GSM-R Procurement Guide

UNION INTERNATIONALE
DES CHEMINS DE FER

INTERNATIONALER
EISENBAHNVERBAND

INTERNATIONAL UNION
OF RAILWAYS

February 2007
www.uic.asso.fr

2007

Paris, February 2007

Document data sheet

Title of the document	**GSM-R procurement guide**
Version number and date	**V. 5.0 – 01.02.2007**
Number of pages	139 pages
Filing name	CLA111D005-5.0
Prepared by	A.F. Neele – S.T.G. Wootton
Checked by	K. Konrad – D. Mandoc
Approved by	G. Dalton

ISBN: 2-7461-1315-5

List of contents

List of abbreviations

ARFCN	Absolute Radio Frequency Channel Number
ASCI	Advanced Speech Call Items
BER	Bit Error Rate
BSC	Base Station Controller
BSS	Base Station Sub-System
BTS	Base Transceiver Station
C/A	Carrier to Adjacent (ratio)
C/I	Carrier to Interference (ratio)
CENELEC	European Committee for Electro-technical Standardisation
CEPT	Conference of European Postal and Telecoms administrations
CUG	Closed User Group
DSD	Driver Safety Device
DSS1	Digital Subscriber Signalling 1
E-FRS	EIRENE Functional Requirements Specification
eLDA	enhanced Location Dependent Addressing
E-SRS	EIRENE System Requirements Specification
ECMA	European Computer Manufacturers' Association
EIRENE	European Integrated Railway Enhanced Network
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
eMLPP	enhanced Multi-Level Precedence and Pre-emption
ENAN	EIRENE Network Access Number
ENF	European Numbering Forum
EPT	EIRENE Project Team

ERC	European Radio communications Committee
ERIG	European Radio Implementation Group
ERO	European Radio Office
ETCS	European Train Control System
ETNS	European Telecommunications Numbering Space
ETSI	European Telecommunications Standards Institute
EUG	EIRENE User Group
FFFIS	Form Fit Functional Interface Specification
FRS	Functional Requirements Specification
GCR	Group Call Register
GIS	Geographical Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HLR	Home Location Register
HMI	Human-Machine Interface
IFN	International Functional Number
IN	Intelligent Node
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
ITT	Invitation To Tender
ITU	International Telecommunications Union
MAP	Mobile Application Part
ME	Mobile Equipment

MMI	Man-Machine Interface
MORANE	MObile radio for RAilway Networks in Europe
MoU	Memorandum of Understanding
MS	Mobile Station
MSC	Mobile (services) Switching Centre
MSISDN	Mobile Station ISDN Number
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NFN	National Functional Number
NMF	Network Management Forum
NSS	Network Sub-System
OMC	Operation and Maintenance Centre
OSI	Open System Interface
PAMR	Public Access Mobile Radio
PMR	Private Mobile Radio
PSDN	Public Switched Data Network
PSTN	Public Switched Telephone Network
RAC	Railways Access Code
RAM	Reliability, Availability and Maintainability
RBC	Radio Block Centre
RxQual	Received Signal Quality
SIM	Subscriber Identity Module
SLA	Service Level Agreement
SMS	Short Message Service

SRS	System Requirements Specification
SS7	Signalling System number 7
SSRS	Sub-System Requirements Specification
TMN	Telecommunications Managed Network
TRX	Transceiver
TSI	Technical Specification for Interoperability
UIC	Union Internationale des Chemins de Fer
UIN	User Identifier Number
UN	User Number
USSD	Unstructured Supplementary Service Data
UUS1	User-to-User Signalling type 1
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
VLR	Visitor Location Register
VPN	Virtual Private Network

1 Procurement guide overview

1.1 General

1.1.1 This procurement guide was developed by Detica Limited for UIC Project EIRENE (the project which created the EIRENE Specifications for the GSM-R system). During 2002, the Procurement Guide has been updated to reflect some of the main developments and changes that have occurred since it was originally written in 1998. This update has been performed under the work of the ERTMS/GSM-R project, which has taken over the management of the EIRENE Specifications from UIC project EIRENE (which closed in 2000).

1.1.2 The purpose of the procurement guide is to provide guidance on the use of the EIRENE System Requirements Specification and the EIRENE Functional Requirements Specification to assist national railways with the procurement of a GSM-R radio system that meets the EIRENE Specifications.

1.2 Procurement guide aims and objectives

1.2.1 The EIRENE System Requirements and Functional Requirements Specifications allow for some flexibility in the allowed procurement approaches and implementation options for an EIRENE-compliant integrated radio communications system. In order to ensure interoperability between national GSM-R networks, it is necessary to provide some guidance on the development of national procurement specifications. The procurement guide is intended to provide help with the interpretation of the EIRENE Specifications in order to:

- provide a framework for interoperability;
- ensure common interpretation of requirements in the context of how EIRENE-compliant systems may be implemented;
- provide guidance in areas where there is flexibility in the implementation options.

1.2.2 The remainder of this section outlines the aspects that are covered by the procurement guide in order to meet these requirements.

1.3 Document scope

1.3.1 In order to provide practical assistance to the implementation of an EIRENE-compliant radio network, this procurement guide:

- provides an overview of GSM-R and gives a single point of reference for all of the relevant documentation;
- describes the various design options available and how these implementations can be made to result in an interoperable EIRENE-compliant system;
- provides guidance on the use of the EIRENE System Requirements Specification and Functional Requirements Specification and explains how this information may be used to develop a national procurement strategy;

– provides guidance on issues, which have an effect on implementation and interoperability, but are not comprehensively covered in the EIRENE Specifications.

1.4 System lifecycle overview

1.4.1 This sub-section provides a summary of the main activities that are likely to be undertaken as part of the full lifecycle of a GSM-R radio system. It also indicates which of these phases are covered by this guide.

1.4.2 The full system lifecycle can be divided into five distinct phases as follows:

1 System planning and specification. This is the preliminary phase of system procurement, mainly dealing with the feasibility and viability of the new system. This phase therefore includes activities such as:

- system feasibility study;
- development of project remit;
- requirements capture;
- business case development;
- system specification;
- procurement strategy definition;
- planning of implementation and migration.

2 Tendering. Once the business case has been accepted and the user requirements defined, the next step is to procure the system. This includes taking the following steps:

- ITT development;
- tendering, which may include a requirement for issuing OJEC notices;
- evaluation of tenders and short-listing of potential suppliers;
- negotiations with potential suppliers;
- final selection of supplier(s);
- contract award.

3 Implementation. Once the contracts have been awarded, the system needs to be implemented. This phase will typically include the following elements:

- development of an operational system;
- installation, testing and commissioning of the system;
- migration from current system(s).

4 Operation and maintenance. Once implementation of the system has been completed, the system enters a 'steady state' situation, in which the system will be operated and maintained. This phase will typically involve the following activities:

– operation and maintenance of the system;

– introduction of minor changes to the system;

– introduction of major changes to the system and intermediate upgrades to allow the system to meet changing demands.

5 Decommissioning. At the end of the life of the system, the current system will be replaced by a new system. The procurement and implementation of this new system will follow a similar approach towards procurement and implementation. Once the new system has become operational (ie the system lifecycle has entered stage 4), the old system will be decommissioned.

1.4.3 The core function of the procurement guide is to give assistance with the planning of the system, the system specification and the overall procurement strategy. There are, however, a number of aspects of the GSM-R system lifecycle that this document does not cover. These include system implementation strategy, system operation and maintenance considerations. Furthermore, it is assumed that individual railways will have their own procedures for the process of tendering. It is therefore outside the scope of this guide to provide assistance with tendering aspects.

1.4.4 Figure 1-1 provides a graphical overview of the activities undertake during each stage of the full system lifecycle. This flowchart is also intended to be used as a 'road map' for this document. It highlights the activities within phases 1 and 2 that are covered by this procurement guide, indicating the sections of the document where relevant information can be found.

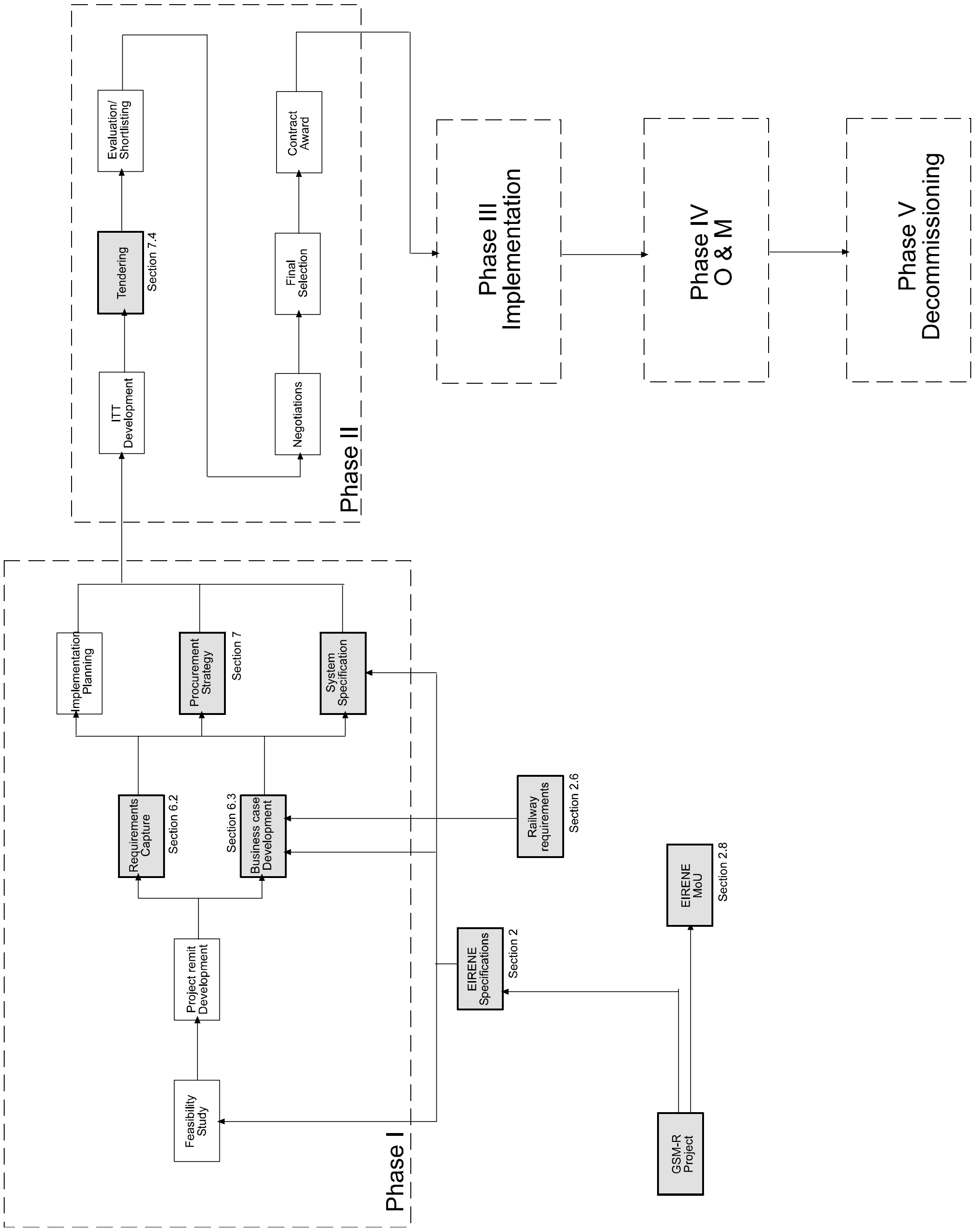

Figure 1-1: Full system lifecycle overview

1.5 Contents of this document

1.5.1 The following list provides a summary of the contents of this document, stating the issues that will be dealt with in each of the sections:

2 **Overview of GSM-R:** Provides an overview of the integrated radio system, detailing what is covered in the EIRENE Specifications and what must be added in order to provide the required end-to-end functionality. In addition, this section considers the definition of railway communications requirements with particular reference to interoperability. It also gives a brief overview of the organisational structure of the GSM-R Project.

3 **System infrastructure provision:** This section deals with technical aspects of procurement and implementation of the GSM-R system with particular reference to the implications of using a private, public or hybrid GSM network.

4 **International interoperability considerations:** This section details some of the functional options allowed by the EIRENE Specifications (such as flexibility in call routing, the numbering plan and location dependant addressing) and considers their implications for international interoperability between GSM-R networks.

5 **System planning and specification:** Provides an overview of the system planning and specification process. It details aspects requiring special attention in this initial stage of the system procurement cycle.

6 **Requirements capture and business case development**. These two activities form an important part of the preliminary phase in the system lifecycle. This section provides general guidelines on how to perform these activities.

7 **Procurement strategy:** Provides guidance on the overall procurement strategy. It considers and discusses the merits of different procurement and contracting strategies.

A **Documentation overview:** This appendix provides an overview of GSM-R documentation, indicating the status of the documents.

B **Examples of available terminal equipment and accessories:** This appendix provides a list of terminal equipment and accessories that are available at the time of writing this report.

2 Overview of GSM-R

2.1 Introduction

2.1.1 The first step in the procurement of an EIRENE-compliant integrated radio communications system is to consider the components of the system, what guidance has been given in the EIRENE Specifications and what aspects of procurement need to be addressed by the individual railways themselves.

2.1.2 This section provides a high-level overview of a generic integrated communications network, identifying those elements covered by the EIRENE System Specifications and those requiring consideration by individual railways. In addition, this section highlights the aspects related to the management and harmonisation of GSM-R across Europe.

2.2 Integrated radio communications system overview

2.2.1 An EIRENE-compliant integrated radio communications system for railway applications will consist of the following main elements:

- mobile network and associated equipment;
- fixed network and associated equipment;
- mobile and fixed terminal equipment;
- interfaces to railway equipment (eg signalling system) and other equipment;
- system management equipment.

2.2.2 Each national GSM-R network may be based on one or more mobile GSM networks, interconnected either directly or indirectly via fixed networks. These physical networks need to be connected together such that they form a single logical network. In addition, National GSM-R networks may be interconnected to provide a consistent service across a number of countries.

2.2.3 Figure 2-1 shows how the system elements relate to each other for the case of interoperation between two separate national GSM-R networks (Country A and Country B). The dotted arrows in the diagram represent logical links between the system elements, although not all of these links will be present for some of the possible EIRENE-compliant system implementation options.

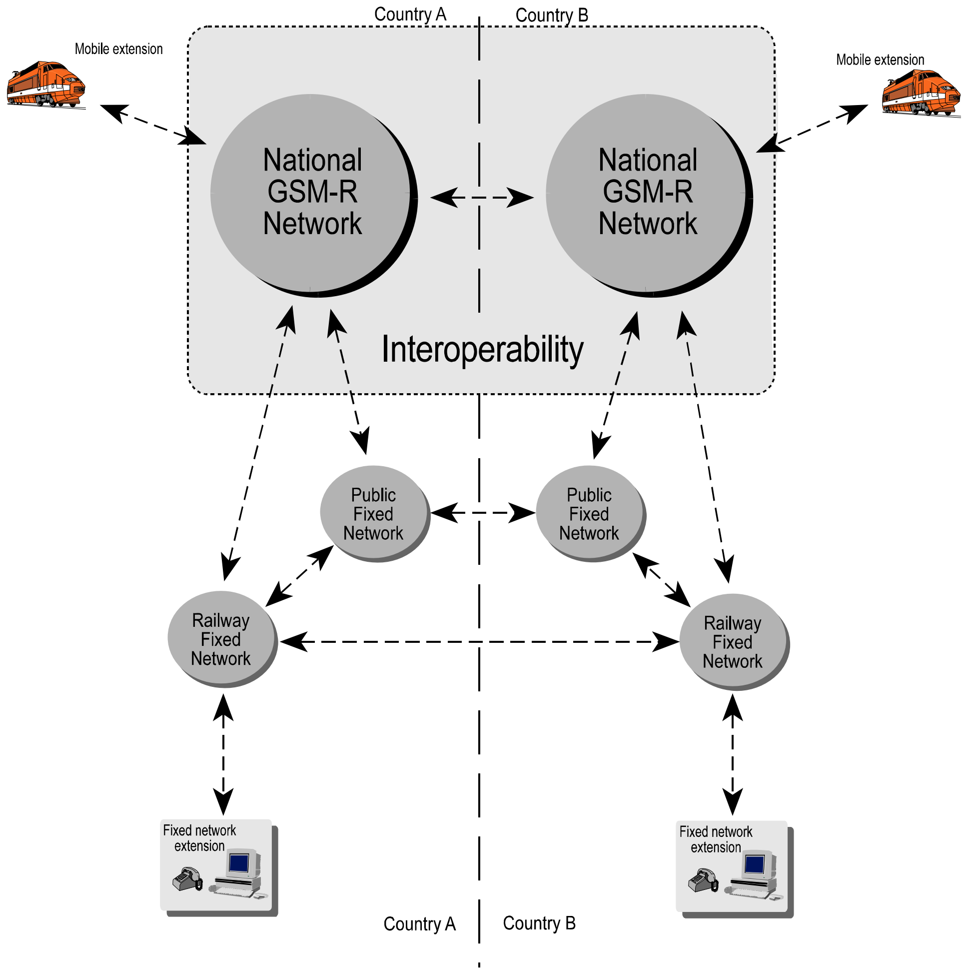

Figure 2-1: National Networks and their logical interconnections

Mobile network

2.2.4 The GSM-R network is based on GSM as the radio bearer and comprises the following elements:

- **Base Station Sub-Systems (BSSs)** of Base Station Controllers (BSCs) controlling Base Transceiver Stations (BTSs) each containing a number of transceivers (TRXs).
- **Network Sub-Systems (NSSs)** interfacing to the BSS via the GSM 'A' interface. The NSS contains Mobile service Switching Centres (MSCs) with primary responsibility for call control. The MSC is supported by a Home Location Register (HLR) holding subscriber details on a permanent basis, and a Visitor Location Register (VLR) containing temporary details of subscribers active within the MSC area.
- **Mobile Equipment (ME)** interfacing to the BSS via the air interface.
- **Subscriber Identity Modules (SIMs)** containing information specific to single subscribers. A standardised interface links mobile equipment to SIM cards. A SIM and ME combined are termed a Mobile Station (MS).

– **Operation and Maintenance Centre (OMC)** responsible for fault monitoring and maintenance of the mobile network.

– **Management Centre** responsible for network configuration, network performance monitoring, management of subscribers to the mobile network, etc.

– **Billing Platform (optional)** to invoice subscribers for the GSM services provided.

– **Fixed links** these are required to connect together the components of the mobile network (eg BSC to BTS links, NSS to Billing Platform links, etc).

2.2.5 The standard GSM system architecture is shown in figure 2-2:

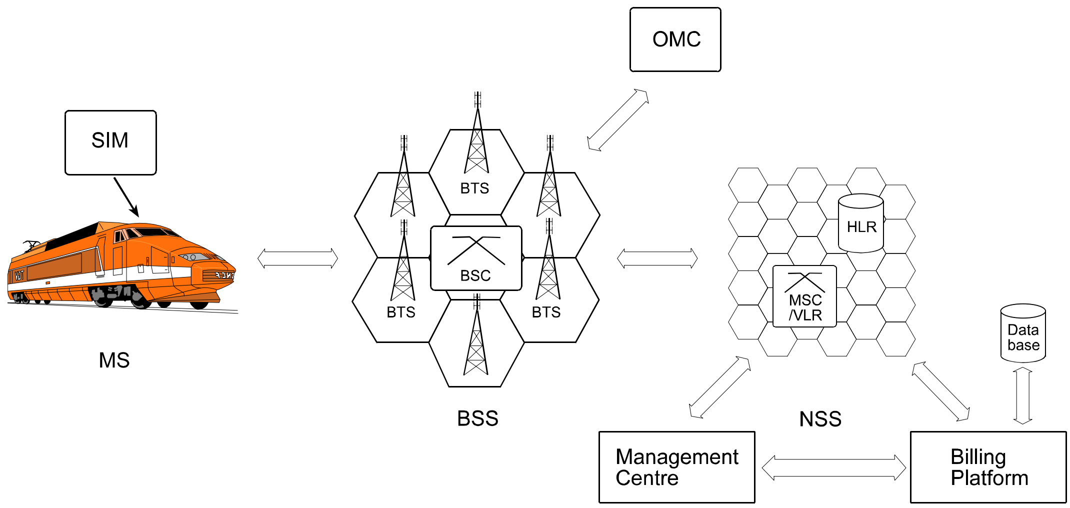

Figure 2-2: Overview of GSM architecture

2.2.6 The basic GSM infrastructure is supplemented by Group Call Registers (GCRs) holding the information necessary to support the voice broadcast and group call services.

2.2.7 Some GSM networks also contain a Short Message Service Centre (SMSC) to be interfaced to the GSM network in order to support specific Short Messaging Service (SMS) applications.

Fixed network

2.2.8 The fixed network implementation depends on the requirements of the individual railway and consists of private railway-specific fixed networks, public fixed networks or a combination of the two.

2.2.9 Whichever type of implementation is chosen, the fixed network will consist of at least the following elements:

- **network switches**: these are required to route the calls through the network to the correct called party;
- **fixed network links**;
- **network termination points**: these are the locations at which terminal equipment can be connected to the fixed network, where fixed networks may be interconnected and where railway-specific supporting systems can be connected to the fixed network;
- **management centre**: required for the configuration of the network, performance monitoring, fault management, management of subscribers, etc.

2.2.10 The fixed network may provide connections between the GSM network and fixed railway locations (control centres, stations, etc). Furthermore, it may provide interfaces to signalling systems and other railway-specific equipment to support the functionality of the integrated radio communications system.

2.2.11 The individual railway is free to define the fixed network and the technology on which this is based. In some cases, the fixed network may be privately owned by the railway. Alternatively, it may be provided by a third party network operator, in which case the fixed network could be a Virtual Private Network (VPN) and the physical network infrastructure will be shared with other users. It should be noted that although there is freedom in the choice of fixed network implementation, the fixed network must provide compatible interfaces and support specified services to ensure the required end-to-end functionality.

Terminal equipment

2.2.12 The terminal equipment for an integrated radio communications system consists of the following elements:

- **mobile equipment**: the main items of which are the mobile terminals, which are located in the drivers' cabs (cab radios). This equipment is either stand-alone and provides only driver-to-ground communications, or as in most cases, the cab radio will be connected to a number of other on-board systems (for example, the public address system). In addition to the cab radio, there will be provision of portable GSM handsets which may be issued to various other users, both on the train and track-side;
- **fixed equipment**: this consists primarily of the consoles used by controllers. In addition, there may be several other terminals, which are used by train operators, maintenance teams, etc.

2.2.13 Railways need to consider the use of International Mobile Equipment Identities (IMEIs) to be able to identify and prevent the use of stolen equipment and equipment which should not be allowed in their network for technical reasons. Mobile equipment identities are managed via black, white and grey lists in the Equipment Identity Register (EIR) and the Central Equipment Identity Register CEIR. The security of the IMEI is vital to the operation of the EIR and CEIR.

2.2.14 There are a number of guidelines that need to be adhered to if the IMEI is to be successfully implemented allowing the use of EIR and CEIR equipment. Failure to do so will make it impossible to implement EIR and CEIR equipment effectively. This information is available from http://www.3gpp.org/.

Network management

2.2.15 In order to operate a communications network, additional equipment is required for the purposes of network management. Equipment may be dedicated to a particular part of the network, or the entire network may be managed by a single network management system. This depends on the way in which the network is procured and implemented.

2.2.16 The basic functionality offered should take the form of distributed network management; to include fault, configuration, accounting, performance and security management functions.

2.3 EIRENE Specifications

2.3.1 The UIC project EIRENE developed a set of specifications for the European railways that form part of the specification for technical interoperability as required by the EC Directive for interoperability of the Trans-European high speed rail system (see below).

2.3.2 The EIRENE Specifications define a radio system satisfying the mobile communications requirements of the European railways. They encompass ground-to-train voice and data communications, together with the ground-based mobile communications needs of track-side workers, station and depot staff and railway administrative and managerial personnel. The application of the specifications will ensure interoperability for trains and staff crossing national and other borders between systems. It also intends to provide manufacturing economies of scale wherever practical.

2.3.3 The EIRENE Specifications consist of:

- **EIRENE Functional Requirements Specification (E-FRS)**: defines a set of high-level functional requirements for the GSM-R railway radio system. This specification facilitates international interoperability between national railways by ensuring that core railway functionality is provided.
- **EIRENE System Requirements Specification (E-SRS)**: defines the set of technical requirements and constraints in order to ensure international interoperability between national railways. It includes the architecture of the target on-board and track-side systems with references to the detailed specifications defining standardised interfaces. The E-SRS contains much of the information and specifications key to achieving international interoperability.
- **MORANE Specifications:** This is a set of detailed technical specifications consisting of the following documents:

- **MORANE Sub System Requirements Specification (SSRS)**: Specifies all the functions which have to be implemented on the GSM equipment in order to fulfil all requirements identified in the E-FRS and E-SRS;
- **MORANE Form Fit Functional Specifications (FFFS)**: details the implementation of functions required from the various network components to meet the technical system requirements defined in the higher-level system specifications;
- **MORANE Functional Interface Specifications (FIS)**: defines the interfaces between network components required to meet the system requirements defined in the higher-level system specifications.

2.3.4 The specifications also make reference to European Standards as well as GSM Technical Specifications and 3GPP Specifications. Technical advice on the contents of these specifications can be obtained from the following bodies:

- UIC (http://www.uic.asso.fr);
- European Radio Implementation Group (http://gsm-r.uic.asso.fr)*;
- ETSI (http://www.etsi.org);
- 3GPP (http://www.3gpp.org);
- CEPT (http://www.cept.org);
- GSM Association (http://www.gsmworld.com).

* The European Radio Implementation Group (ERIG) can provide advice and guidance on the EIRENE and MORANE Specifications.

2.4 Areas covered by the EIRENE Specifications

2.4.1 This section gives an outline overview of the aspects of the integrated radio communications system covered by the EIRENE Specifications by taking each section of the E-SRS and summarising its content and purpose.

2.4.2 It should be noted that the EIRENE and MORANE Specifications are designed to provide the minimum set of requirements necessary to ensure international interoperability between GSM-R networks. Therefore, some additional requirements capture and specification may be necessary to integrate the GSM-R network into the national operational railway at both a systems and procedural level.

2.4.3 A national GSM-R specification would then be produced and used as the basis for the tender documentation necessary to support the procurement of each railway's national network. Railways must to ensure that the mandatory requirements of the EIRENE and MORANE specifications are fully taken into account when developing their national GSM-R specifications.

2.4.4 The areas covered by each section in the E-SRS can be summarised as follows:

- **network services**: this provides an overview of the network services that must be supported by the mobile radio system. The services are grouped as:
  - **GSM Phase 2 tele-services** concerning bearer and supplementary services;
  - **GSM Phase 2+ services** encompassing a number of services at the system level (including the railway driven features such as voice group calls, broadcast calls and priority and pre-emption). Rail specific services are mandated, although other advanced features are optional. Individual operators may choose whether they wish to offer these services based on their individual requirements and objectives. Phase 2+ is currently evolving with new standards being added as required;
  - **railway-specific services** not part of the GSM functionality specified by ETSI; such as functional addressing and railway emergency calls;
- **network planning**: this section draws together specifications and information related to the planning of an GSM-R network, and provides guidance on target performance levels for GSM coverage, hand-over and cell selection, call set-up time requirement and broadcast and group call areas;
- **mobile equipment specification**: within EIRENE, three types of mobile radio are identified and their requirements are covered by four separate sections of the system specifications as follows:
  - **core specification:** this provides an overview of the basic services, facilities and features that an EIRENE-compliant radio must possess to ensure interoperability;
  - **cab radio specification:** this section considers in detail the specific requirements placed on the cab radio. It identifies the system requirements for the radio and the HMI and how the functionality is to be provided;
  - **general purpose radio:** this section defines the functions and physical properties required from an EIRENE-compliant general purpose radio;
  - **operational radio:** this section defines the functions and physical properties required from an EIRENE-compliant operational radio (based on the general purpose radio but with the addition of functions to support railway operations);
- **numbering plan & call routing**: the following issues are amongst those addressed:
  - numbering plan requirements;
  - numbering plan constraints;
  - structure of Functional Numbers;
  - EIRENE numbering plan;
- **subscriber management**: this is a particular aspect of system management dealing with the requirements for provision of subscription details and other user information stored in the network. In particular, requirements for call priorities, encryption and authentication, broadcasts and Closed User Groups are detailed;

- **modes of operation**: the alternative modes to the standard mode of operation for GSM-R systems are outlined as follows:
  - **railway emergency calls:** this section describes the handling of high priority voice calls for railway operational emergencies;
  - **shunting mode**: this will be specified in later versions of the E-SRS. Shunting mode is the term used to describe the application that will regulate and control user access to facilities and features in the mobile while it is being used for shunting communications;
  - **direct mode**: this section states that the implementation of direct mode communication is optional, however in the cases where it is implemented mandatory requirements are stated. Direct mode allows mobile radio users to communicate over short distances without using the mobile network infrastructure. This mode is intended to provide short range fall-back communications between drivers and track-side personnel in the event of the failure of the mobile telephony services normally available.

