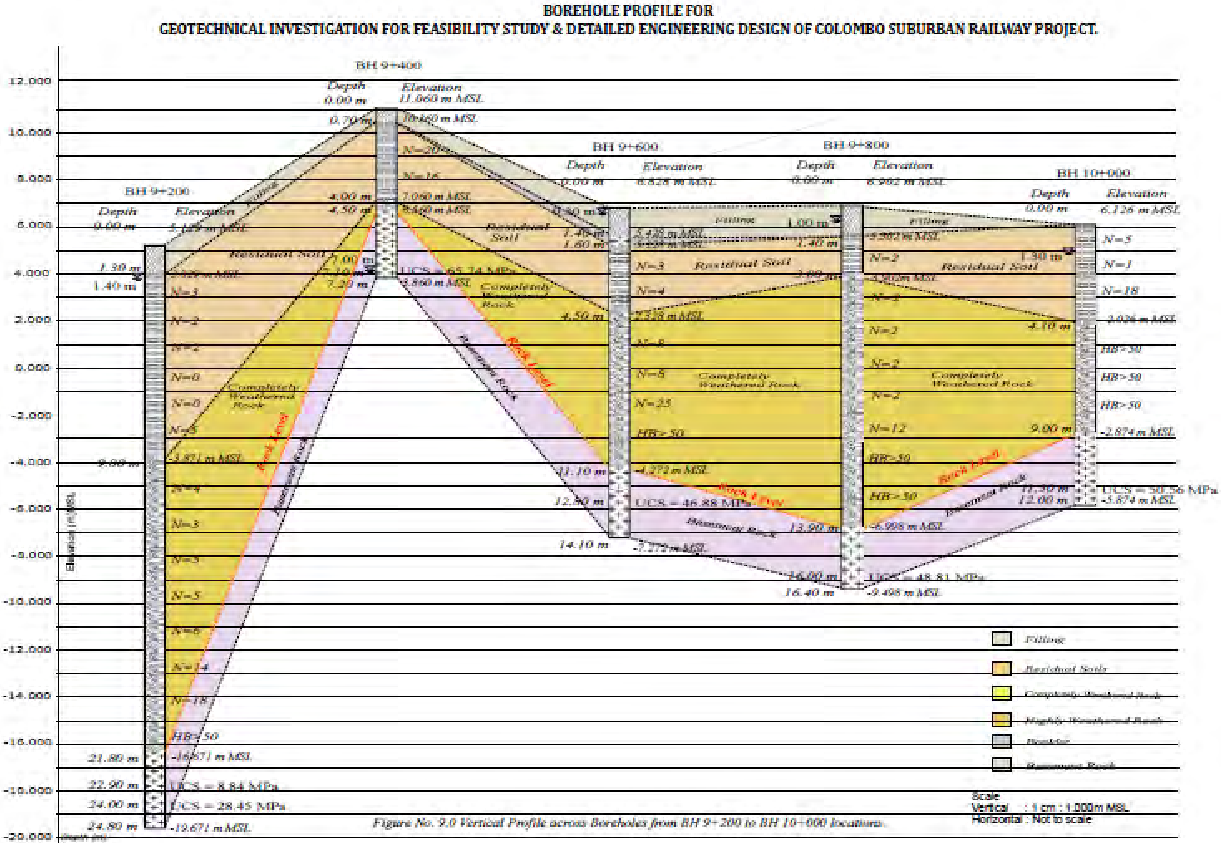


Figure B-13 Borehole Profile-13

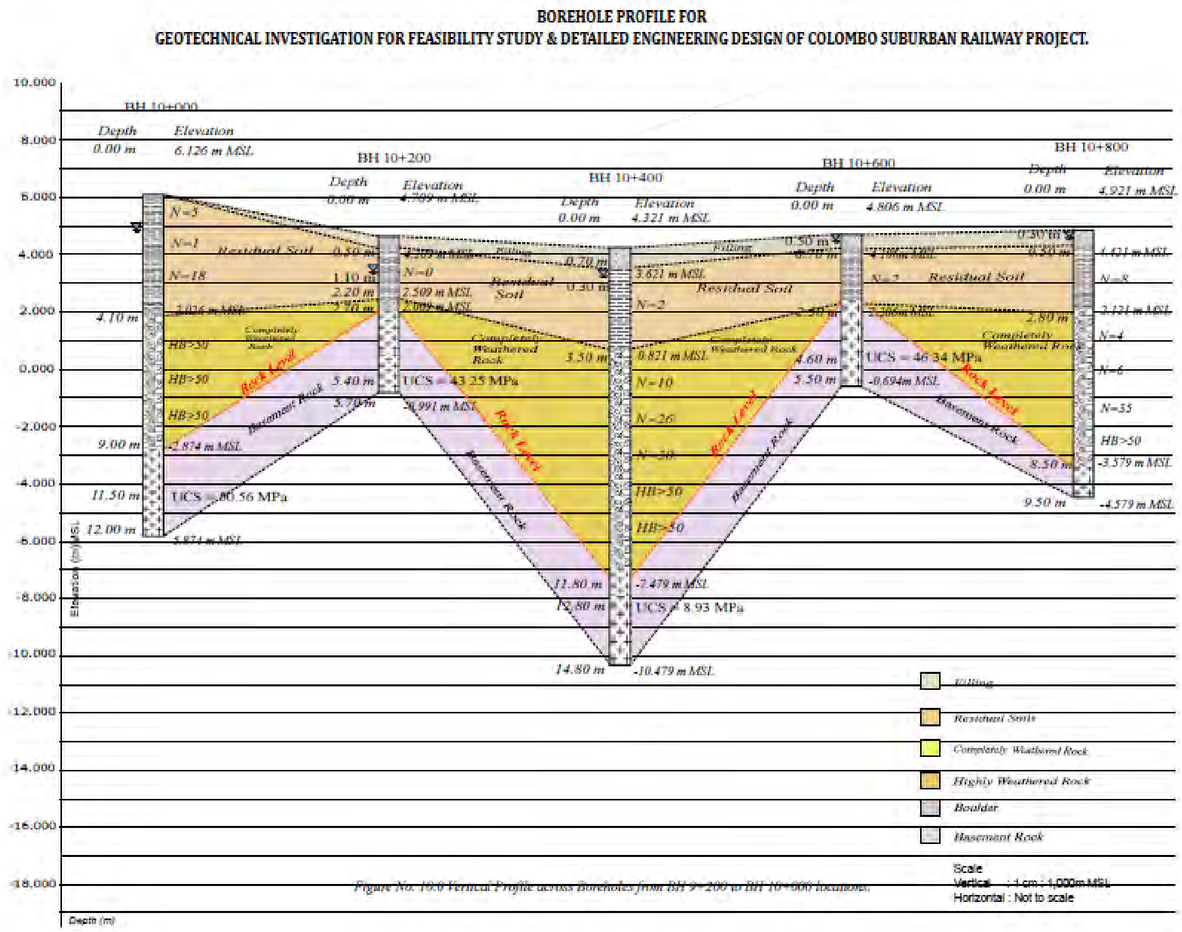


Figure B-14 Borehole Profile-14

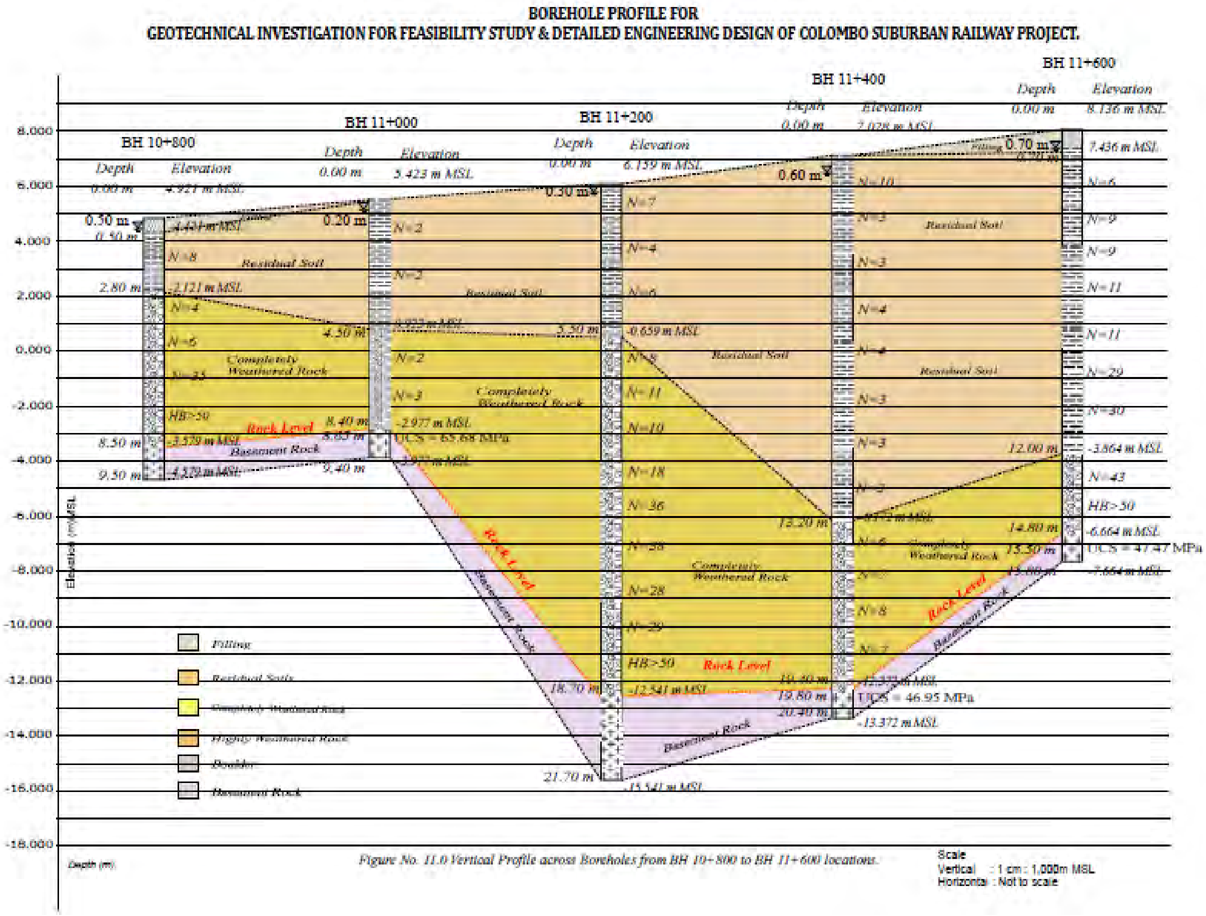


Figure B-15 Borehole Profile-15

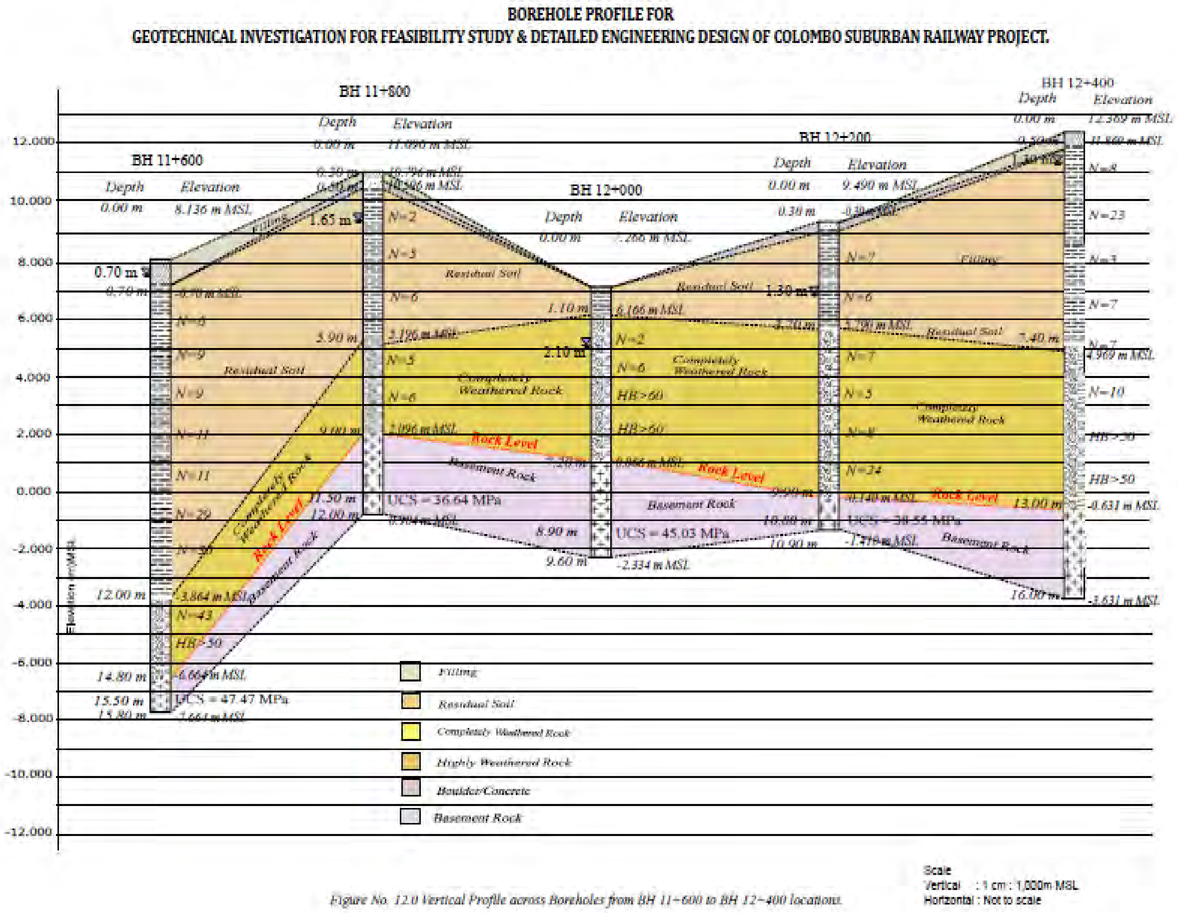


Figure B-16 Borehole Profile-16

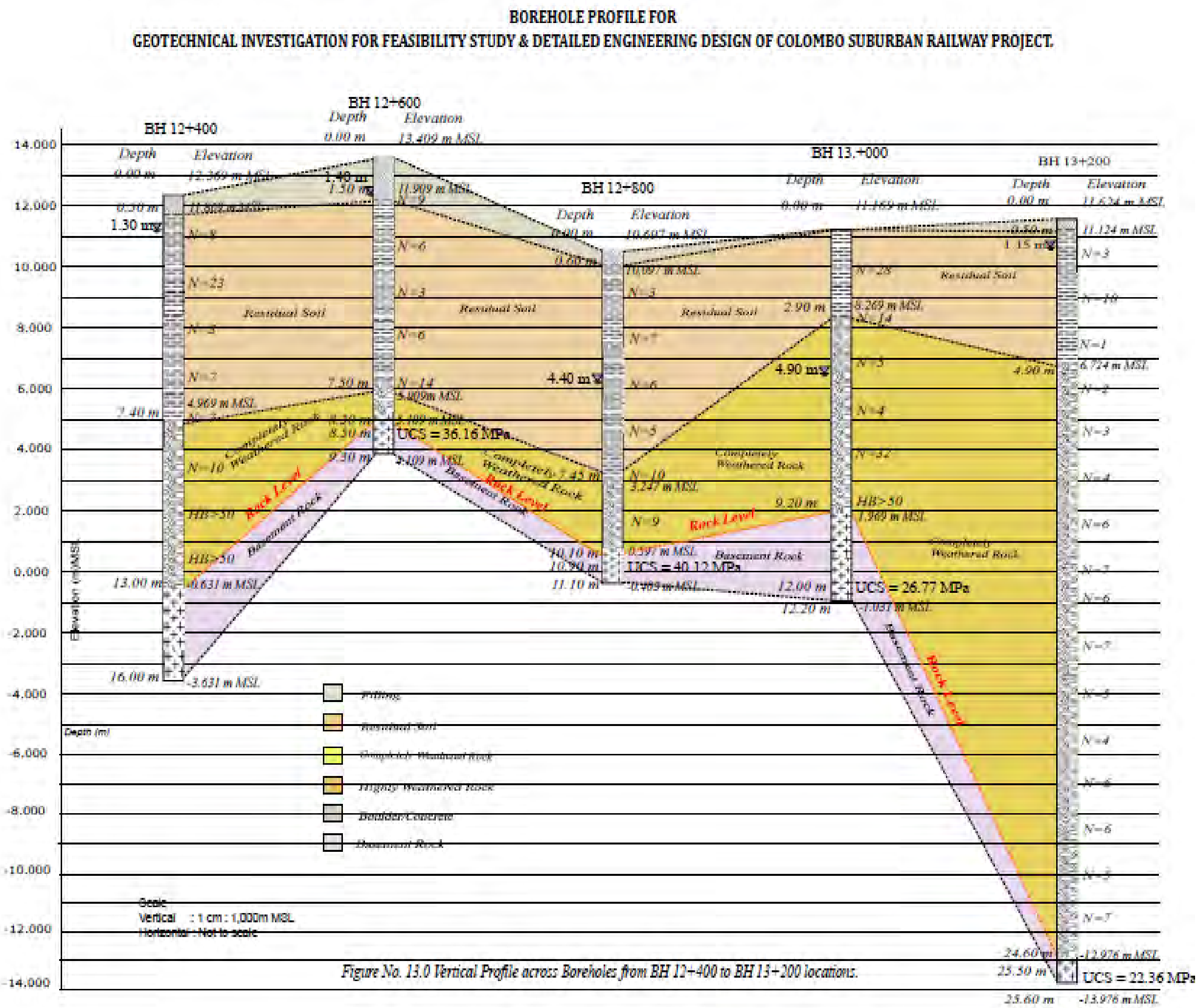


