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Report for the European Railway Agency

Survey on operational communications

(Study for the evolution of the railway communication system)

25 February 2014 • David Taylor, Nils Lofmark, Maria McKavanagh

Introduction

Current status

Spectrum evolution

Future trends

Analysis of future scenarios

Terminal evolution

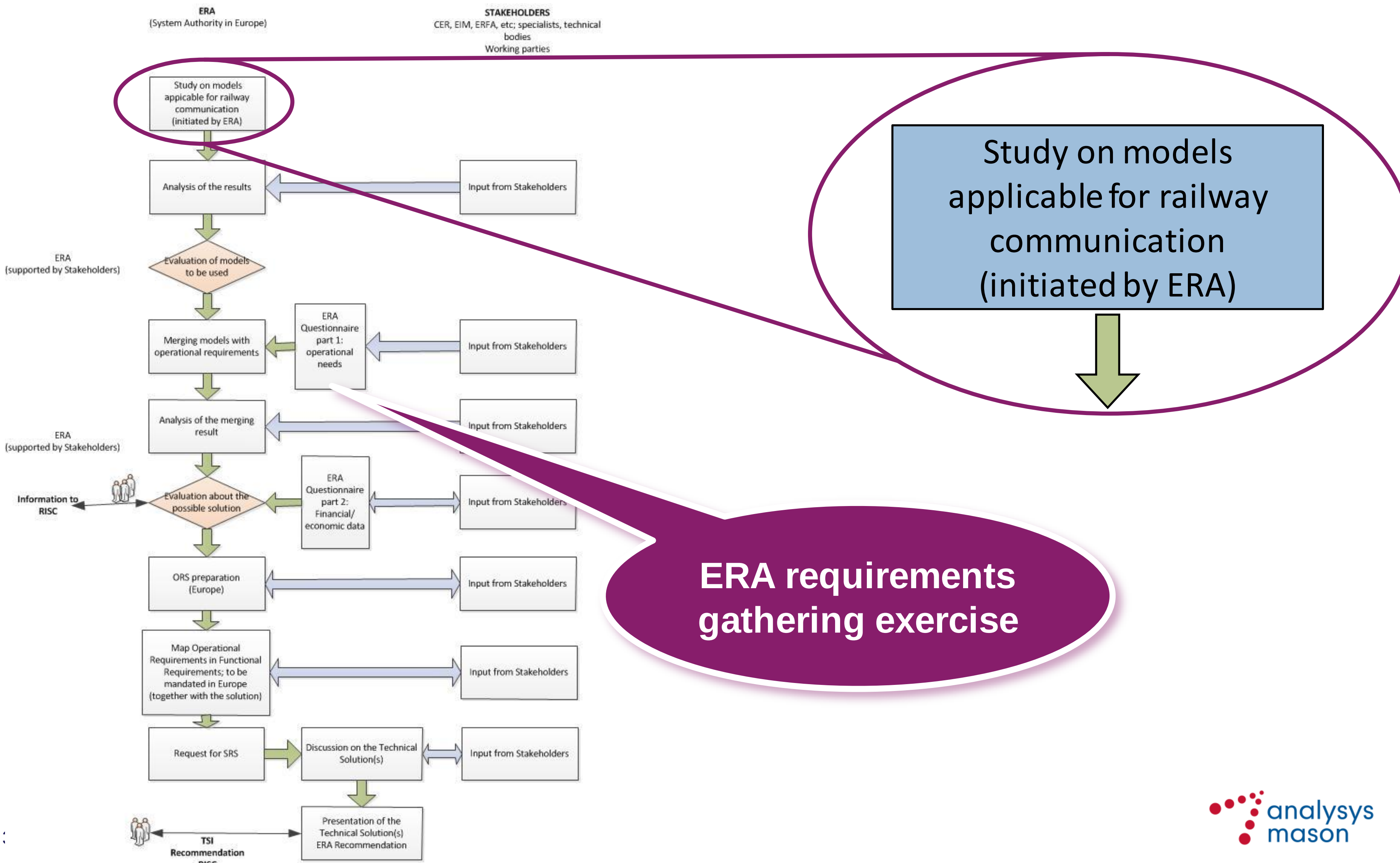
Strategy for system replacement

Summary

This document captures the findings of a study into operational communications for railways