2.5 Areas not covered by EIRENE Specifications

2.5.1 It should be noted that there are a number of components, essential for the functioning of an integrated radio communication system (although not directly affecting international interoperability), which are not covered in the EIRENE Specifications. These include:

- **fixed network elements**: the complete integrated communications system not only consists of the mobile network, it will also require an extensive fixed network consisting of links, switches and terminal equipment. This part of the network will require specification, with particular respect to RAM, network interconnections and capacity. It should be noted that in many cases this infrastructure already exists;
- **network services**: the EIRENE Specifications detail which services need to be supported by the mobile part of the network in order to achieve international interoperability. In addition, to provide end-to-end functionality, the fixed network must also support a specified set of services. The inter-working between the fixed and mobile side of the network must be considered carefully;
- **signalling systems**: it is assumed that the mobile network components support Signalling System Number 7 (SS7) as specified by the ITU-T. This provides signalling within each Network Sub-System (NSS) and between other NSSs, making specific use of the mobile application part (MAP) of the SS7 standard. The EIRENE Specifications do not detail any requirements for signalling systems to be used within the fixed network. It is up to the railway to specify the signalling system, taking into account the network services requirements, the network services supported by the different signalling systems and the inter-working between signalling systems used in different parts of the network;

- **network implementation**: although the EIRENE Specifications define requirements for the mobile network, they do not deal with the way in which the network (including the fixed network) is to be implemented. This will affect not only the procurement strategy to be followed by each individual railway, but also the provision of required functionality;
- **numbering plan and call routing implementation**: the EIRENE Specifications detail the numbering plan and call routing principles but do not detail the way in which it may be realised by an individual railway in terms of how number space is to be obtained, how Functional Number translation takes place, etc;
- **controller equipment**: although the E-FRS mentions controller equipment specifications, it does not pose any mandatory requirements. Instead, it leaves the details of the specification of such equipment, the interface between the equipment and the GSM-R network to the railway operator;
- **system management**: a major part of any communications network is the specification of the system management functionality required. This requires specification of fault, configuration, accounting, performance and security management, as well as the definition of the system management platforms. One particular area of concern is how much the GSM Operation and Maintenance Centres (OMC's) should be integrated with the overall GSM-R OMC;
- **Reliability, Availability, Maintainability (RAM) requirements**: this aspect relates to the design and dimensioning of the communications network, as well as to the on-going operations of the network. This must be considered in conjunction with network design and system management;
- **type approvals**: to allow equipment to be connected to the network, various type approvals are required. In addition, as the communications system may be considered safety related, there could be a requirement for each railway to perform safety approvals;
- **text messaging**: there may be a requirement for individual railways to transmit text messages between users of the network. As the requirements for and contents of such messages will vary per railway and per application used, each railway will be required to specify this as part of the individual national procurement. The GSM Short Message Service has been mandated as the mechanism for GSM-R text messaging and all Cab Radio equipment must be capable of receiving such messages.

2.5.2 It is up to the individual railway to define its requirements for these aspects of the communications system and to include them in the system specification that is part of the tender documentation.

2.5.3 The following sections of this guide are intended to provide guidance on aspects not covered by the EIRENE Specifications by highlighting the critical issues and outlining possible ways of approaching them.

2.6 Railway requirements

2.6.1 General

2.6.1.1 Before specifying any system and tendering for it, it is important to know exactly what the requirements for a railway mobile communications system are. This section discusses these requirements.

2.6.1.2 The requirements can be grouped as follows:

- business needs, drivers and priorities;
- European interoperability requirements;
- national railway requirements (associated with railway-specific operations and telecommunications).

2.6.1.3 These requirements are discussed in the following sub-sections.

2.6.2 Business needs, drivers and priorities

2.6.2.1 Each national railway will have its own individual requirements for a radio communications system depending on the business needs, drivers and priorities of that individual railway. It will therefore be important for each railway to clearly define these needs and ensure that they are accounted for in the specification of the system.

2.6.2.2 The EIRENE Specifications allow a high degree of flexibility in the implementation options available. It is the responsibility of each railway to ensure that the specified radio system provides the required functionality to meet their business needs, whilst complying with the European interoperability requirements discussed in the next sub-section.

2.6.3 European interoperability requirements

2.6.3.1 The E-FRS and E-SRS identify mandatory functional and system requirements to facilitate international interoperability. The following lists summarise the requirements identified as being vital for interoperability and those identified as desirable:

- **Requirements vital for interoperability**:
  - railway emergency calls (driver or controller initiated);
  - controller to driver communications (non-emergency calls);
  - driver to controller communications (non-emergency calls);
  - registration and de-registration procedures;
  - European Train Control System (ETCS);
  - DSD messages;

  - driver to driver calls for assistance;
  - public emergency calls.
- **Requirements desirable for interoperability**:
  - shunting (although some shunting requirements are mandatory);
  - driver to ground (except controller);
  - driver to drivers of other trains in same area;
  - conductors and other onboard teams to ground;
  - direct mode.

2.6.3.2 All of the requirements listed above are clearly covered by the EIRENE Specifications, both in terms of required functionality and in system specification. Other issues such as system maintenance, reliability, fall backs, availability of services and equipment, system management requirements and the meeting of operational requirements will have to be addressed according to the needs and discretion of each individual railway.

2.6.3.3 When specifying the national radio system, each railway must ensure that the requirements for European interoperability, as detailed in the EIRENE Specifications, are met in order for the system to be classified as EIRENE compliant. This implies that the system must comply with all mandatory requirements stated in the E-FRS and SRS. Any conflicts of these requirements with either national business needs or specific national railway requirements (see below) need to be resolved without compromising the interoperability requirements.

2.6.4 National railway requirements

2.6.4.1 The requirements that a national railway will place on an integrated radio system are mainly driven by their operational, safety and business requirements. They include the technical specification of communications network aspects such as:

- construction and manufacturing of equipment;
- interfaces to on-train systems;
- interfaces to ground-based systems;
- the specification of HMIs;
- requirements relating to specific national applications;
- environmental issues;
- installation, testing and commissioning of the system;
- provision of documentation;
- engineering and safety approvals;
- training of personnel.

2.6.4.2 It is outside the scope of this document to consider in detail the national requirements for each railway. However, when specifying the national requirements for an EIRENE-compliant network, the railway must ensure that the requirements placed on roaming trains do not exceed the requirements as specified in the EIRENE Specifications. If this were the case, then interoperability would be jeopardised.

2.7 EIRENE-related document overview

2.7.1 In order to produce a functioning GSM-R system, there are two main issues that need to be addressed. These are the issues of international interoperability and GSM compatibility. As a result of this, two types of documentation are considered; firstly, documents relating to the interoperability issues as directed by the European Commission and secondly, documents related to the implementation of a radio system based on GSM.

EC interoperability directive

2.7.2 The European Commission published a Council Directive on the interoperability of the Trans-European high-speed rail system (Council Directive 96/48/EC). The aim of this document is to establish the conditions that must be met in order to achieve interoperability within Community territory of the Trans-European high-speed rail system. In addition, Council Decision 2001/16/EC was made in relation to conventional rail.

2.7.3 As a result of the Directive, it has become a legal requirement for all Member States to meet interoperability requirements on international high-speed lines.

2.7.4 In order to meet the essential requirements of interoperability between subsystems (as defined in the Directive), Technical Specifications for Interoperability (TSI) have been developed. These TSI provide details about the essential requirements in order to ensure that the subsystems are able to meet interoperability.

2.7.5 The Control Command technical specification specifies core interoperability requirements for traffic management systems including communications. Annexe A of this TSI refers to a number of radio-related specifications and standards including the EIRENE FRS and SRS.

2.7.6 The E-SRS references the MORANE Sub-System Requirements Specification (SSRS), a number of low-level technical specifications developed by the MORANE Project including the Form Fit Functional Interface Specification (FFFIS) and a large number of GSM standards. The MORANE documents are largely concerned with the technical specifications of sub-systems and the interfaces between them. It should be noted that in order for a system to be EIRENE-compliant, it must also be compliant with these MORANE specifications and GSM standards.

2.7.7 An overview of the interoperability documentation hierarchy and the status of the EIRENE Specifications in respect to the EC Directive and other specifications is shown in figure 2-3. Further information about EIRENE-related documentation is available in appendix A.

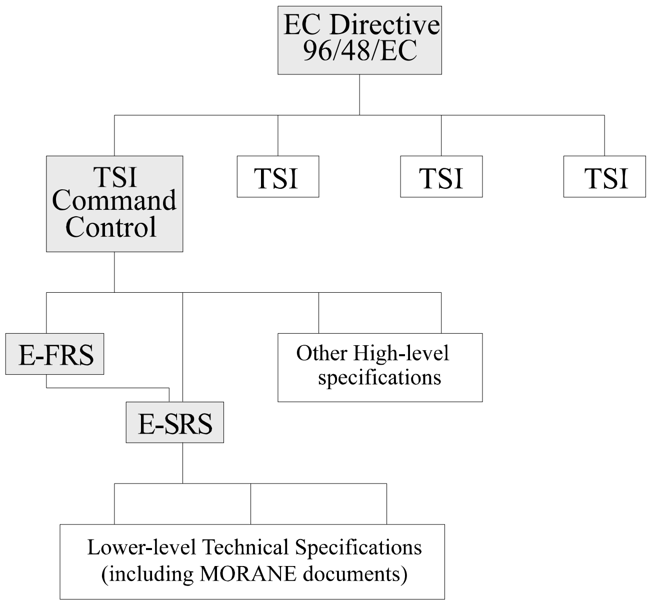

Figure 2-3: EIRENE interoperability documentation hierarchy

GSM related hierarchy

2.7.8 The relationship between the EIRENE Specifications and the GSM standards is shown graphically in figure 2-4. The upper part of the diagram relates to voice communication and the lower part to data communication. The left-hand side relates to the fixed equipment and the right-hand side concerns the mobile equipment. This shows that for both voice and data communication, the core specifications are the GSM air interface followed by the GSM network voice and network data services as specified by ETSI. These are built upon by the CENELEC EURORADIO specification for data communication.

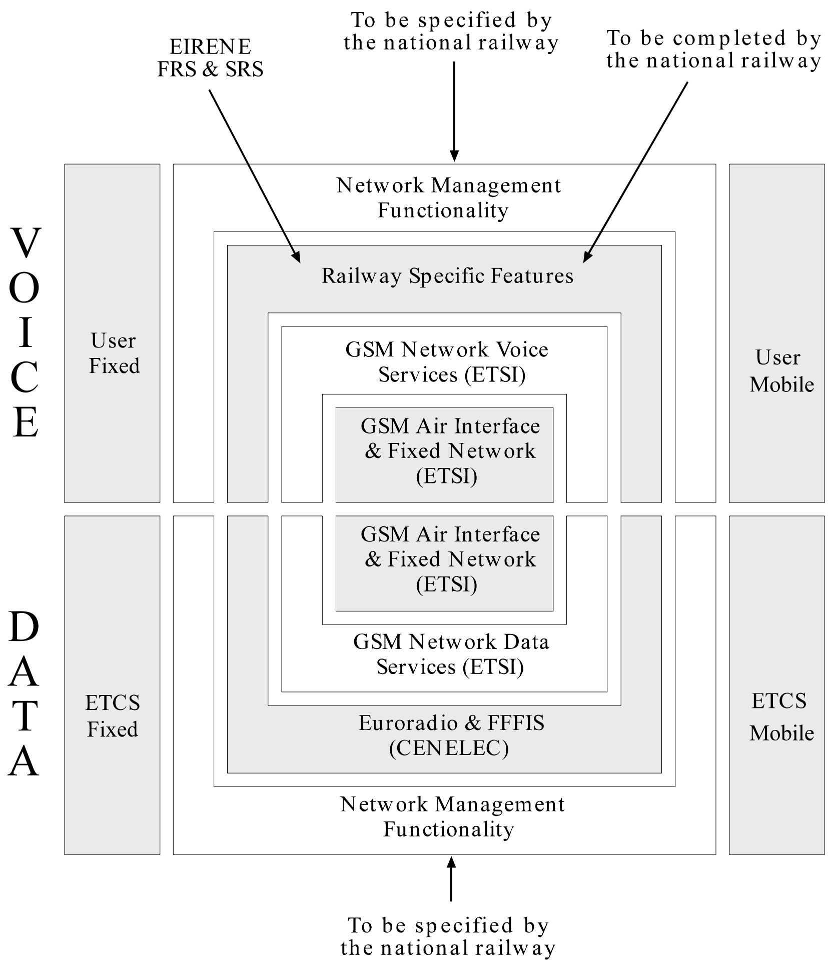

Figure 2-4: GSM specifications

2.8 Project EIRENE & the EIRENE Memorandum of Understanding (MoU)

2.8.1 The EIRENE Memorandum of Understanding (MoU) was been signed by 32 railways and operating companies (April 1998). The signing of the EIRENE MoU demonstrated the importance attached to the development of interoperable train communication by the individual railways in the UIC.

2.8.2 The signatories of this MoU have agreed that in the development and introduction of new radio communications systems for railway operations they will ensure that full interoperability (as defined by the mandatory requirements of the EIRENE Specifications) is supported within the systems of their individual railways.

2.8.3 Under Project EIRENE (now closed), there were three main groups working on the standardisation of GSM-R. These were as follows:

– the EIRENE Project Team;

– the User Group; and
– the 'Early Implementers'.

2.8.4 These groups met regularly to address system requirements, functional requirements and implementation issues respectively. The groups have now been replaced by the UIC European Radio Implementation Group (ERIG), which was founded during the latter stages of Project EIRENE and has now taken over responsibility for the maintenance of the EIRENE Specifications and the co-ordination of implementation activities.

2.9 UIC European Radio Implementation Group (ERIG)

2.9.1 In order to meet the changing needs of GSM-R development as it moved from specification to implementation, ERIG was established at the beginning of 1999 to take responsibility for overseeing the standardisation elements necessary to ensure the interoperability of national GSM-R implementations. The Group is chaired by Klaus Konrad of DB AG, one of the first implementers of GSM-R, and comprises of representatives from MoU signatory railways with an interest in implementing GSM-R networks.

2.9.2 The main responsibilities of ERIG are as follows:
– supporting railways in their procurement of GSM-R systems, which includes setting codes of practice for network planning and supporting in setting up frequency planning agreements;
– further development of issues essential to interoperability (eg billing and tariffing, roaming agreements and network management);
– development of type approval agreements for GSM-R equipment and ongoing type approval management;
– liaising with the GSM MoU Association regarding issues such as ciphering algorithms.

2.9.3 Reports from the ERIG meetings are available from the GSM-R web site (at http://gsm-r.uic.asso.fr/).

2.10 GSM-R Working Groups

2.10.1 In order to support the activities of ERIG, the following working groups have been created:

– **GSM-R Operators' Group** (Leader Robert Sarfati) - its task is to ensure that the EIRENE System Requirements Specification (E-SRS) is harmonised with the FRS and MORANE technical solutions (and subsequent developments in the telecommunications standards) in accordance with the requirements of the Interoperability Directive (48/96/EC). The Operators' Group is responsible for handling issues raised by national implementation projects. This group is also responsible for the inter-working of the change control process.

– **ETSI Project - Railway Telecommunications** (Leader Robert Sarfati) - the ETSI Project Railway Telecommunications (EP-RT) is responsible for the ETSI standardisation of railway telecommunication aspects. EP-RT will develop and maintain ETSI standards (as necessary) for application of GSM-R to railways as required by the European Directive on High Speed Train Interoperability and by other forthcoming European Directives for railways (including the European Directive on Conventional Lines interoperability).

– **GSM-R Functional Group** (Leader Kurt Andersen) - its task is to ensure that the solutions developed by the Operators' Group and ETSI Project Railway Telecommunications are reflected accurately in the EIRENE Functional Requirements Specification (E-FRS). They are also responsible for the specification of new functions for railway operation (for example, GPRS).

2.10.2 Figure 2-5 provides an overview of the ERTMS/GSM-R Project, showing the main Groups and their reporting lines.

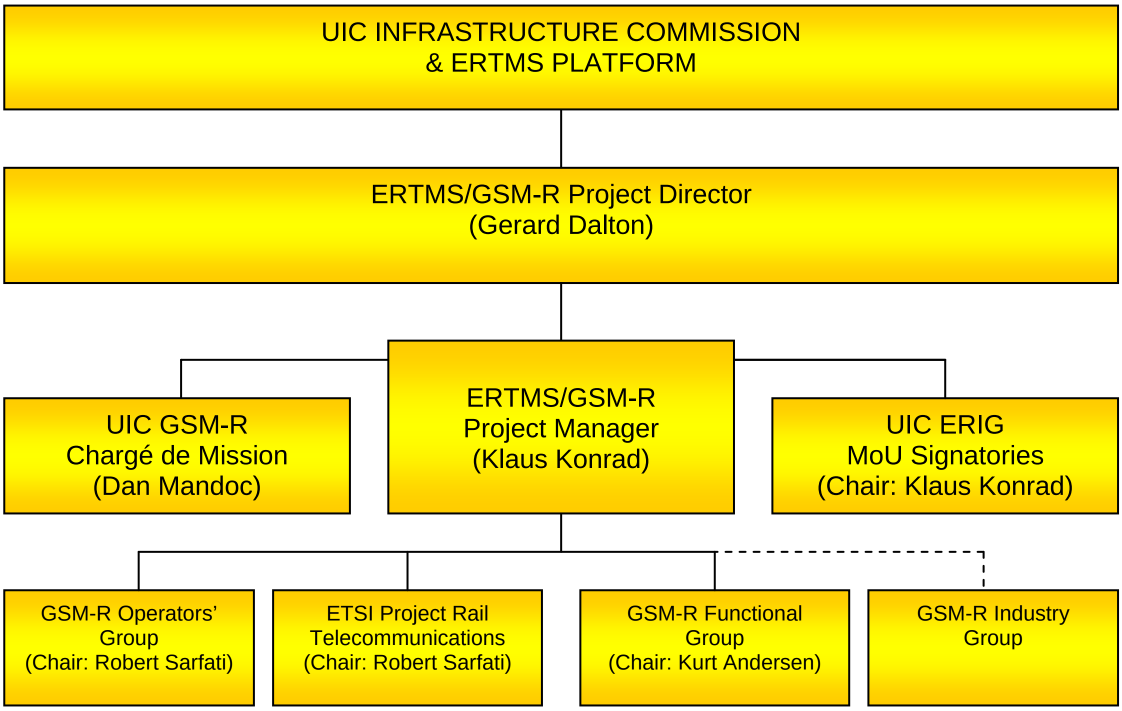

Figure 2-5: ERTMS/GSM-R Project main groups and reporting lines

2.10.3 All railways which have implementation programmes for a GSM-R system may send a representative to ERIG meetings. Further information on becoming a member of ERIG can be obtained from the Group Administrator at the following address:

European Radio Implementation Group
c/o Mr Peter Keer
Thales Telecommunication Services
2 Clerkenwell Green
LONDON
EC1R 0DE

2.11 GSM Association

2.11.1 As the bearer for GSM-R networks is GSM, it is important that the railways know of any specific requirements placed by the GSM Association that will need special consideration when implementing a GSM-R network. Although in the case of a public network, these considerations are the responsibility of the Network Operator.

2.11.2 The GSM Association is the principal body for promoting and evolving the GSM cellular radio platform worldwide. The GSM Association has, at the time of writing, over 400 operators in 182 countries/areas of the world (July 2002).

2.11.3 Membership of the GSM Association is currently open to licensed mobile network operators committed to building and implementing GSM-based systems and government regulators/administrations who issue commercial mobile telecommunications licences. Information on how to become a member of the GSM Association can be obtained from the headquarters staff at the following address:

GSM Association
6-8 Old Bond Street,
London
W1S 4PH
Tel. +44 20 7518 0530
Fax +44 20 7518 0531

2.11.4 Information on the GSM Association can also be obtained from its web site: http://www.gsmworld.com.

2.11.5 Apart from promoting and developing the GSM standard worldwide, the GSM Association is the body that is responsible for the harmonisation of the following aspects:

- frequency allocations;
- international roaming and roaming agreements;
- implementation of supplementary and data services;

– management aspects (e.g. billing agreements);

2.12 Encryption and authentication algorithms

2.12.1 The three principal GSM cryptographic algorithms are:

– A3 and A8 authentication algorithms (commonly combined as A3/A8 or COMP 128)

– A5/3 encryption algorithm

2.12.2 Of interest to railways proposing to implement private GSM networks is securing the use of voice privacy (encryption) algorithms and authentication algorithms for SIM cards. The following points should be noted regarding algorithms:

– The ETSI GSM specifications only refer to the algorithms in general terms (i.e. they do not specify them in detail).

– The use of standardised voice privacy algorithms is mandatory for a GSM-R network.

– Each railway is free to implement its own authentication algorithms providing that there is no resulting loss in cross-border interoperability.

2.12.3 Examples of the A3 and A8 algorithms are freely available (see 3GPP TS 55.205 "Specification of the GSM-MILENAGE Algorithms”). Download, implementation and use of the example algorithm set is subject to the terms indicated in the document only and is available at no cost.

2.12.4 National railways will be able to secure the use of the A5/3 algorithm, which is owned by ETSI by ordering it at a low price via Robert Sarfati (contact details are provided on the GSM-R Website (http://gsm-r.uic.asso.fr/).

3 System infrastructure provision

3.1 Introduction

3.1.1 One of the aspects to be considered when procuring a communications network is the way in which the network is to be implemented. Although the EIRENE Specifications provide a set of requirements for the communications system, they do not give guidance on procurement of the network infrastructure. This section is provided to give a summary of the infrastructure procurement options that are available.

3.1.2 As railways have to comply with the EC Interoperability Directive it is important to consider whether any particular implementation could lead to difficulties in achieving interoperability with other GSM-R networks.

3.1.3 It should be noted that, although this section discusses the implementation options for national GSM-R networks (ie the mobile network part of the overall integrated radio communications network), similar considerations need to be given to the fixed network. This is, however, the responsibility of the individual railway and falls outside the scope of this guide.

3.2 Implementation aspects overview

3.2.1 The options available for the implementation of an EIRENE-compliant network may be considered from two viewpoints:

- the aspects relating to the implementation of GSM-R on a national basis in order to provide a suitable national communications infrastructure;
- the aspects relating to the implementation of GSM-R on an international basis to ensure interoperability with other national GSM-R networks.

3.2.2 This section is concerned with the provision of a suitable national communications infrastructure. Aspects relating to international interoperability will be addressed in section 4.

3.2.3 Section 5 of this guide will then consider additional aspects that have an impact on system planning and specifications and need to be considered whatever implementation is chosen by the individual railway.

3.3 Overview of national implementation options

3.3.1 One of the main factors that will influence the national implementation of GSM-R is the nature of the GSM network to be used. Three main options are available:

- Public GSM network;
- Private GSM network;
- Hybrid GSM network, in which a private and a public GSM network are integrated in order to potentially provide a more cost-effective implementation.

3.3.2 Similar implementations need to be considered for the fixed part of the communications network, leading to a large number of possible combinations for the implementation of the full communications network.

3.3.3 It should be noted that it is outside the scope of this guide to consider each of the full network implementations in detail. Instead, this guide will consider the options for the mobile network (ie the GSM network and air interface) and look at the issues associated with each of the available implementations.

3.4 National implementation using a public GSM network

3.4.1 Using a public GSM network means that the mobile side of the network will be out-sourced to a public network operator. In this case, the railway will have limited control over the way the network is implemented and operated, as the railway will probably form only a small part of the network operator's overall customer base. The network operator may also have conflicting commercial considerations.

3.4.2 It should be noted that some railways are partners in public GSM networks and may therefore find greater advantages than other railways in the choice of this implementation option.

3.4.3 In order to implement a GSM-R network using a public GSM network, the following issues must be addressed, with particular reference to each of the prospective network operators:

- the current areas of coverage provided by the network operator and how this compares with the designated coverage area required for the implementation of GSM-R;
- the level of coverage recommended by the EIRENE Specifications and required by the national railway and how this compares to the level of coverage provided by the network operator;
- the mechanism for the public network operator to provide any additional coverage required by the railway and organisational aspects such as the access to sites for installation;
- the provision of special GSM solutions for tunnels and cuttings, the ability of the network operator to either provide these solutions, sub-contract for their provision or to work with an independent contractor;
- the level of required GSM supplementary services that are provided by the network operator such as USSD, VGCS, VBS, UUS1 and eMLPP. Some public GSM network operators may not provide some or all of the additional services required to meet the EIRENE Specifications;
- compliance with the relevant standards, which include the EIRENE Specifications and the MORANE FFFIS for EURORADIO.

– the standards and methods that will be used to assess the service provided by the network operator and the system of penalties that will be enforced if the network operator does not perform to the required level;
– the extent to which the public GSM network operator will be willing to support all of the railway applications. Some network operators may have concerns over the provision of safety related voice communications or the use of radio for low cost signalling.

3.4.4 Each of these aspects needs to be addressed in the technical specification of the network and the railway needs to consider in which way any deficiencies could be resolved.

3.5 National implementation using a private GSM network

3.5.1 With this option, the railway operator is given a more or less complete degree of freedom and the network could be effectively designed to meet all of the functional and system requirements, albeit at a certain cost. There are, however, specific aspects that need to be addressed when considering the implementation of a private network.

3.5.2 One of the main considerations when deciding on the implementation of a private GSM network is to ensure that the network conforms to the existing GSM regulations. The GSM MoU and ETSI administer these regulations and further details about these standards and how they relate to other EIRENE related standards and regulations are given in section 2.7 of this document.

3.5.3 The availability of frequencies will also need to be considered, given that there is a requirement in the EIRENE Specifications to conform to the correct operational frequency bands. The particular aspects related to the allocation of frequencies are further discussed in section 5.3.

3.5.4 The other major consideration when implementing a private GSM network is to ensure that the proposed network implementation will lead to a fully functional GSM-R system within acceptable budget constraints and that ongoing revenue costs (such as the provision of maintenance and service) will meet the targets set out in the Business Case.

3.5.5 Before implementation, a detailed study may need to be conducted in order to establish the cost of providing private GSM coverage over the designated area. This will require survey data of the rail network and the surrounding area in order to determine where base stations need to be implemented and the number of installations that will be required. In addition, this will highlight any aspects of planning permissions required for the base station implementations.

3.5.6 As with the public network implementation, methods may need to be introduced to assess network performance after implementation, albeit that in this implementation the railway will have more direct control over the levels of performance and the ways in which these can be maintained.

3.5.7 When implementing a private GSM network, the railway has to identify the best sites and characteristics of the base stations. This involves a prediction of radio coverage using dedicated coverage tools to determine the optimum base station parameters (eg location, type, antenna, mast height, etc). In designing the network, the railway should take into account:

- transmission power and receiver levels of the mobiles on the trains;
- location of base stations on railway property;
- provision of telecommunications and power;
- site constraints (e.g. mast heights, environmental restrictions);
- resilience requirements;
- planning permission requirements.

3.5.8 In addition, the railway operator will need to procure the additional equipment of the GSM network (BSCs, MSCs and management systems). Finally, the railway must decide on the way in which the network elements are interconnected.

3.6 National implementation using a hybrid GSM network

3.6.1 A hybrid implementation will usually take one of the following forms:

- the private provision of GSM coverage to operate alongside an existing public GSM network. In this situation, the railway operator will fund, install and interconnect the additional network elements required to meet the railway mobile network requirements. This will lead to areas of private coverage, which will operate alongside the coverage areas provided by the public network. In this situation, there will be interoperability aspects to be addressed for the national use of the system;
- the funding of GSM network infrastructure enhancements by the railway in order to make the provision of required coverage economically viable for the network operator. In this situation, the GSM network operator will own the completed network, but the railway will finance the network enhancements required for the installation of an EIRENE-compliant system. The final result of an implementation of this type will therefore be no different from the case of a public GSM network, although there are additional implementation considerations.

3.6.2 The issues related to this type of network implementation are:

- equipment compatibility considerations with the existing public GSM network;
- that there may be difficulties in providing additional network services (in particular the Phase 2+ supplementary services) if these services are not already supported by the public network;
- any business benefits that the public network receives from the private enhancements should be addressed (for example, in terms of adjustments to the costs incurred by the railway for the services provided by the network operator);

- the cost of implementing the enhancements and the benefits that this will provide to the GSM-R network over and above the service that can already be provided using the existing public network should be considered;
- with whom the responsibility for the maintenance of equipment lies;
- the introduction of methods to monitor network performance after implementation, to determine the performance responsibilities of the network operator and to establish and enforce a system of penalties if the required level of service is not provided.

3.6.3 In this situation, the railway operator must assess what the GSM network operator already provides, what he is willing to provide in addition and whether this will be feasible on a commercial basis. Furthermore, the railway operator must consider the willingness of the GSM network operator to accept the required enhancements to the network and the associated cost implications.

3.6.4 The railway needs to consider whether the public GSM network operator will be willing to support all of the railway applications. Some network operators may have concerns over the provision of safety related voice communications or the use of radio for low cost signalling.

