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Final report for the European Railway Agency

Survey on operational communications (study for the evolution of the railway communications system)

25 February 2014

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Ref: 37760-496v04

The opinions expressed in this study are those of the authors and do not necessarily reflect the views of the European Railway Agency

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List of abbreviations used in this report

Abbreviation	Full term
3/4/5G	Third/fourth/fifth generation (of mobile telecoms technology)
3GPP	Third Generation Partnership Project
ARTC	Australian Rail Track Corporation
ASCI	Advanced Speech Call Items
ATO	Automatic Train Operation
ATP	Automatic Train Protection
CAGR	Compound annual growth rate
CBTC	Communications-Based Train Control
CCS-TSI	Control-Command and Signalling Technical Specification for Interoperability
CCTV	Closed circuit television
CDMA	Code division multiple access
CEPT	European Conference of Postal and Telecommunications
CHS	Cluster hot standby
CSFB	Circuit-switched fall back
EC	European Commission
ECC	European Communications Committee (of CEPT)
ECC/DEC/(02)05	CEPT Report on 169.4-169.8125MHz
EDGE	Enhanced Data Rates for GSM Evolution
EDOR	European Train Control System Data Only Radio
EIRENE	European Integrated Railway Radio Enhanced Network
ERA	European Railway Agency
ERTMS	European Rail Traffic Management System
ETCS	European train control system
ETSI	European Telecommunications Standards Institute
EU	European Union
EUTC	European Utilities Telecom Council
FAT	Factory acceptance test
FDD	Frequency division duplex
GBNR	Ground Based Network (Resilient)
GCSE-LTE	Group Call System Enabler – LTE
GDP	Gross domestic product
GIS	Geographic information system
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSM-R	Global System for Mobile Communications, adapted for Railway
HSPA	High Speed Packet Access
HS Rail	High Speed Rail

Abbreviation	Full term
IM	Infrastructure manager
IMT	International Mobile Telecommunications
IP	Internet Protocol
IPR	Intellectual property rights
ISI	Inter System Interface
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Radiocommunication Sector
LTE	Long Term Evolution
M2M	Machine to machine
MCPTToLTE	Mission Critical PTT over LTE
METIS	Mobile and wireless communications Enablers for the 2020 Information Society
MNO	Mobile network operator
MORANE	Mobile Radio For Railways Networks In Europe
MTBF	Mean time between failure
MUAC	Maastricht Upper Area Control Centre
MVNO	Mobile virtual network operator
NextG	Next Generation
NSW	New South Wales
OFDMA	Orthogonal frequency-division multiple access
OTT	Over-the-top
PA	Public address
PAS	Publicly Available Specification
PFI	Private finance initiative
PLC	Power-line communications
PMR	Private mobile radio
PPDR	Public protection and disaster relief
PPP	Public-private partnership
PTT	Push to talk
RAN	Radio access network
REC	Railway Emergency Call
RF	Radio frequency
RTPI	Real-time passenger information
RU	Railway undertaking (same as TOC)
SAT	System acceptance test
SDR	Software-defined radio
SIM (card)	Subscriber identity module
SLA	Service level agreement
SMS	Short message service
TC	Technical Committee (of ETSI)
TCCA	TETRA + Critical Communications Association
TCCE	TETRA and Critical Communications Evolution
TDD	Time division duplex

Abbreviation	Full term
TEDS	TETRA Enhanced Data Service
Telstra	Australian telecoms operator
TEN-T	Trans-European Transport Networks
TETRA	Terrestrial Trunked Radio
TETRAPOL	An alternative digital radio technology for public safety
TOC	Train operating company
UHF-FM	Ultra High Frequency – Frequency Modulation
UIC	International Union of Railways
UMTS	Universal Mobile Telephone Service (a 3G service)
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
VHF	Very high frequency
VoIP	Voice over Internet Protocol
W-CDMA	Wideband code division multiple access (a 3G technology)
WRC	World Radio Conference

1 Executive summary

Introduction

This report captures the findings of a study into operational communications for railways carried out by Analysys Mason for the European Railway Agency (ERA) over the period August–December 2013.

ERA's overall objective for the study was to identify potential strategies for the evolution of GSM-R over time to a future concept of communications for railways. This required:

- an investigation of the current situation and future trends for mobile communications (for railways and for other sectors facing similar challenges)
- the development of potential scenarios for future evolution
- and an assessment of these to determine the merits of each.

The study is a part of a larger programme of activities for future communications systems for railways being carried out by ERA. A separate operational requirements capture exercise is currently underway and is due to report in the second quarter of 2014. Through subsequent stages of analysis and stakeholder engagement, ERA intends to establish a roadmap for communications evolution by 2015, with new solutions defined by 2018, and available to be ready for deployment to start the transition from approximately 2022. As a consequence, this report identifies issues and potential strategies for further study, rather than drawing conclusions as to the preferred evolutionary path. It does, however, identify several recommendations for consideration.

Analysys Mason carried out desk-based research and held interviews with stakeholders in rail and other sectors, before identifying potential options for the future and assessing these. In total, 23 interviews were held, and the results were used to understand the current situation and future trends, as well as stakeholder expectations of the future communications environment. Organisations represented included:

- railway infrastructure managers (IMs)
- train operating companies (TOCs) also known as railway undertakings (RUs)
- railway equipment suppliers
- railway trade associations
- regulators and government departments
- public-safety organisations
- others (including aviation, space agencies and utilities).

Following the interviews, a set of scenarios or potential paths for evolution were identified, and evaluated against the findings of the research and interview phase.

Current situation

The current situation with rail communications is that GSM-R is well established, and provides a European-wide interoperable system for voice and data communications. While the voice aspect is widespread, there is less use of the European Train Control System (ETCS), although this is increasing. ETCS is specified by the European Commission (EC) for new, renewal and upgrade high-speed rail projects, but there are concerns that the circuit-mode service within GSM-R does not provide enough capacity, and that GPRS services within the GSM-R band are required. GPRS is already used for non-ETCS applications, and tests to approve its use for ETCS are in progress.

Rail-sector communications fall into three categories: critical operational communications, business-supporting communications, and passenger entertainment/general communications. GSM-R is used for the first category, and, in some cases, the second category, but does not have the bandwidth to support the third.

It is clear that the rail sector has and requires mission-critical voice and data services, with a high availability of coverage and good service availability. Voice is important, including features such as the Railway Emergency Call (REC), and it is notable that the special features built in to GSM-R are used on a daily basis. Under normal operation there will be little voice traffic, but voice has to be available for the times when there is an incident or abnormal operation. For ETCS, using data radio coverage is important, in that a relatively continuous data circuit to every train operating under ETCS control is required; if coverage is poor, or interference disrupts the circuit for longer than a set timeout period, the train has to assume loss of control, which in some cases will bring it to a halt. Therefore, while coverage does not necessarily have to be 100%, it has to be very good, and any areas of lack of coverage or of interference have to be known, and of a size such that the circuit will continue to be available.

The rail sector has a number of unique requirements, and is different from other sectors, particularly in its reliance on data. It is similar to the public-safety sector, especially in terms of resilience and coverage, but while public safety (especially policing) relies heavily on voice calls, and can still operate if data services are not present, ETCS requires high-availability data services at all times. Aviation too uses data to minimise voice usage, and to provide more information, but uses voice as the primary control mechanism.

Commercial mobile networks are clearly changing and operators are supporting LTE as the de-facto standard for mobile broadband. There are, at the present time, 77 networks in Western Europe, and 64 networks in Central and Eastern Europe with more planned. Over time, it is anticipated that LTE will replace many 3G services, and some replacement of 2G and 3G services with LTE is already taking place. It is anticipated that 2G (GSM) services will be reduced (initially in higher frequency bands) and from 2020 onwards may disappear, although some residual use for machine-to-machine (M2M) applications may continue until embedded devices have been replaced.

Coverage of commercial mobile networks is increasing, but even where there are coverage targets built into licence conditions these will usually be based on population or postcode/premises coverage, rather than geographic coverage. At the same time the travelling public is a source of revenue for commercial mobile network operators (MNOs), and they have looked to increase coverage along rail lines in some countries. This may lead to increased interference in the 900MHz spectrum used by GSM-R.

The ownership model for GSM-R networks is, generally, that the state controls the ownership and infrastructure, the IMs are responsible for the management of the network, and RUs pay for telecoms access through track access charges, with little if any use of billing by call. Since coverage must be provided, and the network has to be highly available, even though under normal operation there is limited voice usage, there is no business model to justify the network costs. This is similar to public safety, where networks are usually government owned, and are either operated by the state, or by a company set up by the state (although there are exceptions where public-private partnerships (PPPs) have been adopted).

At the present time, there is no sign that ownership models in rail and other sectors will change, but there is recognition that the large government procurements of the early 2000s would not be undertaken in the current financial climate.

Future trends

The significant trend in all sectors is an increase in the use of data, which is mirroring the increase in society as a whole. Public safety has recognised that there is a growing demand for a range of data-intensive applications, including image transfer and video. These organisations see a clear need for mobile broadband communications.

All critical-communications sectors also see a need for low-latency transmissions, with data being received in a timely manner. This is important for the rail sector with ETCS signalling, and also for utilities, which have to react to changes in the loading of the power grids in normal and fault conditions.

The requirements and trends identified for the rail sector are more modest. While the number of transactions of signalling data will increase, there was no suggestion from participants in the study that ETCS data sizes would increase, and our interviews identified few other significant data applications. Those identified included timetable and train time (departure/arrival) information. There was little enthusiasm for live operational video to/from the train, other than at short range in the station. Therefore, there is less demand for mobile broadband than in the public-safety sector, unless the ERA requirements capture exercise being carried out identifies a significant video requirement.

The transition of ETCS signalling to GPRS also moves signalling away from a circuit-mode environment to a packet-mode environment, using IP packet data. This is a significant step, and is important, in that a future IP world is more flexible and is future-proofed against change. While 2G and 3G have circuit-mode voice services, LTE does not, and any voice traffic will be carried as voice over IP (VoIP), or where the mobile automatically switches to a 3G service.

The Third Generation Partnership Project (3GPP) has recognised that normal ‘push to talk’ (PTT) over cellular does not meet the needs of many professional critical-communications users, which include those in public safety, utilities and transportation. Work has started in standards bodies to develop additional specifications which will provide suitable functionality on top of the 3GPP specifications. This work is focused initially on public safety, but elements are transferrable to the rail sector, and the railways could benefit from this work.

Spectrum evolution

Spectrum is key: without availability of spectrum, it is not possible to provide a radiocommunications system. At present GSM-R, which is used for voice radio and as a bearer for ETCS, occupies two 4MHz blocks of spectrum at 876–880MHz (uplink) and 921–925MHz (downlink). These are European harmonised allocations in accordance with ECC/DEC/(02)05. The spectrum is immediately adjacent to commercial GSM spectrum 880–915MHz (uplink) and 925–960MHz (downlink). There is an additional expansion block of 2×3MHz which is available on a shared basis by national agreement. The rail sector in Europe is fortunate in having harmonised dedicated spectrum, and this facilitates operation across borders. Spectrum below 1GHz is very attractive for mobile communications, since the cell sizes will be larger than those for higher frequencies, and lower numbers of sites will be required. The only issue with the current allocation and its use for GSM-R is that it is adjacent to commercial GSM spectrum, and there are cases of interference, which are requiring various solutions, but are being resolved by the sector.

While the existing spectrum is suitable for a narrowband solution such as GSM-R, it does not match the available bandwidths provided by mobile broadband standards at the moment. To continue to use the existing band for future technologies would necessitate changes within the standards organisations to designate the band for mobile broadband, and also potentially changes by the European Communications Committee (ECC) to the allocation. In theory, it would be possible, with suitable planning and agreement, to migrate from a GSM-R network to a broadband network, but migrating to a broadband technology on the existing spectrum is problematic.

There is a good case for the rail sector to share spectrum with a like-minded organisation, which is providing a mission-critical solution for its users. The obvious candidate for this is public safety. Additional sites could be deployed alongside the track, giving more capacity and linking to an existing switch site. This is actively being considered in one country within Europe, but may be difficult to mandate on an EU-wide basis.

The final alternative would be to obtain a new Europe-wide block of spectrum for railways, suitable for the deployment of LTE technology, and when the systems have migrated, to relinquish the current spectrum. Currently, the 3GPP operating bands do not cover this spectrum, but this could be changed, and sub-1GHz spectrum is highly attractive to MNOs. This would ease the migration from an existing 200kHz channelled system to a broadband technology.

It is difficult to see where suitable sub-1GHz spectrum could be located, for a European harmonised block. It is possible a block of spectrum at a much higher frequency would be proposed, which would mean more frequent sites, and a different approach to system solutions.

Future scenarios

Six options for a policy to be recommended for further study for Europe were identified, by our analysis, and these were reviewed against a set of strategic objectives and operational requirements as shown in Figure 1.1.

Figure 1.1: Options fit against high-level strategic objectives and operational requirements [Source: Analysys Mason, 2014]

	Strategic objectives		**Operational requirements**
O1 Retain GSM-R	Interoperability	*Good – single platform*	Good fit for current requirements; introduction of GPRS will alleviate capacity limitations
	Service continuity	*Fair – platform support reduced over time*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – dedicated platform with high costs*	
O2 New technology – same band	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – single platform, limited market*	
O3 New technology – new band	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – single platform, limited market*	
O4 New technology – with third party	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Fair – sharing efficiency benefits*	
O5 Multiple prescribed technologies	Interoperability	*Fair – controlled use of multiple platforms*	Dependent on the technologies chosen, but allows optimum solution to be adopted for local requirements
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Good – allows variation*	
	Economic effectiveness	*Good – allows for most economic solution*	
O6 Multiple technologies – no prescription	Interoperability	*Poor – multiple platforms*	Dependent on the technologies chosen, but allows optimum solution to be adopted for local requirements
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Good – allows variation*	
	Economic effectiveness	*Good – allows for most economic solution*	

In the short term, GSM-R provides the best fit as it is specifically designed for railway requirements. The continued use of GSM-R avoids introducing interoperability complications and difficulties in maintaining service continuity, which are inevitable in any transition. However, GSM-R offers little flexibility to adapt to changing requirements, will be more costly than alternative technologies in many scenarios, and cannot be assumed to be supported indefinitely.

If a new technology is defined for railway use, the most likely candidate, based on the current market, is 4G (LTE). However, for the timescales being considered the market can be assumed to have changed significantly and new '5G' technologies are expected to have been established.

Given the pace of change in the telecoms market and the need for flexibility to cater for variations across Europe, a multi-technology policy approach may be the most attractive. This offers the advantages of:

- allowing new/emerging technologies to be introduced over time
- offering a 'future-proof' approach for the longer term
- allowing the use of commercial network bearers with associated potential for cost reduction where appropriate
- allowing for shared networks (e.g. with PPDR) in countries where this is viable
- allowing for private networks in existing spectrum to be retained in areas where this is considered to be the most appropriate option.

However, a multi-technology approach introduces complexity for interoperability. Achieving interoperability would require terminals capable of working on multiple bearers and workable management/governance arrangements to be defined and agreed. Use of multiple bearer terminal solutions for operational communications (including railway examples) has already been established in some of the study references and is expected to become increasingly less problematic as terminal technology develops over time.

While option O6 in Figure 1.1 assumes that (in theory) any technology might be adopted to suit local priorities, option O5 assumes a limited set of 'authorised' technologies is established that can be amended over time through a controlled process.

Transition

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 unit will have a single radio module, which will support GSM and GPRS within the GSM-900 band (some modules have commercial network filtering). Radio modules are from smaller specialist companies, not normally from the infrastructure providers (at least within Europe), and there is no suggestion that these suppliers have plans to declare 'end of life' on the modules.

There may be additional radio data modems for other services also provided on the train. There may also be applications built into the cab radio which use GSM-R data and assist the driver with their work. An example of this would be a driver advisory system.

Just as in the future there is a clear need to separate the bearer from the application, on the train-borne systems, there is a need to separate the GSM-R voice functionality from the ETCS functionality, to allow a more flexible delivery platform. This does not mean they should be isolated, but that the train systems should have the ability to communicate with trackside systems and control systems through a flexible bearer arrangement.

The use of multiple radios implemented in silicon within a device is common today. A typical mobile phone or smartphone will have up to 12 radios, to cover the various frequency bands and technologies; adding a radio is a case of developing the silicon for that band and technology, and requires harmonisation on at least a European level to justify the development and inclusion.

At present the Control-Command and Signalling Technical Specification for Interoperability (CCS TSI) mandates GSM-R for ETCS, but in the future with the terminal operating in an IP environment, there will be fewer reasons to have this limitation, and many more reasons to design the signalling systems to operate over a variety of bearers, as long as the bearer characteristics meet a recognised level of performance in terms of error rate and latency.

It is unrealistic to expect an IM to maintain two infrastructures from the point that it starts a transition so that it can support any legacy radio unit which may need to operate on its tracks. It is therefore important that the terminal is used as a transition tool, i.e. using terminals that operate on different network technologies can facilitate continued operation while new networks are introduced and old networks are decommissioned.

In terms of timescales, if a detailed system definition and transition strategy is defined by 2018, a new generation cab radio could be available for trials within two years. These could then be rolled out into locomotives, operating in legacy mode. Before an IM is able to transition to the new generation of infrastructure (and in particular turn off its legacy GSM-R system) any locomotives which need to operate on its tracks would need to have transitioned to the new-generation solution.

A possible scenario for transition of terminals is shown below in Figure 1.2.

Figure 1.2: Scenario for terminal transition [Source: Analysys Mason, 2014]

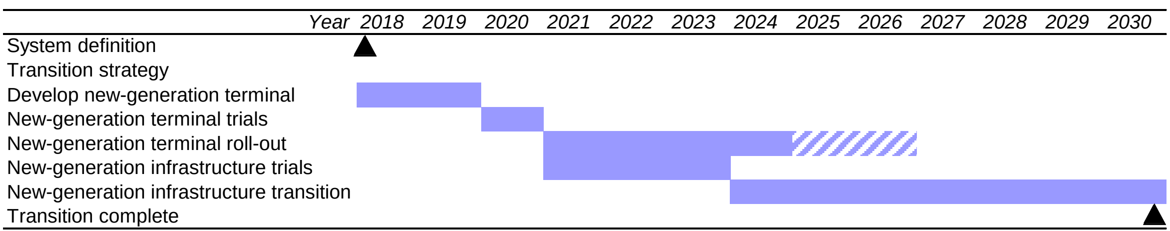


Figure 1.2 is an initial view from current information, and will need refinement. There will be lines or sections of track where there is no real requirement for interoperable trains to travel on that track, and transition could be faster.

Recommendations

As a result of this study a number of recommendations have been identified for consideration by ERA during 2014:

- any future communications solution should separate the bearer from the applications
- any future communications solution should avoid dependence on any single technology, and allow bearers to evolve over time
- transition will be best managed by the use of multi-mode terminals (rather than requiring legacy infrastructure platforms to be retained)
- in determining the transition strategy, lessons learnt from the migration from analogue to GSM-R should be taken into account
- as well as aiding transition, multi-mode terminals can facilitate interoperability in a mixed communications environment, enabling a degree of flexibility, and allowing different bearers to be adopted (to suit local needs or as requirements change over time)
- ERA, UIC and industry groups need to engage with standards bodies, to ensure that railway-specific functionality can be supported as an application on new technology platforms
- considerations regarding spectrum need to be made during 2014 to build, in part, on the EC study that will report later this year.

2 Introduction

2.1 Document purpose

This document captures the findings of the study into operational communications for railways: *'Survey on operational communications (Study for the evolution of the Railway Communication System)'* carried out by Analysys Mason for the European Railway Agency (ERA) over the period August–December 2013.

2.2 Study objectives

ERA's overall objective for the study was to identify potential strategies for the evolution of the Global System for Mobile Communications, adapted for Railway (GSM-R) over time to a future concept of communications for railways. This required:

- an investigation of the current situation and future trends for mobile communications (for railways and for other sectors facing similar challenges)
- the development of potential scenarios for future evolution
- and an assessment of these to determine the merits of each.

The study is part of a larger programme of activities for future communications systems for railways being carried out by ERA, as illustrated Figure 2.1. A separate operational requirements capture exercise is currently underway and is due to report in the second quarter of 2014.

Through subsequent stages of analysis and stakeholder engagement, ERA intends to establish a roadmap for communications evolution by 2015, with new solutions defined by 2018, and available to be ready for deployment to start the transition from approximately 2022.

