UIC ERTMS BENCHMARK PROJECT
FINAL REPORT

Update 2010
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UIC ERTMS Benchmark Project - Final Report: Update 2010
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<td>ATP</td>
<td>Automatic Train Protection</td>
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<tr>
<td>ERTMS</td>
<td>European Rail Traffic Management System</td>
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<tr>
<td>ETCS</td>
<td>European Train Control System</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>GSM-R</td>
<td>Global System Mobile - Railway</td>
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<tr>
<td>INESS</td>
<td>Integrated European Signalling System</td>
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<td>INNOTRACK</td>
<td>Innovative Track Systems</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>KPI</td>
<td>Key Performance Indicator</td>
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<td>LCCA</td>
<td>Life Cycle Cost Analysis</td>
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<td>LCC</td>
<td>Life Cycle Cost</td>
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<td>LS</td>
<td>Limited Supervision</td>
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<td>MA</td>
<td>Movement Authority</td>
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<td>MCS</td>
<td>Modular Cost Structure</td>
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<td>MRM</td>
<td>Multiple Reaction Monitoring</td>
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<td>NPV</td>
<td>Net Present Value</td>
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<tr>
<td>OBU</td>
<td>On Board Unit</td>
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<tr>
<td>ORR</td>
<td>Office of Rail Regulation</td>
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<tr>
<td>PSO</td>
<td>Public Service Obligation</td>
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<tr>
<td>QoS</td>
<td>Quality of Service</td>
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<tr>
<td>SEU</td>
<td>Signalling Equivalent Unit</td>
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<tr>
<td>TOC</td>
<td>Train Operating Company</td>
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<tr>
<td>UIC</td>
<td>International Union of Railways</td>
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<td>WG</td>
<td>Working Group</td>
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Foreword

On 5 December 2009 the Italian Infrastructure Manager, RFI, completed 1 000 km of its “High Speed Subway” with the opening of the Bologna-Firenze high speed line for commercial operations. And on 15 December 2010 the Spanish Royal family inaugurated the new Madrid-Valencia high speed line, continuing Spain’s ambitious railway infrastructure implementation programme.

These two events are very appropriate to define 2010 as a focal year for the development of ERTMS. 2010 is the final year of a ten-year period during which we have seen the growth of the ERTMS/ETCS system: beginning with the legal steps and the European interoperability directives (96/48/CE, 2001/16/CE, 2008/57/CE); moving on to the technical steps such as the final signature on ERTMS specification, Class 1, on 25 April 2000; and culminating in the practical steps as the system was put into operation in many countries in Europe. 2010 also represents a good moment to take stock of the pace of ERTMS deployment in Europe, to ensure the targets of 15 000 km of ERTMS in 2015 and 25 000 km in 2020 are achieved. Finally 2010 is also the year during which the World High Speed Congress was organised in Beijing, China, the country that best demonstrates that ERTMS is not just a European system, but already a worldwide signalling system.

In 2010 UIC continued to work on the ERTMS Benchmark project, contributing to the implementation of this new automatic control system. After creating a common methodology and the framework for an international benchmark based on a life cycle model, UIC has continued to collect cost data by collaborating directly and exchanging information with all the railway undertakings and infrastructure managers involved in the project.

This document is the final project report of the UIC ERTMS 2010 Benchmark Study. It describes the progress of the work stream in 2010 as requested by UIC members. This report contains information on the strategy, difficulties and objectives of the project as it approaches its mid-point.

The ERTMS Benchmark group can be proud that it has developed 21 case studies with UIC members. This fact highlights the great value and extent of the information that has been gathered and guarantees the validity of the results of our benchmark.

On 28 September 2010 the ERTMS Benchmark group presented the results of its own work at a public workshop attended by more than 100 participants from the rail industry. Infrastructure managers, railway undertakings, railway associations and other rail stakeholders accepted UIC’s invitation to discuss recent developments in the field of economic evaluation of ERTMS.

The results presented at the workshop and the profitable and interesting discussion which ensued should be seen as the first steps on the long journey towards a detailed life cycle costing of ERTMS. Further evaluation of real cases and the updating of existing case studies will serve to continuously improve our understanding of the cost situation.

At the workshop last September, railway companies demonstrated their ability to reinforce their market position ahead of their partners in manufacturing, by creating a network of economic experts for ERTMS. This is the right way to achieve greater transparency in the market and thus greater clarity as to the origins of high ERTMS costs.
One of the main challenges of 2010 has been the more in-depth analysis of the operation and maintenance life cycle phase. In the ERTMS implementation, there is still a lack of knowledge concerning the system management once it is in commercial operation. For this reason we have tried to share the different experiences between members so that we can extrapolate the lessons and best practices and present them as guidelines for railway companies entering this important phase.

As it continues to monitor the global deployment of ERTMS, the ERTMS Benchmark group offers itself as an open forum for all the railway companies involved in this new signalling technology and invites them to contribute their work and share their experiences to help decrease the overall ERTMS life cycle costs.
Introduction

The UIC ERTMS Implementation Benchmark Study was launched in March 2008.

Infrastructure managers and railway undertakings have participated in this ambitious project that represents the first economic study on the implementation costs of ERTMS/ETCS on a life cycle cost basis.

Fourteen members of the working group have developed case studies together with UIC gathering real cost and performance data on this new European signalling system on the basis of a commonly agreed Modular Cost Structure (PMP supported UIC on benchmark methodologies).

Regarding the publication of case studies, which was to be the major output, an important issue was raised by work group members who were concerned about the confidentiality of the results and in particular about the presentation of real data concerning the Life Cycle Cost model. Therefore, the final output of this study has been divided in 3 distinct documents taking this concern into consideration.

This document presents the major outputs of the ERTMS Implementations Benchmark Study 2009-2010.

The scope (framework and objectives of the study, project organisation & planning as well as methodological approach) of the ERTMS Benchmark Study 2008 – 2010 is presented in the first chapter.

Then, a short overview of the recent activities with regard to Life Cycle Costing (LCC) methodologies in European railways and an update on current activities at UIC with regard to LCC and Asset Management is provided. Chapter 2 concludes with the presentation of the LCC model devised for this study.

Chapter 3 discusses the work of a dedicated Task Force on ERTMS Operation and Maintenance that has worked in a series of 4 meetings in order to better understand ERTMS strategies and organizations of the Operation and Maintenance phase of the life cycle.

Chapter 4 provides an anonymous cost comparison of 20 ERTMS/ETCS case studies developed in 3 different benchmark pools:

- ERTMS/ETCS L1 trackside (5 case studies)
- ERTMS/ETCS L2 trackside (7 case studies)
- ERTMS on-board (8 case studies).

Chapter 5 reports an overview of ERTMS Regional project in Sweden.

Finally, chapter 6 provides an outlook on the activities proposed for 2011 and beyond in this project.
Data Confidentiality and Database management

Data confidentiality

During the initial phase of the project in 2008, when it became clear that the UIC Members were willing to share real cost data regarding ERTMS implementation projects among each other, the subject of data confidentiality was addressed.

As an outcome of several discussions between UIC and the UIC ERTMS Benchmark WG Members all Parties desired to assure the others that information revealed during discussions and data collection meetings shall be treated as confidential and protected from disclosure.

To this end, a Non-Disclosure and Confidentiality Agreement (NDA) was set up by the legal department of UIC. This agreement was discussed with all WG Members and a final version was presented at a common workshop in May 2008.

This NDA defines the conditions under which the Parties shall mutually disclose confidential information and hold and maintain the confidential information in strict confidence using the same degree of care that they use with respect to comparable, highly confidential information to their own business.

All new Members that joined the Working Group at later stages of the project signed the same NDA. PMP as an external consulting firm assisting UIC with the data base management and elaboration of case studies all along the project also signed the NDA in May 2008.

The NDA has been set up as a bilateral agreement between each UIC ERTMS Benchmark WG Member and the UIC while PMP has signed the agreement with UIC. PMP and UIC keep all data confidential. No data is exchanged between members directly.

Apart from this legal point of view, the UIC ERTMS Benchmark WG Members also agreed on the different reports to be published by the end of 2009.

Considering the concerns of the WG Members in terms of confidentiality of the results and in particular with regard to the presentation of real data concerning the Life Cycle Cost Model, it was decided to divide the results of the study in 3 different documents.

The following three final documents have been provided by UIC by the end of 2009, approved by the WG Members and supported by the CCS&OPE Sector representatives:


- The Case Studies 2008-2009: A collection of case study reports completed with related cost figures provided by the participants in the 3 defined benchmark pools: ERTMS/ETCS L1 trackside subsystem, ERTMS/ETCS L2 trackside subsystem and ERTMS on-board subsystem - confidential document only distributed to the UIC members having carried out a case study.
With regard to the final project documents to be published in 2010, UIC proposes to adopt the same structure of reports and rules of confidentiality for the publication of the updated versions of the above mentioned documents.

**Figure 1: Structure of outcomes of the ERTMS Benchmark Study 2010**

**Data base management**

All data collected from UIC Members during the case study meetings by UIC and PMP are integrated in 3 distinct databases:

- ERTMS/ETCS L1 infrastructure,
- ERTMS/ETCS L2 infrastructure,
- ERTMS/ETCS RS).

UIC and PMP are the only project partners that have unlimited and all time access to these databases. PMP has set up the databases on an operational level and provides UIC with external consulting services to manage, update and analyse these databases.

The databases are used to extract comparison tables and graphs and transformed in anonymous data sets in order to keep the data confidential. Generally, UIC/PMP provides extracts from the databases at the annual UIC ERTMS Benchmark Workshops, in the annual reports of the UIC ERTMS Benchmark Study (2009, 2010) and during dedicated data analysis meetings of the 3 benchmark pools (to be held in 2011). The presentation of the last annual UIC ERTMS Benchmark Workshop held in September 2010 and the UIC ERTMS Benchmark Reports 2009 and 2010 containing anonymous data from these databases are public documents and can be obtain at UIC upon request or downloaded from the UIC website.
In order to provide the UIC ERTMS Working Group Members with the possibility to carry out their own analysis based on data provided in the 3 databases, UIC offers all Benchmark WG Members who have carried out a case study the opportunity to call a bilateral meeting with UIC/PMP at least once a year. During these meetings, Members get access to the databases and can produce specific tables, graphs or extracts that are useful for their own analysis and objectives (e.g. selection of a specific case studies only, integration or exclusion of particular cost elements ...).

This process guarantees that no Member has unlimited access to the 3 databases and minimizes the risk that data spreads outside the Members’ organizations. At the same time, it allows Members to access the databases periodically and carry out specific analysis related to their own objectives.

All data provided by UIC/PMP to the Members throughout the entire process, be it via the provision of reports, during WG data analysis meetings or during the above mentioned bilateral database meetings with UIC are subject to strict confidentiality. This means that Members are only allowed to use this information internally but do not have the right to share with any other party.
1. The UIC ERTMS Benchmark Study 2008-2010

This section gives an overview of the project organisation, objectives and current status of the Benchmark Study 2008 - 2010 performed under the leadership of the CCS&OPE Sector.

It was decided that it would also be included in the document: “Case Studies: Project Context & Company Profile” delivered with this Final Report for each document to be independent from the other.

1.1. Framework and objectives of the study

The Study was initiated in early 2008 in order to respond to growing demand in the railway community for a quantitative economic analysis of ERTMS/ETCS implementation projects in different European countries. The study has been carried out under the leadership of the ERTMS Platform; its members have received regular updates when significant milestones have been reached and they have taken decisions regarding the development and strategic directions of the study.

The objectives of this study can be summarised as follows:

- UIC wishes to support its members in developing design options in order to reduce implementation costs of ERTMS/ETCS projects. Therefore, the framework of an international benchmark was developed in order for ERTMS implementations to be comparable according to jointly agreed Modular Cost Structures and Key Performance Indicators.

- The main project objective was to develop a set of commonly agreed Modular Cost Structure/s and Key Performance Indicators for ERTMS implementation projects from a life cycle perspective.

- The ultimate aim remains to lower the overall ERTMS costs on a life cycle basis (i.e. R&D, components, engineering, maintenance etc.) for all future ERTMS/ETCS projects.

The following figure shows the 2 main phases of the UIC ERTMS Benchmark Study 2008-2010:

So far, the Benchmark Study has been divided into two three main phases between the beginning of 2008 and end of 2010. In an initial phase from March to September 2008 the data set was
gathered and all project participants were encouraged to participate in this UIC project while the second phase dealt with the collection of real data concerning ERTMS implementation projects and the establishment of the working group activity roadmap until June 2009, covering specific adjacent activities. The third phase dealt with on-going case study data collection and the implementation of a dedicated Task Force on ERTMS Operation and Maintenance.

1.2. Project organisation and planning

In order to meet the high expectations of the ERTMS Platform and to ensure efficient governance of the project, UIC set up the following organisational framework for this study:

The following Members have committed themselves actively to participate in the study: ADIF, ATOC, BV, CFL, DB, Infrabel, JBV, Network Rail, ÖBB, OSE, ProRail, NetworkRail, RFI, RHK, SBB, SNCF, SZDC, Trenitalia ZSR/ZSSK/ZSSK Cargo.

Each member railway (infrastructure manager or railway undertaking) has appointed one representative for infrastructure-related issues and one for rolling stock-related issues. They constitute the active working group at railway level.

PMP has been chosen by UIC as an external consultant to cooperate with UIC and its members in the Benchmark supporting the methodology and economic assessment model as well as some project management activities.

It is important to highlight that the project team intensified its efforts between late 2008 and early 2009 in order to collect as many real case studies as possible for the three benchmark pools. This effort led to higher acceptance of the study results and increased the benefits of this benchmark study of ERTMS implementation projects.