3.6.5 Enhancements to an existing GSM network must be considered in terms of how busy the individual routes are and the perceived benefits of implementing them. For example, it may make the most sense to implement a private GSM-R network covering the busiest railway routes and make use of public GSM coverage in the other areas. Alternatively, one may choose to finance enhancements to a public network on the busier sections of the rail system and rely on the existing level of coverage for the remainder of the network. It should be noted that the problem with this approach is that, in general, the public GSM coverage in low traffic areas is low, so the cost of this implementation may not be significantly less than for an entirely private network.

4 International interoperability considerations

4.1 Overview

4.1.1 Although individual railways will not be responsible for the installation of an international network, they are still obliged to achieve international interoperability. This section deals with the options available to accomplish this interoperability, with particular reference to functional considerations such as the numbering plan.

4.1.2 The considerations for international implementation concern the conservation of interoperability requirements of the GSM-R network across national boundaries. In order for interoperability to be achieved, there are several issues requiring consideration:

- the provision of a consistent numbering plan and how this relates to the numbering systems used in other GSM-R networks;
- the call routing mechanism that is used in the network and how this may be interfaced to another GSM-R network;
- the movement of trains across international boundaries and the procedures that are available for addressing the on-board equipment by Functional Number alone (ie without the need for knowledge of the origin of the train);
- the system for call logging and performance monitoring that has been used in the network and how this will operate for international services;
- the compatibility of mobile equipment from network to network and the provision of supplementary services for the Phase 2 and Phase 2+ implementation;
- the additional data and signalling systems integrated with each national GSM-R implementation and how these will operate for international services.

4.2 EIRENE call routing & numbering plan

4.2.1 Introduction

4.2.1.1 One of the main aims of the EIRENE Specifications is to ensure interoperability between railway communications networks of the future. Interoperability is a key feature of communications networks, not only because it will allow trains to roam seamlessly between countries, but also because it will allow co-existence of GSM-R and other networks.

4.2.1.2 A prerequisite of interoperability in communications networks is the agreement on a common standard numbering plan and associated call routing. In public networks, the numbering plan is defined internationally in the ITU-T E.164 recommendation (note that for land mobile networks, compliance with ITU-T recommendations E.212, E.213 and E.214 is also required). These recommendations mandate the structure for ISDN numbers in order to ensure international interoperability for fixed and mobile communications networks throughout the world.

4.2.1.3 The EIRENE numbering plan is designed to include numbers that identify trains and individuals by function as well as by equipment. Part of the numbering plan is concerned with functional numbering whereby the running numbers of services are used to construct Functional Numbers, which are in turn used to access the on-board mobile equipment for the duration of the service. There is therefore a need to map Functional Numbers defined in EIRENE to Subscriber Numbers in a flexible and future-proof manner which will allow railways to develop and enhance their operations throughout the entire lifetime of the network.

4.2.1.4 Although the E-SRS specifies the structure of the numbering plan to be used and the over-the-air protocol, it does not specify the mechanism whereby Functional Numbers are to be mapped onto the appropriate Subscriber Numbers. In addition, the E-SRS specifies the way in which calls based on Functional Numbers can be routed through the network, but does not consider any particular network implementation to achieve this.

4.2.1.5 An associated aspect is the implementation of location dependent routing. The E-SRS requires location dependent addressing based on cell routing as a minimum (E-SRS 10.10), although a more accurate method of location determination for call routing is advised. The method of implementation depends on the national railway requirements.

4.2.1.6 It is up to each individual railway to define an implementation of the EIRENE numbering plan and the network implementation that supports functional addressing and location dependent call routing. The aim of this section is to provide an overview of the main implementation options, detailing the particular aspects associated with each of the options.

4.2.2 Numbering plan principles

4.2.2.1 Train controllers, station staff, etc will normally want to call a train by its running number rather than by the actual Subscriber Number associated with the mobile in the locomotive. This is because the locomotive of a certain regular service may change from day to day, whereas the running number is uniquely identified, at least within a single railway domain. On the other hand, maintenance personnel in depots will only know a locomotive by its engine number and will prefer to set up a call to a mobile or device within the locomotive by this number. In each of these situations, it is necessary to be able to call a mobile on the train without knowing its Subscriber Number.

4.2.2.2 To allow for these requirements, the following numbering plans form part of each GSM-R network:

- **EIRENE numbering plan**: Provides a range of number types to meet railway addressing requirements; for instance, a certain Functional Number identifies the driver of a certain train rather than the number of the phone of the cab radio installed in the locomotive. For example, if the locomotive is changed during the journey, the Functional Number based on the Train Running Number will stay the same. GSM-R network users shall therefore be able to originate and receive calls using Functional Numbers. This need to comply with the requirements specified by EIRENE for the structure of Functional Numbers, whilst taking into account the railway private numbering plan and the national numbering plan.
- **Public numbering plan**: This is the numbering plan used by the public network operator to route calls through the network and which consists of the actual telephone numbers (e.g. MSISDN numbers) of the called party terminal equipment.

4.2.2.3 There may exist an overlap between the EIRENE and Public numbering plans, since for certain Call Types, the User Number (EIRENE numbering plan) may be equal to a Subscriber Number (Public numbering plan).

4.2.2.4 The establishment of the relation between a Functional Number and the Subscriber Number is performed by the user through the Registration Procedure and is removed by the user through the De-registration Procedure. This has to be performed every time the association requires an update. The association between the Functional Number and Subscriber Number is held in appropriate routing databases. When a call is set up, a translation from the Functional Number to the Subscriber Number is performed. Functional Numbers should be de-registered as soon as they are no longer required so that they are made available for subsequent users.

4.2.2.5 The structure for the Functional numbering plan to be used within GSM-R networks is detailed in section 9 of the E-SRS.

4.2.2.6 The EIRENE numbering plan also defines a set of short codes to be used within GSM-R networks. These short codes are not restricted to call set-up to mobile users only. Instead, their prime function is to ease the use of GSM-R for drivers by reducing the number of digits to be dialled when calling the local controller or to place an emergency call.

4.2.2.7 It will be the responsibility of the railway to define in addition to the numbering plan specified in the E-SRS:

- a suitable Numbering plan for fixed network extensions if required;
- how the Functional Numbers used within the GSM-R network can be accessed if a call is to be set up from a fixed network extension.

4.2.2.8 This guide will discuss the possible options for implementing the functionality required to translate[1] the Functional Number into the associated Subscriber number and the impact each of these options has on the fixed-to-mobile interface.

4.2.2.9 The relationship between the aspects considered in the E-SRS, this guide and those that are to be defined by the national railway are shown in figure 4-1. This diagram shows the different components of the integrated radio communications network, the different interfaces, the call set-up information to be passed from the calling party to the network and the location of the 'Call Router' which translates the Functional Number into the Subscriber Number. In addition, the diagram shows that the E-SRS covers the functional requirements (including the EIRENE Numbering plan) within the GSM-R network, whereas the procurement guide details the implementation aspects and the impact these may have on the functionality required in the fixed network implementation

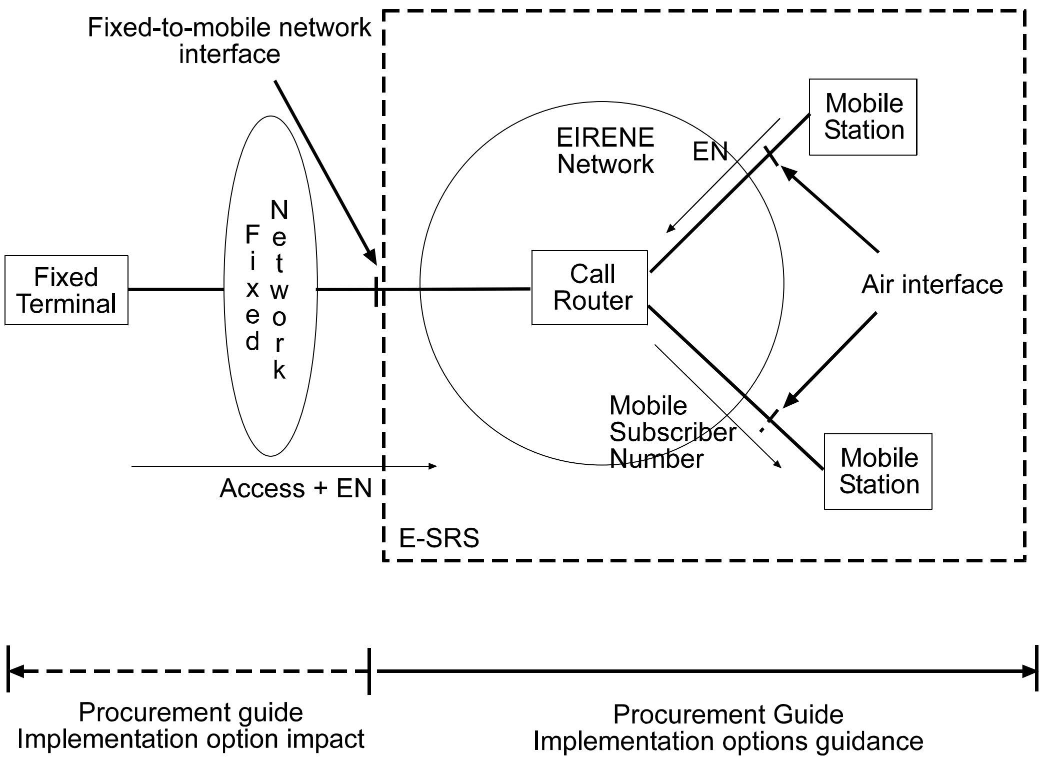

Figure 4-1: Scope of Procurement Guide

[1] Number translation is the mapping of one 'name', the Functional Number into another, the MSISDN number. The mapping of a Freephone number into a public telephone number may serve as another example.

4.2.2.10 Sub-section 4.2.4 considers in more detail the main options available for using functional addressing in GSM-R networks and the associated mechanisms for translating Functional Numbers into Subscriber Numbers. Specific aspects related to the allocation of numbers for different GSM-R network implementations are considered in more detail in sub-section 5.8.

4.2.3 Call routing principles

4.2.3.1 In order to provide international communications, national GSM-R networks will need to be interconnected to allow calls to be routed between users in different networks. The specific aspects related to interconnecting GSM-R networks are addressed in sub-section 5.2 of this guide.

4.2.3.2 When a train is operating in its home network, all Functional Numbers (eg Engine Number and Running Number) associated with the train will be stored in the home network. All users who want to call the train by a Functional Number will need to address the call via the train's home network. For users in the same country this will require only a national call, for users in other countries an international call will be required. The Functional Number will be translated by the home network and routed to the mobile. This type of call routing is shown in figure 4-2.

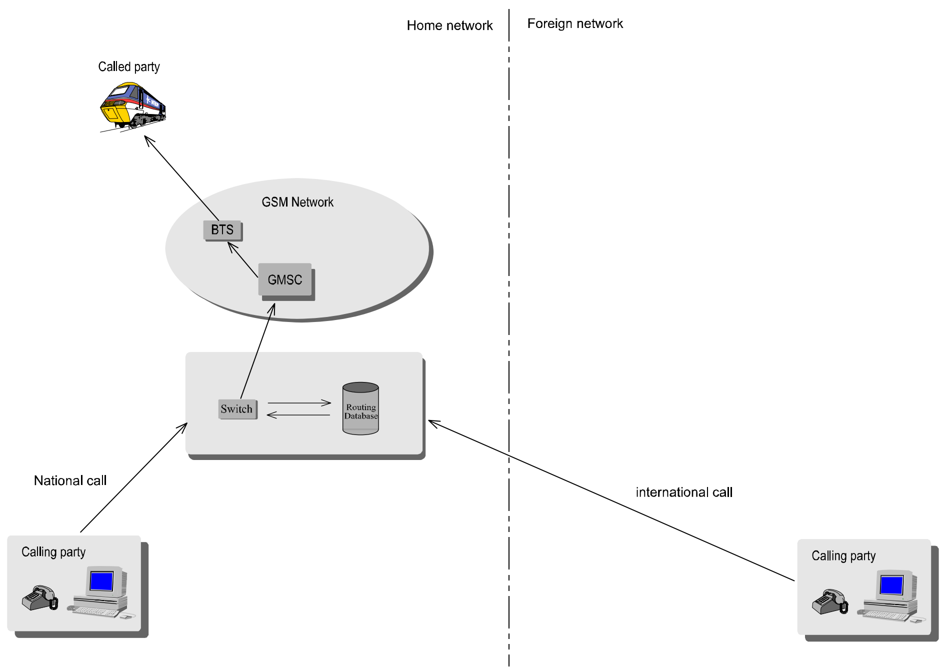

Figure 4-2: Call routing to train operating in home network

4.2.3.3 When a train moves from its home network to a foreign railway network, calls set up using Functional Numbers stored within its home network will be translated to the relevant mobile Subscriber Number and routed to the train through GSM procedures for mobiles roaming on foreign GSM networks. For users in other countries, including the foreign country in which the train is currently operating, an international call set-up will be required. The Functional Number will be translated by the home network and routed to the mobile. This type of call routing is shown in figure 4-3.

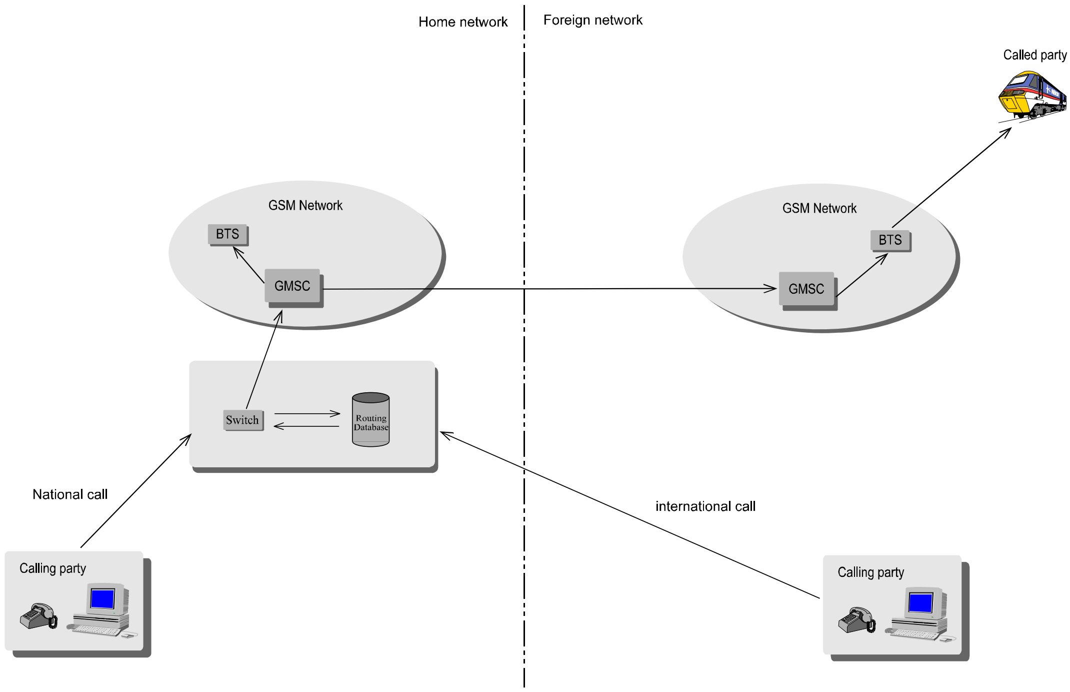

Figure 4-3: Call routing to trains operating in foreign network (scenario 1)

4.2.3.4 Generally, controllers will need to address an international train, operating in their area of control, by a national running number. This avoids the need for the controller to know the originating country of the train. This requires a transfer of Functional Number information associated with the train running number, when a train crosses a boundary. Other Functional Numbers (e.g. those based on engine or coach numbers) should remain with the train's home network. The controller should therefore only be required to set up an international call when there is a requirement to call a train operating in another GSM-R network (the situation as described in paragraph 4.2.3.2).

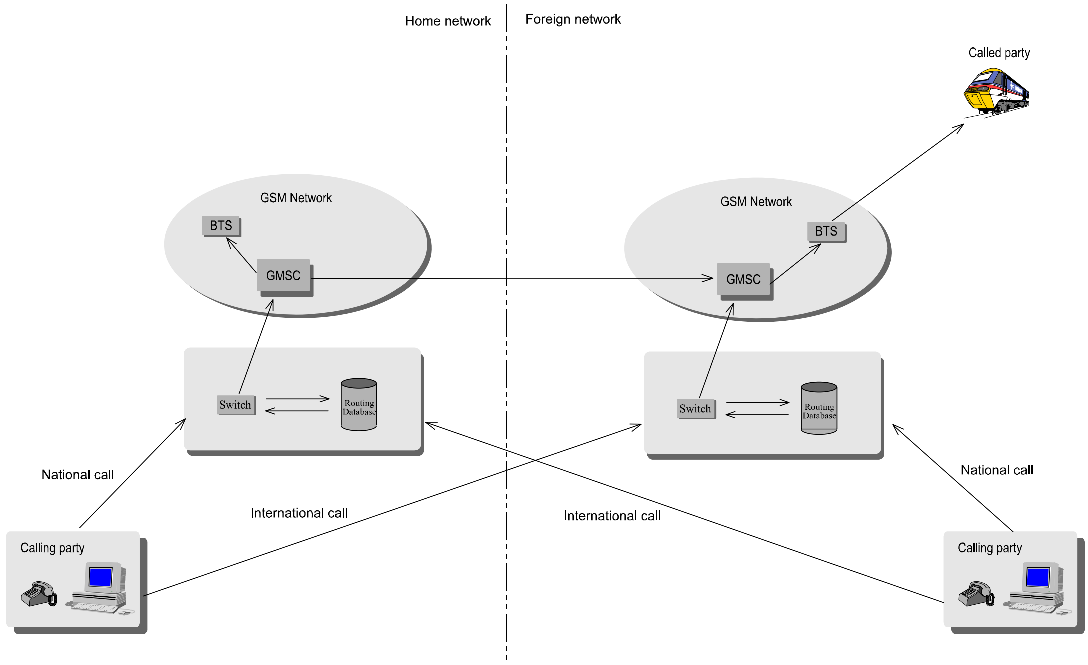

Figure 4-4: Call routing to trains operating in foreign networks (scenario 2)

4.2.4 Number translation implementation options

4.2.4.1 The EIRENE Specifications do not mandate the way in which functional addressing and the associated translation of Functional Numbers into Subscriber Numbers should be implemented within the GSM-R network, only the messages which should be used over the air interface and between networks, to control the functional addressing service.

4.2.4.2 Possible options for implementing a Functional Numbering service include:

- using Intelligent Network (IN) facilities;
- within the GSM network's HLR using the 'follow-me' supplementary service;
- implementation of a dedicated switch with associated databases.

For each of these options, the registration and de-registration aspects need to be considered carefully. In particular, this needs to be done with a view to ensuring that roaming equipment from other railways is fully interoperable with the GSM-R network implementation.

4.2.4.3 This section discusses the options outlined above to implement a GSM-R network with a view to achieving international interoperability.

Intelligent Network implementation

4.2.4.4 In IN-based solutions, call routing is considered separately from the service provision. In these situations, Service Switching Points (SSP) are used to detect whether a calling party wishes to use IN functionality. If this is detected, then the information provided by the calling party is transferred to the Service Control Point (SCP) which will act upon the information provided.

4.2.4.5 If the IN solution is used within the GSM-R network, then the calling party can dial the Functional Number, which is 'trapped' by the SSP and passed on to the SCP. The SCP then performs the translation of the Functional Number into the appropriate MSISDN number and passes this information back to the SSP. The SSP will then set up the call as requested.

4.2.4.6 The key to IN solutions is the ability of the SSP to detect whether a calling party wishes to use IN functionality or not. In public fixed networks this is normally achieved by using specific dialling codes. If the IN solution were to be used in a private network environment, then the initial digits dialled could be used to act as a trigger[2] for the SSP.

4.2.4.7 Within GSM-R networks, the IN solution will rely on the combination of the mobile subscriber profile and the number dialled. When a mobile user, who is registered to use IN services, dials a Functional Number, the GSM SSP will 'trap' this number based on the subscriber profile and pass the information to the SCP, after which the associated MSISDN number is passed back to the SSP. This is shown in figure 4-5.

[2] Triggers are call-related conditions that cause a switch to interrupt its own processing of the call and launch a query to an SCP.

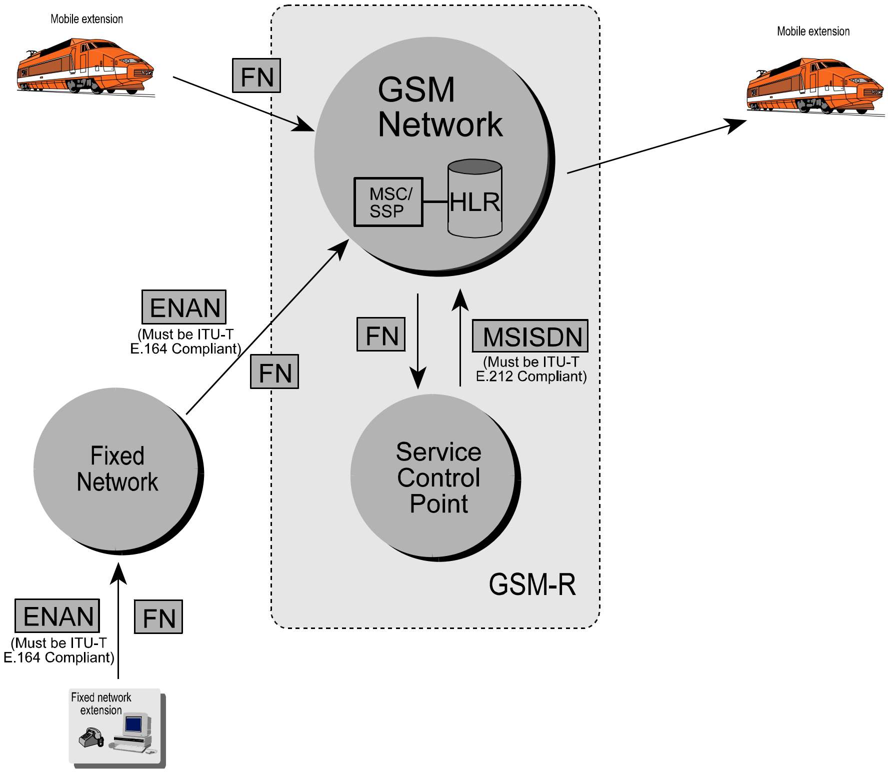

Figure 4-5: IN implementation

4.2.4.8 It is not possible to use the same approach if a calling party wishes to establish a link using a Functional Number from a fixed terminal. For calls from fixed extensions, the calling party would establish contact via the fixed network by dialling the appropriate GSM-R Network Access Number (ENAN), which forms the 'trigger' for using IN services. Once the connection is established, the Functional Number is passed via the fixed network and the MSC/SSP to the Service Control Point, where it will be translated into the MSISDN number of the appropriate mobile equipment. Using this number, the call will then be set up via the GSM network to the correct mobile extension. Alternatively, the Subscriber Number could be called using the National Destination Code plus the MSISDN number.

HLR implementation

4.2.4.9 With the HLR-based solution, the GSM 'follow-me' supplementary service is used to provide the required translation of Functional Number to MSISDN number within the HLR. Although this has the advantage of not requiring additional network elements, there is a danger of making less efficient use of the numbering space as it may not be possible to gain access to the required blocks of numbers to match the required Functional Numbers from the national telecommunications regulator.

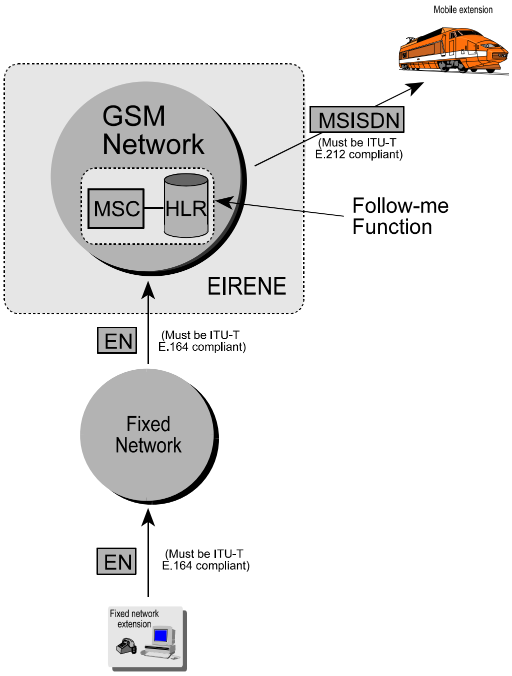

Figure 4-6: HLR implementation

4.2.4.10 In the HLR implementation, shown in figure 4-6, the EN is dialled directly by the calling party and the call is routed through the network to the GSM MSC. The GSM Call Forwarding Unconditional Supplementary Service is then used to translate the dialled EN into the MSISDN number of the relevant mobile equipment and the call is set up.

4.2.4.11 The key to success of this approach is either to ensure that all of the ENs used are ITU-T E.164 compliant (i.e. they must be valid mobile telephone numbers) and available (ie they must not be already taken by other subscribers) or the ENs can be interpreted by the GMSC to allow the call forwarding to be invoked.

Dedicated switch implementation

4.2.4.12 With this implementation, the railway does not use any number translation functionality provided by the GSM network. Calls are routed via a dedicated switch, which performs all necessary number translations. Essentially, this is an “external” Intelligent Node, although the switch does not form an integral part of the GSM network.

4.2.4.13 The calling party (whether mobile or fixed terminal) must first gain access to the switch before passing the Functional Number information, in order to allow calls using Functional Numbers to be made. Once the Functional Number is passed to the switch, it will search its routing databases and translates the Functional Number into the proper MSISDN number. The switch will then attempt to complete call set-up to the mobile. This process is shown in figure 4-7.

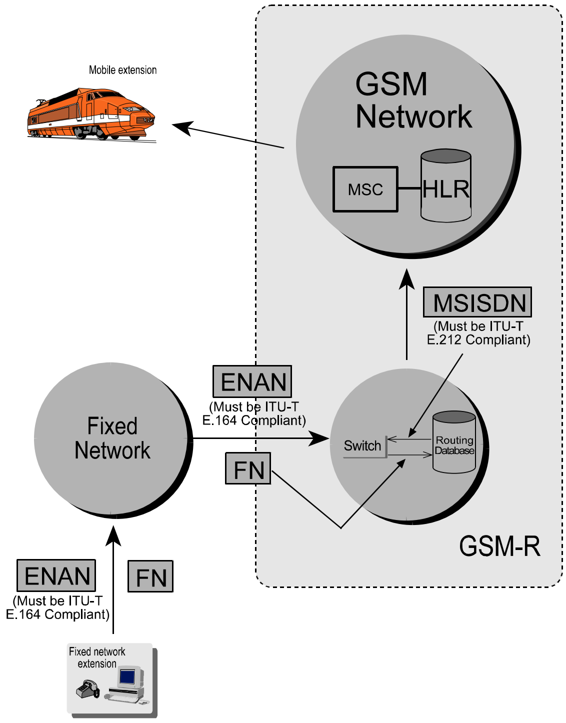

Figure 4-7: Dedicated switch implementation

4.2.4.14 Based on the network procurement option chosen by the railway, access to the dedicated switch could be obtained by dialling a specific number, the ENAN. If a completely private network implementation is used, then the railway will have more freedom in defining the way in which the dedicated switch is accessed.

4.2.4.15 When the railway decides to implement this option, it will be required to specify all aspects of the required functionality for the switch and its databases. In addition, as the switch does not form an integral part of the GSM network, the specification must also include the way in which the switch is connected to the GMSC.

Calls initiated by a mobile user

4.2.4.16 It should be noted that in the case of the implementations discussed in this section, the emphasis has been on the called party being a mobile user. Similar consideration will have to be given to the call routing mechanisms required for calls where the called party is located at a fixed network extension. The railway will have to specify, as part of their technical specification, how calls are to be routed to fixed network extensions. This will largely depend on aspects such as:

- the type of fixed network implementation (private, public, VPN, etc);
- whether functional addressing is extended to cover the fixed network;

– location where number translation is to take place (eg within the GSM network, the fixed network);

– the functionality provided within the network for translation of numbers (IN solution, standard Supplementary Services provided in the fixed network, dedicated switch, etc).

Interconnection aspects

4.2.4.17 Although aspects related to the interconnection of national GSM-R networks will be considered in more detail in section 5 of this guide, table 4-1 summarises some of the aspects that require consideration. Table 4-1 considers the interoperability issues that will be raised in four possible scenarios of a train moving from a home GSM-R network with either an IN or HLR implementation to a foreign GSM-R network with either an IN or HLR implementation.

4.2.4.18 The situation where an GSM-R network has to be connected to another GSM-R network that uses a dedicated switch/database for translation of Functional Numbers and call routing, should be considered separately. In general, the particular interconnection aspects that require attention are the method of interconnection and the protocol for exchange of data.

		Travelling to a Foreign Network with an:	
		IN implementation	**HLR implementation**
Home Network:	**IN implementation**	Protocol for the exchange of data.	. Method of interconnection. Protocol for the exchange of data.
	HLR implementation	Method of interconnection. Protocol for the exchange of data.	Method of interconnection. Protocol for the exchange of data

Table 4-1: Interconnection aspects

4.3 Location dependent addressing

4.3.1 EIRENE aims to offer a system of communication between driver and controller that allows the driver to contact the appropriate controller by the press of a single button or entering a common short dialling code. The driver must also be able to contact others (eg the power controller and the secondary controller) in a similar manner.

