Colombo Suburban Railway Project

Radio Telecommunication System Consultation

Final Report

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1. Introduction

1.1. Document Purpose

This Final Report is part of the Reporting Requirements defined in the Terms of Reference (TOR) document. The Report captures the findings of the Consultancy Services for Design of Radio Telecommunication System for Sri Lanka Railways carried out over the period July 2017 – January 2018. The document also opens a bit more of the global status and current trends for the future development of Radio Telecommunication Systems in Rail Sector.

1.2. Objective

The main objective was to prepare an Islandwide Railway Radio Telecommunication System Project ready for investment and implementation by completing System Requirement Specification (SRS), detailed engineering and Bidding Documents. All designs prepared had to fulfil current and future requirements of SLR Railway Operation for the next 20 years.

1.3. Scope

The scope of the Consultancy Service was to collect the current status of system and the current and future requirements and to prepare System Requirement Specification (SRS), detailed engineering and Bidding Documents.

- System Requirement Specification
- Preliminary Design
- Develop Bidding Documents
- Final Report (this document)

1.4. Information Sources for the Study

Information for the design has been collected from a number of sources, including researching SLR reports, documents and materials, SLR department sessions and personnel interviews. The documentation of the Ministry of Transport and Civil Aviation ¨Colombo Suburban Railway Project´. Also, the global Railways´ Communication Systems development and evolution, trends in Europe and outside Europe and future standards have been reviewed and analysed.

1.4.1. Research

The Primary objective of the research was to capture an understanding of the current status of the SLR Radio Telecommunication Systems; the SLR vision and mission of provision of safe, reliable and punctual rail transport service; Government Aim of the Railway System in Sri Lanka to substantially increase the share of railway in overall passenger and freight traffic.

Another research area was to study and analyse the current status globally and the main trends and possible future scenarios for railways.

1.4.2. Interviews

To survey the entire organization of SLR on department level and train operation in all three divisions (Colombo, Navalapitiya and Anuradhapura).

The interviews aimed to gather data about the SLR current arrangements, their thoughts on the current and possible future requirements.

A List of Meetings, visits and discussions and Activity Schedules are included in Annex B.

1.5. Structure of the Document

The remainder of this document is laid out as follows:

- Section 2 reviews the current status of SLR Radio Telecommunication Systems, Rail Sectors in and outside Europe, and other Critical Sectors.
- Section 3 highlights the Spectrum issues with the Future Technology.
- Section 4 focusing to the Future Trends in Rail Sector.
- Section 5 have analysis of Possible Future Scenarios for Railways including Operational Requirements and Key Considerations for Future Railway Communications.
- Section 6 covers the Terminal Evolution main trends.
- Section 7 introduces the Summary of Findings and Conclusions.

The Report includes a number of Annexes containing supplementary material:

- Annex A outlines the Terms of Reference (TOR) for Consultancy Services for Design of Radio Telecommunication System for Sri Lanka Railways
- Annex B summarises the Lists the Meetings, visits and discussions and Activity Schedules performed during the Consultation.
- Annex C has the User´s System Requirement Specification (SRS)
- Annex D has the Technology Mapping document describing the Process to identify the most suitable Radio Telecommunication System for SLR.
- Annex E is the final Presentation made to the Project Stakeholders (ADB, SLR, MOT & CA) whose approval of the Radio Telecommunication System were achieved.
- Annex F Calculation of the Engineer´s Estimation
- Annex G the Bidding Documents

2. Current Status

2.1. Introduction

This section provides a summary of the current status of the SLR Radio Telecommunication Systems and of the global Railways´ Communication Systems development and evolution, status in Europe and outside Europe. This information is derived from the sources described in Section 1.4.

2.2. SLR Radio Telecommunication Systems

Present Telecommunication System consists of cable-based systems and analog VHF/UHF radio systems as summarized in the table *"Summarized Details of Present Telecommunication System in Sri Lanka Railways"* below.