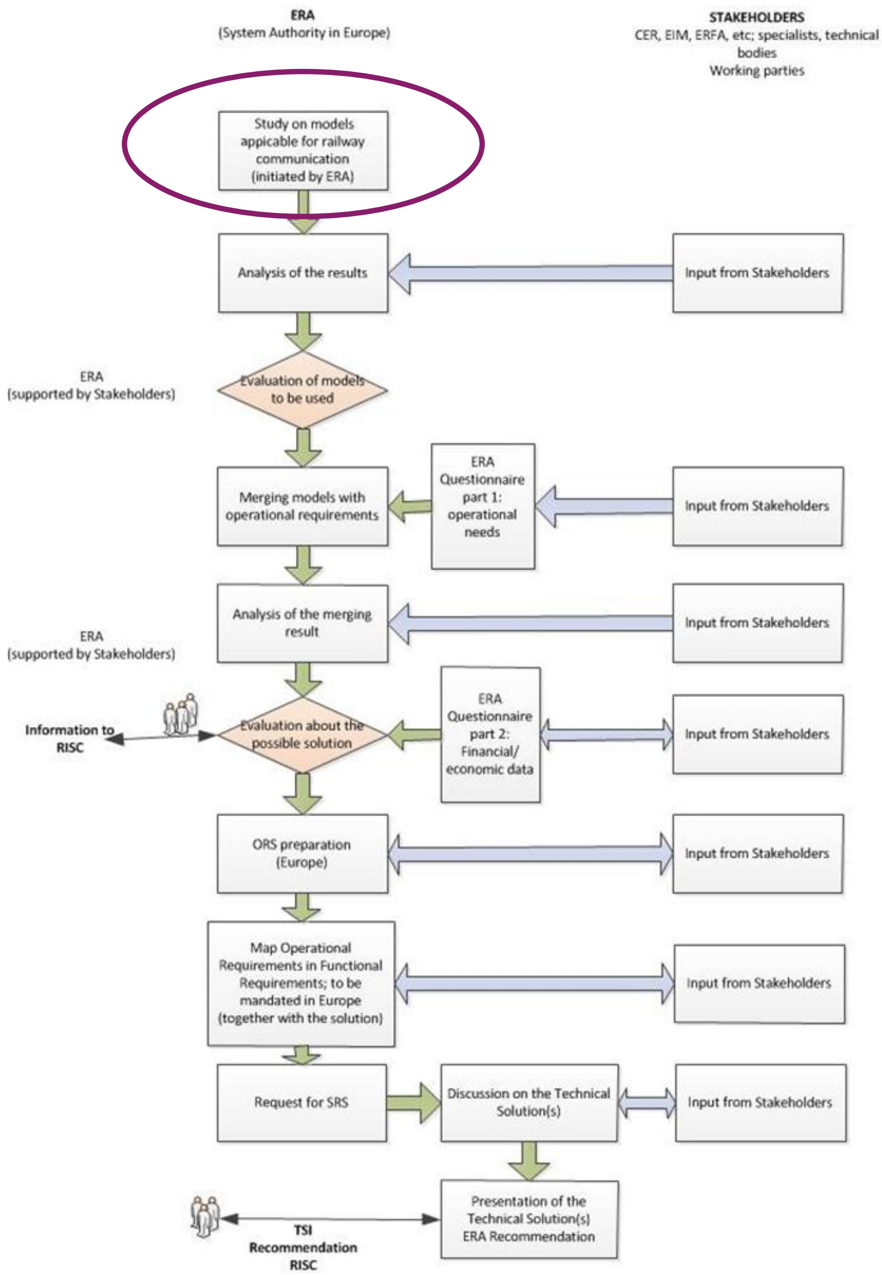


Figure 2.1: Where this study fits in to the overall ERA programme [Source: ERA, 2013]

2.3 Scope of the study

The scope defined for the study can be broadly summarised as follows.

- *Current situation* – determining and assessing the current situation in the railway sector and in other sectors of relevance (e.g. other transport sectors, public safety).
- *Future trends* – determining future trends in the railway sector, including a consideration of operating models, radio frequency spectrum availability, capacity/bandwidth requirements, and a consideration of future trends for other relevant sectors and potential sharing models (for example, sharing with public safety).
- *Strategy* – development and assessment of strategies for future evolution for terminals, network systems, and overall conclusions and recommendations.

2.4 Information sources for the study

Information for this report has come from a number of sources, including research and interviews. The main research areas, a list of interviewees and the key themes discussed are described below.

2.4.1 Research

The primary objective of the research was to capture an understanding of the current status (in rail and other relevant sectors), the likely evolution of radio spectrum access, and future trends (for rail and other sectors). The research inputs include:

- the railways environment
- other relevant sectors (e.g. other transport, public safety)
- economic information (railway and other industries)
- market information (telecoms)
- legal aspects (Europe).

The primary research inputs and outputs are illustrated in Figure 2.2.

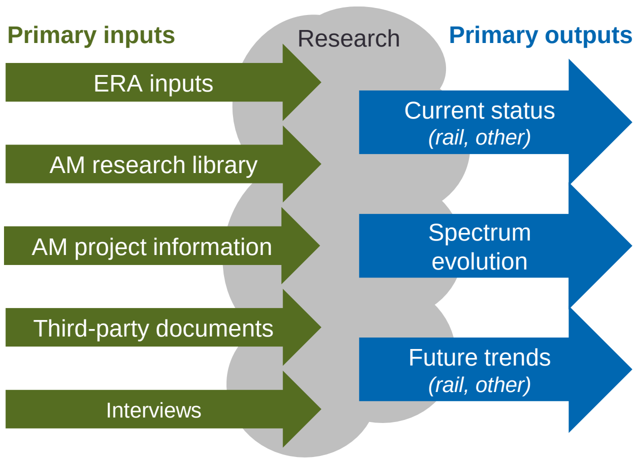


Figure 2.2: Primary inputs and outputs for the research activity [Source: Analysys :2014]

The primary information sources used are listed in Figure 2.3 below.

Figure 2.3: Primary research information sources [Source: Analysys Mason, 2014]

Source
Independent Regulators' Group – Rail, Annual Market Monitoring Report, February 2013
The Rail Journal – railjournal.com
European Railway Review – europeanrailwayreview.com
The Rail Engineer – therailengineer.com
SZDC – szdc.cz (infrastructure manager for Czech railway)
Statistics Denmark – dst.dk
Eesti Raudtee – evr.ee, evrcargo.ee
The European Commission
Finnish Rail Administrator

Source
Lietuvo Gelezinkeliai – litrail.lt
RailwayPro magazine – railwaypro.com
Jane's Railway World
Rail sector conference proceedings, including the International Union of Railways (UIC) 'GSM-R Asset & Evolution Management' Conference 2013 and ERA 'Control Command and Railway Communication Conference' (CCRCC) 2013
Interview notes
Analysys Mason data library

2.4.2 Interviews

To survey the operational communications requirements for railways and to capture perspectives on options for future evolution, a series of interviews was conducted with experts from the railway sector, public safety, aviation, regulators and utilities. Organisations represented included:

- railway infrastructure managers (IMs)
- train operating companies (TOCs) also known as railway undertakings (RUs)
- railway equipment suppliers
- railway trade associations
- regulators and government departments
- public safety
- others (including aviation, space agencies and utilities).

A list of the interviewees is included in Annex A, Section A.2.

The interviews aimed to gather data about the companies' current arrangements, their thoughts on spectrum and predictions for the future. Figure 2.4 gives a summary of the main interview topics.

Interview Area	
Current arrangements	• Ownership and financial arrangements • Functionality and network capacity • Suppliers • Key requirements
Spectrum	• Interference issues • Spectrum sharing • Cost of spectrum
Future trends	• Evolution of the telecoms network • Evolution of terminals • Timetable of network evolution

Figure 2.4: Interview topics [Source: Analysys Mason, 2014]

Specific findings from the interviews have been incorporated, where relevant, within the discussion in the appropriate sections of the report. A summary of the key themes arising from the interviews is given in Annex A.

2.5 Structure of the document

The remainder of this document is laid out as follows:

- Section 3 reviews the current status for rail within Europe, and other sectors, including public safety, utilities and other transport
- Section 4 discusses spectrum evolution
- Section 5 considers future trends in mobile networks, as well as rail and other sectors
- Section 6 analyses possible future scenarios for railways
- Section 7 considers terminal evolution
- Section 8 considers strategies for system replacement and
- Section 9 provides a summary and conclusions.

The report includes a number of annexes containing supplementary material:

- Annex A summarises the interview findings
- Annex B summarises the current status for the rail sector
- Annex C summarises the current status for public safety
- Annex D lists LTE deployments in Western, Central & Eastern Europe.

3 Current status

3.1 Introduction

This section provides a summary of the current status of the railway sector and of the other sectors investigated (public safety, utilities, and other transport sectors). The information is derived from the sources described in Section 2.4.

3.2 Rail sector in Europe

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

3.2.1 Overview of track-to-train mobile rail communications within Europe

Communications to trains generally fit into one of three categories, as outlined in Figure 3.1.

Figure 3.1: Track-to-train communications categories and examples of communications carried [Source: Analysys Mason, 2014]

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	

This study focuses on *critical operational* communications. 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, but the primary focus is critical operational communications and, specifically, the voice and signalling currently supported by GSM-R.

Critical operational communications and, in some cases, business-supporting communications are carried within European main-line services and will usually use GSM-R.[1] GSM-R is a variant of GSM, adapted with some features specific for railway operation. The GSM-R standard was drafted in the 1990s, and finalised in 2000 with the Mobile Radio for Railways Networks in Europe (MORANE) and European Integrated Railway Radio Enhanced Network (EIRENE) projects.

1 In TEN lines, there is an obligation of migrating to GSM-R for new lines, upgrades and renewals.

Current specifications are maintained through ERA (mandatory aspects) and UIC. 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, 874–876MHz and 918–921MHz, but the designation is on a shared basis and is dependent on national administrations. Other non-European countries (China, South Africa, and India) use different 900MHz spectrum for GSM-R, and Australia uses 1800MHz.

GSM-R is used as one of the communications bearers for European Train Control Systems (ETCS) and together they form the European Rail Traffic Management System (ERTMS). Currently ETCS Level 2 information is carried using a circuit-mode service on GSM-R, but can also use General Packet Radio Service (GPRS) within the same GSM-R 200kHz channels.

The mandate for the use of GSM-R is through the Control-Command and Signalling Technical Specification for Interoperability (CCS-TSI). The TSI specifies the use of GSM-R for the mobile communications function for Class A railway systems.

Roll-out of GSM-R is well established within Europe, with some 70 000km of track in operation for voice and a further 150 000km planned. ETCS is less well established (approximately 8000km in operation and a further 19 000km planned), but is being deployed initially on high-speed lines (where it is specified by the EC for new/renew/upgrade TEN-T lines). GSM-R is also widely deployed outside of Europe, with some 138 000km of deployments planned spanning Asia, Australia, the Middle East and Africa.[2]

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. This is in contrast with other sectors such as public safety, where there will be approximately ten times as many portable devices as vehicle-mounted devices and coverage and functionality is optimised for portable devices.

[2] UIC "Implementation Status: GSM-R", CCRCC conference 2013, from Kapsch CarrierCom, Nokia Siemens Networks – GSM-R in operation.

3.2.2 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. One example of this is Germany and DB Netze, a subsidiary of Deutsche Bahn, which is a private company, but with the state as a majority (100%) stakeholder. Another is INFRABEL in Belgium which is a public enterprise receiving capital and operating grants from the federal government, as well as infrastructure fees from transport operators. In the UK Network Rail Telecoms (NRT) is a statutory corporation, but funded by government debt which is, in effect, state ownership.

IMs own the infrastructure, including the GSM-R base stations and backbone. TOCs or rolling stock owners own the cab radio. TOCs and IMs will own portables. The IM will own and supply SIM cards, and so retains control of who can have service.

Once an IM has selected a GSM-R supplier, it is difficult to change supplier unless the IM is undertaking a major change, due to the spares holdings and detailed system knowledge.

Revenue to the IM usually comes from track access charges, and there is little or no use of call charging and billing.

3.2.3 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. One IM had identified that network capacity would be an issue without GPRS, and another identified that due to GPRS network capacity is not perceived as an issue.

While trials for ETCS over GPRS are underway, some IMs are already using GPRS for business-supporting functions such as passenger information.

There are concerns that, in the future, the 4MHz of spectrum will not be sufficient, and some IMs are arranging to make use of the additional 3MHz of E-GSM-R (GSM-R extension band) spectrum.

3.2.4 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) was quoted as a very important feature in interviews.

It was suggested during stakeholder interviews that the rules in place for rail operations have hampered innovation, and that voice has to be present. An incident was quoted by an interviewee, where the trains were halted because voice was not working, even though the ETCS signalling was still working. Railway operations involving signalling are seen by many as conservative, with a long product life.

Not all functionality available within the standard is available in all member states due to national restrictions, and some train operators would like facilities which they are not able to access at the moment, such as a public address (PA) function bypassing the driver to passengers on single-person operating trains. It was also suggested they could make greater use of portables, but that the GSM-R portables available were not satisfactory and coverage for portables within trains was poor.

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.

3.3 Rail sector outside Europe

This section describes a sample of rail markets outside Europe, looking at Australia, Taiwan and Kazakhstan. Australia in particular was chosen for interview as the interviewee had presented at a recent European railway conference, and had an interesting viewpoint.

3.3.1 Rail sector in Australia

In Australia, there are interstate railways operated under a 60-year lease by Australian Rail Track Corporation (ARTC); these are state owned. These use the Telstra NextG 3G commercial networks. The railways have worked with Telstra to ensure coverage, which includes funding additional sites, which are then available for the public to use as well as the railways.

Capital cities use GSM-R, but in 1800MHz spectrum. The channels are distributed through the band, but after 2015 railways will have access to 2×15MHz of spectrum aggregated at the top end of the band. This will also allow mobile network operators (MNOs) to refarm their 1800MHz spectrum to support LTE.

Country rail networks are generally state owned, but in New South Wales (NSW) they have been totally outsourced under a ten-year contract, which is with John Holland. The assets remain in the ownership of the NSW State Government, and include any IPR, which John Holland retains but makes available to NSW through a perpetual licence. The infrastructure for this network uses the commercial Telstra NextG 3G network, with satellite as a back-up. There is also some legacy UHF-FM analogue radio in use. Trains need to be equipped with 3G, satellite and UHF-FM radios as well as GSM-R as they transition through the network. There was a complete change of staff, and the network now uses approximately one third of the workforce, and there are significant savings being demonstrated. Other states in Australia are considering following NSW. The network is funded by access. Country rail has some passenger trains, but the main revenue for the operator comes from freight, where there is competition.

3.3.2 Rail sector in Taiwan

Taiwan is of note as being the only example where TETRA is used for high-speed main-line operations. The high-speed line from Taipei to Kaohsiung is 345km, and operates at speeds up to 350km/hr, with many tunnels in the northern section. TETRA from Motorola was selected, and is used for voice and data communications with the train. It is used for operational control, but there is no suggestion it is used for primary signalling, although it is potentially used as back-up in the event of track circuit failure.

3.3.3 Rail sector in Kazakhstan

Kazakhstan is of note as another example of the use of TETRA for main-line operations. Kazakhstan National Railway chose to implement a TETRA network which also supports ETCS-based signalling, with functionality comparable to ERTMS Level 3. This used Teltronic TETRA equipment, and is believed to use IP packet data. Kazakhstan National Railway has also sourced TETRA from Hytera for another line, but it is unclear if this includes ETCS signalling.

3.4 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. We also look at the utility sector and at the transport sector.

3.4.1 Overview of the public-safety sector

Ownership models for public-safety networks

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, this is the case with ASTRID in Belgium. In some cases, such as C2000 in the Netherlands, the government also directly operates the network. Maintenance will usually be outsourced, for a number of years, which can vary from three to typically ten years.

The users will differ from network to network. Networks in Western Europe will usually support the core blue-light services, as well as other services which require critical communications. In Eastern Europe it is common for the networks to support police and border forces. This is because EU funding was available from the External Borders Fund for suitable projects.

There are a few examples of public–private partnership (PPP) models. These include Austria, Denmark and the UK. In the UK, the public-safety network known as Airwave is totally outsourced as a managed service. The contract was originally let in 2000 for police users, and then ambulance and fire contracted to join at later dates. Current contracted service dates assume that users will roll off the service between 2016 and 2020, migrating to a new service that is currently being defined. The infrastructure assets are owned by Airwave, and police forces pay an annual fee, an element of which is paid by central government, and a further element relating to usage paid by local users. There are a very large number of users, including blue-light services, coastguard, customs and many other sharers which can demonstrate a need to interact with the blue-light services.

The network in Austria is a PPP as well. This is more complicated in that the provincial governments provide sites and make equipment operational, the Ministry of the Interior delivers the backbone, and the private company provides the switching and operational management. Provincial users do not pay, but the federal organisations pay an annual fee.

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.

Terminals will typically be replaced after five years (both vehicle and portables) since newer terminals with better functionality will have become available. Due to the sensitivity of the encryption keys which have been held in the terminal, they will be destroyed, not sold to other users. 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.

Functionality required by the public-safety sector

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 call set-up times demanded are less than 1 second, and typically 300ms. The concept of the group call is to replicate the conventional all-informed call which used to be used with analogue radio systems. There will also be individual unit-to-unit calls (e.g. from a controller to a specific ambulance), and calls to and from telephone extensions, although these will normally be restricted to certain individuals. The group concept is used heavily in police operation across Europe, but the operational behaviour of ambulance and fire users is mainly individual calls from control, with less use of the group call functionality.

The fast call set-up times required are one reason why public safety has always demanded its own systems, rather than using public networks. Public-safety organisations also require very large talkgroups, sometimes with hundreds of officers in a group. 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, although these can be implemented in an external application.

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 in Europe has harmonised spectrum within 380–400MHz, with two blocks of 5MHz (380–385MHz paired with 390–395MHz). There is other spectrum above 400MHz which is used in some countries, especially in Eastern Europe. Most networks have enough spectrum for day-to-day operations, but can be short of capacity in the border areas where two or more countries have to share spectrum, and also during major events where unusually large numbers of users congregate in a limited area. While there is enough spectrum for current operations in most areas, the 2×5MHz does not provide enough capacity for the expected expansion of data-rich applications. There is also insufficient current spectrum in most countries to support TETRA Enhanced Data services (TEDS), which operates in 400MHz spectrum on either 25kHz or 50kHz channels and provides wide-band data capabilities.

Radio-to-radio 'direct mode' communications are commonly used by public-safety organisations and so require spectrum provision within the band; specific channel allocations for air-to-ground communications are also needed.

Network design for public-safety networks

Public-safety networks are designed to high levels of coverage, resilience and redundancy, giving a high degree of availability. This is similar to the approach taken to GSM-R networks for the rail sector, and is different from commercial networks. The following figure compares a typical public-safety network approach to availability and resilience compared with that of mobile networks.

Figure 3.2: Availability/resilience – comparison of public-safety network and mainstream mobile market approaches [Source: Analysys Mason, 2014]

Public safety (typical)	Commercial MNOs
Specification: • originally performance based (*x*% availability for different services) with service level agreements (SLAs) • increasingly prescriptive design constraints through later contract additions – 'no single points of failure', mean time between failure (MTBF) targets for various components, specified duplication and physical separation of main and back-up switches, specified base station rings and power supply back-up, and resilient communications links	**Specification:** • unspecified – up to individual operators to determine • individual sites typically have little/no resilience and short-duration power back-up only • increased convergence of radio access networks (RANs) used by MNOs increases likelihood of concurrent failures on multiple MNOs • extensive cell overlap, typical of urban areas, provides level of resilience against individual site faults
Tender assessment: • analysis of design proposals	**Tender assessment:** • N/A
Service acceptance: • factory acceptance testing (FAT) and system acceptance testing (SAT), including failover testing for resilient components	**Service acceptance:** • N/A
In-life assessment: • service monitoring, reporting, service credits where appropriate	**In-life assessment:** • no formal assessment • some real-time health data (e.g. website 'service status') • market pressure – consumer feedback, good/bad press, etc., e.g. press after major service failure

Costs for public-safety networks

The larger European public-safety network key attributes and approximate costs are listed in Figure 3.3. This shows that only three examples have a completely outsourced (ownership and operator) model, i.e. Austria, Denmark and the UK (as previously explained, although predominantly company owned, the case of Austria is more complex with some network components owned and provided by the government.)

The costs shown are very approximate indicative values based on published figures, but these suggest that the government-owned solutions are generally cheaper than the outsourced examples. The Great Britain example, which uses a completely outsourced model, is far more costly than the others in Figure 3.3, even after adjusting for size. The high cost partly reflects the high specification applied compared with some other networks, but also reflects costs associated with the model, including a high cost of change as users and requirements have changed over the past ten years of operation.

The costs vary significantly and illustrate that there is no easy measure to benchmark these types of service.

Figure 3.3: A selection of larger European public-safety TETRA networks [Source: Analysys Mason, from individual project data 2014]

Country	Year commenced	No. of users (approx.)	No. of sites (approx.)	Ownership	Operator	Approx. cost (EUR bn)
Austria	2005	80 000	1800	Company	Company	1.1
Belgium	2001	10 000	600	Government	Govt/Company	0.4
Denmark	2008	20 000	500	Company	Company	0.2
Finland	1998	30 000	1400	Government	Govt/Company	0.3
Germany	2007	500 000	4500	Government	Company	1.1
Italy	2006	200 000	3100	Government	Company	3.5
Netherlands	2000	85 000	600	Government	Government	0.5
Norway	2006	40 000	2000	Government	Company	0.9
Sweden	2005	50 000	1800	Government	Company	0.4
UK	2000	300 000	3500	Company	Company	5.5

The UK experience has highlighted some of the successes and failures of outsourcing in action, with a higher cost of ownership compared with, for example, Germany, which has a lower cost, for more subscribers.

When the contract was signed in 2000, the network build was wholly financed by the private sector, avoiding the need for the government to raise capital. The national site acquisition and roll-out programme was a major challenge that was successfully delivered by the contractor in a manner that is unlikely to have been achieved had the responsibility been held in house.

Solutions have been found in order to ensure that the security and service quality are fit for the public-safety application. However, arriving at these has required substantial efforts from all parties, and often involved complex contract provisions that intrude heavily on the provider's operating model, limiting its flexibility to introduce efficiencies or other improvements.