4.3.2 As the train progresses along its journey, it will pass through a number of different controlling areas. It is time consuming and dangerous, particularly as far as emergency calls are concerned, if the driver needs to manually determine where the train is located and then type this information into the handset before being able to make the call. Instead, an automatic updating process is required, which routes the driver's call to the correct controller at any given time. In order to be able to route the call correctly through the network, GSM-R requires train location information.

4.3.3 The called party number depends on that party's function and:

- location of train (railway area);
- track number that the train is running on;
- direction of the train running through the railway area.

4.3.4 Another parameter which may influence the routing procedure is:

- time of day and/or date.

4.3.5 The call always has to be routed according to the information available when the call is initiated. The location dependent routing has to be done even if no additional information is available or necessary (e.g. tracks without balises or railway areas not matched to radio cells).

4.3.6 The call is typically initiated by the train driver using the cab radio, but the location dependent routing should ideally be supported for other functional calls, using other terminals (e.g. hand portable radios).

Method of location establishment

4.3.7 Correct routing of the call using a mobile station could be done by using the monitoring function of the radio cells which is an inherent part of the GSM functionality. If a call is being initiated, the cell in which the call originates should then allow the call to be routed to the correct operator. Although this may work under certain circumstances, there are some major disadvantages to this approach:

- cell boundaries do not always coincide with the area boundaries of the controller, as is shown in figure 4-8. This means that knowledge of the radio cell in which the mobile station originates the call alone will not necessarily lead to the correct controller;

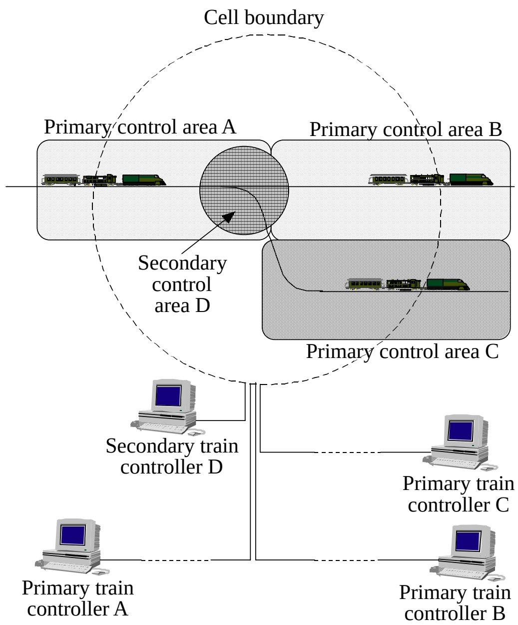

Figure 4-8: Train controller areas

- cell boundaries are 'fuzzy', ie they vary in size and shape due to, for example, weather conditions;
- the cell structure and cell routing functionality does not allow for flexibility in cases where control areas are combined at times of less intensive traffic;
- the requirements for the design of mobile networks are independent of the layout of controller areas, which means that a change of GSM network design leads to a change in the relationship between cells and controller areas. This is of particular importance in those cases where a public GSM network is used.

4.3.8 As call routing based on cell routing may not meet all requirements (ie position may not be determined up to a desired accuracy), some other means of position information collection may be required by national railways.

4.3.9 In order to allow call routing to the appropriate controller, there is some combination of position information and routing algorithm required. Furthermore, there are interoperability considerations to be made about the choice of method by which the position information is obtained. Examples of possible methods are:

- track-side signalling systems (e.g. train describers);
- transponders: in this option, passive transponders (such as loops and balises) are located along the track and inform passing trains of their location. The transponders would be placed at the boundary between signallers' areas and potentially elsewhere if more accurate position information is required;
- navigation system (GPS, beacons etc);

– tagging system: passive transponders are mounted on each train. Track-side interrogators are then placed along the track in order to monitor the passing of trains.

4.3.10 The railway will have to consider these aspects in detail and specify the way in which position information is to be provided to the level of accuracy required by the railway.

Providing position data to routing database

4.3.11 Position information is held in some form of routing database to allow location dependent addressing. The information stored within the database can be obtained via either an on-train positioning system (e.g. balises or GPS) or via a track-side positioning system (e.g. train describers or ERTMS/ETCS RBC).

4.3.12 Train information is used within the network in which a train is currently operating to provide location dependent call routing from mobiles to controllers. Where information is provided from on-train systems, it is important that the requirements the E-SRS places on provision of position information are met in order to ensure that position information from international trains is of the correct format for use by national networks.

4.3.13 The way in which information is provided to the routing database may be implemented in different ways as follows:

- via on-train positioning system:
  1. the positioning system collects the position information in the system specific format;
  2. this information is passed on to a formatter, which converts this system specific format into the required standard position format;
  3. the standard position information is passed on to the cab mobile radio, which adds to the data the train identity;
  4. this position data string is sent across the GSM network to the appropriate routing database;
  5. the routing database stores the information for use when the mobile originates a call requiring location dependent addressing.
- via track-side positioning system:
  1. the positioning system collects the position information in the system specific format;
  2. a train identifier is added;
  3. the position data string is sent across the fixed telecommunications networks to the correct routing database via appropriate data links;
  4. the routing database stores the information for use when the mobile originates a call requiring location dependent addressing.

Figure 4-9 gives an overview of these two possible mechanisms and shows how the relevant systems would relate to each other.

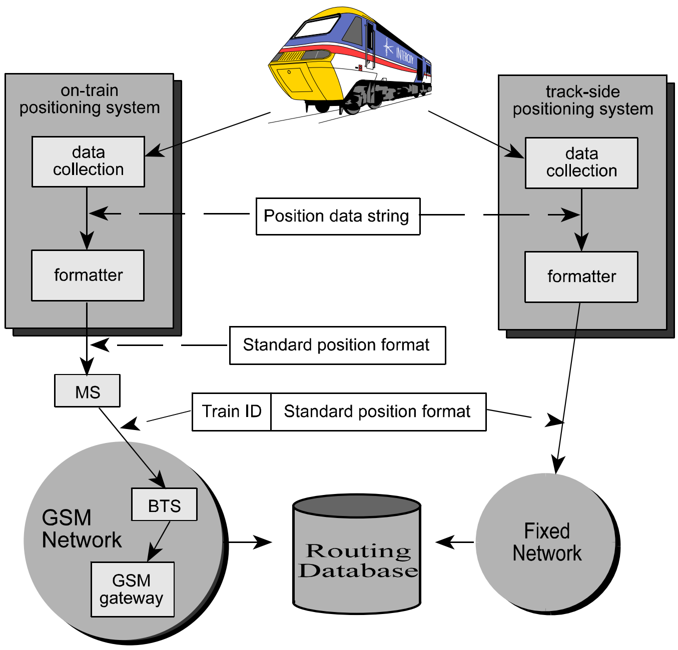

Figure 4-9: Providing train position information to the routing database

4.3.14 When collecting position information it is important to consider the requirements for the accuracy of the location information held in the routing database, and how frequently this should be updated. This will affect the probability that a call is routed to the correct controller, and will be affected by considerations such as controller area size, train speed and the performance of the external system providing the location data. In the case of position information from on-train systems, sufficient capacity will be required in the radio system to allow trains to update their location at the required frequency.

Interoperability aspects

4.3.15 As far as implementation of positioning systems is concerned, the railway should consider the four situations detailed in table 4-2 with regard to trains roaming from their home network into foreign networks and the associated issues related to interoperability.

		Foreign network	
		Track-side	**On-train**
Home network	**Track-side**	No specific interoperability issues	Will lead to interoperability problems
	On-train	Aspect of suppression of position information of on-train system to avoid congestion of network should be considered	No specific interoperability issues

Table 4-2: Position information interoperability issues

4.3.16 In those circumstances where a train with an on-train positioning system roams into a network that primarily relies on track-side train position information, a choice has to be made on whether the on-train position or track-side position information is to be accepted by the gateway switch and routing database. Both systems will provide the same position information, which means that the information provided by the track-side equipment is sufficient. This solution avoids additional implementation cost. However, the on-train equipment has to be informed that no position information is required from this system. This is to avoid the waste of bandwidth caused by sending position messages, which are not needed by the system.

4.3.17 A possible solution for international trains is by sending an SMS to the on-train equipment, switching the SMS feature off when entering the railway domain (ie during the registration phase) and switching the feature on again when leaving the domain (ie during the de-registration phase). The network should trigger the issue of SMS messages. In order to be able to do this, the network must know whether the international train supports an on-train positioning system. This could be deduced from the origin of the train, which can be derived from the Engine Number part of the Functional Number. In addition, the on-train systems must be able to act on the contents of the SMS message.

Specification requirements

4.3.18 Each railway will have to specify the method by which train position information provision is to be implemented, taking into account the following main aspects:

- the E-SRS specifies location dependent routing based on cell routing as a minimum requirement. This option should be available as a fall-back scenario if the railway wishes to implement a more sophisticated system;

- train position information may be obtained by means of either an on-train or track-side system. If the railway decides to use an on-train system, then consideration must be given to international trains roaming into GSM-R networks that rely on a track-side positioning system. In any event, cell routing must be available as a fall-back;
- if a more accurate positioning system is required, then the railway will have to specify the level of accuracy with which position information is required. In addition, there will be a requirement to specify the following:
  - the division of the railway into areas which are allocated to, for example, primary and secondary controllers. This division should also take into account dynamic aspects such as the grouping of areas during times of low traffic intensity;
  - the way the call routing database is to be populated and managed;
  - performance elements for both the system providing the location data and the system processing the data. The interface specifications should include consideration of time delays, processing capacity, etc;
- the requirements for the routing database, which include:
  - location of the routing database;
  - interaction of the routing database with the implemented telecommunications network, in particular in those situations where the mobile network implementation is based on a public network;
  - management of the information contained within the routing database.
- the eLDA (enhanced Location Dependent Addressing) working group is developing the interoperability requirements for providing GSM-R networks with train position information at a higher level of accuracy than the default mechanism which is based on cell routing.

4.3.19 It is important to note that controller areas may change from time-to-time. Furthermore, in some regions, controller areas may change on a daily basis. There must therefore be mechanisms in place to manage these changes (either manually or automatically). In addition railways need to consider the following:

- fallback in the case of a busy operator;
- fallback in the case of a fixed terminal failure;
- sudden changes required, e.g. in the event of an incident occurring.

4.3.20 In addition, railways should give consideration to the overlap aspects and whether more than one terminal should be the destination for these calls if cell based routing is used.

5 System planning and specification

5.1 Introduction

5.1.1 This is the preliminary phase of system procurement, mainly dealing with the feasibility and viability of the new system. It therefore includes the following activities:

- **A system feasibility study**, to perform an initial assessment of the proposed system. The aim is to determine whether the system can meet its business requirements and whether there is a sound financial case for developing it. The study consists of defining the reasons for the introduction of the new system, establishing implementation options and the assessment of their implications.
- **A requirements capture**, leading to a clear definition of user requirements, both functional and non-functional. This will determine requirements relevant to the size of the network, coverage levels, interconnections, migration, terminal design, etc.
- **A business case development**, which will lead to the formal acceptance of the system procurement and will secure the funding for the project.
- **Development of a system specification**, which will look at the system requirements and address issues such as interfacing the network to other networks and systems (eg location systems, signalling systems, train control systems and other telecommunications networks). It will also consider operational requirements, provision of services and facilities, system design, equipment requirements, management systems, implementation requirements, safety aspects, RAM requirements and EMC.
- **Development of a procurement strategy**, which will detail how the network is to be procured and will deal with issues such as implementation options (private versus public network) and service provision (privately operated or outsourced).
- **Development of a migration plan**, which will include aspects such as the rollout plans and plans for the transfer from the old system to the new system.

5.1.2 The basis for the mobile part of the integrated radio system specification is provided by the E-SRS and the E-FRS. However, the E-FRS provides top-level user requirements and constraints and the E-SRS provides technical standards and constraints required for international interoperability. Therefore, neither document alone could serve as a technical system specification for the entire integrated radio system as part of an ITT.

5.1.3 Due to the nature of the E-FRS and E-SRS, there are several options for implementing an EIRENE-compliant radio system. The previous section of this document has pointed out where the specifications allow for flexibility in design and how this can be used in the development of the national system specification.

5.1.4 In addition, the EIRENE Specifications do not comprehensively cover certain aspects of implementation and design such as coverage, frequency allocation or performance monitoring. These additional aspects of system design form an important part of the technical specification, but their needs are mainly driven by operational and business requirements. Since these will differ between individual railways, the railways must be responsible for the specification of their own system designs.

5.1.5 This section discusses several of the particular aspects to be considered by the individual railway when specifying the radio system, but which are not fully addressed in the EIRENE Specifications:

– network interconnections;
– European Train Control System (ETCS) requirements;
– licensing and frequency allocation;
– radio coverage;
– type and safety approvals;
– RAM requirements;
– network management;
– international roaming.

5.1.6 For a more comprehensive list and description of the aspects not addressed by the EIRENE Specifications, please refer to sub-section 2.5 of this document.

5.1.7 It should be stressed that it is not the aim of this procurement guide to detail the way in which the feasibility study, requirements capture and business case need to be performed. The way in which these are carried out is entirely driven by the procedures each railway has for these aspects of system planning. However, general guidelines are provided at the end of this section.

5.1.8 The procurement strategy, which forms the final part of system planning, is considered in the next section of this document.

5.2 GSM-R network interconnection

5.2.1 Introduction

5.2.1.1 The GSM-R network is unlikely be stand-alone. It may be connected to a number of other voice and data networks (eg PSTN, PSDN, railway fixed network). This section discusses the technical issues related to the interconnection of GSM-R networks operated by different railways. It covers the following areas:

– **physical interconnection:** the actual interfacing of equipment;
– **logical interconnection:** the information to be transported over the interface;
– **procedural interconnection:** the procedural interface requirements.

5.2.1.2 Interconnection of networks is required to support the transfer of network management information and also for hand-over of ongoing calls. The method of interconnection will define whether it is possible to hand over calls without interruption to support roaming mobiles.

5.2.2 Physical interface

5.2.2.1 The physical interface describes the link between the GSM-R networks of different railways. This link is connected to the break out/break in points of the network, which are considered to be the GSM-R Gateway Switches.

5.2.2.2 The link between the Gateway Switches of different GSM-R networks may be either via the private pan-European Railway network or via one or more public networks. Three main inter-GSM-R network interfaces can be considered, regardless of implementation:

- **Private link**. In this situation, the GSM-R networks and interconnections form a private network. This situation potentially gives the railways the highest degree of flexibility in interface definition and use of numbering plans. However, achieving the full potential advantages from this approach (whilst ensuring international interoperability) will require a high degree of co-ordination between the national railways. Furthermore, the adoption of bespoke solutions in this implementation may lead to problems.
- **Public leased line**. In this situation, the GSM-R networks are connected as a Virtual Private Network. However, as the leased line is part of one or more public networks, care should be taken that information specific to GSM-R is passed transparently. Furthermore, as the GSM-R networks are connected to public networks, the network interfaces and associated 'low level' protocols (see below) need to be agreed with the public network operators.
- **Public switched link**. In this situation, the networks are connected via public networks without any specific arrangements. This interconnection gives the lowest level of flexibility as the protocols and any information passed during call set-up have to comply with the public network requirements.

5.2.2.3 In general, in the situation of using GSM-R network interconnections via the public network, the interface between the GSM-R networks and public networks requires standard interfaces and signalling protocols for call set-up.

5.2.2.4 The interface needs to support the standard voice and data bearer services specified in the EIRENE System Specification.

5.2.3 Logical interface

5.2.3.1 The logical interface deals with the protocols to be used over the physical interconnection and the information to be conveyed.

Protocols

5.2.3.2 Depending on the approach, the interconnection of the GSM-R networks could be completely private, or partly via public networks. To provide full functionality, two types of protocol need to be considered:

- **Call set-up protocols**. These are the low-level protocols that are used by networks to establish calls. The protocols referred to are DSS1, SS7, etc. As long as EIRENE does not require any specific functionality from these protocols, then there are no specific requirements to be set. However, the E-SRS refers to UUS1, sub-addressing, etc, which may have an impact on the call set-up for international roaming trains. The degree to which the different network and protocols support these features during call set-up need to be considered.
- **Information exchange protocols**. These protocols relate to the exchange of information between applications after the link between the Gateway Switches has been established and are considered to be 'high level', ie are passed on the voice or data channel, rather than conveyed via the signalling channel.

Functional Number registration and de-registration

5.2.3.3 The information related to a train's ***Functional Number*** registration is held in the routing databases of the Gateway Switch in the GSM-R network in which the train is currently operating. However, when a train crosses a network border, the Gateway Switch of the network entered needs to be informed of the on-train users. This registration and de-registration can take place via manual actions of the on-train users, or the information can be passed from the 'old' Gateway Switch to the 'new' Gateway Switch, in which case registration and de-registration is done automatically.

5.2.3.4 If the on-train users have to perform the re-registration procedure, then the interface between the Gateway Switches will not be required to convey any ***Functional Number*** information. The question is then, at what point the user should de-register from the 'old' Gateway Switch and whether there should be a consistency check. Furthermore, what time interval is available for the user to register at the 'new' Gateway Switch and what would happen if a user fails to re-register? These are issues that need to be addressed in the procedures to be followed, which are discussed in the following section.

5.2.3.5 If the re-registration takes place automatically, the boundary crossing of the train needs to be registered and the information exchange between the two Gateway Switches needs to be initiated. This can either be a manual activity of one of the controllers at either end of the boundary, or via the position information system detecting the train passing over the boundary. Whatever approach is taken, the two Gateway Switches have to establish a link, after which the routing database information can be exchanged.

Hand-over of calls

5.2.3.6 During boundary crossings, calls between train drivers and signallers may still be ongoing. It is expected that there will be a degree of overlap between the GSM-R networks and the call can therefore be continued for some time after crossing the boundary.

5.2.3.7 Once the train reaches the border, a hand-over is required between the two GSM-R systems. This hand-over requires information transfer between the two networks. An issue to be considered here is whether it is desirable for the driver to continue a conversation with a party belonging to the 'old' network. It will probably be necessary for the driver to finish an ongoing conversation before attempting to register to the new network.

5.2.3.8 This issue should also be considered for other on-train users (eg catering staff), although hand-over requirements for these users will be less strict than those required for train drivers. In practice, this facility may be implemented between two national networks if both parties are in agreement that it is required.

Position information

5.2.3.9 It is not envisaged that any position information is to be exchanged between GSM-R networks when a train crosses a boundary for the purpose of (location dependent) call routing. It is, however, assumed that each railway will have an appropriate train position information system at boundaries of their network to allow sufficient detection of trains entering and leaving the railway network.

5.2.3.10 It should be noted that this aspect also needs to be considered as part of the roll-out of the GSM-R network as trains may enter and leave areas covered by the GSM-R network on a national basis.

5.2.3.11 For more information on position information requirements and call routing, the reader should refer to section 4.3 of this guide.

Functional Number transfer

5.2.3.12 The inter-network transfer of ***Functional Number***s takes place in two situations of call set-up:

– **Call routing without roaming**. This situation arises when the calling party as subscriber to one railway network wants to contact a called party registered in another railway network. In this situation, the calling party will dial an International Functional Number, which is translated by the Gateway Switch into a National Functional Number with an appropriate prefix to get the call routed to the destination network. The way in which this is achieved depends on the way in which the numbering plan is implemented and how Functional Numbers are used in call set-ups. The protocol and format for the exchange of data between the Gateway Switches of different GSM-R networks should be as defined in the EIRENE Specifications.

- **Call routing with roaming**. This situation arises when a calling party of one railway network wants to contact a called party belonging to the same railway network, but currently positioned outside its own railway network boundary. In this situation, a National Functional Number is dialled and the translation into the MSISDN number of the mobile takes place before the international link is established. Therefore, this situation does not require the transfer of any Functional Number information.

5.2.4 Procedural interface

5.2.4.1 These interfaces cover the procedures related to trains crossing boundaries. These procedures describe the way in which, for example, hand-over between controllers takes place or how re-registration is performed.

5.2.4.2 The procedures need to be established on a bilateral basis and fall outside the scope of this document.

5.3 Licensing and frequency allocation

5.3.1 Frequency allocations

5.3.1.1 To establish a new pan-European radio system, the UIC identified at an early stage a common frequency band as a key element to ensure economies of scale and international operation.

5.3.1.2 The UIC has, on a European level, negotiated with the Frequency Management Working Group of the ERC for a block of frequencies for GSM-R. This resulted in Recommendation T/R 25-09 E, in which the CEPT (now ERO) recommends designating the band 876-880 MHz (up-link) paired with 921-925 MHz (down-link) for GSM-R systems, as follows:

1. *that in CEPT countries the international requirements without excluding national requirements of railways for non-public digital radio communications system in the 900 MHz band should be covered by selecting appropriate sub-bands from the designated band 876-880 MHz (mobile station transmit) paired with 921-925 MHz (base station transmit) with a duplex separation of 45 MHz.*

2. *that close liaison between CEPT and UIC should be established in order to provide by the year 2005 the designated frequencies for international use.*

5.3.1.3 It should be noted that the recommendation also states that *'after the introduction of the radio system most of the frequencies presently used would be liberated by the railways'*.

5.3.1.4 The recommendation of introducing frequencies for railways in the 900 MHz band leads to the classification of frequency allocation for GSM 900 as detailed in table 5-1 [GSM TS 05.05].

	Uplink	Downlink
Primary GSM	890 – 915 MHz	935 – 960 MHz
Extended GSM	880 – 915 MHz	925 – 960 MHz
Railways GSM	876 – 915 MHz	921 – 960 MHz

Table 5-1: GSM frequency allocations

5.3.1.5 EIRENE-compliant radios are expected to be able to operate in the Railways GSM band as stated in section 4.2 of the E-SRS.

5.3.1.6 Although the European Radio Implementation Group manages the international aspects of frequency allocation, it is the responsibility of each railway to go to its individual frequency administration and negotiate the exact frequency requirements. This is of particular interest in those situations where a railway decides to implement either a private network or a hybrid solution.

5.3.1.7 When implementing a private or hybrid network, the railway must ensure that a frequency band is allocated in the UIC frequency range.

5.3.1.8 Although a specific frequency band has been allocated for use by railways, on a country-by-country basis, this band may currently be in use by other organisations and not be available at the time the railway seeks to implement an EIRENE-compliant network. This will have an effect on the ease of implementation and interoperability, which will vary according to the individual circumstances encountered at the time of implementation. This aspect also needs to be considered when implementing a network using public GSM network providers (see section 3.3).

5.3.2 Licensing

5.3.2.1 Originally, railways included all aspects of railway operations within a single organisation. However, more and more railways find themselves split into various organisations responsible for railway operations. This trend makes it less clear whether an EIRENE-compliant communications system can be considered as a true private network, or whether the railways are providing services to third parties.

5.3.2.2 It is important for a railway to investigate how the national Administration considers the GSM-R network and its users and whether this has any implications for obtaining licenses to operate the network and to provide services.

5.3.2.3 It should be noted that even in the situation where the GSM-R network is provided by a public network operator, the complete integrated radio system may still be considered as run by the railway and therefore needing a licence. This is due to the fact that the complete network also consists of fixed network elements and an associated management system which are most likely procured and operated by the railway.

5.4 Radio coverage

5.4.1 A fundamental part of the design of a radio network is the radio coverage requirement. For railways, this is mainly driven by the safety and performance requirements of train operations.

5.4.2 It is up to individual railways to determine their requirements for coverage levels. The E-SRS does, however, provide guidelines for the level of coverage required. These guidelines are as follows:

5.4.3 The following minimum values shall apply: (M)

- coverage probability of 95% based on a coverage level of 38.5 dBµV/m (-98 dBm) for voice and non-safety critical data;
- coverage probability of 95% based on a coverage level of 41.5 dBµV/m (-95 dBm) on lines with ETCS levels 2/3 for speeds lower than or equal to 220km/h.

Note 1: The specified coverage probability means that with a probability value of at least 95% in each location interval (length: 100m) the measured coverage level shall be greater than or equal to the figures stated above. The coverage levels specified above consider a maximum loss of 3 dB between antenna and receiver and an additional margin of 3 dB for other factors such as ageing.

Note 2: The values for ETCS levels 2/3 concerning coverage and speed-limitations are to be validated and, if necessary, reviewed after the first operational implementation of ETCS.

5.4.4 In order to understand the meaning of these guidelines, it should be appreciated that due to various conditions, the signal strength at any particular point on the network will vary as a function of time. This aspect and the availability of the network need to be factored into any coverage level calculations.

5.4.5 Finally, it is not sufficient to provide coverage requirements as outlined above. In addition, the railway must guarantee that coverage levels are actually maintained at the right level over time. This requires performance measures and an associated performance monitoring strategy to be defined. This is particularly important when procuring services from a public network operator as this will form a major part of the Service Level Agreement.

5.5 Type & Safety approvals

5.5.1 General

5.5.1.1 EIRENE type approval issues primarily concern mobiles since it is the mobiles on trains that will roam between different railway networks. Various forms of type approval can be identified for GSM-R:

- **EIRENE functional approval**: to ensure that GSM-R equipment provides functionality in accordance with the EIRENE standards;
- **EIRENE safety approval**: to ensure that GSM-R will operate and be used safely on the railway;
- **Railway environmental type approval**: to ensure that equipment used on the railway is fit for purpose and meets the various statutory health and safety requirements.

5.5.1.2 Type approvals are well established and show a large amount of harmonisation across Europe. The situation with respect to safety approvals is different.

5.5.1.3 Safety involves careful consideration of both the functionality of GSM-R and the operational procedures, which control the use of the system. The fundamental difficulty with carrying out GSM-R safety approvals work at a European level is that operational procedures are not harmonised amongst national railways. Safety approvals will need to be carried out nationally based on national requirements. No European safety approval is planned beyond the functions provided for interoperability and specifications for reliability and availability levels.

5.5.2 Type approvals

5.5.2.1 The procedures for GSM type approval are well established. Type approval specifications are drawn up and maintained by ETSI and are adopted by national regulators throughout Europe using approved test-houses.

5.5.2.2 Railway environmental specifications are becoming increasingly harmonised across Europe through the work of CENELEC. However, many national requirements remain.

5.5.2.3 The Interoperability Directive requires a conformity assessment process consisting of procedures chosen from modules defined in Directive 93/465/EEC. This Directive lays down the general framework of the modular system. Based on this general framework, it is the specific Directive, and in this case the relevant TSI, that determines the conformity assessment procedures that the supplier must apply.

5.5.2.4 The GSM-R type approval regime, which will form part of the conformity assessment process, will need to consist of several layers, defined as follows:

- **Core GSM type approval**: This covers testing of features available in public networks against a set of harmonised standards covering the GSM specifications GSM TS 11.10, GSM TS 11.21 and the associated Common Technical Regulations (CTRs);
- **Enhanced GSM type approval**: This covers additional GSM features, which have been introduced as part of the development of the GSM-R radio system such as ASCI and R-Band. Tests are carried out against a set of harmonised standards covering the relevant GSM specifications GSM TS 11.01 and the associated CTRs.

- **Railway specific type approval**: This covers features specific to the GSM-R radio system, which include functional and location dependent addressing and specific environmental requirements. Tests are carried out against harmonised CENELEC standards, which are currently being drafted. These standards are partly based on the EIRENE Functional Requirements Specification and the EIRENE System Requirements Specification.
- **Other type approval**: In addition to the type approval elements described above, there may be additional requirements, which are the result of other applicable Directives such as the Low Voltage and the EMC Directives. Specific type approval is required according to the harmonised standards defined in these Directives.

5.5.2.5 Based on the conformity assessment process modules defined in Directive 93/465/EEC, combined with the type approval regime outlined above, the following strategies need to be considered:

1 **Full type approval**: This relates either to the type examination as defined in module B[3] of the Directive or to the unit verification of the design and production of each product controlled by a notified body as defined in module G. If module B is chosen, then this needs to be followed by one of the modules specifically covering the production phase;

2 **Self certification**: The manufacturer ensures and declares that the product satisfies the directives that apply to it without the intervention of a notified body. This is based on module A of the Directive;

3 **Hybrid solution**: The manufacturer is responsible for all tests according to a certified quality system covering design, manufacturing, testing and production. This total quality system must be based on EN ISO 9001 and must be approved by a notified body, which performs the audit role.

5.5.2.6 Both strategies 1 and 3 require intervention from the notified body. The difference is in the involvement of the Notified Body in testing of the equipment. Strategy 1 requires the notified body to take an active role in the conformity assessment process, whereas strategy 3 only requires the Notified Body to approve and audit the quality process, with the manufacturer having the responsibility for testing. Strategy 2, on the other hand, does not require the intervention of a notified body. This may not be ideal for type approving an GSM-R radio system.

5.5.2.7 Notified Bodies play an important role since they are designated to carry out the conformity assessment procedures as set out in the Directives to ascertain that a product conforms to the essential requirements of the applicable Directives. These actions are carried out under the authority and control of the national authorities of the Member States.

[3] A short explanation of the modules defined in Directive 93/465/EEC is given in appendix D of this document.