	Line	From	To	Telecommunication		
				Train Dispatching	**Maintenance**	**General**
1	Coastal	Maradana	Matara	OFC based ATM system (Wenzel)		Public Telephones
2	Main	Maradana	Rambukkana	Copper cable-based system Station call type	Copper cable-based system Generator ringing code type	
		Rambukkana	Badulla	UHF/VHF Radio Communication		
3	Puttalam	Ragama	Negambo	Copper cable-based system Station call type	Copper cable-based system Generator ringing code type	
		Negambo	Puttalam	UHF/VHF Radio Communication		
4	Kelani valley	Colombo	Avissawella	Public Telephones		
5	Matale	Peradeniya	Matale	UHF/VHF Radio Communication		
6	Northern	Polgahawela	Maho			
		Maho	Anuradhapura			
		Anuradhapura	Kankesanturai	OFC base System + Radio Communication		
7	Talai Mannar	Medawachchiya	Talai Mannar			
8	Batticoloa	Maho	Batticoloa	Radio Communication + Public Telephones		
9	Trincomalee	Galois Junction	Trincomalee			

2.2.1. Copper Cable based Telephone System

This system has been installed in mid 1960s with the introduction of CLS system to SLR. Performance of this system is poor, and the system does not have capacity to meet the present needs nor any of the future needs. Complete replacement with modern communication facilities is needed.

Sections from Maradana to Pallewela and from Ragama to Negambo are provided with omnibus type communication facilities using paper insulated, copper cables as follows:

- Train dispatcher's system connecting stations and the Signal Post Telephones.
- Station call bell system is used by the Train dispatcher to originate a call and the dispatcher can hear through the speaker phone when a station master is calling
- Maintenance Telephone system – Generator ringing code type

2.2.2. Optical Fibre based Telephone System

Optical Fibre Cable based on ATM telephone system (Wenzel, Germany) is in operation from Colombo Fort to Matara. This system provides the facilities for train dispatching, maintenance and other operational purposes with selective dialling and includes the train radio system. SLR is facing difficulties for maintaining the signal post telephones due to lack of weather proof telephones. This system is performing well **except the Train Radio system**.

Twenty-four core Optical fibre cable has been laid from Anuradhapura to Kankasanturai and from Medawachchiya to Talai Mannar Pier in 2013/2014 under the rehabilitation of Northern Railway lines. This OFC based system is used for fixed voice communication and backup connection for Block instruments.

2.2.3. Existing Radio Communication

UHF/VHF Radio communication system is in operation for stations areas shown in the Table above since early 1980s. This system operates in 430 MHz range and 160 MHz range. SLR is using the Sri Lanka Telecom towers as repeater stations for its backbone network. Main antenna tower is located near Maradana station. Presently three operating consoles are assigned for Mainline, Northern line and Puttalam line to communicate with the stations beyond the Centralized Traffic Controlling area.

Main switching equipment of this system has been completely damaged due to a heavy lightning strike in 2007. Damaged equipment was replaced in 2008/09 and the system has been brought back to normal.

However, this system is not in operation for some station due to lack of spare parts and aging of equipment. Modern radio communication facilities are essential for the CTC area as well in order to have more effective train operation directly with train drivers, leaving the fixed cable system as a backup system.

The recently installed Radio Communication system for northern lines too does not provide continuous communication with the operating staff and the expected operational features have not been met.

2.2.4. Problems and Drawbacks with the existing Radio Communication Systems

- Performance of the existing telecommunication facilities very poor; and the system is very old, outdated and unable to maintain due to lack of spare parts
- The above system does not provide train communication facilities which is essential for effective Train controlling. **Today the train communication is handled through third party (mainly via Station Master) or using private mobile phones.**
- Not having a proper system to communicate with all sub stations (Train halts) causing inconvenience to passengers.
- Existing magneto telephones system to communicate with level crossing gates do not function properly due to lack of spare parts and contribute for train delays.
- Even though the existing ATM communication system serves train operation **(if the driver stops the train to the signal post**) and maintenance purposes, **the train radio system is inoperative and most of the signal post telephones also not functioning** due to lack of suitable weather proof telephones.
- Existing UHF/VHF radio communication system is unable to maintain and expand the system due to lack of spare parts and does not have the capacity for providing train radio system and data transmission.
- Voice recording facilities are not available.
- Proper mobile communication system for the field staff (Shunting Operation, Technical, Security, etc.) not available and provision of such facilities will enhance the operational and maintenance efficiency.
- Present system does not provide communication facilities for all technical divisions for effective maintenance management.
- Inability to transmit data.

2.3. Rail Sector in Europe

This Section gives an overview of Rail Sector Status in Europe as a reference to the Status in Sri Lanka.

Operational communications are vital to the running of railways, for both passenger and freight services. The communication may be voice or data communications.

