

## Design guidelines

# Railway telecommunications system

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# 1. Introduction

## 1.1. Telecommunication sub-systems

The telecommunication sub-systems shall provide access to the telecommunication network users and shall support the different required railway services (voice and data). The required network services and the number of different network users will have a direct influence on the telecommunication sub-system dimensioning hence to the provided network.

The following sub-systems shall be provided:

- a) Railway related radio systems
- b) Backbone Transmission Network system
- c) Operational and administrative Telephone system
- d) Echo cancelation system
- e) Direct line telephone system (Intercom)
- f) Voice and data recording system
- g) Billing mediation device
- h) Network Management System (NMS)
- i) Over The Air (OTA) SIM card provisioning
- j) Network synchronization and time distribution system (Master Clock System)
- k) CCTV and recording system
- l) Intrusion Detection System
  - a. Access control system
  - b. Fence protection
- m) Public Address System (PAS)
- n) Passenger Information Display System (PIDS)
- o) Fire detection and alarm system
- p) Automatic Fare Collection system (AFC) / Ticketing
- q) Telematics systems for freight services
- r) Li-Fi
- s) Cyber security

## 1.2. Norm / Standard

Here below an extraction of the applicable main norms and standards:

Standard ID	Title
EN 12665	Light and lighting - Basic terms and criteria for specifying lighting requirements
EN 300220-1	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Short Range Devices (SRD) - Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW - Part 1: technical characteristics and test methods (V2.4.1)
EN 300220-2	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Short Range Devices (SRD) - Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW - Part 2: harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive (V2.4.1)
EN 300328	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Wideband transmission systems - Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques - Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive (V1.9.1)
EN 300330-1	Electromagnetic compatibility and radio spectrum matters (ERM) - Short range devices (SRD) - Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz - Part 1: technical characteristics and test methods (V1.8.1)
EN 300330-2	Electromagnetic compatibility and radio spectrum matters (ERM) - Short range devices (SRD) - Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz - Part 2: harmonized EN covering the essential requirements of article 3.2 of the R&TTE directive (V1.6.1)
EN 300386	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Telecommunication network equipment - ElectroMagnetic Compatibility (EMC) requirements (V1.6.1)
EN 300392-1 series	Terrestrial trunked radio (TETRA) - Voice plus data (V+D)
EN 300440-1	Electromagnetic compatibility and radio spectrum matters (ERM) - Short range devices - Radio equipment to be used in the 1 GHz to 40 GHz frequency range - Part 1: technical characteristics and test methods (V1.6.1)
EN 300440-2	Electromagnetic compatibility and radio spectrum matters (ERM) - Short range devices - Radio equipment to be used in the 1 GHz to 40 GHz frequency range - Part 2: harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive (V1.4.1)
EN 301 515	Global System for Mobile communication (GSM) - Requirements for GSM operation on railways (V2.3.0) (Publishing 2 (2014-08-01))
EN 301489 series	Electromagnetic compatibility and Radio spectrum Matters (ERM) - ElectroMagnetic Compatibility (EMC) standard for radio equipment and services
EN 301502	Global system for mobile communications (GSM) - Harmonized EN for base station equipment covering the essential requirements of article 3.2 of the RTTE Directive (V12.1.1)
EN 301515	Global System for Mobile communication (GSM) - Requirements for GSM operation on railways (V2.3.0) (Publishing 2 (2014-08-01))
EN 301893	Broadband radio access networks (BRAN) - 5 GHz high performance RLAN - Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive (V1.8.1)
EN 301908-1 series	IMT cellular networks - Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive

Standard ID	Title
EN 303035-1	Terrestrial Trunked Radio (TETRA) - Harmonized EN for TETRA equipment covering essential requirements under article 3.2 of the R&TTE Directive - Part 1: Voice plus Data (V+D) (V1.2.1) (Publishing 2 (2014-08-01))
EN 303035-2	Terrestrial Trunked Radio (TETRA) - Harmonized EN for TETRA equipment covering essential requirements under article 3.2 of the R&TTE Directive - Part 2: Direct Mode Operation (DMO) (V1.2.2)
EN 45011	General requirements for bodies operating product certification systems.
EN 50123-series	Railway applications - Fixed installations - D.C. switchgear
EN 50124-series	Railway applications - Insulation coordination
EN 50128	Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems (Publishing 2 (2010-09-01))
EN 50129	Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling (Publishing 2 (2010-09-01))
EN 50131-series	Alarm systems - Intrusion and hold-up systems
EN 50132-series	Alarm systems - CCTV surveillance systems for use in security applications
EN 50133-series	Alarm systems. Access control systems for use in security applications.
EN 50152-series	Railway applications - Fixed installations - Particular requirements for a.c. switchgear
EN 50159	Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems
EN 50164-series	Lightning Protection Components (LPC)
EN 50310	Application of equipotential bonding and earthing in buildings with information technology equipment
EN 50360	Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300 MHz - 3 GHz) (Publishing 2 (2006-09-01))
EN 50385	Product standard to demonstrate the compliance of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz - 40 GHz) - General public
EN 50463-4	Railway applications - Energy measurement on board trains -- Part 4: Communication
EN 50562 series	Railway applications - Fixed installations - Process, protective measures and demonstration of safety for electric traction systems
EN 54 series	Fire detection and fire alarm systems
EN 55011	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
EN 55016 series	Specification for radio disturbance and immunity measuring apparatus and methods