Figure B-17 Borehole Profile-17

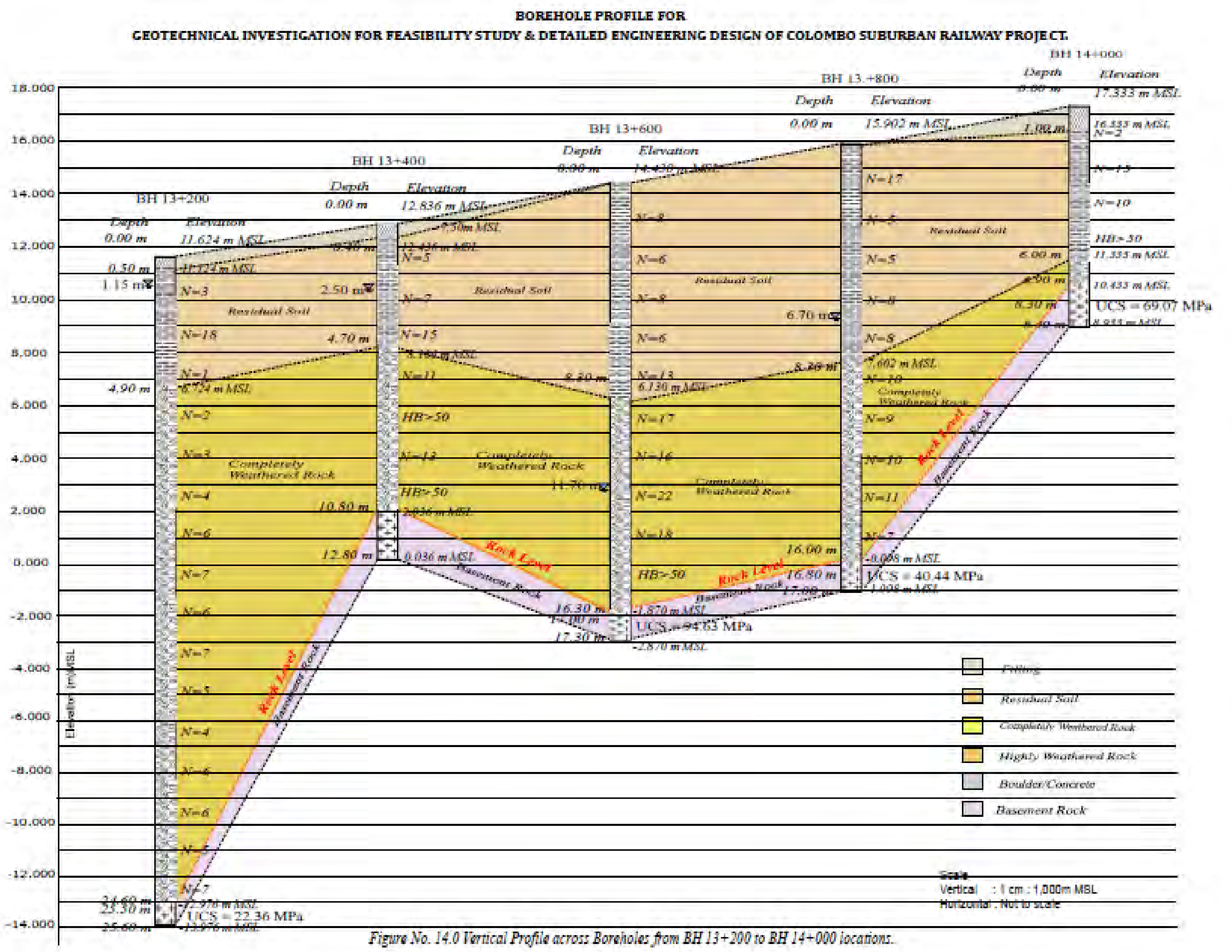


Figure B-18 Borehole Profile-18

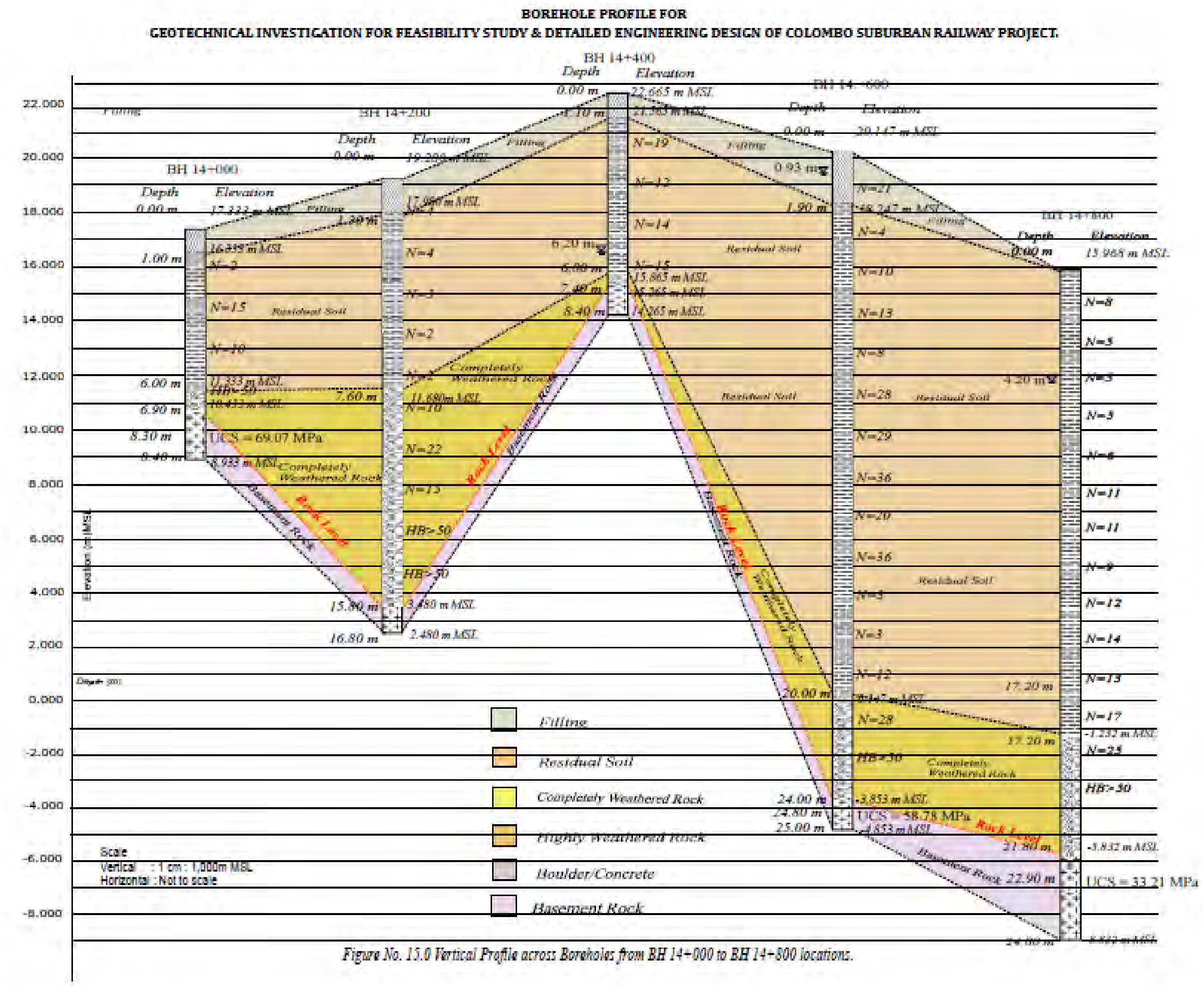


Figure B-19 Borehole Profile-19

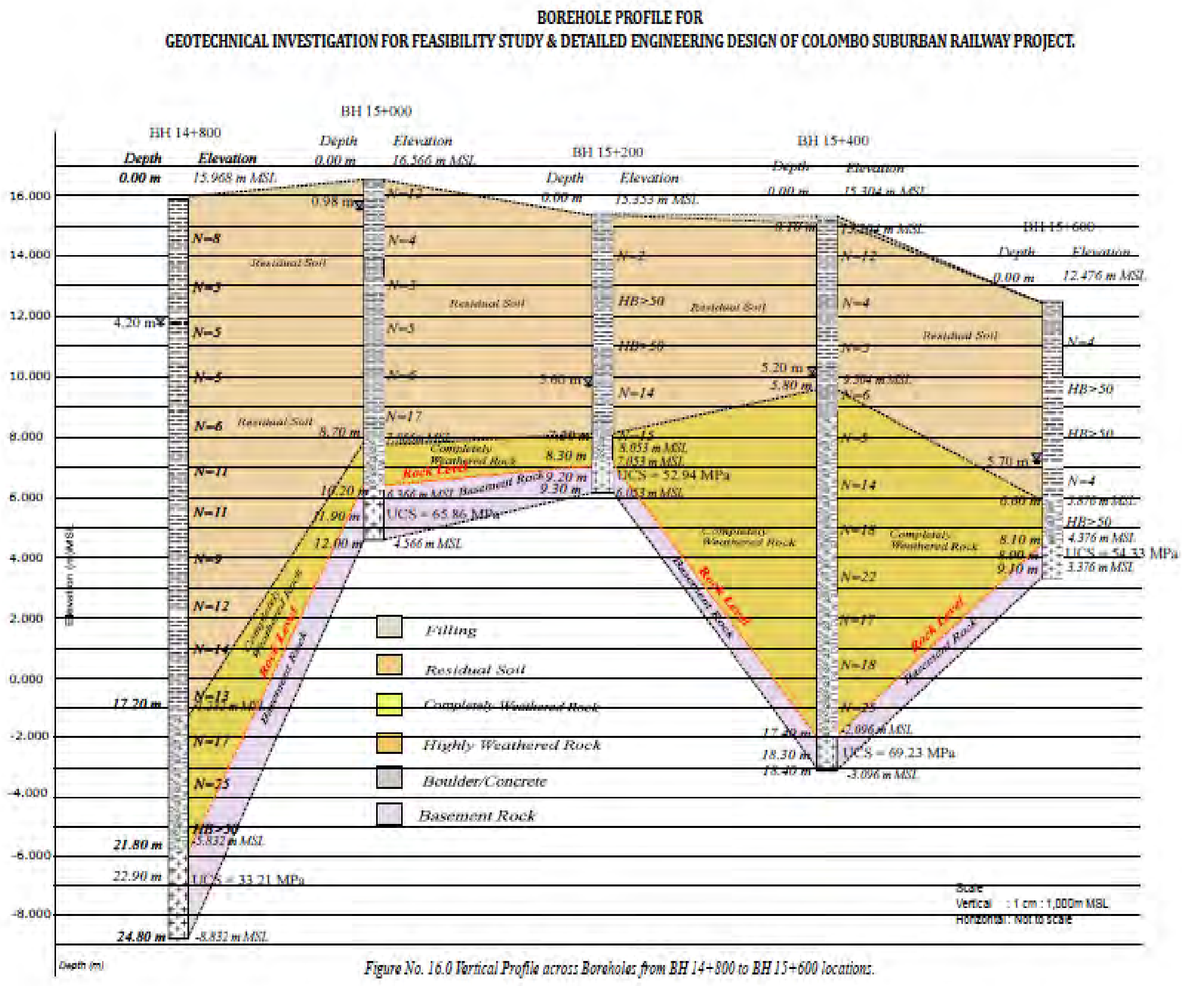


Figure B-20 Borehole Profile-20

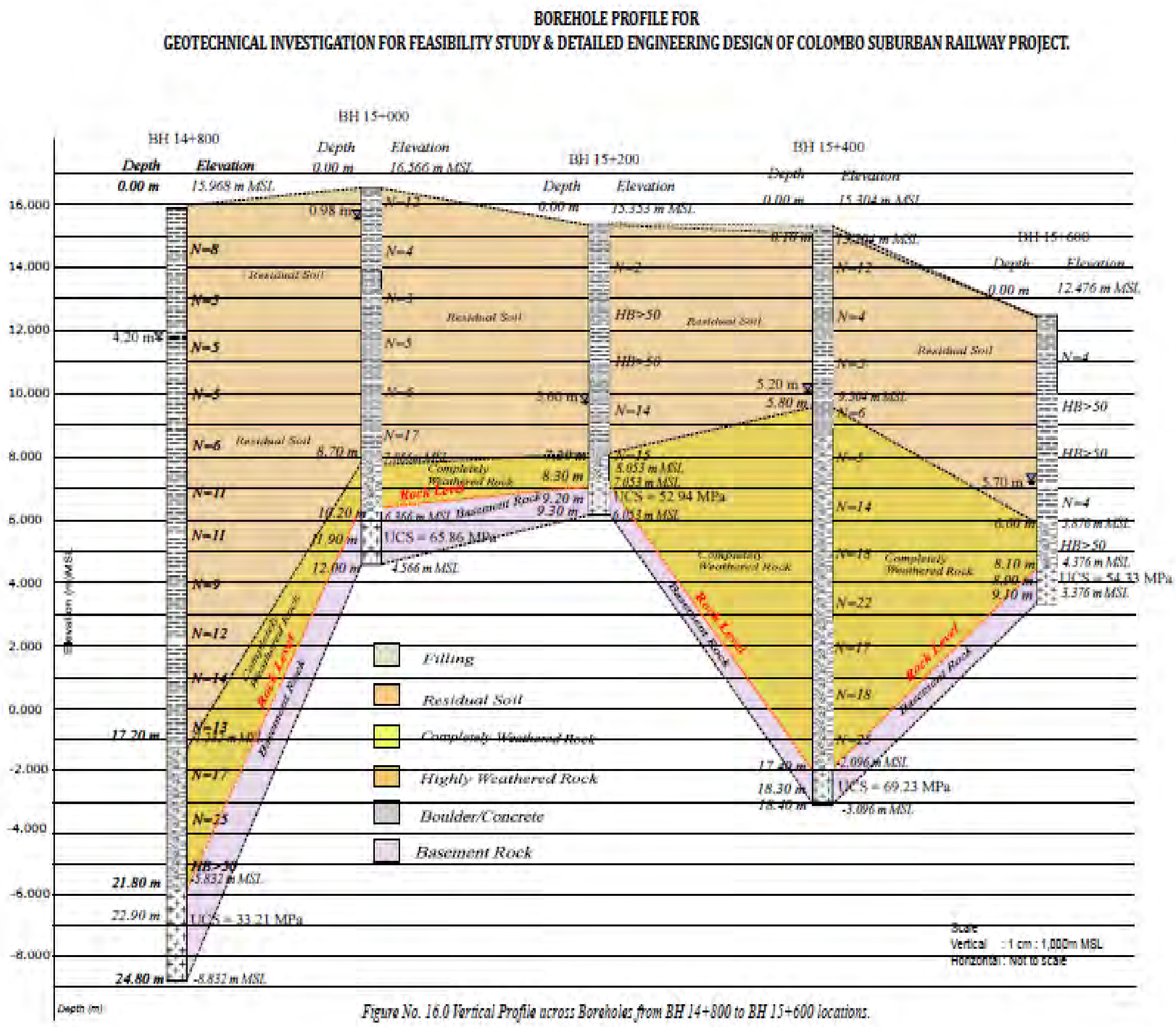


Figure B-21 Borehole Profile-21