5.5.2.8 The Directives lay down the minimum criteria to be fulfilled by Notified Bodies. Key elements in this are:

- availability of personnel and equipment;
- independence and impartiality of the body, its management and staff in carrying out the conformity assessment procedures in relation to those directly or indirectly concerned with the product (e.g. designer, manufacturer, supplier, installer);
- technical competence (training, knowledge and ability to carry out test examinations, draw up certificates, etc) and professional integrity of personnel;
- maintenance of professional secrecy;
- subscription to civil liability insurance unless that liability is covered by the state under national law.

5.5.2.9 Bodies may be accredited to carry out tasks under one or more of the conformity assessment modules defined in Council Directive 93/465/EEC.

5.5.2.10 A body wishing to offer 'one stop testing and certification' under a directive will need to be notified for the modules indicated in the Directive that cover both design and production phase.

5.5.3 Safety approvals

5.5.3.1 Safety approvals for train communications systems are carried out on a national level. However, two articles of Council Directive 96/48/EC need to be considered by the national railway operator with respect to obtaining safety approvals for EIRENE-compliant systems:

- **Article 20** requires that each Member State notifies the Commission and other Member States of the bodies responsible for *"assessing the conformity or suitability for use of an interoperability constituent"* in compliance with the Directive;
- **Article 9** suggests that an GSM-R system which meets the safety approval requirements of the notified body of one Member State may, by implication, be considered to possess safety approval for operation in all other Member States. Practical enforcement of this principle is, however, likely to prove difficult. Co-ordinating effort will be required at European level to resolve differences in safety approval procedures and in the functionality and use of EIRENE-compliant systems.

5.5.3.2 However, several of the railways of the Member States, as well as the UIC Safety Committee have stated that the GSM-R system itself does not possess any safety requirements. The basis of this assertion is as follows:

- telecommunications services are used to support safety-related railway applications. However, safety is assured by means of applications external to the telecommunications bearer, or by means of operational procedures. Telecommunications are simply used as a non-safety-related bearer service;

- in order to ensure adequate safety of those applications which use telecommunications services, the telecommunications systems themselves have certain dependability requirements (in terms of reliability, availability and maintainability) but no specific safety requirements as such;
- the GSM-R system is no exception to this rule. It has no specific safety requirements and need not therefore be associated with a specific safety integrity level (SIL);
- certification will however be required for certain GSM-R system elements. For example:
  - compliance with ETSI norms, assurance of transmission and frequency aspects, health and safety of individual persons, etc;
  - certification of railway-specific elements such as EMC, interoperable functions, ability to be used in a railway environment and supplementary national functions. Certification requirements are likely to be identified either by European Norms (CENELEC, CEN) or by UIC rules (UIC leaflet 751-4 etc).

5.5.3.3 In order to interpret the assertion that no safety requirements are to be placed upon GSM-R, it is important for each railway to identify exactly which applications are being referred to. In particular:

- there are many applications *external* to GSM-R (eg ETCS) which will make use of GSM-R as a bearer service;
- there are also several applications internal to GSM-R (eg railway emergency calls, driver-controller calls, DSD messages) which are provided by the GSM-R telecommunications service and which use a GSM network as a radio bearer.

5.5.3.4 Demonstrating that an EIRENE-compliant system is safe for railway operation therefore depends to a large extent on:

- the functionality and performance provided by the system, and the integrity with which it is provided;
- the manner in which the system will be used, and the operational procedures to be employed to support its use;
- the other applications that will use the system and the level of integrity which they will assume.

5.5.3.5 At a European level, there are a number of standards available or under development which may be relevant to the safety of railway communications:

- IEC 61508, *Functional Safety: Safety Related Systems;*
- EN 50126, *Railway Applications: Dependability for Guided Transport Systems;*
- EN 50128, *Railway Applications: Software for railway control and protection systems;*
- ENV 50129, *Railway Applications: Safety-related Electronic Railway Control and Protection Systems;*

– EN 50159-1, *Railway Applications Part 1: Requirements for Safety-Related Communication in Closed Transmission Systems;*

– EN 50159-2, *Railway Applications Part 2: Requirements for Safety-Related Communication in Open Transmission Systems.*

5.5.3.6 The first four standards are aimed at the development, maintenance and operation of systems. Each embodies the Safety Lifecycle concept, defining the key stages of safety assurance and the processes and procedures to be adopted at each stage according to the required safety integrity. The last two standards apply to communications systems, which involve the transfer of safety-related data. Since GSM-R simply provides a bearer for data messaging, these standards do not appear to apply to GSM-R directly. They would however apply to any application, which employs GSM-R for the transmission of safety-related data.

5.5.3.7 Some railways/bodies have their own safety standards and procedures in addition to the European and international standards. By definition, these additional standards/procedures must be consistent with the relevant European and International safety standards.

5.5.3.8 When procuring an EIRENE-compliant system the railway needs to gain approval from the notified body for its country as required by Article 20 of the EC Directive on Interoperability. This body should state whether any additional requirements over and above those advocated by existing safety standards need to be imposed.

5.6 RAM requirements

5.6.1 General

5.6.1.1 The RAM requirements placed on the radio system will depend largely on the application(s) being run over the radio system. The requirements fall into two categories, operational requirements and safety requirements, while the applications can be split into two general classes, driver to controller communications and train control applications.

5.6.1.2 In order to assess the RAM requirements placed on a given application, the impact on train running of an application failure due to a radio system problem needs to be quantified. For example, in a driver to controller communication application, the loss of radio communication may not physically stop the train from running. However, it will have an impact in terms of safety, as the driver and controller will not be able to communicate in the event of an accident or emergency, which may lead to train running being suspended.

5.6.1.3 In comparison, for a train control application such as full in-cab signalling, the loss of the radio bearer will lead to a loss of signalling information, and may in some cases result in the train being forced to stop. It should be noted, however, that the signalling system is assumed to be fail-safe and there will be no safety implications of losing communications.

5.6.1.4 The impact of any system failure will also depend on the location and extent of the failure. For example, the effect of the loss of radio coverage on a small stretch of a lightly used, isolated section of line will be small compared to the loss of radio coverage at a major junction or over many kilometres of busy, intersecting lines.

5.6.1.5 Therefore, the availability requirements of the communications network, as well as being specified for the application being used, may also need to be specified by line or by geographical area.

5.6.1.6 Once the effects of failures of the application due to each identified failure mode have been identified, the potential end user is then in a position to set the availability requirements for the network.

5.6.1.7 This is achieved by deciding what levels of availability are acceptable for each of the failure modes. As each of the failure modes can affect different lengths of track and therefore can have significant differences in their impact on train running, the availability requirements may be different for each of the different failure modes.

5.6.1.8 This therefore indicates that a single availability figure for a system may not be appropriate. Typically, a system's availability is expressed as its ability to provide full functionality and, conversely, it is deemed to be unavailable if any of its components becomes unavailable, leading to a loss of functionality. This implies that the loss of coverage over a small length of track has the same impact, and hence is equally undesirable, as the loss of coverage over a large length of track. Therefore in some instances there will be a need to specify system availability in terms of the system's different failure modes.

5.6.1.9 Care should also be taken in setting availability levels for a given system. Whilst an overall availability can be quoted either for a whole system or for its differing failure modes, the impact of this on system design will depend on the size of the system. For example, if two systems have the same overall availability, but one covers twice the area of the other and therefore has twice the number of components, these components will need to be twice as reliable to meet the same system-wide availability target.

5.6.1.10 The availability of the radio system should also be computed in conjunction with the availability of the rest of the railway infrastructure. There is no point in designing and paying for a radio system, which provides availability some orders of magnitude higher than the availability of other system elements.

5.6.1.11 For example, a failure of the in-cab radio will, from the point of view of the train driver, be the same as a failure of the whole radio network. If the failure of cab radios is the dominant failure mode, then improving the reliability of the GSM network by an order of magnitude will not improve the overall reliability of the railway. Similarly, in the example of train control, if other parts of the train control system have a low availability, e.g. the infrastructure providing train location information, then the overall availability of the train control system will be low, regardless of the availability of the GSM network.

5.6.1.12 Therefore, the availability requirements of the radio system should be set with the size and physical extent of the system in mind and with respect to the availability of the rest of the railway infrastructure.

5.6.1.13 Also, certain parts of the network may need enhanced availability, thus requiring extra resilience in those areas. The enhanced availability will need to be determined for each of the failure modes and, if it is required at a sufficiently high level (eg the network-wide failure mode), the enhanced requirements may effectively become the requirements for the whole system.

5.6.1.14 Finally, availability of a system is closely related to the maintainability of the system. The maintainability of the system, which is a function of the system design, will be related to the fault management and maintenance strategy employed, as availability is directly related to the speed with which failures in the system can be detected, located and functionality restored. These aspects need to be considered carefully by the railway when specifying performance parameters.

5.6.2 Methodology

5.6.2.1 A methodology for producing availability requirements for a communications network depending on the application(s) being run over the radio system and the needs of the end users of the system includes the following main steps:

- determine the application(s) running over the GSM network;
- determine the failure modes of the GSM network;
- determine the failure modes of the application, based on the failure modes of the GSM network;
- determine the operational and safety requirements of the train operator based on the failure modes of the application;
- determine the impact on train running of the various GSM failure modes, based on the above requirements;
- determine the level of impact deemed acceptable by the train operator and use this to set the requirements on the GSM network's availability.

5.6.2.2 Once the requirements have been set according to the steps outlined above, it is then possible to carry out a cost-benefit analysis by comparing the available network architectures and to consider what steps need to be taken to increase network resilience to support the required performance levels. The cost of any proposed solution should then be compared to the cost savings arising from the increased resilience.

5.6.2.3 When specifying the RAM requirements, the railway should bear in mind that in some instances separate availability requirements will need to be specified for the various system failure modes and not just for the system as a whole. It also demonstrates that the requirements will vary on an installation-by-installation basis.

5.6.2.4 The railway should keep in mind that, when specifying the end-to-end performance parameters, a similar methodology needs to be followed for the fixed network. The results then need to be combined with those obtained for the mobile network to derive the optimum end-to-end solution.

5.6.3 Availability and reliability issues

5.6.3.1 End-to-end performances of voice and data services are the main points of interest for railway users. In order to determine the performance requirements for a communications network, the following availability issues need to be taken into account for both private and public network implementations:

– networks have many different failure modes which may have different impacts on train running, leading to a degraded service or a complete failure of the application;

– the same failure mode may have different impacts on train running, depending on the location of the failure, the level and type of traffic using the line and even where the trains are at the time of failure;

– the availability of a system will vary with the size of the system and the number of elements in the system or, conversely, to achieve the same level of availability from two systems, where one has double the number of components of the other, these components will need to be twice as reliable;

– the availability of the system needs to be set in the context of the availability of the rest of the railway infrastructure contributing to the application in question.

5.6.3.2 As national railway authorities specify and install GSM-R systems, they will need to base their reliability and availability requirements around the requirements of the applications running over the system. The particular demands of any application will therefore depend on the national railway authority implementing the application and the type of traffic using the application.

5.6.3.3 Reliability requirements are often expressed in terms of the Mean Time Between Failures (MTBF) of specific equipment components (ie the average period for which an item of equipment will continue to operate before failure).

5.6.3.4 Availability is generally specified as a combination of the MTBF and Mean Time To Repair (MTTR) of a given equipment item. It is a measure of the percentage of time for which an item of equipment is in operation.

5.6.4 Performance monitoring

5.6.4.1 In the case of a public GSM network, RAM requirements and the associated levels of service required from the network operator(s) will need to be carefully considered and set out in the Service Level Agreement (SLA) between the network operator(s) and the railway. In order to be able to assess the actual quality of service provided by the network, methods should be devised to monitor, on an ongoing basis, quantities such as:

- call set-up times;
- coverage reliability and signal strength;
- hand-over times;
- hand-over interruption;
- byte error rates;
- end-to-end transmission delays;
- number of calls dropped.

5.6.4.2 The railway should consider the aspect of performance monitoring and the way in which this can be achieved. In most cases, the method by which this on-going monitoring can be achieved will be subject to discussion between the railway and the network operator(s).

5.6.5 Maintainability

5.6.5.1 The *maintainability* of an object, system or service is a measure of how easy it is to repair a fault within the system. It is also a measure of how easy it is to perform routine and preventative maintenance, which enhances the object, system or service's reliability. Maintainability is therefore closely related to the system and component design and should as such be considered in conjunction with these aspects of system specification and procurement.

5.6.5.2 The ease with which an object, system or service is repaired is usually expressed as its Mean Time To Repair (MTTR), although the acronym MTTR is also sometimes used as Mean Time To Replace. This is particularly the case in modern systems, where individual sub-systems can be replaced upon failure, thus effecting a repair on the overall system.

5.6.5.3 Note that the definition of MTTR includes not only the ease with which the object, system or service can be repaired, but also the speed with which the fault is detected and identified and the speed with which the relevant maintainer is notified and can attend to the problem. Maintainability therefore includes the aspects of fault detection, fault identification and the notification and attendance of the relevant maintenance personnel.

5.6.5.4 Maintainability will also include preventative and routine maintenance, especially the ability of an object, system or service to maintain full functionality while undergoing maintenance.

5.6.5.5 Maintainability of the communications system is not covered by the EIRENE Specifications. It is the responsibility of the railway to define its requirements, which are most likely driven by its business and operational needs.

5.6.5.6 As part of the maintainability specifications to be included in the ITT, the railway should consider the following particular aspects:

- specification of fault management functionality required;
- definition of a maintenance strategy, which should include both preventative and corrective maintenance;
- definition of responsibilities and clear lines of reporting.

5.6.5.7 Fault management is a set of functions which enables the detection, identification, localisation and, where possible, isolation and correction of abnormal operation of the communications system. It provides facilities for the performance of maintenance phases from ITU-T Recommendation M.20:

- **alarm surveillance**: provides the capability to monitor the quality of service provided through network elements. When an event indicates a measured degradation of service or equipment performance, surveillance features either inform the system manager or invoke other operations which minimise and correct the faults, thus allowing proactive maintenance capabilities.
- **fault localisation**: where the initial failure information provided by the system is insufficient for fault localisation, it has to be augmented with information obtained by additional failure localisation routines. The routines can employ internal or external test systems and could be controlled by the system management platform(s).
- **fault correction**: fault correction normally requires change or repair of equipment. One or more fault corrections can be performed in the course of a maintenance visit. It is desirable that strategies be developed to accomplish fault correction satisfying overall maintenance objectives within a minimum number of visits, using the concept of logistic delay.
- **verification testing**: after the fault has been corrected, checks must be carried out to assure that the equipment is working correctly. The diagnostics testing can either be carried out locally or remotely. Two principal methods are available:

  - analysis is carried out by equipment and results reported to the management platform;
  - analysis is carried out by the management platform.
- **trouble administration**: records should be kept, detailing current trouble status, additional information, actions that have been executed, are being executed or will be executed, which troubles have been resolved, etc. Accurate record keeping will allow organisation of maintenance and optimisation of the maintenance policy.

5.6.5.8 To allow this, fault management must include functions to:

- generate, maintain and examine error logs;
- accept and act upon error detection notifications;
- trace and identify faults;
- carry out sequences of diagnostics tests;
- correct faults.

5.6.5.9 The maintenance strategy should build on the fault management functionality provided. It should cover aspects such as:

- preventative and corrective maintenance activities;
- maintenance support (eg sub-contracting maintenance aspects);
- spares holding, supply lead times, etc;
- logistics, including response times and accessibility of sites;
- resource requirements.

5.6.5.10 When defining the maintenance strategy, the railway should also take into account the performance and availability requirements placed on the system, as these will be a main driver for most of the aspects to be considered.

5.6.5.11 Finally, the railway should ensure that clear lines of communication for fault reporting are defined. It should consider in particular the way in which users are to report faults and how maintenance teams, or a network operator in case of a public network implementation, are to be informed. Streamlining of fault reporting will lead to a reduction of duplication and resource requirements and ultimately to a more efficient handling of the failures. In addition, feedback on progress needs to be considered.

5.6.5.12 Effective preventative maintenance/maintenance are essential to the successful operation of a GSM-R network. Aspects such as the training and qualification of maintenance staff need to be defined in detail by each national railway.

5.6.5.13 Persons, who are allowed to undertake maintenance work, must have the relevant training experience and supervision. Knowledge of the relevant standards, operating conditions, regulations and rules is also essential. Work instructions for each maintenance procedure need to be carefully defined, documented and disseminated to the staff responsible for undertaking the work. These work instructions need to cover the safety aspects of the work.

5.7 Network management

5.7.1 Introduction

5.7.1.1 As is the case with any telecommunications network, a network management system is a vital and fundamental part of system management as it is the means to streamline network operations processes, leading to correct and efficient operations.

5.7.1.2 Network management is the set of processes for the monitoring, control and co-ordination of all network elements within the communications system. Network management is therefore an integral part of the day-to-day running of the system.

5.7.1.3 In order to describe management operations on network elements in the GSM-R environment, the resources are viewed as managed objects with defined properties. Information required for network management purposes may be provided through local input, may result from input from other systems through network management (application layer) communication or may be a result of lower layer protocol exchanges.

5.7.1.4 The network management discussed in this document is based on the Telecommunications Managed Network (TMN) philosophy. TMN, which was developed by the ITU, is a management architecture framework that provides an environment for interfacing a telecommunications network with the management platforms that are used to manage it. Its architecture and interfaces are defined in the ITU-T M.3000 recommendation series. The basis for these recommendations is the ITU-T X.700 recommendation series, which define the ISO network management standards for the OSI reference model. Since their introduction, the standards have been promulgated by other standards bodies, most notably by the Network Management Forum (NMF) and ETSI.

5.7.1.5 The TMN architecture supplies a model of logical layers that partition management of a network into five domains, or layers. Starting at the top, the hierarchy consists of the following layers:

- **business management layer**: handles the specific business goals and deals with aspects related to high-level business planning, budgeting, external relationships and legal arrangements;

- **service management layer**: this handles the contractual aspects of services, such as the definition of required services to be provided, interfaces between customers and the service provider; service level agreements; what statistical data a customer should have access to, usage and billing, etc;
- **network management layer**: controls and co-ordinates all elements within the network. It permits network modifications and interacts with the service management layer in matters related to performance, usage and network availability;
- **network element management layer**: controls and co-ordinates a subset of network elements. It compiles statistics, logging data and other data related to the network elements;
- **network element layer**: this contains the functionality of managing at element level and providing the required data of an individual network element in a useful form to the network element management layer.

5.7.1.6 The requirements to be satisfied by network management activities within each of the management layers can conveniently be grouped into five functional areas, each of which gives rise to one or more standards covering one or more functions. These areas, as defined by the OSI Management Framework and adopted by the TMN architecture, are:

- **fault management**: used to detect, isolate and repair problems. It encompasses activities such as the ability to trace faults through the system, to carry out diagnostics and to act upon the detection of errors in order to correct faults;
- **configuration management**: this defines the procedures for initialising, operating and closing down the managed objects, and the procedures for re-configuring the managed objects;
- **accounting management**: this defines how network usage, charges and costs are to be identified;
- **performance management**: this supports the gathering of statistical data and applies the data to various analysis routines to measure the performance of the system;
- **security management**: this provides the rules for authentication procedures, the maintenance of access control routines, authorisation facilities and security logs.

5.7.1.7 Many items of information, their associated management operations and the communication protocols are known to be common to more than one functional area. Therefore, in performing management activities, sets of management functions may be combined to effect a particular management policy. For these reasons, network management standards form a closely interrelated set of standards.

5.7.1.8 As a result, three main groupings within the set of network management standards are identified within the OSI framework. They are:

- a set of standards specifying network management functions;

- a set of standards relating to the specification of managed objects;
- a set of application layer service and protocol standards for communicating information relating to management functions.

5.7.2 Network management platform

5.7.2.1 The purpose of a TMN is to support the network operator in the management of the communications system in a flexible and efficient way. The TMN provides the telecom network with management functions and offers facilities for communication between the TMN and the telecom network. The basic principle underlying the TMN is therefore to provide an organised network structure that allows various types of Operations Support Systems, the system management platforms, to be connected to the telecommunications equipment.

5.7.2.2 The TMN is ***logically*** a separate network that interfaces the telecommunications network at several points to receive information from its elements and to control its operation. However, physically, a TMN often uses different parts of the network for its communications.

5.7.3 Network management specification

5.7.3.1 When developing the technical specification for the communications network, it is important to consider network management in detail. The way in which the network management functionality has been defined will, to a large extent, determine the flexibility in operations and maintenance of the system.

5.7.3.2 The technical specification for network management should, for each of the functional areas, define the specific requirements, state which parties should be allowed access to this functionality and how the access is to be achieved. In addition, the specification should consider aspects of interfacing the network management platform with management platforms of other network operators. This is of particular interest if the communications system is only partly outsourced.

5.7.3.3 Finally, the specification should not only include what information needs to be collected by the various network elements, but consideration should be given to how the collected data can be processed and presented by the system.

5.8 Numbering plan

5.8.1 Introduction

5.8.1.1 Although the E-SRS specifies the structure of the numbering plan to be used in GSM-R networks when using functional addressing, it does not address the way in which numbers are allocated. This depends on the national network implementation and the parties involved.

5.8.1.2 In general, it is the responsibility of the national railway to implement a numbering plan according to the EIRENE Specifications. This section will detail what is required under the various implementations. For more details on the use of functional addressing and call routing, please refer to sub-section 4.2 of this document.

5.8.2 Overview of numbering requirements

5.8.2.1 The EIRENE numbering plan, which consists of the Functional Numbers, is in principle a private numbering plan, although provisions will have to be made in order to allow routing through public networks. The following sub-sections detail the implications of using, firstly, a fully private network and, secondly, a network comprising a public fixed network and/or a public GSM network.

5.8.3 Allocation of numbers

Mobile numbers

5.8.3.1 The E-SRS mandates that each mobile is allocated an MSISDN number to allow authorised subscribers to call the mobiles using the appropriate MSISDN number rather than the Functional Number. Each railway will therefore be required to obtain MSISDN numbers for the mobiles from the relevant authorities.

5.8.3.2 There is an overlap between Functional Numbers and MSISDN Numbers. This overlap consists of the National Functional Number being equal to the Subscriber Number part of the MSISDN number as shown in figure 5-2.

5.8.3.3 The E-SRS mandates this overlap for Call Type = 8. However, railways may find that this overlap can also be achieved for other Call Types, depending on the implementation of the EIRENE numbering plan and the allocation of MSISDN numbers.

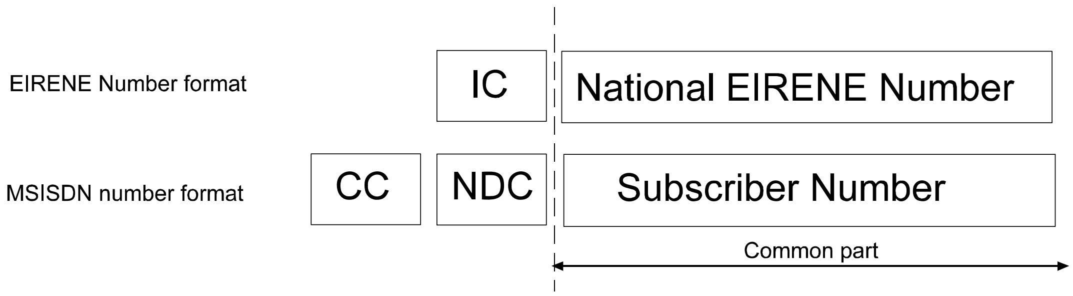

Figure 5-2: Functional Number - MSISDN number overlap

Fixed network extensions

5.8.3.4 Each fixed terminal connected to the GSM-R network requires an extension number. The exact requirements for number allocation depend on the national implementation of the communications network. If the fixed network is based on a public fixed network, then the numbers will probably be allocated by the fixed network operator. If the network is implemented as a private network, then no allocation is required and the railway will be free to allocate numbers to the fixed extensions as required.

5.8.3.5 Special care should be taken, however, that correct allocation of numbers is achieved when a public network is connected to a private network . In these situations, the railway needs to ensure that the overall numbering plan for the integrated radio communications system is unambiguous with the numbering plan used in the public networks.

Functional Numbers

5.8.3.6 The Functional Numbers allocated in the national network must comply with the structure as detailed in the E-SRS. This means that the railway must be careful in specifying the required numbers and achieving allocation of the numbers depends very much on the implementation and the availability of numbers.

5.8.3.7 The following specific situations need to be considered:

1 **Follow me in public network.** In this case, the Functional Numbers require routing through public networks and must therefore comply with the ITU-T E.164 numbering structure. The required numbers must be obtained from the network operators or, if the numbers are not available, from the national Administrator. With this implementation, there is a risk that the required numbers are not available, thus hampering a correct implementation of the EIRENE numbering plan. In addition, obtaining the correct numbers for future extensions may prove difficult.

2 **Intelligent Node implementation.** In this situation, if the IN is accessed before the Functional Number information is passed on to the node (ie by using the ENAN), then the railway only needs to obtain an ENAN and is then free to define the Functional Numbers according to the E-SRS. If the IN is ***not*** accessed via an ENAN, then the allocation requirements depend on the actual implementation of the network. If a public network solution is chosen, then the railway must obtain numbers as detailed in situation (1) above, otherwise the railway must obtain numbers as detailed in situation (3) or (4) below.

3 **VPN implementation.** If the network is based on public networks, but as a VPN, then the railway will have some flexibility in defining the required numbering scheme as the information is, in this case, passed transparently through the public networks. However, the railway must ensure that the numbers can be translated into the proper extension numbers as required.

4 **Private network implementation.** If the network is based on a private network, then the railway can design the numbering plan according to their own requirements (to ensure compliance with the EIRENE Specifications) and does not require allocation of numbers from any operator or the national Administration. It should be noted that this will only apply in those situations where both the fixed and mobile networks are private. If any part of the integrated radio network is based on a public network, then number allocation will be required as detailed in (1), (2) or (3) above, depending on the implementation.

Short codes

5.8.3.8 The railway must ensure that short codes are recognised by the network and this must be specified in the technical specifications.

5.9 Roaming aspects

5.9.1 There are two basic methods supported by GSM-R to handle the movement of trains from one national network to another. These are:

- **roaming:** describes a train which is registered in one GSM-R network, but is operating in another network;
- **non-roaming:** describes a train which has moved from its home GSM-R network to another national network and has temporarily registered there.

5.9.2 In the roaming situation, the train may be contacted from its home network using its (national) Functional Number even after it has crossed an international border (this functionality is provided by the GSM networks and is known as *GSM roaming*). However, in order for signallers in the GSM-R network that the train has roamed into to access the on-board mobile equipment, they will be required to use International Functional Numbers. The disadvantage of this is that it is undesirable for the signallers to have to look up the home networks of trains before they are able to contact them.

5.9.3 In the non-roaming situation, the mobiles will be registered in both GSM-R networks for a limited period of time, allowing signallers on either side of the boundary to call the mobiles using (national) Functional Numbers. The routing mechanism that will be used to achieve this is described in paragraph 10.6.11 of the E-SRS. The advantage of this is that the signallers can access the on-board mobile equipment without the need to determine the home network of the train.

5.9.4 In addition, there are situations where trains roam between an EIRENE and non-EIRENE network (note that this can also be the case when an GSM-R network is rolled out in phases). This particular aspect is not covered by the EIRENE Specifications.

5.9.5 Any specific issues related to the hand-over of trains between the radio systems used in each of these cases need to be identified by the railway and addressed in the technical specification. Issues that will need to be considered here include:

- location of boundaries;

- registration and de-registration when crossing boundaries;
- dual equipping of cabs;
- use of location information systems and passing information between the systems when crossing a boundary;
- membership of CUGs;
- private numbering plan and VPN access/membership;
- operational procedures, both for signallers and drivers.

6 Requirements capture and Business case development

6.1 Introduction

6.1.1 This section discusses two main aspects to be carried out at the early stages of system procurement: requirements capture and business case development.

6.1.2 It is vitally important to provide an adequate statement of requirement at the outset, particularly where requirements have significant impact on the design of the core infrastructure. The operational and financial consequences of failing to get the initial specification right could have a major impact on the railway's ability to meet its business and operational objectives and would consequently lead to higher costs. Sub-section 6.2 provides an overview of the different stages that can be identified as part of the requirements capture process.

6.1.3 Of equal importance is the development of a business case as this is generally the only way in which funds for the development and implementation can be made available. It is without doubt that the business case must reflect as close as possible the true costs of the investment as any underestimate may lead to additional funds not being available, therefore leading to an inferior solution. Sub-section 6.3 considers the aspects of the business case development.

6.1.4 It should be kept in mind that this section only provides general guidelines as it is likely that each railway will have particular ways of dealing with these aspects.

6.2 Requirements capture

6.2.1 Introduction

6.2.1.1 The task of defining requirements for any major new system and of expressing these by way of a formal User Requirements Specification is complex. It is, arguably, the most critical stage of the procurement process in that the downstream consequences of failing to provide the chosen supplier with an adequate requirements specification can be severe. The costs of subsequent changes to resolve the differences, if indeed this is practical, are likely to be very much greater than the cost of preparing an adequate specification in the first place. Furthermore, the corrective action will result in delay of the successful utilisation of the system.