It was therefore deemed crucial that each project participant provide UIC with real case data for the benchmark pools using the “standard cost model” issued beforehand.
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<td><a href="mailto:michael.leining@bahn.de">michael.leining@bahn.de</a></td>
<td>DB</td>
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<tr>
<td>Christoph Gralla</td>
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<td>Karsten Kamps</td>
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<td>Klaus Ruediger Hase</td>
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<tr>
<td>Helges Sigrid</td>
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<tr>
<td>Ioanna Petasi D.Pagarliotas Georgios Vetsis</td>
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<tr>
<td>Piero Petruccioli</td>
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<td>Massimo Franceschini</td>
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<td>Alessandro Bini</td>
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<tr>
<td>Giovanni Zanelli</td>
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<td>Pasquale Petriccione</td>
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<td>Marc.Hoffmann Robert Sturm</td>
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<td>Lex Moscou</td>
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<td>Henrico Platinga Wim Vrooland</td>
<td><a href="mailto:HENRICO.PLANTINGA@PRORAIL.NL">HENRICO.PLANTINGA@PRORAIL.NL</a> <a href="mailto:wim.vrooland@prorail.nl">wim.vrooland@prorail.nl</a></td>
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<td>Glowacki Kasper</td>
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<td>Thomase Krasuski</td>
<td><a href="mailto:t.krasuski@plk-sa.pl">t.krasuski@plk-sa.pl</a></td>
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<td>Marjan Zaletelj Bohuslav Dohnalik</td>
<td><a href="mailto:marjan.zaletelj@slo-zeleznice.si">marjan.zaletelj@slo-zeleznice.si</a>; bohnalik@<a href="mailto:bohuslav@zsr.sk">bohuslav@zsr.sk</a></td>
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<td>Cambronero Maite Jorge Iglesias</td>
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<td>ADIF</td>
<td>Spain</td>
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<tr>
<td>Sven Hakan Nilsson</td>
<td><a href="mailto:sven-hakan.nilsson@banverket.se">sven-hakan.nilsson@banverket.se</a></td>
<td>Banverket</td>
<td>Sweden</td>
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<tr>
<td>Jorgen Ohrstrom: Lars Olof Ersson Anders Malmberg</td>
<td><a href="mailto:jorgen.ohrstrom@trafikverket.se">jorgen.ohrstrom@trafikverket.se</a> <a href="mailto:lars-olof.ersson@trafikverket.se">lars-olof.ersson@trafikverket.se</a> <a href="mailto:anders.malmberg@trafikverket.se">anders.malmberg@trafikverket.se</a></td>
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<td>Richard jan Sommer Stefan Ulrich Huegli Valera Gomez Jesus</td>
<td><a href="mailto:JAN.RICHARD@sbb.ch">JAN.RICHARD@sbb.ch</a> <a href="mailto:stefan.sommer@sbb.ch">stefan.sommer@sbb.ch</a> <a href="mailto:ulrich.huegli@sbb.ch">ulrich.huegli@sbb.ch</a>; <a href="mailto:jvalera@renfe.es">jvalera@renfe.es</a></td>
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<td>Martin Mayer</td>
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<td>Snejana Markovic</td>
<td><a href="mailto:markovic@uic.org">markovic@uic.org</a></td>
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**Figure 4 ERTMS benchmark members**
1.3. Methodological approach

1.3.1. Detailed working methodology and review of Phase 1 (March 2008 – September 2008)

The methodological approach for the first phase of this project between March and October 2008 can be described in the following 5 phases:

PHASE 1.1 – Preparation phase

- This phase was dedicated to the preparation of a basic discussion paper and the organisation of initial informal discussions with the technical and economic representatives of the project participants;
- A questionnaire regarding cost elements, cost structures, key performance indicators, system specifications etc. was created at UIC level in cooperation with ETCS and GSM-R experts;
- An initial draft of KPIs and Modular Cost Structures was elaborated as a basis for discussion in the upcoming interview phase.

In this phase of the project UIC provided the working group participants with a discussion paper highlighting the key elements and objectives of the study and describing the ERTMS system configurations and modes of implementation at a generic level.

PHASE 1.2 – Individual interviews with project participants’ ERTMS experts

- The draft version of the questionnaire for interview preparation was enhanced and completed.
- With regard to the preparation of the Workshop on 27 and 28 May 2008, UIC organised a series of face-to-face interviews with a number of project participants between April and May 2008. The objectives of these meetings were to discuss the project in general terms, identify points of view regarding Modular Cost Structures and Key Performance Indicators for ERTMS/ETCS Level 1, Level 2 and ONBOARD systems, collect feedback on the approach proposed by UIC and prepare the two-day workshop with all the project participants.
- A two-day technical workshop was prepared, integrating all feedback and comments received during the interview phase and preparing the decisions that would need to be taken by the working group.

PHASE 1.3 – Technical workshops (ERTMS/ETCS Levels 1 and 2) including analysis and documentation

- The working group members gathered for a two-day technical workshop in order to discuss the input of the interview phase and develop a commonly agreed framework of modular cost structures and KPIs for the benchmark; this two-day workshop was held in Paris on 27 and 28 May 2008. One day was dedicated to the ERTMS/ETCS Level 1 system and the second day to the ERTMS/ETCS Level 2 system together with on board. After an initial discussion on the draft modular cost structures for Levels 1 and 2, UIC identified a number of critical issues which would require particularly close attention during the workshop. These issues included, inter alia, the general discussion and decision concerning the Life Cycle Cost approach:
  - The level of detail used in the modular cost structures according to the number of cost elements;
  - The way of integrating Research and Development costs into the Benchmark Study;
- The number of different categories of “benchmark pools” to be set in order for homogeneous contexts to be comparable;
- How to integrate GSM-R costs into the study;
- The identification of two volunteers for the initial two case studies to challenge the Modular Cost Structures and the Key Performance Indicators identified.

- The results of the workshop were analysed in detail and the decisions thoroughly documented.
- The final framework of the modular cost structures for ERTMS/ETCS Level 1 trackside subsystems, ERTMS/ETCS Level 2 trackside subsystems and ONBOARD equipment subsystems was set, as well as the KPI database (Excel).
- The intermediate results of the project and decisions were presented to the ERTMS Steering Group and Platform members by the Project Manager in June 2008.
- A presentation of the project methodology was made by the Project Manager at the UIC ERTMS training seminar held on 1-3 July 2008 in Paris.

PHASE 1.4 – Pilot Case studies
Two case studies were carried out with ProRail and SBB and the “proof of concept” was successful:
- ProRail’s experience of the Betuwe Route for the ERTMS/ETCS Level 2 trackside subsystem;
- SBB’s experience on the equipment of 20 locos with the ERTMS on-board equipment system.

The feedback regarding the usability of the database was documented.
Following these case study meetings, UIC provided ProRail and SBB with their respective case studies covering the following items:
- Cost models completed with real data
- Context description of: network, migration strategy, project context, fall-back philosophy, line specifications, etc.

Phase 1.5 – Elaboration of the UIC ERTMS Benchmark Project Report 2008
- The final project report of the first phase of the ERTMS Benchmark Study 2008 was drafted and distributed to the ERTMS Platform and Steering Group as well as all working group members.
- The final project report was presented on 18 Nov. 2008 at the tenth Platform Steering Board meeting (it is available at UIC upon request – ISBN 978-2-7461-1561-3 English version).

Project deliverables - Phase 1:
- Discussion paper on ERTMS cost and performance benchmarking (24 March 2008 ver.01);
- Meeting reports of the preparatory meetings with the study participants (April-May 2008);
- Two-day Workshop on 27-28 May 2008 - Documentation ;
- Intermediate Project Report (4 June 2008 ver. 1);
• COST MODEL: ERTMS Modular Cost Structures (4 Sept. 2008 ver. 3.1):
  - ERTMS/ETCS Level 1 trackside subsystem;
  - ERTMS/ETCS Level 2 trackside subsystem;
  - ERTMS ONBOARD subsystem.
• List of Key Performance Indicators (March-August 2008);
• Progress reports to UIC ERTMS Steering Group (March, June, Sept., Nov. 2008);
• 2 Pilote case study reports (August-September 2008):
  - ERTMS/ETCS Level 2 infrastructure – The Betuwe Route – ProRail;
  - Rolling Stock - ERTMS on-board – SBB.
• Final Project Report 2008 (delivered on 18 November 2008).

1.3.2. Detailed working methodology and review of Phase 2 (October 2008 – July 2009)
The different steps of Phase 2 of the project are presented were:

PHASE 2.1 – Case study data collection

Based on the ERTMS cost framework and list of key performance indicators developed in Phase 1 of the project between March 2008 and September 2008, the second phase consisted of the collection real data from 14 different cases of ERTMS/ETCS implementation projects (some Level 1, some Level 2, some rolling stock ERTMS on-board units).

The data collection was organised in the following meetings on the working group members’ premises:
• CFL (Luxembourg, infrastructure and rolling stock);
• RFI and Trenitalia (Italy, infrastructure and rolling stock);
• Network Rail (UK, infrastructure) – real data on the Cambrian line was not available, the case study was considered not representative in terms of cost data;
• DB (Germany, infrastructure): real data on the 135 km of ERTMS/ETCS lev.2 Halle-Leipzig line was not available, the case study was considered not representative in terms of cost data;
• ADIF (Spain, infrastructure);
• SBB (Switzerland, infrastructure);
• ÖBB (Austria, infrastructure and rolling stock);
• OSE (Greece, infrastructure and rolling stock);
• ZSSK/ZSSK Cargo and ZSR (Slovakia, infrastructure and rolling stock): no real data available on 18 locos’ OBUs, the on-board ase study was considered not representative in terms of cost data.

After these meetings, where costs and performance indicators were discussed in detail, a case study report was drafted, providing all information required understanding the specific situation and results of the cost and performance assessment.
The results of these case study meetings and the specific case study reports are the basis for the final project report integrating the cost comparison analysis within the three different benchmark pools. It is important to note that the agreed cost structures – in the three different pools – have always been used for all case studies developed. In fact, the absence of a uniform cost methodology is often considered a weakness in economic assessments that hinders the interpretation and comparison of studies. Standardisation is therefore an important topic within this field, and this is why the benchmark working group has worked for almost the whole first phase on laying down the basis for a common methodology and choosing cost categories. A uniform cost model has been developed and agreed on; the aim is for it to become a standard document that will be used in tender processes at European corridor level.

**PHASE 2.2 – Roadmap (action plan) of the Benchmark Working Group activities in 2009 and drafting of an up-to-date summary document on ERTMS/ETCS migration along the six European freight corridors**

This phase consisted of a brainstorming session involving UIC and the WG members in order to identify all planned and potential action in the field of economic assessment of ERTMS projects for 2009 and the documentation of this action in a roadmap document.

Furthermore, this phase also represented Platform’s initiative to contribute to the migration towards ERTMS along the six ERTMS freight corridors. For this purpose, the existing UIC documentation and public data on the corridors were reviewed in order to provide the Platform and other stakeholders with a short document summarising the status of migration along these corridors.

On the basis of this document UIC identified fields of further investigation that should support the corridor organisations in clearly identifying the benefits of the new European signalling system and understanding the economic impact of migration.
PHASE 2.3 – ERTMS Benchmark Study Workshop 2009

On 19 May 2009, UIC organised a follow-up workshop involving the members of the Benchmark Working Group in order to share the initial results of the real data collection phase and take some necessary decisions with regard to the publication of the final project report. Open questions were discussed and the priorities in the WG activities for 2010 and beyond were set.

PHASE 2.4 – Data harmonisation and drafting of the final report on economic assessment of ERTMS implementation projects (on the basis of the case study reports)

During this final phase of the project the detailed final benchmark report was drafted, drawing conclusions from different cost and performance positions seen in the various case studies.

For this purpose, the case studies needed to be reassessed in detail and a common presentation structure had to be developed. Comparable data was prepared in an efficient and meaningful way in order to provide insight and conclusions from the study.

Since data availability and quality was sometimes problematic due to difficulties faced by the railways, particularly in obtaining data for the R&D and O&M phases of the system life cycle, UIC decided in its workshop on 19 May 2009 to initiate dedicated task force meetings for the three “benchmark pools” (ERTMS/ETCS L1 trackside subsystems, ERTMS/ETCS L2 trackside subsystems and ERTMS onboard subsystems). The objectives of these meetings were to harmonise data where appropriate, due to differences in the quality or availability of data, and find a way to show a consistent picture of the true cost situation with regard to the different project contexts.

The description of the data harmonisation process has finally been integrated in the final project report 2009.

Project deliverables - Phase 2:

- Roadmap of UIC activities on ERTMS economic assessment for 2009/2010;
- Summary document on the status of ERTMS migration along the 6 ERTMS corridors for freight: “6 corridors – ERTMS implementation update” (March 2009);
- Organisation of a Signalling Equivalent Unit (SEU) workshop in December 2008, a follow-up meeting with a task force group of four member railways and related documentation (presentations, minutes, preparation of decisions to be taken, etc.) (December 2008 – June 2009);
- Preparation, organisation and documentation of the ERTMS Benchmark WG operational workshop 2009 held on 19 May in Paris: presentations, handouts, minutes and documentation, follow-up/proposal of next steps, preparation of decisions to be taken, etc. (May 2009);
- Benchmark report on cost and performance comparison as a conclusion to the results from the case studies and presentation of compared data – Final Report (September 2009);
- 14 case study reports for the following ERTMS implementation projects
<table>
<thead>
<tr>
<th>IMs/RUs</th>
<th>INFRASTRUCTURE ERTMS/ETCS LEV.1 and 2</th>
<th>ROLLING STOCK ERTMS ONBOARD units</th>
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<tr>
<td>ProRail</td>
<td>Utrecht, 29-30/07/08: Betuwe line – ETCS lev.2 freight -110 km DT (Alstom) – Pilot case study</td>
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</tr>
<tr>
<td>CFL</td>
<td>Luxembourg, 06/10/08: CFL – Luxembourg-Ettelbruck line, ETCS lev.1 - 39 km double track (Alcatel/Thales)</td>
<td>Luxembourg, 06/10/08: 22 EMU 2000 (Alstom)</td>
</tr>
<tr>
<td>RFI Trenitalia</td>
<td>Rome, 27/10/08: RFI – Rome/Naples ETCS lev.2 - 204 km double track (Alstom/Ansaldo)</td>
<td>Florence, 28/10/08: 30 ETR 500 (Alstom)</td>
</tr>
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<td>ADIF</td>
<td>Madrid, 03/02/09: Barcelona-Figueres section, part of the Madrid-Barcelona-French border line, ETCS lev.1 – 132 km DT (Thales)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Madrid, 03/02/09: Barcelona-Figueres section, part of the Madrid-Barcelona-French border line, ETCS lev.2 – 132 km DT (Thales)</td>
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<tr>
<td>SBB</td>
<td>Paris, 11/02/09: Mattstetten–Rothrist – ETCS lev.2 - 45 km DT plus 10 km ST (Alstom/Thales)</td>
<td>Berne, 27-28/08/08: 20 locos TRAXX family (Bombardier) – Pilot case study</td>
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<td>ÖBB OBB cargo</td>
<td>Vienna, 16/04/2009: Vienna – Hegyeshalom – (Budapest) ETCS lev.1 – 65 km DT (Siemens/Alcatel)</td>
<td>Vienna, 17/04/2009: 13 locos type “1116 TAURUS” (Siemens)</td>
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<td>ZSR ZSSK</td>
<td>Bratislava, 25/05/09: Bratislava-Nové Mesto – ETCS lev.1 - 89 km DT (Siemens)</td>
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</table>

**Figure 6 Case studies carried out before 2010**

These case study documents include the following information:

- Description of network migration strategy, project context, fallback philosophy, line specifications, etc.
- Cost models completed with real data and interpretation of the results.