2.3.1. Overview of Track-to-Train Mobile Rail Communication within Europe

Communications to trains generally fit into one of three categories, as outlined in the Table below:

Critical operational	Business Supporting	Entertainment
Voice (Signaller/Controller to Train Driver)	Monitoring and Supervision of Trackside Equipment	Passenger Wi-Fi
Signalling (ETCS)	Traction Power Control and Monitoring	On-Train News/Entertainment
Automatic Train Protection (ATP)	Passenger Information	
Automatic Train Operation (ATO)	Closed Circuit Television (CCTV)	
	Rolling Stock Condition Monitoring	
	Ticketing and Revenue Collection	

Track-to-Train Communications Categories and Examples of Communications carried.

Let´s focus on Critical Operational Communications although the Business Supporting and Entertainment categories is good to remember for the future development of the SLR services. There may be synergies with elements of the Business Supporting Category and potentially also the Entertainment Category, which should be taken into account when considering any strategy.

Critical Operational Communications and, in some cases, Business Supporting Communications are carried within Europe main-line and will usually use GSM-R. GSM-R is a variant of GSM, adapted with some features specific for Railway Operations.

Current Specifications are maintained through UIC and ERA. It is mandated within the Technical Specification for Interoperability (TSI) for certain lines within Europe by European Directive, and, through the UIC, has been adopted in many other countries, including China and Australia.

In Europe the frequency bands 876-880 MHz and 921-925 MHz are designated to GSM-R by the European Conference of Postal and Telecommunications (CEPT). CEPT has also designated Spectrum below this band for GSM-R use, 874-876 MHz and 918-921 MHz, but the designation is on a shared basis and is dependent on national administrations.

Roll-out of GSM-R is well established within Europe. At least 35 different GSM-R Networks exist in Europe alone. There was around 100 000 km of track in operation (ERA data from 2013) for voice and a further 150 000km planned. GSM-R is also widely deployed outside of Europe, with some 138 000km of deployments planned spanning Asia, Australia, the Middle East and Africa.

In terms of infrastructure, there are two main suppliers within Europe who are Kapsch and Nokia Solutions and Networks (NSN). Other suppliers who are part of the GSM-R Industry group are Alstom, Frequentis, Funkwerk, Selex ES, Siemens, Sierra Wireless and Wenzel. Alcatel-Lucent is also an integrator, while Huawei and ZTE have infrastructure and sell worldwide, but have no products within Europe. Cab radio is supplied by a range of suppliers.

One specific feature of GSM-R systems in Europe is that although there are portables as well as mobile devices on trains (cab radio), it is very much seen as a track-to-train communications system, with limited use of portable radios, although station staff and other train staff may carry portables.

2.3.2. Ownership of Mobile Rail Communications Networks

Ownership of Railway Infrastructure assets, including Telecoms, usually lies with the State or Government, although it may be via a company set up by the State (Germany, Belgium, UK, etc.)

Infrastructure Manager (IM) own the Infrastructure, including the GSM-R base stations and backbone. Train Operating Company (TOC) or Rolling Stock owners own the Cab Radio. TOCs and IMs will own portables.

2.3.3. Network Capacity

Network capacity is not seen as a concern for voice services, but is a concern for ETCS, while circuit-mode data is used. The Network Capacity would be an issue without GPRS.

Some IMs are already using GPRS for business-supporting functions such as passenger information.

There are concerns that, in the future, the 4 MHz of spectrum will not be sufficient, and some IMs are arranging to make use of the additional 3 MHz of E-GSM-R (GSM-R extension band) spectrum. The data capacity of the new generation of the Rail Telecommunications is seen to grow significantly.

2.3.4. Functionality Required by the Rail Sector

The voice functionality of GSM-R is regarded as absolutely vital by IMs and Train Operators, and the Railway Emergency Call (REC) is considered as a very important feature.

GSM-R provides short message service (SMS) data services and includes the GPRS packet switched data service to the train, which may be used for business-supporting functions at the moment (often with multiple radio units on board the train). There are also applications built into cab radio, which use the SMS data capabilities of the GSM-R standard.

2.4. Rail Sector outside Europe

This section describes a sample of rail markets outside Europe.

GSM-R is used internationally, for example in Asia, India, Northern Africa, Kenya and South-Africa, Australia, and for example China having largest GSM-R deployment with 33 750 km of route covered. TETRA is used in Rail Sector as well (in Taiwan and Kazakhstan for example), but mainly in Public Safety, Police, Fire, etc departments.