- The 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 which required
  - an investigation of the current situation and future trends
    - for railways and other users of critical communications
  - the development of potential scenarios for future evolution
  - an assessment of the scenarios to determine the merits of each

This study is part of a programme of activities for future railway communication systems



The scope of the study required research into the current situation and an assessment of future trends

Phases

Research

Assessing current situation…

…in rail and related sectors (e.g. other transport sectors, public safety)

Scenario development and analysis

Determining future trends…

…in rail and related sectors, covering

- operating models
- spectrum
- bandwidth requirements

…as well as assessing potential sharing models (e.g. with public safety)

Final reporting

Developing strategies…

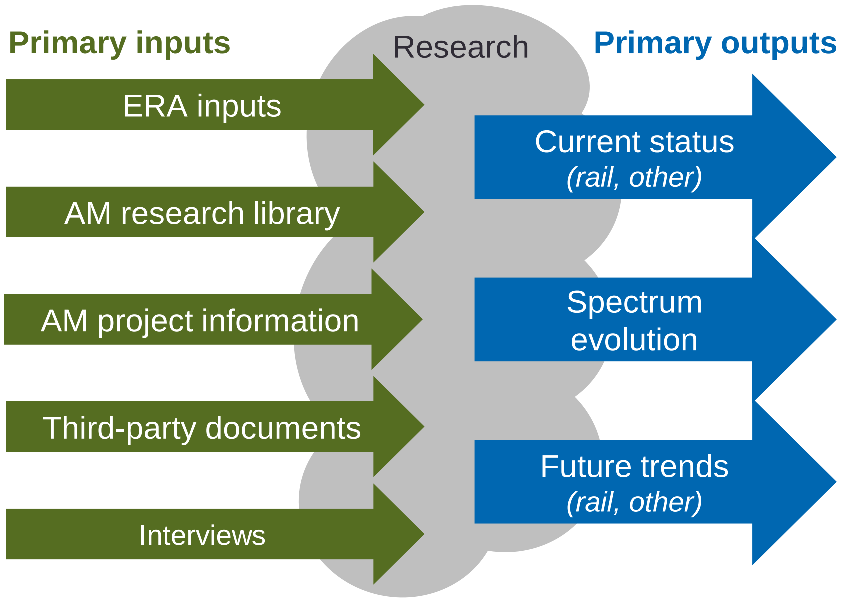
…for future evolution of

- terminals
- network systems

…as well as providing overall conclusions and recommendations

Information for the study came from both research and interviews

Primary research inputs and outputs



Interview summary

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
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

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Rail sector inside Europe

- Operational communications are carried within main-line services using **GSM-R** which is
  - an adaptation of GSM to provide features for railway operation
  - mandated as the interoperability standard for certain cross border lines within Europe through the CCS-TSI
  - one of the bearers for ETCS, together forming the ERTMS standard
- Ownership of infrastructure (including telecoms) usually lies with the state
- Network capacity is not a concern for voice services, but is for ETCS while circuit-mode data is used
- Voice functionality is regarded as absolutely vital, as is the **Railway Emergency Call (REC)**

Other sectors

- **Public safety**
  - two major technologies, TETRA and TETRAPOL, for voice and low-speed critical data services
  - increasingly relies on commercial networks for data
  - some interoperability, mainly by extending the network
- **Utilities**
  - use radio networks to communicate with an estate of fixed assets for monitoring and control, rather than voice services
  - use PMR, cellular, satellite and DSL
- **Transport**
  - little use of GSM-R, rather a wide range of private and public solutions, often with hybrid solutions for voice and data

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Sub-1GHz spectrum for railways would make the communications system evolution easier