**1.3.3. Detailed working methodology and review of Phase 3 (July 2009 – October 2010)**

In terms of working methodology the third phase of the UIC ERTMS Benchmark Project the following steps:

**PHASE 3.1 – Case study data collection**

Based on the ERTMS cost framework and list of key performance indicators developed in Phase 1 of the project, this step consisted of the continuation of real data collection from 7-9 new case studies.

The data collection was organised in the following meetings on the working group members’ premises:

- ProRail (The Netherlands, infrastructure)
- ÖBB (Austria, on-board)
- ÖBB (Austria, infrastructure)
- Trafikverket (Sweden, ERTMS Regional and on-board)
- RFI (Italy, infrastructure)
PHASE 3.2 – Improving of the understanding of Operation & Maintenance strategies and costs in the field of ERTMS

This step consisted in the set-up of a UIC ERTMS O&M Task Force. The first two phases of the project revealed a lack of in-depth knowledge of this phase of the system life cycle and since many projects are now implemented and in operations, the focus of the information exchange among the peers of the UIC ERTMS Benchmark Project was shifted on the Operation and Maintenance phase of the system where knowledge was built on common ground.

Within this context, UIC organized 4 dedicated Task Force meetings on this subject and the results of this work are presented in chapter 3 of this report.

PHASE 3.3 – UIC ERTMS Benchmark Study Workshop 2010

This step consisted in the preparation of the annual workshop of the UIC ERTMS Benchmark Project including the presentation of intermediate results and a first open discussion among European railway stakeholders.

After 2 years of work, on September 28th 2010, more than 100 participants from rail industry, infrastructure managers, railway undertakings, railway associations and other stakeholders in the railway business followed the invitation of UIC to discuss recent developments in the field of economic evaluation of ERTMS. At this occasion, speakers from the European Railway Agency (ERA), the European Commission (EC), UNIFE and a Representative of the Railways Notified Bodies (No-Bos) shared their respective views on the subject and UIC presented some intermediate results of the work carried out by the UIC ERTMS Benchmark Working group between 2008 and 2010.

The huge interest in the UIC ERTMS Benchmark Project and the high number of participants at the Workshop confirmed UIC in its initiative to continue working with the ERTMS Benchmark Working Group on economic issues and enhance collaboration between the various railway stakeholders in order to properly analyze past experiences, get a better knowledge and control over costs and increase transparency in the market.

PHASE 3.4 – Update of the UIC ERTMS Benchmark Project Report and the related LCC databases

This last phase consisted of the publication of this report and the update of the LCC databases in the 3 Benchmark Pools with regard to the new case studies carried out in 2010.

The report provides the conclusions from the different cost positions observed in the existing and new case studies. In total, some 20 case studies on ERTMS LCC have been carried out since 2009.
The case studies have been evaluated in detail and presented at the annual workshop mentioned above. Comparable data has been prepared in an efficient and meaningful way in order to provide insights and conclusions form the new results.

Project deliverables - Phase 3:

- 7-9 new case study reports for the following ERTMS implementation projects:

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<tr>
<td>Prorail</td>
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<td>Luxembourg 06/10/2008: 22 EMU 2000</td>
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<td>RFI Trenitalia</td>
<td>Rome, 12/02/2010: RFI- Rome/Naples ETCS lev. 2 High Speed line- 204 km double track</td>
<td>Florence, 28/10/2008: 30 ETR 500</td>
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<td>Madrid 03/02/2009: Barcelona- Figuerer section, part of the madrid- Barcelona-French border line, ETCS lev 1 - 132km DT</td>
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<td>Paris, 11/02/09: Mattstetten- Rothrist- ETCS lev. 2 45km double track plus 10 km single track</td>
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<td>OBB OBB Cargo</td>
<td>Vienna 16/04/2009: Vienna Hegyeshalom-(Budapest) ETCS lev 1- 65km DT</td>
<td>Vienna, 17/04/2009: 13 locos type &quot;1116 Taurus&quot;</td>
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<td>Vienna, 25/05/2010: Vienna St. Pthen new line construction ETCS level 2-60 km double track</td>
<td>Vienna, 06/04/2010: 50 locos type &quot;1216 Taurus&quot;</td>
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<td>OSE/ERGOSE</td>
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<td>Athens, 29-30/04/2009: 122 vehicles of 6 different types</td>
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<tr>
<td>ZSR/ZSSK</td>
<td>Bratislava, 25/05/2009: Bratislava-Nové Mesto ETCS leve.1- 89 km double track (Siemens)</td>
<td></td>
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<tr>
<td>Trafikverket</td>
<td>Borlange, 15/06/2010: ERTMS Regional Line Repbadken-Malung ETCS Regional</td>
<td>Borlange, 15/06/2010: 25 vehicles (of a total sampleof 1800 vehicles) in a joint procurement program between Jernebanverket and Banverket</td>
</tr>
</tbody>
</table>

Figure 7: Case studies carried out till end 2010 (in red new case studies 2010)

- Documentation of the annual UIC ERTMS Benchmark Project Workshop: presentations, handouts, minutes, press release ...);
- Report of the series of Task Force meetings on ERTMS Operation & Maintenance;
- Realisation of a survey and documentation of the feedback of the survey by the ERTMS O&M Task Force Members;
- Updated and automated versions of the UIC ERTMS LCC databases in the 3 Benchmark Pools (L2, L2, On-board);
- Updated version of the UIC ERTMS Benchmark Report 2010;
- Roadmap of UIC activities on ERTMS economic assessment for 2011.
1.4. Current ERTMS projects in Europe

Information on ERTMS implementation plans has been collected and stored in UIC, as part of the ERTMS Platform activity, since 2006, in a comprehensive data base per line sections and per country, reporting detailed information on infrastructure and rolling stock.

The data base is built on official information given by Platform members with the objective of offering them an on-going added-value service and to maintain our strategic position and understanding of the rail business.

The following ERTMS implementation projects could be identified:

![Figure 8 ERTMS lines outside Europe under commercial service and under construction](image-url)
## Figure 9: ERTMS lines in Europe under commercial service

<table>
<thead>
<tr>
<th>Country</th>
<th>Rail Operator</th>
<th>Year</th>
<th>Corridor</th>
<th>Line section</th>
<th>Section length (km)</th>
<th>Single</th>
<th>High speed</th>
<th>Category</th>
<th>Infrastructure specifications</th>
<th>Rolling stock</th>
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<tr>
<td>Austria</td>
<td>ÖBB</td>
<td>2003</td>
<td>E</td>
<td>Vienna - Heggshelm - Bratislava</td>
<td>67</td>
<td></td>
<td></td>
<td>Siemens</td>
<td>1 + Still loop</td>
<td>2.2.2</td>
</tr>
</tbody>
</table>
| Belgium  | Infrael        | 2003 | D        | HSL1 - Lille - DLH (German border) | 36 |        |           | Abellio | Siemens | 2 | 2.2.2 | ETCS Level 1 | SNCF | 17 | Thalys / + 2.2.2 | PESA (Thalys), PESA (Thalys), ICE3
|          |               | 2009 | D        | HSL4 Amsterdam - NL (Dutch border) | 30 |        |           | Abellio | Siemens | 1 | 200 | 1.2.2 | DB | 130 | 1 type of EMU 12 classes of bogies |
| Bulgaria | NRC           | 2001 | E        | Sofia - Burgas | 86 |        |           | Abellio | Siemens | 2 | 2.2.1 | ETCS Level 1 | DB | Siemens, Abellio, Bombardier | 86 | BR-1200M, 450.5mph THM, Locom: Vossloh G2000, ICE3 |
| Greece   | EFGOSE        | 2008 | D        | Corinth - Athens | 120 |        |           | Siemens | Abellio | 1 | 100 | 1.2.2 | MAV | Thalys | 20 | VES Loco |
| Hungary  | MAV           | 2004 | D        | Hodmez - Zalakaros | 23 |        |           | Abellio | Siemens | 1 | 100 | 1.2.2 | MAV | Siemens | 20 | VES Loco |
|          |               | 2007 | E        | Budapest - Heggshelm | 190 |        |           | Siemens | Abellio | 1 | 100 | 1.2.2 | MAV | Siemens | 20 | VES Loco |
| Italy    | FF             | 2005 | A        | Torino - Novara | 90 |        |           | Alstom | Abellio, Asstati STS | 2 | 300 | 2.3.1d | TREMAT | thalys | 110 | HST ETR 470 (1S/2V), HST ETR 500 (2V), HST ETR 600 (2V), EMU E 400 (1S/2V), EMU E 400 (2V/3V) |
|          |               | 2006 | B        | Roma - Napoli | 300 |        |           | Alstom, Asstati STS | 2 | 300 | 2.3.0 | Trevital, thalys, thalys | 100 | HST ETR 470 (1S/2V), HST ETR 500 (2V), HST ETR 600 (2V), EMU E 400 (1S/2V), EMU E 400 (2V/3V) |
|          |               | 2005 | A        | Milano - Bologna | 110 |        |           | Alstom, Asstati STS | 2 | 300 | 2.3.0 | Trevital, thalys, thalys | 100 | HST ETR 470 (1S/2V), HST ETR 500 (2V), HST ETR 600 (2V), EMU E 400 (1S/2V), EMU E 400 (2V/3V) |
|          |               | 2005 | A        | Bergamo - Ferrara | 90 |        |           | Siemens | Abellio | 1 | 120 | 2.2.2 | Siemens | 120 | 1.2.2 | Alstom, Abellio, ASST | 18 | EMU F 720, 180km/h, EMU F 720, 180km/h, EMU F 720, 180km/h |
| Luxembourg | CFL     | 2007 | D        | Luxembourg - Bettendorf (Luxembourg - Bertrichem) | 11 |        |           | Abellio | Siemens | 1 | 140 | National ATP | CFL | Siemens | 10 | Siemens EMU 720, 180km/h, EMU F 720, 180km/h, EMU F 720, 180km/h |
|          |               | 2005 | E        | Ettelbruck - Luxembourg (Luxembourg - Dommersbach, Luxembourg, Mersch, Courden Eisenbruch) | 35 |        |           | Siemens | Abellio | 2 | 300 | 2.3.0 | NS Hoped, Thalys | 100 | Siemens EMU 407, 180km/h, EMU 407, 180km/h, Siemens EMU 407, 180km/h |
| Netherlands | NSrail | 2007 | A        | Betuwe Line | 110 |        |           | Siemens | Siemens | 2 | 300 | ETCS Level 1 | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
| Germany  | DB            | 2005 | A        | Madrid - Linares | 400 |        |           | Siemens | Siemens | 2 | 300 | National ATP | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
| Spain    | Adif          | 2005 | A        | Madrid - Las Palmas de Gran Canaria | 100 |        |           | Siemens | Siemens | 2 | 300 | National ATP | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
|          |               | 2006 | F        | Lisbon - Lagos (east Terceira) | 90 |        |           | Siemens | Siemens | 2 | 300 | National ATP | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
|          |               | 2007 | A        | Madrid - Valladolid | 200 |        |           | Siemens | Siemens | 2 | 300 | National ATP | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
| Switzerland | BLS   | 2007 | A        | Luzern - Rorschach | 35 |        |           | Siemens | Siemens | 1 | 200 | National ATP | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
|          |               | 2006 | A        | Lunz - Linz | 30 |        |           | Siemens | Siemens | 2 | 250 | 2.2.2 | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
|          |               | 2007 | A        | Mittelthun - Rustsch | 45 |        |           | Siemens | Siemens | 2 | 1000 | 2.2.2 | Siemens | 1 | 160 | Siemens EMU 407, 180km/h, Siemens EMU 407, 180km/h |
### General Project Information

<table>
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<tr>
<th>Country</th>
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<th>Year</th>
<th>Consider</th>
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<th>Section Length (km)</th>
<th>Single-Track</th>
<th>Double-Track</th>
<th>Rolling Stock</th>
<th>Revenue-Payer</th>
<th>Considered</th>
<th>Considered</th>
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<td>2012</td>
<td>E</td>
<td>Innsbruck - Graz</td>
<td>204</td>
<td>1</td>
<td>2</td>
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<td>Natural ATP</td>
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<td></td>
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<td>2013</td>
<td>E</td>
<td>Salzburg - Vienna</td>
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<td>1</td>
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<td>Siemens Trains</td>
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<td>Natural ATP</td>
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<td>Berlin - Hamburg</td>
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<td>C</td>
<td>Tallinn - Riga</td>
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### Infrastructure Specifications

- **Country**: Austria
- **CR**: OEBB
- **Year**: 2012
- **Considered**: E
- **Line Section**: Innsbruck - Graz
- **Section Length (km)**: 204
- **Single-Track**: 1
- **Double-Track**: 2
- **Rolling Stock**: Siemens Trains
- **Service Level**: 180
- **Max Speed**: 2.3
- **ETCS** version: 462
- **Revenue-Payer**: OEBB Siemens Trains
- **Considered**: 4 classes, OIB trains

### Rolling Stock

- **Type of Operation**: Natural ATP
- **Model**: Siemens Trains
- **Version**: 462
- **Considered**: 4 classes, OIB trains

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**Figure 10: List of European ERTMS/ETCS projects**
2. Life Cycle Cost methodology

This chapter provides a brief overview of recent activities undertaken by European railways with regard to Life Cycle Cost methodologies, an update on current activities at UIC relating to LCC and Asset Management and presents the LCC model used in this Benchmark study.