The nature of the outsourcing and associated contracts has limited flexibility (with a long-term commitment necessary to recover the initial investment) and, where service and contract changes have been necessary, the costs of accommodating these have been high. With the outsourced provider delivering a critical service in an effective monopoly position, there is limited/no opportunity to use competitive pressure to bring prices down. As the contracts approach expiry (due from 2016), the outsourced ownership and operation is significantly complicating the government's efforts to determine the best approach to future service provision.

3.4.2 Overview of the utilities sector

Critical wireless communications are used widely in the utilities sector for monitoring and control. This is predominantly for communications with an estate of fixed assets, rather than a mobile communications requirement. Mobile communications can be useful but not essential, e.g. for maintenance personnel responding to a fault. Some utilities also operate helicopters. There is less commonality of approach across Europe when compared with public safety or rail. As there is typically no movement of users or equipment between countries, there is no operational requirement for commonality/compatibility across countries. The primary case for standardisation efforts is commercial, e.g. to improve competition and reduce costs for products serving the utility market.

Among the various solutions in place, conventional VHF private mobile radio networks are widely used; there is also some use of TETRA, there are current trials of WiMAX in the UK at 1.4GHz and in Ireland at 2.3GHz, and a CDMA450 network is being rolled out by Alliander in the Netherlands.

There is no EU harmonised spectrum, and a range of different situations across Europe. For example, Spanish utilities have access to a very limited number of channels which are distributed through the various PMR bands. The UK used to have a small dedicated block of VHF spectrum (2×1MHz), but has relinquished this in some areas.

For switching of power transmission, communications reliability and latency is critical and this is typically carried out using fixed-line connections (e.g. optical fibre).

The majority of wireless networks are privately owned and this model is generally preferred by users. There is some use of public networks, e.g. satellite communications provided as a managed service. GPRS (on commercial networks) is also often used and this is generally considered acceptable on a small scale, e.g. for connecting to a small number of renewable sites which, if lost (due to communications failure), would not have a dramatic impact on the energy network.

Critical applications are kept separate from other communications, which will be carried on separate networks (typically public commercial networks).

Key requirements for utility wireless communications are:

- resilience
- continued operation during power outages
- controlled latency
- coverage (to suite the estate)
- long product life cycles
- availability of equipment (avoiding niche/custom products).

The EU's renewable energy targets of 2020 are driving demand for communications and more investment in the energy sector. The trend over time is for communications with more and more devices and fewer people. Applications and individual device communications demands are not changing dramatically, but overall data volumes are growing rapidly as the number of devices expands. As the utility networks become increasingly intelligent, the role of telecoms in the successful operation becomes greater.

There is limited synergy between the utility sector and the rail sector's use of GSM-R. The specialist GSM-R functions are not required by utilities and there will normally be very little overlap between a GSM-R coverage area and a utility's estate.

However, there are some areas of common interest, e.g. a rail operator will typically be distributing power on a similar scale to an electricity distribution company. Both need a resilient network backbone and solution design and seek long-term stability without requirements for equipment refresh. The utilities also have common interests with rail in obtaining private spectrum, deploying critical wireless solutions, managing contracts and support, etc. While the user requirements are quite different, there could be merit in shared network models with rail, utilities, and others, provided that the critical requirements of all parties are met.

Spectrum arrangements vary from country to country. The European Utilities Telecom Council (EUTC) is currently working on an effort to harmonise utility requirements for spectrum to create a coherent case for harmonised spectrum across Europe. Spectrum potentially available varies in different countries, but current EUTC efforts are focused on elements of the 450–470MHz band as well as 1.4/1.5GHz.

3.4.3 Overview of the wider 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. Signalling will usually be a dedicated system, and may well be a Communications-Based Train Control (CBTC) signalling system using 802.11 Wi-Fi networks which allow signalling, CCTV, platform TV and passenger information to be carried on the same network.

Bus and tram

There is a wide range of ownership and delivery models for communications in the bus and tram market. Bus and tram radiocommunications networks may be owned by local transport authorities, or be owned by bus operators themselves. There are also arrangements where the communications have been outsourced for a period of time to private companies, which run the systems on behalf of the transport operator.

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.

Some of the systems have sophisticated control. Many bus systems allow controllers to use a geographic information system (GIS) to select various scenarios, such as all buses on a particular route, all buses travelling in the same direction in a section, or buses in a defined geographic area, and then group those buses into a special group so voice or data calls can be made to them.

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. In Belgium, Belgocontrol is an autonomous public company in charge of the safety of air traffic in the civil airspace for Belgium (ground level to flight level 245 (24 500 feet)) and Luxembourg (flight level 14/165 (14 500/16 500) to flight level 245 (24 500 feet)). In the UK NATS is a PPP licensed from 2001 for 20 years. NATS performs all ‘en route’ control, however, in the airport air traffic control space, there is competition for each airport, with NATS and other companies competing. Funding for en route control is from plane movements, with costs determined by time in national airspace, size of plane, etc.; landing fees finance airport air traffic control.

Within parts of mainland Europe[3] control of air space above 24 500 feet is the responsibility of Maastricht Upper Area Control Centre (MUAC), which is managed by Eurocontrol, an intergovernmental organisation governed by convention and made up of 40 member states and the European Union.

There is a lot of international standardisation, including data, in order that a flight plan is recognised by national systems.

3 Belgium, the Netherlands, Luxembourg and North West Germany.

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. There were projected capacity concerns and they have changed their channels from 25kHz to 8.33kHz, to increase capacity, but there are no plans to go digital. The ‘party line’ concept where all aircraft in a sector hear each other is important and is expected to continue. The future trend is to have more data links to pass information which will reduce the voice usage, but not replace it.

It was noted that aircraft can pick up information from other nearby craft, and have avoidance systems which will warn or take action if they think two aircraft are in danger of colliding.

3.5 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 800MHz. IMs are happy with the functionality, although RUs would like to do more with the systems.

ETCS is being rolled out, but there was feedback from the interviews that circuit-mode operation on GSM-R did not give enough capacity, and GPRS is required. While GPRS is used on GSM-R spectrum for business-supporting communications, it is not yet available for ETCS data, although it is an optional feature in GSM-R documents. In terms of railway infrastructure, ownership is with the state, and the network operating companies are generally state owned. Costs for the telecoms service 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.

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), and in New South Wales (Australia) a solution using multiple radio bearers has been successfully established.

Public safety is very similar to rail, in that there is a 400MHz 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.[4]

There is some interoperability across borders, but this is mainly done by extending coverage into the neighbouring country, although TETRA does have an Inter System Interface (ISI).

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.

Utilities are different, in that they tend to use radio networks to communicate with an estate of fixed assets, and use the systems for monitoring and control, with data, rather than voice services.

[4] There is a w ideband TETRA service called TEDS, but there is little deployment of the technology.

They use a wide range of services, including PMR, cellular, satellite and DSL, and for critical points in the network will use at least two different communications nodes.

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.

Reliance wholly on commercial networks by utilities is a problem, since the electricity control system has to operate during power cuts, which in a black start situation may be 72 hours, and the commercial networks do not have this level of autonomy.

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.

4 Spectrum evolution

4.1 Introduction

In this section we assess the current situation in terms of spectrum use and availability, before looking at the future technology developments (4G and even '5G') and the potential changes in critical-communications requirements, and the impact these issues will have on spectrum. We also address the issue of sharing spectrum with other similar sectors, and the possibility of securing new spectrum for the rail sector.

4.2 Current situation regarding spectrum

At present GSM-R, which is used for voice radio and a bearer for ETCS, occupies two 4MHz blocks of spectrum at 876–880MHz (uplink) and 921–925MHz (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 1800MHz is used.

The spectrum is immediately adjacent to commercial GSM spectrum 880–915MHz (uplink) and 925–960MHz (downlink).

Channels are 200kHz bandwidth channels. In the case of GPRS and Enhanced Data Rates for GSM Evolution (EDGE), the channel bandwidth is also 200kHz.

ECC Decision (04)06 (amended December 2011) provides for the possibility of a GSM-R extension into the bands 873–876MHz and 918–921MHz. However, this is on a national basis and there are other potential sharers of the spectrum including defence systems and low-power devices. This limits the areas where the spectrum can be used, and it has been suggested it is suitable for use in shunting yards rather than main-line operations.

CEPT as recently as March 2013, reaffirmed the spectrum at 876–880MHz and 921–925MHz for railway purposes.

4.3 Future technology requirements and their impact on spectrum

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

In the case of 3G, channels for UMTS use wideband code division multiple access (W-CDMA) with 5MHz bandwidth.

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

It is instructive that in Australia, where the GSM-R frequencies used by rail were distributed throughout the 1800MHz band, the network operators, including the railways, have lobbied and collaborated to secure 15MHz of contiguous spectrum at the top of the band. This allows both the commercial operators as well as the rail sector to deploy mobile broadband solutions at 1800MHz.

4.4 Future technology and voice calls and their impact on spectrum

A consensus view from interviews was that 3G technologies are not regarded as suitable to support railway communications. This view is with the exception of Australia, where the Telstra NextG 3G network is used for rail communications for interstate trains. Generally, the concern with 3G is the degree of latency.

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, or as circuit-switched fall back (CSFB), where the mobile automatically switches to a 3G service. There are a number of different implementations of VoIP.

The Third Generation Partnership Project (3GPP) has recognised that normal 'push to talk' (PTT) over cellular does not meet the needs of many professional critical-communications users, and has started a work item for Mission Critical PTT over LTE (MCPTToLTE), which is likely to be in Release 13.

The group call enablers (GCSE-LTE) that are being developed within 3GPP for public safety would be applicable to rail communications, and support group calls. Unit-to-unit communications outside of the network, which are part of the Proximity Services (ProSe) capability would also be useful. However, for these to work there is a need for further development, and ETSI Technical Committee TETRA and Critical Communications Evolution (TC TCCE) is specifying the application which turns the enablers into a full solution. While WG1 (user requirements) of the TC TCCE has received input from a combined list of requirements which includes railway-specific functionality, there is a good argument for ETSI Technical Committee Railway Telecommunications (TC RT) to work with ETSI TC TCCE to ensure a final specification which includes some railway-specific functionality and is suitable for railways as well as public safety. ETSI TC TCCE operates on a European basis, but has links to other worldwide standards organisations.

4.5 Use of current spectrum for broad band communications

New broadband technologies tend to work on units of bandwidth of 5MHz, with 5, 10, 15 and 20MHz channel bandwidths. The higher bandwidths are preferred since a network with 10MHz of bandwidth is more efficient than two networks of 5MHz. LTE does, however, have channel bandwidths of 1.4MHz and 3MHz within the standard. Since GSM-R has available two blocks of 4MHz, there is a disconnect between the harmonised GSM-R band and new technologies. Either 3MHz in the existing spectrum allocation is used, meaning data rates will be lower and not all the band is used, or more adjacent spectrum is harmonised, or changes in 3GPP will be required, or a new block of spectrum is obtained.

LTE Advanced 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.

One possibility would be to work with 3GPP to introduce a 4MHz bandwidth variant of LTE into the standards. This would require significant support from both Europe and the wider railway community to sponsor the work, and to help develop the standard. Work is also required to extend the LTE band designations into the GSM-R band. 3GPP works in two-year cycles between releases, so that to get anything into Release 13, input would be required within the next 24 months, for specification freeze in 2016. Pursuing a specific variant of the standard for the rail industry is to be avoided, if possible; a number of stakeholders consulted during the study stressed the desire to avoid creating an 'LTE-R', where the railway version diverges from the development path of the mainstream technology.

Another possibility would be to work with ECC to harmonise – for dedicated rail use part – of the 875–876MHz and 920–921MHz, to add to the existing harmonised band, allowing two 5MHz blocks to be created.

In theory, it would be possible, with suitable planning and agreement, to migrate from a GSM-R network to a broadband LTE network. A number of elements would need to be put in place for it to be able to happen:

- a reduced bandwidth LTE mode will need to be specified, so that terminals can be designed to support this, as well as the full bandwidth mode, and the legacy GSM-R mode
- cab radio and other terminals/equipment would need to operate in multi-mode
- the multi-mode would include GSM-R, **as well as** a minimal bandwidth LTE mode, **as well as** a final (full) bandwidth mode
- existing networks would need GSM-R channels to be re-aligned into a compressed part of the spectrum, to clear the portion of the spectrum where the narrow LTE bandwidth is to be deployed.

In this way the GSM-R and LTE networks can be deployed in parallel, on an area-by-area basis. Once the cab radios are operational on the LTE system, the GSM-R system can be turned off. Once all the GSM-R users have switched to the LTE system, base station equipment will need to be powered down, reconfigured for full bandwidth, and then the system will operate on the final frequency and channel bandwidth.

While deploying an LTE network on the same spectrum as a GSM network appears not to be feasible, there are solutions being proposed. One example is the ZTE Magic Radio Spectrum

Solution, which allows GSM/LTE dual mode in 900/11800MHz bands. It includes a spectrum overlay solution as well as a collaborated spectrum scheduling solution. This has only recently been announced and details are very limited. For example, it is not clear if both networks have to be ZTE networks. It does, however, illustrate that there is a great interest in the refarming of bands from GSM to future technologies while minimising disruption to subscribers.

4.6 Spectrum discussions at the World Radio Conference 2015

The discussions concerning the preparation for World Radio Conference (WRC) in 2015 are based on Resolutions from the last WRC, in 2012.

In WRC12, there were two resolutions which have resulted in the following agenda items for WRC15.[5]

- 'A.I. 1.1 to consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution COM6/8 (WRC‑12).'
- 'A.I.1.2 to examine the results of ITU‑R studies on the use of the frequency band 694–790MHz by the mobile, except aeronautical mobile, service in Region 1 and take the appropriate measures, in accordance with Resolution COM5/10 (WRC‑12).'

This is known as digital dividend 2, and is the leading to discussions on a potential band plan for mobile broadband at 700MHz. Asia–Pacific and North America already use 700MHz for mobile broadband, and have band plans in place.

A further resolution in WRC12 concerned public safety, which is known as public protection and disaster relief (PPDR) to the International Telecommunications Union (ITU), has led to the following agenda item.

- 'A.I.1.3 to review and revise Resolution 646 (Rev.WRC‑12) for broadband public protection and disaster relief (PPDR), in accordance with Resolution COM6/11 (WRC‑12).'

Resolution 646 invited ITU Radiocommunication Sector (ITU-R) to continue studies and make recommendations for advanced solutions to meet the needs of PPDR, and to identify frequency ranges to meet the needs of particular Region 1 countries. It also recommended administrations to identify regionally harmonised frequency bands for PPDR.

FM49 is a CEPT Project Team devoted to broadband PPDR spectrum, and so far has identified a requirement for at least 2×10MHz of broadband spectrum, but has not identified the band other than commenting that both 400MHz and 700MHz are under discussion. The discussions on where

[5] http://w w w .itu.int/dms_pub/itu-r/oth/12/01/R12010000014A01PDFE.pdf

the spectrum could come from are still ongoing, and are scheduled to be published in a report in 2014.

It is not clear at this stage that public safety will get an allocation of harmonised mobile broadband spectrum, and if they do, what band it will be in. What is clear is that to be in the current position has taken a large amount of work and lobbying by users, industry and the global industry body the TETRA + Critical Communications Association (TCCA).

4.7 Sharing of spectrum

Several of the interviewees, from both the supplier and user side, did not rule out the possibility of sharing spectrum and networks. However, it was commented that the availability and resilience requirements of the rail sector would need to be met by any shared network, and several interviewees suggested sharing with like-minded organisations, such as public safety.

For example, in the Netherlands the IM has already had some discussions with the relevant ministries and public-safety bodies, on the possibility of sharing broadband spectrum, should this be designated as a result of WRC15.

The European Commission (EC) has also started a study looking at the potential for sharing of spectrum by critical users such as public safety, transport and utilities, and the evaluation of how well commercial networks would meet the user requirements. This study will report in the third quarter of 2014.

Since the other parties are highly likely to want national coverage, sharing of spectrum also means sharing of the network (at least the core network). Typically, half the cost of the network will be for the core, so sharing of this brings benefits. 4G mobile broadband networks are single-frequency networks, and increases in capacity are achieved by adding more sites, and having smaller cells. Many sites could also be shared, but in order to ensure the rail sector has enough capacity, it could deploy its own base stations alongside the railway, which will provide extra capacity, and these can be linked back to the core network using a resilient arrangement. It is likely that these base stations would be used by the both the rail sector and the sharing party, which, if it is public safety, has a role to play in providing a secure environment for the travelling public.

4.8 New spectrum for rail communications

The alternative would be to obtain a new Europe-wide block of spectrum for railways, suitable for the deployment of LTE technology, and – when the systems have migrated – to relinquish the current spectrum. Currently, the 3GPP operating bands do not cover this spectrum, but this could be changed, and sub-1GHz spectrum is highly attractive to MNOs. This would ease the migration from an existing 200kHz channelled system to a broadband technology.

It is difficult to see where suitable sub-1GHz spectrum could be located, for a European harmonised block. It is possible a block of spectrum at a much higher frequency would be proposed, which would mean more frequent sites, and a different approach to system solution.

As previously noted, LTE is a single-frequency network. If there is a single harmonised spectrum block used for rail operations in all countries care will be needed in the border areas, to achieve seamless handover for international trains. With GSM-R, the carriers can be agreed between rail IMs and regulators, but LTE is a very different technology. Agreement would need to be reached between the IMs on the 'fractional frequency re-use'.

4.9 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-1GHz 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.

The difficulty is identifying where suitable spectrum could come from, and being able to justify the need for dedicated spectrum. Rail could learn from public safety in terms of the recent campaign in which its organisations have engaged regarding spectrum.

While the concept of sharing spectrum with a like-minded organisation has merit, and would provide significant economic benefit, it is unlikely to be achievable as an EU-wide arrangement, since each of the like-minded organisations, which are likely to be public safety or utilities, also operate on a national basis.

5 Future trends

5.1 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. We consider likely changes in the mobile market in Western Europe and Central and Eastern Europe, as well as looking at technology trends (such as 4G and even '5G' services), and likely trends in mobile coverage provision.

5.2 Trends in the mobile market

5.2.1 Telecoms landscape

The largest wireless telecoms markets in Western Europe are Germany, Italy and the UK. In each case, the markets are saturated, with well over 100% penetration.

The high level of penetration throughout Europe, and the fact that there are multiple operators competing, leads the major players to drive growth and revenues through encouraging customers to use more data, using the deployment of new technologies. An example of this is the way MNOs are increasing their involvement in machine-to-machine (M2M) communications, with dedicated platform within their systems.

Existing networks with 2G (GSM and GPRS/EDGE) are available in all countries, as are 3G (UMTS and HSPA) networks.

3G (UMTS and W-CDMA) networks started being launched in the early 2000s, and now number 77 networks in Western Europe, and 63 networks in Central and Eastern Europe – 140 in total. There are 90 HSPA, HSPA+ and DC-HSPA+ networks in Western Europe, and 72 networks in Central and Eastern Europe – 162 in total.[6] These were launched from 2006 onwards, and show the increase in demand for, and accelerated roll-out of, data networks.

Mobile broadband is required to support the large increase in smartphone usage, and the need for an always-connected device. Across the world, 4G networks are being rolled out, initially in urban centres. These 4G networks are based on LTE, and are now getting established, with 77 networks in Western Europe, and 64 networks in Central and Eastern Europe. A list of LTE network deployments is provided in Annex D.

Worldwide, some 400+ 4G networks are either operational, planned or in trials.

6 Planned, in deployment and operational, at July 2013 [Source: Analysys Mason]

Figure 5.1: Worldwide 4G (LTE) deployments [Source: Analysys Mason, 2014]

Region	In deployment	Operational	Planned	Testing	Trials	Total
Central and Eastern Europe	3	24	20	2	15	64
Developed Asia–Pacific	1	21	12	1	3	38
Emerging Asia–Pacific	1	18	35	1	15	70
Latin America	1	14	32	10	2	59
Middle East and North Africa	1	14	7		5	27
North America	2	28	24		2	56
Sub-Saharan Africa		8	14		6	28
Western Europe	4	41	20		12	77
Total	**13**	**168**	**164**	**14**	**59**	**419**

5.2.2 Western Europe key trends

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 EUR274 billion in 2012 to EUR239 billion in 2018.

Five main factors are driving this continued shrinkage:

- the generally poor European macroeconomic situation, which affects fixed and mobile providers in different ways
- European regulation, which sustains overcapacity and encourages price reduction but can appear to discourage risk-taking and investment
- the decline in the cost of running networks and services, which reduces the unit costs of transport and drastically reduces market entry costs by over-the-top (OTT) service providers
- fixed–mobile convergence, which manifests itself in quadruple play and public Wi-Fi, bringing value-destruction to the market as a whole and mobile in particular
- (potentially) mobile operators' loss of influence in device distribution.

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.

5.2.3 Central and Eastern Europe key trends

Telecoms operators in Central and Eastern Europe are now facing the same challenges of market maturity as Western Europe. Service revenue is expected to peak in 2013, five years after Western Europe, and to decline thereafter, at a compound annual growth rate (CAGR) of –0.6% in 2012–2018.

Service revenue growth throughout the forecast period will only occur in Turkey and Ukraine, in which the mobile market is under-penetrated. Russia will reach the peak in 2014.

Five main factors will contribute to this decline:

- GDP per capita will continue to grow, but non-commoditised goods will tend to absorb most of the extra income, leaving little extra for telecoms expenditure
- price competition will remain strong because voice and messaging services have reached maturity, and new MNOs and mobile virtual network operators (MVNOs) might enter the markets
- smartphone penetration will increase, but this will drive cannibalisation from OTT services
- the influence of EU policy and regulation (cut to mobile termination rates, spectrum auctions, MVNOs) is putting pressure on revenue
- fixed–mobile convergence is gaining momentum in some Central and Eastern European countries and is likely to bring value-destruction for the market, particularly for mobile operators.