Standard ID	Title
EN 55022	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
EN 55024	Information technology equipment - Immunity characteristics - Limits and methods of measurement
EN 60038	CENELEC standard voltages
EN 60598 series	Luminaires
EN 60794 series	Optical fibre cables
EN 60870 series	Telecontrol equipment and systems
EN 60950	Information technology equipment - Safety
EN 61375-1	Electronic railway equipment - Train communication network (TCN) -- Part 1: General architecture
EN 62305 Series	Protection against lightning
EN ISO 11064 series	Ergonomic design of Control Centres
EN ISO 24014-1	Public transport - Interoperable fare management system - Part 1: architecture
EN ISO 7250-1	Basic human body measurements for technological design - Part 1: body measurement definitions and landmarks
ERA/ERTMS/003204	ERTMS/ETCS Functional Requirements Specification (FRS)
ETS 300683	Radio Equipment and Systems (RES). ElectroMagnetic Compatibility (EMC) standard for Short Range Devices (SRD) operating on frequencies between 9 kHz and 25 GHz.
ETS 300826	Electromagnetic compatibility and Radio spectrum Matters (ERM). ElectroMagnetic Compatibility (EMC) standard for wideband transmission systems and High Performance Radio Local Area Network (HIPERLAN) equipment.
ETSI ES 201 168	Speech processing, Transmission and Quality aspects (STQ); Transmission characteristics of digital Private Branch eXchanges (PBXs) for interconnection to private networks, to the public switched network or to IP gateways
ETSI TR 100 392-series	Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D);
ETSI TR 102 281	Railways Telecommunications (RT); Global System for Mobile communications (GSM); Detailed requirements for GSM operation on Railways
ETSI TR 102 300 series	Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Designers' guide
ETSI TR 102 580	Terrestrial Trunked Radio (TETRA); Designer's Guide; TETRA High-Speed Data (HSD); TETRA Enhanced Data Service (TEDS)
ETSI TS 100 587	Digital cellular telecommunications system (Phase 2+); General Aspects on the BSS-MSC Interface (3GPP TS 08.01 version 8.0.1 Release 1999)
ETSI TS 100 594	Digital cellular telecommunications system (Phase 2+); Base Station Controller - Base Transceiver Station (BSC - BTS) interface; Layer 1 structure of physical circuits (GSM 08.54 version 8.0.0 Release 1999)

Standard ID	Title
ETSI TS 102 610	Railways Telecommunications (RT); Global System for Mobile communications (GSM); Usage of the User-to-User Information Element for GSM Operation on Railways
ETSI TS 102 933-1	Railway Telecommunications (RT); GSM-R improved receiver parameters; Part 1: Requirements for radio reception
ETSI TS 103 066	Railway Telecommunications (RT); Rel-4 Core Network requirements for GSM-R
ETSI TS 103 169	Railway Telecommunications (RT); ASCI Options for Interoperability for GSM operation on Railways
ETSI TS 103 389	Railway Telecommunications (RT); Global System for Mobile communications (GSM); Usage of Session Initiation Protocol (SIP) on the Network Switching Subsystem (NSS) to Fixed Terminal Subsystem (FTS) interface for GSM Operation on Railways
IEC 60215	Safety requirements for radio transmitting equipment
IEC 60268 series	Sound system equipment
IEC 60297 series	Mechanical structures for electronic equipment Dimensions of mechanical structures of the 482,6 mm (19 in) series
IEC 60331 series	Fire resistance of electric cables
IEC 60364 series	Low-voltage electrical installations
IEC 60529	Degrees of protection provided by enclosures (IP/ Ingress Protection Code)
IEC 60664 series	Insulation coordination for equipment within low-voltage systems
IEC 60721 series	Environmental conditions appearing in nature
IEC 62280:2014	Railway applications - Communication, signalling and processing systems - Safety related communication in transmission systems
UIC 751 series	Railway Radio Equipment (e.g. techn. Spec., ground-train radio comm., GSM-R cross-border requirements, etc.)
UIC 753 series	Technical regulations concerning international railway telephone circuits



## 2. General requirements

To avoid general data protection regulation conflicts concerning privacy and security issues etc. (local governmental laws concerning subscriber information and database sharing etc.) dedicated independent telecommunication systems for each country shall be deployed respecting the Control Command Signalling Technical Specification for Interoperability (CCS TSI).

Dedicated independent telecommunication networks increase both the availability and reliability of the whole RFC8 extension.

Operator working groups between the different countries shall be organized in advanced to synchronize the different special country related needs.

The objective shall be to solve all operator related discrepancies in advanced, to optimize the tender document quality and to minimize special expensive add on requirements after contract signature.

The general requirements are applicable to the complete telecommunication systems provided by the contractor.

- a) Link redundancy shall be requested including links used for roaming.
- b) The provided equipment shall be RoHS (Restriction of Hazardous Substances) compliant.
- c) Different languages shall be supported (local languages and English).
- d) Technical rooms for railway operators and e.g. public radio operator shall be separated to respect security aspects.
- e) The contractor shall provide the floorspace requirements for the different equipment.
- f) General life cycle shall be compliant with design life requirements written in RBDG-RPT-012 general requirements. During the design life, the provided system shall be supported without any limitations to:
  - a. Extensions HW/SW
  - b. Spare parts
  - c. Repair & return
  - d. Etc.
- g) The provided system shall be modular in design.
- h) Cards and modules shall be hot swappable.
- i) A plug and play system shall be provided by the contractor.
- j) Sufficient spare capacity for all sub-systems shall be requested.
- k) Local earthing, bonding and lightning protection rules shall be respected.
- l) Overvoltage protection shall be provided by the contractor.
- m) The provided systems shall be protected against single point of failure.

All plans and provided equipment shall be under employer approval.

## 3. Environmental conditions

Local climatic conditions as described in document RBDG-RPT-012-General requirements shall be respected.

Following some examples of telecom related requirements (list not exhaustive):

- The provided equipment and installation related material shall be adapted to the special local environmental conditions e.g. stainless-steel fixations, housings etc.
- Based on the different installation sites the different ingress protection requirements shall be specified.
- Air conditioning calculation and air conditioning systems shall be provided for the different required technical rooms in and outside of buildings.

## 4. Call profile

The Call profile shall be used as basis for the telecommunication network dimensioning.

The call profile shall include the information (brief description) concerning the following operational and administrative related voice and data topics:

- Number of mobile users
- Maintenance staff
- Number of different rail vehicles
- Number of ETCS\_L2 trains
- Number of train attendants
- Number of Dispatchers
- Number of Administrative users
- Information concerning shunting yards (shunting groups, teams, general staff etc.)
- Number of different simultaneous group calls (VGCS / VBS)
- LDA / eLDA zones
- REC / eREC zones
- Busy Hour Call Attempt (BHCA) per user
- Call Holding Time (CHT) per user
- Call routing (who is calling who) per call type (communication matrix)
- Train diagnostic (data)
- Other railway related users and functionalities based on EIRENE and FRMCS.

This information is used to derive amongst others the required sub-system, number of mobiles and associated SIM cards, the different sub-system interfaces which shall be provided during design and construction.

A comfortable margin shall be added to allow an easy potential extension later on, without additional costly licenses or system extensions.