2.1. Life Cycle Costing for railways

“Infrastructure managers (IMs) increasingly have to deliver defined performance levels, related to system reliability, availability and life cycle costs, as a result of increasing pressures from governments and operators. IMs have difficulty in adapting to the quickly changing expectations on reliability and affordability. Several methods and tools for asset maintenance management have been developed, but their application in practice is still scarce. Significant challenges currently being tackled are the design of computerised maintenance management systems and their implementation in a traditionally fragmented (budget-driven) maintenance organisation.”

This statement, published by Arjen Zoeteman from the Netherlands Railway Infrastructure manager ProRail, reflects the current situation with regard to the subject of life cycle costing within European railways. LCC is widely accepted as an appropriate method for identifying cost drivers and drawing together the costs of a system, module or component over its whole lifetime, including development, investment, operation and maintenance and disposal costs. Different views and evaluations enable comparison of system alternatives and deliver the necessary information for optimised technical and economic decisions.

The European research project INNOTRACK brought together railway infrastructure managers and the railway supply industry to investigate and evaluate cutting-edge track system technologies, adopting a controlled methodology to assess life cycle cost benefits. This project showed an interesting picture in early 2006. The project team made the following statements about LCC in one of its first analytical state of the art reports:

- RAMS (Reliability, Availability, Maintainability, Safety) and LCC programme analysis are at a very early stage within IMs and manufacturers;
- Data quality and data availability are the major problems in meeting LCC targets;
- A great variety of different tools are used by IMs to calculate RAMS and LCC;
- LCC and RAMS are in their infancy in most participant cases;
- ...

As areas of improvement INNOTRACK proposed to:

- integrate environmental costs while modelling LCC;
- consider risk analysis in LCC calculations;
- improve spare part planning to achieve availability targets;
- clearly define RAMS and LCC specifications in contracts with manufacturers and contractors;
- ...

2. INNOTRACK D6.1.2 on www.innotrack.eu
INNOTRACK is now in its third and final year. At the end of 2009 approximately 130 deliverables will have been produced by this project. Of these, 15 to 25 will be classified as guidelines and special attention will be paid to them. They will be formally reviewed and the necessary training sessions planned.

The European research project INESS1 will bring together – for three years - railway infrastructure managers, the railway supply industry and Academia to define and develop specifications for a new generation of interlocking systems with interfaces towards adjacent subsystems in ERTMS environment.

The project is in its early stage; however one of the six technical work streams is currently developing a complete interlocking business model. They have already started with the definition of a Life Cycle Cost model, based on the European Norm EN 60300-3-3, to be used for the cost analysis. After data acquisition in a second phase the model will be used to evaluate the commercial effects of other work streams and gives essential input to the whole Business Model.

Links have been established between the INESS Business Model work stream and the ERTMS Benchmark work group enabling synergies. It has to be noted, however, the difference in time frame and resources committed to the two projects. One important result has been reached: the INESS LCC model will use the SEU concept developed by the Benchmark group (refer to chapter 5).

2.2. Asset management and LCC benchmarking at UIC

UIC has been involved in benchmarking activities together with a number of its member railways for over ten years, particularly in the area of infrastructure maintenance and renewals.

The following UIC projects have been carried out by members in this area:

- In 1996 the UIC “Infrastructure Costs” project performed an international cost comparison for investment and maintenance of railway infrastructure as a pilot study based on six European railway companies’ figures for 1995. Maintenance and renewal data covers total network costs for all infrastructure components and has been collected for the last ten years. A meaningful comparison of data was possible due to a sophisticated harmonisation process.

- In 2003 UIC developed a Lasting Infrastructure Cost Benchmarking (LICB) as a follow-up activity to the Infra Cost Project that had come to an end. A «lasting benchmarking function» was established to guarantee a platform for a continuous comparison of costs and the tracking of trends.

- Also in 2003, as an extension of the UIC Infracost project, six infrastructure managers carried out an Infrastructure Performance Analysis in order to get a clear view of a wider range of asset management issues. The relationship between various quality aspects, the physical condition of infrastructure and the resulting costs were explored. On the basis of this specific analysis it can be stated that cost-optimised infrastructure quality is an appealing but as yet unrealised objective:
  - The level of standardisation of infrastructure quality parameters in Europe is very low. At present, due to a lack of harmonised definitions, a fully-developed benchmark has not been carried out.
  - There is no evidence that low life cycle costs coincide with poor quality parameters. Higher costs cannot simply be justified by higher quality.

1. INESS web site: www.iness.eu
- RAMS aspects of railway infrastructure are more amenable to benchmarking. Again, there is no clear evidence that railway companies with high cost figures turn out superior reliability and availability.

- Quality and safety go hand in hand. Investing in modern, high-quality infrastructure improves safety. For Europe, additional safety gains may depend on a careful value-for-money analysis in order to deploy available financial resources more efficiently.

- In 2006 the participating railway companies and UIC decided to publish a 10-year benchmarking report to evaluate the figures collected over the last 10 years and show trends regarding the structure, substance and quality of the management of railway infrastructure throughout Europe.

As a conclusion of this report it can be stated that benchmarking of infrastructure costs has generally proven to be a valuable tool for mutual learning and tracking progress over time. From a broader perspective the most important conclusions are the following:

- Different levels of cost efficiency obviously exist. Cost reductions appear possible on some networks, but other factors must also be borne in mind, such as current quality of assets, safety and performance. Therefore, cost reduction strategies need to be developed on an individual basis for each infrastructure organisation.

- Maintenance cost improvements in recent years have been moderate on average in Europe. Thus a more detailed understanding is required of the elements making up these costs in order to develop coherent strategies for both maintenance and renewals, which will lead to optimised lifetime management.

- Asset conditions, such as quality and age, bear a strong correlation with cost. Enhanced renewal activities should pay off in terms of quality improvements and can lead to lower maintenance costs.

- High infrastructure utilisation can be expected to result in higher absolute maintenance and renewal costs but can produce reduced costs per train kilometre. At the same time, unfavourable conditions such as short track possession periods and high proportions of night work have a major impact on maintenance and renewal costs and an effective balance must therefore be struck.

- By applying an integrated approach to cost, quality, safety and performance, railway infrastructure managers can take advantage of further improvements.

In the light of these conclusions and as a result of European legislation infrastructure managers and railway undertakings need to adopt a more business-like attitude: their management focus has shifted from a pure technical approach towards a cost and performance perspective.

UIC reacted to this development by deciding to implement an “Asset Management Group” led by the UIC Infrastructure Department with the aim of drawing together and building on new and existing UIC projects such as INFRACOST, Maintenance and Renewal Optimisation (MRO), Lasting Infrastructure Cost Benchmarking (LICB), INNOTRACK, etc. This UIC group will oversee a programme made up of individual projects and should be a long-term and stable group of experts dealing with asset management questions.

The main objectives of this Asset Management Group for the years ahead are:

- To develop a common view and understanding of asset management;

- To define the principles of asset management;
• To develop methods and instruments for managing LCC and risk;
• To provide UIC members with the necessary instruments/tools to develop their own asset management plans to optimise the level of performance while minimising LCC in a homogenous manner.

On 27 October 2010 UIC organised a worthwhile Workshop to fix the guidelines for the Asset Management Policy in the future years. The UIC members have decided to follow up these activities in order to improve and to refresh the life cycle benchmark concept in this way:

• Improving and comparing performances by learning from good practices and by analysing the processes;
• Identifying the single cost elements;
• Developing and integrate new IT tools to increase the coverage of Asset Info Processes.

Keeping in mind the most important references in this sector, such as PAS 55 (Asset Management Part 1 : Specification for the optimized management of physical assets 2008): UIC and his members will collaborate to achieve:

• a common interpretation of asset management defining the component inside this system;
• a common framework to evaluate possible gaps in their own management systems and to clarifying the competencies for the next generation of asset managers.

Since a shared vision and understanding is still to be developed on a railway asset management and life cycle model, the LCC methodology used in the ERTMS Benchmark Study is based on the best available knowledge. The following chapters describe in detail the advantages, constraints and the economic boundary conditions taken into account and reflect the problems faced in the real data collection phase of the project. The current LCC model can be further developed if necessary in cooperation with the Asset Management Group.
2.3. Definitions, advantages and limits of LCC

Determining costs is an integral part of the asset management process and is a common feature of many asset management tools, particularly economic appraisal, financial appraisal, value management, risk management.

Previously comparisons of asset alternatives, whether at the concept or detailed design level, were based mainly on initial capital costs. However, increasing pressure to obtain better performance from assets means that on-going operation and maintenance costs must be considered, as they consume more resources over the asset’s service life. For example:

• The operational costs of a hospital consume an equivalent of the capital cost every two to three years and can continue to do so for forty years or more;

• The operating costs of a school can consume the equivalent of its capital cost every four to five years and remain in service for a century.

These observations demonstrate quite clearly that both capital and ongoing operating and maintenance costs must be considered wherever asset management decisions involving costs are made.

The following definitions give an overview of this methodological approach:

• Life Cycle Costing is a process for determining the sum of all the costs associated with an asset or part thereof, including acquisition, installation, operation and maintenance and disposal costs. It is an economic evaluation method that generates a net present value of actual and future payments.

• Life Cycle Cost Planning concerns the assessment and comparison of alternatives during the design/acquisition phase of a system. It utilises similar techniques as for Economic Appraisal in that future nominal costs are discounted to today’s cash values.

• Life Cycle Cost Analysis enables the costs over the whole life cycle of an asset to be monitored and therefore accurate and timely decision-making as to how these costs can be minimised; where ownership of assets changes over time each owner takes responsibility for decisions required during the period of ownership only.

When developing physical asset strategies it must be borne in mind that the asset owner’s influence on cost and performance levels is greatest during planning, design and acquisition. Once installation and commissioning have taken place corrective actions are needed to make up for shortfalls in quality. Costs for such actions multiply, ultimately “because the house has to stay open during reconstruction”. Over an asset’s lifetime margins to improve or reduce costs decrease gradually: the asset ages. It therefore pays off to invest significantly in initial quality. The following figure shows a well-known diagram which demonstrates that once an asset is installed and put into service the committed life-cycle cost is already much larger than the actual out-of-pocket costs. The impact on these future costs must be considered in acquisition and maintenance strategies.
Life Cycle Costing can be carried out during any or all phases of an asset’s life cycle. It can be used to provide input for decisions regarding asset design, manufacture, installation, operation, support and disposal.

The following figure shows the principles of a LCC analysis as decision support for a given system:

For a given set of functional requirements there can often be more than one investment or system alternative. Each alternative has specific characteristics in terms of distribution of future payments (costs) along the system life cycle. LCC analysis consists of defining the LCC of each element and reducing each element cost to a common basis. In LCC analysis escalation and discount rates must be considered. The most commonly used LCC analysis method is the net present worth method.
In this method costs are estimated in current cash values, escalated to the time when they would be spent and then corrected to a present worth using a discount rate. When inflation and discount rates are equal LCC can be computed as current cash values, totalled for the project life and compared. Where escalation and discount rates are different the escalation and present worth calculations must be performed. Through LCCA different alternatives can be compared and the best economic solution chosen.

Although the methodological approach of life cycle costing is widely accepted in most industries including railway infrastructure management, there are a number of limitations that should be taken into consideration when carrying out LCC analyses:

• Estimations made early in the life of a project are of limited accuracy;
• Assuming that the alternative has a finite life cycle;
• Anticipating future technological changes that can have a major impact on LCC costs;
• Considering that the high cost of performing LCC analyses may not be appropriate for all projects;
• Taking into account a high sensitivity to changing requirements.

Despite these limitations and some common errors in life cycle cost analysis (such as the omission of important data, poorly structured cost models, misinterpretation of data, wrongly or misused estimation techniques or failure to assess uncertainty) the ERTMS Benchmark working group has agreed to define a simple and commonly agreed LCC model for evaluating ERTMS costs over the entire life cycle of the system.

However, the experience of this study shows that there is still much progress to be made in terms of reinforcing the common understanding of life cycle costing techniques within European railways and the results of this benchmark project are to be interpreted in the light of the evolution of these technical-economic competences.

2.4. Development of a life cycle cost model as part of this ERTMS Benchmark Study

As discussed above life cycle costing has many variables, so it is important to record the purpose, scope, form and level of economic evaluation and also all the underlying assumptions, information and data sources used.

LCC analysis is used to evaluate alternative design configurations, alternative manufacturing methods, alternative support schemes, etc.

To obtain a robust LCC model the ERTMS Benchmark WG implemented the following project phases:
In order to clearly identify the scope of the ERTMS Benchmark Study it was important to agree upon a unique approach. It is emphasized that due to the limited budget and tight timescale for the production of the benchmark study (compared to similar LCC methodology work undertaken as part of major European research projects such as INNOTRACK and INESS) the ERTMS Benchmark Working Group decided to adopt a very simple cost framework structure based on the LCC phases presented in the figure below:

The detailed cost structures of the three defined benchmark pools (ERTMS/ETCS Level 1 trackside sub-system, ERTMS/ETCS Level 2 trackside sub-system, ONBOARD sub-system) were set out in the final report of the ERTMS Benchmark Study 2008, which was presented to WG members and UIC ERTMS Platform members in November 2008.
Some important observations relating to the definition of the scope of the system of the ERTMS Benchmark Study 2008-2010:

- The scope of the LCC model applied in this study was adopted following the real data collection phase among members of the working group in 2009. Since ERTMS is in the very early development phase at all European railways and no disposal data was available in any of the real data collections it was decided that the phase “system phase out – disposal” would be removed from the scope of the model at this stage. Once the cost items of this phase such as residual value, replacement of the system and disposal are identified in due course it will be possible to integrate this phase into future LCC calculations for the systems evaluated.

- In addition, future technological changes that could have a major impact on the LCC of the ERTMS system under evaluation have not been taken into account. To do this, the scope of the system would have to be set at a very detailed functional and technical level (which radio future technology for railways, technological changes at which stage of the future life cycle, which SRS, integration of modification costs at which stage? etc.) and the working group decided not to go into this level of detail at this stage of the project.