5.2.4 Trends regarding 4G technologies (LTE)

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.

Smartphones will take an increasing share of a stable, consolidated handset base. Mobile broadband subscriptions will increase steadily, while M2M connections will accelerate towards the end of the forecast period. 3G+ connections will expand apace, with 4G reaching 55% of total non-M2M connections by 2018.

Data-only services will migrate to 4G faster than handsets, if only because they have had a head start. By 2018, 65% of mobile broadband subscriptions are forecast to be 4G, compared with 54% of handsets.

A standard LTE system would not possess the rail-specific features that are built on to the GSM standard. This means the numbers of units which would be involved in a group call would be limited. With the work within 3GPP mentioned in Section 4.5, future LTE standards will have many of the features required, but this does not guarantee that a supplier or MNO will implement them into their network, unless there is a business case for the inclusion.

5.2.5 Trends regarding 5G technologies

4G technologies have come to market between 2010 and 2012. Based on the ten-year cycle for 2G and 3G, there should be replacement technologies (known by some as 5G) by 2020 to 2022. The EC has announced EUR50 million EU research grants in 2013 to develop '5G' technology. Some of this grant is for the Mobile and wireless communications Enablers for the 2020 Information Society (METIS) project which aims to provide:

- 1000 times higher mobile data volume per area
- 10–100 times higher number of connected devices
- 10–100 times higher typical user data rate
- ten times longer battery life for low-power devices
- five times reduced end-to-end latency.

At the present time, there are no firm proposals as to how 5G may be realised, and indeed whether it will be a step change, as happened with 2G and 3G, or a gradual change as happened with 3G, 3.5G and 3.9G. However, the current expectation of 5G services becoming established in the next ten years is consistent with expected timescales for transitioning from GSM-R (currently assumed to be from 2022 – see Section 2.2).

5.2.6 Mobile network coverage trends

While mobile markets are saturated, which means that there are more SIM cards than population in most countries, this does not mean that coverage is saturated in countries. Commercial networks tend to define coverage as a percentage of population covered, rather than geographic coverage. The degree of coverage will typically reduce for the higher data rate technologies, so that 3G coverage will be less than 2G coverage.

While availability of mobile coverage in most European countries exceeds 99% based on population (premises), this assumes a user can use any network. For a user limited to one network (as is typically the case), the coverage is reduced, often below 98%. Where geographic coverage is considered instead of population coverage, the contrast is more dramatic, for example, >99% mobile population coverage in Ireland amounts to approximately 95% geographic coverage, and in Sweden, 99% population coverage amounts to approximately 90% geographic coverage.[7]

The above figures illustrate the difference between premises and geographic coverage, and the difference in coverage between a user who is limited to one network and one where any network could be used. There may well be a lack of coverage in rural areas for rail lines, especially where the line runs in a cutting. Whether an IM could rely on mobile coverage instead of deploying its own network coverage would have to be analysed; either additional sites would then need to be installed, or the system would have to operate while recognising that there are gaps in coverage, which may be in areas where there is no need to exchange data. Australia is an example where the

7 Sample figures source: Analysys Mason *Wireless networks tracker 4Q 2013*.

interstate trains use the commercial Telstra NextG network and the rail sector has paid for additional sites to improve coverage.

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. O2 advised us that Network Rail Telecoms is one of its biggest corporate users, which provides a driver to ensure the rail network is covered, and Deutsche Telekom is supplying Internet services to the travelling public on German trains.

A small number of mobile operators showed interest in providing service to the rail sector, but other potential mobile operators declined to be interviewed, and had no interest. One example of an interested party is Deutsche Telekom, which suggested that professional organisations such as the rail sector or public safety should rely as much as possible on public networks, as they offer the most efficient and cost-effective solution. However, they cautioned that any arrangement would need to be viable financially and a business case would need to be developed.

5.3 Trends in specific sectors

5.3.1 Rail sector trends

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. The interviewees generally saw a need to move from the circuit-mode data service of GSM-R to GPRS for ETCS. Without this move, there would be a significant risk of congestion and lack of capacity. GPRS is already used in some situations for business-supporting functions such as timetabling, and this is seen to be on the increase. The use of packet-switched transmissions and IP for ETCS were seen as vital evolutions for signalling.

Voice and the REC were seen as important and continuing into the foreseeable future, but it was questioned whether the REC would always require a voice call, or perhaps the function could be performed in some other way.

Some RUs felt that they could use more terminal devices, including portables, if the functionality, size and performance on trains of the devices were improved.

It was generally recognised that GSM-R would reach end of life in the later 2020s. Some suppliers did not believe there were issues with the supply of cab radio modules, but had concerns that infrastructure suppliers would no longer support GSM-R.

5.3.2 Other transport sector trends

There is a trend towards more and more data, principally for real-time passenger information (RTPI).

In bus services this is related to passenger information, and fare collection data, as well as passenger counting. With a need to control emissions, there is also a demand to pass information on the performance of the bus and the engine, to ensure the emissions are as low as possible. Some of this data can be downloaded when the bus returns to the depot, using Wi-Fi, but some is real time and has to be transmitted using commercial networks.

For many years, bus and tram RTPI systems have been able to use different bearers, such as PMR, TETRA, GSM, GPRS, etc. Typical systems have used an adaptation layer with interchangeable modules so that the RTPI application would not need to change as the bearer changed from technology to technology and customer to customer.

For civil aviation, use of data is increasing, but data alongside voice, to reduce the amount of voice usage, and to pass more accurate data than would be possible using voice transmissions. Voice will still be there as the primary service.

5.3.3 Public-safety sector trends

The overriding future trend in public safety is mobile broadband to support a wide range of applications. These include video for situational awareness, as well as evidence gathering and information transmission to front-line officers.

At the same time there is still a recognised need for voice communications, specifically group voice, with groups from a few users to several hundred. This is especially vital to the police forces, which, during an incident or major event, need to control large numbers of officers, and need the immediacy of voice, since the officer dealing with an encounter does not want to remove eye contact to access a data device, to either send or read a message. In the case of fire and ambulance, these services already make use of more data, but can see the advantage of increasing this.

Public-safety users have a need for very fast call set-up (less than 1 second), which has meant that most of the current mobile networks, including GSM, have been classified as unsuitable for front-line policing, although they are used for non-critical communications and data.

The ownership model of the public-safety networks is not anticipated to change. Most networks were purchased by the government, and operation of the network is either by the government or a company set up specially to run the network. This allows the public-safety users to continue to use their narrowband networks for voice and interoperability, while looking in the short term to public networks for broadband data services. A good example of this is the planned ASTRID MVNO in Belgium.

ASTRID is the Belgium public-safety operator which has a TETRA narrowband national network. It is setting up an MVNO working through a roaming partner into all four mobile networks, using the multiple access into the radio networks to improve coverage and equipment availability, on the basis that if one network does not provide coverage, another probably will, and if one network has a site failure, the other networks will continue to operate. The MVNO is only for data, the existing TETRA PMR network will be used for voice and there will not be voice on the MVNO.[8]

This shows a way in which coverage, reliability and end-to-end security, while using commercial networks, can be enhanced, and may provide an acceptable solution as a bearer for ETCS. The weakness is that if a wide-area power outage occurred, all networks would be affected.

Certainly feedback from public-safety organisations is that there is little appetite in the current economic climate for the large procurements of dedicated public-safety networks which have taken place throughout Western Europe.

5.3.4 Utility sector trends

Utilities are seeing a need for more radiocommunications. Some of these are very time critical.

Smart metering is an application which is not critical, but is increasing, with virtually every home in Europe scheduled to have a smart meter. Security and encryption is important, to protect customer data, but if the communications network fails the meter can store readings and then send them later. Smart meter communications use a wide range of bearers, including signalling over the power line (power-line communications (PLC)), long range UHF radio, unlicensed mesh radio and GPRS.

Smart grid, on the other hand, is an application which is critical. The proliferation of many power generation sources, such as solar generation on houses and wind farms, connected to an electricity grid which was designed to feed power from a few large power stations to many users, is giving rise to a situation where there has to be a fine level of control with a fast response time, otherwise there is a significant risk of instability, which in turn can lead to large power outages. Latency times of between 5 and 10ms are required, and since control of the network must continue into a power cut or blackout, it is not realistic to depend on commercial networks as the only bearer, although they may be used with other bearers as back-up.

The majority of utility communications are data related, but utilities do have requirements for voice. These are for power control and are point to point, from one person at the control point to an individual in the field. In most cases, this can be carried on commercial networks, but there is a need to maintain communications in a power failure situation, using a combination of PMR and wired telephone at substation or satellite phone.

8 http://w w w .radioresourcemag.com/onlyonline.cfm?OnlyOnlineID=346

5.4 The trend towards software-defined radio

Software-defined radio (SDR) involves the use of software modules running on a generic hardware platform to implement radio functions, for example:

- modulation techniques
- wide-band or narrowband operation
- communications security functions
- protocols (waveforms)
- operating frequency range.

The primary value of SDR lies in its ability to emulate a range of radios and reconfigure between them quickly. Radios can be updated, upgraded and added through software downloads. SDRs can also be tuned to cover a range of frequencies, however, the wider this frequency is, the greater the cost will be. Similarly antennas working over a larger range will be more expensive and may experience performance problems.

5.4.1 Could software-defined radio be used for railway communications?

SDR could bring benefits to the railways, both economically and in terms of deployment. As each new wireless network standard is defined, new cab radios have to be procured, and there are migration issues due to some railways still using legacy technology. Different European countries have different link-layer and air-interface protocols, so one option would be to use multi-mode radios; however, this would be expensive and would require more space in the cab. Implementing radio functions as software modules instead would allow different standards to co-exist in the same equipment and the appropriate module to either be manually selected or implicitly selected by the network.

An SDR with discrete antennas and amplifiers that operate within the radio frequency (RF) bands controlled by the railroads would provide a generic radio platform on each train and also alleviate any problems associated with wide-band antennas. This could then be coupled with a communications package that would provide access via the SDR to the communications and train control networks covering the territories in which the train operates. The SDR would then reconfigure the radio to provide the optimal RF link, selecting the frequency and modulation scheme to match the local infrastructure. A minimum set of parameters, with room for expansion, must be supported by all participating railroads to ensure full interoperability.

For example, ZTE (reported to be the world's fifth largest telecoms manufacturer) has developed a new-generation distributed SDR base station (ZXG10 B8700). This solution is for its GSM-R integrated networks, can be applied in all environments, and is suitable for railways.

5.5 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 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.

This mirrors the trends in public safety, with increases in data, but retention of the voice service, in particular the group call voice facility. The public-safety networks are looking to implement data networks, in many cases from commercial operators, while retaining their narrowband networks for voice and critical data, until a full mission-critical voice and data mobile broadband solution is available. These hybrid networks will fill the gap until such a solution is available, which in the case of most users is expected to be after 2020. By that time the narrowband networks will need replacement, and with a full solution available, there will be no incentive to maintain two networks.

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 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 refarmed from earlier 2G and 3G services to support 4G. This is taking place in spectrum where the operator has a contiguous block of spectrum. 2G services will continue for many years, with a significant number of M2M services, and new platforms for M2M being introduced, but are expected to reduce from 2020 onwards.

There is a trend to increase coverage of commercial networks, but licence requirements are still based on population percentage coverage, rather than geographic coverage. Any requirements for radio or switch site battery autonomy or improved resilience is the responsibility of the operator, who will need to justify the expense with a business case.

6 Analysis of possible future scenarios for railways

6.1 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.

6.2 Requirements for railway communications

The requirements are considered in terms of key strategic objectives and the primary operational requirements identified during the study. These are shown in Figure 6.1 and described below.

Strategic objectives	• Interoperability
	• Service continuity
	• Flexibility
	• Economic efficiency
Operational requirements	• Communications to/from dispatcher
	• ETCS support
	• Railway Emergency Call

Figure 6.1: Key strategic objectives and operational requirements identified in the study [Source: Analysys Mason, 2014]

6.2.1 Strategic objectives

Four high-level strategic objectives influencing the study have been identified: interoperability, service continuity, flexibility, and economic efficiency. These were derived from the study brief and subsequent discussions with ERA. They are addressed in more detail in the following sections.

Interoperability

The highest level strategic objective and the motivator for defining railway communications standards at a European level is interoperability, which is a necessary ingredient for achieving an integrated rail network.[9]

Interoperability is expected to be achieved on railway lines covered by the EU directives,[10] increasing over time to cover all European railways.

9 The trans-European rail network is a component of the Trans-European Transport Network ('TEN-T'), originally defined in 1996 by European Parliament decision no. 1692/96/EC.

10 EU Directive 2008/57/EC establishes requirements for railway interoperability within the European Economic Area, drawing on the earlier separate directives 96/48/EC (high-speed rail) and 2001/16/EC (conventional rail).

Service continuity

GSM-R has been rolled out progressively across Europe over the past decade and the GSM-R Industry Group[11] has committed to support the technology until at least 2025. If a successor technology is to be introduced there will inevitably be a lengthy transition period with the new technology operating in parallel with GSM-R.

Maintaining current service continuity with minimal disruption while successor solutions operate in parallel with GSM-R is a key consideration for any future communications strategy – both to minimise the service impact of transition and to avoid discouraging current investments in GSM-R.

Flexibility

Where specific standards are applied this can have the positive impact of facilitating interoperability as well as encouraging a competitive market through a choice of suppliers offering compatible equipment. However, imposing standards also limits flexibility, which may limit the ability to tailor solutions to suit local circumstances, to adapt as requirements change over time, or to adopt competing standards that may emerge offering better performance or value for money.

A key strategic objective, therefore, is to retain flexibility where possible while recognising that defining a minimum set of essential requirements will be necessary to achieve interoperability and service continuity.

Economic efficiency

A key strategic objective is that it should be possible to obtain future solutions cost effectively. A current concern highlighted is that the cost of the communications technology has been a barrier to rapid roll out of GSM-R and this has not been given appropriate focus in the past.

Other candidate objectives

Additional potential objectives that were considered but determined *not* to be strategic objectives for the study include the following.

- *Communications support for other services* – the focus of the study is the operational requirement currently fulfilled by GSM-R (see Section 6.2.2). There may be synergy between operational communications solutions and the provision of communications for other services (e.g. equipment status monitoring, passenger information, entertainment services), but there is no strategic objective of identifying a harmonised approach to communications for these applications.

[11] An industry body promoting GSM-R technology: http://w w w .gsm-rail.com/

- *Safety* – while there is a general objective to standardise rail safety requirements across Europe, the operational communications system is *not* considered to be a safety-critical system. The safety protection is contained within the railway signalling application (ETCS) which is designed to 'fail safe' in the event of a communications failure.
- *Quality of service* – the quality of the communications service (and its impact on the quality of the railway service) is not addressed directly by ERA. This depends on the operation and use of the infrastructure and remains a local matter, provided that interoperability requirements are met.

6.2.2 Operational requirements

The operational requirements for railway communications are being considered in detail in a parallel study (see Section 2). The principal operational requirements as currently understood are summarised here. Three core requirements were identified by the majority of stakeholders consulted during the study and are as follows.

Communications to/from dispatcher

This covers provision of mobile communications between train driver and dispatcher/signal controller. This 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.

ETCS support

Communications for the ETCS signalling between train and trackside equipment must be supported.

Railway Emergency Call

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

Other requirements identified but typically not noted as key requirements when consulting stakeholders included:

- 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.

6.3 Hypotheses regarding future railway communications

Before considering different scenarios for future communications, a number of hypotheses have been proposed to consider where changes to the current environment are likely, and may influence options for the future. These consider the period relevant to the study (i.e. the next 15+ years) and are listed in Figure 6.2 and described below.

- **Organisational model** – *will not change*
- **Voice requirements** – *may change*
- **ETCS** – *will operate on IP*
- **Signalling reqs** – *will not change*
- **Communications** – *will change*
- **Other applications** – *will change*
- **Radio spectrum** – *will be scarce*

Figure 6.2: Hypotheses influencing the future environment (next 15+ years) for railway communications [Source: Analysys Mason, 2014]

Organisational model – will not change

The organisation model of railways in Europe will not change substantially (but is already flexible and varied, with different approaches adopted in different member states).

Regulation for all member states will come from the EU, but overall responsibility will continue to be held at a national level.

The model will continue to allow for separation between IMs, RUs, and rolling stock companies, with further separations possible (e.g. separate management of stations, separate provision of telecoms infrastructure).

Voice requirements – may change

Voice requirements may change over time – this is currently being considered in a parallel ERA study.

Some stakeholders have indicated some interest in making use of voice communications facilities to the train which are rarely used today, e.g. for communications with train crew and/or passenger announcements independently of the communications between driver and controller.

Some of the 'special' voice functions of GSM-R, such as the REC, may cease to be critical voice requirements if alternative solutions are available (e.g. if the emergency call and halt to train movement is handled through data/signalling).

ETCS – will operate on IP

ETCS (which currently uses GSM circuit-switched data) is being evolved to allow operation over IP packet networks. (Work to achieve ETCS operation over GSM-R GPRS is already underway.)

Signalling requirements – will not change

Signalling requirements and the application (ETCS) will not change substantially over the period.

Communications – will change

The communications market and technologies in use will continue to change rapidly, e.g. major change/evolution in networks, services and devices will continue over 3–5-year cycles.

Other applications – will change

Demand for more data applications (not necessarily on GSM-R or successor platforms) will increase, e.g. more support services such as condition monitoring, more passenger services, including some data-hungry services such as on-train CCTV.

Radio spectrum – will be scarce

Radio spectrum in key bands for mobile use will continue to be in high demand, becoming increasingly scarce and costly to acquire.

6.4 Key considerations for future railway communications

A series of key considerations influencing options for future communications are shown in Figure 6.3 and discussed in the following sections.

- Requirements
- Separation of application and bearer
- Extent of prescription (technology and other)
- Spectrum
- Criticality
- Segregating non-critical traffic
- Ownership models
- Deployment, migration & ease of evolution
- Cost

Figure 6.3: Key considerations influencing the choice of future communications [Source: Analysys Mason, 2014]

Requirements

The operational requirements clearly influence the potential solutions available, but some requirements have more impact than others and specific individual requirements can have a major impact on potential options. Any individual requirements that appear to rule out options or require significant change to existing solutions should be carefully examined and challenged to ensure that they are balanced against the cost impact.

A number of stakeholders consulted highlighted a desire to avoid a railway-specific variation to a mainstream technology.

Separation of application and bearer

Elements of the rail application are currently incorporated into the GSM-R bearer technology (e.g. specialist voice functions such as REC and the reliance on GSM circuit-switched data for current ETCS).

For future solutions, these should be separated from the bearer technology to create a clean architectural separation and to allow ‘bearer independence’, providing flexibility in the choice communications bearer used in future.

Many stakeholders consulted during the study proposed or supported this approach.

Extent of prescription (technology and other)

There is scope to debate the appropriate extent of technology prescription to be adopted at a European level (e.g. ‘light touch’ or ‘heavy prescription’). A more prescriptive approach will tend to lead to more commonality and simpler interoperability, but it also limits flexibility and choice which can result in higher costs and hinder developments that might otherwise occur.

A heavily prescriptive approach might prevent the use of multiple bearer technologies and will also limit the ease with which the bearer technology can change over time as the market evolves.

Where specific technologies are prescribed, the choice of technology will have a major impact on the market and all stakeholders.

Spectrum

The policy adopted for radio spectrum is inter-linked with the approach to technology prescription discussed above. A highly prescriptive technical approach suggests the use of common spectrum in a band identified and mandated for the purpose, while a less prescriptive technical approach might allow a less prescriptive approach to spectrum.

However, a less prescriptive approach to spectrum may undermine/complicate interoperability if different bands are in use in different areas, although mass-market mobile devices now routinely operate in multiple bands and having to use multiple bands is likely to become increasingly less problematic for devices over time.

The policy adopted for spectrum also affects shared network options, e.g. the current separation of public-safety and rail spectrum presents a barrier which discourages the use of common mobile networks for both user communities.

Criticality

As discussed in Section 6.2.1, the communications bearer is not a safety-critical system in its own right. However, there are varying attitudes to how critical the bearer solution is and, if ETCS is used, the communications bearer needs to provide sufficient coverage and availability to avoid any coverage hole or loss of service from disrupting the train services. The standards set for criticality can have a major impact on the solution, affecting the design and costs if unusually high levels of redundancy, overlapping coverage, etc. are required.

Segregating non-critical traffic

Critical operational traffic and non-critical traffic are currently segregated, with critical traffic carried on GSM-R and alternative systems used for other communications, and there is some benefit to having a clear separation between the two. (Different standards and expectations apply to critical and non-critical applications which are often more easily managed when the platforms are segregated. Also, changes affecting the critical platform can be minimised if non-critical applications are kept separate, reducing the risk of disruption to critical services arising from changes.)

However, if (as expected) demand for additional non-critical applications increases, there will be an economic case for allowing a common platform to carry both critical and non-critical traffic (avoiding the cost of needing two separate networks covering the railway), and this should be allowed provided that the quality of service for the critical traffic is appropriately protected.

Ownership models

A variety of network ownership models is possible for the communications infrastructure and equipment including full ownership by the IM, shared ownership (e.g. with other transport bodies or other agencies), a fully outsourced model, or various combinations (e.g. using public networks for back-up). Most stakeholders consulted did not have strong views on ownership and were comfortable with any of the possible models, provided that the operational requirements are met.