- Due to channel bandwidths it would not be feasible to operate a narrowband system, e.g. GSM-R, and a broadband system; this creates restrictions when considering an on-frequency migration to a new technology solution
- The availability of sub-1GHz spectrum would simplify the transition as it may allow re-use of sites
  - however, identifying where the spectrum could come from, and justifying the need for dedicated spectrum would be difficult
- While the concept of spectrum sharing with a like-minded organisation has merit, and would provide economic benefit, it is unlikely to be achievable on a pan-European basis
  - since such like-minded organisations operate on a national basis

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Future communication trends in the mobile market [1/2]

- The largest wireless telecoms markets in Western Europe are Germany, Italy and the United Kingdom with all markets at over 100% penetration
  - LTE is becoming established with 77 networks in Western Europe, and 64 networks in Central and Eastern Europe
- In **Western Europe**, the total telecoms market is expected to shrink from EUR274 billion in 2012 to EUR239 billion by 2018
  - which explains the interest in other revenue streams, e.g. M2M
- In **Central and Eastern Europe**, telecoms operators are also experiencing market maturity with service revenue expected to peak in 2013

Future communication trends in the mobile market [2/2]

- **LTE** will become the dominant technology for commercial networks in Western Europe of the next five years
  - based on the ten-year cycle which happened with 2G and 3G, a replacement technology (known by some as ‘5G’) should be implemented by 2020–2022
- **Coverage** is defined in terms of percentage of the population covered rather than geographic coverage
  - the degree of coverage will reduce for higher data rate technologies
  - the trend is for MNOs and government to improve coverage by filling in ‘not spots’ where there are users who are not able to access mobile networks

Future communication trends in specific sectors [1/2]

- The primary trend in **rail** operational communications is an increase in data connectivity
  - in parallel to moving to an IP environment for signalling
- In **bus services**, more and more data is being used for passenger information and fare collection
  - with a need to control emissions there is a demand to pass information on about the performance of the bus and engine
- In **civil aviation**, data use is increasing, to provide more accurate data than is possible with voice transmissions

Future communication trends in specific sectors [2/2]

- **Mobile broadband** is the overriding future trend in **public safety**, however, there is still a recognised need for voice applications, specifically group voice
  - users have a need for a very fast call set-up of less than one second so most of the current mobile networks are unsuitable
- **Utilities** are seeing a need for more radiocommunications
  - smart metering is increasing with a wide range of communication bearers used, e.g. signalling over the power line
  - smart grid is a critical application that requires a fine level of control with a fast response time, otherwise there is a risk of instability

Software-defined radio could bring economic and deployment benefits to the railways

- As each new wireless technology standard is defined, new cab radios have to be procured
  - resulting in migration issues due to some railways using legacy technology
- Implementing radio functions as software modules would allow different standards to co-exist in the same equipment, manually selected or implicitly selected by the network
- The SDR could be coupled with a communications package that it would reconfigure to provide the optimal RF link
  - selecting the frequency and modulation scheme to match the local infrastructure

A minimum set of expandable parameters must be supported by all railways to ensure interoperability

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Identifying the requirements allowed a range of hypotheses to be made