- It must also be borne in mind that most of the input parameters are inherently uncertain. A thorough understanding of the theoretical engineering and economics background to each parameter value is critical for conducting a reliable LCCA. Among these, correct choices of economic boundary conditions, such as discount rates, period of consideration and criteria for calculating residual values are recognised as some of the most critical issues for LCC results. However, the WG and the project management team did not carry out a data sensitivity analysis or calculate any risk or uncertainty values for the given data. It was considered necessary in a first stage to align and harmonise the data provided and at a later stage to develop the economic calculation model to a level where sensitivity analyses would be more meaningful. The data presented in the later chapters of the present report is therefore to be considered with this in mind.

A number of potential problems were identified relating to the ERTMS/ETCS systems to be evaluated in this benchmark study:

- Since the ERTMS/ETCS system is at a very early stage of implementation throughout Europe there is very little experience of the real costs of operation and maintenance of the system;

- For infrastructure installations maintenance activities are often included in general signalling maintenance work;

- Operation and maintenance costs are highly dependent on the organisational productivity of the different railway companies, while R&D + Investment costs seem to be more easily comparable on a European scale.

Establishment of the rules and methodologies to be applied in the life cycle cost model (economic boundary conditions)

According to IEC 60300-3-3 life cycle costing is the process of economic analysis to assess the total cost of acquisition, ownership and disposal of a product and its primary goal is to provide input for decision-making in any or all phases of a product’s life cycle.

In line with this definition a LCC model is essentially an accounting structure that contains mathematical expressions for the estimation of each cost element constituting the life cycle cost of a product.
Detailed costs are sometimes difficult to obtain, especially for a long time period where costs can be assumed to vary due, for example, to technology improvement. Throughout the whole process expert analysis is required to improve, calibrate and validate the cost estimation relationships.

To obtain the results and estimate the total costs of a given investment solution or strategy and compare it with an alternative, the LCC calculation involves the application of capital budgeting techniques, being the net present value (NVP).

In order to obtain the life cycle costs of the ERTMS/ETCS implementations, the following economic boundary conditions were taken into account:

- Year 2008 was defined as T0 (=first year of cash flow); all prior cash flows from the development and investment phase were calculated with an annual 3 % inflation adjustment to 2008 values;
- The future cash flows of the operation and maintenance phase beginning from T0 are calculated with a 3 % annual increase to 2028 (T20), which represents an average inflation adjustment of 3 %;
- The net present value of these cash flows (operation and maintenance phase) will be calculated with a 6 % discount rate (the discount rate represents the time value of money: it reflects the opportunity cost of capital or what it can be expected to earn if the capital is placed in other investments of equivalent risk). As a result of this mathematical operation all future cash flows will be transferred to the first year of cash flow (T0).

The discount rate factor is known to be highly variable depending on the country and the project being considered. The 6 % selected represents an average value of the following study carried out by the French government which collected the different discount rates and the time horizon usually considered for project appraisal.

![Figure 15: Usual practices concerning discount rates](image)

Figure 15: Usual practices concerning discount rates

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1. Based on internal data and information from the study « Economic Evaluation Methods for Road Projects » carried out by the Commissariat Général du Plan (2005)
Real data collection and setting of this data into context

A case study document was produced for each case providing all the necessary information in order to understand the specific situation and results of the evaluation. These case study documents contain:

• Cost models completed with real data
• Context description of:
  - Network
  - Migration strategy
  - Project context
  - Fallback regime
  - Line specifications, etc.

The presentations of the quantitative results of this study are discussed in chapter 4 of the present report.

A detailed analysis of the functional and RAMS requirements which can have a major impact on the cost levels of the different implementation projects has not been carried out to date. However, this could be undertaken in a further activity of the working group.
3. Task Force on ERTMS operation and maintenance

After implementing several ERTMS projects throughout Europe, the UIC Members are now facing different needs. Railways are entering a phase of system operation that will last for some 20 years or more. To date, the parties involved in ERTMS have primarily focused on the various ERTMS versions and have made sure they become operational. Now that the system is up running in many cases, operation and maintenance aspect becomes an important issue to railways.

Consequently, the UIC ERTMS Benchmark Study group decided to create a dedicated Task Force on Operations & Maintenance. The objectives of this Task Force were to improve the members’ knowledge on O&M key aspects and share their different experiences.

3.1. Objectives of the UIC ERTMS Task Force on Operations and Maintenance

The UIC ERTMS Task Force on Operation and Maintenance was set up to improve the common understanding of this important phase of the life cycle. Further effort will be done by UIC throughout 2011 in order to obtain improved data sets for the ERTMS case studies realized within the UIC ERTMS Benchmark project since 2008. However, the aim of the dedicated Task Force was related to a qualitative exchange of experiences and the identification of best practices with a focus on the explanation of O&M strategies, concepts and strategic choices. Data collection and comparison was not an explicit subject of this Task Force and will be treated within dedicated data analysis meetings per benchmark pool to be held in 2011.

In June 2010, a survey was conducted by UIC/ PMP among the Task Force participants in order to identify the detailed objectives and priorities of the work of the UIC ERTMS Task Force on Operation and Maintenance to be conducted.

The results of the survey showed the expected objectives of the Task Force Members as follows:

- **Focus on cost reduction, standardisation and creation of real competition in the market**: all sorts of maintenance activities could be done by a number of suppliers, irrespective of the original industrial supplier of the system;
- Find an **optimized maintenance formula leading to reduced costs** without losing system availability;
- Investigate on **O&M activities, processes, responsibilities and procurement strategies**:
  - Create a common cost structure for benchmarking;
  - Create a catalogue of O&M activities;
  - Define optimized procedures of O&M activities;
  - Formulate common contractual terms for O&M outsourcing;
  - Analyse different O&M organization and strategies.
- **Improve the understanding and knowledge of new issues such as software upgrades, bug-fixings and computer equipment obsolescence** which rarely feature in traditional signalling systems.

Although participants expressed a strong focus on cost savings to be achieved, there is no clear baseline for the comparison of ERTMS O&M costs and therefore this objective is difficult to quantify.
In addition to these main aims of the Task Force, the results of the survey pointed out some **efficiency and productivity objectives** as well:

- The expectations of cost saving potentials vary widely among the survey participants:
- Most Task Force participants communicated the objective that the O&M costs of ERTMS may not exceed those of existing national traffic management systems;
- There seems to be a general assumption that quality and type of ERTMS equipment installed on track and train will have major effect on reliability and O&M costs;
- Since the system is very young, real cost data on O&M is rare and observation times, if any, are very short: ERTMS implementation projects are in the middle of a building knowledge on O&M phase;
- In the short term, there are limited expectations for cost savings on O&M activities.

The results of the survey also showed that there is still a lack of common language and understanding of ERTMS terminology and that the Task Force should contribute to a better understanding of ERTMS O&M strategies, organizational designs and decisions taken by the different participants to tackle the important challenges of this new European Railway Traffic Management System.

The Task Force also contributed to the establishment of a network of experts from different countries that will facilitate the direct communication of UIC Members on important issues with regard to ERTMS.

During the first meeting, the Task Force Members agreed on the following priorities to be covered:

- **ERTMS maintenance organization and strategy**: Importance of the maintenance function of ERTMS, outsourcing vs. in-house, service level agreements, organization of maintenance activities, etc.;
- **ERTMS Procurement strategies on a life cycle view of the system with a special focus on maintenance contracting**: expected system availability and other system performance measures, system engineering, main aspects of service level agreements in place, intervention times, monitoring and remote systems, duration and volumes of maintenance contracts, performance regimes and penalty schemes, etc.;
- **ERTMS SRS version and migration management** (impact of software upgrades, etc.): cost analysis of SRS version migrations as real experiences or in form of cost studies, state of development of the “Open ETCS” initiative, etc.;
- **Exchange of experiences with regard to system reliability and availability of ERTMS** for lines that are already in service;
- **ERTMS Maintenance activities and procedures with a special focus on the interdependencies of ERTMS maintenance activities with other track works** (maintenance and renewal of ballast, sleepers or tracks): analysis of preventive, corrective, condition-based maintenance activities, performance measurement and indicators of maintenance realization, management of maintenance teams, logistics, etc.
3.2. Organization of the O&M Task Force

3.2.1. Meeting schedule
So far, the UIC ERTMS O&M Task Force has scheduled 4 meetings between June 2010 and February 2011:

- **1st meeting on June 18th 2010**: presentation of the status-quo of the ERTMS Benchmark Project, objectives of the UIC ERTMS Task Force on Operation and Maintenance and proposition of a short survey on the main objectives and priorities to be covered by the Task Force;

- **2nd meeting on September 14th 2010**: presentation of the results of the survey and some general presentations by Task Force participants;

- **3rd meeting on November 16th 2010**: presentation by members on different subjects according to the priorities set by the Task Force participants via the results of the survey;

- **4th meeting to be held on February 8th 2011**: presentations by members on different subjects according to the priorities set by the Task Force participants via the results of the survey, feedback and conclusions of the Task Force meetings.

3.2.2. UIC ERTMS Task Force on O&M 2010 members and attendees
To date, over 20 railway organizations have contributed to the UIC ERTMS Benchmark Study. The following table presents the active participants of the UIC ERTMS Task Force on O&M:

![Members of UIC ERTMS O&M Task Force](image)

*Figure 16: UIC ERTMS Task Force on O&M active members of 2010*

The UIC ERTMS O&M Task Force also used the intervention of external experts on specific matters. **Strukton Rail** shared their expertise on ERTMS Maintenance organization and strategy, as well as **Italcertifer** on ERTMS testing and certification procedures.

It is important to note that the Railway members volunteered to participate to the different Task Force meetings and that the UIC ERTMS Benchmark Study did not aim to judge the performances of any of the participating Infrastructure Managers or Railway Undertakings, but that it should help to increase the level of knowledge and therefore lead to a better learning curve of the participating organisations.

The following table shows the meeting participants of the UIC ERTMS Task Force on Operation & Maintenance along the series of 4 meetings from June 2010 to February 2011:
### 3.3. Sharing experiences and information on ERTMS Operation & Maintenance

#### 3.3.1. Key issues of the ERTMS O&M strategies

After implementing several ERTMS projects throughout Europe, railways are now entering the important phase of operation and maintenance. Up to now, the different railways have used their own and independent strategies regarding O&M activities. This situation has led to more or less efficient solutions.

In their presentations during the 4 dedicated Task Force meetings, RUs and IMS have shared their experiences and identified best practices and lessons learned. Based on UIC’s June 2010 Survey on O&M, the key issues related to ERTMS O&M strategies that were approached by the Task Force participants during the 4 dedicated meetings were the following:

- **Procurement strategies:** the work of the Task Force should improve the way ERTMS systems are purchased. Presentations on applied ERTMS procurement strategies with specific clauses to open up the supply market of ERTMS are therefore considered highly valuable. The results of this information exchange could contribute to the elaboration of the ERTMS procurement guide to be published by UIC later in 2011.

- **Maintenance contracting:** how to better integrate all signalling and track maintenance works into the scopes of competencies of maintenance contractors? How can maintenance contractors be trained to be in a position to maintain all kinds of interlocking and ERTMS/ETCS equipment? etc.

- **Presentations and exchange of information regarding structural approaches to lower lifecycle costs of ERTMS maintenance for on-board equipment:** combination of antennas, separation of telecom and signalling developments (since they have different innovation cycles), integration of odometric functionalities required by ETCS into the traditional odometric train equipment, integration of functionalities of the ETCS juridical recorder into the existing box in order to avoid double equipment, etc.

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**Figure 17: UIC ERTMS Task Force on O&M meetings attendees**

<table>
<thead>
<tr>
<th>Member Railway</th>
<th>June 18th meeting Participants</th>
<th>September 14th meeting Participants</th>
<th>November 16th meeting Participants</th>
<th>February 8th meeting participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATOC</td>
<td>Tony CRABTREE</td>
<td>Tony CRABTREE</td>
<td>Tony CRABTREE</td>
<td>Tony CRABTREE</td>
</tr>
<tr>
<td>DB</td>
<td>Detlef SCHWARZ</td>
<td>Christoph GRALLA</td>
<td>Detlef SCHWARZ</td>
<td>Klaus- Rüdiger HASE</td>
</tr>
<tr>
<td>Prorail</td>
<td>Henrico PLANTIGA</td>
<td>Lex MOSCOU</td>
<td>Lex MOSCOU</td>
<td>Lex MOSCOU</td>
</tr>
<tr>
<td>OeBB</td>
<td>Robert KABELAC</td>
<td>Gerhard ARNHOLD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADIF</td>
<td>Maite CAMBRONERO</td>
<td>Daniele MARI</td>
<td>Pasquale PETRICCIONE</td>
<td></td>
</tr>
<tr>
<td>SNCF</td>
<td>Thierry HUET</td>
<td>Vincent AMARANTI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBB</td>
<td>Jan RICHARD</td>
<td></td>
<td></td>
<td>Radek CECH</td>
</tr>
<tr>
<td>SZDC</td>
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<tr>
<td>Network Rail</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>PMP</td>
<td>Martin MAYER</td>
<td>Frédéric JOVER</td>
<td>Martin MAYER</td>
<td>Martin MAYER</td>
</tr>
<tr>
<td>UIC</td>
<td>Paolo De Cicco</td>
<td>Snejana MARKOVIC-CHENAIS</td>
<td>Snejana MARKOVIC-CHENAIS</td>
<td>Snejana MARKOVIC-CHENAIS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vincenzo CARPINELLI</td>
<td>Vincenzo CARPINELLI</td>
<td>Vincenzo CARPINELLI</td>
</tr>
</tbody>
</table>
• State of development of the “Open ETCS” initiative;
• Presentations of the conception of ERTMS O&M training programs: what population is trained? What content? Who are the trainers? How long do these programs take? What are the costs? Etc.
• Exchange on experiences of system reliability and availability in an ERTMS L2 configuration for lines that are already in service (specific cases that show the real values reached in the first years of ERTMS operations);
• ERTMS software upgrades: how have these updates been integrated in the initial equipment projects by the Task Force participants? How much do they cost? How can they be anticipated in a better way in order to prevent “bad surprises” in later years of the lifecycle? How can suppliers be “motivated” to give better visibility?
• Presentation of ERTMS maintenance cost estimations for L1 and L2 and challenge of the underlying assumptions by the peers of the UIC ERTMS Task Force.
• Etc.