The appropriate ownership model follows to some extent from other decisions, e.g. provision of dedicated radio spectrum for railway use and mandating a bespoke technology will tend to point towards 'private' solutions, whereas adopting a commercial technology and/or not prescribing bands will tend to point towards more outsourced solutions.

Deployment, migration and ease of evolution

Migration from GSM-R to a new platform (and to other future platforms as technology evolves) is a major consideration given the scale and timescales required for implementing/upgrading infrastructure and train-borne equipment across Europe.

The approach taken to technology prescription and ownership models had some impact, e.g. options using common standards and potentially sharing networks with others may ease migration.

Cost of future solutions

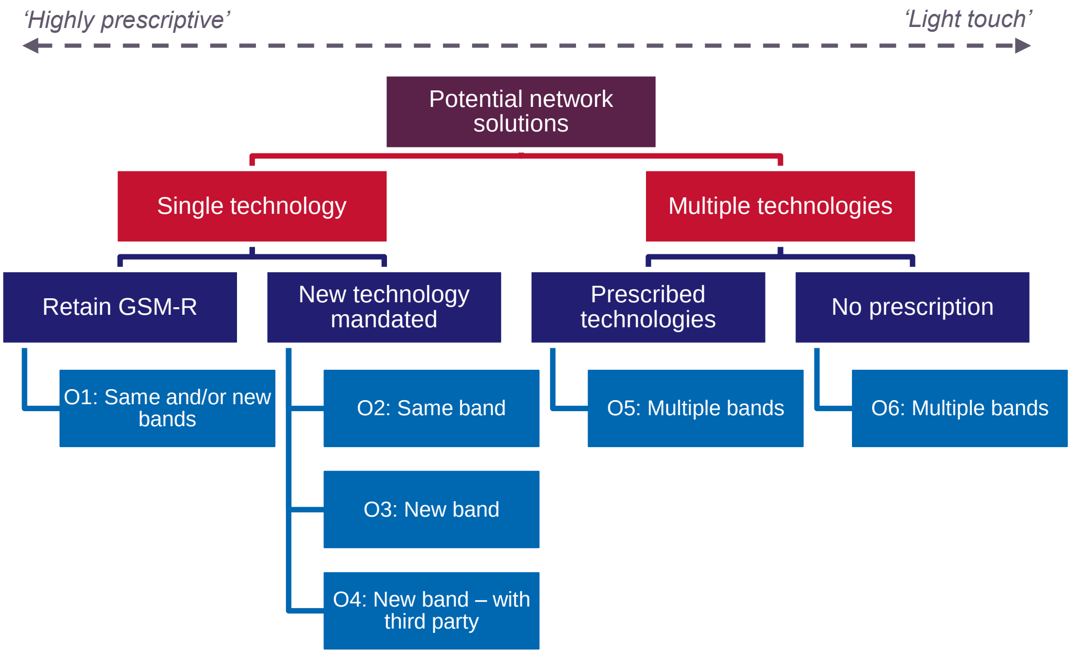
Cost will inevitably be a key factor influencing preferred approaches and the rate and extent of adoption of future communications solutions. While it is not realistic to try to estimate likely costs of alternative platforms and technologies that will be in the market a decade from now, it is reasonable to make some assumptions relating to cost, e.g. models involving shared infrastructure will typically cost less than dedicated networks as the infrastructure costs are partly financed by other sharers.

6.5 Options for future railway communications

6.5.1 Options tree

For IMs, options for the future relate to the technology adopted and method of implementation. However, for ERA, the options available relate to the policy to be recommended for adoption for Europe and the extent and nature of the regulations that are to be prescribed. The future options that have been identified for the European approach (options O1–O6) are shown in the tree illustration in Figure 6.4.

Figure 6.4: Future options tree for the network solution approach [Source: Analysys Mason, 2014]



The far left of the figure represents a highly prescriptive approach (i.e. the use of GSM-R in specified bands) while the far right represents a loose approach with multiple technologies in multiple bands permitted. The broad implications of a highly prescriptive approach compared with a 'light-touch' approach are summarised in Figure 6.5 below.

Highly prescriptive	Low prescription/high flexibility
Technology bespoke to rail requirements	Less bespoke; more difficult to get a harmonised match against the rail requirements
Good interoperability	Interoperability more complex
Low flexibility – users bound by the rules prescribed	High flexibility – more scope for users to vary their approach to suit local priorities
Niche market/products, limited choice	Wider market, more choice (products and suppliers)
Slow development	Faster development
High costs	Lower costs

Figure 6.5: Level of prescription and implications [Source: Analysys Mason, 2014]

The options shown on the tree in Figure 6.4 are described in Figure 6.6.

Figure 6.6: Descriptions of future options [Source: Analysys Mason, 2014]

Option	Description
O1: Retain GSM-R	For this option, GSM-R continues to be specified for use in its existing frequency band. GPRS can be deployed in the GSM-R band, but no new technology or frequency is adopted.
O2: New technology – same band	For this option, a single new technology is specified, but no new frequency band is made available for rail specific use. The rail sector will have to remain on the existing spectrum, either migrating using existing spectrum, or possibly using temporary spectrum.
O3: New technology – new band	For this option, a single new technology is specified and a new frequency band is obtained for rail-specific use. The rail sector will migrate to the new band as the new technology is adopted.
O4: New technology – sharing with third party	For this option, a new technology is specified and the rail sector shares the network and spectrum with another organisation that has similar requirements for specialist mobile communications. This is most likely to be the public-safety sector.
O5: Multiple prescribed technologies	For this option, a number of technologies are prescribed and any combination of the prescribed technologies can be adopted. This may include GSM-R as well as newer network technologies such as LTE and 5G technologies as they emerge. The number of technologies adopted can be limited to avoid too many variations emerging, but additional technologies may be adopted for inclusion if justified over time (e.g. a limited set of 'authorised' technologies can be established and then amended over time through a controlled process). As this option allows different technologies to be adopted on different railways, additional provisions to deal with interoperability will be needed.
O6: Multiple technologies/ bearers (non-prescriptive)	For this option, there is no prescription and (in theory) any technology can be adopted to suit local priorities on a country or localised basis.

6.6 Implementation examples/scenarios for future railway communications

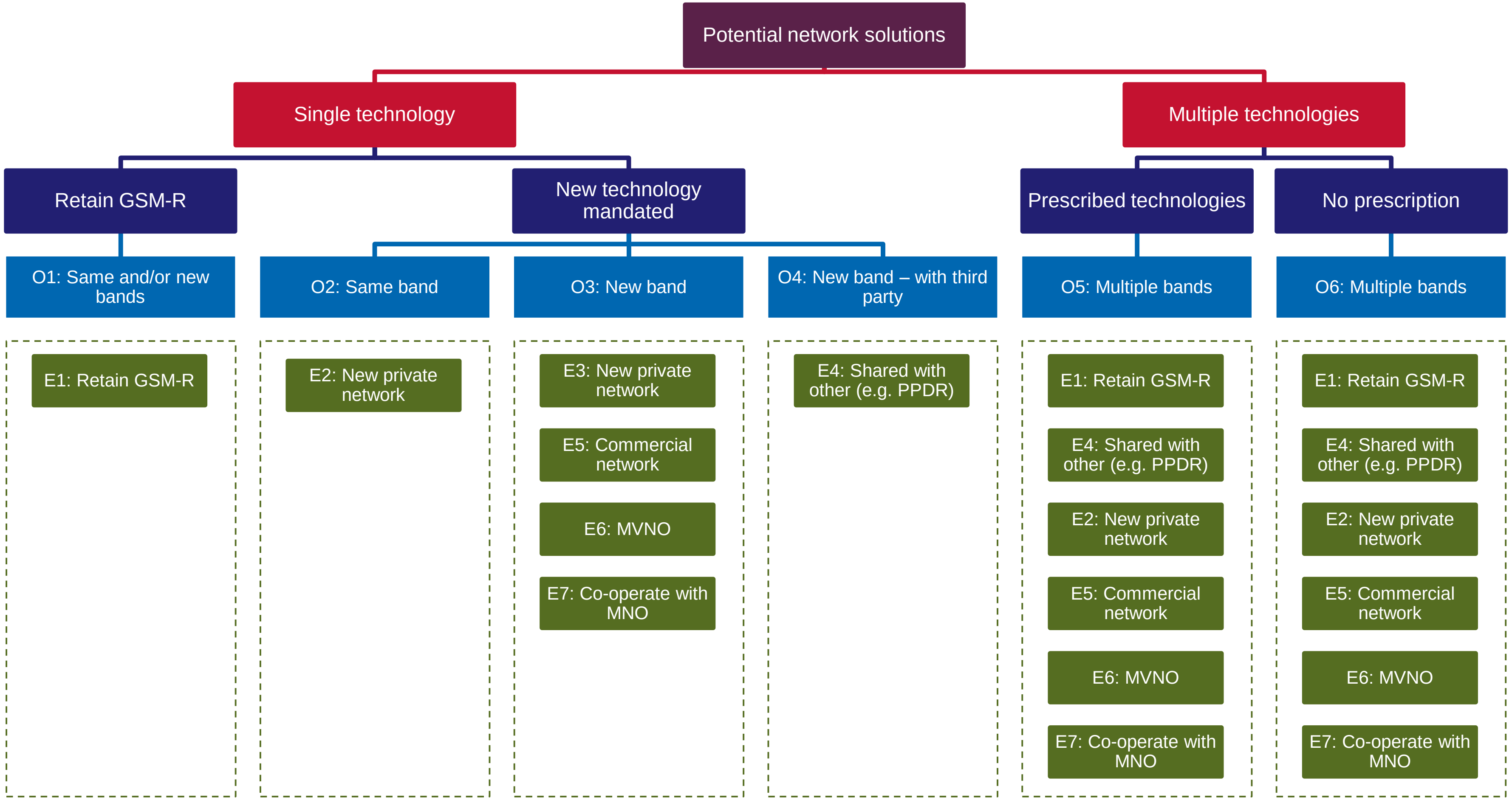
Depending on the policy option adopted (O1–O6 in Figure 6.6), different solutions can be implemented to replace the current use of GSM-R. A series of example implementation scenarios has been identified and is laid out in Figure 6.7. Some of these scenarios could apply to multiple options within the tree, e.g. a new technology in a new band (O3) might be delivered using a commercial network or a private network, depending on the detail of the technology and bands adopted. Figure 6.8 shows the options tree with the example scenarios applicable to each option.

Note that where an option shows multiple scenarios, it is possible for combinations of multiple scenarios to be adopted across different countries or regions.

Figure 6.7: Descriptions of example scenarios [Source: Analysys Mason, 2014]

Example scenario	Description
E1: Continue with GSM-R and retain frequency band	In this scenario the rail sector continues to operate GSM-R in its existing band, with deployment of GPRS in the GSM-R band, but no new technology or frequency is adopted.
E2: New private network technology mandated in existing band	In this scenario a new technology will be specified but no new frequency band will be available for rail specific use. The rail sector will have to remain on the existing spectrum, either migrating using existing spectrum, or possibly using temporary spectrum.
E3: New private network technology and new frequency band mandated	In this scenario a new technology will be specified and a new frequency band will also be obtained for rail specific use.
E4: Shared network with similar organisation.	In this scenario the rail sector shares spectrum and network with another organisation, that has a similar view regarding resilience and availability. This is most likely to be public safety. The rail sector may assist in increasing coverage for the railway, but will share the switch elements.
E5: Commercial network service	In this scenario the rail sector takes service from a single commercial operator, to an agreed service level.
E6: Commercial network service: MVNO	In this scenario the rail sector establishes or takes service from a mobile virtual network operator (MVNO), to an agreed service level. The MVNO may arrange service with two (or more) commercial operators as a means of increasing coverage and resilience. Special technical and commercial provisions may also be required to give appropriate priority to railway traffic.
E7: Railway works with commercial operator	In this scenario the rail sector negotiates/co-operates with a commercial operator for the deployment of a network suited to the railway application. If the rail sector has dedicated spectrum available, this may be used as part of the agreement. This may be a dedicated solution or a shared solution where the commercial operator is allowed to sell excess capacity to commercial customers.

Figure 6.8: Future options tree with applicable example scenarios shown [Source: Analysys Mason, 2014]



Scenario SWOT analysis of rail communications changes

The different example scenarios have been analysed in terms of their strengths, weaknesses, opportunities and threats (SWOT). The SWOT analysis is defined in the following way:

- strengths – characteristics which give the scenario an advantage over others
- weaknesses – characteristics which give the scenario a disadvantage over others
- opportunities – characteristics which could be exploited
- threats – characteristics which may create a disadvantage, if they happen.

The results of the SWOT analysis are shown in Figure 6.9 through to Figure 6.12.

Strengths

Figure 6.9: SWOT analysis – strengths [Source: Analysys Mason, 2014]

Example scenario	Strengths
E1: Continue with GSM-R and retain frequency band	• Functionality proven and no need for high data rates in railway communications • Spectrum available • Narrowband solutions allow increased flexibility in network planning • GSM-R infrastructure built or planned across Europe already • Interoperability straightforward
E2: New private network technology mandated in existing band	• Better support for IP data • Can encourage separation of bearer and application • Existing frequency band (<1GHz) good for long-range communications • May not need more sites (spectrum characteristics already understood)
E3: New private network technology and new frequency band mandated	• Better support for IP data • Can encourage separation of bearer and application
E4: Shared network with similar organisation	• Better support for IP data if the network is IP based • Can encourage separation of bearer and application • Shared cost of infrastructure switch element • May require less spectrum than two separate networks • Both parties will save money relative to independent networks
E5: Commercial network service	• Better support for IP data • Can encourage separation of bearer and application • Network services evolve with commercial network • Overall cost lower (lower capital cost and maintenance)
E6: Commercial network service (MVNO)	• Better support for IP data • Can encourage separation of bearer and application • Network services evolve with commercial network • Improvements in availability and resilience, by virtue of using multiple networks • Control over the users (SIM cards)
E7: Railway works with commercial operator	• Better support for IP data • Can encourage separation of bearer and application • Can specify requirements to operator – solution tailored to railway requirement • If own spectrum held, this provides negotiating power

Weaknesses

Figure 6.10: SWOT analysis – weaknesses [Source: Analysys Mason, 2014]

Example scenario	Weaknesses
E1: Continue with GSM-R and retain frequency band	• Obsolescence/GSM platforms may not receive investment • Tight coupling of bearer and application retained • As MNOs roll out broadband technologies, interference issues may increase • Limited supplier market leads to high costs • Have to build own network • Inflexible – future migration difficult
E2: New private network technology mandated in existing band	• Specialist GSM-R functions may result in proprietary technology (modifications to standards) • Limited supplier market leads to high costs • Have to build own network – new infrastructure and terminals • New technologies tend to work on 5MHz blocks (GSM-R is 4MHz) – may only use part of band, lowering data rate • New technology yet to be identified • Will require solution (e.g. dual-mode operation) during migration – difficult to accommodate in existing band • Inflexible – may be further migration issues in future
E3: New private network technology and new frequency band mandated	• Specialist GSM-R functions may result in proprietary technology • Limited supplier market leads to high costs • Have to build own network – new infrastructure and terminals • New frequency likely to be higher, with a need for more sites • New technology yet to be identified • Will require solution (e.g. dual-mode of operation) during complete migration due to use of separate bands • Inflexible – may be further migration issues in future
E4: Shared network with similar organisation	• Specialist GSM-R functions may result in proprietary technology • Limited supplier market (but larger than E3/E4) leads to medium costs • Have to build network (with third party) – new infrastructure and terminals • Bringing organisations and spectrum together is complex • Have to agree network access priorities • Third-party requirements may impose additional constraints • Likely sharing organisations do not have the same pan European coordination directives as the railways; fragmentation at member state level is more likely
E5: Commercial network service	• New terminals required in commercial bands • Devices are more complex • May have to use commercial voice services rather than rail-specific voice services • No control on coverage or availability, except by SLA – inflexible and subject to market interests • Charging model likely to change – e.g. revenue costs for calls and data

Example scenario	Weaknesses
E6: Commercial network service (MVNO)	• New terminals required • Devices are more complex • May have to use commercial voice services rather than rail-specific voice services • No control on coverage or availability, except by SLA – inflexible • Overhead in creating the MVNO
E7: Railway works with commercial operator	• New terminals required • Locked in with the chosen commercial operator

Opportunities

Figure 6.11: SWOT analysis – opportunities [Source: Analysys Mason, 2014]

Example scenario	Opportunities
E1: Continue with GSM-R and retain frequency band	• GPRS and IP can be used for signalling in future • Other non-European vendors may be encouraged to enter the market • Achieve interoperability across Europe
E2: New private network technology mandated in existing band	• New technology likely to be broadband, providing further capacity and reduced latency • Could use E-GSM-R for migration, where available, or to provide a 5MHz band for new technology • May get more suppliers, increasing competition • More flexible solutions possible (e.g. making use of increased bandwidth)
E3: New private network technology and new frequency band mandated	• New technology likely to be broadband, providing further capacity and reduced latency • Could use E-GSM-R for migration or to provide a 5MHz band for new technology, where available • May get more suppliers, increasing competition • More flexible solutions possible (e.g. making use of increased bandwidth) • New spectrum may be cleaner and suffer less interference
E4: Shared network with similar organisation	• New technology likely to provide further capacity and reduced latency • May get more suppliers, increasing competition – particularly given a larger customer base from combining with a third party • More flexible solutions possible (e.g., making use of increased bandwidth) • May be able to share some of the base station kit • Could also have additional sites covering rail, increasing capacity and ensuring efficient use of spectrum for a single-frequency network • May be an advantage for interoperability if the sharer also needs to operate on the railway, or for a rail incident
E5: Commercial network service	• New service likely to be broadband, providing further capacity and reduced latency • Mass-market technology increases competition/reduces costs • Can 'future proof' the communications element • Will force separation of application and bearer • International roaming could be easier

Example scenario	Opportunities
E6: Commercial network service (MVNO)	• New service likely to be broadband, providing further capacity and reduced latency • Mass-market technology increases competition/reduces costs • Can 'future proof' the communications element • Will force separation of application and bearer • International roaming could be easier • MVNO 'insulates' railways from MNO disruption and changes, since there is an alternative bearer
E7: Railway works with commercial operator	• New service likely to be broadband, providing further capacity and reduced latency • Mass-market technology increases competition/reduces costs • Can 'future proof' the communications element • Commercial operator can build the network faster and at less cost • Opportunity for sharing the spectrum with the commercial operator, so it can use it in places not needed by rail

Threats

Figure 6.12: SWOT analysis – threats [Source: Analysys Mason, 2014]

Example scenario	Threats
E1: Continue with GSM-R and retain frequency band	• Existing players may see it as too niche, and withdraw • Costs may increase, while telecoms costs are generally reducing
E2: New private network technology mandated in existing band	• Suppliers may not develop radios in the GSM-R band • Technology selected may end up being a dead end • Cost and interoperability issues during migration – particularly challenging if existing band used • Rail-specific features may cease to be supported. • Possible interference issues with neighbouring bands • Work required in standards bodies to add GSM-R band to standards
E3: New private network technology and new frequency band mandated	• Suppliers may not develop radios in the new band • Technology selected may end up being a dead end • Cost and interoperability issues during migration • Rail-specific features may cease to be supported. • New frequency needs to be in 3GPP band plans for a standard technology or work will be required in standard bodies to add the new band to standards • New frequency band may need to be added by 3GPP
E4: Shared network with similar organisation	• Technology selected may end up being a dead end • Cost and interoperability issues during migration • Rail-specific features may cease to be supported. • Sharers may want their communications to evolve at different rates, putting pressure on each party • Railway community may be forced to adopt a non-optimal solution from other parties • Voice may have to become another application – will it be standardised?

Example scenario	Threats
E5: Commercial network service	• Suppliers may not make environmentally suitable rail-dedicated equipment • Commercial networks can change configuration or service levels, which may have a big impact on the service for railways • Little recourse if the commercial operator stops service, due to a fault or external action
E6: Commercial network service (MVNO)	• Suppliers may not make environmentally suitable rail-dedicated equipment • MVNO supplier has to be carefully chosen and may have difficulty working with the commercial MNOs • MVNO approach will suit some member states better than others, due to national variations (e.g. multiple RAN versus shared RAN available in the country – where there is consolidation of RANs this will reduce the effectiveness of the MVNO approach)
E7: Railway works with commercial operator	• Suppliers may not make environmentally suitable rail-dedicated equipment • Competing priorities from other commercial network customers may affect the service for rail • Returns for commercial operators may not be realised, and they may withdraw

Summary of example scenario SWOT analysis

On the surface E1, the continuation of GSM-R has many strengths and provides a known interoperable pan-European platform. However, it does not provide a future upgrade path, and it is accepted that it has a finite life, and there is no clear evolution route.

E2 assumes a new technology is deployed as a private system in the existing band. There is an advantage in having existing spectrum below 1GHz, but this is not a good match with any of the likely new technologies (based on the current market), and there is a risk of proprietary solutions emerging with special GSM-R functions and a limited supplier base. Migration within the existing band would also be challenging.

E3 is equivalent to E2, but with a move to a new spectrum band. Apart from the migration being easier, the weaknesses are very similar to E2, and the dependency on the availability of a new spectrum band is a distinct threat.

In E4, the rail sector shares spectrum with a similar like-minded organisation, which is likely to be one or more organisations that carries mission-critical traffic and has similar requirements for system performance. Public-safety organisations are the most likely candidates, and in one country discussions have taken place already. However, to set up such arrangements will be complex, and since these organisations operate on a national basis, a pan-European solution would be almost impossible to achieve. If public safety is allocated spectrum during WRC15 (see Section 4.6) there may be pressure on the rail sector to share.