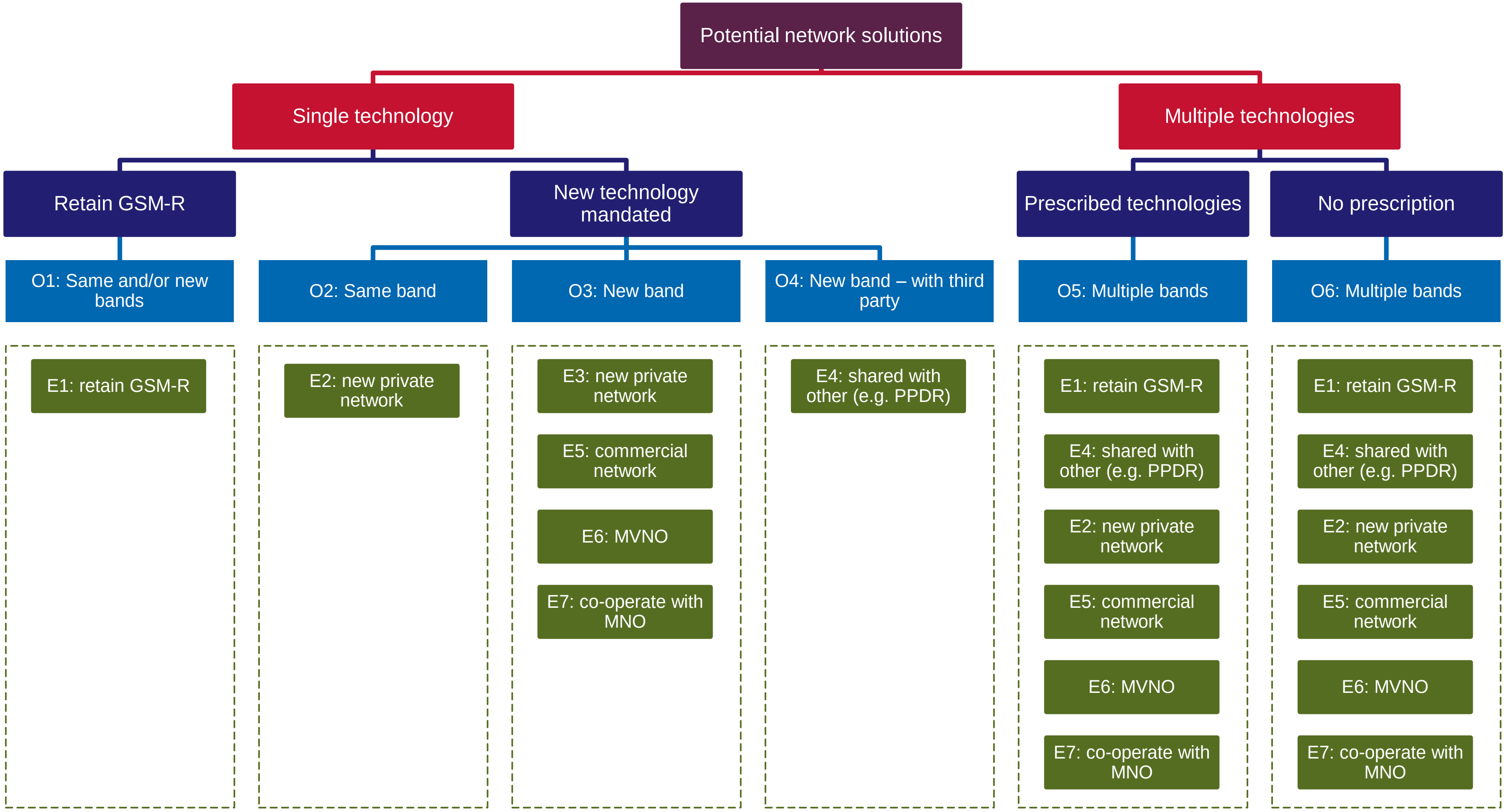
Strategic objectives	• Interoperability
	• Service continuity
	• Flexibility
	• Economic efficiency
Operational requirements	• Communications to/from dispatcher
	• ETCS support
	• Railway Emergency Call

- **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*

- Four high-level strategic objectives influencing the study have been identified
- The operational requirements are being considered in a parallel study
- Hypotheses have been proposed to consider changes to the current environment that will influence options for the period relevant to the study (15+ years)

These objectives and hypotheses allowed a range of options to be developed

For each future option there are example scenarios that could be implemented



SWOT analysis: strengths

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

SWOT analysis: weaknesses

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

Example scenario	Weaknesses
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
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

SWOT analysis: opportunities

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

Example scenario	*Opportunities*
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
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

SWOT analysis: threats

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

Options

The options were assessed for their fit against the high-level strategic objectives and operational requirements

Option	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*	

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In the future, terminals may evolve to have more than one radio module