Figure 18 Radio Block Center Maintenance
General aspects of ERTMS Maintenance organization and strategy

This table gives a brief overview of the different ERTMS O&M working approaches:

<table>
<thead>
<tr>
<th>In-house vs. outsourcing</th>
<th>ERTMS maintenance procurement strategy</th>
<th>Development of ERTMS maintenance competencies</th>
<th>Software version management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DB Infra</strong></td>
<td>ERTMS supplier is responsible for preventive and corrective maintenance until the end of the warranty (1 to 5 years depending on the contract); after the warranty → in-house; intermediate models (partly by supplier, partly by IM) should be further investigated to find an optimum strategy!</td>
<td>Specific in-house development of competencies for integrated maintenance for ERTMS and electronic IXL with synergies and for short intervention times (decentralized maintenance organization); plus increased motivation for in-house staff</td>
<td>Software upgrades are contracted to the supplier of ERTMS (proprietary task)</td>
</tr>
<tr>
<td><strong>ProRail</strong></td>
<td>Maintenance is outsourced to both supplier and maintenance contractors (SLA/SFA)</td>
<td>Maintenance is contracted via SLA/SFA in the same tender as the purchasing of the system</td>
<td>No information available</td>
</tr>
<tr>
<td><strong>RFI</strong></td>
<td>For the first year of system operation RFI outsources with the supplier (integrated assistance especially focused on training on the job of RFI signaling specialists) → progressive reduction of assistance</td>
<td>Build-up of in-house know-how as much as possible; supplier services consist of telephone helpdesk, fix electronic damaged boards and special interventions on demand</td>
<td>Training on the job and job rotation; share of experiences of different geographical signaling-plants (workshops); supplier training on demand</td>
</tr>
<tr>
<td><strong>ÖBB</strong></td>
<td>Purchasing and installation outsourced to supplier, maintenance carried out in-house</td>
<td>As much as possible via in-house experts</td>
<td>In-house competencies in the field of maintenance activities through supplier training</td>
</tr>
<tr>
<td><strong>DB On-Board</strong></td>
<td>Decision is taken case by case, but the philosophy is to realize as much as possible in-house</td>
<td>As much as possible via in-house experts</td>
<td>Special training program planned for all staff responsible for ERTMS on-board maintenance → program related to the commissioning of the ICE-trains</td>
</tr>
<tr>
<td><strong>ADIF</strong></td>
<td>High speed lines: one single tender for the installation and the maintenance of ERTMS (outsourcing to the same contractors); Commuter lines: the maintenance is performed in-house Contract duration: 2 years after installation often re-conducted for another 4 years with the initial contractors</td>
<td>No information available.</td>
<td>No real experience to date. Set-up of a migration group with participation of RENFE and Ministry of Transport</td>
</tr>
<tr>
<td><strong>SBB</strong></td>
<td>SBB is currently going through a change in strategic directions. Up to now, ERTMS L2 deployment was not a big issue on its agenda and the company focused on the deployment of ERTS L1 LS. However, due to capacity issues on some of the main lines, SBB started thinking about an alternative ERTMS deployment strategy that integrates some more L2 implementations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Network Rail</strong></td>
<td>No info to date - Rob Ireland will present NetworkRail procurement strategy during one of the next meetings.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Comparison table on general aspects of ERTMS Maintenance organization and strategy*
Conclusions:

• There seems to be a **tendency to build-up in-house competencies in O&M of ERTMS** in the long term;

• In a short term, **outsourcing to industrial suppliers seems to be indispensable to assure the high system requirements** in terms of availability and the know-how transfer in terms of maintenance expertise;

• The UIC Task Force could **focus on the conditions and programs developed by the different railway organizations to assure this know-how transfer and the organization** and coordination of the transition phase from an outsourced solution towards an in-house realization of ERTMS O&M tasks (with a focus on the impacts of either solution in terms of costs and performances).

3.3.2. **ERTMS Trackside Procurement Strategies**

**ProRail**

Lex Moscou presented ProRail’s ERTMS Trackside Procurement Strategies. His presentation covered tender aspects and its context as well as maintenance aspects such as the content of ProRail’s Service Framework Agreement and specific Service Level Agreements.

ProRail focuses on one single tender procedure per ERTMS project covering the realisation, commissioning, maintenance, standard railway infrastructure changes and the integration of specific options such as ERTMS software upgrades. ProRail considers that it is very important to integrate as much as possible in an initial tender procedure, even if not all options are transformed right away in an initial contract. However, the fact that ProRail asks its industrial suppliers to price some specific options such as software upgrades makes provides ProRail with a better cost anticipation and avoids future bad surprises.

Another important aspect of ProRail’s presentation was the structure and conception of its Service Framework and Service Level Agreements including the related penalty scheme that works for both endogenous and exogenous disruptions.

**RFI**

Pasquale Petriccione presented RFI’s view on ERTMS Trackside Procurement Strategies. He first presented the evolution of spare part procurement costs between 2009 and 2010 and described the mode of cooperation between RFI and its industrial suppliers for the first years of system operation.

RFI has chosen a scheme where the amount of services provided by the industrial suppliers is gradually reduced in the first couple of years of operation. RFI has drawn up different types of maintenance contracts, for each technology in a system of ten-year framework contracts with three-year application contracts. For IXL, RBC, Encoder, Audio Frequency Track Circuits and GSMR, RFI has drawn up framework contracts for all Italian High Speed Lines and application contracts for each line, while for SCC and Tunnel Emergency System RFI has drawn up different contracts for each line.

RFI has also defined a penalty scheme in case of failure to assist RFI to restore services, for time delay in restoring damaged boards, for time delay in case of intervention on demand and for each train late and levels of delay minutes. RFI has split required intervention times in urgent and non-urgent interventions with different service level agreements according to the type of intervention. The maximum amount of penalty payments is capped at 10% of the total amount of each application contract.
ÖBB

Gerhard Arnhold presented ÖBB’s vision on ERTMS procurement strategies as well as the infrastructure organization in place to guarantee ERTMS services.

ÖBB prepared an ERTMS/ETCS maintenance cost model with some assumptions regarding the frequency of maintenance activities and related costs and asked the UIC ERTMS Task Force participants to provide ÖBB with their view and experiences with regard to the underlying assumptions. The meeting participants agreed to have a look at the cost model and give ÖBB some inputs to improve the assumptions and the quality of the calculations in order to provide answers to ÖBB’s main questions: Does the cost model and underlying assumptions correspond to the reality? What needs to be changed in the model to approach a more realistic situation? Are there any items that have not been integrated in the model?

ADIF

Maite Cambronero presented ADIF’s ERTMS Trackside Maintenance Management. The technical structure of the system was presented in detail as well as the interfaces and components.

In general, ADIF contracts in one single tender the installation and maintenance of ERTMS on a given line and distinguishes between High Speed Lines (where maintenance is contracted out) and Commuter Lines (where in-house maintenance is foreseen).

ADIF contracted maintenance for 2 years after the construction of the line has finished. This contract contains spare parts management and warranties, possible hidden or systematic defects control, the manufacturer installer involved in the maintenance and reliability control of all elements. After this period, for a period of 4 years these contracts are normally concluded with the initial contractor. They include penalty payments for delays caused by the systems covered by the contracts. Penalties also arise due to the number of system failures and an indicator that is comparing the theoretical availability with the real availability.

Today, ADIF has commercial relations with 4 ERTMS maintenance contractors (one for any given High Speed Line) and is observing a progressive decrease of maintenance cost. Experiences of different lines with different suppliers have been made and average costs for the different technical solutions have been obtained.

DB

There are two main aspects of maintenance activities for ERTMS/ETCS, namely the maintenance of the balises in the track and the maintenance of the RBC’s according to the manufacturer’s manual.

Concerning the maintenance of the balises, DB proceeds as follows:

- Temporary disassembly and reassembly for track maintenance work, when: operating ballast plough, brushing, additional ballasting and brushing, tamping and ballasting and brushing;
- Verification of the correct sequence of EB (especially in EB groups);
- Replacement on the same sleeper (if not possible, involving manufacturer and replacement as new projected EB) and checking of the correct EB-ID;
- No disassembly necessary when: tamping without additional ballasting and brushing, replacement of rails but no temporary storing of new rails between old rails on the track.
Within the RBC, it is not possible to carry out maintenance works that affect 2 RBC’s while trains are running. The maintenance intervals and tasks in the RBC are the following:

- Preventive maintenance to avoid failures;
- Planned maintenance at least once a year, etc.

Based on a recently signed modular contract for ERTMS/ETCS in Germany, the following aspects of the contracting process are outlined:

- Once the contract is signed, projects can be calculated and awarded more accurately and in a shorter time. ETCS –modules are listed as needed in the project which is to be tendered and the module prices can be used to set up a first project calculation.

- Frame contract is valid for a few years. Parties which don’t sign the contract lose the entrance to entire ETCS market until frame contract is set up again. This enlarges the motivation of the bidders to make a good offer.

- Negotiating the contract with modules provides more possibilities to put pressure on the prices because the offer of different companies is 100 % comparable. Questions can be aimed specifically to the content of modules where the price differs significantly between the different bidders.

The optimum strategy for maintenance is a combination of both manufacturers being responsible for maintenance until the end of the guarantee period (mainly corrective maintenance) and the railways taking over the responsibility for the maintenance after the end of this guarantee period (mainly preventive or condition based maintenance).

**SBB**

Jan Richard from SBB presented the latest developments in terms of ERTMS in Switzerland. SBB is currently going through a change in strategic directions. Up to now, ERTMS L2 deployment was not a big issue on its agenda and the company focused on the deployment of ERTS L1 LS. However, due to capacity issues on some of the main lines, SBB started thinking about an alternative ERTMS deployment strategy that integrates some more L2 implementations.

With regard to Operation and Maintenance, Jan Richard gave brief overview of the cost categories and levels for the existing ERTMS L2 line Mattstetten – Rothrist. However, with the potential deployment of some more lines with ERTMS L2 SBB will also have to intensify its assessment of different operation and maintenance strategies, particularly since the organization in place for the Mattstetten – Rothrist line is considered as quite expensive.

**Network Rail**

Rob Ireland from Network Rail, who is new to the UIC ERTMS Benchmark Project, presented Network Rail’s interest in further engagement with the project. Network Rail is particularly interested in the upcoming data analysis meetings since some important decisions regarding the roll-out of the UK ERTMS strategy shall be taken in the upcoming weeks and months. Therefore, Rob could not yet come up with a detailed presentation about Network Rail’s ERTMS strategic issues such as procurement principles, ERTMS maintenance organization, etc. However, Rob will outline Network Rail’s position on these issues in the next meeting.

In the meantime, Network Rail will take the necessary steps to further engage with the project and
carry out a case study for infrastructure and on-board with regard to the Cambrian project. Network Rail is also highly interested in the existing data since it will shed some light to the cost expectations regarding ERTMS deployment in the UK.

3.3.3. ERTMS On-Board Procurement Strategies

ÖBB

Robert Kabelka presented the ÖBB ERTMS on-board equipment project of some 382 locos and 67 train sets until 2012. ÖBB ordered the delivery and installation of OBUs on 382 locos (“Taurus” classes 1016, 1116, 1216) and 67 driving trailers (“Railjet” 80-90) from Alstom including authorisation in several countries. For the equipment of these vehicles, ÖBB Technical Services is a subcontractor of Alstom.

The amount of preventive maintenance was limited by the requirement specification to six man hours per year and vehicle. For the corrective maintenance ÖBB ordered an all-inclusive package for maintenance at a fixed price of 2 000 € per unit for the first 5 years with an option for further 10 years. In these costs of 2 000 € per vehicle and year all works on the vehicles as well as the repair of the components are included (preventive and corrective maintenance). ÖBB Technical services will probably continue working as a subcontractor for Alstom during the maintenance and exchange of components beginning with the end of the guarantee phase.

Software updates are considered as investment costs and ÖBB asked for an hourly rate of engineering costs to be taken as a basis for future works to be carried out with relation to software upgrades. However, software upgrades are not integrated in the initial contract.

ATOC

Tony Cabtree from ATOC (Association of Train Operating Companies) presented the association’s view on Signalling Equivalent Units and the conversion of this concept used in traditional signalling towards ERTMS. The “SEU count” for a particular signal box or interlocking relates to the number of signals, track circuits, points, level crossings, etc. Therefore, SEU is not related directly to the number of km of track. For example, a complex location can have hundreds of SEUs but only a few track km; at the same time, a lightly used rural line or higher speed line with little equipment may have few SEUs and 100's of track km.

ATOC considers that the value of each equivalent SEU is constant, however, the cost of renewing an SEU depends on what you plan to do (life extension → x % unit cost; renewal like-for-like → y % cost; renewal ERTMS → z % cost)

ATOC is very much interested in the results of the benchmark study in order to define the target costs for IM’s and TOC’s in terms of ERTMS equipment.

With regard to maintenance of SEUs, the system in the UK follows logically that signal maintenance can be related to SEUs. Annual maintenance cost can be expressed as follows:

- Mechanical signal box = b % unit cost
- Electronic interlocking = c % unit cost
- Relay interlocking = d % unit cost
- ERTMS level 2 = e % unit cost
The maintenance function in ERTMS needs an extensive provision for software upgrades. ERTMS moves the safety function of the signalling system that was traditionally executed by the infrastructure managers towards the On-board units. Giving the rolling stock more “responsibility” of the railway system in terms of safety makes infrastructure management less complex and should make it therefore less expensive.

In the UK, calculations have shown that the shift from traditional signalling to ERTMS L2 helps the infrastructure manager (Network Rail) save 15 times the costs that the TOC invest in the equipment of an ERTMS on-board system (no more signals, centralized and remote maintenance, etc.). Therefore, Network Rail partly compensates the expenses of TOCs for the ERTMS equipment.

**DB**

Mr. Gralla from DB presented some key elements for ERTMS Maintenance according to DB Fernverkehr. DB performs ERTMS inspection and maintenance in-house. The system is maintained during the general inspection schedules of the EMU’s and the documentation necessary to carry out these activities is provided by the industrial system supplier and is adapted due to DB requirements according to internal quality standards.

DB staff is well trained to carry out the different inspection schedules defined by DB in cooperation with the industrial supplier. Testing tools are provided by the supplier in order to test and check hardware elements.

DB then presented some examples of activities with the related frequency for specific components as well as some details for future service level agreements of the ICE T and ICE 3 fleets.