# 5. Railway related radio networks

Based on European Railway Agency (ERA) / Union Internationale des Chemins de Fer (UIC) the European Railway Traffic Management System (ERTMS) is actually composed of European Train Control System (ETCS) and the Global System for Mobile Communication – Railway (GSM-R).

ERTMS is legally mandated in the Technical Specifications for Railway Interoperability which are applicable in the European Member States.

*“The predicted obsolescence of GSM-R by 2030, combined with the long-term life expectancy of ETCS (2050) and the Railway business needs, have led to the European Railway community initiating work to identify a successor for GSM-R. The successor has to be future proof, learn from past experiences / lessons and comply with Railway requirements.”*  
 Source UIC ([http://uic.org/IMG/pdf/frmcs\\_user-requirements.pdf](http://uic.org/IMG/pdf/frmcs_user-requirements.pdf))

To have a successor technology for GSM-R in place by 2022 for deployment, the International Railway Union (UIC) have published a first user requirement specification in their paper “Future Railway Mobile Communication System - FRMCS”.

Based on ERA (Mr. Chiel Spaans UIC 3rd World Conference on Rail Transport Telecoms 17-18 May 2017) an important Control Command Signalling Technical Specification for Interoperability (CCS TSI) update is planned for 2021-2022 which includes a full solution and provides the Legal framework for FRMCS deployment.

Regarding the above information the UIC European Integrated Radio Enhanced Network (EIRENE) and FRMCS specifications shall be applicable in the latest version at the day of deployment to assure the requested interoperability with the neighbour countries.

All system and functional standards and norms specified by UIC (EIRENE FRS/SRS, FRMCS), ERA, 3GPP, ETSI for ERTMS shall be applicable. All functionalities shall be supported without any limitation and restrictions and shall be able to work in parallel.

ETCS\_L2 and an operational speed of 250km/h shall be supported.

The latest known system releases supported shall be requested to avoid a costly network upgrade directly after the system hand over is completed.

An optional radio network shall be specified in case the FRMCS is limited in bandwidth to support shunting yards, train controllers etc. applications as it is today with GSM-R.

## 5.1. Radio coverage

The future specified FRMCS frequencies and the GSM-R frequencies shall be considered for the radio planning.

The radio coverage for all operational related radio systems shall be realized for the entire railway line infrastructure. This includes the OCC; all stations; depot and the whole tracks.

The radio coverage for the public radio systems are limited to the track (on-board) and station areas.

To avoid interferences between the future deployed radio systems (railway operator / public radio systems), the public radio operator shall be invited to share the different sites and antenna masts.

For more details see: <http://www.era.europa.eu/Core-Activities/ERTMS/Pages/Interferences-information.aspx>

A detailed Radio Frequency (RF) planning respecting the different border crossing agreements shall be provided. All roaming requirements shall be realized by the contractor.

The radio coverage shall respect the indicated standards. Double radio coverage shall be considered with minimum 99.99% availability.

Depending on the different radio systems MIMO and diversity etc. (e.g. state of the art technology at the time of deployment) shall be provided.

Radiating cables shall be used in tunnels to realize a more homogeneous radio coverage. Remote monitoring of repeaters shall be requested.

The fully redundant operational related on-board radio modules (voice/data) shall support the potential required “old” GSM-R and FRMCS technology to assure the interoperability with existing older GSM-R networks. Redundant roof top antennas shall be provided.

Based on the deployed radio solution the handhelds shall support the potential required “old” GSM-R and FRMCS technology.

## 5.2. Quality of Service (QoS) measurements

The objective of the QoS measurement campaign is to verify the real radio coverage after system integration is completed and before the commercial operation of the line starts.

The final / detailed QoS measurement procedure shall be based on EIRENE, Subset 093 and future FRMCS specifications and shall be defined by the contractor 6 months before the measurements will start. The provided procedure shall be under the employer approval.

The contractor shall be responsible for:

- Providing measurement equipment
- Setting up the measurement chains
- Executing the measurements
- Providing documentation and measurement reports
- Providing all raw data
- Overall planning
- Etc.

The measurement results shall be verified and confirmed by a qualified independent third party.

To classify the voice quality the Mean Opinion Score (MOS) shall be used. Minimum MOS value accepted shall be 3.

To cover fast fading the Radio Frequency (RF) measurement shall be minimum  $\lambda/2$ . Lee criteria shall be not accepted.

The railway operator shall decide if the required measurement train is provided for free.

# 6. Network Management System

The following special Network Management Systems (NMS) shall be considered:

- Railway radio network NMS
- Railway Management System (RMS)

In general, for all telecommunication sub-systems a management system shall be considered.

## 6.1. Radio Network Management System

The geo-redundant (active and backup OCC) radio Network Management System shall be used by the radio network administrator to manage, supervise and configure the core and access network related equipment.

The NMS shall provide the following operational and management functionalities (the list is not exhaustive):

- Logfile search functionalities based on timestamp, events etc. All alarms and events from the network elements shall be stored and time-stamped with an accuracy of 1 second
- Maintain a backup configuration database for all network elements

- Detailed fault management on card level and interface level. Alarm information provided shall enable quick identification of the fault and its source.
- Easy link and system parameter configuration of new and existing circuits (adding / modifying / deletion)
- Offline configuration tool with consistency check (online synchronization with the network database)
- Consistency check before application of changes.
- Configuration / management of any EIRENE/ FRMCS functionalities
- Performance management / down to network element including EIRENE / FRMCS specific functionalities
- Detailed performance report on interface level (usage) and threshold alarms including EIRENE / FRMCS specific functionalities
- Key performance indicator, real-time monitoring, query and reporting functionality for all links (core and access) and functionalities including EIRENE/ FRMCS
- Any critical resource monitoring
- Security management
- Software management
- Topology management
- Subscriber signalling tracing
- Subscriber call routing tracing
- Customer counters & network alarms management
- System / user / inventory management
- Time Management for the Entire Network
- Network health check
- Network integration monitoring
- Provide any network related information in printed and soft copy

The NMS shall give the possibility to provide the statistics concerning (non-exhaustive):

- Detailed information about the different used interfaces
- Detailed information about the different calls per interface
- Detailed information about the call drops per interface
- Detailed information about traffic and congestion per interface
- Detailed information about group calls (successful vs. failed, cells per GC...
- Detailed information about used group call resources
- Detailed information about pre-empted calls per call type and interface
- Detailed information about Hand Over (HO) (radio cell reselection etc.), successful HO versus unsuccessful, HO retry