6.2.1.2 Railway requirements considered in this document relate to the procurement of an integrated radio communications system, which meets an agreed set of performance criteria (e.g. coverage, capacity, grade of service, reliability, etc), partly specified by the EIRENE Specifications and partly the result of national railway requirements.

6.2.1.3 A number of important benefits stem from the development of a good requirements specification:

- its preparation forces the various interested parties within the railway organisation to consider their specific requirements carefully and to review the integration and rationalisation of the overall service within the context of each other's sets of requirements;
- the improved visibility of the requirements provides enhanced communication between the railway and supplier and provides a sound basis for contractual relationships;
- it provides a firm foundation for the design phase of the system;
- it enables the planning of validation, verification, and acceptance procedures to be made against a baseline for compliance;
- it provides a starting point for all subsequent control and management of the project, for example, estimates of cost, time and resource scheduling.

6.2.1.4 Requirements definition is the total process of moving from an initial statement of requirements to a precise and detailed requirements specification. In general, this process can be broken down into five sub-processes as follows:

- **Define terms of reference –** the scoping of the requirements definition process, comprising a clear statement of the objectives of the project, its scope, and the tasks to be carried out;
- **Requirements acquisition –** the process of extracting requirements from representative users, technical, management and support staff to ensure that all aspects of the requirement are defined;
- **Requirements capture and analysis –** the process of capturing these requirements in such a way as to facilitate analysis, checking, sorting, rationalising, prioritising and validating raw requirements to allow more meaningful information to be obtained;
- **Requirements specification –** the process of expressing the requirements in concise written form, comprising a series of higher level statements which are distilled from the individual user views. This represents the main output from the requirements definition process and serves as the basis for future procurement action;
- **Validation –** the process of ensuring that the requirements specification is complete and consistent, that it adequately reflects the requirements of users as agreed and endorsed, and that it is technically achievable taking into account any design constraints.

6.2.1.5 The remainder of this sub-section will consider the main aspects of each of these five steps in more detail.

6.2.2 Definition of 'terms of reference'

6.2.2.1 It is important at the outset to have a clear 'terms of reference' for the requirements definition task. This should be a straightforward description of:

- the objectives of the requirements capture process:
  - to raise awareness among users and other parties involved in the specification process;
  - to produce a high level Requirements Specification;
- the scope and boundaries of the user requirement:
  - identification of the core system/services to be procured;
  - identification of external systems with which the core system/services will interact (i.e. fixed networks, control rooms, information systems, terminals);
  - time period over which the service will be operational;
  - major dependencies and constraints;
- the tasks to be carried out:
  - requirements elicitation;
  - requirements capture and analysis;
  - requirements specification;
  - validation;
- the responsibilities of those involved in the process:
  - who provides information (user groups, technical staff etc);
  - who captures and interprets the information;
  - who reviews the requirements and checks validity;
  - who acts as the final approval authority.
- identification of likely timescales and resources.

6.2.3 Requirements acquisition

6.2.3.1 The main purpose of the requirements acquisition process is to obtain, through a variety of mechanisms (questionnaires, interviews, scenario workshops, activity logs, current system data, etc) the basic data and information from which to compile the Requirements Specification.

6.2.3.2 Typical inputs to the requirements acquisition process, and methods to be used, are likely to be:

- existing documentation and reports (eg Project Initiation Document, Feasibility Study Report, Business and Operational Strategy);
- the EIRENE Specifications;
- documentation defining the scope of the task and the methodology to be employed;
- interviews with selected users, technical staff, management and support staff;
- current system data (volume of voice and data traffic, etc).

6.2.3.3 The main outputs from the acquisition process will be:

- an initial problem/requirements catalogue;

- a logical description of the existing communications processes – ie who communicates with who, how frequently, for what reason etc (overall picture agreed with users and management);
- a set of raw data, obtained from the various sources including the E-FRS and E-SRS;
- identification of major issues requiring resolution and a record of the decisions made to resolve them.

6.2.4 Requirements capture and analysis

6.2.4.1 The aim of the requirements capture process is to establish a mechanism whereby most (if not all) of the data and information extracted during the requirements elicitation process can be recorded. This should be done in such a way as to facilitate the analysis of requirements (leading to the production of the Requirements Specification) and to ensure that all requirements are traceable back to its source.

6.2.4.2 The analysis of requirements should consist of detailed logical analysis, consolidation (ie grouping similar requirements from different sources together into coherent groups), consistency checking, and clarification. The use of a simple computer based tool to support this process can offer a number of significant benefits including:

- storage of all requirements data;
- cross-referencing and verification of requirements;
- production of summary statistics and data;
- data input into document production.

6.2.4.3 The planning stage of the requirements capture process involves determination of a structured method for collating and interpreting the raw requirements data, for example, establishing a requirements catalogue with entries containing:

  - heading (descriptive title);
  - identification of source (workshop, interview/name, etc);
  - date that the information was acquired;
  - labelling of requirement to enable it to be allocated to various categories (high level function, user group, application etc);
  - initial priority assigned to the requirement;
  - text description of the requirement;
  - any measures or metrics associated with the requirement;
  - follow up action required/clarification to be sought etc.

6.2.4.4 The execution stage of the requirements capture process involves the collation, analysis and validation of requirements.

6.2.4.5 Note that the requirements acquisition and requirements capture processes overlap. The planning stage for requirements capture will need to be completed before the requirements acquisition process gets underway in earnest.

6.2.4.6 The main output from the requirements capture process is a comprehensive set of system requirements, providing a complete and traceable record of the outputs from the requirements acquisition process.

6.2.5 Requirements specification

6.2.5.1 The main purpose of a requirements specification is to express, through a series of high-level requirements statements, a description of what the railway expects to be delivered. The specification should define at least the railway's requirements in terms of:

- function;
- performance;
- interfaces;
- design constraints.

6.2.5.2 The implications of under- or over specifying the service requirements must be considered. On the one hand, it is dangerous to under-specify as this will limit operational capabilities, and might lead to change requests which turn out to be expensive. On the other hand, any over-specification may lead to unacceptably high investments, which in turn will stress available budgets and/or limit operational capabilities due to tighter restrictions on use.

6.2.5.3 The complementary purpose of a requirements specification is to enable the system developer or designer who is required to deliver the service to understand exactly what it is that the purchaser wants. This bilateral understanding establishes the basis for agreement between the purchaser and supplier on what is required. It also assists the potential users in determining whether their needs will be met by the system as specified.

6.2.5.4 The aim of the requirements specification is to provide a clear, consistent, precise and unambiguous statement of the requirements. The requirements should be stated in such a way that it is possible to verify objectively whether the delivered system and services provided meet the requirements.

6.2.5.5 Thus it must be possible for the supplier to produce compliance matrices that relate their service components to specific requirements. It should also be possible to define the acceptance criteria and methods which will be used to test the conformance of the delivered service.

6.2.5.6 The following six characteristics should be borne in mind when preparing a requirements specification. It should be:

- **Unambiguous –** every requirement should have only one interpretation. A glossary of terms can help, but in general, users must be aware of the potential pitfalls of requirements expressed in natural language;

- **Complete –** all significant requirements and aspects of the environment, whether relating to functionality, performance, design constraints, etc, should be included;
- **Verifiable –** used here in the sense that the requirement must be stated in such a way that the system or service can be checked that the requirement has been fulfilled;
- **Consistent –** there should be no conflict between individual requirements;
- **Traceable –** proper referencing is needed to allow backward traceability (to previous documents and databases) and forward traceability (to spawned documents);
- **Useable during operation and maintenance phase –** attention needs to be paid to operation and maintenance needs and the updating of the requirements specification to meet these needs especially where failure of a component of the system or service could be critical or where temporary changes are made.

6.2.5.7 The requirements specification should be reviewed as it is developed, and once agreed, should be put under change control.

6.2.6 Validation

6.2.6.1 Validation can be considered to be the process whereby individual requirements are checked for their relevance, clarity, accuracy, and their consistency with similar requirements expressed by other users. It is not unusual to find that requirements expressed by different individuals, even if they belong to the same user group, may be contradictory, and these will need to be resolved through further discussion.

6.2.6.2 An important aspect of validating requirements is to check that they fall within the scope of the service requirements as defined in the terms of reference for the requirements definition phase. Adherence to this is necessary to ensure that the requirements set does not become swamped with unnecessary information.

6.2.6.3 An important part of the validation process involves the circulation of the final requirements specification to end users to ensure that they are happy with the document and that their requirements are adequately represented.

6.2.6.4 However, the validation of requirements should not be seen as a one-off process at the end of the requirements definition phase. Validation is an ongoing process, and indeed, the whole of the requirements definition process from requirements elicitation through to validation can best be described as an iterative process of gathering and analysing requirements until a final product (the Requirements Specification and it's supporting database) has been completed and checked for validity.

6.3 Business Case development

6.3.1 Introduction

6.3.1.1 The main method for allocating funds to the development and implementation of a new communications system is the business case. This should detail the particulars of the system, including the degree to which the solution can meet the requirements, how the solution was selected, the cost of such a solution and the way in which the solution is to be implemented.

6.3.1.2 It should be remembered that although the business case requires a large amount of detail, the main aim is to allocate the funds. The railway should therefore ensure that sufficient information is available to justify the funds for the solution chosen without going into too much technical detail, in particular regarding the implementation of the system.

6.3.1.3 This sub-section provides an overview of the business case document, indicating the main elements that should be part of such a document.

6.3.1.4 As the financial appraisal forms most likely the key part of the business case, since this will form the financial justification for the selection of a particular implementation, a separate sub-section has been dedicated to this aspect, highlighting the main aspects of the cost analysis.

6.3.2 Contents of the business case

6.3.2.1 Although each railway will have their own rules for writing the business case for new systems, the following overview may serve as a general guideline for the contents of a business case document:

1 Introduction

General introduction
Background
Requirements statement

2 Choice of solution

Approach taken to assess solutions
Overview of existing system(s)
Technologies, standards and architectures
Realisation options
Overview of analysis of costs - based on the financial appraisal
Solutions shortlist

3 Financial appraisal

Approach
Definition of options under consideration

SWOT[4] assessment
Cost comparison
Recommended solution

4 Implementation of recommended solution

Approach
Procurement strategy
Ownership
Management
Migration
Risks

5 Conclusions and recommendations

6.3.3 Financial appraisal

6.3.3.1 A crucial step in the procurement of an integrated radio communication system is the calculation of the potential financial impact of the system implementations under consideration. Attempting to compare the cost of different implementations is complicated by the differing nature of the expenditure on each. Procuring a private network is composed mainly of a large up-front investment, followed by a smaller expenditure on maintenance over the lifetime of the equipment. When outsourcing, service provision costs can be attributed to a constant, but not insignificant annual rental. In comparing the two implementations, it is necessary to derive either a total lifetime cost or an equivalent annual cost.

6.3.3.2 There are several methods to compare investments with each other. When evaluating total costing, which involve expenditure over a number of years, the best method for comparison is the Net Present Value (NPV) method. This method recognises the cost of capital. Expenditure that does not occur for a period of time or is performed over several years should be discounted to reflect the fact that, for example, instead of making the expenditure now, capital could be invested so that by the time the expenditure is made, some additional capital has accrued. This discounting favours expenditures which can be postponed to the future and penalises large initial investments.

6.3.3.3 Once the capital expenditure required for each year has been estimated, the NPV for each option under consideration can be derived as follows:

$$NPV = \sum_{n=0}^{m} \left[\frac{-E_n}{(1+i)^n} + \frac{R_n}{(1+i)^n} \right] \qquad \text{6-1}$$

[4] SWOT = Strengths, Weaknesses, Opportunities and Threats

where E_n is the annual expenditure in year n, R_n the annual revenues in year n, i the discount rate and m the number of years considered (i.e. lifetime).

6.3.3.4 In order to perform these calculations for different options, it is necessary to agree the following parameters:

- the period over which to perform the costing (e.g. 10, 15 or 20 years);
- the discount rate;
- the moment at which payments are made (e.g. once a year at the beginning of the year[5]).

6.3.3.5 The following sub-section provides an extensive list of costs and revenues related to calculating the NPV for each possible network option, whereas the final part of this sub-section considers the way in which the information should be used.

6.3.4 Expenses

6.3.4.1 The life-cycle of a product begins as a decision is evaluated and a choice is made to acquire the product. Costs are then incurred throughout the acquisition process, throughout the use of the product, and due to disposal of any old equipment at the end of its lifetime. Cost components may be incurred immediately or they may be deferred.

The following types of costs can be identified:

- **Direct costs**: These are the costs that are typically included when options are compared in conventional cost analysis. These costs are typically attributed to the products under consideration and the processes in which they are used.
- **Indirect costs**: Those costs that are usually not attributed to or directly associated with a given product.
- **Uncertain costs**: Costs that may be incurred by the railway, and can be either direct or indirect. These potential costs are uncertain in magnitude and/or timing.

6.3.5 Direct and indirect costs

Capital expenditure

6.3.5.1 The capital expenditure (CAPEX) is the investment that the railway must make in the installation of the radio communications system during the lifetime of the system. The CAPEX consists at least of the following items:

- market price of transmission equipment and cables, cab radios, fixed network terminals, etc;

---

[5] In this context, a year is considered to be a 12 month period counted from the initial investment date. The initial investment date is considered to be Year 0.

- cost of a network management system. The network management system is expected to be able to support fault management, configuration management, accounting management, performance management and security management;
- design costs for the telecommunications side of the project. If this is not clear, a percentage of overall project costs should be agreed upon;
- cost of project management;
- cost of labour;
- costs associated with installation, testing and commissioning. This should also include cost of possessions (when taken, how much notice was given, planning etc will lead to any discounts);
- general expenses (hire of goods, overnight accommodation etc);
- costs associated with provision of documentation;
- costs of initial stock of spares;
- recovery costs of current transmission equipment, cabling and any other equipment.

6.3.5.2 The railway should keep in mind that any subsequent investment once the initial system has been installed and commissioned should also be entered as CAPEX. These investments will be related to any major upgrades and modifications to be carried out during the lifetime of the system.

Operating expenditure

6.3.5.3 Once the asset is installed and put into service, there will be ongoing costs involved with its operation, the operating expenditure (OPEX). These costs include at least the following items:

- cost of maintenance (eg an annual figure of 10% of the initial capital expenditure for the transmission equipment, radios and fixed terminals and 5% of the initial capital expenditure for cables);
- insurance costs;
- costs related to managing and keeping the equipment in good working order;
- costs related to spares holdings;
- upgrades and replacements of equipment (due to new requirements, new technology etc);
- costs related to transfer of staff, training of staff etc.

Other costs

6.3.5.4 These are costs that need to be taken into account but cannot be categorised as either part of the initial outlay or annual ongoing costs. These costs include:

- depreciation: although this is not a cash flow, it is used to calculate corporate taxes to be paid, and should be regarded as an indirect contributable factor in the whole life cost calculations;
- taxes;
- inflation: this is not included directly into the NPV calculations. It must be taken into account when estimating the costs of renewal, maintenance, etc. This factor could, however, be taken into account as part of the discount rate;
- salvage value at the end of the normal life span of the asset;
- disposal/removal costs at end of equipment lifetime;
- recovery of assets when replacing the system.

6.3.6 Uncertain costs

6.3.6.1 Uncertain costs are those cost elements that are uncertain in magnitude and timing. These costs are mainly related to the operation of the system. Costs to be considered include costs related to reliability and availability of the system, leading to unscheduled maintenance and replacement.

6.3.7 Revenues

Asset residual value

6.3.7.1 In general, it is assumed that telecommunications equipment has a life span of 7 to 10 years, whilst cabling has a life span of 25 to 30 years. These assumptions lead to the requirement of replacing the transmission equipment after about 10 years.

6.3.7.2 There may be some residual value in the replacement of the current radio infrastructure.

6.3.7.3 Although it is not likely that any railway will consider provision of telecommunications services as a core business, opportunities may arise to provide mobile services to third parties once the GSM-R network is in place. Any proceeds from the service provision should be entered as revenues in the analysis.

6.3.8 Baseline whole life costs

6.3.8.1 Strictly, the NPV calculations should be carried out on changes in cash flows. This means that the allocation of costs and revenues should be relative to current expenditure and revenues. This may not always be easy to identify, in particular if the current implementation is significantly different from the new implementation.

6.3.8.2 As an alternative, it may be more practical to consider the current situation as a base case and compare the NPV figures for different implementation options against the NPV of the base case.

6.3.8.3 The initial step in the financial assessment is therefore to obtain an estimate of the costs of the current system(s) over the investment period under consideration. This should include all costs associated to the current system(s), including any modifications and upgrades that would be required to extend the lifetime of the current system(s).

6.3.9 Option comparison

6.3.9.1 Once the baseline has been established, option comparison can take place.

6.3.9.2 For each of the implementation options under consideration, a financial assessment needs to be carried out. It is important to perform the estimates as accurately as possible, as it will in most cases be difficult to justify further allocations of investment capital at a later stage.

6.3.9.3 For each of the options, the investments (initial and subsequent), OPEX and CAPEX need to be determined for each year over the assessment time interval. These values then need to be discounted to derive the NPV for each of the options. These values can then be compared against the NPV of the baseline and can be used to rank the options from a financial perspective.

7 Procurement strategy

7.1 Introduction

7.1.1 An important aspect of the implementation of a radio system is the nature of the procurement and contracting strategies that are to be followed. There are several approaches to this problem, which will be considered in this section. The procurement strategy will be considered first and this will lead on to the contracting strategy options.

7.2 Procurement strategies

7.2.1 The procurement strategy choices available fall into the following categories:

- staged versus non-staged procurement approach;
- the use of a turn-key contractor as opposed to a multiple contractor.

7.2.2 In a staged approach, the implementation of the integrated communications system is split into distinct phases and contracts for each of the phases will be awarded over a period of time. When a non-staged approach is chosen, the implementation may still be split into distinct phases, but the contract(s) for each of the phases will be awarded at the same time.

7.2.3 In a turn-key solution, the contract for implementation will be awarded to a single contractor. This contractor will be the responsible party towards the railway, although the contractor is most likely to sub-contract various elements of system implementation. In a multiple contractor situation, the railway will have to decide what elements of implementation are to be allocated to what type of implementer, and will have to award and maintain multiple contracts. In this situation, each of the contractors will have a direct responsibility towards the railway.

7.2.4 The railway will be required to define its approach towards the procurement of the radio system, deciding upon the phasing of the implementation and the aspects that need to be contracted to implementers.

7.2.5 Table 6-1 gives an outline of the benefits and drawbacks of employing the various combinations of these procurement approaches.

	Turn-key	Multiple
Staged	**Pro**: Able to keep track of each deliverable in turn. The specifications of the next deliverable may be subject to amendment by the contractor in order to ensure maximum compatibility with the deliverables so far received. Responsibility for the production of each deliverable lies with the contractor. The customer may be provided with partial system functionality (and the associated business benefits) at each stage. **Con**: Usually an expensive option. Little to no control over the project for the customer.	**Pro**: Option where the most control lies with the customer. The specifications of the next deliverable may be amended by the customer in order to ensure compatibility with the deliverables so far received. **Con**: Most time-consuming option for the customer to manage. If a mistake is made in the procurement process, the result will be the responsibility of the customer. Customer takes overall responsibility for system integration aspects.
Non-staged	**Pro**: A working system is to be handed over by the deadline if the contract is to be fulfilled. **Con**: No control over the process. Usually the most expensive option.	**Pro**: Usually one of the cheapest options. **Con**: Many contractors to keep track of, all of whom should deliver at the same time. If a single deadline slips, it will compromise the project schedule. If the final system does not work, it is the customer's responsibility to make the necessary amendments.

Table 6-1: Procurement strategy overview

7.3 Contracting strategy

7.3.1 The nature of the contracting strategy is largely defined by the procurement strategy that is employed. A contracting strategy, whereby contracts for the infrastructure supplier, the mobile equipment supplier, the Network Operator and the Service Provider are awarded in stages, may result in reduced risk. This risk is largely associated with contract boundaries and the impact of equipment development problems upon the time-scales and requirements of the later contractual elements.

7.3.2 One may further consider the benefits of in-house as opposed to outsourced service provision. Outsourcing has become popular and has been adopted by many organisations on the basis that:

– outsourcing can be more cost effective because the third party organisation can obtain economies of scale;

– the third party has more flexibility to recruit staff with different terms of employment;

- the client organisation can concentrate its management and resources on its core business.

7.3.3 Inevitably, there are risks associated with these benefits which need to be carefully considered. It is also much harder to bring the service function in-house at a later stage because of the lack of skills. It is consequently essential to ensure at the outset that:

- which services are to be provided, and which not, are clearly specified and understood;
- the services provided by the third party will remain available on favourable terms;
- there are mechanisms for agreeing new services on favourable terms;
- there are mechanisms for monitoring the effectiveness of the service being provided.

7.3.4 Furthermore, there are a number of positive reasons to provide telecommunications services in-house. These include factors such as:

- using in-house service provision, the organisation has direct control over the services provided. This is particularly important in those areas where an organisation is dependent upon the operation of its telecommunications facilities for the functioning of its core business;
- it is likely to be easier to offer a rapid response time and tailored services using in-house staff;
- arrangements between the users and telecommunications staff can be less formal and constrained by contractual rigidity, since the parties have common business objectives;
- any 'profit' made by the service provider at the users' expense is kept within the organisation.

7.3.5 The advantages and disadvantages will need to be carefully considered. It is possible that the optimum arrangement may be to continue to provide core services, which are essential to the operation of the business, in-house but less critical services could be organised with the assistance of third parties.

7.3.6 Assuming some telecommunications functions will be provided in-house, it will then be necessary to consider whether the provider should remain as a cost centre or to what extent it should operate as a profit centre and charge users for the services it provides.

7.4 Procurement legislation

7.4.1 The EC has set Directives related to the procurement of services. These Directives are issued to stimulate a competitive market mechanism within the European Community. The following Directives are concerned with service, supply and works contracts:

- 92/50/EEC: Directive of June 1992 relating to the co-ordination of procedures for the award of public services (ie all contracts other than works or supply contracts) contracts;
- 93/36/EEC: Directive of June 1993 co-ordinating procedures for the award of public supply (ie purchase, lease, rental or hire-purchase of products) contracts;
- 93/37/EEC: Directive of June 1993 co-ordinating procedures for the award of public works (ie building and engineering activities) contracts;
- 90/531/EEC: Directive of January 1993 on the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors;
- 93/38/EEC: Directive of June 1993 co-ordinating the procurement procedures of entities operating in water, energy, transport and telecommunications sectors;
- 98/4/EC Directive of 16 February 1998 amending Directive 93/38/EEC co-ordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors.

7.4.2 The EC Directives 90/531/EEC, 93/38/EEC and 98/4/EEC will be the Directive relevant to the procurement of GSM-R networks as they apply to contracts for works, supplies and services relating to the water, energy, transport and telecommunications sectors.

7.4.3 As a result of these directives, utilities[6] are obliged to publish notices inviting interests to tender and make this information available in all EU member states. The legislation is applicable to the supply of products and services and the carrying out of works above particular threshold levels.

7.4.4 It should be noted that, where a contract is sub-divided into several lots, the value of the lots are aggregated. If the value of the aggregate reaches or exceeds the relevant threshold, the Directive applies to each of the lots.

7.4.5 In awarding contracts, the railway is obliged to follow one of the following procedures:

- **Open Procedure**: a Contract Notice to this effect is published in the EC Official Journal (OJEC Notice). All interested suppliers or contractors may submit tenders.
- **Restricted Procedure**: a Contract Notice is published in the EC Official Journal. Suitable suppliers are selected by the contracting authority from those who apply to tender. The shortlisted suppliers are then issued with an Invitation To Tender.
- **Negotiated Procedure**: the contracting entity consults suppliers or contractors of its choice, and negotiates the terms of the contract with one or more of them. This procedure is only allowed in certain limited circumstances.

[6] Utilities are defined as being authorities and undertakings in the sectors of water, energy, telecommunication and transport. Although some railways may be a private company, they are still classified as a utility under EC law, and must as such comply with the relevant Directives when procuring services and/or infrastructure.

7.4.6 In addition, there is an Accelerated Procedure under which shorter advertising periods are permitted due to urgency. A justification must be published as part of the tender notice.

7.4.7 Contracting entities in the utilities sector have the 'privilege' to establish and operate a system of qualification of suppliers or contractors, with the idea of setting up a list of companies capable and willing to execute future contracts. It is understood that it is allowed to directly negotiate with these suppliers for the services required, as long as call-off contracts are in place. Care should be taken that the services to be procured fall within the scope of the terms set to compile the list of pre-qualified suppliers in the first place. If this is not the case, or if there is any doubt, then the procurement should follow the rules set by the EC. In those cases, it is possible to use the *Restricted Procedure*. This procedure leads to the award of a contract whereby only companies chosen in pre-selection by the contracting authority will be allowed to submit a tender.

Structure of Contract Notices

7.4.8 Under the Directives, the railways will be required to advertise the Invitation to Tender/Request for Proposal in the EC Official Journey in order to allow suppliers to apply or receive it.

7.4.9 Of particular interest to the railways are the following:

- **ITT/RFP notice**, the actual invitation outlining the contract (ITT) or outlining a general framework, inviting the tenderers to make proposals for the product or services they can offer.
- **Contract award notice**, indicating that the tender has been accepted, which company won the tender and for what price, although in selected cases the name of the company and/or the value of the contract are omitted due to confidentiality.
- **Pre qualification notice**, which is a notice that precedes, most commonly, restricted tenders. Only companies chosen in the pre-selection will be allowed to tender for the restricted tender.

7.4.10 The notices are published in the Supplement to the Official Journal of the European Communities, following standard templates, particular to the Directive applicable. The notices must contain specified items of information and must be presented in accordance with models published in the relevant Directive. The standard content and layout saves time and ensures that all tenders give the same amount of information.

7.4.11 Examples of the standard templates for the European Community ITT/RFP notices Type d - Water, energy, transport and telecommunications sectors (ie notices published pursuant to Council Directive 93/38/EEC, which abrogates Council Directive 90/531/EEC) are given in appendix C. The railways are, however, strongly advised to check the latest regulations regarding the templates and placement of OJEC notices.

Contact details

7.4.12 For particular aspects of the Directives and the procedures to be followed when placing an OJEC Notice, in particular the type and format of the Notice and the timescales, each railway should contact the Office for Official Publications of the European Communities in Luxembourg or their national representative.

7.4.13 The contact details for the Office for Official Publications of the European Communities are as follows:

Office for Official Publications of the European Communities
Sales Department
2 rue Mercier
L-2985 Luxembourg

Telephone: +352 29 29 42 563
Fax: +3 52 29 29 44 623

7.4.14 Further information can be obtained from the following web site: http://simap.eu.int/

7.5 Services required for private network implementation

7.5.1 In order to implement a private network solution, the following services will be required;

- coverage design;
- site selection, survey;
- construction;
- system integration and optimisation.

7.6 Other aspects

7.6.1 In addition, there are several other aspects that need to be considered as part of the procurements strategy. These include:

- requirements on organisational changes;
- migration and decommissioning of current systems.

These aspects should probably be considered as part of the definition and assessment of a suitable procurement strategy.

8 Network planning

8.1 Overview

8.1.1 This section provides guidelines and information for National Railways to assist them in the development of a cell and frequency plan for their GSM-R network. The information presented in this section is derived from a standard network planning methodology, with particular reference to the special circumstances of radio planning for the railway environment.

8.2 Spectrum considerations

8.2.1 One of the most important constraints on GSM-R network planning is the availability of spectrum.

8.2.2 The core UIC GSM-R spectrum allocation is as follows

- 876 – 880 MHz (mobile station transmit); paired with
- 921 – 925 MHz (base station transmit).

8.2.3 This equates to up to 19 pairs of useable frequency channels. The carrier frequency is designated by the absolute radio frequency channel number (ARFCN). For GSM-R carriers the following convention is used, where Fl(n) is the frequency value of the carrier ARFCN n in the lower band, and Fu(n) the corresponding frequency value in the upper band:

- $Fl(n) = 890 + 0.2*(n-1024)$ MHz $955 \leq n \leq 973$
- $Fu(n) = Fl(n) + 45$ MHz

8.2.4 Each pair will henceforth be referred to as a "frequency channel".

8.2.5 Aside from the 19 channels, this allocation also includes a 200 kHz guard band to protect against interference between the GSM-R band and the adjacent E-GSM band at the upper end. In addition, a 400–600 kHz guard band is recommended to prevent interference with PMR/PAMR services below the GSM-R spectrum allocation, of which 100 kHz is taken from the UIC band (note, this has also been reserved for UIC Direct mode). The following figure provides an overview (not to scale) of how the spectrum is allocated:

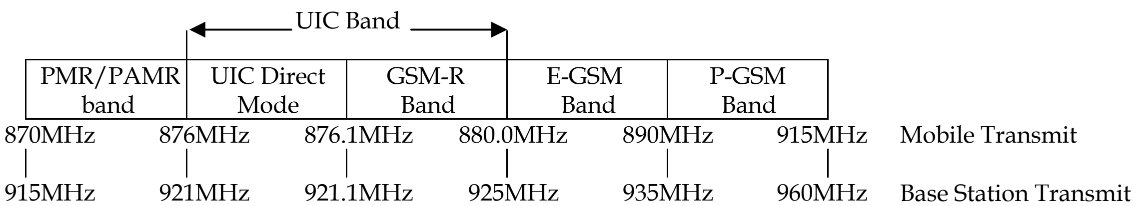

Figure 8-1: Overview of spectrum allocation

8.2.6 Where available, additional spectrum for railway use may be sought on a national basis. For example, the E-GSM band is suitable for this purpose because all GSM-R equipment will be capable of functioning at these frequencies. However, the remainder of this section focuses on the case where 19 useable frequency channels are available.