E5 assumes service is taken solely from commercial networks, using their spectrum. While this is a low-cost scenario and will allow for evolution of services as the networks develop, there is little control of coverage and service availability. This arrangement is used in some countries already as a fall-back option. It may be more applicable in a smaller country where there is already very good coverage of the rail network, or where an operator is prepared to work with the rail organisation to enhance the coverage and availability of the network along the rail corridors, perhaps with funding from the rail operator – as in scenario E7.

E6, which is a variation of E5, provides additional resilience and coverage compared with E5, and can provide more control of the end-to-end communications. The effectiveness of the MVNO is enhanced if there are several national networks with complementary coverage. Increasingly commercial operators are sharing RANs, and this erodes some of the benefit of the MVNO approach.

E7 is a variation of E5, but assumes the rail organisation works with the operator, to ensure coverage is suitable, and may finance additional sites or resilience. Costs will therefore be higher, but the service can be tailored to meet rail requirements.

Based on the SWOT analysis, two infrastructure-related items (the cost of providing telecoms and the risk that the service may not be available in 2022), and two cab-radio-related items (the cost of a cab radio and the risk that a suitable product may not be available) have been compared across the seven example scenarios. The scores are 'low', 'medium' or 'high', and are subjective.

Figure 6.13: Infrastructure and cab radio impact [Source: Analysys Mason, 2014]

	Telecoms service fee (cost)	Risk of telecom service not being available	Cab radio costs (2022–2030)	Risk of unavailability of cab radios
E1	High	Low	High (obsolescence)	Medium
E2	High	Low	High	High
E3	High	High (spectrum availability)	Unknown (band not known)	High
E4	Low/medium	Low	Medium	Low
E5	Low/medium	Medium	Low	Medium
E6	Medium (MVNO attracts additional costs)	Medium	Low	Medium
E7	Medium (rail operator pays for enhancements)	Medium	Low	Medium

Cost factors in implementing new technologies in rail communications

Given the pace of change in the telecoms market, it is not realistic to try to estimate the likely costs of alternative platforms and technologies that will be in the market a decade from now. However, the following broad attributes of the approach adopted will influence the overall cost to users.

- *Niche/mainstream technology* – although based on GSM standards, GSM-R has split from the mainstream technology and is a niche product used only for railway applications. GSM-R therefore has a limited market and supplier base, resulting in increased costs compared with the mass-market GSM products. If future railway communications solutions are based on mainstream technologies (e.g. standard mobile technologies offering IP data), there will be better scope for lower-cost solutions compared with adopting a heavily customised 'railway-specific' version.

- *Dedicated/shared network* – where the railway application shares network infrastructure with others, this will typically offer a lower-cost solution as many of the costs can be spread across other stakeholders. For example, a dedicated public-safety radio network will typically be designed to have a level of coverage across much of the railway infrastructure, and so much of the cost of the network to provide railway coverage could be shared if a joint rail and public-safety network were adopted. Similarly, public network operators require coverage for passengers on railways and are motivated to continue to improve railway coverage over time, and so solutions using public networks will enable part of the infrastructure costs to be shared, in effect.

- *Extent of prescription (i.e. alternative approaches allowed)* – without knowing in detail what future solutions the market will offer, a less prescriptive approach (allowing a variety of technologies to be used) will give users fuller access to that market which tends to enable lower-cost solutions to be implemented and allows more flexibility for the best solution to be chosen to suit local circumstances. There is a potential counter-argument if specific development is required for the railway application and this has to be repeated multiple times (to cater for multiple bearers). However, if the application and bearer are effectively separated (see Section 6.4), then a range of bearer solutions should be possible, providing better opportunity for lower-cost solutions to be found.

6.7 Comparison of policy options

With the exception of example scenario E3 (which relies on the identification of new spectrum for railways), all of the example scenarios in Figure 6.9 are theoretically viable approaches to providing operational railway communications. Where there is reliance on third parties (e.g. E4 – sharing with a third party such as public safety, or E5–E7 – involving commercial operators) there is some risk that these approaches will not deliver the desired outcome, depending on the perspectives and actions of those third parties (which will vary on a local basis). However, in environments where the railways and third parties are well aligned, these scenarios may offer the most compelling business case for providing operational communications for railways, as well as offering synergies with other communications requirements.

Given that there are multiple solutions that could provide operational communications, that the options available will change over time, and that the 'best' solution is often dependent on local factors, a policy allowing for more than one solution to be adopted might be preferred. However, moving away from the single GSM-R approach to a mixed environment complicates interoperability, and so the merits of introducing more flexibility need to be traded against the impact on interoperability.

For each of the policy options identified in Figure 6.4, an assessment against the high-level strategic objectives and operational requirements has been carried out. Each option has been ranked 'good', 'fair' or 'poor' and has been colour coded depending on how well the option matches the objective or requirement.

The basis of the rankings given is as follows.

- *Interoperability* – options using a single platform are ranked 'good', as achieving interoperability will be relatively straightforward. For options involving a change of platform, maintaining interoperability will be a challenge during the transition period (likely to be many years) which will require dual running and/or workarounds, and so these options are ranked 'fair'. For options involving multiple technologies, maintaining interoperability will be more complex and will require management and technical solutions (e.g. terminals supporting multiple bearers) on an ongoing basis, and so these options are ranked 'poor' from an interoperability perspective.
- *Service continuity* – the assessment of service continuity takes account of whether there is a change of platform (likely to result in a level of disruption during the transition) as well as whether there is a risk of difficulty in maintaining support for the platform over time. All options involve some change or (in the case of GSM-R) are exposed to a risk of support problems as the technology becomes obsolete and so have been ranked 'fair'.
- *Flexibility* – where options involve a single technology platform there is little scope for approaches to be adjusted to suit local requirements/priorities or to offer different approaches over time, and so these options have been ranked 'poor' for flexibility. Where multiple technologies are allowed, there is scope for different technology choices (and accompanying delivery models) to be adopted to suit specific requirements, e.g. for particular regions or types of route, or to introduce new capabilities over time, and so these options have been ranked 'good' for flexibility.
- *Economic effectiveness* – the assessment of economic effectiveness takes account of the likely strength of the competitive market for provision of the communications platform and any efficiency benefits relating to the option. Options relying on a single platform are likely to result in higher costs overall due to the limited market choice, particularly if the platform requires niche products for the relatively small railway market (as with GSM-R), and so these options have been ranked 'poor'. Where a single platform is adopted, but is shared with a third party, there are efficiency benefits which should result in reduced costs, and so the option has been ranked 'fair'. Where multiple technologies are allowed, users are presented with a broader market and the opportunity for the most cost-effective communications technologies to be adopted by the railways as they emerge over time, and so these options have been ranked 'good'.

- *Requirements* – a consideration of the likely fit against the railway requirements is given. For most options, specific technologies are not yet defined, but will be chosen (at the appropriate time) for their suitability for the application. Based on the requirements as currently understood (see Section 6.2.2), it is reasonable to assume that a good fit can be found from the market and so all options have been ranked 'good'.

The result of the assessment described above is given in Figure 6.14.

Figure 6.14: Options fit against high-level strategic objectives and operational requirements [Source: Analysys Mason, 2014]

	Strategic objectives		Operational requirements
O1 Retain GSM-R	Interoperability	*Good – single platform*	Good fit for current requirements; introduction of GPRS will alleviate capacity limitations
	Service continuity	*Fair – platform support reduced over time*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – dedicated platform with high costs*	
O2 New technology – same band	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – single platform, limited market*	
O3 New technology – new band	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Poor – single platform, limited market*	
O4 New technology – with third party	Interoperability	*Fair – single platform but change disruptive*	Dependent on the new technology chosen, but assumes a good fit can be found
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Poor – limited scope for variation*	
	Economic effectiveness	*Fair – sharing efficiency benefits*	
O5 Multiple prescribed technologies	Interoperability	*Fair – controlled use of multiple platforms*	Dependent on the technologies chosen, but allows optimum solution to be adopted for local requirements
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Good – allows variation*	
	Economic effectiveness	*Good – allows for most economic solution*	
O6 Multiple technologies – no prescription	Interoperability	*Poor – multiple platforms*	Dependent on the technologies chosen, but allows optimum solution to be adopted for local requirements
	Service continuity	*Fair – transition challenge*	
	Flexibility	*Good – allows variation*	
	Economic effectiveness	*Good – allows for most economic solution*	

It should be noted at this stage there is no single option which is rated as a 'good' fit against all of the strategic objectives; there are advantages and disadvantages particular to specific options, and at a detailed level, these are likely to change as the communications market and technology develop over time, and as the rail requirements and implications are evaluated in further detail. At this time, option O5 (‘Multiple prescribed technologies’) is the only option which does not have a ‘poor’ match against any strategic objective. A consideration with this option is that although multiple technologies may be prescribed, evolution to future technologies must be included in the prescription.

From the summary in Figure 6.14, option O1 (‘Retain GSM-R’) meets current requirements and provides the strongest option for interoperability as it employs a single common technology. As this option involves no transition, maintaining service continuity is straightforward over the short-to-medium term, but there is a risk of support problems presenting a challenge for continuity in the longer term as the technology becomes obsolete. The option also offers little or no flexibility to adapt to changing requirements or to local circumstances where priorities differ. Economic effectiveness is poor as it relies on the relatively high-cost specialist products produced for the niche market.

All options other than option O1 present challenges for achieving service continuity as they require some form of transition, which is likely to last for many years before a ‘new norm’ is established across Europe.

Options O2–O4 all assume a single technology is adopted which is attractive from an interoperability perspective. However, the change of platform complicates maintaining interoperability during the transition period. Options O2 and O3 rely on a single dedicated technology, which suggests a limited market and so economic effectiveness would be poor (although this would depend on the technology adopted). Option O4 introduces the benefits of sharing, and so has improved economic effectiveness.

Options O5 and O6 offer the most flexibility for solutions to be adapted to suit local requirements and/or to evolve over time. Option O6 (no prescription) is the most challenging for interoperability as (at least in theory) a wide range of different solutions could emerge across Europe. It is assumed that options O5 and O6 would be the most economically effective as these options allow solutions to be chosen from the broader market of competing technologies rather than being locked into one particular platform.

Option O5 assumes some control over the technology platforms that are ‘authorised’ for railway use, limiting the scope for too much variation to emerge. This option includes the continued use of GSM-R in cases where it provides the best solution for as long as the technology is supported, but also allows other technologies to be adopted. Based on the current market, the most obvious candidate might be LTE – in which case railways would have an opportunity to work with organisations in the public-safety community planning to adopt LTE or with commercial network operators, or (subject to spectrum constraints) to implement dedicated railway LTE networks. Over time, new ‘5G’ technologies or other technologies for which a case is justified (e.g. satellite services for some areas) could be added to the set of accepted technologies.

Implicit in all options other than O1 ('Retain GSM-R') is the assumption that the ETCS application can be migrated to work over an IP bearer. Also, all options that involve a change from GSM-R require special provisions to maintain interoperability during the transition. It is not realistic to require all GSM-R networks to be maintained until full transition is achieved across Europe and so, in practice, interoperability will rely on the use of terminals capable of supporting multiple bearers for those trains moving across multiple networks.

For options O5 and O6, terminals able to support multiple bearers will continue to be required post-transition for interoperability, and the bearers supported may need to be updated over time as new technologies are introduced.

6.8 Conclusions for future scenarios for railways

A variety of solutions have been identified that could be applied for future operational railway communications based on:

- the analysis of the railway requirements
- the hypotheses and key considerations identified
- the examination of the market and of examples in use or being considered in other sectors.

In the short term, GSM-R provides the best fit as it is specifically designed for railway requirements. The continued use of GSM-R avoids introducing interoperability complications and difficulties in maintaining service continuity, which are inevitable for any transition. However, GSM-R offers little flexibility to adapt to changing requirements, will be more costly than alternative technologies in many scenarios, and cannot be assumed to be supported indefinitely.

If a new technology is defined for railway use, the most likely candidate, based on the current market, is 4G (LTE). However, for the timescales being considered the market can be assumed to have changed significantly and new '5G' technologies are expected to have been established.

Given the pace of change in the telecoms market and the need for flexibility to cater for variations across Europe, a multi-technology policy approach may be the most attractive. This offers the advantages of:

- allowing new/emerging technologies to be introduced over time
- offering a 'future-proof' approach for the longer term
- allowing the use of commercial network bearers with associated potential for cost reduction where appropriate
- allowing for shared networks (e.g. with PPDR) in countries where this is viable
- allowing for private networks in existing spectrum to be retained in areas where this is considered to be the most appropriate option.

However, a multi-technology approach introduces complexity for interoperability. Achieving interoperability would require terminals capable of working on multiple bearers and workable management/governance arrangements to be defined and agreed. Use of multiple bearer terminal solutions for operational communications (including railway examples) has already been established in some of the study references and is expected to become increasingly less problematic as terminal technology develops over time.

While option O6 assumes that (in theory) any technology might be adopted to suit local priorities, option O5 assumes a limited set of 'authorised' technologies is established that can be amended over time through a controlled process.

7 Terminal evolution

7.1 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 also the interface to the driver. It provides voice services, and may also provide data services for ETCS, which, under current rules, are circuit-mode data services.

7.2 Current situation regarding terminal evolution

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 unit has a single radio module, which supports GSM and GPRS within the GSM-900 band (some modules have commercial network filtering). Radio modules are from smaller specialist companies, not normally from the infrastructure providers (at least within Europe), and there is no suggestion that these suppliers have plans to declare end of life on the modules. It has been suggested that the TSI mandates a single-mode cab radio: while there is no evidence to support this, it does mandate GSM-R and the GSM-R band for Command Control-Signalling (CCS) on Class A railways.

There may be additional radio data modems for other services also provided on the train. There may also be applications built into the cab radio which use GSM-R data and assist the driver with their work. An example of this would be a driver advisory system.

While existing cab radio RF modules are susceptible to interference, there are newer modules which have better performance, and the possibility of fitting an external filter, although this creates issues for a locomotive roaming onto another network (the filter may need to be disabled).

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). There is a high cost of integration into the locomotive, and recertification when changes are made, which does not encourage evolution and product enhancement, although suppliers are trying to increase functionality and make more use of the driver display.

7.3 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 such as the REC (shown in Figure 7.1).

Figure 7.1: Australian multi-mode train unit [Source: 4TEL, 2014]

There are already multiple radios on many trains, but these are usually piecemeal solutions, with the radio data modems connecting to other train systems.

Just as in the future there is a clear need to separate the bearer from the application, on the train-borne systems there is a need to separate the GSM-R voice functionality from the ETCS functionality, to allow a more flexible delivery platform. This does not mean they should be isolated, but that the train systems should have the ability to communicate with trackside systems and the control through a flexible bearer arrangement.

At present only 2G and 3G systems support voice as a circuit-mode service. 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 is underway to develop GCSE and MCPTToLTE as part of the LTE development. As noted in Section 4.4, there is merit in ETSI TC RT working with ETSI TC TCCE to develop a suitable application which will work over LTE and future technologies.

The use of multiple radios implemented in silicon within a device is common today. A typical mobile phone or smartphone will have up to 12 radios, to cover the various frequency bands and technologies; adding a radio is a case of developing the silicon for that band and technology, and requires harmonisation on at least a European level to justify the development and inclusion.

At present, the Control-Command and Signalling Technical Specification for Interoperability (CCS TSI) mandates GSM-R for ETCS, but in the future with the terminal operating in an IP environment, there will be fewer reasons to have this limitation, and many more reasons to design the signalling systems to operate over a variety of bearers, as long as the bearer characteristics meet a recognised level of performance in terms of error rate and latency.

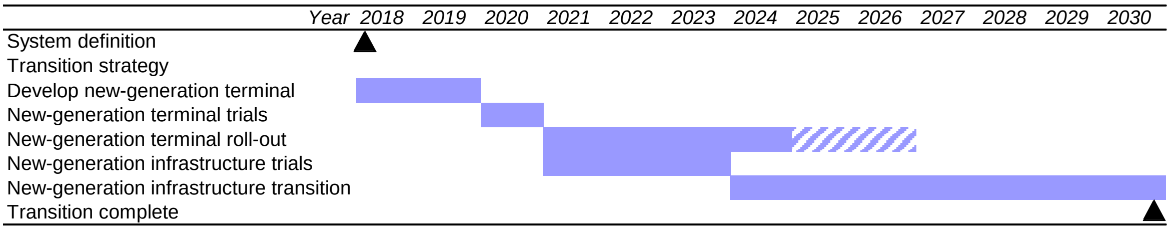
7.4 Terminals as a tool for transition

It is unrealistic to expect an IM to maintain two infrastructures from the point that they start a transition so that they can support any legacy radio unit which may need to operate on its tracks. It is therefore important to consider the terminal as the transition tool, i.e. using terminals that operate on different network technologies can facilitate continued operation while new networks are introduced and old networks decommissioned.

In terms of timescales, if a detailed system definition and transition strategy is defined by 2018, a new generation cab radio could be available for trials within two years. These could then be rolled out into locomotives, operating in legacy mode. Before an IM is able to transition to the new generation of infrastructure (and in particular turn off its legacy GSM-R system) any locomotives which will need to operate on its track will need to have transitioned to the new-generation solution.

A possible scenario for transition of terminals is shown below in Figure 7.2.

Figure 7.2: Scenario for terminal transition [Source: Analysys Mason, 2014]



The above is an initial view from current information, and will need refinement. There will be lines or sections of track where there is no real requirement for interoperable trains to travel on that track, and transition could be faster.

7.5 Interoperability of terminals

At present, interoperability is controlled by only having GSM-R as the bearer. Soon GPRS within the same frequency band will also be available for ETCS, and at the same time as this, the use of IP data services may be introduced.

Interoperability in the future can be achieved using multi-mode terminals which may also be multi-technology. A decision has to be taken on whether interoperability is relating to both voice and data services, or just to one type of service. For ETCS with an IP environment, interoperability will be simpler, and a case of the terminal having a compatible bearer. For voice, the voice application in the terminal will need to be interoperable with the one in the infrastructure, and will need to support the required feature set.

The IM could specify what modes are required for a locomotive to operate on its tracks, in both a full operational mode and in a degraded mode. This is similar to aviation where a national air traffic control service can set a minimum standard for planes entering its control.

Based on our discussions with stakeholders, there is limited need for voice communications during normal operation, but voice becomes critical when operations are abnormal, such as an accident or loss of data communications. In the case of the accident, there may be other ways of signalling the emergency by using data with basic voice services.

From discussions with IMs, we have heard of commercial networks being used as back-up, and this may be a solution for the degraded mode, since it will be not relying on IM infrastructure. This may include basic voice services, as opposed to the full railway feature set.

7.6 Portable radios

Based on stakeholder feedback from interviews, GSM-R is considered to be predominantly a solution for communication with train-mounted radios, and although there are portable radios available, the networks are optimised for mobile rather than portable coverage; portables are also lower power devices. As a consequence, portables are not considered to be very effective operationally, and if a driver leaves their cab to attend an incident outside the train, or in a different carriage, they may have to rely on a mobile phone to communicate. Also the train manager/guard may have to rely on their own commercial data device to receive operational information about their service, due to the shielding effect of the train and the coverage design.

Feedback from the study was that a lot more could be achieved with a hand-portable device that would work reliably inside the train.

In the evolution to a new rail communications solution the use of both devices which are incorporated into the locomotive as well as hand-portable devices should be considered.

8 Strategy for system replacement

8.1 Introduction

In this section, the different issues considered in this study which can be used by ERA in developing the strategy for future rail communications are considered, with discussion on the options which will need to be taken into account.

This builds on the options identified in Section 6.

8.2 Overall strategic options

Here, we look at the key issues to be considered in the strategy development, specifically: technology, bearer independence, the required functionality, spectrum, and delivery models.

8.2.1 Technology

High-level requirements have shown a need for moderate levels of data which would struggle to be carried on GPRS, and could not be carried on circuit-mode data. If pure signalling data was the only user need, GPRS may well be sufficient, but when data supporting the business is included, wideband and broadband mobile data is required. 3G services are generally felt to be unsuitable, but 4G, and in particular LTE, may be suitable, having high data rates and low latency, making it an acknowledged acceptable bearer for real-time applications.

Within the mobile communications industry, the near future is clearly recognised as being based on LTE. 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.

However, just as 1G was replaced by 2G, and 2G is expected to be phased out in the 2020–2025 timeframe (although the use of 2G for M2M applications could mean that some 2G in specific bands is maintained), 5G is already being discussed, and will be available in the 2020–2022 timeframe. Any future solution for the rail sector should be structured to allow a continuing evolution of technology.

8.2.2 Bearer independence

A large number of the interviewees expressed a desire for bearer independence. Currently this does not happen with GSM-R and circuit-mode data over GSM-R.

As GPRS and IP data is deployed, there will be an element of independence. The radio modules which cab radio uses support GPRS as well as circuit-switched networks, and suppliers either have train communications racks which will support a circuit-switched module and a GPRS module or separate circuit-switched cab radio and an additional data-only radio modem (also known as European Train Control System Data Only Radio (EDOR)).

With a narrowband system such as GSM-R and GPRS, if there is a need to maintain a continuous data circuit to the train, there has to be two radios. Once we move to a broadband mobile solution the need for two radios will disappear, in that the one bearer could support both a data connection and a voice application.