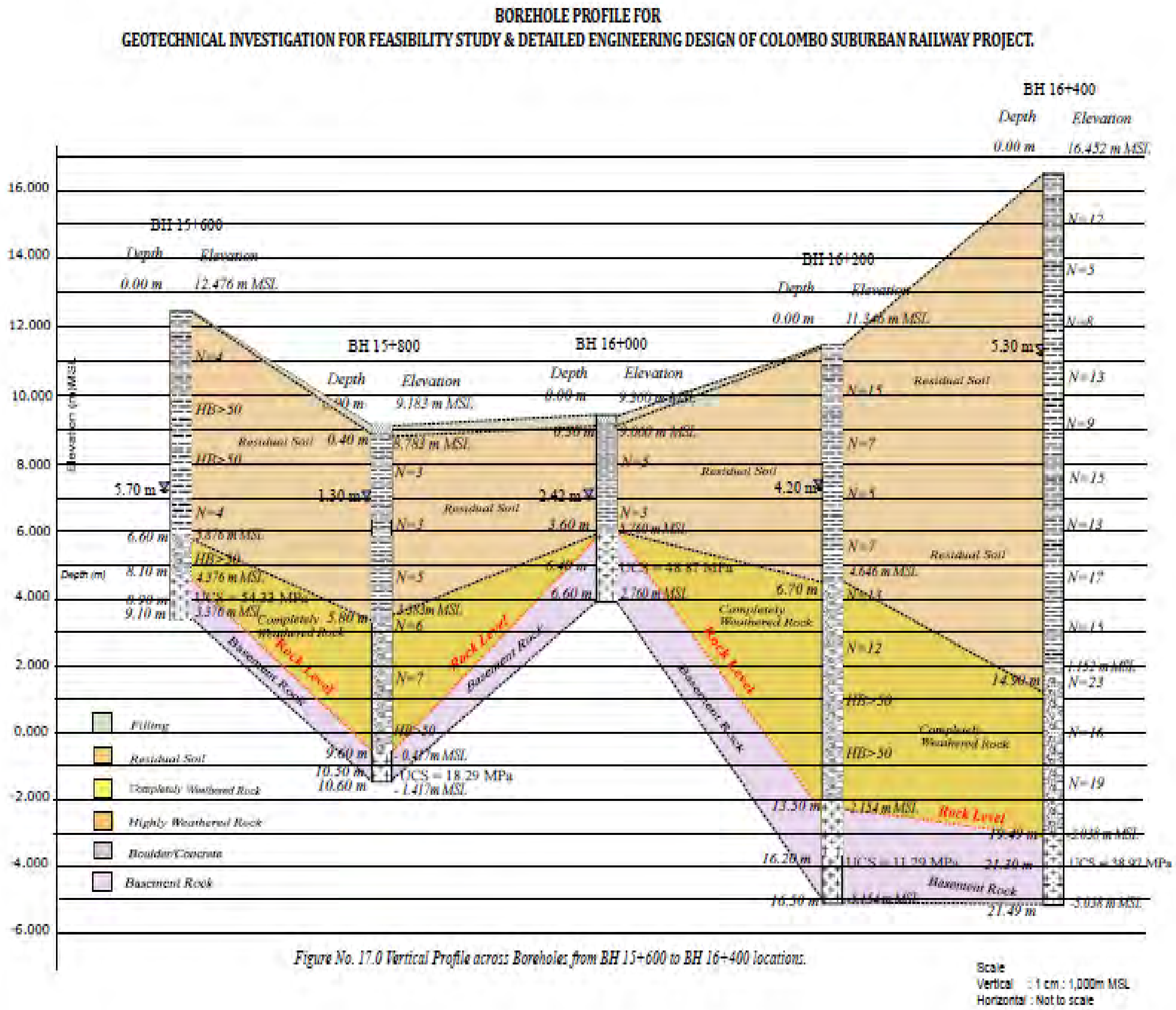


Figure B-22 Borehole Profile-22

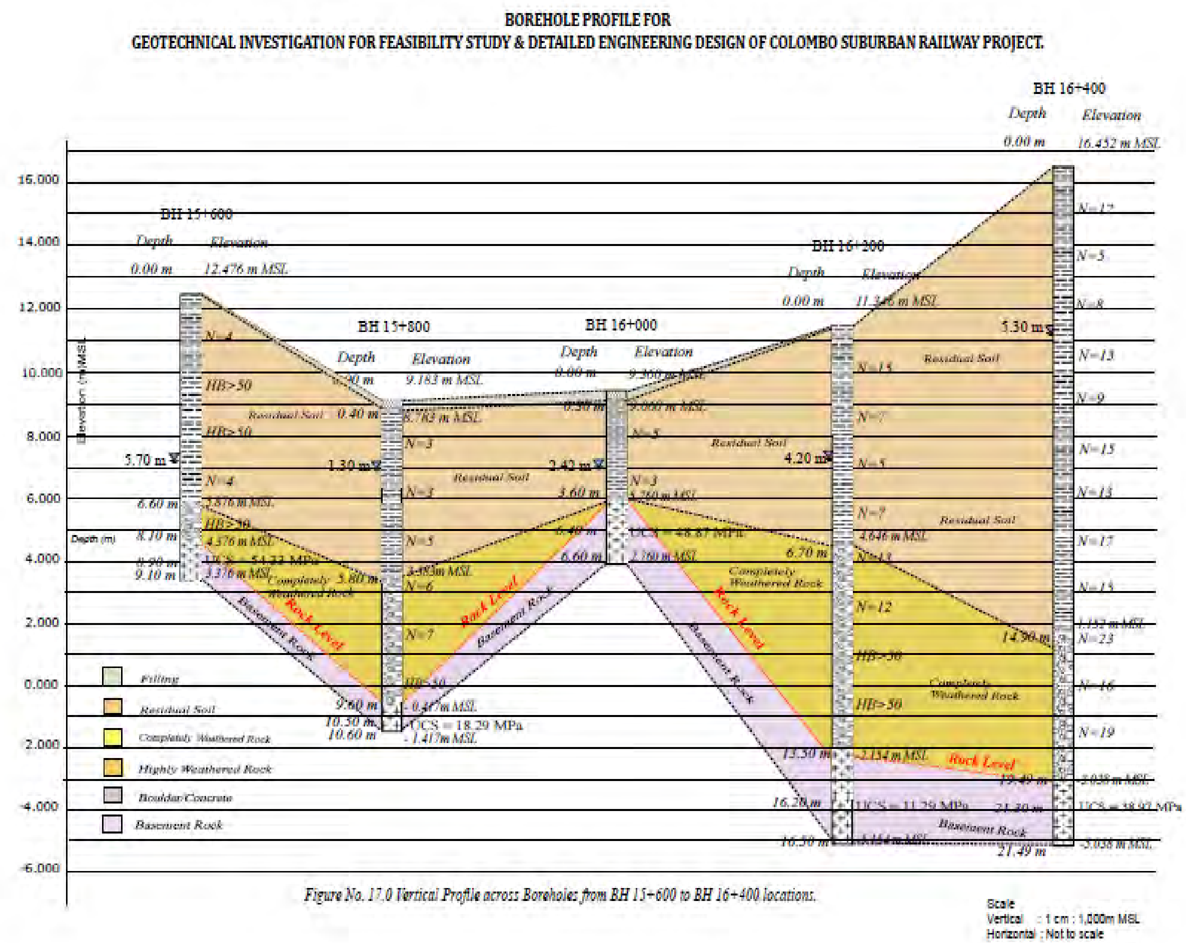


Figure B-23 Borehole Profile-23

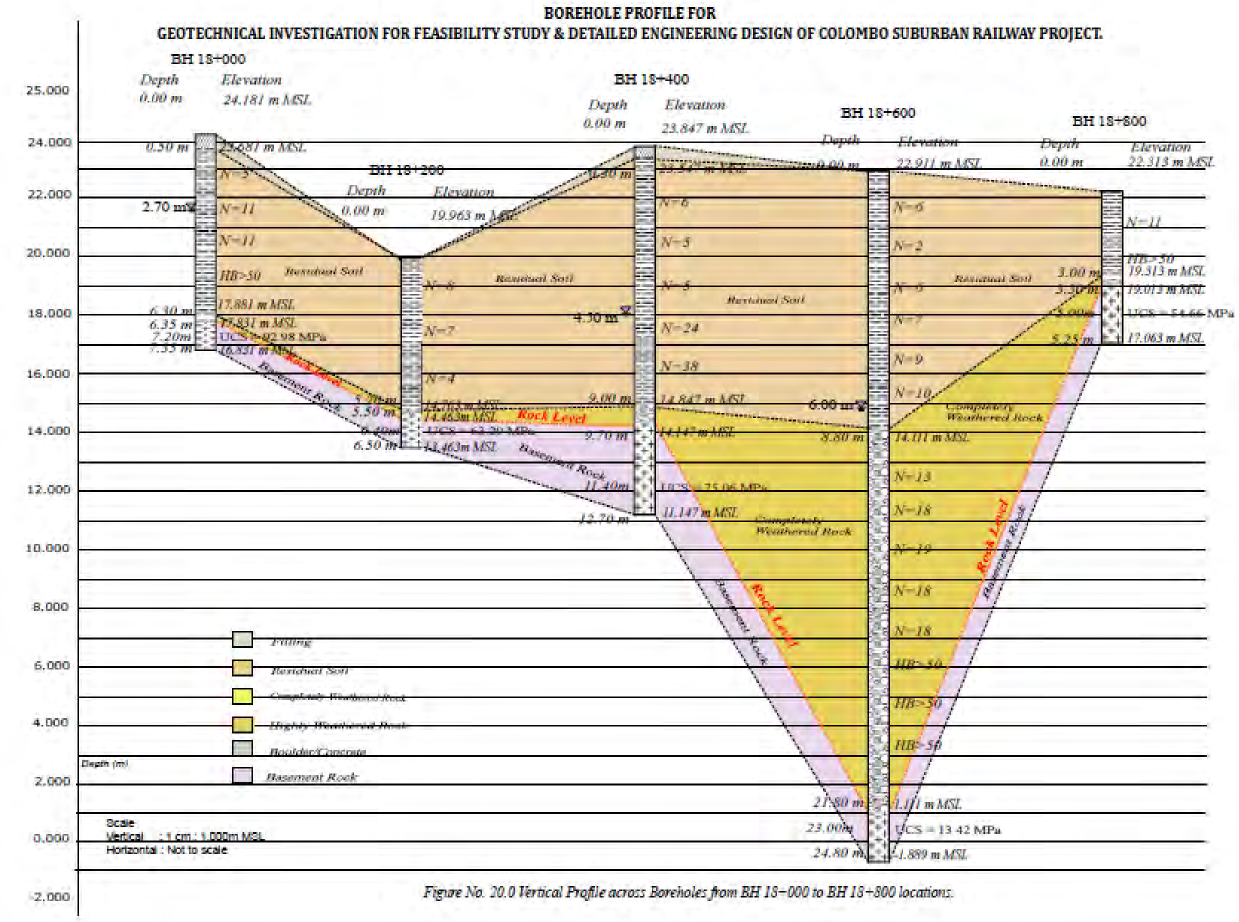


Figure B-24 Borehole Profile-24

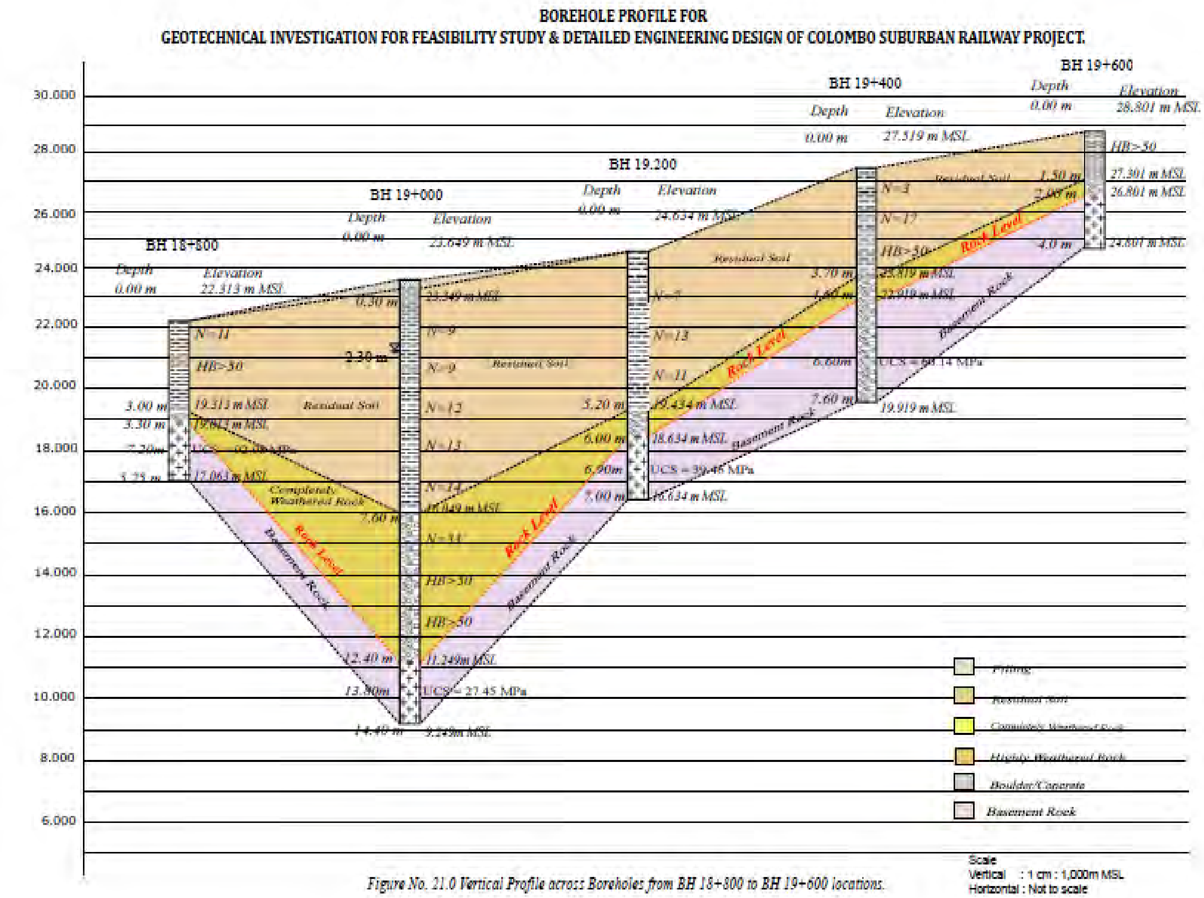


Figure B-25 Borehole Profile-25

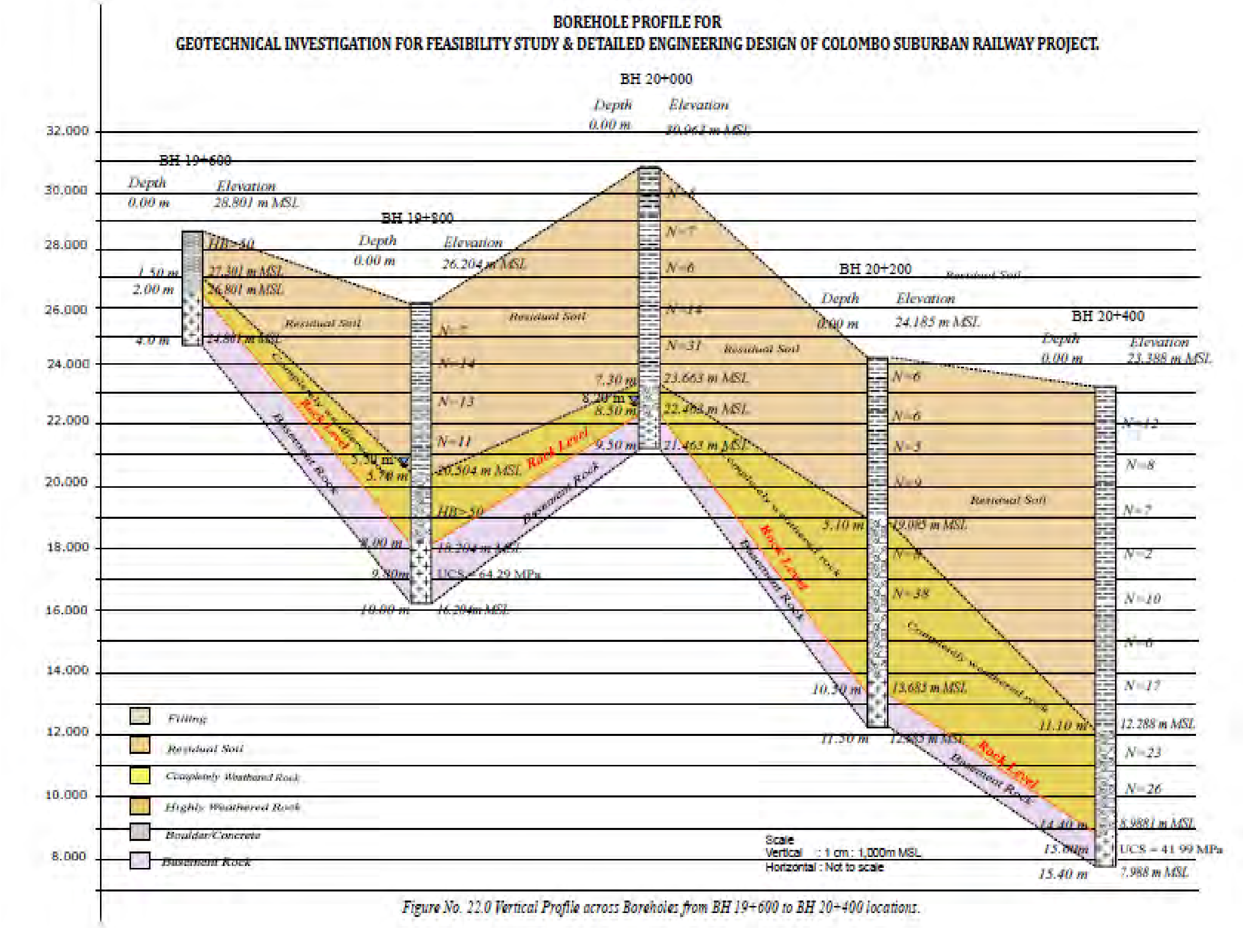