## 6.2. Railway Management System

The Railway Management System (RMS) shall be limited to Dispatcher related EIRENE functionalities. The RMS shall be used by the dispatcher to manage and configure for example the following railway related functionalities:

- Location depending Addressing (LDA)
- Enhanced Location depending Addressing (eLDA)
- Voice Group Call Service (VGCS)
- Voice Broadcast Service (VBS)
- Group Call AREA (GCAREA)
- Railway Access Matrix

- Global Positioning System (GPS) related applications
- Railway Emergency Call (REC) and enhanced Railway Emergency Call (eREC)
- Direct Mode (DMO if applicable)
- enhanced Multi-Level Precedence and Pre-emption (eMLPP)
- Others railway related functionalities specified by UIC / ERA

The tool shall be able to pre-check new configurations (offline) and to display existing configurations (online). The tool shall be able to identify configurations which are in contradiction and hence to protect the users (Dispatchers) for errors. An offline simulation functionality shall be included. The simulation shall reflect the reality. Each modification shall be linked to an ID and an execution number. Log file shall be requested. The ID specifies the person which has executed the modification. The execution number is linked to the modification. The execution number shall be used to automatically undo (remove) the modification after confirming twice by an authorized user.

## 7. Operational and administrative telephone system

The operational and administrative telephone systems are two independent telephone systems. The telephone system consists mainly of a dedicated operational related fixed line telephone system and a separate dedicated administrative related fixed line telephone system.

The fixed line telephone systems shall be realized via dedicated IP-PABX's. The interconnection of both telephone systems shall be realized via a DMZ. A direct non-protected access shall be avoided.

### 7.1. Operational related fixed line telephone system

The operational related fixed line telephone system shall be realized via a dedicated geo-redundant dispatcher system installed in the active and backup OCC. The dispatcher system shall be directly connected to the local operational related radio system (e.g. FRMCS). All types of traffic shall be recorded via the voice and data recording system.

The dispatcher system shall be used for the operational railway traffic management.

Special dispatcher terminals with touch screen and gooseneck microphone used for the traffic management shall be provided. The special dispatcher terminals are located at the active and backup OCC, stations, substations etc... The implemented numbering plan shall be compliant with EIRENE.

All EIRENE FRS and SRS specified railway dispatcher requirements shall be supported in parallel without any exception.

The following functionalities shall be supported:

For example, the following functionalities shall be provided:

- Touch screen with adjustable backlight,
- An alphanumeric keyboard (including \* and #),
- Functional buttons for short code calls,
- SMS functionalities
- Push To Talk (PTT) button
- Multiple simultaneously role handling
- Functional buttons for extended functions like:

- Call mute,
- Call hold,
- Call forward,
- Call transfer,
- Call history,
- Electronic directory / Phone book
- Conference,
- Call wizard for simple composition of functional numbers
- Etc ...

## 7.2. Administrative related fixed line telephone system

The administrative related communication shall be realized via a dedicated geo-redundant IP-PABX system. Voice and data traffic shall be supported.

A video and audio conference system shall be provided and installed in meeting rooms and shall give the possibility to setup video conference calls with multiple external and internal participants including media sharing possibility. The camera inside the conference room shall automatically switch to the talking person and present the image to the other remote participants. Conference recording shall be possible. In case the conference is recorded the participants shall be clearly notified. A conference room reservation tool shall be provided.

The system shall provide the following functionalities:

- Desk phone fix line connections including hands-free speakerphone
- Telephone calls via PC (headphone)
- Electronic phone book
- Calling party identification
- Multiparty calls
- Standard functionalities like call hold, call transfer
- etc.

# 8. Direct line telephone system

The direct line telephone system includes:

- a) Passengers or Public related telephones (intercom)
- b) Operations-related telephones along the track and stations

These types of calls shall be recorded via the centralized voice recording system.

## 8.1. Passengers or Public related telephones (intercom)

Passengers in the station shall have the possibility of calling for help or to setup an emergency call. These telephones are to be connected (automatically call routing – intercom system) directly to the relevant operator. The intercom system shall be connected with the CCTV system. Passengers or public related telephone intercom systems are planned at each station, platform, buildings, on-board the passenger trains etc.

They include:

- Emergency telephones
- Passenger help points
- Intercom system for example elevators
- etc.

A multifunctional emergency telephone column which includes a CCTV camera, a heart defibrillator and a fire extinguisher shall be requested. In case the heart defibrillator or the fire extinguisher will be used an alarm at the OCC shall be raised and the image of the CCTV camera shall be automatically recorded and displayed to a predefined monitor. The monitor shall display in the same time the exact location of the emergency telephone and indicate the responsible first aide or security staff for this area (telephone number etc. shall be displayed on the monitor...). In case the emergency is confirmed the operator in the OCC can inform the first aide staff (ambulance).

An intercom system with an embedded CCTV camera shall be used for example in elevators, at platforms, on-board the train etc. In case of use an alarm at the OCC shall be raised and the image of the CCTV camera shall be automatically recorded and displayed to a predefined monitor. The monitor shall display in the same time the exact location of the call originator and shall indicate the responsible maintenance / security staff for this area (telephone number etc. shall be displayed on the monitor...).

## 8.2. Telephones along the track

Direct line telephones at predefined locations along the track shall be used by maintenance personnel or, in case of on-board radio module failure, by train drivers.

Direct line telephones installed beside the railway track shall be powered via a local battery charged via a solar panel. The telephone shall be direct connected to the optical fibre cable laid beside the track. Remote control functionality shall be provided.

Other operations related direct line telephones shall be planned for:

- Section breaks
- Substations
- Paralleling stations
- Sectioning and paralleling stations
- etc.

# 9. Voice and data traffic recording system

All operational related voice and data traffic including direct line telephone system shall be recorded. Recorded information shall contain at least:

- The sender's identity
- The receiver's identity
- The message contents (any voice and any data traffic)
- The sending time (start / stop)
- The reception time or the failure cause
- Involved interfaces
- Etc.



A geo-redundant network recording system shall be provided. All messages shall be recorded and stored at least 30 days. Special local operational requirements shall be taken into account. Managed user access and export functionality shall be provided.

Administrative and public traffic recording is out of scope.

## 10. Echo cancelation

The provided telecommunication systems shall take care of (avoid) potential echo problems for in-outgoing communication.