2.5. Other Critical Sectors

The most obvious sector for comparison with Critical Railway Communications is the Public-Safety Sector. Public-safety agencies rely on specialist mobile networks for critical communications and face many similar challenges to the railway sector deploying, operating and upgrading these.

2.5.1. Public-Safety Sector

Within Europe the model for the majority of public-safety networks is that the network infrastructure assets are procured and owned by the government. Operation will then often be provided by a state-owned company set up specifically to act as network operator (for example ASTRID in Belgium.)

There are a few examples of public–private partnership (PPP) models. These include Austria, Denmark and the UK.

Terminals in almost all European networks are procured by the end-user organisations, either directly, or often through a managed service contract which will run for a period of years and will include maintenance and in some cases a technology refresh after, typically, five years (both vehicle and portables) since newer terminals with better functionality will have become available.

A typical police force will have ten times as many portable radios as vehicle radios.

Most public-safety organisations will also use commercial mobile networks for data, and this will be contracted through a local arrangement.

The functionality required for public-safety users is primarily mission-critical voice and some elements of mission-critical data. Voice calls will usually be group voice calls, where a group might be officers in a specific beat or area, or a specific discipline (such as firearms).

The way public safety uses data also differs significantly between organisations. Police use relatively small, but growing, amounts of data, often for interrogating database systems and transmitting the location of vehicles and hand portables. Ambulance and fire services typically use data to dispatch to incidents and use

Global Positioning System (GPS) technology with command-and-control systems so they know where their resources are located.

Public safety is very similar to rail, in that there is a 400 MHz harmonised band, and two major technologies, which are TETRA and TETRAPOL. These networks are used for voice and low-speed critical data services, but public safety does not have widespread access to an equivalent private data service such as GPRS – instead is increasingly relying on commercial networks.

As mission-critical systems the functionality of the TETRA/P25/TETRAPOL standard meets most of the railway-specific requirements, with the exception of functional addressing, location-dependent addressing and train run numbers.

2.5.2. Transport Sector

Metro Systems

Unlike main-line operations, there are no interoperability requirements for metro systems, and GSM-R is not commonly used in this environment, although there are some examples, such as Kolkata metro line in India. TETRA and other PMR technologies are common for voice communications, and status data, but less common for signalling use.

Bus and Tram

There is a wide range of ownership and delivery models for communications in the bus and tram market.

A number of real-time passenger information (RTPI) suppliers offer to provide a service to a council or bus operator, using their central servers and a communications network, which used to be a PMR system, but increasingly will be a commercial network.

GPRS is commonly used for data, and trunked radio for voice.

Air Traffic Control

Ownership of the civil aviation air traffic control is a state responsibility but is typically delivered in the private sector.

Voice is analogue, and the primary communications channel, although there is an increased use of data links using radio channels to pass information to aircraft.

2.6. Summary of the Current Status

The current status for main-line train service is that there is a good use of GSM-R as an interoperable standard, using a harmonised spectrum band at 800 MHz. In terms of railway infrastructure, ownership is with the state, and the network operating companies are generally state owned.

GSM-R is also used in various markets outside of Europe, but there are examples of other technologies in use, e.g. TETRA has been used for high-speed rail in Taiwan and

Kazakhstan (and is also widely used for metro/light rail, both inside and outside of Europe).

Public safety is very similar to rail, in that there is a 400 MHz harmonised band, and two major technologies, which are TETRA and TETRAPOL. These networks are used for voice and low-speed critical data services, but public safety does not have widespread access to an equivalent private data service such as GPRS – instead is increasingly relying on commercial networks.

Ownership of the majority of networks is with the government, although there are three instances, Austria, Denmark and the UK, where they have been outsourced under a private finance initiative (PFI) or PPP.

There is no European-wide harmonisation, and different countries have differing amounts of spectrum, in different frequency bands. With the proliferation of many distributed generation sources the prime consideration is very good latency, with signalling latency of less than 5ms.

In the wider transport sector there is little use of GSM-R, but instead a wide range of private and public solutions, often with hybrid solutions for voice and data.

3. Spectrum Evolution

3.1. Introduction

In this section the current situation in terms of spectrum use and availability is highlighted, before looking at the future technology developments of LTE (4G and even 5G) and the potential changes in critical-communications requirements, and the impact these issues will have on spectrum.