Figure B-26 Borehole Profile-26

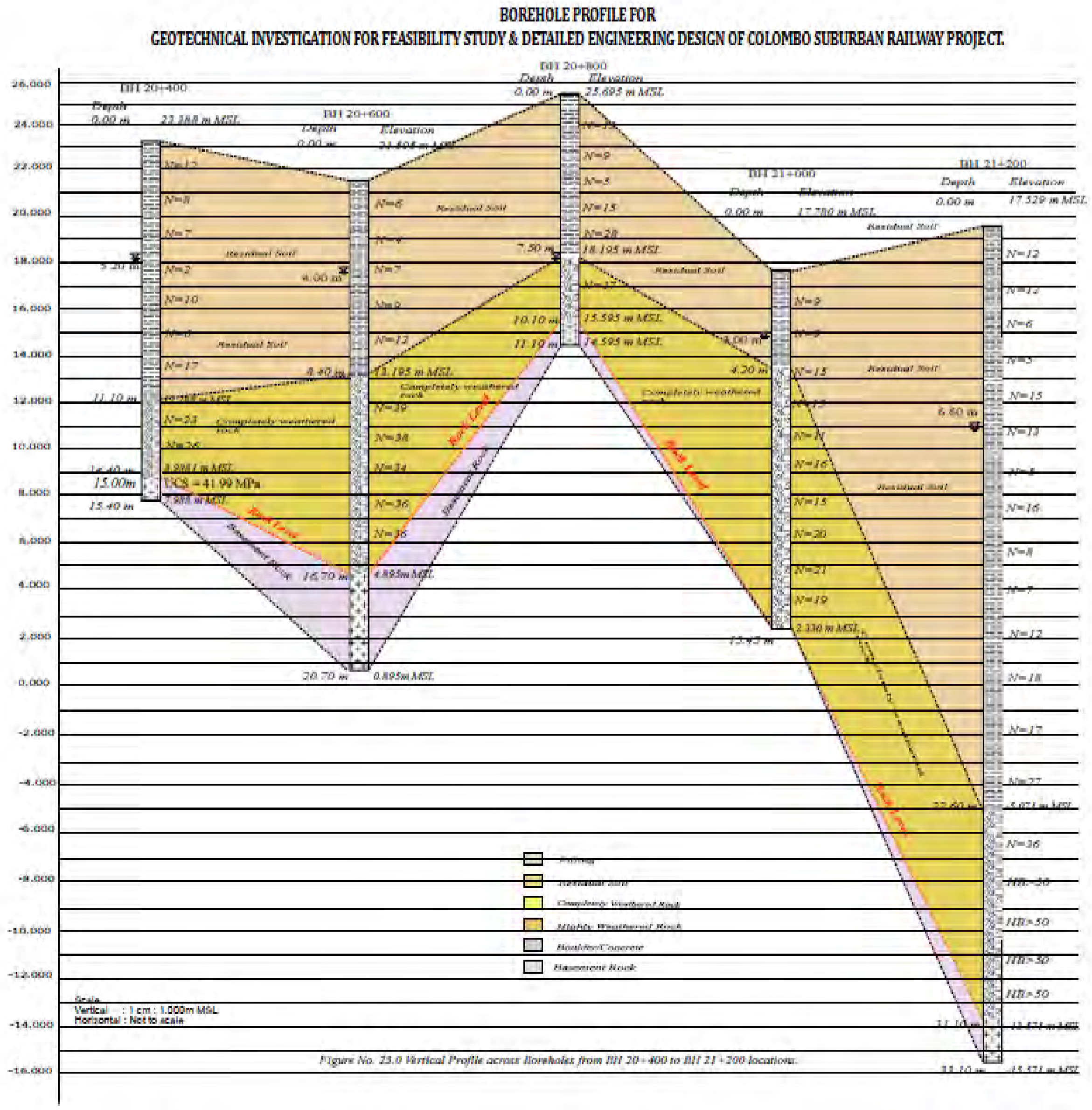


Figure B-27 Borehole Profile-27

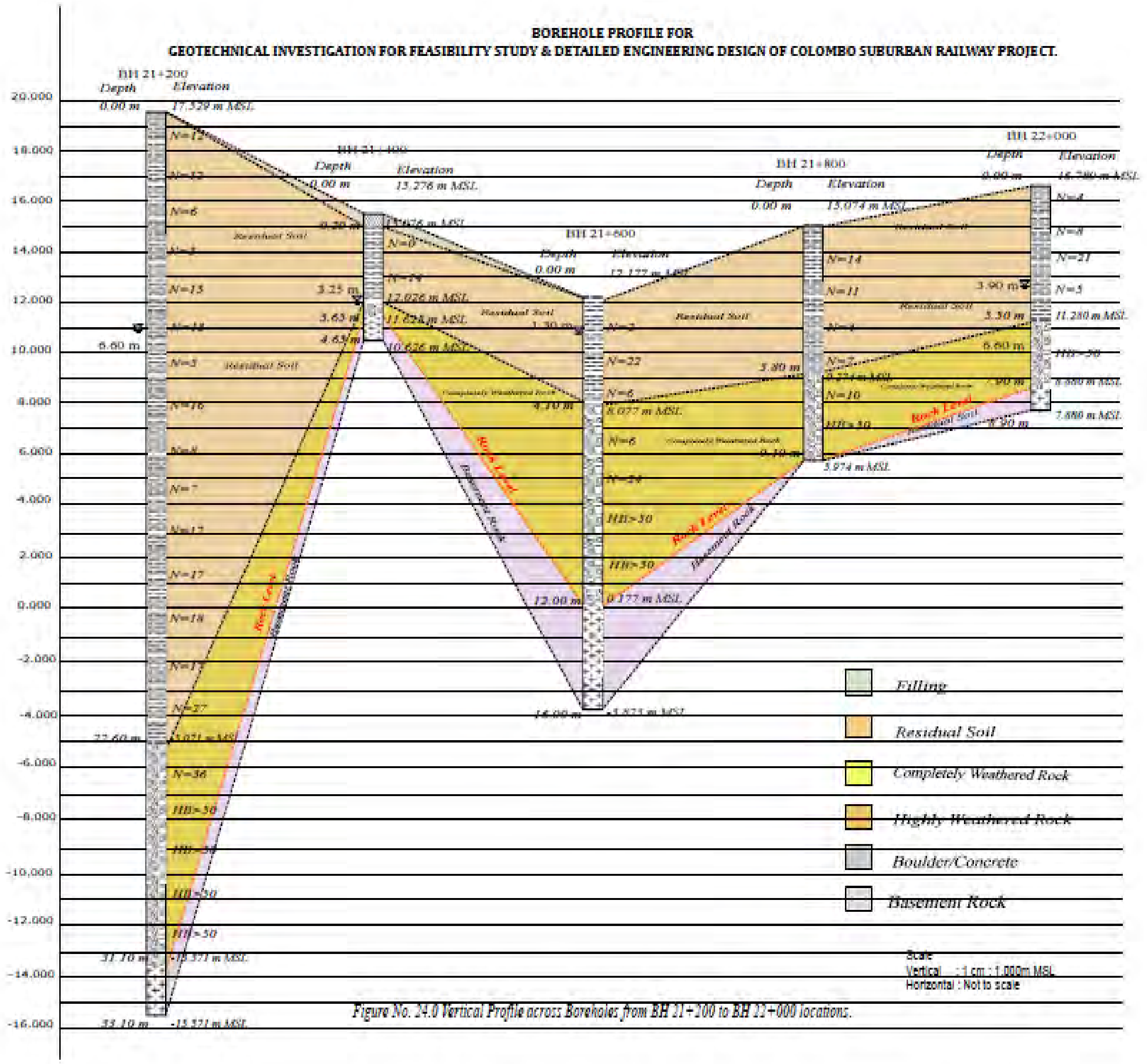


Figure B-28 Borehole Profile-28

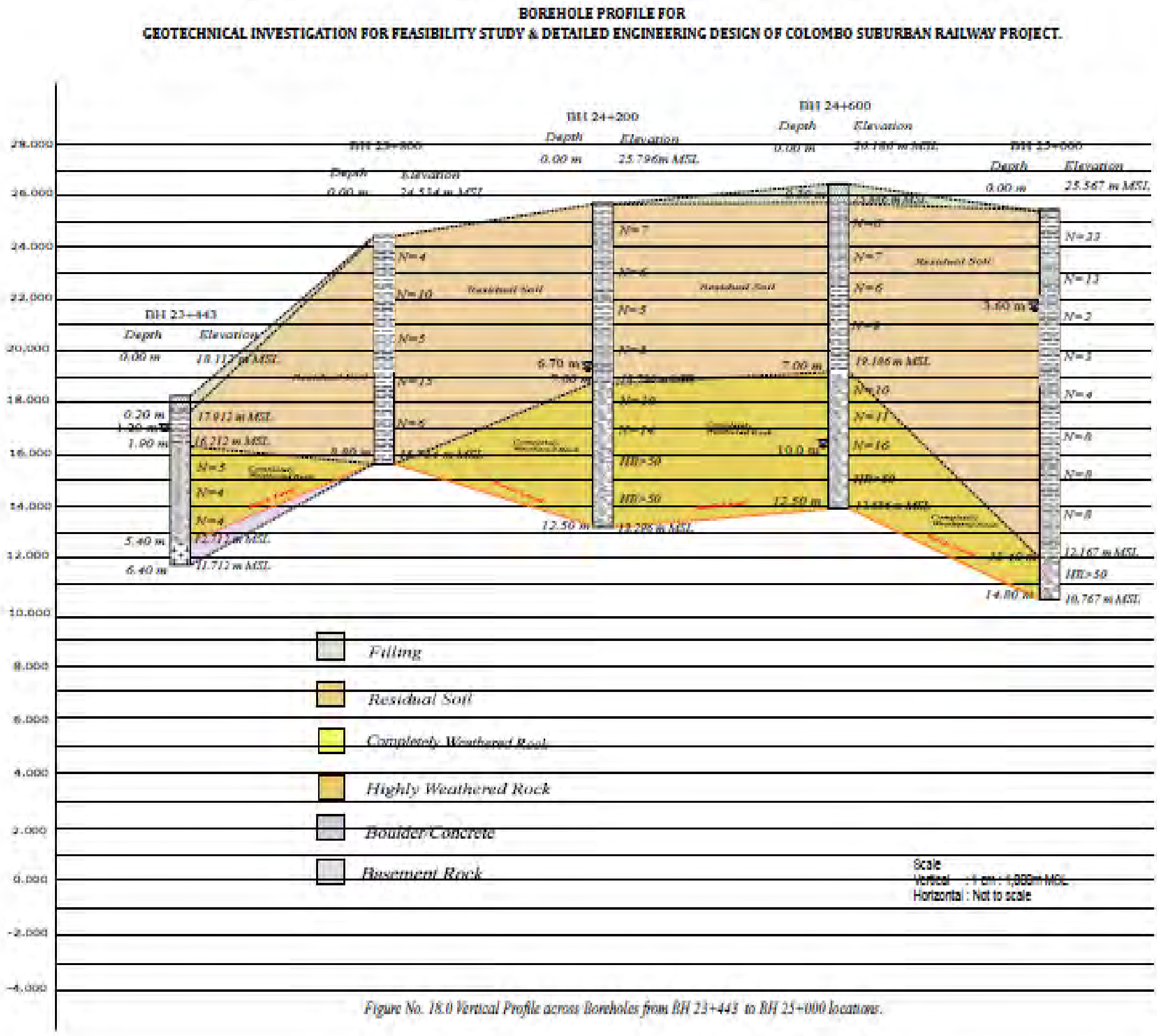


Figure B-29 Borehole Profile-29

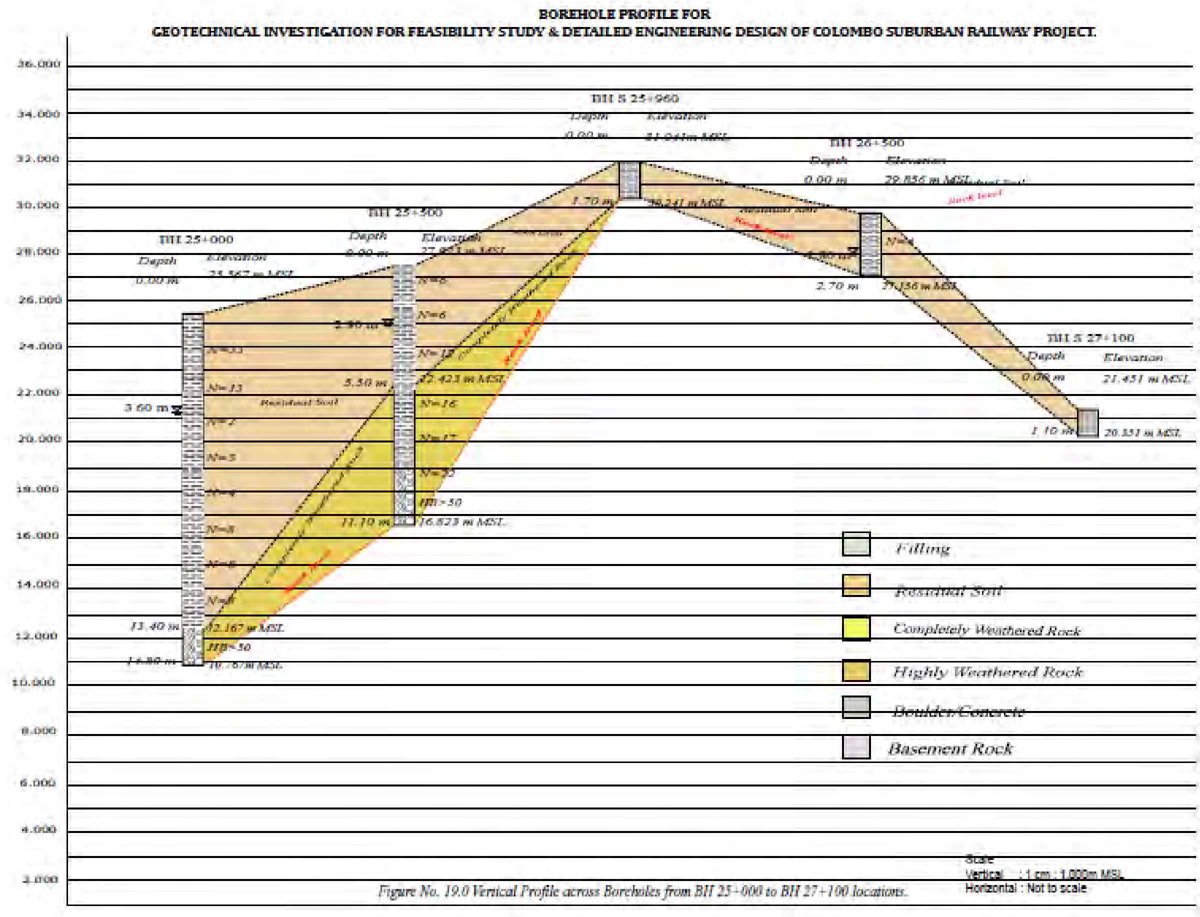


Figure B-30 Borehole Profile-30