- The train-borne kit (**cab radio**) currently provides the GSM-R functionality
  - it has a single radio module supporting GSM and GPRS in the GSM 900 band
- The cab radios used in county rail in Australia may indicate what the future will look like
  - they have five transmitter/receivers (GSM-R, Satellite, UHF and two 3G) as well as a GPS receiver
- There is a need to separate the GSM-R voice functionality from the ETCS functionality for flexibility
- Any future communications will only support voice over IP and so the functionality of GSM-R voice services will need to be developed as an application running over the future radio network

Multi-mode terminals could be used as a tool for transition and provide interoperability

- IMs will have difficulty supporting legacy radio units after they transition to the new technology
  - therefore the terminal should be considered as a transition tool, with a ‘legacy mode’
- **Interoperability** in the future can be achieved using multi-mode terminals which may also be multi technology
  - the IM could specify the mode required to operate on its tracks
- GSM-R is predominantly a solution for communications with train-mounted radios, but future networks should be able to support portables

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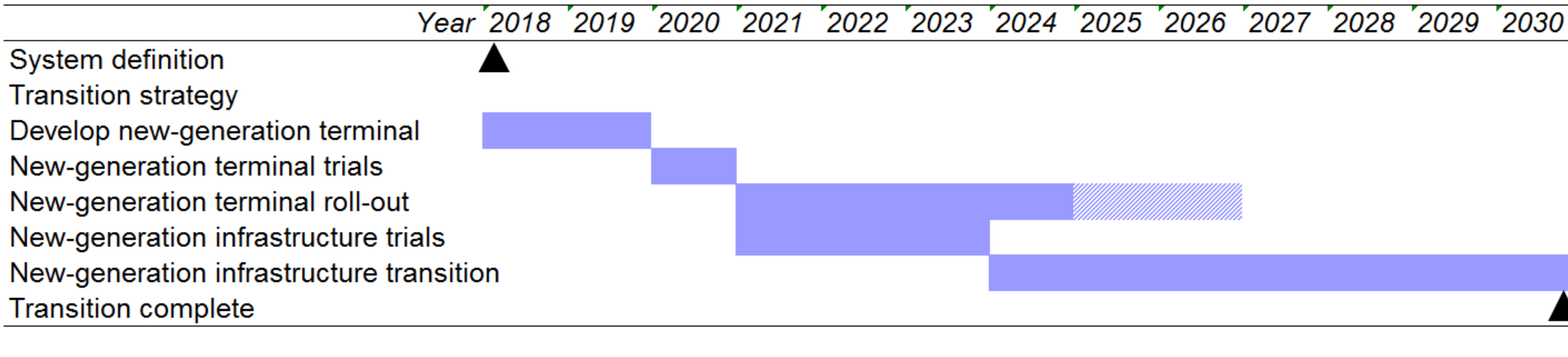
Low-latency, high-data-rate technologies will be required with separation from the bearer

- **Moderate levels of data** will be required in the future and GPRS will not be suitable
  - 4G may be better due to its low latency and high data rates
- However, in the 2020–2022 timeframe, other more advanced technologies will develop, so any future solution for rail should be structured to allow continued evolution
- **Bearer independence** should be encouraged, while still providing suitable interoperability
  - rather than optimising the bearer for signalling, a specification should be provided to the bearer with characteristics such as error performance and latency

Possible scenario for the transition of terminals



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- For main-line train services there is good use of GSM-R as an interoperable standard
- ETCS is being rolled out, however, circuit-mode operation on GSM-R does not give enough capacity and GPRS is required
- Use of current spectrum for future solutions is possible, and sub-1GHz is ideal for the future, but the transition would be complex
- Options for the future policy have been identified and considered against the strategic objectives and operational requirements
- However it is clear that while evolution is necessary, it is going to be challenging, but brings benefits

Next steps: this study is part of a larger programme of activities being carried out by ERA; the findings from this report will be used to inform the subsequent activities which will take place in 2014 and will result in a finalised strategy

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