## 11. Over The Air SIM card provisioning

The contractor shall provide a redundant management system to allow the SIM card provisioning via the concerned radio network (over the air).

## 12. Billing system

The contractor shall provide a geo-redundant centralized billing system which allows the recording of Call Detail Records (CDR) for all voice and all data traffic. The CDR's shall be stored respecting local operational and governmental requirements.

The CDR shall contain minimum the following information:

- Phone number of the subscriber originating the call (calling party, A-party)
- Phone number receiving the call (called party, B-party)
- Starting time of the call (date and time)
- Call duration
- Billing phone number that is charged for the call
- Identification of the telephone exchange or equipment writing the record
- A unique sequence number identifying the record
- Additional digits on the called number used to route or charge the call
- Disposition or the results of the call, indicating, for example, whether or not the call was connected
- Route (interface) by which the call entered the exchange
- Route (interface) by which the call left the exchange
- Call type (voice, SMS, FN, CT, GC, eMLPP, REC, data, etc.)
- Any fault condition encountered / Rejected calls / blocked calls
- Involved parties for any type of multiparty call
- Radio cell information (optional)

- Other railway related information based on EIRENE / FRMCS

## 13. Public radio

The contractor shall take into account the realisation of public radio coverage in new stations, buildings, on-board the train etc... Therefore, the Contractor is responsibility to liaise with the public network operators to identify their specific needs for:

- 2G / 3G,
- UMTS,
- Wi-Fi,
- LTE
- Etc.

in terms of:

- Floorspace,
- Power requirements,
- Transmission network,
- Antenna positions,
- Etc.

The required equipment shall be provided by the public network operator.

The installation of the equipment shall be under the responsibility of the public network operator.

## 14. Transmission Network

For the railway line a fully redundant self-healing ethernet GMPLS (Generalized Multi-Protocol Label Switching) backbone transmission network shall be requested for each main line section. Each ethernet node shall be fully redundant (doubled). Single point of failure shall be avoided.

Optical fibre cables shall be deployed (special country related requirements shall be respected) to support routing and path diversity between the nodes.

The cable shall interconnect all stations, buildings, depot etc. in a geo-redundant or ring way and shall be compliant with conceptual solution examples described in chapter 10.4.3 of RBDG-RPT-012 General Requirements:

- In case of a geo-redundant connection, the common path of the first and second optical fibre cable shall not exceed 6m.
- In case of a ring connection, the optical fibre cable shall enter a station or building from one side and leave at the other / opposite side. The cable shall not enter and leave a location at the same place.

One of the objectives shall be to assure the interconnection and secured interoperability to existing railway operator related transmission networks. Special required gateways shall be identified and delivered by the contractor.

QoS assurance shall be supported by the network nodes.

To respect cyber security aspects, independent transmission nodes shall be provided for administrative related voice and data applications. The objective is to realize a clear network separation between security related railway operational applications and administrative (public) applications.

50% spare capacity for each sub-system shall be provide. The provided equipment shall be extendable without replacing existing equipment.

The design and performance of the Transmission System shall conform to all applicable Telecommunication Standards. The Contractor shall describe the configuration, operation and interoperability and the synchronization of the network, including its operation during different possible fault scenarios.

The GMPLS network shall be dimensioned to provide the interconnected for the following sub-systems:

- Signalling / ETCS\_L2 /3 related systems
- Closed Circuit Television (CCTV)
- Passenger Information [Display] System (PIS / PIDS)
- Public Address [Announcement] System (PAS)
- Telephone Network
- Operational related telephone system (Dispatcher system)
- Administrative related telephone system
- Intercom
- Voice / data / video recording
- Maintenance Management system
- Operation & Maintenance sub-systems
- Different radio systems
- RFID – container tracking
- Fire alarm
- Intrusion Detection System
  - Access control system
  - Fence protection
- Light Fidelity (Li-Fi)
- Master clock system
- SCADA
- Detection systems (such as cross wind, hot box etc.)
- Wayside equipment
- Ancillary systems
- Power supply systems
- Traffic management system
- Mechanical, Electrical and Plumbing (MEP)
- External national systems (e.g. public radio network operator etc.)
- External international systems (example: roaming with other operational related mobile networks)













## 15. Cable

Detailed cable routing planes shall be delivered by the contractor. All cable shall be labelled in a permanent manner. Cable colour codes shall be unique for the whole project and shall be in compliance with IEC 60304. All cable shall be fire and flame retardant, halogen free, not corrosive, protected against rodent etc. The cable plans and cables shall be under the approval of the employer.

The following colour code shall be applied:

**Fibre colour code (in accordance with IEC 60304)**

(up to 12 fibres)

Fibre no.	colour	
1		red
2		green
3		blue
4		yellow
5		white
6		grey
7		brown
8		violet
9		turquoise
10		black
11		orange
12		pink

# 16. CCTV

The CCTV system is divided into two main categories:

- a) General monitoring (stations and buildings etc.)
- b) Railway lines monitoring

The classification of the CCTV system is required because of the different nature of monitoring requirements. A centralized geographically redundant CCTV system (active and backup OCC) shall be requested. In addition, it shall be verified if at each station a local control centre and a dedicated equipment room shall be provided including local recording system. In case the CCTV equipment shall share a single equipment room with other sub-systems e.g. telecommunication equipment, the CCTV shelter shall be lockable. The CCTV shelters shall be equipped with dry contact used for remote monitoring.

For the active and backup OCC and depot a dedicated security equipment rooms shall be provided.

Pan Tilt Zoom (PTZ) and fixed IP cameras and different analytic features shall be provided. The contractor shall provide an exhaustive planning including simulations of the camera view. The contractor shall be responsible to respect Operational and governmental requirements and be responsible for the approval procedures.

Following an example of analytic functionalities which shall be taken into account:

- Face recognition
- Abandoned baggage detection
- Virtual border crossing detection
- Automatic emergency detection
- Others...

For the CCTV bandwidth dimensioning the worst case per camera shall be assumed. 25% margin shall be taken into account and blocking shall not apply.

The CCTV system shall be interconnected with the intrusion detection and access control system. In case of intrusion the image of the nearest camera shall be displayed on a predefined monitor in the active and backup OCC. The monitor shall clearly indicate the location of intrusion (e.g. GPS coordinates, floor level etc.) and the information of nearest security staff (e.g. telephone number etc.).