8.3 Overview of cell and frequency planning for GSM-R

The cellular concept

8.3.1 The cellular network concept is founded upon the principle that breaking a large desired coverage area (served region) up into a series of much smaller coverage areas (cells) increases the available capacity and spectral efficiency of the system as a whole.

8.3.2 Envisage a service area (A), represented by the yellow hexagon in Figure 8-2, limited to the use of just two radio channels. The installation of a tall mast at the centre to provide wide area coverage would quickly become congested and overloaded by the subscriber base.

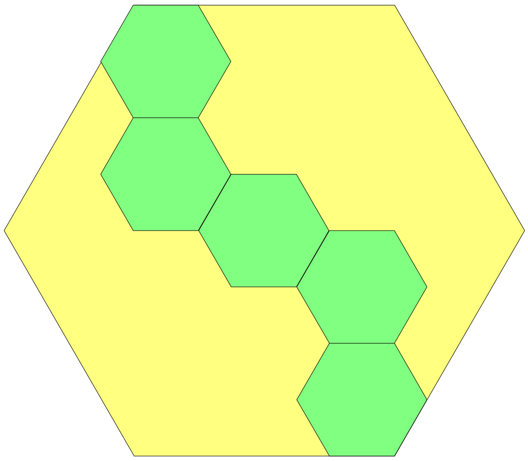

Figure 8-2: The basic cellular concept

8.3.3 The cellular concept allows smaller service areas to be deployed, each using a limited part of the available radio spectrum – in this example just one channel – to provide much more localised service. This is represented by the green hexagons in Figure 8-2, which could for example be used to provide service to a railway line. The key is that such an approach allows multiple re-use of the same radio channels in the same global service area, providing much more efficient service to the intended subscriber base and much more efficient use of the available radio spectrum.

8.3.4 The cellular solution is typically more expensive, but a network design process is employed to find an optimal position with respect to all system constraints. This will serve to maximise the subscriber base and therefore (in a commercial sense) increase the revenue that can be generated from the available spectrum.

Overview of radio planning

8.3.5 A key challenge for the radio engineer is to design the network to re-use the available frequencies so that the system is able to provide the radio capacity that is required in each area, whilst ensuring that the levels of service remain within acceptable limits for the applications it must support.

8.3.6 The following aspects are important inputs to the cell and frequency planning process (many of these will need to be visualised geographically):

- The radio capacity that is to be provided in each location by the network.
- The required quality of service for all of the applications to be supported (this encompasses coverage requirements, handover breaks, dropped calls, error rates, latencies, etc).
- Cell site planning considerations (e.g. available sites for construction of base stations, permitted mast heights, provision of power and communications to cell sites, permitted broadcast power, etc).
- Operational considerations that may dictate where cell boundaries need to be located (for example, emergency call areas, shunting areas, controller areas, etc)
- Terrain types and geographical features (e.g. hills, woods, urban areas, large buildings, cuttings and tunnels).
- The available frequencies (e.g. whether there are any limitations on the use of the UIC GSM-R spectrum allocation in the area and whether additional frequencies, for example, in the E-GSM band are available).

8.3.7 The cell and frequency planning process results in the generation of the following design information for each GSM-R base station:

- Geographic location of each site.
- Mast height.
- Antenna types and position.
- Required cabling, feeders and fixed links.
- Frequencies and transmission powers to be used.

8.3.8 It should be noted that the use of computer based radio planning tools is central to undertaking successful cell and frequency planning. These tools are discussed in more detail later in this section.

Simple illustration of GSM-R frequency reuse

8.3.9 Each frequency channel is divided into eight timeslots. A minimum of one timeslot is required per base station to serve as a control channel, leaving seven timeslots available to be used as traffic channels to support voice or circuit switched data calls. The addition of more frequency channels by the addition of more transceivers (TRXs) to each base station will add up to a further 8 traffic channels (alternatively, it could add 7 traffic channels and an additional control channel, depending on the amount of signalling traffic to be supported).

8.3.10 If coverage is required over a wide area, for example to support communications across a city with many railway lines and stations, a 7 cell repeat pattern[7] could be used of the type shown in the following diagram, where each circle represents a different radio cell and the colours (and the letters A-G) define 7 sets of cells in which the same frequencies are re-used:

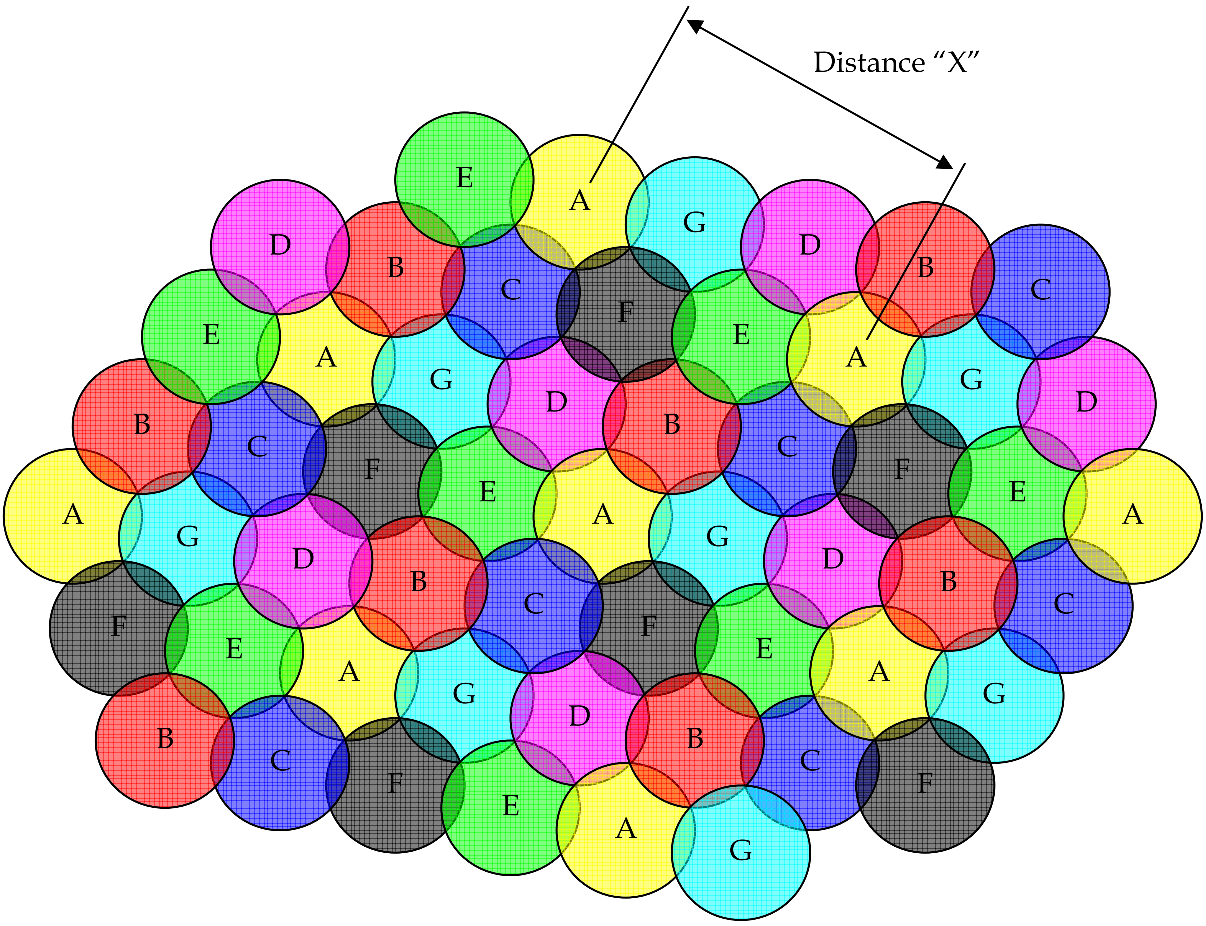

Figure 8-3: Illustration of a 7 cell repeat pattern

[7] A 7 cell repeat pattern has been considered because this gives a reasonably close reuse pattern with signal to noise characteristics that are acceptable for many configurations.

8.3.11 One of the most important considerations in the development of a viable cell and frequency plan is to maximise the distance between base stations transmitting/receiving at the same frequencies otherwise co-channel interference will arise, thus degrading service. Interference will also arise from adjacent channel assignments between neighbouring cells and this too must be minimised. If this distance is too small, it will have a detrimental effect on the co-channel interference in the network (and hence the C/I and the bit error rate). In order to provide radio capacity, whilst minimising the co-channel and adjacent channel interference, the 19 channels could be distributed between the differently coloured cells as shown in the following table.

Cell	**Frequency Channels**	**No of traffic channels (No of signalling channels)**
Set A (Yellow)	n = 955, 962 & 969	22 (2) or 23 (1)
Set B (Red)	n = 956, 963 & 970	22 (2) or 23 (1)
Set C (Blue)	n = 957, 964 & 971	22 (2) or 23 (1)
Set D (Magenta)	n = 958, 965 & 972	22 (2) or 23 (1)
Set E (Green)	n = 959, 966 & 973	22 (2) or 23 (1)
Set F (Grey)	n = 960 & 967	15 (1)
Set G (Cyan)	n = 961 & 968	15 (1)

Table 8-1: Possible distribution of frequency channels for 7 cell repeat pattern

8.3.12 In a real situation, it is highly likely that some areas will need more capacity than others (for example, large stations). This and other factors such as geographical features, the need to optimise group call areas, and considerations related to location dependent addressing will also have an effect on the optimal cell and frequency plan. This is likely to result in a much less regular distribution of cells and channels than the one shown in this simplified example (in practice, a radio planning tool would be used to simulate the coverage and traffic capacity requirements).

8.3.13 The example of providing coverage over a wide area can be contrasted with that of providing coverage along a linear corridor (for example along a reasonably straight section of railway line). This is shown in the following diagram:

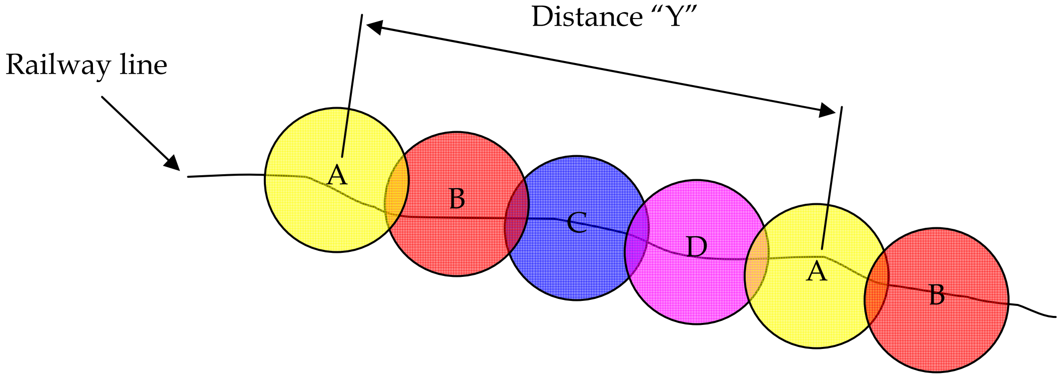

Figure 8-4: Illustration of a linear repeat pattern

8.3.14 It can be seen from the above example that a greater cell separation between cells of the same type can be achieved using a four cell repeat pattern than can be achieved with a seven cell repeat pattern in the previous example (compare distance "X" to distance "Y" in the two diagrams).

8.3.15 Since there are fewer cells in the repeat pattern, a larger number of channels can be allocated to each cell and hence greater radio capacity is achievable.

8.3.16 The following list gives examples of features that need to be given special consideration when planning coverage for the GSM-R network:

- Tunnels
- Cuttings
- Regions shadowed by structures such as bridges
- Obstructed sections of track that fall on a bend
- Railway stations
- Terrain height profiles
- Shunting areas
- Emergency call areas

8.4 Operational planning

8.4.1 Operational planning is vital to the design of a successful GSM-R network and encompasses the following elements:

- The number/types of applications that the network needs to support.
- Their quality of service requirements.

- The capacity demand that the applications will place on the radio system. This needs to be estimated for each proposed GSM-R cell site, based on factors such as the following:
  - the peak number of active trains that will occupy that cell;
  - the volume of voice and data traffic expected from these trains;
  - the volume of network traffic arising from handhelds and other devices such as possession management terminals, customer information systems, diagnostic systems, etc that are expected in that cell;
  - scope for future expansion.
- The locations where cell boundaries should be planned (supports cell dependent routing for location dependent addressing and group call functionality including emergency areas, shunting areas and controller areas).
- Planning of GSM-R location areas, MSC and BSC boundaries and border areas between national networks.
- Planning for the operational needs of ETCS including appropriate coverage, capacity, quality of service, support of RBC-RBC handovers, etc.

8.4.2 All of these operational planning aspects need to be considered when developing an appropriate cell and frequency plan for the area under analysis. This is covered in more detail in the remainder of this section.

8.5 Radio planning tools, modelling and surveys

8.5.1 Radio planning tools are used to develop more accurate predictions of pathloss, coverage and interference taking into account terrain data and clutter data for the areas under analysis and the presence of multiple base station sites. The software is used to model and develop viable GSM-R cell and frequency plans for specific areas.

8.5.2 Typically, radio planning tools incorporate Geographical Information System (GIS) software to allow the user to display digital mapping data overlaid with the model's calculations. This may include provision for the display of the following features:

- Map as backdrops suitable for display at various levels of magnification.
- Line (vector) data, for example railway lines, coastlines and roads.
- Terrain height (elevation) data, land usage (clutter) data and positional information (e.g. in longitude-latitude and national grid co-ordinates).
- Aerial photographs and building plans.
- Display of signal coverage and co-channel/adjacent channel interference predications overlaid onto the above mapping data.

8.6 Frequency planning methodology

Overview

8.6.1 The fundamental problem to be addressed during the assignment of radio channels to planned cells is to ensure the allocation and reuse of any given channel maximises usable radio signal and minimises the interference generated.

8.6.2 Every plan will have an associated signal to noise ratio: represented in the radio environment as the carrier to interference ratio, or C/I, and is expressed in decibels (dB). The fundamental quality of a frequency plan is reflected in the C/I for a given area.

8.6.3 In the following methodology, it is assumed that there exists a proposed cell site distribution with an associated channel requirements profile (driven from the projected capacity demand in each area). It is also assumed that the software tools required for the processing and production of appropriate data sets are available.

Inputs

8.6.4 The following inputs are required:

1) The available radio spectrum.
   - Absolute radio frequency channel numbers that may be used.
   - Forbidden channels, test channels, guard bands.
   - Any other specific requirements.

2) A schedule of cells to be frequency planned.
   - Channel/transceiver requirements (driven by the demand for capacity).

3) An appropriate radio coverage model for the cluster of cells under consideration.
   - This cluster may be a few cells or many hundreds.
   - Typically represented as an 'nth Best Server' array, modelling the expected radio signal levels from all detectable cells in the immediate area at discrete geographical locations.

4) An appropriate 'Interference Table'.
   - This is derived from the nth Best Server Array and is a representation of the ability of each cell to interfere with any other.
   - The derivation from the best server array comes from the associated areas covered by each cell.
   - Typically this is represented as a proportion of overlap between different cells.

  - An interference table is not a carrier to interferer assessment, but simply an indication of potential inter-cell interaction.

5) Inter cell handover data (not essential).
   - A dataset showing the actual passage of mobile terminals from cell to cell.
   - Physical handover activity is represented by these data.
   - Used to validate theoretically defined neighbour cells.

Methodology

8.6.5 A classic algorithm used, is to define a set of rules for channel assignment with associated penalties – or costs – to be incurred should any rule be broken.

8.6.6 Initially channels are assigned in a quasi random fashion and the resultant plan modelled/evaluated in terms of its 'cost', then, by application of simple differential methods, the associated minimum cost function may be found by selective reassignment of individual radio channels.

8.6.7 Due to the nature of the problem and the fact that the associated cost is calculated on radio channels assigned, the determination of the cost function minimum is cyclical, and not instantaneous such as finding minima associated with least squares regression techniques.

8.6.8 A useful parallel may be drawn with the Newton-Rhapson approach for the solution of polynomial equations, where each successive iteration renders the solution closer to the ideal. The quality of the final plan is therefore highly dependant on the number of iterations permitted and the quality of the 'cost rules' assigned.

8.6.9 An example rule set may be as follows:

- Channel separation between TRXs in the same cell:
  - At least 2 channel separation (can be hardware dependant, may require 3 channels), otherwise assign a cost of 100,000
- Channel separation between control channels for first order neighbour cells:
  - At least 2 channel separation, otherwise assign a cost of 10,000
- Channel separation between control channels for second order neighbour cells:
  - At least 2 channel separation, otherwise assign a cost of 5,000
- Channel separation between traffic channels for first order neighbour cells:
  - At least 2 channel separation, otherwise assign a cost of 1,000
- Channel separation between traffic channels for second order neighbour cells:
  - If the same channel is used then assign a cost of 100
- Handover data threshold counts:

  - Used to override theoretical neighbours
  - Apply same rules as first order neighbours
- Specific forbidden allocations:
  - Channel separation/elimination as required
  - Cost as required
- Specific forbidden combinations:
  - Channel separation/elimination as required
  - Cost as required

8.6.10 Whilst the cost values are arbitrary, an appropriate level may be found to apply the desired scaling of preference given to allowed/preferred route of rule breakage. Provided the actual cost values do not exceed variable provision within the computer program code, the individual values do not physically affect the functionality of the mathematics.

Assessment and the key performance indicators

8.6.11 Once radio channels have been assigned to the appropriate cellular transceivers one is then in a position to create a carrier to interference ratio matrix. With respect to cellular network engineering tools, these are produced in a similar way to coverage matrices, and evaluate the carrier to interference ratio across defined areas of given resolution (typically 50m squares).

8.6.12 Normally, this would be presented on a map and plotted in defined bands: 0, 3, 6, 12 and 15 dB. Typically, radio engineers would plan for at least 9 dB for voice and at least 12 – 15 dB for data applications.

8.6.13 It should be noted that adjacent channel allocation is typically modelled under C/I, assigning a C/A equivalent. In practice co-channel interference dominates but adjacent channel interference must still be considered. If 2 equal power GSM carriers are adjacent to one another, the power leaking from one into the other's bandwidth is approximately 18 dB below the wanted carrier's level by virtue of the GSM signal's sideband characteristics. 18 dB may therefore be used as an equivalent figure for C/A to C/I mapping.

8.6.14 Two key performance indicators are normally used to represent network performance with respect to interference control. These are

- **Carrier to interference ratio (C/I):**
  - This has been addressed above and is typically represented as geographical plots in predefined bands.
  - When implementing new plans this is the only indication of the likely performance of that formulated.
- **Received Signal Quality (RxQual)**

- When frequency plans have actually been uploaded onto a given network, the BSS is capable of detecting real time interference.
- This is captured as bit error rate (BER) and is then quantised and 'Received Signal Quality' (RxQual).
- There are 8 indices ranging from 0 to 7. 0 reflects the lowest BER, 7 reflects the highest.

Outputs and documentation

8.6.15 Whilst formal documentation may vary from network to network and between operators, the inputs, method, and outputs above would typically give rise to the following documents, schedules or other deliverables:

- Spectrum Specification
- Schedule Of Planned Cells
- "n"th Best Sever Array
- Interference Table
- C/I and C/A Matrices
- Inter-Cell Handover Profile
- Appropriate Cost Schedule
- Frequency Plan
- Exception Report
- Per Carrier Analysis
- Co-Channel Assignment Schedule
- Adjacent Channel Assignment Schedule
- Pre And Post Implementation RxQual Data Set

8.7 GSM-R cell and frequency planning at international borders

8.7.1 Issues related to cell planning at borders are covered in UIC fiche Number 75 X - "The co-ordination of GSM-R systems and radio planning at borders" (E- 2575, O-2578).

8.8 GSM-R and its role in switching international fixed network traffic

8.8.1 In addition to this, it should also be noted that GSM-R networks have a potentially important role to play in the switching of international fixed network traffic as well as mobile calls. For example, national GSM-R networks and the international connections between them could be used as the backbone for an international fixed railway network. This is being considered by the UIC's "IntergrERNST Project".

8.9 Link budget and coverage design levels

8.9.1 The link budget is a calculation encompassing all of the technical factors associated with the uplink, transceiver, and downlink to determine, amongst other things, the maximum permissible air interface path loss. The link budget can be separated into two calculations, one for the downlink and one for the uplink. These will be considered in the following subsections:

Link budget, downlink

8.9.2 In order to calculate the link budget for the downlink, the first step is to calculate the BTS EIRP (Effective Isotropic Radiated Power) this is the effective power that is radiated from the Base Station antenna. The following typical elements contribute to this (example values are provided for guidance):

Base Station		
Base Station Transmit Power	45	dBm
Duplexer (Loss)	-1	dB
Internal Jumper (Loss)	-1	dB
Tx Filter (Loss)	-1	dB
Tx Power Splitter (Loss)	-3	dB
Antenna Feeder (Loss)	-3	dB
BTS Antenna (Gain)	15	dBi
Calculated EIRP	**51**	**dBm**

(The line items may vary according to the specific BTS configuration.)

8.9.3 The calculated EIRP is the sum of all of the above figures (losses are all negative, gains and power are all positive).

8.9.4 The next step is to calculate the Mobile Station's minimum permissible received signal. The following elements contribute to this (example values are provided for guidance):

Mobile Station

Mobile Receiver Sensitivity	-104	dBm
Mobile Antenna Feeder (Loss)	-2	dB
Mobile Antenna (Gain)	0	dBi
Antenna Position/Mounting (Loss)	0	dBi
Body Loss for Handhelds (Loss)	0	dB
Interference Margin (Loss)	0	dB
Fast Fading Margin (Loss)	-3	dB
Degradation due to Doppler Shift (Loss)	0	dB
Min Rx Signal	**-99**	**dBm**

8.9.5 Please note the following:

- Body Loss is the attenuation of the received signal due to the Mobile Station being close to a human body (this chiefly applies to handhelds).
- Interference Margin accounts for the increased radio noise level due to mobile users located in other cells. This is not normally a significant factor unless the network employs frequency hopping.
- Antenna Position/Mounting accounts for attenuation due to non-optimal positioning of the antenna due to the presence of other equipment on the train roof and/or the shape of the roof itself.
- Losses due to the Fast Fading Margin principally affect slow-moving mobiles.
- Receiver sensitivity degradation due to Doppler Shift principally affects fast-moving mobiles.

8.9.6 The minimum permissible received signal is the Mobile Receiver Sensitivity minus the sum of the gains and the losses (where gains are positive and losses are negative). In the above case, this equates to -99 dBm.

8.9.7 The minimum permissible received signal should be lower (i.e. more negative in dBm) than the minimum coverage levels specified in the EIRENE SRS, otherwise the Mobile Station may not be suitable for operation on GSM-R Networks.

8.9.8 Please see the following extract from the EIRENE SRS for the required values:

3.2 Coverage

3.2.1 *For network planning, the coverage level is defined as the field strength at the antenna on the roof of a train (nominally a height of 4m above the track). An isotropic antenna with a gain of 0dBi is assumed. This criterion will be met with a certain probability in the coverage area. (The target coverage power level is dependent on the statistical fluctuations caused by the actual propagation conditions.) (I)*

3.2.2 *The following minimum values shall apply: (M)*

- *coverage probability of 95% based on a coverage level of 38.5 dBμV/m (-98 dBm) for voice and non-safety critical data;*
- *coverage probability of 95% based on a coverage level of 41.5 dBμV/m (-95 dBm) on lines with ETCS levels 2/3 for speeds lower than or equal to 220km/h.*

3.2.3 *The following minimum values are recommended: (I)*

- *coverage probability of 95% based on a coverage level of 44.5 dBμV/m (-92 dBm) on lines with ETCS levels 2/3 for speeds above 280km/h;*
- *coverage probability of 95% based on a coverage level between 41.5 dBμV/m and 44.5 dBμV/m (-95 dBm and –92 dBm) on lines with ETCS levels 2/3 for speeds above 220km/h and lower than or equal to 280km/h.*

3.2.4 *The EIRENE mobile installation shall be designed to operate in a network meeting the criteria in 3.2.2 and 3.2.3. (M)*

Note 1: The specified coverage probability means that with a probability value of at least 95% in each location interval (length: 100m) the measured coverage level shall be greater than or equal to the figures stated above. The coverage levels specified above consider a maximum loss of 3 dB between antenna and receiver and an additional margin of 3 dB for other factors such as ageing. (I).

Note 2: The values for ETCS levels 2/3 concerning coverage and speed-limitations are to be validated and, if necessary, reviewed after the first operational implementation of ETCS. (I)

8.9.9 The Maximum Pathloss is calculated from the difference between the calculated EIRP and the minimum Rx Signal. In this example, the Maximum Pathloss equates to 150dB.

8.9.10 However, in order to meet the EIRENE coverage requirements, the Maximum Pathloss should be calculated on the basis of the difference between the calculated EIRP and the applicable EIRENE coverage requirement at the stated probability.

Link budget, uplink

8.9.11 In order to calculate the link budget for the uplink, the first step is to calculate the EIRP (Effective Isotropic Radiated Power) for the mobile. This is the effective power that is radiated from the Mobile Station antenna. The following elements contribute to this (example values are provided for guidance):

MS

Mobile Transmitter Power (max 8W)	39	dBm
Mobile Antenna Feeder (Loss)	-2	dB
Mobile Antenna (Gain)	0	dBi
Antenna Position/Mounting (Loss)	0	dBi
Body Loss (Loss)	0	dB
Mobile EIRP	**37**	**dBm**

8.9.12 The next step is to calculate the Base Station's minimum permissible received signal. The following elements contribute to this (example values are provided for guidance):

BTS

BTS Receiver Sensitivity	-110	dBm
BTS Antenna (Gain)	17	dBi
Antenna Feeder (Loss)	-3	dB
Duplexer (Loss)	-1.5	dB
Rx Power Splitter (Loss)	-3	dB
Internal Jumper Losses (Loss)	-1.5	dB
Fast Fading Margin (Loss)	-3	dB
Degradation due to Doppler (Loss)	0	dB
Min Rx Signal	**-115**	**dBm**

8.9.13 The minimum permissible received signal is the BTS Receiver Sensitivity minus the sum of the gains and the losses (where gains are positive and losses are negative). In the above case, this equates to -115 dBm.

8.9.14 As before, the maximum permissible pathloss is the difference between the mobile EIRP and the minimum Rx signal at the BTS. In the above case, this equates to 152 dB.

8.9.15 In this example, the maximum permissible pathloss in the uplink and the downlink are reasonably similar. This helps to ensure that there is good balance between the qualities of reception at either end of the call. The link budget is slightly "downlink limited". This means that it is likely that the downlink of the call will break up before the uplink in areas of poor coverage.

8.10 Estimation of path loss

8.10.1 There are a number of mathematical models used for signal estimation but the Hata-Okumura model is the most widely used in cellular networks. The Hata-Okumura computation model is an empirical formula to provide an estimation of the path loss in certain types of propagation environments. This model is useful for initial estimates of typical cell size, etc but not for detailed planning.

8.10.2 Only a few parameters are involved in the calculation, making it very easy to work with. In order to keep the formula simple, Hata and Okumura made the assumption that the transmitters would be located on high ground. Furthermore, the model neglects the terrain profile between transmitter and receiver (i.e. hills and other obstacles between the base station and mobile are not considered in the calculation).

8.10.3 The four parameters with their valid limits are:

- Frequency *f* (150...2000 MHz)
- Distance between transmitter and receiver *d* (1...20 km)
- Antenna height of the transmitter h_{eff} (30...200 m)
- Antenna height of the receiver h_{RX} (1...10 m)

8.10.4 The following equations show how to calculate the basic path loss *pl* (in dB) with the model of Hata-Okumura.

$$pl = 69.55 + 26.16 \times \log(f) - 13.82 \times \log(h_{eff}) - a(h) + (44.9 - 6.55 \times \log(h_{eff})) \times \log(d)$$

The term *a(h)* is a correction term, which can differ depending on the particular environment. For a basic suburban environment, the correction term *a(h)* is calculated as follows:

$$a(h) = (1.1 \times \log(f) - 0.7) \times h_r - (1.56 \times \log(f) - 0.8)$$

8.10.5 This equation may be used to estimate the height gain associated with different train antenna mounting options (note that the EIRENE coverage level is defined as the field strength at an isotropic antenna with a gain of 0dBi on the roof of a train, nominally at a height of 4 metres above the track).

8.11 50% confidence design threshold

8.11.1 In general, mobile radio planning tools work to 50% confidence level. In order to convert the 95% confidence levels quoted in the EIRENE specifications to 50%, a conversion margin must be used.