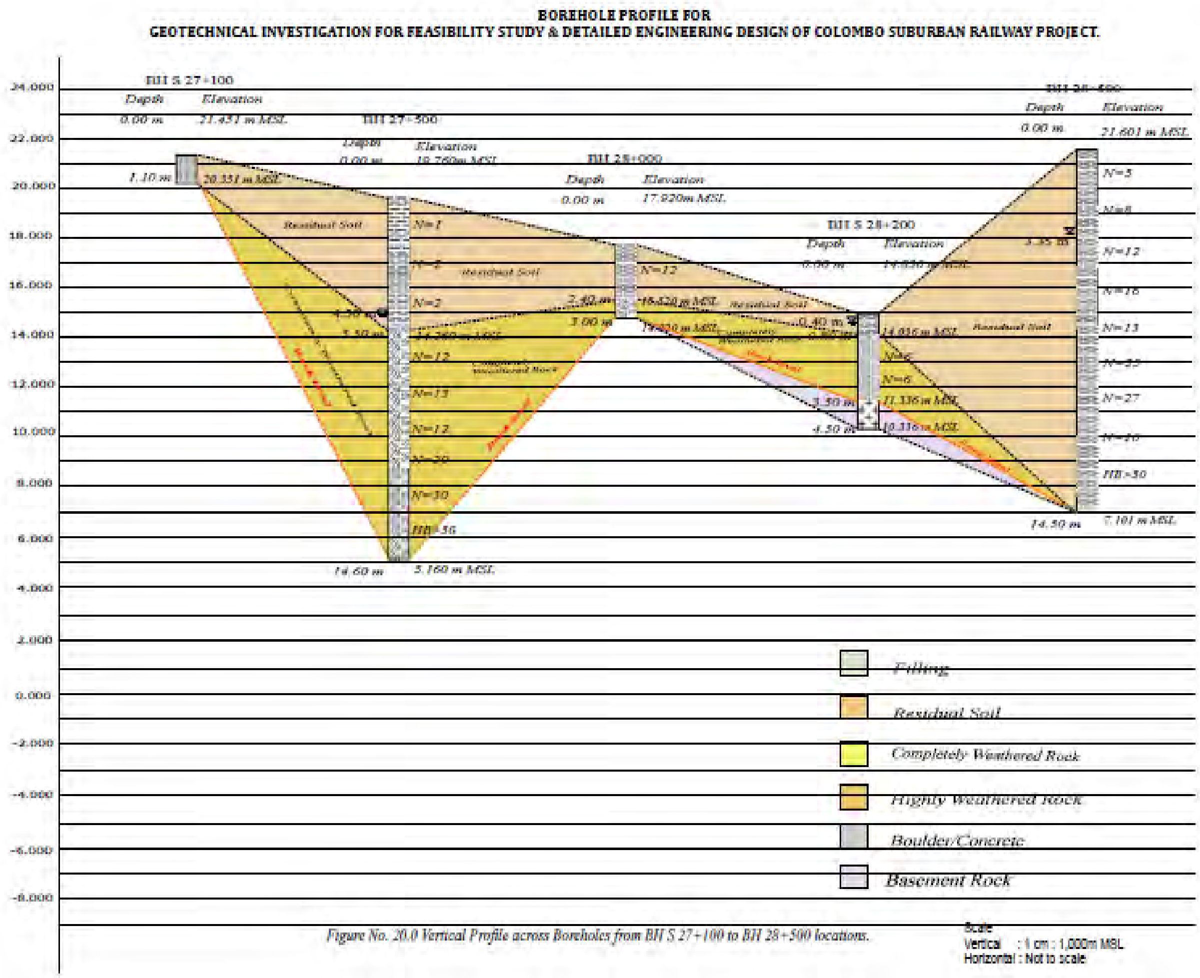


Figure B-31 Borehole Profile-31

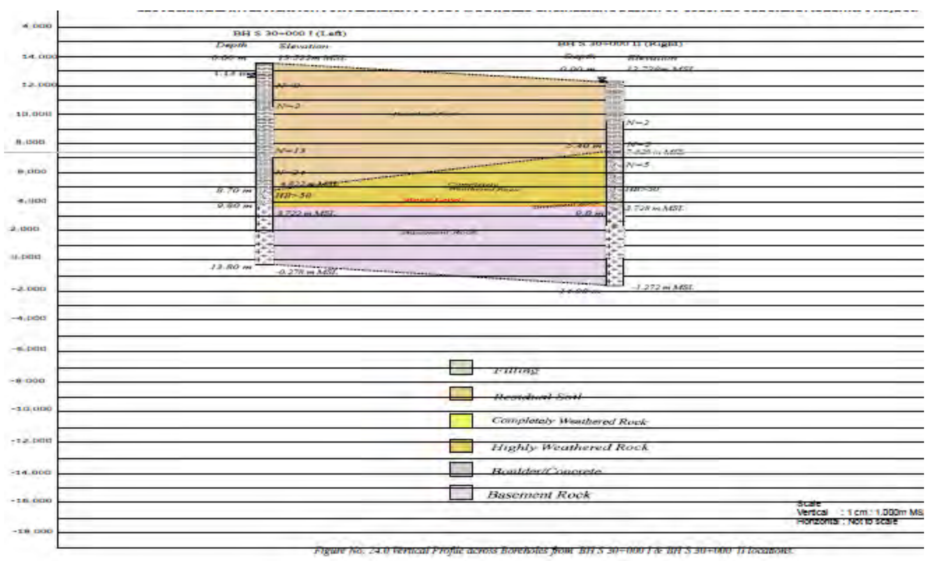


Figure B-32 Bridge at Chainage 30+000

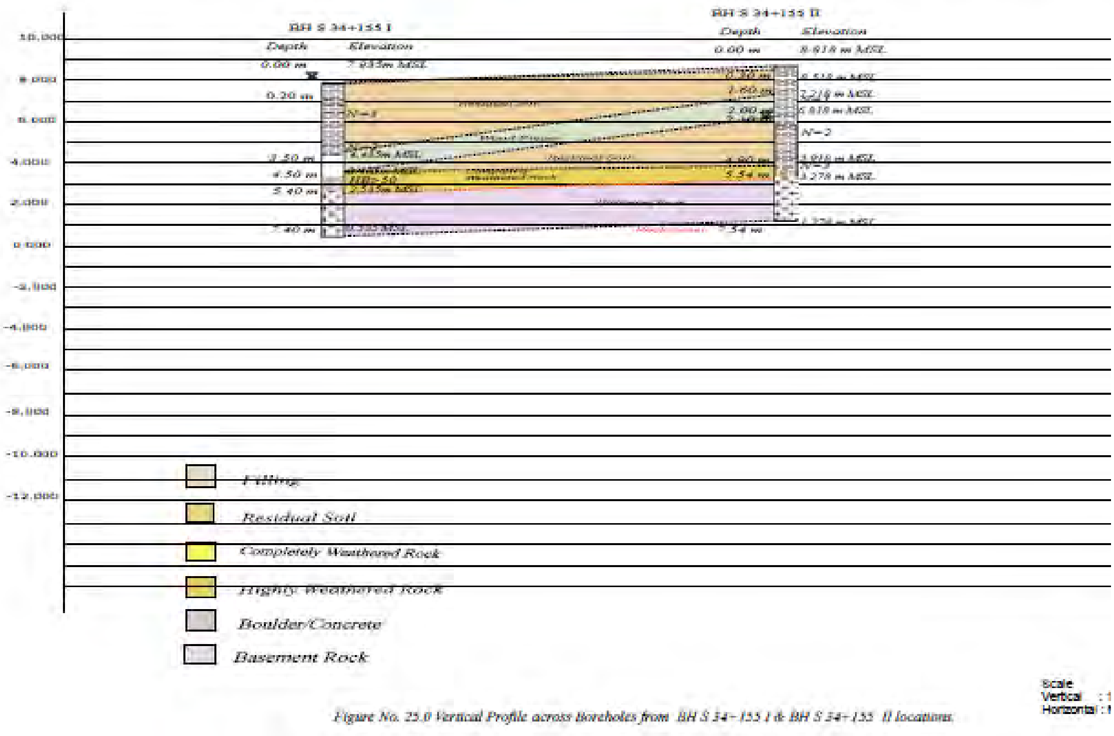


Figure B-33 Bridge at Chainage 34+155

Appendix C
Geotechnical Studies:
Summary of Results of the Laboratory Test
KV Line