## 16.1. General monitoring

All strategic locations (for example in and around stations, ancillary buildings, technical rooms, depots, workshops, freight terminals, tunnels and tunnel entrances, radio sites, interlocking, substation, platforms, the passenger movements throughout the railway property in and outside of trains etc.) shall be monitored.

It shall be clarified if platform monitors usable by the train driver to survey the passenger boarding process are required.

To which extent thermal imaging cameras are required to survey the surrounding territory shall be part of the design study.

## 16.2. Railway lines monitoring

The need of railways lines and road crossings monitoring shall be identified. Continuously monitored shall be realized via:

- a) Long-range thermal imaging cameras installed for example on top of antenna masts.

or

- b) Cameras installed on dedicated camera masts in a predefined distance along the railway line  
 c) A combination of a) and b)

These cameras shall be connected with the wired fence perimeter protection system installed along the railway line and the intrusion detection system. In case of intrusion the nearest camera will point automatically to the zone of intrusion. Each camera shall be able to identify a person (night & day) at a predefined distance. In normal operation the cameras shall follow the running train and the image shall be shown on a predefined monitor in the active and backup OCC.

## 16.3. CCTV recording system

Based on operational and governmental requirements a local redundant recording system or a geo-redundant CCTV recording system (active and backup OCC) shall be provided. Minimum the following functionalities shall be provided:

- Meta data recording
- Search functionality based on time, day, event, etc.
- Storage of minimum 30 days (7/7/24)
- 30 minutes backward recording at the time an emergency is triggered
- Different recording rates shall be supported
- Etc.

# 17. Intrusion Detection System

The Intrusion Detection System consists mainly of the Access Control System and of the perimeter protection (fence protection). To optimize the intrusion detection an interconnection to the CCTV system and Intercom system shall be established.

## 17.1. Access Control System

All technical facilities along the railway line, stations and depot shall be protected via an access control system. The access shall be controlled via access cards, fingerprint scanning or face recognition technologies (linked to CCTV) and shall be controlled and monitored from the active and backup OCC. All buildings shall be equipped with a local slave access control system. In case the connection to the centralized access control system fails the access to the buildings are not blocked. Each main door shall be equipped with an intercom system with an embedded camera. The intercom system shall be used for example by someone having problems with the finger print reader or with the ID card. The embedded camera (CCTV) shall be used by the security team for identifying the person and to activate after positive identification the remote-controlled release busser to open the door.

The centralized access control system shall be connected to the CCTV and intercom system. As soon as someone tries to enter a building the CCTV shall start recording.

In case of unauthorized access (intrusion) an alarm shall be triggered via for example door dry contacts and the image of the best positioned camera shall be automatically displayed to a predefined monitor at the active and backup OCC indicating the exact position and the telephone number of the nearest security staff.

## 17.2. Fence protection

The sensitive property of the railway operator along the railway line, depot, shunting yards etc. shall be protected e.g. with a centralized monitored wire fencing. To detect intruder the fence shall be equipped for example with optical fibre detectors. Based on a special algorithm in the centralized control and processing unit an intrusion can be identified based on the movement of the wire fence.

The fence protection system shall be connected to the CCTV system. In case an intrusion is detected the nearest camera shall automatically point to this area and the image shall be displayed on a predefined monitor at the OCC. The monitor shall indicate in the same time the coordinates of the intrusion and the telephone number of the local security team responsible for this area.

An alternative solution like infrared and ultrasonic or a combination of different systems shall be as well acceptable. The system shall be controlled and monitored from the active and backup OCC.

# 18. Fire detection and alarm system

The Fire detection and Alarm System shall consist of a central processing unit (the Fire Alarm Control Panel – FACP) and the associated automatic fire detection and reporting devices. The detection devices can be diverse types of sensors and manual fire alarm boxes.

The operating and supervision of the system can be done locally and remotely from the active and backup OCC. All local fire control systems are connected in a ring structure via optical fibre cables to the active and backup OCC where the centralized fire control system is located. An interface to the SCADA shall be provided.

It is assumed that the systems will be remotely monitored. Therefore, to increase detector reliability it is possible to install a minimum of 2 detectors per room to avoid false alarms and untimely activation of sprinklers, etc.

In the event of an outbreak of fire, occupants will be alerted by means of an audible signal (e.g. loudspeakers, bells, pre-recorded announcements etc.) and exit marking devices (e.g. emergency lighting) may be used.

All fire protection systems (emergency lighting, ventilation, door release contacts, the station fire alarm system, sprinklers etc.) connected to the OCC shall be remote activatable in the event of incident.

An independent qualified third party shall be in charge of respecting local governmental and operational related approval processes.

The firefighting system (e.g. sprinkler system and automated door closing system, etc.) and visible indications such as emergency exit signs, emergency lighting, etc are not part of this document.

# 19. Public Address System (PAS)

The Public-Address System (PAS) shall be installed at strategic locations such as stations, platforms and ancillary buildings and shall support manual and automated audio announcements.

Each location shall be equipped with a local microphone (local announcements possibility). Broadcast messages recording shall be provided.

Zone and multi zone announcements including environmental noise sensing shall be supported. The system shall be interconnected with the signalling system, fire and intrusion alarm system and shall support automatic announcements. The geographical redundant PAS system shall be installed in the telecommunication equipment rooms and controllable from the active and backup OCC. The installed PAS system shall be adapted (fine-tuned) to cope with the environmental conditions. An interface to the SCADA and TMS shall be provided. Required on-board equipment shall be taken into account.

## 20. Passenger Information Display System (PIDS)

The Passenger Information Display System (PIDS) shall be installed at strategic locations at stations and platforms. PIDS at platforms shall be double sited and legible from a distance of 25 meters. The distance between the displays shall be maximum 50 meters.

- The PIDS shall consist of a multiple language display (local languages, English), and shall provide real time information:
- actual time,
- train number;
- arrivals;
- departures;
- delays;
- destinations
- supplementary information like temperature
- etc.

Individual and predefined messages capability shall be supported. The system shall be interconnected with the signalling, fire and intrusion alarm system. An interface to the SCADA and TMS shall be provided. The requested geographical redundant PIDS system shall be installed in the telecommunication equipment rooms and controllable from the active and backup OCC. The local station PIDS shall be controllable from a local station control room. For stations where an interaction with other public transport is planned for example METRO and BUS a dedicated display system shall be provided. These displays shall be connected to the responsible public transport operator. Required on-board equipment shall be taken into account.