3.2. Current Situation regarding spectrum

At present GSM-R, which is used for voice radio and a bearer for ETCS, occupies two 4 MHz blocks of spectrum at 876–880 MHz (uplink) and 921–925 MHz (downlink). These are European harmonised allocations in accordance with ECC/DEC/(02)05. There are some differences where GSM-R is used outside of Europe in China, India and South Africa, and in Australia 1800 MHz is used. The spectrum is immediately adjacent to commercial GSM spectrum 880–915 MHz (uplink) and 925–960 MHz (downlink).

CEPT has reaffirmed the spectrum at 876–880 MHz and 921–925 MHz for railway purposes.

When having a meeting with Telecommunications Regulatory Commission of Sri Lanka (TRCSL), they highlighted that allocation of 10 MHZ or even 5 MHz bandwidth would be difficult. TRC informed to reduce the SLR bandwidth requirement to 1.4 MHz otherwise they think that SLR will underutilize the bandwidth as comparing to the existing use of the bandwidths in Sri Lanka.

The 450 MHz band already congested, used by Dialog for CDMA, TV band starts from 470 MHz to 733 MHz. TRC has already allocated 418 MHz – 430 MHz frequency band to Police department.

The message from TRC:
To utilize the Private/Public Networks available should be considered as an option. TRC would support of this solution. However, to make a request for the expected frequency band indicating the bandwidth and enclosing a copy of the technical descriptions of the system. The request will be submitted to the committee which will have a meeting once a month.

3.3. Future Technology Requirements and their impact on Spectrum

While GSM and GPRS/EDGE systems use narrowband technology with 200 kHz channels, 3G Universal Mobile Telephone Service (UMTS) and 4G Long Term Evolution (LTE) (also 5G in the future) systems require access to wide bands of contiguous spectrum.

In the case of LTE, channels use orthogonal frequency-division multiple access (OFDMA) with bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz. In practice, most commercial solutions use either 5 MHz or 10 MHz, but there is an argument that even wider channels are more efficient. There are some suppliers offering the 1.4 MHz and 3 MHz channel bandwidths for 400 MHz LTE systems, but these are less common at the higher frequencies.

3.4. Future Technology and Voice Calls and their impact on Spectrum

A consensus view is that 3G technologies are not regarded as suitable to support Railway Communications. 2G and 3G both support voice as a bearer service. 4G or LTE, as it stands, is targeted as a data service, and voice services are implemented as VoIP services.

The Third Generation Partnership Project (3GPP) recognised that normal 'push to talk' (PTT) over cellular did not meet the needs of many professional critical-communications users and worked for Mission Critical PTT over LTE (MCPTToLTE), which was included in Release 13.

3.5. Use of Current Spectrum for Broad Band Communications

New broadband technologies tend to work on units of bandwidth of 5 MHz, with 5, 10, 15 and 20 MHz channel bandwidths. The higher bandwidths are preferred since a network with 10 MHz of bandwidth is more efficient than two networks of 5 MHz. LTE does, however, have also channel bandwidths of 1.4 MHz and 3 MHz within the standard.

LTE has the possibility of band aggregation, where the terminal is able to simultaneously operate on two bands, and combine the two data streams, which results in an overall higher data rate.

3.6. Summary of Spectrum Evolution

Due to the channel bandwidths it is not feasible to operate a narrowband system such as GSM-R and a wide band system such as LTE in the same spectrum band in the same area. Since GSM-R roll-out is extensive, this creates restrictions when considering an on-frequency migration to a new technology solution. While the restrictions can be overcome, there are significant disadvantages in the use of the existing spectrum for LTE or similar technologies.

The availability of sub-1 GHz new spectrum for railways, for future technology solutions would make the transition a lot easier. It would allow parallel working of networks during transition. Once the transition was complete the current allocations would be released and could be taken up by other services.

4. Future Trends

4.1. Introduction

In this section we look at trends that are likely to have an impact on ERA’s decision regarding the strategy for the evolution of railway communications: Likely changes in the mobile market in Western Europe and Central and Eastern Europe, the technology trends (such as 4G and even ‘5G’ services), and likely trends in mobile coverage provision.

4.2. Trends in Europe

Telecoms operators in Western Europe are expected to face a period of steady decline during the next five years. Total telecoms service revenue is already in decline. The total telecoms market is expected to shrink from EUR 274 billion in 2012 to EUR 239 billion in 2018.

Telecoms operators in Central and Eastern Europe are now facing the same challenges of market maturity as Western Europe.