8.11.2 The following diagram proposes a means of doing this. It assumes that the probability function follows a normal distribution. The standard deviation of this distribution is assumed to be equivalent to the standard distribution of slow fading (the long term variation in the mean signal level principally caused by shadowing).

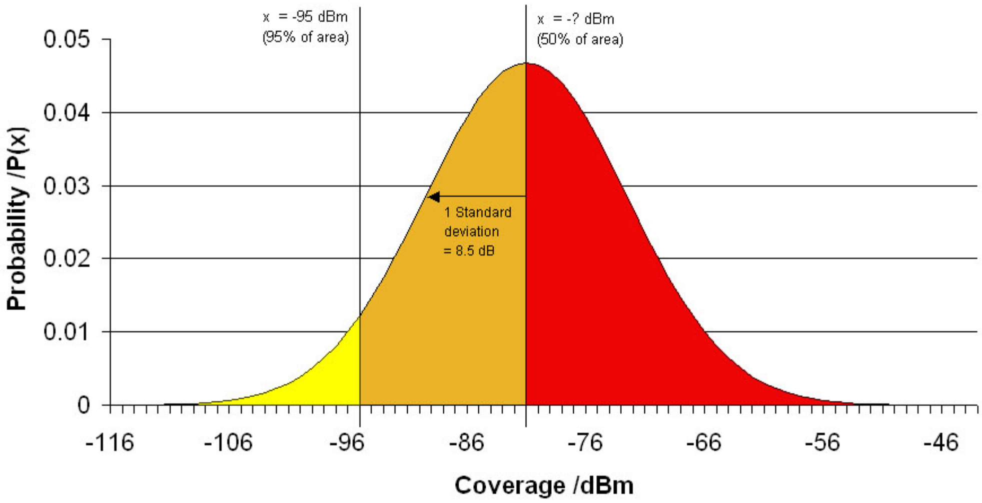

Figure 8-5: Conversion of 95% to 50% confidence level

8.11.3 In this example, the standard deviation of the prediction (analogous to the standard deviation of slow fading) is assumed to be 8.5dB. However, this value will vary depending on type of terrain, the type and density of vegetation/tree foliage present, the number of buildings, etc.

8.11.4 In this example, the following EIRENE requirement will be assumed:

> – *coverage probability of 95% based on a coverage level of 41.5 dBμV/m (-95 dBm) on lines with ETCS levels 2/3 for speeds lower than or equal to 220km/h.*

8.11.5 We can calculate the number of standard deviations between the 95% confidence level and the 50% confidence level by using the =NORMSINV() function of Microsoft Excel. This function returns the inverse of the standard normal cumulative distribution. The distribution has a mean value of zero (i.e. is centred on the y-axis) and has a standard deviation of one. The required calculation is therefore as follows:

= NORMSINV(0.95) – NORMSINV(0.5)

8.11.6 Note that the "0.95" in the function relates to the probability (i.e. is equal to 95%). Please also note that NORMSINV(0.5) is equal to zero. This can therefore be simplified as follows:

= NORMSINV(0.95)

8.11.7 By multiplying this value by the standard deviation (in this example, 8.5dB), we obtain the margin required to convert between 95% and 50% confidence levels.

8.11.8 In this example, the corresponding 50% confidence level for the above requirement can therefore be calculated as follows:

≈ 8.5*NORMSINV(0.95) + -95dBm

≈ 14dB + -95dBm

≈ - 81dBm (at 50% confidence)

8.12 Direct mode considerations

8.12.1 The operational requirement for direct mode is to:

1) provide short range fall-back communications between train drivers and trackside personnel in the event of failure of all railway and/or public GSM services normally available;

2) provide short range communications for railway personnel operating in remote areas where no GSM facilities are available.

8.12.2 Direct mode implementation is optional, however if implemented, the EIRENE SRS states that the equipment shall be capable of operation in the channels defined in the following table:

Channel	Frequency
1	876.0125 MHz
2	876.0250 MHz
3	876.0375 MHz
4	876.0500 MHz
5	876.0625 MHz

Table 8-2: Direct mode channels

8.12.3 In order to minimise the effect of direct mode interference on the neighbouring GSM-R and PMR/PAMR bands, the EIRENE specifications mandate that direct mode equipment shall have a maximum transmit power of 1 Watt and a sensitivity of at least –107dBm.

8.12.4 Notwithstanding these requirements, practical direct mode system solutions may need to employ other frequency ranges. The areas of the spectrum that could be used to support direct mode systems may include:

- Parts of the E-GSM band (frequency will not be available in all countries).
- Parts of the GSM-R band if the railway operator is able to spare the bandwidth.
- Other parts of the spectrum depending on national availability/licensing considerations.

8.13 Radio coverage in tunnels

8.13.1 Tunnel provision of radio coverage for cellular application requires special attention. Directional/high gain antennas may be used to direct a radio signal into a tunnel portal; however the actual propagation once inside the tunnel bore is limited. Under a pure railway application it is usually possible to gain access to the portal superstructure itself, thus eliminating dominant diffraction mechanisms with respect to signal entry, but in many cases this may be untenable due to catenary apparatus or other installations/physical (or other) restrictions.

8.13.2 Installation of rack mounted radiating cable is often a more suitable solution, particularly for longer tunnels or sites where access to the tunnel portals is limited. Radio coverage from radiating cables is highly reliable and the required signal levels easily calculated and realised. Loss per given length of the cable is easily measured as is that for train signal penetration. Transmission loss between cable and train is very small and due to the distances involved and there is little opportunity for Rician fading to manifest.

8.13.3 It is normal for coverage in tunnels to be provided to 200%, thus implementing 100% redundancy, across the radio element. The RAM metrics of radiating cable generally do not indicate the requirement of redundant cable installations or runs. Environmental conditions may impact this and should always be individually evaluated.

8.14 SIM card management

8.14.1 Subscriber Identity Modules commonly referred to as ‘SIM Cards’ are small memory devices that are configurable, according to a defined structure, rather like a ‘SMART’ card or E/PROM.

8.14.2 SIM cards contain information and service rights of access for the subscriber. New SIM cards require configuration with respect to access numbers, call groups, barred/debarred services and access numbers for other terminals (fixed or mobile) on the network.

8.14.3 Configuration of the SIM cards is typically achieved, via computer, with dedicated SIM cards writing interfaces. Whilst actual possession of the hardware required for SIM cards profile configuration may not be required, access to facilities to achieve it certainly is. Similarities may again be drawn with E/PROMs or SMART cards as used in other technologies.

8.14.4 Remote or broadcast SIM card update can be provided as an 'over the air' (OTA) facility. This allows packets of SIM card update commands and information to be individually addressed to a card or to a group of cards in order to change their configuration. This is typically offered to the mobile terminal user as a 'SIM update' and is simply accepted by the user and saved to the SIM. This may be anything from a call group identity addition, to PSTN access debarring, or to activation of GPRS for that particular SIM and therefore that particular mobile terminal.

8.15 Network Management Centre and Operational Maintenance Centre

8.15.1 The Network Management Centre (NMC), sometimes called the Network Operations Centre (NOC), and the Operational Maintenance Centre (OMC) would typically be co-located since responsibility of the OMC normally falls under the remit of the NMC.

8.15.2 The NMC should provide access to all facilities and resources that may be required during the course of day-to-day running of the network. Access to emergency facilities or services and disaster recovery resources is also necessary.

8.15.3 The OMC normally consists of a terminal interface providing direct access to the network operating system, via software applications that are shipped with the network hardware. Technically the OMC is part of the core network equipment and most OMCs are mounted on the UNIX operating system.

8.16 Disaster recovery

8.16.1 Disaster recovery needs to be planned from the highest level components of the network down to elements such as individual cards and fixed telecommunications links. The highest level components of the GSM-R network are the MSC(s) and gateway(s) to external networks. In the case of an MSC failure, the whole part of the GSM-R system dependent on that MSC would fail unless redundancy is provided. Therefore a standby MSC is recommended, particularly for networks supporting ETCS.

8.16.2 Where practical, redundant routing should be adopted for all fixed telecommunication links and redundant equipment should be installed within critical components (for example additional transceivers in radio cell sites and additional redundant cards at the BSC/TRAU).

8.16.3 Activation (and, where necessary, reconfiguration) of redundant equipment should be possible in the 'live' environment, ideally with the facility to initiate these procedures remotely from the NMC/OMC.

A Documentation overview

A.1 Introduction

A.1.1 Currently, there exist a number of documents related to the GSM-R system that have an impact on the development of the national system procurement specification. This section provides an overview of the documentation available to date.

A.1.2 There will be a requirement for regular amendments to this Procurement Guide in order to keep up to date with changes in the EIRENE Specifications and related documents as a result of future developments both in service provision and technologies available. This will not only include updates in the formal documentation listed in this appendix, but may also include amendments to the contents of the previous sections of this document. This will be one of the responsibilities of the European Radio Implementation Group.

A.1.3 Furthermore, it should be noted that there will be a number of national projects and regulations which will have an impact on each national railway implementing EIRENE-compliant systems. It is, however, outside of the scope of this guide to provide a detailed summary and explanation of these national regulations and projects.

A.2 Overview of relevant documentation

A.2.1 Tables A-1, A-2 and A-3 provided in this section represent respectively the set and status of EIRENE Specifications, the MORANE normative documentation and the MORANE informative documentation up to and including September 2006.

Specification	Version	Date
EIRENE FRS	7	May 06
EIRENE SRS	15	May 06

Table A-1: Overview of EIRENE Specifications

Normative Documents	Version	Date
Radio Transmission FFFIS for EURORADIO	12	Mar 04
MORANE FFFS for Functional Addressing	3	Aug 00
MORANE FFFS for Location Dependent Addressing	3	July 00
MORANE FFFS for Confirmation of High Priority Calls	3	July 00
MORANE FFFS for Presentation of Functional Numbers to Called and Calling Parties	3	July 00

MORANE FIS for Functional Addressing	4	Sept 00
MORANE FIS for Location Dependent Addressing	2	July 00
MORANE FIS for Confirmation of High Priority Calls	3	July 00
MORANE FIS for Presentation of Functional Numbers to Called and Calling Parties	3	July 00
MORANE FFFIS for GSM-R SIM Cards	3	June 04
MORANE ASCI Options for Interoperability	1	Dec 00
MORANE Specification on Usage of the UUIE in the GSM-R Environment	2	Aug 00

Table A-2: Overview of normative MORANE documentation

Informative Documents	Version	Date
MORANE Sub-System Requirements Specification (SSRS)	3	Jan 00
MORANE FFFIS for Shunting Mode	2	Aug 00
MORANE FFFIS for Direct Mode	2	Feb 99
MORANE FFFIS for Multiple Driver Communication	1	Nov 97
ASCI Features Summary of Performance Tests on the MORANE Trial Site	2	Nov 00
Summary of Performance Test Results obtained on the 3 Trial Sites	3	Oct 98
Data Transmission on the French MORANE Trial Site	2	Apr 98

Table A-3: Overview of informative MORANE documentation

A.2.2 All of these documents are available from the GSM-R web site at the following address:

http://gsm-r.uic.asso.fr/specifications.html

A.2.3 In addition to the EIRENE-specific documents, there are a number of other European initiatives, which may have an impact on the development of the national system, for example ETCS and HEROE.

B Examples of available equipment and accessories

This section provides a list, which illustrates the range of GSM-R equipment and accessories that are currently available. For full details of available equipment, national railways should contact representatives of the supply industry. Contact details are provided on the GSM-R web site at http://gsm-r.uic.asso.fr/.

B.1 List of principal suppliers in each area

B.1.1 Network suppliers

- Nortel
- Siemens
- Huawei

B.1.2 Cab radio suppliers

- Alstom
- Hörmann Funkwerk Kölleda
- Kapsch
- Siemens

B.1.3 Operational radio and General purpose radio suppliers

- Sagem
- Selex
- Triorail (without ASCI)

B.1.4 Modem suppliers

- Kapsch
- Sagem
- Triorail

B.1.5 Data card suppliers

- Kapsch
- Sagem
- Triorail

B.1.6 Dispatch and control centre suppliers

- Frequentis
- Kapsch
- Siemens
- Hörmann Funkwerk Kölleda

B.2 Cab Radio Variants

B.2.1 Cab Radio Box Standard for Train Radio - Shunting- Data Transmission

Consists of:

	Qty
Standard box with control software	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Power-Smoother PSM	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital Interfaces for connection of operator equipment	1

B.2.2 Cab Radio Box Air-Conditioned for Train Radio - Shunting- Data Transmission

Consists of:

	Qty
Air-conditioned box with control software	1
MS 8 W	1
Peltier Module (PLM)	1
PS - Module A/2E-T//9	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1

B.2.3 Cab Radio 19'' Rack Standard for Train Radio – Shunting – Data Transmission

Consists of:

	Qty
19" Rack with control software	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Power-Smoother PSM	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1

B.2.4 Cab Radio Box Standard (tall unit) for Train Radio – Shunting – Data Transmission

Consists of:

	Qty
Standard box (tall unit) with control software:	1
(Pos.12 may be fitted with ETCS)	
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Power-Smoother PSM	1
Power Supply PS - 2 (2x12, 0V, 5A)	1
Secondary voltage: 2x12V / 2x5A	
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1

B.2.5 Cab Radio Box Air-Conditioned (tall unit) for Train Radio – Shunting – Data Transmission

Consists of:

	Qty
Air-conditioned box (tall unit) with control software	1
(Pos.12 may be fitted with ETCS)	
MS 8 W	1
Power Supply PS - 5 (2x5, 0V / 5x12, 0V) / max power 350VA	1
Peltier Module (PLM)	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1

B.2.6 Cab Radio Box Standard (tall unit) for Train Radio - Shunting- Data Transmission and ETCS

Consists of:

	Qty
Standard box (tall unit) with control software:	1
MS 8 W	3
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Power-Smoother PSM	1
Power Supply PS - 2 (2x12, 0V, 5A)	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1
1 Interface (FFFIS for Euroradio) for ETCS	2

B.2.7 Cab Radio Box Air-Conditioned (tall unit) for Train Radio - Shunting- Data Transmission and ETCS

Consists of:

	Qty
Air-conditioned box (tall unit) with control software	1
MS 8 W	3
Power Supply PS - 5 (2x5, 0V / 5x12, 0V) / max. Power 350VA	1
Power Supply PS - 1 (1x5, 1V, 12 A and 2x12, 0V, 3 A)	2
Power Supply PS - 2 (2x12, 0V, 5A)	1
Peltier Module (PLM)	3
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1
1 Interface FFFIS for Euroradio for ETCS	2

B.2.8 Cab Radio Box Standard (tall unit) for Dualmode, GSM-R Train Radio – Shunting - Data Transmission and Analogue Train Radio

Consists of:

	Qty
Box with control software: *(Germany, Austria, Switzerland, analogue and GSM-R)*	1
MS 8 W	1
Transceiver, analogue	1
Power Supply PS - 1 (1x5, 1V, 12 A and 2x12, 0V, 3A)	2
Power-Smoother PSM	1
Power Supply PS - 2 (2x12, 0V, 5A)	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1
1 Interface UIC 568	1
Evaluation and filter unit (EFU)	1
CI - Control-IF (CI)	1

B.2.9 Cab Radio 19'' Rack Standard (tall unit) for Dualmode, GSM-R Train- Shunting- Data Transmission and Analogue Train Radio

Consists of:

	Qty
Box with control software: *(Germany, Austria, Switzerland, analogue and GSM-R)*	1
MS 8 W	1
Transceiver, analogue	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Power-Smoother PSM	1
Power Supply PS - 2 (2x12, 0V, 5A)	1
2 Analogue interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1
1 Interface UIC 568	1
Evaluation and filter unit (EFU)	1
CI - Control-IF (CI)	1

B.2.10 Cab Radio Box Air-Conditioned (tall unit) for Dualmode, GSM-R Train Radio - Shunting- Data Transmission and Analogue Train Radio

Consists of:

No information available.

B.2.11 Cab Radio 19'' Rack (tall unit) for Dualmode, GSM-R Train Radio - Shunting- Data Transmission and Analogue Train Radio

Consists of:

	Qty
19'' Rack with control software: *(Germany, Austria, Switzerland, analogue and GSM-R)*	1
MS 8 W	1
Transceiver, analogue	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Power-Smoother PSM	1
Power Supply PS - 2 (2x12, 0V, 5A)	1
1 Controller card with 2 Interfaces for connection of operator equipment	1
2 Digital interfaces for connection of operator equipment	1
1 Interface UIC 568	1
1 Analogue train radio controller card inc. evaluation and filter unit (EFU)	1

B.3 Accessories pack for base Cab Radio

B.3.1 Interfaces FFFIS consists of:

	Qty
Card with 2 Interfaces FFFIS RS 422	1
Interface cable with connector in box	2

B.3.2 Interfaces UIC 568 consists of:

	Qty
An additional 2 analogue operator equipment interfaces plus 1 UIC 568 *(Optionally, may have just 2 additional operator equipment interfaces instead of a UIC interface)*	1
Interface cable with connector in box	1

B.4 Accessories pack for installation with one user MMI

B.4.1 Kit 1 for driver console consists of:

Controls

Dualband - Controls for digital and analogue train radio
inc. application software module for handling train and shunting radio
- incl. Data interface
- LC - Display (Technology: FSTN black and white with backlighting)
- Keyboard consists of hard and soft keys
- Interfaces
    - NF analogue and data interfaces
    - Interface to handset
    - Interface to loudspeaker
    - Power supply for GPH charging bracket
    - Interface for turn around switch
- Front panel
- Housing

B.4.2 Complete cabling for 1 driver console with Antenna K 70 20 61 consists of:

	Qty
Cable loom and 1 driver console	1
Antenna K 70 20 61 with coaxial cable *(Frequency range 450 – 470 MHz and 806 – 960 MHz)*	1

B.4.3 Hand set and loudspeaker for 1 driver console consists of:

	Qty
Hand set 750	1
Loudspeaker	1

B.4.4 Bracket for Driver Handheld consists of:

	Qty
Charging bracket for GPH	1
Cable loom	1

B.5 Accessories pack for installations with two user MMIs

B.5.1 Kit for 1st and 2nd driver console consists of:

	Qty
User MMI	2

B.5.2 Complete cabling for 1st and 2nd driver console with Antenna K 70 20 61 consists of:

	Qty
Cable loom and 1st driver console 1	
Antenna K 70 20 61 with coaxial cable *(Frequency range 450 – 470 MHz and 806 – 960 MHz)*	1
Cable loom for 2nd driver console	1

B.5.3 Hand sets and loudspeakers for 1st and 2nd driver console consists of:

	Qty
Hand set 750	2
Loudspeaker	2

B.5.4 Bracket for Driver Handheld for 1st and 2nd driver console consists of:

	Qty
Charging bracket for GPH	2
Cable loom	2

B.6 Accessories pack: Antennae for Cab Radio Box Standard (tall unit) for Train Radio – Shunting – Data Transmission and ETCS

B.6.1 Antennae and cable consists of:

	Qty
Antennae K 70 20 61 with coaxial cable *(Frequency range 450 – 470 MHz and 806 – 960 MHz)*	2

B.7 Accessories pack for Dualmode/Shunting vehicles

B.7.1 Accessories for Shunting vehicles

	Qty
"Swan's neck" microphone	1
Foot switch	1
Cross over switches for up to 2 "swan's neck" microphones and foot switches including cable loom (for 1 MMI)	1

B.8 Accessories pack duplexer for Dualmode

Duplexer 728 954 with Coaxial cable for Dualmode consists of:

	Qty
Duplexer Type 728 954 with 2 Coaxial cables complete with plug/connector	1

- Frequency range Input 1: 68 - 470 MHz
- Frequency range Input 2: 870 - 970 MHz
- Output loss: < 0.5 dB
- Coupling loss: > 45 dB
- VSWR: < 1,2
- Impedance: 50 Ohm
- Input power: < 50 W
- Working temperature: -20°C to +50°C
- Connector: N–type female
- Mounting: over 4 bolts (M3)
- Measurements: (W x H x D) 296 x 32 x 112 mm (incl. connectors)

Accessories pack - "Country-specific" software for Dualmode with licence

Austria
Switzerland
Sweden
Italy

B.8.1 Country-specific software for 0.7m band (450 MHz – Frequency band), Packet consists of:

	Qty
Software module and licence for EURO-Analogue, one-off payment for corporate licence for the following package:	1

7.1.1 Netherlands (450 MHz – Frequency band)
7.1.2 France
7.1.3 Belgium
7.1.4 Luxembourg
7.1.5 Denmark
7.1.6 Poland (450 MHz – Frequency band)
7.1.7 Czech Republic (450 MHz – Frequency band)

B.8.2 Country-specific software for 0.7m-Band (450 MHz – Frequency band), on request consists of:

	Qty
Software module and licence for EURO-Analogue, one-off payment for corporate licence. Available on request:	1

7.2.1 Norway
7.2.2 Croatia
7.2.3 FYR
7.2.4 Slovakia
7.2.5 Slovenia
7.2.6 Bulgaria

B.8.3 Country-specific software for 2m-Band (160 MHz – Frequency band), on request consists of:

	Qty
Software module and licence for EURO-Analogue, one-off payment for corporate licence. Available on request:	1

7.3.1 Hungary
7.3.2 Poland
7.3.3 Czech Republic
7.3.4 The Netherlands

B.9 Accessories pack 160 MHz Antenna only for Dualmode for country pack for Hungary, Poland, Czech Republic and The Netherlands

B.9.1 160 MHz radio equipment in separate housing or as a 19'' rack insert consists of:

	Qty
Radio equipment 160 MHz	1
Cabling	1

B.9.2 Antenna 160 MHz

	Qty
Antenna type 733 707 with Coaxial cable *(Frequency range 146 – 147 MHz and 166 – 172 MHz)*	1

B.10 Upgrades

B.10.1 Upgrade UIC 568 Interface consists of:

	Qty
Card with 1 UIC 568 Interface	1
Interface cable with connecting socket	1

B.10.2 Upgrade FFFIS (RS422) Interfaces consists of:

	Qty
Card with 2 FFFIS (RS422) Interfaces	1
Interface cable with connecting socket	2

B.11 Cab Radio for ETCS

B.11.1 Cab Radio basic unit Standard for ETCS consists of:

	Qty
Standard Box	1
MS 8 W	2
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Interface FFFIS for Euroradio for ETCS	2

B.11.2 Cab Radio basic unit Air-Conditioned for ETCS consists of:

	Qty
Air-conditioned box	1
MS 8 W	2
Peltier Module (PLM)	2
PS - Module A/2E-T//9	2
Interface FFFIS for Euroradio for ETCS	2

B.11.3 Cab Radio basic unit in 19'' Rack for ETCS consists of:

	Qty
19" Rack	1
MS 8 W	2
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Interface FFFIS for Euroradio for ETCS	2

B.12 Accessories pack - Cable loom and antennae for Cab Radio ETCS

B.12.1 Antennae and cable consists of:

	Qty
Antenna K 70 20 61 with coaxial cable *(Frequency range 450 – 470 MHz and 806 – 960 MHz)*	2

B.12.2 Cable loom for connection to onboard power supply and ETCS computer consists of:

	Qty
1 x cable (10m) for voltage supply (one end fitted with plugs, 2nd end finished with sleeved wire)	1
1x cable (10m) for ETCS application (one end fitted with plugs, 2nd end is unwired, plug connectors are enclosed)	1

B.13 General Purpose Handheld

B.13.1 GPH consists of:

	Qty
Standard GSM-R GPH	1
Standard battery (Li-Ion battery or same/higher value)	1
Journey charger	1
User instructions	1
Packaging	1

B.13.2 Accessories for GPH

Accessories for (GPH) consist of:

		Qty
1	Table-top charger	1
2	Car-kit with hands-free	1
3	Portable hands-free kit	1
4	PC data cable	1
5	PC data cable for car-kit	1
6	Li-Ion battery (880mAhrs)	1
7	Leather pocket	1
8	Cable for cigarette lighter	1
9	Journey charger	1

B.14 Operational Purpose Handheld (OPH)

B.14.1 OPH consists of:

	Qty
Standard GSM-R OPH	1
Standard OPH battery	1
Charger	1
User instructions	1
Packaging	1

B.14.2 Accessories for OPH consist of:

		Qty
1	Standard OPH battery	1
2	Table-top charger	1
3	Charger with charging control	1
4	Leather pocket	1
5	Car-kit with hands-free	1

B.15 Operational Purpose Handheld-Shunting (OPS)

B.15.1 OPS consists of:

	Qty
Standard GSM-R OPS	1
Standard OPS battery	1
Charger	1
User instructions	1
Packaging	1

B.15.2 Accessories for OPS consist of:

		Qty
1	Standard OPS Battery	1
2	Table-top charger	1
3	Charger with charging control	1
4	Leather pocket	1
5	Mounting with additional speech button, connection protection, dead-man's button, emergency button, microphone, battery mounting, status display and harness in accordance with requirements from the shunting workgroup	1

B.16 Data Transmission Module 2 Watt

B.16.1 MS2 consists of:

MS2

Area of application still open

B.17 GSM-R Data Terminal equipment

B.17.1 GSM-R Data terminal equipment for ETCS with one Mobile (MS) in Standard Box

Consists of:

	Qty
Standard box	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.17.2 GSM-R Data terminal equipment for ETCS with two Mobiles (MS) in Standard Box

Consists of:

	Qty
Standard box	1
MS 8 W	2
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Interface FFFIS for Euroradio for ETCS	2

B.17.3 GSM-R Data Terminal equipment for ETCS with one Mobile (MS) in Air-Conditioned Box

Consists of:

	Qty
Air-conditioned box	1
MS 8 W	1
Peltier Module (PLM)	1
PS - Module A/2E-T//9	1
Interface FFFIS for Euroradio for ETCS	1

B.17.4 GSM-R Data Terminal equipment for ETCS with two Mobiles (MS) in Air-Conditioned Box

Consists of:

	Qty
Air-conditioned box	1
MS 8 W	2
Peltier Module (PLM)	2
PS - Module A/2E-T//9	2
Interface FFFIS for Euroradio for ETCS	2

B.17.5 GSM-R Data Terminal equipment for ETCS with a Mobile (MS) in 19" Rack

Consists of:

	Qty
19" Rack	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.17.6 GSM-R Data Terminal equipment for ETCS with two Mobiles (MS) in 19" Rack

Consists of:

	Qty
19" Rack	1
MS 8 W	2
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	2
Interface FFFIS for Euroradio for ETCS	2

B.18 Accessories pack - Cable loom and antenna for fixed GSM-R Data Terminal equipment for ETCS with one Mobile

B.18.1 Antenna, antenna mast and accessories consist of:

	Qty
Antenna K 75 11 61 and coaxial cable *(Frequency range 806 – 960 MHz)*	1
Antenna mast and accessories *- Aluminium telescopic mast: maximum length 5.40m with 2 positions for wall fastening* *- Extension* *- Lightning protection connection with 3m ribbon conductor*	1

B.18.2 Cable loom consists of:

	Qty
1x cable (10m) for voltage supply (one end fitted with plugs, 2nd end finished with sleeved wire)	1
1x cable (10m) for ETCS application (one end fitted with plugs, 2nd end is unwired, plug connectors are enclosed)	1

B.19 Special speech equipment

B.19.1 OPH (without charger)

	Qty
Standard GSM-R OPH	1
Standard OPH battery	1
User instructions	1
Packaging	1

B.19.2 Accessories for OPH

		Qty
1	Standard OPH battery	1
2	Table-top charger	1
3	Charger with charging control	1
4	Leather pocket	1
5	Car-kit with hands-free	1

B.20 GSM-R vehicle equipment (data only)

B.20.1 GSM-R vehicle equipment (data only) for Train Control Network in Standard Box

Consists of:

	Qty
Standard box	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.20.2 Vehicle equipment GSM-R (data only) in 19" rack for Train Control Network in passenger vehicles

Consists of:

	Qty
19" Rack	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.20.3 Cable loom consists of:

	Qty
1x cable (10m) for voltage supply (one end fitted with plugs, 2nd end finished with sleeved wire)	1
1x cable (10m) for ETCS application (one end fitted with plugs, 2nd end is unwired, plug connectors are enclosed)	1

B.21 Vehicle equipment GSM-R (data only) MS for goods wagons

B.21.1 Vehicle equipment GSM-R (data only) MS for goods wagons in Standard Box

Consists of:

	Qty
Standard box	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.21.2 Vehicle equipment GSM-R (data only) in 19" rack MS for goods wagons

Consists of:

	Qty
19" Rack	1
MS 8 W	1
Power Supply PS - 1 (1x5, 1V, 12A and 2x12, 0V, 3A)	1
Interface FFFIS for Euroradio for ETCS	1

B.21.3 Cable loom consists of:

	Qty
1x cable (10m) for voltage supply (one end fitted with plugs, 2nd end finished with sleeved wire)	1
1x cable (10m) for ETCS application (one end fitted with plugs, 2nd end is unwired, plug connectors are enclosed)	1

C Examples of available network equipment and accessories

In later versions of this document, this section will provide a list to illustrate the range of GSM-R network equipment and accessories that are available. For full details of available equipment, national railways should contact representatives of the supply industry. Contact details are provided on the GSM-R web site at the following address:

http://gsm-r.uic.asso.fr/.