## 21. Time distribution system (Master Clock System)

The geographical redundant Master Clock system equipped with GPS receivers is planned to be installed in the active and backup OCC, and shall be used to synchronize all systems requiring a synchronisation. Slave clocks are planned for each station, depots etc.

The Master clock system shall be used as well for the synchronisation of the planned analogue and digital platform clocks.

Clocks in buildings (control and technical rooms, depot, stations etc.) shall be provided and shall be synchronized via the master clock / slave clock system.



Potential required dedicated on-board equipment shall be taken into account.

## 22. Telematics systems for freight services

The optional telematics system for freight services shall be used to monitor the freight trains and wagon fleets including the container transported. The objective is to know exactly which container is on which wagon and where it can be found on the track. The specifications for the overall system (system, functionalities, database etc.) shall be provided by the contractor.

The following tracking solutions shall be considered:

- RFID tracking system
- CCTV tracking system (Optical character recognition (OCR))
- Manual tracking via mobile handhelds

To secure the interoperability between the different countries, the standardised number scheme ("BIC Codes" or "ISO Alpha-codes" / ISO 6346) for containers and the TSI requirements shall be applied.

The system of wagon numbering has been laid down by the International Union of Railways (Union Internationale des Chemins de Fer or UIC) and is similar to that used for the locomotives and multiple units.

## 23. Maintenance Management System (MMS)

The Contractor shall provide a Maintenance Management System (MMS) with the following functionalities:

- Information concerning building access – how to go there – information concerning password requirements
- In case of failure - Location indication e.g. GPS coordinates for telecom equipment shelters along the railway line
- The system shall be able to provide the following information concerning the equipment:
  - Failure type – short description – eventually system configuration requirements
  - Equipment type
  - serial number of the effected equipment
  - etc.
- Spare part information
  - Location and amount of spare parts
  - Order and delivery status
  - Guarantee status
  - etc.
- Maintenance planning tool, date, time, expert in charge including his telephone number etc.
- etc.

## 24. Cyber security

The following proposed cyber security specifications shall be applied / modified according the project context. They are not exhaustive.

Standard code	Standard title
ISO/IEC 27001:2013	Information technology -- Security techniques -- Information security management systems -- Requirements
ISO/IEC 27002:2013	Information technology -- Security techniques -- Code of practice for information security management
ISO/IEC 27005:2011	Information technology -- Security techniques -- Information security risk management
ISO/IEC 27011:2008	Information technology — Security techniques — Information security management guidelines for ICSs organizations based on ISO/IEC 27002
ISO/IEC 15408-1:2009	Information technology -- Security techniques -- Evaluation criteria for IT security
ITU-T E.408	ICS networks security requirements
ITU-T E.409	Incident organization and security incident handling
ITU-T X.805	Security architecture for systems providing end-to-end communications
ITU-T X.1051	Information security management guidelines for ICSs organizations based on ISO/IEC 27002
IEC 60950	Safety of Information Technology Equipment
ISA 99/IEC 62443	Cybersecurity for industrial systems
NIST 800	United States federal government computer security policies, procedures and guidelines. NIST (National Institute of Standards and Technology)

To satisfy with systems security specifications the contractor shall define an appropriate security policy for the whole provided telecommunication system. The implementation of security policy concerning infrastructure shall be validated via an audit conducted by specialized and certified third-party companies.

The implementation of infrastructure and systems shall be performed following the approach of "Plan Do Check Act" defined in ISO 27001.

A risk analysis based on standard methodology (EBIOS or ISO 27005) shall be performed before system and architecture definition and prior security policy construction. This analysis shall be carried out considering the specificities of each sub-system.

The contractor shall assess for each sub-system (e.g. SCADA, passenger information, CCTV etc....) the potential risks and threats based on the following criteria:

- Availability
- Integrity
- Confidentiality
- Non-repudiation

In any case, the ISO 27002 reference standard shall be followed.

Following some requirements examples (non- exhaustive):

- The contractor shall provide a detail description concerning the proposed firewall architecture for zones isolation (Internet/Unsafe, Common/DMZ, Company/Safe).
- Telecommunication networks shall be supervised by a centralised hypervisor allowing real-time management and surveillance of the related components. The information coming from the hypervisor system shall be displayed at the operational control centre (OCC).
- Telecommunication networks shall provide network segmentation in order to guarantee isolation of applications.
- Telecommunication networks shall provide QoS (Quality of Service) support at OSI model layer 2 and layer 3.
- Telecommunication networks shall provide network access authentication (802.1X) based on login/password and/or digital certificates.
- Network client's configuration shall be accessible only by system administrators. Devices configurations features shall be password locked.
- Layer 7 firewall (application layer filtering) shall be installed to protect Telecommunication networks from malicious access.
- The contractor shall propose a secured mechanism for patches and updates deployment on telecommunications equipment including workstations, servers, etc...
- Integrated system software shall be developed with respect to state of the art secured code programming.
- Provided software shall be developed based on the OWASP methodological guides.
- Specific software shall be validated by a certified third party specialised in software code auditing.
- Only software component really used by the system shall be installed. This requirement shall be applicable but not limited to Operating Systems, packaged software, server software and all other modular software e.g. HTTP Apache, MTA PostFix, Windows OS, Linux OS, etc...
- Server software exposed to the public network shall be installed on "hardened hosts". These "hardened hosts" shall be deployed in isolated zones of the administrative network (demilitarized zone - DMZ). Special attention for these systems shall be provided.
- The administrative and operation related network shall be separated via DMZ.
- The administrative and public related network shall be separated via DMZ.
- Etc.

The systems provided by the contractor shall be compliant with the state of the art cybersecurity politic and norms which are worldwide applicable.

The contractor shall demonstrate how the provided system solutions comply with the above stated norms and standards.

## 25. EMC

The contractor shall provide an Electromagnetic Compatibility (EMC) study based on the international standards.

## 26. ICNIRP

A radiation study shall be provided by the contactor.

Based on international standards, the Contractor shall demonstrate on a theoretical basis that the system design will not cause exposure to electromagnetic radiation levels exceeding the current standards.

The radio field shall never exceed the levels described in the guide published by the International Committee on Non-Ionizing Radiation Protection (ICNIRP).

## 27. Reliability, Availability and Maintainability (RAM)

The system availability of each telecom sub-system shall be at least equal to 99.998%

The MTBF of each telecom equipment shall be higher than 200.000 hours.