The reduction of service revenue from public users explains the interest in other revenue streams, such as the M2M market, where MNOs are developing dedicated platforms for professional users. There is also some interest from MNOs in the developing public-safety requirement for mobile broadband.

The number of deployed networks shows that LTE will become the dominant technology within Western Europe for commercial networks over the next five years. It will account for 55% of total non-M2M mobile connections by 2018. The trend is for MNOs and government to improve coverage and fill in ‘not spots’ where there are users who are not able to access mobile networks. The MNOs want to provide coverage to their customers, and this includes the travelling public on Railways. (This is an important point not to pay the extra coverage costs to the MNOs!)

4.3. Trends in Rail Sector

The primary future trend in Rail Operational Communications is an increase in data connectivity. This is in parallel with a move to an IP environment for signalling. It is generally recognised that GSM-R would reach end of life in the later 2020s. Some suppliers do not believe there will be issues with the supply of cab radio modules, but there are concerns that the infrastructure suppliers would no longer support GSM-R.

The vision for the next-generation system is not only to fulfil operational requirements, both voice and data, but to also service business applications such as asset performance and condition monitoring, together with traveller facilities such as on-train Wi-Fi, customer information and ´infotainment´. The 4G has been seen as the natural successor to GSM-R and fulfils the above requirements. All the above would be on a single IP based converged network.

4.4. Summary of Future Trends

The principal future trend in Rail Communications is a significant increase in the use of data, and a move towards an IP world.

The operational signalling load requirements are not high, and are not expected to grow significantly, although as the number of units exchanging data grows, the composite data rates at terminus locations will increase as the number of trains increases.

The significant increase is more due to data services supporting the operation of the railway, with more passenger information, and tele-maintenance. These help improve the efficiency of the railway and improve the passenger experience. These are differentiated from the entertainment services such as on-board Wi-Fi for the travelling public.

It is expected that voice will continue for a significant time into the future, although it is recognised that some of the current functionality, such as the Rail Emergency Call (REC), may be implemented in a different non-voice way in the future. Voice in the future communications solution will be VoIP, and the networks must support this.

The clear trend in Commercial Mobile Networks is a significant demand for data, leading to the deployment of increasing levels of mobile broadband which are currently LTE 4G Networks.

It is clear that this is seen as the future, and networks are rolling out throughout Europe. It is such a strong future solution that in several networks spectrum is being reframed from earlier 2G and 3G services to support 4G.

4G Networks began to roll out for public mobile use in 2013. Things have moved on rapidly since then and 4G LTE is now a commercially available technology that is used all over the world. There are at least 331 4G LTE Networks in 156 countries with approximately 300 million 4G users worldwide. It is truly an international system, so the amount of research and development, support, competency and availability of systems dwarfs anything the Rail Industry could resource for any alternative bespoke solution.

5. Analysis of Possible Future Scenarios for Railways

5.1. Introduction

Building on the summary of current status and future trends described in the preceding sections, this section considers the high-level requirements and key considerations influencing the study before going on to identify and assess potential future scenarios for operational communications.

5.2. Operational Requirements

The principal operational requirements as currently understood are summarised here. Three core requirements were identified:

1) Mobile communications between Train Driver and Dispatcher/Controller is currently achieved with a one-to-one voice call, but the nature of the communications between Driver and Control may change over time. GSM-R provides functional addressing and location-dependent addressing facilities to route calls depending on the function assigned to a user or the most appropriate party to call based on a train's current location.
2) Communications for the ETCS signalling between train and trackside equipment must be supported (not critical in Sri Lanka for quite a long time).
3) The REC function is a warning that can be triggered to inform drivers (and other personnel) in a particular area to stop train movements and is a key requirement. This is currently achieved in GSM-R by initiating a priority voice group call with intelligent addressing used to determine which radios to include in the call.

Other requirements identified but typically not noted as key requirements:

- communications with personnel on the train other than the driver, e.g. other train staff or passengers via the PA.
- support for other on-train systems such as passenger information and CCTV
- support for infrastructure monitoring and tele-maintenance systems
- non-railway related services for passengers, e.g. entertainment, on-train Internet access.

Underlying the requirement to support the functions identified above is an assumption that there is a supporting communications platform that is fit for purpose. The detailed standards expected vary for different implementations, but this typically implies:

- coverage throughout the railway (including tunnels, cuttings and covered areas e.g. stations)
- adequate capacity to maintain continuous signalling communications for all trains in any particularly area
- effective operation at high running speeds

- very high levels of service availability to avoid disruption to train services arising from communications failure.