Table C-1 Summary of Results of the Laboratory Test – KV Line

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m³]	Dry Density [kg/m³]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m²]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-00+000	7.50	SPT	Elastis SILT with Sand (MH)	89	90	41	49				79	21	0	2.64										
	21.00	CORE													14.54									
	24.80	CORE													6.33									
BH-00+200	2.20	WATER																				0.005	<1x 10-6	6.51 at 28.5 0C
	3.00	SPT	Clayey GRAVEL with Sand (GC)	49	47	26	21				41	22	36	2.56										
	26.00	CORE													16.82									
BH-00+400	4.50	SPT	Clayey GRAVEL with Sand (GC)	52	48	26	22				43	28	29	2.61										
	18.40	CORE													17.84									
	22.00	CORE													25.98									
BH-00+600	9.00	SPT																						
	40.30	CORE													12.15									
	41.40	CORE													8.91									
BH-00+800	6.00	SPT																						
	21.00	CORE													26.47									
BH-01+000	6.00	SPT	Silty SAND with Gravel (SM)	26	23	N/A	N/A				18	61	21	2.59										
	21.50	CORE													24.92									
BH-01+200	4.50	SPT	Silty SAND (SM)	31	26	N/A	N/A				23	72	5	2.62										
	28.50	CORE													11.48									
BH-01+400	9.00	SPT	Fat CLAY (CH)	99	83	36	47				90	10	0	2.65	17.68									
BH-01+600	0.90	WATER																				0.072	<1x 10-6	6.3 at 28.5 0C
	6.00	SPT	Organic CLAY with Sand (OH)	90	89	38	51				78	22	0	2.36										
	33.40	CORE													3.98									
	41.70	CORE													21.24									
BH-01+800	10.50	SPT	Sandy Elastic SILT (MH)	75	53	36	17				62	37	1	2.65										
	40.60	CORE													62.44									
BH-02+000	3.00	SPT	Organic CLAY (OH)	95	91	35	56				88	12	0	2.39										
	29.70	CORE													29.20									
BH-02+200	4.50	SPT	Elastic SILT with Sand (MH)	91	83	44	39				78	18	4	2.62										
	24.60	CORE													6.85									
BH-02+400	7.50	SPT	Sandy Elastic SILT (MH)	82	61	46	15				58	42	0	2.61										
	19.90	CORE													47.96									
BH-02+600	12.00	SPT	Elastic SILT (MH)	92	84	42	42				90	9	1	2.63										
	21.00	CORE													88.08									
BH-02+800	2.60	WATER																				0.091	<1x 10-6	6.78 at 28.5 0C
	16.50	SPT	Silty SAND (SM)	72	46	33	13	28.9			41	59	0	2.64										
	22.50	CORE													45.18									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-03+000	7.50	SPT	Organic CLAY (OH)	98	90	33	57	56.2			94	6	0	2.10										
	12.50	CORE													48.52									
BH-03+200	19.60	CORE													45.54									
BH-03+400	6.00	SPT	Clayey SAND (SC)	77	45	25	20	26.1			35	65	0	2.59										
	9.20	CORE													57.54									
BH-03+600	3.00	SPT	Well Graded SAND with Silt and Gravel (SW-SM)	21				11.9			8	60	32	2.59										
	15.30	CORE													49.67									
BH-03+800	12.00	SPT	Sandy Lean CLAY (CL)	98	33	12	21	31.8			54	46	0	2.64										
	20.50	CORE													47.98									
BH-04+000	3.00	SPT	Silty SAND (SM)	65	22	N/A	N/A	17.0			29	71	0	2.58										
	19.70	CORE													41.90									
BH-04+200	10.50	SPT	Sandy Elastic SILT (MH)	68	66	42	24	41.3			53	47	0	2.62										
	14.50	CORE													32.74									
BH-04+400	7.50	SPT	Sandy Fat CLAY (CH)	78	61	24	36	34.3			64	36	0	2.64										
	17.30	CORE													27.54									
BH-04+600	18.00	SPT	Sandy Fat CLAY (CH)	79	60	28	32	34.4			58	42	0	2.61										
	24.70	CORE													35.32									
BH-04+800	2.50	WATER																				0.027	<1x 10-6	6.04 at 28.5 0C
	4.50	SPT	Fat CLAY with Sand (CH)	90	76	26	50	31.9			76	22	2	2.66										
	9.00	UD	Fat CLAY (CH)	97	89	34	55	138.8			96	4	0	1.78		UU	55		2.459	0.438	80			
	17.40	CORE													21.95									
BH-05+000	12.00	SPT	Clayey SAND (SC)	70	53	20	33	32.2			42	58	0	2.62										
	20.60	CORE													23.91									
BH-05+200	6.00	SPT	Sandy Elastic SILT (MH)	83	54	32	22	43.4			64	36	0	2.63										
	13.40	CORE													41.10									
BH-05+400	4.50	SPT	Clayey GRAVEL with Sand (GC)	58	55	26	29	36.7			47	26	27	2.60										
	7.50	CORE													83.70									
BH-05+600	30.00	CORE													33.41									
	30.10	CORE													18.74									
BH-05+800	14.40	CORE													52.81									
BH-06+000	27.00	SPT	Sandy Elastic SILT (MH)	92	63	35	28	33.5			64	36	0	2.64										
	32.70	CORE													58.17									
BH-06+200	13.50	SPT	Well Graded SAND with Silt (SW - SM	50	N/A	N/A	N/A	26.1			9	91	0	2.58										
	23.30	CORE													37.97									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-06+400	1.20	WATER																				0.116	<1x 10-6	6.72 at 28.3 0C
	3.45 - 3.90	UD	Elastic SILT (MH)	94	88	42	46	54.7			92	8	0	2.49		UU	15		3.678	2.777	75			
	6.00	SPT	Sandy Elastic SILT (MH)	86	53	36	17	26.1			63	36	1	2.66										
	20.70	CORE													30.06									
BH-06+600	9.25	CORE													17.02									
BH-06+800	22.50	SPT	Silty SAND (SM)	69	36	N/A	N/A	35.4			41	58	1	2.61										
	29.40	CORE													31.74									
BH-07+000	3.00	SPT	Sandy Elastic SILT (MH)	72	61	32	29	32.7			57	38	5	2.64										
	14.50	CORE													44.11									
BH-07+200	15.00	SPT	Silty SAND (SM)	89	45	28	17	37.6			48	52	0	2.58										
	20.20	CORE													37.91									
BH-07+400	3.00	SPT	Sandy Fat CLAY with Gravel (CH)	74	65	31	34	33.6			64	19	17	2.63										
	6.70	CORE													43.15									
BH-07+600	9.00	SPT	Sandy Elastic SILT (MH)	86	52	31	21	38.0			50	50	0	2.60										
BH-07+800	6.00	SPT	Sandy Elastic SILT (MH)	80	75	43	32	43.5			61	39	0	2.64										
BH-08+000	3.00	SPT	Poorly Graded SAND (SP)	53	N/A	N/A	N/A	13.3			4	96	0	2.62										
	11.40	CORE													38.39									
BH-08+200	1.40	WATER																				0.026	<1x 10-6	6.57 at 28.4 0C
	6.00	SPT	Silty SAND (SM)	63	28	N/A	N/A	21.4			31	66	3	2.56										
BH-08+400	6.00	SPT	Sandy Elastic SILT (MH)	74	63	37	26	44.2			51	47	2	2.65										
	13.00	CORE													37.33									
	13.70	CORE													1.41									
BH-08+600	16.50	SPT	Clayey SAND (SC)	76	40	25	15	23.1			34	66	0	2.58										
	23.70	CORE													36.87									
BH-08+800	3.00	SPT	Clayey SAND (SC)	57				25.0			46	40	14	2.63										
	11.60	CORE													52.96									
BH-09+000	10.60	CORE													37.90									
BH-09+200	1.40	WATER																				0.021	<1x 10-6	7.11 at 27.8 0C
	19.50	SPT	Clayey SAND (SC)	77				24.8			40	57	3	2.63										
	22.90	CORE													8.84									
	24.00	CORE													28.45									
BH-09+400	3.00	SPT	Sandy SILT (ML)	68	43	30	13	9.6			54	33	13	2.62										
	7.10	CORE													65.74									
BH-09+600	9.00	SPT	Clayey SAND (SC)	73	51	28	23	29.6			44	56	0	2.62										
	12.80	CORE													46.88									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m³]	Dry Density [kg/m³]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m²]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-09+800	1.00	WATER																				0.021	<1x 10-6	7.72 at 27.8 0C
	3.00	SPT	Elastic SILT with Sand (MH)	91	87	46	41	51.8			77	23	0	2.63										
	16.00	CORE													48.81									
BH-10+000	6.00	SPT	Silty SAND (SM)	78	28	N/A	N/A	20.4			25	75	0	2.59										
	11.50	CORE													50.56									
BH-10+200	5.40	CORE													43.25									
BH-10+400	1.00	WATER																				0.010	<1x 10-6	7.5 at 27.8 0C
	4.50	SPT	Silty SAND (SM)	81	32	N/A	N/A	33.4			37	60	3	2.61										
	12.80	CORE													8.93									
BH-10+600	4.60	CORE													46.34									
BH-10+800	0.30	WATER																						
	6.00	SPT	Silty SAND (SM)	78	32	N/A	N/A	29.1			36	64	0	2.60										
BH-11+000	3.00	SPT	Clayey SAND (SC)	80	43	25	18	29.1			48	52	0	2.61										
	8.65	CORE													65.68									
BH-11+200	0.30	WATER																				0.010	<1x 10-6	7.64 at 27.8 0C
	16.50	SPT	Clayey SAND (SC)	77	48	28	20	28.8			49	51	0	2.61										
BH-11+400	9.00	SPT	Elastic SILT (MH)	97	76	37	39	51.1			88	12	0	2.65										
	19.80	CORE													46.95									
BH-11+600	4.50	SPT	Fat CLAY with Sand (CH)	83	81	34	47	54.5			74	15	11	2.66										
	15.50	CORE													47.47									
BH-11+800	1.65	WATER																				0.040	<1x 10-6	7.52 at 27.8 0C
	7.50	SPT	Clayey SAND (SC)	85	42	25	17	34.6			41	59	0	2.58										
	11.50	CORE													36.64									
BH-12+000	3.00	SPT	Silty SAND (SM)	80	47	29	18	37.2			42	58	0	2.58										
	8.90	CORE													45.03									
BH-12+200	9.00	SPT	Clayey SAND (SC)	66	53	24	29	28.8			39	61	0	2.61										
	10.80	CORE													38.55									
BH-12+400	3.00	SPT	Clayey GRAVEL with Sand (GC)	35	32	19	14	23.7			25	37	38	2.66										
BH-12+600	6.00	SPT	Clayey SAND (SC)	72	31	12	19	19.5			32	67	1	2.62										
	8.50	CORE													36.16									
BH-12+800	3.00	SPT	Clayey GRAVEL with Sand (GC)	47	43	26	17	18.4			36	28	37	2.66										
	10.90	CORE													40.12									
BH-13+000	7.50	SPT	Silty SAND (SM)	50	21	N/A	N/A	23.8			24	63	13	2.55										
	12.00	CORE													26.77									
BH-13+200	1.15	WATER																				0.010	<1x 10-6	7.04 at 27.8 0C
	22.50	SPT	Well Graded SAND with Silt (SW-SM	25	N/A	N/A	N/A	18.0			10	90	0	2.62										
	25.50	CORE													22.36									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-13+400	3.00	SPT	Clayey SAND with Gravel (SC)	49	33	19	14	23.3			29	46	25	2.63										
	12.10	CORE													45.24									
BH-13+600	9.00	SPT	Sandy Elastic SILT (MH)	92	86	45	41	54.9			66	34	0	2.59										
	17.00	CORE													94.63									
BH-13+800	15.00	SPT	Clayey SAND (SC)	83	51	15	36	33.4			37	63	0	2.60										
	16.80	CORE													40.44									
BH-14+000	3.00	SPT	Clayey GRAVEL with Sand (GC)	42	36	22	14	20.0			31	29	40	2.64										
	8.30	CORE													69.07									
BH-14+200	12.00	SPT	Sandy Elastic SILT (MH)	74	55	33	22	29.7			53	47	0	2.62										
	16.70	CORE													52.70									
BH-14+400	3.00	SPT	Clayey GRAVEL with Sand (GC)	41	39	22	17	20.7			34	21	45	2.67										
	8.20	CORE													58.92									
BH-14+600	21.00	SPT	Sandy Elastic SILT (MH)	88	69	42	27	49.6			61	39	0	2.64										
	24.80	CORE													58.78									
BH-14+800	4.20	WATER																				0.016	<1x 10-6	6.4 at 27.8 0C
	6.00	SPT	Sandy Elastic SILT (MH)	77	56	30	26	43.3			56	44	0	2.63										
	22.90	CORE													33.21									
BH-15+000	3.00	SPT	Silty GRAVEL (GM)	19				14.9			16	7	77	2.60										
	11.90	CORE													65.86									
BH-15+200	7.50	SPT	Well Graded SAND with Silt (SW - SM	66	N/A	N/A	N/A	33.8			10	90	0	2.60										
	9.20	CORE													52.94									
BH-15+400	5.20	WATER																				0.010	<1x 10-6	7.22 at 27.8 0C
	15.00	SPT	Silty SAND (SM)	82	56	38	18	34.6			41	59	0	2.57										
	18.30	CORE													69.23									
BH-15+600	6.00	SPT	Silty SAND with Gravel (SM)	55	44	28	16	19.7			38	34	28	2.64										
	8.90	CORE													54.33									
BH-15+800	7.50	SPT	Fat CLAY (CH)	99	82	30	52	63.4			96	4	0	2.64										
	10.50	CORE													18.29									
BH-16+000	3.00	SPT	Clayey SAND with Gravel (SC)	62	44	18	26	41.7			40	44	16	2.64										
	6.40	CORE													48.87									
BH-16+200	10.50	SPT	Silty SAND (SM)	65	32	N/A	N/A	21.6			32	68	0	2.60										
	16.20	CORE													11.29									
BH-16+400	18.00	SPT	Clayey SAND (SC)	82	47	26	21	31.8			44	56	0	2.59										
	21.30	CORE													38.97									
BH-16+600	4.50	SPT	Silty SAND (SM)	59	47	29	18	24.9			41	53	6	2.63										
	19.90	CORE													54.39								0.013	<0.001	6.82 at 27.8°c

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-16+800	6.00	SPT	Sandy Elastic SILT (MH)	87	62	35	27	34.5			67	33	0	2.65										
	16.90	CORE													23.55									
BH-17+000	5.97	WATER																				0.013	<1x 10-6	7.27 at 27.8 0C
	19.50	SPT	Silty SAND (SM)	64	31	N/A	N/A	28.0			29	71	0	2.56										
	23.50	CORE													61.86									
BH-17+200	6.00	SPT	Clayey SAND (SC)	73	59	29	30	35.6			47	53	0	2.62										
	23.50	CORE													69.80									
BH-17+400	9.00	SPT	Silty SAND (SM)	57	24	N/A	N/A	9.0			27	71	2	2.63										
	15.50	CORE													37.58									
BH-17+600	3.00	SPT	Clayey SAND with Gravel (SC)	39	28	18	10	12.3			22	62	16	2.63										
	10.70	CORE													61.32									
BH-17+800	6.00	WATER																				0.009	<1x 10-6	7.04 at 27.8 0C
	10.50	SPT	Clayey SAND (SC)	72	48	15	33	25.5			32	67	1	2.58										
	12.40	CORE													51.86									
	12.80	CORE													4.40									
BH-18+000	3.00	SPT	Clayey GRAVEL with Sand (GC)	38	43	18	25	21.4			23	33	44	2.57										
	7.20	CORE													92.98									
BH-18+200	4.50	SPT	Silty SAND (SM)	61	23	N/A	N/A	21.7			26	73	0	2.60										
	6.40	CORE													63.20									
BH-18+400	11.40	CORE													75.06									
BH-18+600	7.25	WATER																				0.012	<1x 10-6	7.41 at 27.8 0C
	22.65	CORE													24.41									
	23.00	CORE													13.42									
BH-18+800	5.00	CORE													54.66									
BH-19+000	13.80	CORE													27.45									
BH-19+200	6.90	CORE													39.46									
BH-19+400	6.60	CORE													60.14									
BH-19+600	3.90	CORE													19.06									
BH-19+800	9.80	CORE													64.29									
BH-20+000	9.40	CORE													57.02									
BH-20+200	11.40	CORE													65.57									
BH-20+400	15.00	CORE													41.99									
BH-20+600	4.00	WATER																				0.011	<1x 10-6	6.21 at 27.8 0C
	20.60	CORE													57.91									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-20+800	3.00	SPT	Sandy Fat CLAY (CH)	75	58	29	29	25.3			64	31	5	2.60										
	4.50	SPT	Silty SAND (SM)	53	56	34	22	28.3			39	55	6	2.57										
	9.00	SPT	Silty SAND (SM)	72	58	N/A	N/A	24.8			35	65	0	2.60										
	10.90	CORE													60.14									
BH-21+000	1.50	SPT	Well Graded GRAVEL with Silt and Sand (GW-GM)	10				7.9			6	40	54	2.64										
	3.00	SPT	Silty GRAVEL with Sand (GM)	30	N/A	N/A	N/A	18.9			22	25	53	2.62										
	7.50	SPT	Sandy Fat CLAY (CH)	82	53	24	29	42.8			70	30	0	2.60										
	9.00	SPT	Sandy Elastic SILT (MH)	81	64	36	28	44.2			69	31	0	2.54										
	13.50	SPT	Sandy Elastic SILT (MH)	83	60	35	25	51.9			70	29	1	2.56										
BH-21+200	3.00	SPT	Poorly Graded Gravel with SILT and SAND (GP-GM)	11				14.4			7	25	68	2.53										
	6.00	SPT	Sandy Elastic SILT (MH)	72	58	34	24	32.9			54	43	3	2.58										
	10.50	SPT	Clayey SAND (SC)	64	54	24	30	38.0			47	53	0	2.56										
	15.00	SPT	Silty SAND (SM)	62	56	31	25	34.7			46	54	0	2.57										
	24.00	SPT	Clayey SAND (SC)	76	57	25	32	22.3			47	53	0	2.56										
BH-21+400	1.50	SPT	Silty SAND (SM)	52	73	38	35	22.7			37	51	12	2.53										
BH-21+600	1.50	SPT	Sandy Lean CLAY (CL)	76	37	25	12	48.8			58	34	8	2.58										
	3.00	SPT	Silty SAND (SM)	36	N/A	N/A	N/A	11.2			16	79	5	2.60										
	6.00	SPT	Silty SAND (SM)	61	28	N/A	N/A	27.6			30	66	4	2.59										
BH-21+800	1.50	SPT	Clayey SAND with Gravel (SC)	39				14.1			30	38	32	2.57										
	3.00	SPT	Clayey SAND with Gravel (SC)	57	41	19	22	11.8			45	37	19	2.62										
	4.50	SPT	Silty SAND (SM)	83				35.1			37	58	5	2.57										
	7.50	SPT	Clayey SAND (SC)	82	54	30	24	25.4			35	56	9	2.53										
BH-22+000	1.50	SPT	Silty SAND with Gravel (SM)	43				21.1			30	40	30	2.57										
	3.00	SPT	Clayey SAND (SC)	52	28	13	15	17.2			30	67	3	2.59										
	4.50	SPT	Silty SAND (SM)	49	N/A	N/A	N/A	22.9			22	72	6	2.61										
	6.00	SPT	Silty SAND (SM)	45	38	N/A	N/A	21.6			27	64	9	2.57										
BH-22+290	1.50	SPT	Silty SAND (SM)	39	21	N/A	N/A	21.0			28	66	6	2.59										
BH-22+500	3.00	SPT	Clayey SAND with Gravel (SC)	54				29.7			39	38	23	2.61										
	6.00	SPT	Clayey SAND (SC)	52	51	33	28	29.1			45	55	0	2.62										
	10.50	SPT	Sandy Elastic SILT (MH)	71	57	31	26	34.9			53	47	0	2.63										
BH-22+976	1.50	SPT	Clayey SAND with Gravel (SC)	40				20.1			28	52	20	2.63										
	4.50	SPT	Silty SAND (SM)	71	53	N/A	N/A	26.5			39	61	0	2.59										
	9.50	CORE													55.06									
BH-23+443	1.50	SPT	Silty SAND (SM)	46	23	N/A	N/A	26.7			31	69	0	2.56										
	4.50	SPT	Silty SAND (SM)	75	65	N/A	N/A	44.6			37	63	0	2.56										
	5.60	CORE													60.51									