Finally, Mr. Gralla provides some ideas how to reduce costs of ERTMS on-board equipment, such as: the substitution of radars by intelligent odometer systems without equipment under the car body, integration of the JRU into the existing “black boxes” of the EMU, the application of bearing systems with combined wheel sensors for different train control systems with only one cable, the standardization of interfaces and the “openETCS” initiative.
3.3.4. SRS version and migration management

ProRail

Lex Moscou presented ProRail’s experience with ERTMS SRS upgrading. Currently, ProRail has the following versions in place:

<table>
<thead>
<tr>
<th>Existing projects</th>
<th>Future projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- HSL (L2): 2.3.0d;</td>
<td>- Kfh (L1): 2.3.0d overlay;</td>
</tr>
<tr>
<td>- BetuweRoute (L2): 2.2.2nn;</td>
<td>- ZvO (L1 or L2): 2.3.0d = BL3;</td>
</tr>
<tr>
<td>- Harbourline (L1): 2.2.2nn;</td>
<td>- Upgrade BetuweRoute from 2.2.2nn to 2.3.0d</td>
</tr>
<tr>
<td>- Amsterdam – Utrecht (L2): 2.3.0d overlay;</td>
<td></td>
</tr>
<tr>
<td>- HZL (L2): 2.3.0d overlay;</td>
<td></td>
</tr>
</tbody>
</table>

ProRail has contracted its projects with different suppliers:

<table>
<thead>
<tr>
<th>Projects</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Betuweroute and Harbourline</td>
<td>- Alstom</td>
</tr>
<tr>
<td>- HSL South¹</td>
<td>- Siemens</td>
</tr>
<tr>
<td>- Hanzeline</td>
<td>- Alstom</td>
</tr>
<tr>
<td>- Amsterdam-Utrecht</td>
<td>- Bombardier</td>
</tr>
</tbody>
</table>

Up to date, ProRail has realized one SRS upgrade for the HSL South line from SRS 2.2.2c to 2.3.0d. The effort has been important both in terms of additional delay for engineering, installation, testing and certification (+10 months) and in terms of costs. However, there has also been a positive effect and this line is now the first ERTMS fitted line that is truly interoperable and border crossing has been successfully achieved prior to subset 97 and 98. The costs caused by this SRS upgrade added up to some 27,64 M€ for:

<table>
<thead>
<tr>
<th>Activities</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalling</td>
<td>18,10 M€</td>
</tr>
<tr>
<td>Trackworks</td>
<td>0,23 M€</td>
</tr>
<tr>
<td>Reimbursable tests</td>
<td>4,05 M€</td>
</tr>
<tr>
<td>Project Management</td>
<td>3,3 M€</td>
</tr>
<tr>
<td>Operational procurement</td>
<td>0,96 M€</td>
</tr>
<tr>
<td>Update ISA stat.</td>
<td>1,00 M€</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27,64 M€</strong></td>
</tr>
</tbody>
</table>

¹. Not contracted by ProRail but by The State of The Netherlands, represented by the Ministry of Transport.
In 2012/2013 ProRail plans to realize a second SRS upgrade for the BetuweRoute from SRS 2.2.2c to 2.3.0d. This line is part of the European Corridor A and therefore the upgrade is necessary to an EU specified SRS version. The costs need to be confirmed by the procurement procedure, but ProRail hopes and expects to be these costs considerably lower than those of the HSL South line, in particular since tests will be realized mostly in a testlab and only limited real tests are foreseen.

For ProRail, once again the main lessons learned from their first upgrade experience is to better integrate future system version changes in the initial contracts and to minimize real tests by replacing them as much as possible with lab tests.

ADIF

Maite Cambronero presented ERTMS Migration in Spain. ERTMS deployment in Spain is quite complex with a large variety of lines already equipped by different industrial suppliers. In total, ADIF has equipped 1.686 km of lines with ERTMS (4 lines in commercial operations, 4 lines under construction). In addition, various train types are running on different ERTMS lines and cross-acceptance is therefore an important issue.

Most of the high speed lines are equipped with SRS 2.2.2+, while two lines are already constructed with the newer version 2.3.0. Conventional lines and the Madrid-Valencia HSL are equipped with 2.3.0d.

ADIF has created a special migration group with the participation of the Ministry of Transport, RENFE (incumbent train operator) and ADIF. Suppliers are consulted by this group, but do not participate on a regular basis. While the migration objectives are known and clear for the trackside subsystem, the trainborne migration strategy is under evaluation. Special testing and certification procedures are foreseen for future upgrades; however ADIF has no real experience to date.

In terms of costs, ADIF has only one reference value with regard to the upgrade of one line (L1 and L2) from 2.2.2+ to 2.3.0d: 2,7 M€. Migration is considered as the new challenge for ERTMS in Spain.

SZDC’S ERTMS STRATEGY

Radek Cech presented SZDC’s ERTMS strategy: SZDC finish with pilot project ETCS L2 on line Poricany – Kolin. They prepare ETCS implementation in context of EC decision 2009/561/EC. They prepare tender for ETCS Kolin – Brno – Breclav border CZ/SK and CZ/AT in summer of 2011 with realisation in next 2 years.

SZDC plans following timetable of ETCS implementation:

• Kolin – Praha – Decin – border CZ/DE up to 2015
• Border CZ/PL – Ostrava – Břeclav - border CZ/SK and CZ/AT up to 2020
• Border CZ/DE – Nymburk – Kolin (line outside Prague area convenient for freight) up to 2020
• Prague – Tabor – Ceske Budejovice – border CZ/AT up to 2020

All years will be confirmed through new strategy of CZ infrastructure development by government.
3.3.5. External contributions to specific issues

Strukton Rail

Strukton was privatised in 1997 and NS (Dutch National Railways) remains its sole shareholder. The company has two divisions: civil engineering & railway maintenance with an annual turnover of about 1 B€ (50 % from railway maintenance) and 5000 employees. Strukton holds a 50 % market share in the Netherlands for railway maintenance; its principle competitors are VolkerRail (30 %) and BAM (20 %). Strukton has worldwide international operations.

Today, as the market gets more and more complex and international competitors are entering the European market, Strukton is developing an international business strategy.

ERTMS maintenance is complex since there are many elements involved in the system (line side equipment, line side electronic units, radio block centres, train borne equipment, GSM-R network elements, etc.). Also, the shorter life cycle of the system (20 years vs. 50 years for conventional signalling systems) increases costs due to a number of ERTMS cost drivers:

- Inspections;
- Data storage & maintenance;
- Hourly labour rates of supplier engineering;
- Higher costs for renewals;
- Shorter time for build-up of competencies/capabilities (lower learning effects);
- Etc.

The current 3 line structure (line 1: field elements, decentralized organisation necessary; line 2: remote control centres, centralized monitoring and remote maintenance; line 3: suppliers’ experts teams, centralized) of ERTMS maintenance is economically inefficient due to the following facts:

- Multiple suppliers at Line 3 with equipment that is often without inter-operability (no standardized interfaces)
- Line 3 suppliers are the big industrial partners of IM’s and RU’s and tend to have competitive bidding advantage through prime contracting
- Line 2 suppliers are remote but highly skilled, but there is a lack of coordination with Level 3 suppliers
- Line 1 maintenance is for regional infrastructure, LEU’s and rolling stock and requires people in the field

Strukton Rail believes that there should be a business case to determine how ERTMS maintenance could be performed in a more economical way (contracting to industrial suppliers vs. contracting to independent maintenance companies). There is a need to shift prime contracting for maintenance away from the industrial suppliers, and for greater coordination between L3 and L2 suppliers. Sharing knowledge lowers costs. There could be significant savings if the second line maintenance was contracted directly to a company like Strukton.

The presentation led to an interesting discussion about the design of ERTMS purchasing that could drive the opening of the market and create better conditions for competition.
Italcertifer

Mr. Luigi Caccamo and Mr. Luca Rimassa from the Italian Notifying Body Italcertifer presented the trackside sub-system and trainborne sub-system testing and certification procedures of ERTMS and highlighted the important issues in terms of delay, costs and organization of certification projects.

Certification is the process through which a “certification body” demonstrates whether specific requirements relating to a product, process, service, system have been fulfilled or not. The “certification body” is a third-party entity, independent from the organisation or the product it assesses, which performs a conformity assessment activity. If a component is covered by the EC declaration of conformity and if a subsystem is covered by the EC declaration of verification, Member States will consider it as being interoperable and meeting the essential requirements.

As a matter of fact, all conformity assessment activities for the EC verification of a subsystem shall begin at the design stage and shall cover the whole manufacturing period, up to the type approval stage before the subsystem is placed into service. Related costs have to be budgeted since the beginning as investment costs and not as belated add-on or extra costs. They will make the system widely accepted, with quality guarantee and interoperable. All in all, certification is for the free movement of people/goods within the European Union.

A Notified Body (NoBo) is a conformity assessment body notified by a Member State to the European Commission and other Member States authorized to carry out third-party conformity assessment tasks under Community harmonised legislation. The European Commission has set up a coordination group of Notified Bodies: “NB-RAIL”, which is a Forum for sharing experiences and exchanging views on the conformity assessment procedures in order to understand better and apply more consistently the Interoperability Directives. Their major activities relate to the drafting and issuing technical recommendations on matters relating to Railway Conformity Assessment and ensuring consistency with European standardisation work: (http://forum.europa.eu.int/Public/i...).

ATOC: cost analysis of on-board equipment projects

Tony Crabtree from ATOK (UK) presented a specific data analysis he has carried out with publicly available information and cost data on some 20 case studies.

In his presentation, he outlined that the UK need cost data to improve the certainty of costs in order to make a budget and to construct and agree the optimum deployment plan in the UK.

ATOC is in particular looking at European on board costs to determine if costs are stabilising and understand the high level costs for the budgets.

In recent discussions with industry, ATOC has identified an interest among suppliers to participate in this data analysis and work together with their clients on strategies to lower the overall lifecycle costs of ERTMS.

Description of the dataset:
• 23 Deployments randomly chosen;
• Austria, Germany, Greece, Italy, Luxembourg, Spain, Switzerland and UK;
• From 1999 order date to 2010;
• From 5 trains to 450;
• Retro fitting and new fitment.
Possible conclusions (to be confirmed by further case studies):

- After about 2006, the market stabilises;
- The price highly depends on no. of OBUs and not no. of trains. (Longer trains need 2 x OBU);
- There is a fixed cost per contract of about €3.4M for the design and certification plus about €1.7M per design for further types in the same contract;
- German fitments seem to be €8M more expensive per contract (certification costs??);
- After deducting the fixed cost of the contract, the cost per OBU is about €160k (the formula is: COST = fixed cost + variable cost * no of OBUs)
- This matches the UNIFE graph handed round our meeting
- in December and it matches present UK budget assumptions
- Emerging data seems to be “converging”

Tony Crabtree also proposed some actions for the next steps:

- Get more data to prove or disprove theory (via UIC ERTMS Benchmark case studies on on-board equipment projects after 2006);
- If the results proof to stabilize, circulate the results to help focus future contracts;
- For the UK:
  - Outline UK plan exists for retro fitment of nearly 2,000 trains over 15 years and new fitment of another 2,000 as they are replaced;
  - Endeavour to put large numbers of trains together into the same contract; maybe five or fewer contracts for all the trains?

To ATOC, the completion of this UIC benchmark work is vital to understand the whole life cost.

3.4. Conclusions of the Task Force, feedback of participants

In a final round of feedback by the participants of the UIC ERTMS Benchmark Task Force on Operation and Maintenance the participants thanked UIC for the organization of the series of 4 meetings on O&M and stressed the importance to continue the work of ERTMS Benchmarking Project.

To the participants, the lessons learned meetings were quite interesting, but they need to be completed with real data exchange meetings in order to fully understand the real implications of different strategies and organization.

Therefore, the initiative of the upcoming data analysis meetings with the case study developers per benchmark pool are highly welcome and should be prepared in detail by UIC and the meeting participants.

Furthermore, new data collection should be carried out in order to invite new participants to the project and update the cost database with recent implementation projects.
UIC proposed to set up a report on the work carried out during the 4 meetings of the UIC ERTMS Benchmark Task Force on Operation and Maintenance that should be circulated among the Task Force Members before publication.

Then, this report should also be part of the updated version of the UIC ERTMS Benchmark Report 2010 that will be ready by March 2010.

Figure 19 Balises’ maintenance
4. Results of the ERTMS/ETCS Cost benchmark

Before presenting a selection of real figures from the ERTMS Benchmark Study 2008-2010 the following aspects are emphasized:

- All results are presented anonymously to prevent individual railways being identified by this study.

- However, as it has already been stated on several occasions in the present report, all figures must be considered in their specific context and can only be fully understood in conjunction with additional information such as:
  - The ERTMS strategy of the railway in question;
  - The technical requirements of the system;
  - Specifications and functional requirements;
  - Infrastructure parameters in general and signalling parameters in particular;
  - The level of experience with ERTMS (learning curve);
  - etc.

- The importance of taking account of context when interpreting results must be borne in mind at all times hereafter as the elements listed above are not presented with the raw figures in this report. A separate report presenting all case studies, project context and company profile has been produced. A complete report presenting all context situations and real data will be provided only to the participants of the different benchmark pools, for confidentiality reasons.

The ERTMS Benchmark Study collected data in three separate benchmark pools and the results are presented over the different life cycle phases for the 3 pools:

*Case study developers 2008 – 2010*

*Figure 20: ERTMS Benchmark Pools and Participants*
NOTE:

It is recommended that the LCC model provided in this study be updated as soon as first experiences of annual operation and maintenance costs are acquired in order to review the first assumptions and improve the quality of the model over time. One occasion for such an update will be the some dedicated in-depth data analysis meetings per benchmark pool organized by UIC in 2011.

The aim of these meetings is to exchange real data of all elaborated case studies within each benchmark pool (L1, L2, On-board) and understand in detail the costs of all phases of the system life cycle in a highly confidential setting (only among case study developers) in order to:

• Exchange real data and compare life cycle costs (according to the UIC ERTMS LCC model);
• Explain cost differences and cost drivers per phase of the life cycle (R&D, CAPEX, OPEX);
• Explore strategies and recommendations to improve cost situations for future projects;
• Complete/Modify the datasets due to new insights (esp. for the O&M phase of the system).