The local Operational Requirement can be found in the SRS document attached to this report in Annex C.

5.3. Key Considerations for Future Railway Communications

Within the mobile communications industry, the near future is clearly recognised as being based on LTE, has a flat architecture, unlike the hierarchical architecture of 2G and 3G systems, and is based on IP platforms. For a commercial operator this gives the promise of a lower cost per bit for the LTE solution, while the simpler architecture also makes it viable for other users, providing suitable spectrum can be acquired. Public-safety organisations have recognised the characteristics of LTE, especially the low latency, and have very clearly indicated they see this as the preferred technology for the evolution of their networks.

Replacing GSM-R with a more modern technology is inevitable and LTE 4G has been seen as the natural successor. It is offering the opportunity of having a single track to train radio system for operational, security and customer purposes by incorporating voice and data for train control, train management, train performance monitoring, on board video surveillance, trackside staff communication, trackside warning systems, as well as infotainment and Wi-Fi for passenger communication services. **All of this would be on a single IP based converged network.**

5.4. Rail Experience of LTE 4G to date

At the Berlin Innotrans Exhibition in 2016, a number of companies made an effort to promote their understanding and commitment to replacing GSM-R with a LTE 4G solution. The situation at that time revealed a number of initiatives.

- **Huawei**
  Already has 4G radio technology in use in the Rail Sector with investment continuing into various aspects of 4G Rail Applications. Twelve metro networks are currently using 4G radio with nine more contractually committed. Most are in China and one in Ethiopia. Another 4G application is in the heavy haul sector in Shuo Huang Railway.

  Working with Thales and Bombardier Huawei is developing and testing LTE Applications in Shanghai and in other countries.

- **Samsung**
  Collaboration between SK Telecom and Samsung launched LTE for railways in Korea. The new LTE service was launched along the 41 km long Busan Metro line 1 that covers 40 stations.

- **Nokia**
  A successful Trial of an LTE system on the Paris Metro took place to prove safety critical operation for CBTC over a radio link. One train on Line 14 was equipped and ran in normal day to day service but without passengers from October 2015 to May 2016.

Korea, world's first 3GPP-complaint LTE network for high-speed train operation modernization of Wonju-Gangneung line in preparation for the XXIII Olympic Winter Games in 2018.

- **Other**

  Other companies such including Siemens, Alstom and Kapsch are working to develop LTE 4G systems for Rail Operation.

5.5. The Option of 5G

Whilst 4G is still evolving, nothing stands still in the telecom industry and the fifth generation of mobile technology is already well advanced in its development. The standards are under definition and it is expected that there will be gradual introduction from the 2020s.

The Internet of Things is very much to the forefront of 5G developments, and it is anticipated that many thousands of Internet connected devices for monitoring of both fixed and mobile assets (including personal wearable devices) will proliferate in the everyday world. This concept will have big implications for the rail industry as condition monitoring, failure prediction and maintenance routines become even more sophisticated in the pursuance of capacity gains and reliability. **It is also foreseen by some manufactures that 4G services should be capable of migrating to 5G without wholesale replacement of equipment.**

6. Terminal Evolution

6.1. Introduction

This section looks at terminal considerations, in particular the cab radio installed into locomotives. The cab radio is the device which is the locomotive end of the air interface with the infrastructure, and the interface to the driver.

6.2. Current Situation

The current situation is that the train-borne kit – the Cab Radio – is a discrete device which provides the GSM-R functionality, in some cases integrated with the driver display, in other cases as a rack mount unit with external display.

The life expected for a Cab Radio is longer than is typical in other sectors and may well be ten years (Netherlands) or more (e.g. 20–25 years in Denmark).

6.3. Future Terminal Options

An example of a possible future trend in Railway Communications can be seen in the equipment used in country rail in Australia. Here, they have a unit which includes five transmitter/receivers (GSM-R, Satellite, UHF and two 3G) as well as a GPS receiver. This is a true multi-mode device supporting voice and data, including GSM-R functionality.

At present only 2G and 3G systems support voice as a circuit-mode service. LTE 4G and any future communications bearer will only support voice as a voice over IP (VoIP) service. This means that since voice is still required in the future, this will be as VoIP, and the functionality of GSM-R voice services will need to be developed as an application running over the future radio network. Within 3GPP, work has been done to define Mission Critical Push-to-Talk over LTE (MCPTToLTE) as part of the LTE development (already available in Release 13) and Mission Critical Data and Mission Critical Video (Release 14 frozen in 2017 and available in 2018).