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m^3]	Dry Density [kg/m^3]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG	[MPa]	TYPE	Cu [KN/m^2]	F Deg.	e_o	C_c	Pc(kPa)	Cl^{-1} (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-23+800	3.00	SPT	Clayey SAND (SC)	45	50	28	22	21.2			29	65	6	2.54										
	4.50	SPT	Sandy Elastic SILT (MH)	78	52	32	20	28.3			52	48	0	2.64										
	6.00	SPT	Silty SAND (SM)	64	52	27	25	27.2			48	52	0	2.61										
BH-24+200	1.50	SPT	Sandy Lean CLAY with Gravel (CL)	61	46	21	25	27.3			51	33	16	2.63										
	4.50	SPT	Sandy Elastic SILT (MH)	62	51	33	18	28.7			50	40	10	2.62										
	9.00	SPT	Sandy Elastic SILT (MH)	74	56	38	18	43.2			51	47	2	2.61										
	12.00	SPT	Sandy flat CLAY (CH)	82				41.7			67	32	1	2.65										
BH-24+600	1.50	SPT	Clayey SAND with Gravel (SC)	57				29.3			44	30	25	2.60										
	3.00	SPT	Clayey SAND (SC)	55	28	13	15	24.0			31	62	7	2.57										
	4.50	SPT	Clayey SAND (SC)	40	42	25	17	23.4			31	55	14	2.59										
	9.00	SPT	Clayey SAND (SC)	50	38	N/A	N/A	26.3			23	63	15	2.57										
BH-25+500	1.50	SPT	Clayey SAND (SC)	50	29	14	15	14.0			24	76	0	2.61										
	4.50	SPT	Sandy Elastic SILT (MH)	61	67	39	28	32.2			53	43	4	2.65										
	9.00	SPT	Silty SAND (SM)	74	39	N/A	N/A	22.0			34	66	0	2.61										
BH-25+960	1.50	SPT	Well Graded SAND with Silt (SW - SM)	14	N/A	N/A	N/A	13.0			6	81	13	2.58										
BH-26+500	1.50	SPT	Silty SAND (SM)	63	28	N/A	N/A	19.7			35	60	5	2.53										
BH-27+500	1.50	SPT	Silty SAND (SM)	56	57	31	26	27.5			48	45	7	2.62										
	4.50	SPT	Silty SAND (SM)	76	51	31	20	26.8			44	56	0	2.56										
	7.50	SPT	Clayey SAND (SC)	65	39	22	17	27.1			35	65	0	2.52										
	10.50	SPT	Clayey SAND (SC)	59	32	15	17	20.3			37	63	0	2.53										
BH-28+000	1.50	SPT	Silty SAND (SM)	49	21	N/A	N/A	15.5			26	69	5	2.54										
BH-28+200	4.00	CORE													54.66									
BH-30+000 I	1.50	SPT	Silty SAND (SC)	85	37	N/A	N/A	39.3			46	54	0	2.61										
	3.00	SPT	Poorly Graded SAND (SP)	57	N/A	N/A	N/A	2.8			2	98	0	2.63										
	4.50	UD	Clayey SAND (SC)	61	32	14	18	19.0			39	57	4	2.60										
	7.50	SPT	Silty SAND (SM)	54	23	N/A	N/A	15.7			24	74	2	2.67										
BH-30+000 II	3.00	SPT	Fat CLAY with Sand (CH)	96	89	37	52	42.1			84	16	0	2.62										
	4.50	SPT	Clayey SAND (SC)	92	42	18	24	19.8			45	54	1	2.62										
	6.00	SPT	Silty SAND (SM)	91	42	N/A	N/A	27.2			38	61	1	2.59										
	9.50	CORE													20.45									
BH-30+160	1.50	SPT	Well Graded SAND with Silt (SW - SM)	53	N/A	N/A	N/A	20.2			8	91	1	2.56										
BH-30+500	1.50	SPT	Silty SAND with Gravel (SM)	53	22	N/A	N/A	35.4			27	55	18	2.55										
	4.50	SPT	Silty SAND (SM)	82	N/A	N/A	N/A	18.4			16	84	0	2.58										
	6.00	SPT	Sandy Elastic SILT (MH)	87	63	36	27	51.0			56	41	3	2.63										
	9.00	SPT	Elastic SILT with Sand (MH)	87	65	40	25	42.9			72	28	0	2.66										

SAMPLE DETAILS				Classification Tests											Unconfined Compressive Strength [MPa]	Shear Strength			Consolidation			Chemical Analyses		
BH	DEPTH	TYPE	DESCRIPTION	425µm [%]	LL [%]	PL [%]	PI	MC [%]	Bulk Density [kg/m³]	Dry Density [kg/m³]	Clay & Silt [%]	Sand [%]	Gravel [%]	SG		TYPE	Cu [KN/m²]	F Deg.	e_o	C_c	Pc(kPa)	Cl^1 (g/L) [mg/l]	SO_4^{-2} (g/L) [%]	pH
BH-31+084	1.50	SPT	Well Graded SAND with Silt (SW - SM	31	N/A	N/A	N/A	13.6			10	83	6	2.61										
	3.00	SPT	Poorly Graded SAND with Silt (SP - SM	22				8.8			11	77	12	2.58										
	4.50	SPT	Clayey SAND (SC)	71	47	28	19	32.0			49	48	3	2.64										
BH-31+561	3.00	SPT	Well Graded SAND with Silt (SW - SM	32	N/A	N/A	N/A	13.8			10	88	2	2.55										
	4.50	SPT	Well Graded SAND with Silt (SW - SM	41	N/A	N/A	N/A	16.8			10	89	0	2.59										
	6.00	SPT	Sandy Elastic SILT (MH)	66	59	34	25	33.0			56	44	0	2.64										
BH-32+000	1.50	SPT	Clayey SAND with Gravel (SC)	36	30	18	12	18.7			26	44	30	2.64										
	4.50	SPT	Clayey SAND with Gravel (SC)	35	26	15	11	16.6			24	55	22	2.62										
BH-32+500	1.50	SPT	Silty SAND with Gravel (SM)	26				12.7			16	45	39	2.62										
	4.50	SPT	Clayey SAND (SC)	66	53	28	25	48.2			47	52	1	2.64										
	7.50	SPT	Silty SAND (SM)	71	50	31	19	34.0			47	51	2	2.58										
	12.00	SPT	Clayey SAND (SC)	65	34	22	12	24.2			37	61	1	2.60										
BH-33+000	1.50	SPT	Clayey SAND with Gravel (SC)	46				25.2			36	39	25	2.62										
	4.50	SPT	Sandy Elastic SILT (MH)	72	55	30	25	38.4			53	47	0	2.65										
	9.00	SPT	Sandy Fat CLAY (CH)	64	50	26	24	33.8			52	48	0	2.63										
	13.50	SPT	Clayey SAND (SC)	72	38	20	18	23.7			45	55	0	2.60										
BH-34+155 I	2.00 - 2.50	UD	Fat CLAY (CH)	100	88	32	56	38.1			93	7	0	2.36		UU	53		0.859	0.138	65			
	7.30	CORE													20.00									
BH-34+155 II	6.60	CORE													63.67									

Appendix D
Financial and Economic Analysis:
Economic Analysis of KV Line

Table D-1 Demand Declined by 10%

(US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											Discounted Cash Flow
		Cost					Benefit Stream						
		Capital	O&M	Replace	Total	Discounted	VOC	VOT	Acc	Emm	Total	Discounted	
2018													
2019													
2020		70.80			70.80	59.76							-59.76
2021		429.59			429.59	333.58							-333.58
2022		429.59			429.59	306.90							-306.90
2023		429.59			429.59	282.35							-282.35
2024	1		18.27		18.27	11.05	412.48	106.88	17.38	29.56	566.30	342.42	331.37
2025	2		18.42		18.42	10.25	395.55	90.25	14.46	24.63	524.89	291.99	281.75
2026	3		18.57		18.57	9.50	378.73	73.35	11.40	19.26	482.75	247.06	237.56
2027	4		18.72		18.72	8.81	366.17	59.89	9.03	15.14	450.23	211.99	203.17
2028	5		18.87		18.87	8.17	357.40	49.21	7.16	11.94	425.70	184.40	176.23
2029	6		19.02		19.02	7.58	352.10	40.75	5.67	9.41	407.93	162.57	154.99
2030	7		19.19		19.19	7.03	350.02	34.10	4.47	7.39	395.98	145.18	138.15
2031	8		19.35		19.35	6.53	350.99	28.90	3.50	5.76	389.15	131.26	124.74
2032	9		19.51		19.51	6.06	354.92	24.89	2.69	4.43	386.93	120.07	114.02
2033	10		19.69	25.01	44.70	12.76	361.77	21.85	2.02	3.32	388.96	111.05	98.29
2034	11		19.86		19.86	5.22	371.57	19.60	1.45	2.39	395.00	103.75	98.53
2035	12		20.06		20.06	4.85	384.38	17.99	0.97	1.60	404.94	97.85	93.00
2036	13		20.06		20.06	4.46	384.38	17.99	0.97	1.60	404.94	90.02	85.56
2037	14		20.06		20.06	4.10	384.38	17.99	0.97	1.60	404.94	82.82	78.72
2038	15		20.06		20.06	3.78	384.38	17.99	0.97	1.60	404.94	76.20	72.42
2039	16		20.06		20.06	3.47	384.38	17.99	0.97	1.60	404.94	70.10	66.63
2040	17		20.06		20.06	3.20	384.38	17.99	0.97	1.60	404.94	64.49	61.30
2041	18		20.06		20.06	2.94	384.38	17.99	0.97	1.60	404.94	59.33	56.39
2042	19		20.06		20.06	2.70	384.38	17.99	0.97	1.60	404.94	54.59	51.88
2043	20		20.06	103.42	123.49	15.31	384.38	17.99	0.97	1.60	404.94	50.22	34.90
2044	21		20.06		20.06	2.29	384.38	17.99	0.97	1.60	404.94	46.20	43.91
2045	22		20.06		20.06	2.11	384.38	17.99	0.97	1.60	404.94	42.51	40.40
2046	23		20.06		20.06	1.94	384.38	17.99	0.97	1.60	404.94	39.11	37.17
2047	24		20.06		20.06	1.78	384.38	17.99	0.97	1.60	404.94	35.98	34.19
2048	25		20.06		20.06	1.64	384.38	17.99	0.97	1.60	404.94	33.10	31.46
2049	26		20.06		20.06	1.51	384.38	17.99	0.97	1.60	404.94	30.45	28.94
2050	27		20.06		20.06	1.39	384.38	17.99	0.97	1.60	404.94	28.01	26.63
2051	28		20.06		20.06	1.28	384.38	17.99	0.97	1.60	404.94	25.77	24.50
2052	29		20.06		20.06	1.17	384.38	17.99	0.97	1.60	404.94	23.71	22.54
2053	30		20.06	0.00	20.06	1.08	384.38	17.99	0.97	1.60	404.94	21.81	20.73
		1360	591	128	2079	1137	11355	892	98	164	12508	3024	1887

EIRR	15.28%
ENPV	1887
B/C	2.66

Table D-2 Capital Cost increase by 10% +Demand Declined by 10% (US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											
		Cost					Benefit Stream						Discounted Cash Flow
		Capital 10%	O&M	Replace	Total	Discounted	VOC	VOT	Acc	Emm	Total	Discounted	
2018													
2019													
2020		77.88			77.88	65.74							-65.74
2021		472.55			472.55	366.94							-366.94
2022		472.55			472.55	337.59							-337.59
2023		472.55			472.55	310.58						0	-310.58
2024	1		20.10		20.10	12.15	412.48	106.88	17.38	29.56	566.30	342.42	330.27
2025	2		20.26		20.26	11.27	395.55	90.25	14.46	24.63	524.89	291.99	280.72
2026	3		20.42		20.42	10.45	378.73	73.35	11.40	19.26	482.75	247.06	236.61
2027	4		20.59		20.59	9.69	366.17	59.89	9.03	15.14	450.23	211.99	202.29
2028	5		20.76		20.76	8.99	357.40	49.21	7.16	11.94	425.70	184.40	175.41
2029	6		20.93		20.93	8.34	352.10	40.75	5.67	9.41	407.93	162.57	154.23
2030	7		21.10		21.10	7.74	350.02	34.10	4.47	7.39	395.98	145.18	137.44
2031	8		21.28		21.28	7.18	350.99	28.90	3.50	5.76	389.15	131.26	124.08
2032	9		21.47		21.47	6.66	354.92	24.89	2.69	4.43	386.93	120.07	113.41
2033	10		21.66	27.51	49.17	14.04	361.77	21.85	2.02	3.32	388.96	111.05	97.01
2034	11		21.85		21.85	5.74	371.57	19.60	1.45	2.39	395.00	103.75	98.01
2035	12		22.07		22.07	5.33	384.38	17.99	0.97	1.60	404.94	97.85	92.52
2036	13		22.07		22.07	4.91	384.38	17.99	0.97	1.60	404.94	90.02	85.12
2037	14		22.07		22.07	4.51	384.38	17.99	0.97	1.60	404.94	82.82	78.31
2038	15		22.07		22.07	4.15	384.38	17.99	0.97	1.60	404.94	76.20	72.04
2039	16		22.07		22.07	3.82	384.38	17.99	0.97	1.60	404.94	70.10	66.28
2040	17		22.07		22.07	3.52	384.38	17.99	0.97	1.60	404.94	64.49	60.98
2041	18		22.07		22.07	3.23	384.38	17.99	0.97	1.60	404.94	59.33	56.10
2042	19		22.07		22.07	2.98	384.38	17.99	0.97	1.60	404.94	54.59	51.61
2043	20		22.07	113.76	135.84	16.85	384.38	17.99	0.97	1.60	404.94	50.22	33.37
2044	21		22.07		22.07	2.52	384.38	17.99	0.97	1.60	404.94	46.20	43.68
2045	22		22.07		22.07	2.32	384.38	17.99	0.97	1.60	404.94	42.51	40.19
2046	23		22.07		22.07	2.13	384.38	17.99	0.97	1.60	404.94	39.11	36.97
2047	24		22.07		22.07	1.96	384.38	17.99	0.97	1.60	404.94	35.98	34.02
2048	25		22.07		22.07	1.80	384.38	17.99	0.97	1.60	404.94	33.10	31.29
2049	26		22.07		22.07	1.66	384.38	17.99	0.97	1.60	404.94	30.45	28.79
2050	27		22.07		22.07	1.53	384.38	17.99	0.97	1.60	404.94	28.01	26.49
2051	28		22.07		22.07	1.40	384.38	17.99	0.97	1.60	404.94	25.77	24.37
2052	29		22.07		22.07	1.29	384.38	17.99	0.97	1.60	404.94	23.71	22.42
2053	30		22.07	0.00	22.07	1.19	384.38	17.99	0.97	1.60	404.94	21.81	20.63
		1,495.54	649.76	141.27	2,286.58	1,250.21	11,354.96	891.51	97.60	163.57	12,507.64	3,024.02	1,773.81