The MTTR (Mean Time To Repair) shall be 4 hours after the failure is reported the first time.

The repair and return process shall be described / proposed by the contractor and approved by the employer.

The repair and return process reporting process and associated metrics shall be described / proposed by the contractor.

After system designs is completed the Contractor shall prove and explain how the RAM's requirements are meet.

## 28. Power supply

Uninterruptible Power Supply (UPS) shall be provided for the telecommunication sub-systems. In case of main power outage of the main feeder(s), a minimum 8h battery backup shall be available.

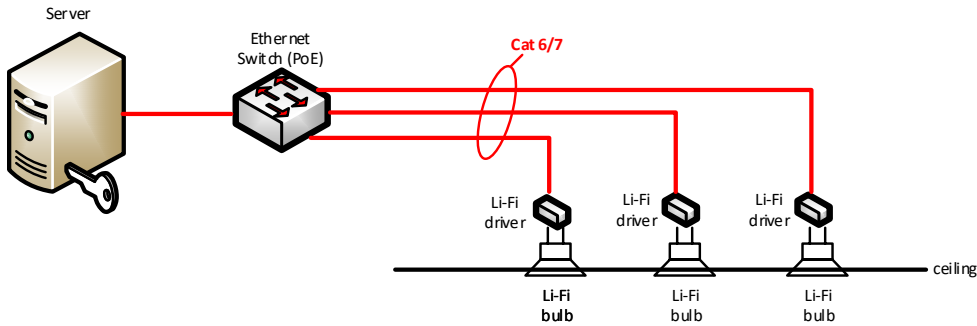
The contractor shall provide the detailed power requirements for the proposed equipment / system.

## 29. Li-Fi

Li-Fi is a promising technology and considered as a potential access option for 5G.

Therefore, the contractor shall provide an option when Li-Fi in EU is operational to equip new buildings, stations, depot etc. (new light installations) with LED-bulbs powered over Ethernet (RJ45 Cat 6/7). The objective is to prepare the different locations for Li-Fi. The cable management (RJ45) shall take into account a later replacement of the interim centralized power supply with Ethernet switches (PoE). It shall be possible to easily replace at any time already installed LED-bulbs with Li-Fi bulbs and connect them to an Ethernet switch. Extra space for potential requested Li-Fi (bulb) drivers shall be foreseen in the ceiling.

The following figure provides an overview of the basic Li-Fi network structure:



## 30. Milestones

To assure the project timeline the following milestone applicable to each sub-system shall be respected:

- a) All relevant certifications and documentation shall be delivered.
- b) Successfully executed factory acceptance tests.
- c) Installation – acceptance procedure with independent third party.
- d) Functional acceptance – acceptance procedure after system integration is completed.
- e) QoS / radio coverage measurements – acceptance procedure with independent third party.
- f) End to end functional tests – acceptance procedure at Test platform and on live network.
- g) The contractor shall provide 10 weeks in advanced a proposal (document) for each acceptance procedure (a – f) which will be validated by the employer.
- h) A verification that the requirements have been taken into consideration shall be performed and documented by the contractor between the successive design phases, as well as during the successive testing phases until final validation of the system by the employer.

## 31. Automatic Fare Collection

It should be taken into account, that several railway undertakings (train operating companies) are foreseen operating on the Rail Baltica line. In accordance with the Article 13 of the Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area, the Automatic Fare Collection from the different railway undertakings shall be considered in the design without discrimination.

The Automatic Fare Collection (AFC) system shall satisfy the following requirements:

- Ensure payment of transport services, and those supplied by other complementary modes of transport. To do this, the system shall be endowed with:
  - A vending system enabling each user to buy the transport ticket through various points of sale;
  - A validation system enabling the access control to the transport network by ticket validation;
- Ensure a strict and easy control of ticket vending;
- Ensure sales accounting, control of financial flows, supply of sale and traffic statistics,

- Ensure good record of the users' demand, by recording the number of sold and utilities tickets which shall be useful statistics afterwards;
- Reduce fraud by offering the users the possibility of buying a ticket and validating it;
- Ensure control of security as a whole;
- Ensure fare evolution within a determined policy of the public transport promotion.

Recommended High Level Requirements:

- Shall offer a high level of service;
- Shall be multi-lingual;
- Shall be customized to multi-cultural usages;
- Shall be accessible to any person; Shall be compliant with European and national accessibility requirements and shall be interoperable with accessibility services;
- Shall be compliant with International and European standards;
- Shall be compliant with TAP TSI, Directive 2008/57/EC;
- Shall be designed for to support environmental conditions;
- Shall have a booking system and shall manage customers' profiles;
- Shall reduce time of transit between transport modes, so shall offer minimal time to buy tickets;
- Shall be interoperable with other local -around stations in each city, country- and international ticketing systems;
- Shall provide End-to-End mobility service (travel agency) (+ Car +Bike +Hotel...);
- Shall be MaaS compliant (Mobility As A Service);
- Shall be fully digital, but inclusive (may deal with local specificities. Ex: Usage of ID Card in Estonia);
- Shall provide customer services online, in station, and on-board;
- Shall be fully integrated with passenger information system, including PIS of Each area deserved by the rail;
- Shall integrate NFC technologies;

System development program

Subject	Requirements from Client	Detailed Design
<b>Input data needed for first level of design of AFC system</b>		
– Governance	Inputs	Inputs
– Fare policy	Inputs	Inputs
– Security Policy	Inputs	Inputs
– Sale strategy	Decision	Inputs
– Control strategy	Decision	Inputs
– Operation strategy	Inputs	Inputs
– Maintenance strategy	Inputs	Inputs
– Input data needed for dimensioning the system	Inputs	Inputs
<b>System engineering</b>		
– Fare media	Decision	Outputs
– Sales equipment and systems	Decision	Outputs
– Control equipment	Decision	Outputs
– After sales services		Outputs
– Customer services (may include luggage service)	Decision	Outputs
– Mobility services integration	Decision	Outputs
– System monitoring platform (statistics, finance, security...)		Outputs
– System architecture and interfaces		Outputs
– Transport system interfaces and civil work reservations	Identification	Sizing
– Installation requirements.		Outputs
– Testing & Commissioning requirements.		Outputs
– Training requirements.		Outputs
– Documentation requirements.		Outputs

– AFC Cost Estimate.		Outputs
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