In the evolution to a new Rail Communications solution the use of both devices, Cab Radios in the locomotive as well as hand-portable devices should be considered.

7. Summary of Findings and Conclusions

7.1. Introduction

This Final Report as part of the Reporting Requirements defined in the TOR, opens the global current status and with the attached documents introduces also the local needs for new Islandwide Radio Telecommunications System for Sri Lanka Railways.

7.2. Findings

The current status for main-line train services is that there is a good use of GSM-R as an interoperable standard, using a harmonised spectrum band at 800 MHz. The REC is an absolutely vital function, which currently is a voice call, but may in the future be implemented in another way.

In terms of railway infrastructure, ownership is usually with the state, and the network operating companies are generally state owned. Costs for the telecoms services are incorporated into the track access charges, and there is little or no use of call-by-call charging, making it difficult to estimate service costs.

It is clear that GSM-R (since it is based on GSM) has a finite life and will cease to be supported between 2020 and 2030.

It is also very clear from the current telecoms market that LTE 4G systems are being widely deployed to meet the data needs of smartphone users, and that LTE is seen as a very important step in the future of mobile communications. It is being actively developed for Mission-Critical Applications; Voice in Release 13 and Data & Video on Release 14, by the public-safety community. This will deliver many of the functions provided within GSM-R, and any specific changes to support all railway functionalities are likely to be small.

The current GSM-R solutions very closely couple together the bearer and application, and that this is unsuitable for future systems. There is a move towards using GPRS for signalling and towards IP data.

7.3. Recommendations

As a result of the study there are five documents which have been provided on top of the Bidding Documents. They all are part of this Final Report, listed in the Section 1.5 Structure of the Document and attached in the end of this document.

As the Technology Mapping document showed, the result of the study was to go for the chosen technology, LTE. There were two different options available to build the Communication to SLR:

1) To build the SLR own Communication Network (LTE Network)
2) To Outsource the Communication Services to Public Operators (who already have LTE Network)

The Recommendation is to Outsource the Communication Services to Public Operators, Mobile Network Operators (MNOs).

Advantages

- Very limited investment costs: First years CAPEX (including three years Warranty Period) will be allocated for a long period of yearly OPEX
- Services available after shorter period since the service provider already has the major component of the infrastructure in place (Here we talk about months instead of years)
- No need to request for frequency bandwidth from TRC, no frequency or license costs. Those costs are covered by MNOs.
- No need to train and maintain a separate maintenance cadre, except few persons for manage and control the service provider performance according to the Service Level Agreement of the main contract (Reference: SRS document for Training and Maintenance Requirements)
- No need to maintain spare parts, testing facilities, vehicles etc. (Reference: Requirements in the SRS document)
- Keep pace with the Technological advancements (Include the Network updates and upgrades with new features for railways to the contract)

Disadvantages

- SLR may first ´**feel**´ that they do have only a limited control over the system (To overcome the ´feeling´ to establish monthly meetings with the service provider to go through the statistics, trends, issues, etc. to manage and control their performance)

Engineer´s Estimation for the two options

According to the European Commission report five different scenarios were examined and commercial mobile LTE is the lowest cost broadband solution.
In general, the capex per user for commercial LTE networks, hardened and with full coverage, would be less than the capex per user for dedicated LTE networks. This is also the most attractive option in terms of value for money when capex and opex are combined, although the cost advantages vary according to which frequency bands are used. When 10 years of opex is taken into account, the sharing of infrastructure costs favours the commercial networks, when operating at 450, 700 or 800 MHz. A commercial

LTE network operating at 800 MHz can give a capex cost per user that is lower by some 40% than a dedicated LTE network at 700 MHz.

Annex F has a more detailed Engineer´s Estimation to the Outsourced Solution.

8. Annexes

Annex A

Terms of Reference (TOR)

TOR Telekom Expert Sri Lanka Railway 17

Annex B

List of Meetings, Visits and Discussions and Activity Schedules

List of Meetings.docx

Annex C

User´s System Requirement Specification (SRS)

Users´ System Requirement Specifi

Annex D

Technology Mapping

Technology Mapping.pdf

Annex E

Final Presentation

20180125 Presentation of Rad

Annex F

Engineer´s Estimation

Engineer´s Estimation.pdf

Annex G

Bidding Documents

Final Bidd Documents - PDF - E