EIRR		13.33%
ENPV		1,773.81
B/C		2.42

Table D-3 Benefit Declined by 10% +Demand Declined by 10%

(US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											
		Cost					Benefit Stream						Discounted Cash Flow
		Capital	O&M	Replace	Total	Discounted	VOC 10%	VOT 10%	Acc 10%	Emm 10%	Total	Discounted	
2018													
2019													
2020		70.80			70.80	59.76							-59.76
2021		429.59			429.59	333.58							-333.58
2022		429.59			429.59	306.90							-306.90
2023		429.59			429.59	282.35							-282.35
2024	1		18.27		18.27	11.05	371.24	96.19	15.64	26.60	509.67	308.18	297.13
2025	2		18.42		18.42	10.25	355.99	81.22	13.02	22.17	472.40	262.79	252.55
2026	3		18.57		18.57	9.50	340.86	66.01	10.26	17.34	434.47	222.36	212.85
2027	4		18.72		18.72	8.81	329.55	53.91	8.12	13.63	405.21	190.79	181.97
2028	5		18.87		18.87	8.17	321.66	44.29	6.44	10.74	383.13	165.96	157.79
2029	6		19.02		19.02	7.58	316.89	36.68	5.10	8.47	367.14	146.31	138.73
2030	7		19.19		19.19	7.03	315.02	30.69	4.03	6.65	356.38	130.66	123.63
2031	8		19.35		19.35	6.53	315.89	26.01	3.15	5.19	350.23	118.14	111.61
2032	9		19.51		19.51	6.06	319.42	22.40	2.42	3.99	348.23	108.07	102.01
2033	10		19.69	25.01	44.70	12.76	325.59	19.66	1.82	2.99	350.06	99.94	87.18
2034	11		19.86		19.86	5.22	334.41	17.64	1.31	2.15	355.50	93.38	88.16
2035	12		20.06		20.06	4.85	345.94	16.19	0.87	1.44	364.44	88.07	83.22
2036	13		20.06		20.06	4.46	345.94	16.19	0.87	1.44	364.44	81.02	76.56
2037	14		20.06		20.06	4.10	345.94	16.19	0.87	1.44	364.44	74.54	70.44
2038	15		20.06		20.06	3.78	345.94	16.19	0.87	1.44	364.44	68.58	64.80
2039	16		20.06		20.06	3.47	345.94	16.19	0.87	1.44	364.44	63.09	59.62
2040	17		20.06		20.06	3.20	345.94	16.19	0.87	1.44	364.44	58.04	54.85
2041	18		20.06		20.06	2.94	345.94	16.19	0.87	1.44	364.44	53.40	50.46
2042	19		20.06		20.06	2.70	345.94	16.19	0.87	1.44	364.44	49.13	46.42
2043	20		20.06	103.42	123.49	15.31	345.94	16.19	0.87	1.44	364.44	45.20	29.88
2044	21		20.06		20.06	2.29	345.94	16.19	0.87	1.44	364.44	41.58	39.29
2045	22		20.06		20.06	2.11	345.94	16.19	0.87	1.44	364.44	38.26	36.15
2046	23		20.06		20.06	1.94	345.94	16.19	0.87	1.44	364.44	35.19	33.26
2047	24		20.06		20.06	1.78	345.94	16.19	0.87	1.44	364.44	32.38	30.60
2048	25		20.06		20.06	1.64	345.94	16.19	0.87	1.44	364.44	29.79	28.15
2049	26		20.06		20.06	1.51	345.94	16.19	0.87	1.44	364.44	27.41	25.90
2050	27		20.06		20.06	1.39	345.94	16.19	0.87	1.44	364.44	25.21	23.83
2051	28		20.06		20.06	1.28	345.94	16.19	0.87	1.44	364.44	23.20	21.92
2052	29		20.06		20.06	1.17	345.94	16.19	0.87	1.44	364.44	21.34	20.17
2053	30		20.06	0.00	20.06	1.08	345.94	16.19	0.87	1.44	364.44	19.63	18.55
		1,359.58	590.69	128.43	2,078.71	1,136.55	10,219.46	802.36	87.84	147.21	11,256.88	2,721.62	1,585.07

EIRR		13.13%
ENPV		1,585.07
B/C		2.39

Table D-4 Cost Increase by 10% + Benefit Declined by 10% + Demand Declined by 10%

(US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											
		Cost					Benefit Stream						Discounted Cash Flow
		Capital 10%	O&M	Replace	Total	Discounted	VOC 10%	VOT 10%	Acc 10%	Emm 10%	Total	Discounted	
2018													
2019													
2020		77.88			77.88	65.74							-65.74
2021		472.55			472.55	366.94							-366.94
2022		472.55			472.55	337.59							-337.59
2023		472.55			472.55	310.58							-310.58
2024	1		20.10		20.10	12.15	371.24	96.19	15.64	26.60	509.67	308.18	296.02
2025	2		20.26		20.26	11.27	355.99	81.22	13.02	22.17	472.40	262.79	251.52
2026	3		20.42		20.42	10.45	340.86	66.01	10.26	17.34	434.47	222.36	211.90
2027	4		20.59		20.59	9.69	329.55	53.91	8.12	13.63	405.21	190.79	181.09
2028	5		20.76		20.76	8.99	321.66	44.29	6.44	10.74	383.13	165.96	156.97
2029	6		20.93		20.93	8.34	316.89	36.68	5.10	8.47	367.14	146.31	137.97
2030	7		21.10		21.10	7.74	315.02	30.69	4.03	6.65	356.38	130.66	122.93
2031	8		21.28		21.28	7.18	315.89	26.01	3.15	5.19	350.23	118.14	110.96
2032	9		21.47		21.47	6.66	319.42	22.40	2.42	3.99	348.23	108.07	101.40
2033	10		21.66	27.51	49.17	14.04	325.59	19.66	1.82	2.99	350.06	99.94	85.91
2034	11		21.85		21.85	5.74	334.41	17.64	1.31	2.15	355.50	93.38	87.64
2035	12		22.07		22.07	5.33	345.94	16.19	0.87	1.44	364.44	88.07	82.73
2036	13		22.07		22.07	4.91	345.94	16.19	0.87	1.44	364.44	81.02	76.11
2037	14		22.07		22.07	4.51	345.94	16.19	0.87	1.44	364.44	74.54	70.03
2038	15		22.07		22.07	4.15	345.94	16.19	0.87	1.44	364.44	68.58	64.42
2039	16		22.07		22.07	3.82	345.94	16.19	0.87	1.44	364.44	63.09	59.27
2040	17		22.07		22.07	3.52	345.94	16.19	0.87	1.44	364.44	58.04	54.53
2041	18		22.07		22.07	3.23	345.94	16.19	0.87	1.44	364.44	53.40	50.17
2042	19		22.07		22.07	2.98	345.94	16.19	0.87	1.44	364.44	49.13	46.15
2043	20		22.07	113.76	135.84	16.85	345.94	16.19	0.87	1.44	364.44	45.20	28.35
2044	21		22.07		22.07	2.52	345.94	16.19	0.87	1.44	364.44	41.58	39.06
2045	22		22.07		22.07	2.32	345.94	16.19	0.87	1.44	364.44	38.26	35.94
2046	23		22.07		22.07	2.13	345.94	16.19	0.87	1.44	364.44	35.19	33.06
2047	24		22.07		22.07	1.96	345.94	16.19	0.87	1.44	364.44	32.38	30.42
2048	25		22.07		22.07	1.80	345.94	16.19	0.87	1.44	364.44	29.79	27.98
2049	26		22.07		22.07	1.66	345.94	16.19	0.87	1.44	364.44	27.41	25.75
2050	27		22.07		22.07	1.53	345.94	16.19	0.87	1.44	364.44	25.21	23.69
2051	28		22.07		22.07	1.40	345.94	16.19	0.87	1.44	364.44	23.20	21.79
2052	29		22.07		22.07	1.29	345.94	16.19	0.87	1.44	364.44	21.34	20.05
2053	30		22.07	0.00	22.07	1.19	345.94	16.19	0.87	1.44	364.44	19.63	18.44
		1,495.54	649.76	141.27	2,286.58	1,250.21	10,219.46	802.36	87.84	147.21	11,256.88	2,721.62	1,471.41

EIRR	11.31%
ENPV	1,471.41
B/C	2.18

Table D-5 Implementation Delay (1 Year) + Demand Declined by 10%

(US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											
		Cost					Benefit Stream						Discounted Cash Flow
		Capital	O&M	Replace	Total	Discounted	VOC	VOT	Acc	Emm	Total	Discounted	
2018													
2019													
2020													
2021		70.80			70.80	54.98							-54.98
2022		429.59			429.59	306.90							-306.90
2023		429.59			429.59	282.35							-282.35
2024		429.59			429.59	259.76							-259.76
2025	1		18.27		18.27	10.17	412.48	106.88	17.38	29.56	566.30	315.03	304.86
2026	2		18.42		18.42	9.43	395.55	90.25	14.46	24.63	524.89	268.63	259.21
2027	3		18.57		18.57	8.74	378.73	73.35	11.40	19.26	482.75	227.30	218.56
2028	4		18.72		18.72	8.11	366.17	59.89	9.03	15.14	450.23	195.03	186.92
2029	5		18.87		18.87	7.52	357.40	49.21	7.16	11.94	425.70	169.65	162.13
2030	6		19.02		19.02	6.98	352.10	40.75	5.67	9.41	407.93	149.56	142.59
2031	7		19.19		19.19	6.47	350.02	34.10	4.47	7.39	395.98	133.57	127.10
2032	8		19.35		19.35	6.00	350.99	28.90	3.50	5.76	389.15	120.76	114.76
2033	9		19.51		19.51	5.57	354.92	24.89	2.69	4.43	386.93	110.47	104.90
2034	10		19.69	25.01	44.70	11.74	361.77	21.85	2.02	3.32	388.96	102.16	90.42
2035	11		19.86		19.86	4.80	371.57	19.60	1.45	2.39	395.00	95.45	90.65
2036	12		20.06		20.06	4.46	384.38	17.99	0.97	1.60	404.94	90.02	85.56
2037	13		20.06		20.06	4.10	384.38	17.99	0.97	1.60	404.94	82.82	78.72
2038	14		20.06		20.06	3.78	384.38	17.99	0.97	1.60	404.94	76.20	72.42
2039	15		20.06		20.06	3.47	384.38	17.99	0.97	1.60	404.94	70.10	66.63
2040	16		20.06		20.06	3.20	384.38	17.99	0.97	1.60	404.94	64.49	61.30
2041	17		20.06		20.06	2.94	384.38	17.99	0.97	1.60	404.94	59.33	56.39
2042	18		20.06		20.06	2.70	384.38	17.99	0.97	1.60	404.94	54.59	51.88
2043	19		20.06		20.06	2.49	384.38	17.99	0.97	1.60	404.94	50.22	47.73
2044	20		20.06	103.42	123.49	14.09	384.38	17.99	0.97	1.60	404.94	46.20	32.11
2045	21		20.06		20.06	2.11	384.38	17.99	0.97	1.60	404.94	42.51	40.40
2046	22		20.06		20.06	1.94	384.38	17.99	0.97	1.60	404.94	39.11	37.17
2047	23		20.06		20.06	1.78	384.38	17.99	0.97	1.60	404.94	35.98	34.19
2048	24		20.06		20.06	1.64	384.38	17.99	0.97	1.60	404.94	33.10	31.46
2049	25		20.06		20.06	1.51	384.38	17.99	0.97	1.60	404.94	30.45	28.94
2050	26		20.06		20.06	1.39	384.38	17.99	0.97	1.60	404.94	28.01	26.63
2051	27		20.06		20.06	1.28	384.38	17.99	0.97	1.60	404.94	25.77	24.50
2052	28		20.06		20.06	1.17	384.38	17.99	0.97	1.60	404.94	23.71	22.54
2053	29		20.06		20.06	1.08	384.38	17.99	0.97	1.60	404.94	21.81	20.73
2054	30		20.06	0.00	20.06	0.99	384.38	17.99	0.97	1.60	404.94	20.07	19.08
		1,359.58	590.69	128.43	2,078.71	1,045.63	11,354.96	891.51	97.60	163.57	12,507.64	2,782.10	1,736.47

EIRR		15.28%
ENPV		1,736.47
B/C		2.66

Table D-6 All Worse Cases

(US $ Mn.)

Year	Years of Ope.	Cash Flow Statement											
		Cost					Benefit Stream						Discounted Cash Flow
		Capital 10%	O&M	Replace	Total	Discounted	VOC 10%	VOT 10%	Acc 10%	Emm 10%	Total	Discounted	
2018													
2019													
2020													
2021		77.88			77.88	60.48							-60.48
2022		472.55			472.55	337.59							-337.59
2023		472.55			472.55	310.58							-310.58
2024		472.55			472.55	285.73							-285.73
2025	1		20.10		20.10	11.18	371.24	96.19	15.64	26.60	509.67	283.52	272.34
2026	2		20.26		20.26	10.37	355.99	81.22	13.02	22.17	472.40	241.77	231.40
2027	3		20.42		20.42	9.62	340.86	66.01	10.26	17.34	434.47	204.57	194.95
2028	4		20.59		20.59	8.92	329.55	53.91	8.12	13.63	405.21	175.53	166.61
2029	5		20.76		20.76	8.27	321.66	44.29	6.44	10.74	383.13	152.69	144.41
2030	6		20.93		20.93	7.67	316.89	36.68	5.10	8.47	367.14	134.61	126.93
2031	7		21.10		21.10	7.12	315.02	30.69	4.03	6.65	356.38	120.21	113.09
2032	8		21.28		21.28	6.60	315.89	26.01	3.15	5.19	350.23	108.69	102.08
2033	9		21.47		21.47	6.13	319.42	22.40	2.42	3.99	348.23	99.42	93.29
2034	10		21.66	27.51	49.17	12.91	325.59	19.66	1.82	2.99	350.06	91.95	79.03
2035	11		21.85		21.85	5.28	334.41	17.64	1.31	2.15	355.50	85.91	80.63
2036	12		22.07		22.07	4.91	345.94	16.19	0.87	1.44	364.44	81.02	76.11
2037	13		22.07		22.07	4.51	345.94	16.19	0.87	1.44	364.44	74.54	70.03
2038	14		22.07		22.07	4.15	345.94	16.19	0.87	1.44	364.44	68.58	64.42
2039	15		22.07		22.07	3.82	345.94	16.19	0.87	1.44	364.44	63.09	59.27
2040	16		22.07		22.07	3.52	345.94	16.19	0.87	1.44	364.44	58.04	54.53
2041	17		22.07		22.07	3.23	345.94	16.19	0.87	1.44	364.44	53.40	50.17
2042	18		22.07		22.07	2.98	345.94	16.19	0.87	1.44	364.44	49.13	46.15
2043	19		22.07		22.07	2.74	345.94	16.19	0.87	1.44	364.44	45.20	42.46
2044	20		22.07	113.76	135.84	15.50	345.94	16.19	0.87	1.44	364.44	41.58	26.08
2045	21		22.07		22.07	2.32	345.94	16.19	0.87	1.44	364.44	38.26	35.94
2046	22		22.07		22.07	2.13	345.94	16.19	0.87	1.44	364.44	35.19	33.06
2047	23		22.07		22.07	1.96	345.94	16.19	0.87	1.44	364.44	32.38	30.42
2048	24		22.07		22.07	1.80	345.94	16.19	0.87	1.44	364.44	29.79	27.98
2049	25		22.07		22.07	1.66	345.94	16.19	0.87	1.44	364.44	27.41	25.75
2050	26		22.07		22.07	1.53	345.94	16.19	0.87	1.44	364.44	25.21	23.69
2051	27		22.07		22.07	1.40	345.94	16.19	0.87	1.44	364.44	23.20	21.79
2052	28		22.07		22.07	1.29	345.94	16.19	0.87	1.44	364.44	21.34	20.05
2053	29		22.07		22.07	1.19	345.94	16.19	0.87	1.44	364.44	19.63	18.44
2054	30		22.07	0.00	22.07	1.09	345.94	16.19	0.87	1.44	364.44	18.06	16.97
		1,495.54	649.76	141.27	2,286.58	1,150.19	10,219.46	802.36	87.84	147.21	11,256.88	2,503.89	1,353.70

EIRR		11.31%
ENPV		1,353.70
B/C		2.18