Bearer independence will increase, and in the IP environment should be encouraged, within the constraints of providing suitable interoperability. There should be a move away from the need to optimise the bearer for signalling, but instead a specification should be available for the bearer, with characteristics such as error performance and latency, and as long as these are met by the bearer, the channel should be able to be used for signalling purposes.

8.2.3 GSM-R functionality

There were a number of changes made to GSM to create the GSM-R standard. These included Advanced Speech Call Items (ASCI) which included Voice Group Call Service (VGCS) and Voice Broadcast Service (VBS) as well as multi-level priorities and pre-emption. A specific use of the VGCS is the REC. There is also location-dependent and functional addressing. The GSM-R standard is now the responsibility of the EIRENE project.

With bearer independence enabling the use of GPRS, LTE or future IP bearers for ETCS, this leaves specialist voice services for consideration. Addressing requirements can be met within the future IP network, but the application and functionality needs to be defined.

The majority of rail industry interviewees confirmed that there was a continuing need for voice services, particularly when there is a problem with signalling communications or as a result of non-normal train operation. A number of interviewees suggested that a function equivalent to the REC was required, but questioned if this would remain as a voice call in the future.

Although there is a possibility that by the time the transition to a future communications concept will be taking place, voice services will be in decline, the strategy must assume that voice services will be required in the future. With new technologies being IP based, a VoIP solution will be required. While there are features for mission-critical group communications being developed for LTE within 3GPP, these are enablers, and some form of application to give railway-specific features is likely to be required. It will be important that these are developed so that there is true interoperability between vendors, and in a way that they can be adopted worldwide by users of GSM-R outside Europe.

This activity would be similar to the work being done initially for public safety by the ETSI TC TCCE, which is developing a mission-critical application which will use the enablers, and manage group membership and priorities. This is taking requirements from the TCCA Critical Communications Broadband Group (CCBG), which already includes rail requirements. This may be a suitable vehicle for the development of voice services, with the involvement of the rail sector in the refinement of the requirements and the development of the mission-critical application. Alternatively, the model could be used in the future by railways using other standards groups.

8.2.4 Spectrum

Spectrum is key to the future communications concept, with a clear need for contiguous frequency division duplex (FDD) spectrum. FDD spectrum is needed for voice services; for data-only services time division duplex (TDD) would be a suitable solution. As detailed in Section 4.5, use of the existing spectrum is possible, but problematic, and creates an issue for the transition phase.

With high-speed trains and a relatively low density of users, spectrum below 1GHz has to be preferred, since higher frequency spectrum will require far more trackside sites. The ideal situation would be for CEPT to designate a new block of spectrum for railways. Ideally this would be at least 2×5MHz of FDD spectrum below 1GHz. Once transition has taken place, the existing GSM-R band could be released for use by commercial networks.

If no spectrum is available, alternatives are to take service from a commercial network or reach a sharing agreement with an organisation which does have access to spectrum.

8.2.5 Delivery options

If new suitable spectrum is available to the rail sector, this would allow private dedicated systems to be deployed. It must be noted that having spectrum available does not mean that all IMs in Europe need to deploy dedicated private networks. They could take the spectrum to a MNO and agree an arrangement where the MNO rolls out a network for the use of the IM, possibly with sharing. The possible delivery options are shown in Figure 8.1.

Figure 8.1: Delivery options [Source: Analysys Mason, 2014]

Network	Advantages	Disadvantages
Own build	• Total control	• High cost
Own build, but allow commercial use	• Own control • Can offset opex against revenues	• High capital cost
Commercial build, but dedicated use	• Can influence design • Commercial operator can develop network faster and more efficiently	• Could still be a high cost • Operator lock-in
Commercial build, commercial use with rail priority	• Can influence design • Commercial operator can develop network faster and more efficiently	• Some commercial sharing • Operator lock-in
Dedicated network in core areas, roaming to commercial network if no rail coverage	• Can influence design • If commercial partner involved can develop network faster and more efficiently • Can provide more capacity when needed	• Some risk when using commercial network • Operator lock-in

This illustrates there are many different delivery options. They all are based on having the rights to spectrum, so that the IM has power to negotiate with the MNO with which they are partnering, and the choice to take those rights if necessary to another MNO.

With this arrangement, each national IM would have the freedom to decide on the most suitable delivery mechanism, while still preserving interoperability.

8.3 Timescales

There are a number of factors to consider in developing a plan for a new concept of communications. On the assumption that the concept will make use of a mainstream broadband technology, these are considered in Figure 8.2.

Figure 8.2: Timescale factors [Source: Analysys Mason, 2014]

Factor	Comment	Timescale
Technology	Broadband technology such as LTE is now available and is being deployed widely. Developments continue to improve the technology.	Available now.
Mission-critical LTE features such as group calls	The general view is that mission-critical group enablers will be in Release 12, which will be available in late 2014, but will require further development outside 3GPP to use the enablers.	May be available from 2016 onwards, but EU public-safety community is assuming post-2020.
Railway-specific features	May need to standardise functional and location-dependent addressing, and REC, among others.	Will be 2–3 years of activity following stable 3GPP release.

Factor	Comment	Timescale
3GPP spectrum changes if new concept uses existing spectrum	Need to add the band to 3GPP band plans and possibly introduce new 4MHz channel bandwidth.	If introduced with enough support in 2014, could be in Release 13 in 2016, otherwise Release 14 in 2018.
New spectrum for railway use	Minimum of 2×5MHz of FDD spectrum, preferably sub-1GHz.	If CEPT route used, introduce in WRC15, for decision in WRC18, and clearance (typically five years).
System migration timescales	There will need to be parallel running of old and new system, with trials and testing, before trains are able to cut over to the new system. This will take many years in the case of most member states.	Minimum of three to five years (but more accurate estimates required for each member state).

While these timescales do not seem a problem, if there are to be trial systems and pilots prior to a transition taking place from 2022 onwards, the strategy must be determined by the end of 2014, and in the case of spectrum, a plan developed before that if any input is required for WRC15.

In considering timescales it would be advantageous to review the transition from analogue to GSM-R as a 'lessons learnt' exercise, to inform the transition to a future concept.

9 Summary of findings and recommendations

9.1 Introduction

As discussed in Section 2, this study and report is part of a larger programme of activities for future communications systems for railways being carried out by ERA. This also includes an operational requirements capture exercise that is currently underway.

The findings from this report will be used to inform the subsequent activities that will take place during 2014, and will result in a finalised strategy and technical solution approach.

This report does not, therefore, seek to make definitive recommendations for the ultimate strategy, but aims to identify viable options and to describe the advantages and disadvantages of the different approaches.

9.2 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 800MHz. IMs are happy with the functionality, although RUs would like to do more with the systems. The REC is an absolutely vital function, which currently is a voice call, but may in the future be implemented in another way.

ETCS is being rolled out, but there was feedback that circuit-mode operation on GSM-R did not give enough capacity, and GPRS is required. While GPRS is used on GSM-R spectrum for business-supporting communications, it is not yet available for ETCS data.

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. There is no evidence that this situation will change.

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 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 by the public-safety community. This will deliver many of the functions provided within GSM-R, and the changes to support all railway functionality are likely to be small. They can be identified during the operational requirements capture exercise being conducted by ERA.

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. This needs to continue and there needs to be separation of the bearer and signalling in future systems to enable ETCS to be operated on alternative bearers.

The situation as far as spectrum is concerned is that railways currently have access to their dedicated harmonised block of 2×4MHz of spectrum at 800MHz, with an additional 2×3MHz on a national shared basis. While the use of this spectrum for the future communications solution is possible, and sub-1GHz spectrum is ideal for railway use, the transition would be problematic.

There is a good case for railways having the rights to a new block of at least 2×5MHz sub-1GHz spectrum. There are then a number of potential delivery methods, as detailed in Section 8.2.5, which span from private networks to working with a commercial operator. These include the possibility of the rail sector sharing spectrum with other sectors, and the EC has commissioned a study which will report later in 2014 on the potential for sharing of spectrum by critical users such as public safety, transportation and utilities, and the evaluation of how well commercial networks would meet the user requirements.

In the short term, GSM-R provides the best fit as it is specifically designed for railway requirements and the continued use of GSM-R avoids introducing interoperability complications and difficulties in maintaining service continuity, which are inevitable for any transition. However, GSM-R offers little flexibility to adapt to changing requirements, will be more costly than alternatives technologies in many scenarios; it will also cease to be supported between 2020 and 2030.

If a new technology is defined for railway use, the most likely candidate, based on the current market, is 4G (LTE). However, for the timescales being considered, the market can be assumed to have changed significantly, and new '5G' technologies are expected to have been established.

Given the pace of change in the telecoms market and the need for flexibility to cater for variations across Europe, a multi-technology policy approach (option O5 or O6 as described in Section 6.5) may be the most attractive.

However, a multi-technology approach introduces complexity for interoperability. Achieving interoperability would require terminals capable of working on multiple bearers and workable management/governance arrangements to be defined and agreed. Use of multiple bearer terminal solutions for operational communications (including railway examples) has already been established in some of the study references and is expected to become increasingly less problematic as terminal technology develops over time.

9.3 Recommendations

As a result of this study a number of recommendations have been identified for consideration by ERA during 2014:

- any future communications solution should separate the bearer from the applications
- any future communications solution should avoid dependence on any single technology, and allow bearers to evolve over time
- transition will be best managed by the use of multi-mode terminals (rather than requiring legacy infrastructure platforms to be retained)
- in determining the transition strategy, lessons learnt from the migration from analogue to GSM-R should be taken into account
- as well as aiding transition, multi-mode terminals can facilitate interoperability in a mixed communications environment, enabling a degree of flexibility, and allowing different bearers to be adopted (to suit local needs or as requirements change over time)
- ERA, UIC and industry groups need to engage with standards bodies, to ensure that railway-specific functionality can be supported as an application on new technology platforms
- considerations regarding spectrum need to be made during 2014 to build, in part, on the EC study that will report later this year.

Annex A Interview data and findings

A.1 Interviews

To survey the operational communications requirements for railway, a series of interviews were conducted with experts from the railway, public-safety, aviation, and utilities sectors. Organisations represented included:

- railway infrastructure managers (IMs)
- train operating companies (TOCs)
- railway equipment suppliers
- railway trade associations
- regulators and government departments
- public-safety organisations.

A.2 List of interviewees

Figure A.1: Interviewees for the study [Source: Analysys Mason, 2014]

Organisation type	Organisation name	Contact	Title	Date of interview (2013)
Railway IMs	**UK NRT**	Tim Lane	Principal Strategy & Innovation Manager	23 September
	ProRail	Allard Klomp	Connectivity Manager	02 October
	DB Netze	Achim Vrielink Bernd Kampschulte Klaus-Dieter Masur	Requirements and performance management	22 October
TOCs	**UK HS2**	Trevor Foulkes	Head of Signalling & Telecommunications	25 September
	4Tel	Derel Wust	Managing Director	27 September
	ATOC	Phil Barrett Daniel Mann	Head of Major Projects Operations Manager	30 September
Railway equipment suppliers	**Huawei**	Norman Frisch	Business Development Railway Solutions	18 September
	Alstom	Pierre Cotelle	Telecom Solution Director	26 September
	Teltronic	Marta Fontecha	Business Development Manager	9 October
	Kapsch	Jean Michel Evanghelou Rainer Lasch	Head of Railway Solutions Railway Regulatory Affairs	10 October
	NSN	Ola Bergman Michael Kloecker Dirk Lewandowski	Head of GSM-R Standardisation Head of Customer Business Team Railway Solutions	21 October
	Siemens	Ciro De Col John Williams	Head of Sales and Marketing	28 October

Organisation type	Organisation name	Contact	Title	Date of interview (2013)
Railway trade associations, regulators and government departments	Ofcom	Paul Jarvis	Head of Business Radio	19 September
	UNISIG	Michel Van Liefferinge	General Manager	07 October
	DfT	Farha Sheikh	Technical Manager	08 October
	UIC	Dan Mandoc Chiel Spaans	Railway Telecom Senior Advisor EIM representative in UIC	31 October 18 September
Public safety	PSCE	Manfred Blaha	President	30 September
	TCCA	Phil Godfrey	Chairman	11 September
Others	EUTC	Adrian Grilli	Technical Advisor	18 September
	NATS	Stephen Parry	Spectrum Manager	27 September
	ESA	Rob Postema Frank Zeppenfeldt	Feasibility Study Manager	29 October
	Telefónica/O2	Andrew Arthur Simon MacDermott	Account Director - Passenger Services Network Strategy & Architecture	14 November
	Deutsche Telekom	Wendelin Reuter Karl-Heinz Laudan	Spectrum Policy & Projects	13 December

A.3 Interview findings

The data gathered during the interviews is summarised in the following figures. The key requirements have been included as a separate section.

Figure A.2: Data from interviews with railway operators [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	• Inefficiency in the way GSM-R data is transmitted – only a few control centres across the country, so have to send data all the way there and all the way back for a train 100 miles away • Fibre cut by vandals thinking it was copper caused 5% of failures – changing to a mesh network would reduce the impact of this • High-speed trains are getting closer together so signalling must work within milliseconds • Operators would like to see more hand-portables, however they are expensive on GSM-R • Operators believe ETCS will bring disruption during the transition period, and although they fundamentally agree with it they think it brings more benefits to IMs than to them • Non-critical communications such as customer information, reservations, and Wi-Fi would be desirable if the capacity was available • Suppliers: some GSM-R suppliers are not forward looking, multi-disciplined suppliers do think about future more, in some cases not responsive as they have a monopoly

Topic	Notes
Key requirements	• Infrastructure monitoring and tele-maintenance are important • The Railway Emergency Call (REC) facility must be available (most think this requires voice) • ETCS data must be reliable and easy to upgrade • Desirable for control staff to communicate with passengers directly to explain reasons for delays etc., allowing the driver to concentrate on troubleshooting the problem • A data link could be used to provide passenger information (desirable) • Railways should individually decide what to do when signal is lost, i.e. stop or continue through the holes
Spectrum	• GSM-R spectrum is filling up in large cities such as London • Dedicated spectrum is required along the line, but it could be shared geographically if the powers levels are controlled • Spectrum could be shared with blue-light services as they are 'like-minded', whereas commercial networks are perceived to be more concerned about their own customers and could take the network down at any time • Interference is a concern of some operators when moving from old systems to new systems • Interoperability of operations is important, not the hardware – however, there is a limit to the number of radios that can be installed on the train • Co-operation may be necessary with mobile operators so passengers can use their mobile phones; repeaters on trains and infrastructure in tunnels may also be required • CCTV could be transmitted through the public network
Future trends	• Trains will be dual-fitted with GSM-R as well as the new solution • Data will be sent by packet-switching rather than circuit-switching networks • It is important to have harmonisation at the minimum technical level to get competitive supply • CCTV is important for fault detection • Voice will not disappear for the foreseeable future • There will be more handhelds, more stable software, a greater volume of data and a decrease in the use of voice • Applications should be separate from the bearer • Some operators predict robust out-of-the-box radio systems that will last decades • One operator felt the most important thing for the future was to secure spectrum, keeping future options open

Figure A.3: Data from interviews with IMs [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	• IMs own the SIM cards which they provide to rail companies which pay a track access fee • Some provide data communications which is beyond the monthly track access charge; they pay an extra monthly fee for this (not charged per call as the billing system would be too complicated) • Some allow emergency services to use their networks when required, e.g. in tunnels, but governments are charged for this • Some IMs are planning to implement new cab radios in the near future

Topic	Notes
Key requirements	• REC is an absolute necessity and at present voice is the easiest way to implement it, however this may change • The network must carry data and voice and provide passenger information on platforms and timetabling information on board • Kapsch/NSN are the current infrastructure suppliers of choice – everyone is fairly happy with their suppliers though they recognise it would be difficult to change
Spectrum	• All see interference as a problem and would like more spectrum • Some have attempted to boost coverage with repeaters • If more spectrum were required in future the problem would not be the cost of the spectrum itself, rather it would be the cost of replacing the equipment • One commented that spectrum sharing was definitely an option in future
Future trends	• More monitoring functions along the tracks • Voice will still be important • Software-defined radio may be necessary for future migrations • May be beneficial to use public networks in parallel with own networks • More off-the-shelf systems will be developed in future, such as LTE rather than LTE-R etc. • EU requirements should be reduced to what is "sufficient and necessary"

Figure A.4: Data from interviews with suppliers [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	• Trials have begun with LTE for railway communications; currently transmitting data – voice will come later • Requirements need to be defined, frequency availability checked, then technology chosen • Railways should control their own networks as they provide mission-critical systems • GSM-R is becoming obsolete – something new is definitely required • Although GPRS is perceived as a new technology for railways, one of the suppliers interviewed said they have customers who have been using it for 10+ years • Cab radios are mostly modular allowing hardware to be interchanged • Critical applications can be fulfilled with GSM-R – there may be no need to change • Suppliers all felt they had a good relationship with customers, lots of face-to-face time etc.
Key requirements	• The link must work perfectly at 350km/hour • Voice transmission between train and trackside • Small volumes of data for signalling • Passenger information and CCTV etc. though these are not critical • Signalling strategy should be to avoid changes in general
Spectrum	• Interference will be a bigger issue in the future and the technology must deal with this

Topic	Notes
Future trends	• Packet switching rather than circuit switching • Although it would be feasible to mix operational services with information and entertainment services there is a legal issue – cannot generate revenues from frequencies licensed for operational services • Everything will be sent over IP eventually • Intelligence in terminals to detect problems before they occur • 4G/5G will be used – 3G will be skipped • Suggestion by one supplier that railways should undertake a lessons learnt exercise from the analogue-to-GSM-R migration as an input into the migration to any new solution • Voice will still be required but data will be used for signalling

Figure A.5: Data from interviews with public-safety organisations [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	• For one off events, e.g. football matches base stations can be upgraded • Austrian TETRA users can operate 20km across Italian border, have base stations on Bavarian territory and vice versa
Spectrum	• Harmonisation is important as shown by the way 400MHz was harmonised for PS narrowband systems; should be on at least a European basis. • Having your own dedicated spectrum does not mean you have to have your own dedicated network. • Sharing a dedicated network between public-safety and other 'critical' communications users makes good business sense as long as users share a common philosophy
Future trends	• Regulators do not lay down network requirements but do give target response times which drives the public-safety networks to have high availability

Figure A.6: Data from interviews with railway trade associations, regulators and government departments [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	• ETCS can be fulfilled by technologies other than GSM-R – GPRS is under trial • Signalling should be separate as it has a slower speed of evolution than everything else • Railways have invested a lot in GSM-R so they will not be prepared to change the system yet • IP and broadband technologies not as good for RECs as GSM-R
Key requirements	• Information must be sent between the driver and the dispatcher and how this happens needs to be defined in the next three years, some believe this will still be voice
Spectrum	• Interviewees reacted positively to spectrum sharing, particularly in more rural areas • Interference is a political problem solved by technical means
Future trends	• Not much appetite for mixing critical and non-critical communications • Trains travelling at ever-increasing speeds creates a more challenging environment • Terminals will be key to the evolution of railway communications – from 2023 onward GSM-R and other technologies will exist in one multi-mode terminal • There will be more functionality on trains, reducing intelligence and cables at trackside

Figure A.7: Data from interviews with other organisations [Source: Analysys Mason, 2014]

Topic	Notes
Current arrangements	**European Space Agency** • Looking at satellite applications in railway domain • Some vehicles have satellite navigation systems for tracking and tracing particularly when carrying dangerous goods, other feasibility studies have been carried out on using satellites to improve safety at level crossings, passenger information services and Internet access • Use of satellite for voice and data still being evaluated, circuit-mode services emulated via satellite • Coverage guaranteed by satellite – good for interoperability • Looking at whether present systems can be modified for train control or if new infrastructure would be required **European Utilities Telecom Council** • Critical wireless communications is used widely in utilities for monitoring and control – predominantly communications with fixed assets, rather than mobile • Mobile communications are useful but not essential e.g. maintenance personnel responding to a fault • There is less commonality of approach with utilities across EU compared with public safety or rail, no movement of users between countries so no operational requirement • Data volumes are growing rapidly as the number of devices expand • Limited synergy between utility sector and rail sector – utilities do not need GSM-R – however, they could have a shared network model with rail and others provided the critical requirements of all parties are met • Key requirements: resilience, controlled operation during power outages, controlled latency, coverage to suit the estate, long product life cycle, high equipment availability (avoiding custom products) **National Air Traffic Services (NATS)** • Charges based on parameters of a flight, on route charges collected across all states then passed back to each individual state • Airports charge landing fees • A flight plan must be filed beforehand - it does not contain details of frequencies, rather the air traffic controller gives details of next frequency to tune in to before handing off • Looking at using data links to do detail the frequencies in future • Voice has to be there but NATS seek to replace more functions with data
Spectrum	• ESA - spectrum should be reserved for future railway communications • EUTC - building a case for harmonised spectrum across Europe • NATS - everything must be agreed on an international level however actual spectrum allocations are done on a national basis
Future trends	• Satellite-based systems could be used for both communications and navigation • There will be a move towards more data-based systems but voice will always be there in some form • GSM-R must be protected due to the past investment in it • Seamless handover between satellite and terrestrial is required as in rural areas satellite will be better, whereas in urban areas terrestrial is preferred • An integrated solution required which is likely to have an LTE component

During the interviews there were some key themes on which everyone reached a consensus view:

- GSM-R will definitely become obsolete at some point in the future however when it happens is still under debate
- data will become more important in the future however voice will still remain
- packet-switching networks will be used instead of circuit switched
- the REC is an absolute necessity i.e. group call functionality
- signalling should not be carried out on commercial networks and there should be a separation between signalling and all other services
- there should also be a separation between the application and the bearer
- tele-maintenance should be implemented, however, other non-critical communications such as passenger information services are not necessary and should only be considered if the capacity is available
- problems with a lack of capacity are likely to occur in the near future, particularly in urban areas
- spectrum sharing is definitely possible but preferably with public safety or a similar organisation that have a similar viewpoint – commercial networks would not be suitable
- the requirements for the new railway telecoms network should be defined by the ERA, not the technology to implement them and they should be "sufficient and necessary"
- future railway communications technology will be IP-based and the new system and legacy system must co-exist
- the railways must look towards 4G and '5G' for the future communications networks – there should not be a rail-specific technology as with GSM-R.

Annex B Current status – rail sector

Figure B.1: Current status of the railway network in Europe [Source: UIC / Analysys Mason, 2013]

	Infrastructure ownership	Infrastructure organisation	Track km in operation[12] (voice)	Track km planned (voice)	Track km in operation[13] (ETCS)	Track km planned[13] (ETCS)	Number of cab radios (activated)	EDOR (activated)[14]
Austria	Public	ÖBB-IKT	2800	3500	100	-	1800	N/A
Belgium	Public	Infrabel	3000	3000	100	1000	2290	Few tests
Czech Republic	Public	SŽDC	700	5400	N/A	1300	1022	<5
Croatia	Public	Railways Infrastructure	N/A	1300	N/A	N/A	N/A	N/A
Denmark	Public	DSB	0	2000	0	1800	180	N/A
Finland	Public	Transport Agency	5100	5100	N/A	N/A	A few	N/A
France	Public	RFF	3200	16000	5800	N/A	12120	2020
Germany	Public	DB Netz	26900	29300	N/A	N/A	16500	390
Greece	Public	OSE	700	700	N/A	N/A	120	N/A
Hungary	Mixed	MÁV	N/A	4350	N/A	N/A	0	N/A
Ireland	Public	Córas Iompair Éireann						

12 These figures have been rounded to the nearest 10

13 Coverage for ETCS Level 2

14 These figures have been rounded to the nearest 5

	Infrastructure ownership	Infrastructure organisation	Track km in operation[12] (voice)	Track km planned (voice)	Track km in operation[13] (ETCS)	Track km planned[13] (ETCS)	Number of cab radios (activated)	EDOR (activated)[14]
Italy	Public	RFI	9850	11200	600	600	N/A	N/A
Lithuania	Public	Lithuanian Railways	1550	1550	0	0	500	0
Netherlands	Mixed	NS Railinfratrust	3100	3100	400	400	2600	520
Norway	Public	Jernbanever ket	3800	3800	0	3800	1090	<5
Poland	Public	Polskie Koleje Państwowe	0	15000	0	5000	0	0
Portugal	Private	REFER	0	1950	0	-	4	0
Romania	Mixed	CFR-SA	N/A	8000	N/A	2000	N/A	N/A
Slovenia	Public	Slovenske železnice	0	1250	0	600	30 dual mode (analogue only)	N/A
Spain	Mixed	ADIF	2100	10700	500	1600	530	1060
Sweden	Public	Trafikverket	N/A					
Switzerland	Mixed	SBB		11000	N/A	450	2700	180
United Kingdom	Statuary corporation; funded by government.	Network Rail Telecoms	7250	15100	200	200	3100	50

Annex C Current status for public safety

Figure C.1: Current status of the public safety networks in Europe [Source: Analysys Mason, 2014]

	Network name	Network owner	Network users	Network model	Cost of contract (EUR)
Austria	TETRON	Ministry of the Interior	PPDR, mountain rescue, water rescue, cave rescue, civil protection	Public/private partnership, built owned and operated by BMI and a consortium of Motorola (65%) and Alcatel-Lucent (35%).	1.1 billion
Belgium	ASTRID	Ministry of the Interior	PPDR, Ministry of Defence, prison services, customs, border guard, civil security, nature conservation, maritime affairs	Government owned, government established management company, outsourced four-year maintenance contract	400 million
Bulgaria	Stranja	Ministry of the Interior	PPDR, Ministry of Defence, border police	Government owned, separated into 3 TETRA networks; MoD, MoI and border police, outsourced 4 year contract to EADS/Ericsson to extend and upgrade	
Croatia	MUPnet	Ministry of the Interior	Police, Border police	Government owned, outsourced network build to Motorola	
Czech Republic	PEGAS	Ministry of the Interior	PPDR, Ministry of Defence, civil defence	Government owned, outsourced network build to EADS	
Denmark	SINE	Ministry of Finance	PPDR, Emergency Management Agency (DEMA), Home Guard, Maritime Safety Administration, private companies	Built and owned by DBK, a Motorola subsidiary	215 million
Estonia	ESTER	Ministry of Internal Affairs	PPDR, healthcare agencies, border police, prison services	Government owned, and operated by government owned company	

	Network name	Network owner	Network users	Network model	Cost of contract (EUR)
Finland	VIRVE	Ministry of Internal Affairs	PPDR, border guard, customs, defence forces, rescue, power generation and distribution, public transport	Owned and operated by government owned company	300 million
France	ANTARES	Ministry of the Interior	PPDR, gendarmerie, civil defence, armed forces	Government owned, outsourced network build to EADS	495.4 million rental (plus 142.3 opex over 9 years)
Germany	BOS	Ministry of the Interior	PPDR, rescue services, customs, Federal Agency for Technical Relief, disaster and civil defence authorities	Government owned, operations outsourced to Alcatel Lucent	1.1 billion
Greece	Unknown	Hellenic Government	PPDR	Unknown	216 million
Hungary	United Digital Radio System	Ministry of Development	PPDR, customs, Directorate General for National Disaster Prevention	Government owned but construction, management and operation outsourced to a dedicated company	37.3 million
Ireland	NDRS	Department of Finance	Police, Fire, Ambulance	Public /private partnership with private consortium TETRA Ireland	
Italy	PIT	Ministry of Internal Affairs	Police	Government owned, outsourced to Selex ES	3.5 billion
Lithuania	Unknown	Ministry of the Interior	PPDR, border police, customs, State Secret Service	Government owned, outsourced to Motorola/INTA	27.4 million
Netherla nds	C2000	Ministry of Internal Affairs	PPDR, military police, customs, rescue services, military intelligence, security services	Government owned and operated.	489 million
Norway	Nødnett	Ministry of Justice	Police, Fire, Ambulance	Government owned, management outsourced	988 million (projected)
Portugal	SISREP	Ministry of the Interior	PPDR, Secret Service, border police, national guard	Capital build funded by government, managed service operations by consortium	

	Network name	Network owner	Network users	Network model	Cost of contract (EUR)
Romania	Phoenix	Ministry Administration and Interior	PPDR, government departments, border police	Government owned but managed by the Special Telecommunications Service (military organisation)	
Slovakia	SITNO	Ministry of the Interior	PPDR, government departments, civil protection, military police, military intelligence, border police	Built and operated by RCTT (a subsidiary of EADS)	
Slovenia	ZARE	Ministry of the Interior	Police	Built and operated as a managed service	
Spain	SIRDEE	Ministry of the Interior	PPDR, naval forces, civil authorities, Royal House, military emergency unit	Owned and operated by Telefónica as a managed service	
Sweden	RAKEL	Civil Contingencies	PPDR, customs, coastguard, rescue services, defence forces, Civil Aviation Administration, municipalities, private companies	Government owned, operations outsourced	400 million
Switz-erland	POLYCOM	Office of Communications	Emergency services, army, civil defence, civil administrations, public health authorities, private user groups	Government owned, maintenance outsourced	577 million
UK	Airwave	Home Office	Police, Fire, Ambulance plus other sharers.	Private finance outsourced to Airwave private company	5.5 billion

The following countries either have no modern public-safety network or there is no information available about their network and so they have been omitted from Figure C.1:

- Cyprus
- Latvia
- Luxembourg
- Malta.

Annex D LTE deployments in Western, and Central and Eastern Europe

Figure D.2: LTE deployments [Source: Analysys Mason, 2014]

Region	Country	Operator	Technology	Launch date	Network status
Central and Eastern Europe	Abkhazia	Aquafon	FD-LTE	No data	Trials in progress
Western Europe	Andorra	Andorra Telecom STA	FD-LTE	Expected 2013	Planned
Western Europe	Austria	A1 Telekom Austria	FD-LTE	Nov-10	Operational
Western Europe	Austria	Hutchison 3G Austria	FD-LTE	Nov-11	Operational
Western Europe	Austria	Orange Austria	FD-LTE	No data	Trials in progress
Western Europe	Austria	T-Mobile Austria	FD-LTE	Jul-11	Operational
Western Europe	Austria	T-Mobile Austria	LTE-A	No data	Trials in progress
Central and Eastern Europe	Belarus	best / Life	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Belarus	Dialog	FD-LTE	No data	Planned
Central and Eastern Europe	Belarus	MTS with Beltelcom	FD-LTE	No data	Trials in progress
Western Europe	Belgium	BASE	FD-LTE	No data	In deployment
Western Europe	Belgium	Belgacom Mobile SA (Proximus)	FD-LTE	Nov-12	Operational
Western Europe	Belgium	BUCD	FD-LTE	No data	Planned
Western Europe	Belgium	Clearwire Belgium (b lite)	TD-LTE	No data	Planned
Western Europe	Belgium	Mobistar SA	FD-LTE	Expected 2013	Planned
Western Europe	Belgium	Telenet Belgium	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Bulgaria	Mobiltel EAD (M-Tel)	FD-LTE	Expected 2012	Planned
Central and Eastern Europe	Bulgaria	M-Tel	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Croatia	T-Mobile Croatia	FD-LTE	Mar-12	Operational
Central and Eastern Europe	Croatia	VelaTel Global Communications	TD-LTE	No data	Planned
Central and Eastern Europe	Croatia	VIPnet d.o.o.	FD-LTE	Aug-12	Operational

Region	Country	Operator	Technology	Launch date	Network status
Central and Eastern Europe	Czech Republic	Telefónica O2 Czech Republic	FD-LTE	Jun-12	Operational
Central and Eastern Europe	Czech Republic	T-Mobile Czech Republic	FD-LTE	No data	In deployment
Central and Eastern Europe	Czech Republic	U:fon	FD-LTE	No data	Planned
Western Europe	Denmark	H3G Denmark ApS (3)	Dual FD/TD-LTE	2H 2011	Operational
Western Europe	Denmark	Mobile Nordic (formerly TDC Mobil)	FD-LTE	Expected in 2011	Planned
Western Europe	Denmark	TDC	FD-LTE	Oct-11	Operational
Western Europe	Denmark	Telenor Denmark w ith TeliaSonera	FD-LTE	Expected in 2011	Planned
Western Europe	Denmark	Telia Mobile Denmark	FD-LTE	Dec-10	Operational
Central and Eastern Europe	Estonia	Eesti Mobiltelefon (EMT)	FD-LTE	Dec-10	Operational
Central and Eastern Europe	Estonia	Elisa Mobiilsideteenuse d AS	FD-LTE	Not announce d	Trials in progress
Central and Eastern Europe	Estonia	Tele2 Eesti AS	FD-LTE	Nov-12	Operational
Western Europe	Finland	DNA Verkot Oy	FD-LTE	Dec-11	Operational
Western Europe	Finland	Elisa Corp. (Mobile Services)	FD-LTE	Dec-10	Operational
Western Europe	Finland	TeliaSonera Finland Oyj	FD-LTE	Nov-10	Operational
Western Europe	France	Bollore	TD-LTE	No data	Planned
Western Europe	France	Bouygues Telecom	FD-LTE	Expected H1-2013	Trials in progress
Western Europe	France	Orange France	FD-LTE	Jun-12	Operational
Western Europe	France	Orange France	TD-LTE	Expected H1-2013	Trials in progress
Western Europe	France	SFR (Societe Francaise de Radiotelephone)	FD-LTE	No data	Trials in progress
Western Europe	Germany	E-Plus Mobilfunk GmbH & Co. KG	FD-LTE	No data	Trials in progress
Western Europe	Germany	E-Plus Mobilfunk GmbH & Co. KG	TD-LTE	No data	Trials in progress
Western Europe	Germany	O2 Germany	FD-LTE	Jul-11	Operational
Western Europe	Germany	T-Mobile Deutschland GmbH	FD-LTE	Apr-11	Operational
Western Europe	Germany	Vodafone D2 GmbH	FD-LTE	Dec-10	Operational

Region	Country	Operator	Technology	Launch date	Network status
Western Europe	Greece	Cosmote	FD-LTE	Nov-12	Operational
Western Europe	Greece	Vodafone - Panafon SA (Vodafone Greece)	FD-LTE	Nov-12	Operational
Central and Eastern Europe	Hungary	Telenor Hungary (Pannon)	FD-LTE	Jul-12	Operational
Central and Eastern Europe	Hungary	T-Mobile Hungary (MTel)	FD-LTE	Jan-12	Operational
Central and Eastern Europe	Hungary	Vodafone Hungary	FD-LTE	No data	Planned
Western Europe	Ireland	Hutchison 3G Ireland Ltd (3 Ireland)	FD-LTE	Expected 2011	Planned
Western Europe	Ireland	Meteor Mobile Communications Ltd	FD-LTE	No data	Planned
Western Europe	Ireland	O2 Ireland	FD-LTE	No data	Planned
Western Europe	Ireland	Vodafone Ireland	FD-LTE	Expected Q2-2013	Planned
Western Europe	Italy	3 Italy	FD-LTE	Oct-12	Operational
Western Europe	Italy	TIM Italia SpA	FD-LTE	Nov-12	Operational
Western Europe	Italy	Vodafone Omnitel NV (Vodafone Italy)	FD-LTE	Oct-12	Operational
Western Europe	Italy	Wind Telecomunicazion i SpA	FD-LTE	Expected 2013	In deployment
Western Europe	Jersey	Clear Mobitel Jersey	FD-LTE	no data	Planned
Central and Eastern Europe	Latvia	Bite Latvia	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Latvia	Latvijas Mobilais Telefons SIA (LMT) TeliaSonera	FD-LTE	May-11	Operational
Central and Eastern Europe	Latvia	Tele2	FD-LTE	No data	Planned
Central and Eastern Europe	Latvia	Triatel	FD-LTE	No data	Testing
Central and Eastern Europe	Lithuania	Bite Lithuania	FD-LTE	No data	Planned
Central and Eastern Europe	Lithuania	Tele2 Lithuania	FD-LTE	No data	Operational
Central and Eastern Europe	Lithuania	UAB Omnitel Lithuania (TeleSonera)	FD-LTE	Apr-11	Operational

Region	Country	Operator	Technology	Launch date	Network status
Western Europe	Luxembourg	LuxGSM	FD-LTE	No data	Planned
Western Europe	Luxembourg	Orange (Mobistar)	FD-LTE	Expected by 2015	Trials in progress
Western Europe	Luxembourg	Tango	FD-LTE	Oct-12	Operational
Central and Eastern Europe	Moldova	InterDnestrCom (IDC)	FD-LTE	Apr-12	Operational
Central and Eastern Europe	Moldova	Moldcell (TeliaSonera)	FD-LTE	Nov-12	Operational
Central and Eastern Europe	Moldova	Orange Moldova	FD-LTE	Nov-12	Operational
Western Europe	Monaco	Monaco Telecom (C&W)	FD-LTE	Expected 2013	Planned
Central and Eastern Europe	Montenegro	Telenor Montenegro	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Montenegro	Velatel	TD-LTE	No data	Planned
Western Europe	Netherlands	KPN Mobile	FD-LTE	May-12	Operational
Western Europe	Netherlands	Tele2 Netherlands Holding N.V.	FD-LTE	May-12	Operational
Western Europe	Netherlands	T-Mobile Netherlands	FD-LTE	Aug-13	In deployment
Western Europe	Netherlands	Vodafone Netherlands (Vodafone Libertel)	FD-LTE	Feb-13	Operational
Western Europe	Netherlands	Ziggo	FD-LTE	May-12	Operational
Western Europe	Norway	Netcom / TeliaSonera Norway	FD-LTE	Dec-09	Operational
Western Europe	Norway	Telenor ASA	FD-LTE	Oct-12	Operational
Central and Eastern Europe	Poland	Aero2	Dual FD/TD-LTE	Sep-11	Operational
Central and Eastern Europe	Poland	CenterNet / Mobiland	FD-LTE	Sep-10	Operational
Central and Eastern Europe	Poland	PTK Centertel (Orange) and P4 (Play)	FD-LTE	No data	Planned
Central and Eastern Europe	Poland	SferaNet	FD-LTE	Jan-13	Operational
Central and Eastern Europe	Poland	T-Mobile Poland	FD-LTE	No data	Planned
Western Europe	Portugal	Optimus Telecomunicações SA	FD-LTE	Mar-12	Operational
Western Europe	Portugal	Telecomunicações Móveis Nacionais	FD-LTE	Mar-12	Operational

Region	Country	Operator	Technology	Launch date	Network status
		SA (TMN)			
Western Europe	Portugal	Vodafone Portugal	FD-LTE	Mar-12	Operational
Central and Eastern Europe	Romania	Cosmote Romania (formerly Cosmorom)	FD-LTE	Apr-13	Operational
Central and Eastern Europe	Romania	Orange Romania	FD-LTE	Dec-12	Operational
Central and Eastern Europe	Romania	Telemobil SA (ZappMobile)	FD-LTE	No data	Planned
Central and Eastern Europe	Romania	Vodafone Romania	FD-LTE	Nov-12	Operational
Central and Eastern Europe	Russia	Antares	FD-LTE	No data	Planned
Central and Eastern Europe	Russia	Base Telecom	TD-LTE	No data	Planned
Central and Eastern Europe	Russia	Enforta	TD-LTE	No data	Planned
Central and Eastern Europe	Russia	Megafon	TD-LTE	Mar-13	Operational
Central and Eastern Europe	Russia	MTS	TD-LTE	Sep-12	Operational
Central and Eastern Europe	Russia	OAO Voentelecom	TD-LTE	No data	Trials in progress
Central and Eastern Europe	Russia	Osnova	FD-LTE	No data	In deployment
Central and Eastern Europe	Russia	Osnova	TD-LTE	No data	Trials in progress
Central and Eastern Europe	Russia	Rostelecom	TD-LTE	No data	Planned
Central and Eastern Europe	Russia	Sibirtelecom / Svyazinvest	FD-LTE	No data	Planned
Central and Eastern Europe	Russia	Skylink	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Russia	SMARTS Group	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Russia	Tele2	FD-LTE	No data	Planned
Central and Eastern Europe	Russia	Vainah Telecom	TD-LTE	No data	Planned
Central and Eastern Europe	Russia	Vimpelcom /Beeline	FD-LTE	2H 2103	Trials in progress
Central and Eastern Europe	Russia	Yota (Scartel)	TD-LTE	May-12	Operational
Central and Eastern Europe	Slovakia	Orange Slovensko a.s.	FD-LTE	Expected by 2015	Trials in progress

Region	Country	Operator	Technology	Launch date	Network status
Central and Eastern Europe	Slovakia	Telefónica O2 Slovakia s.r.o.	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Slovakia	T-Mobile Slovensko a.s.	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Slovenia	Mobitel d.d.	FD-LTE	Mar-13	Operational
Central and Eastern Europe	Slovenia	Si.mobil – Vodafone	FD-LTE	Jul-12	Operational
Western Europe	Spain	Consortium of Advanced Telecommunications	TD-LTE	No data	Trials in progress
Western Europe	Spain	Orange Spain	FD-LTE	Expected 2012	Planned
Western Europe	Spain	Telefónica Móviles España SA (Movistar)	FD-LTE	No data	Trials in progress
Western Europe	Spain	Vodafone España	FD-LTE	No data	Trials in progress
Western Europe	Sweden	H3G Access (3)	Dual FD/TD-LTE	Apr-12	Operational
Western Europe	Sweden	Tele2 / Telenor (Net4Mobility)	FD-LTE	Nov-10	Operational
Western Europe	Sweden	Tele2 / Telenor (Net4Mobility)	LTE-A	No data	Trials in progress
Western Europe	Sweden	TeliaSonera Sweden	FD-LTE	Dec-09	Operational
Western Europe	Switzerland	Orange Communications SA	FD-LTE	Jun-13	In deployment
Western Europe	Switzerland	Sunrise	FD-LTE	Jun-13	Planned
Western Europe	Switzerland	Swisscom Mobile	FD-LTE	Nov-12	Operational
Central and Eastern Europe	Turkey	Avea Iletisim Hizmetleri AS	FD-LTE	No data	Planned
Central and Eastern Europe	Turkey	Turkcell Iletisim Hizmetleri AS	FD-LTE	No data	Trials in progress
Central and Eastern Europe	Turkey	Vodafone Telekomünikasyon AS	FD-LTE	No data	Planned
Western Europe	UK	Clear Mobitel Jersey	FD-LTE	Mar-11	Operational
Western Europe	UK	Everything Everywhere	FD-LTE	Oct-12	Operational
Western Europe	UK	Hutchison 3G UK Ltd	FD-LTE	Expected 2013	Planned
Western Europe	UK	Manx Telecom	FD-LTE	No data	Planned

Region	Country	Operator	Technology	Launch date	Network status
Western Europe	UK	O2 UK	FD-LTE	Expected 2013	Planned
Western Europe	UK	UK Broadband	TD-LTE	Jun-12	Operational
Western Europe	UK	Vodafone Ltd (Vodafone UK)	FD-LTE	Expected 2013	Planned