The following steps in order to best prepare these meetings were defined:

• UIC invites the participants of the in-depth data analysis meetings and PMP will provide an updated database for each benchmark pool with some data comparison slides for the meeting;
• Case study developers will be asked in preparation of the meetings to
  - Review their cost data along the UIC ERTMS LCC model and complete/update the figures if any new insights have occurred (especially for the running operation and maintenance costs of the system);
  - Prepare background information and reasoning behind the obtained cost data in order to understand the figures in detail (e.g. labour costs: how many engineers were involved over how many years, doing what kind of developments, etc.; equipment costs: how many equipments of which type, what were the related installation costs, etc.);

These meetings shall help the case study developers understand their own cost situation on each of the cost elements presented in the UIC ERTMS LCC model compared to the costs of their peers. Therefore, it is important to gather as much background information as possible and provide real insights in the levers of cost/performance improvements for future ERTMS projects.

Apart from new case studies carried out, the next version of the UIC ERTMS Benchmark Report 2011 shall integrate the results of these in-depth analysis meetings with the explanation of cost differences and eventually the update of cost data (in particular for the O&M phase of the system).
4.1. ERMS/ETCS Level 1 trackside subsystems

In this benchmark pool 5 case studies were carried out representing about 796 km double track equipped with ERTMS lev.2 systems. The following data sets were analysed:

Total number of evaluated ERTMS/ETCS lev. 1 km by September 2010:

796 km double track

Figure 21: Data Sets ERTMS Benchmark L1 case studies 2010

The global distribution of costs per phase of the life cycle (no costs were available for the disposal phase of the system) is shown in the graph below:

Figure 22: ERTMS/ETCS L1 LCC per phase of the system life cycle

The results of the case studies are presented in detail in the following chapters.
4.1.1. R&D costs

Of the five projects evaluated in this benchmark pool four could provide data for the R&D phase of the system life cycle.

R&D data reported relate in particular to expenditure for ERTMS programme management on the respective network and equipment development and test costs.

In the cases with the lower costs it was confirmed that a large part of the R&D costs were borne by the industrial suppliers who integrated them into their system costs (cf. investment costs case B and C).

Case D seem to be a particularly competitive offer considering both R&D and Investment costs were far below the average of the group.

![R&D cost comparison ERTMS/ETCS L1 trackside subsystems](chart.png)

*Figure 23: R&D cost comparison ERTMS/ETCS L1 trackside subsystems*

4.1.2. Investment costs

The investment costs of the L1 system comprise the following cost elements:

- General investment costs: project management, engineering and system design, certification costs
- Trackside equipment costs: Eurobalises (switchable and fixed), Euroloop, Euroradio infill unit, LEU, etc.
- Taking into service costs: functional tests, training, documentation, etc.

With reference to the investment phase of the system only, the following graph shows the result of the five case studies evaluated in this benchmark pool.
The following chart shows the average distribution of investment costs per cost category:

**Figure 24: Investment cost comparison ERTMS/ETCS L1 trackside subsystems**

**Figure 25: Distribution of Investment costs of ERTMS L1 case studies per category**

### 4.1.3. Operation and maintenance costs

Within this benchmark pool, yearly operation and maintenance costs could be provided by four benchmark participants. Case E could not provide UIC with O&M values.

It is therefore recommended that the LCC model provided in this study be updated as soon as first experiences of annual operation and maintenance costs are acquired in order to review the first assumptions and improve the quality of the model over time.

Nonetheless, the related graph is reported below.
4.1.4. LCC costs

Out of the 5 case studies carried out for ERTMS L1 track-side systems, 4 could come up with complete data sets over the entire system life cycle. The results of these 4 cases are presented below:
Share comparison of each LCC component shows that investment is always the most important phase starting from about 90% of total costs to about 50% at minimum.

4.2. ERTMS/ETCS Level 2 trackside subsystems

In this benchmark pool 7 case studies were carried out representing about 806 km double track equipped with ERTMS lev.2 systems. The following data sets were analysed:
The global distribution of costs per phase of the life cycle (no costs were available for the disposal phase of the system) is shown in the graph below:

![Graph showing the distribution of costs per phase of the life cycle](image)

Figure 30: ERTMS/ETCS L2 LCC per phase of the system life cycle

The results of the case studies are presented in detail in the following chapters.

4.2.1. Different assumptions were used in the four ERTMS/ETCS implementation projects carried out:

- An ERTMS/ETCS project at one railway: R&D was carried out by an extensive team of system engineers including both internal resources and external consultants; the project management philosophy is a hands-on approach; the company considers that a large part of these developments are “sunk costs” for the company and they face high development costs for future projects as well as a result a large proportion of the R&D costs were attributed to this project.

- An ERTMS/ETCS implementation project where the R&D was carried out by a small team of internal system engineers; however, a big part of the development was borne by the industrial supplier as a result a relatively small proportion of R&D was attributed to the project.

- Another implementation project of the same type was carried out by another railway; R&D was already finished and a large proportion of the results were incorporated into the new project as a result nearly no R&D costs were attributed to this project.

Examination of the underlying assumptions thus demonstrates that comparison of R&D costs alone is not meaningful. However, find below the related graph.
To give an indication of the level of average R&D cost that may arise under those different set of assumptions, it amounted to some € 85 K per km of double track line.

4.2.2. The investment costs of the L2 system comprise the following cost elements:

- General investment costs: project management, engineering and system design, certification costs
- Trackside equipment costs: Vital ETCS related management system, Radio Block centres, Interlocking costs, Eurobalises (switchable and fixed), etc.
- Incremental GSM-R costs: network and frequency planning, site acquisition, cabling, extension of BTS
- Taking into service costs: functional tests, training, documentation, etc.

With reference to the investment phase of the system, the following graph shows the result of the four case studies evaluated in this benchmark pool. Case E is considered to be a specific case since it is the fifth implementation project of the same type in the country in question.

NOTE: Since not all case studies could deliver their GSM-R and Interlocking costs, the graph below shows the investment costs without those two elements. The costs can be considered as pure ETCS investment costs.
The following chart shows the average distribution of investment costs per cost category:

![Weighted Average](image)

*Figure 33: Distribution of Investment costs of ERTMS L2 case studies per category*

Compared to the R&D and investment costs of L1 trackside subsystems it is evident that the technological complexity of level 2 systems is much greater, presenting an average value which is about 8 times that of level 1 systems.

### 4.2.3. Operation and maintenance costs

The operation and maintenance costs of the ERTMS/ETCS L2 trackside subsystems participating in the ERTMS Benchmark Study 2009 range from 10 to 30 % of the total LCC. Identifying all future costs of the O&M phase proved difficult for the participating railways as most systems were put into service relatively recently and the level of experience with and knowledge of annual system operation and maintenance costs remains rather low. The challenge of estimating future cash-outs for the entire life cycle of a system and experience with data collection for this benchmark has confirmed these problems.
It is therefore recommended that the LCC model provided in this study be updated as soon as first experiences of annual operation and maintenance costs are acquired in order to review the first assumptions and improve the quality of the model over time.

One occasion for such an update will be the organisation of in-depth data analysis meetings per benchmark pool by UIC in 2011 as described earlier in this chapter.

In general there are two different strategies for maintaining the new European signalling system: 

- Contracting maintenance works to the initial industrial partner;
- In-house system maintenance together with conventional trackside maintenance activities for signalling.

While the first approach provides railways with a good basis for the planning of costs the identification of ERTMS related maintenance activities within railway organisations is not necessarily straightforward as information systems do not always provide these specific costs.

Bearing these limitations and challenges in mind the following graph gives a first indication of the potential levels of O&M costs on a life cycle basis (net present value of a 20 year lifetime with an internal discount rate of 6 %):

![Graph showing operation and maintenance costs for ERTMS/ETCS L2 trackside subsystems](image)

*Figure 34: Operation and maintenance costs for ERTMS/ETCS L2 trackside subsystems*
4.2.4. LCC costs

On a life cycle basis, the datasets of 7 case studies could be collected and provide the following values:

- C: 322,264
- A: 2,026,051
- B: 1,014,629
- D: 300,760
- E: 147,462
- F: 890,614
- G: 672,091

The case studies at the upper end of the cost scale can be considered as the more complex ERTMS/ETCS L2 implementations with infrastructure managers negotiating long term and high quality maintenance contracts. The lower cases will be discussed in detail in the upcoming data analysis meetings in order to make sure the comparability of the data is assured.

The graph below shows another way of looking at the total LCC cost, where it is possible to identify the different phases which constitute the LCC (R&D, Investment and O&M).
4.3. ERTMS On-board subsystems

In this benchmark pool 8 case studies were carried out representing about 346 OBUs. The following data sets were analysed:

60 On-Board Units High Speed Train
20 On-board Units freight locos
22 On-board Units EMU
13 On-board Units freight locos
122 vehicles of different types
50 On-board Units locos
25 On-board Units (locos of different types)
34 On-board Units (ICE 3M)

Total number of evaluated OBU's by September 2010: 346

Figure 37: Data Sets ERTMS Benchmark On-board case studies 2008-2010

The results of the case studies are presented below.

4.3.1. R&D costs

While three of the case studies analysed presented almost no R&D costs for the equipment of their ERTMS on-board units, the three other projects indicate an average value of over 100 K€ per OBU in terms of R&D costs. The total average is reported in the graph below.

Figure 38: R&D costs of ERTMS on-board subsystems
4.3.2. Investment costs

The investment costs for the on-board subsystems comprise the following cost elements:

- General investment costs: project management, engineering and system design, certification costs
- Train borne equipment costs: EVC, TIU, JRU, BTM, LTM, odometer, DMI, fitting costs, etc.
- Taking into service costs: functional tests, training, documentation, etc.

The following table shows the investment costs of the 8 cases analysed in this benchmark pool. Cases D to G were carried out in a quite narrow timeframe by different companies and seem to represent the “best in class”. Case H represents a very expensive On-Board equipment project due to the high system complexity and integration of different parallel systems.

![Figure 39: Investment costs of ERTMS on-board subsystems](image)

The GSM-R costs for on board equipment were generally not identifiable from the participating railways since they had been integrated into overall GSM-R or other contracts. However, based on the analysis of one case GSM-R costs for on board equipment can amount to some €75 K per OBU. GSM-R costs are not presented in the investment graph.

The distribution of investment costs is presented in the following graph:
4.3.3. Operation and maintenance costs

As stated above the data for the O&M phase of the on-board equipment are difficult to be interpreted. The reasons for this are as described above. However, to provide an indication of the cost levels that have been communicated to UIC for this phase of the life cycle the following graph shows the five different values on the basis of a net present value.

It is highlighted again here that UIC recommends updating the LCC model provided in this study as soon as more precise knowledge of annual operation and maintenance costs is available in order to review the first assumptions and improve the quality of the model over time.
### 4.3.4. LCC costs

The following graph shows the overall LCC of the five projects analysed in this study including all costs for R&D, the investment phase and O&M phase of ERTMS on-board subsystems.

The average value in this benchmark pool is approximately € 440 K per OBU. The majority of these costs arise in the investment phase of the system, amounting to an average of € 330 K per OBU.

![Figure 42: Total LCC of ERTMS on-board subsystems](image)

The graph below shows another way of looking at the total LCC cost, where it is possible to identify the different phases which constitute the LCC (R&D, Investment and O&M) and their incidence on the total LCC.

![Figure 43: Total LCC of ERTMS On-board subsystems per phase](image)
4.4. Conclusions of the data analysis

Between March 2008 and December 2010 UIC held some 50 meetings in different venues with different members. From initial discussions on setting up a benchmark project, the development of modular cost structures, the agreement on a methodological approach, discussions about the implementation of SEU models, exchange of experience about ERTMS O&M strategies and finally the real data collection extensive effort has gone into achieving the results first presented in the UIC 2009 report on ERTMS Benchmarking and now in this updated version that contains 7 new case studies to complete the existing data.

However, differences in understanding of the LCC model, difficulties in collecting existing and future cost data and the challenge of dealing with multiple working group members in different locations impose that the data collection process must be improved continuously and that in-depth data analysis activities are required to create a common understanding of the different study participants.

The results presented in the present study are therefore to be seen as milestone in a long journey towards a lasting life cycle costing Benchmark of ERTMS. The project management team hopes that the study will provide UIC Members with the necessary support to reinforce their knowledge about costs within their own organisations and those of their peers. Further real case evaluations and the updating of existing case studies will serve to continuously improve the quality and in-depth understanding of the cost situations.

The following synoptic table gives an overview of the average cost reported in the three benchmark pools. As for infrastructure, the average values are given in €/km of double track. For on board we give the average values in €/on board unit.

<table>
<thead>
<tr>
<th></th>
<th>ERTMS/ETCS Level 1 (€/km double track)</th>
<th>ERTMS/ETCS Level 2 (€/km double track)</th>
<th>ERTMS/ETCS On-Board (€/On-board Unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
<td>20 000 €</td>
<td>85 000 €</td>
<td>55 000 €</td>
</tr>
<tr>
<td>Investment</td>
<td>90 000 €</td>
<td>355 000 €</td>
<td>330 000 €</td>
</tr>
<tr>
<td>Operation &amp; Maintenance</td>
<td>15 000 €</td>
<td>155 000 €</td>
<td>55 000 €</td>
</tr>
<tr>
<td>LCC</td>
<td>125 000 €</td>
<td>590 000 €</td>
<td>440 000 €</td>
</tr>
</tbody>
</table>

*Figure 44: Average costs per phase per benchmark pool (rounded values)*
5. Special case study report: ERTMS Regional

In 2010, UIC and Trafikverket carried out the first economic evaluation of an ERTMS Regional application. Therefore, this chapter presents a dedicated analysis of this project, namely the Västerdal Regional Line.

It is structured to first present the Swedish Transport Administration TRAFIKVERKET and after give a brief overview of the ERTMS migration strategy of TRAFIKVERKET. Västerdal Regional Line project in detail is described in the Case Studies Company Profile document.

5.1. The Swedish Transport Administration TRAFIKVERKET

TRAFIKVERKET, the Swedish Transport Administration, began operations on 1 April 2010. Formally known as Banverket, it is a public authority that takes on responsibility for long-term planning of the transport system for road, rail, maritime and air traffic.

The authority is also responsible for the construction, operation and maintenance of public roads and railways. The Swedish Transport Administration includes activities and operations that before 1 April 2010 were undertaken by the Swedish Rail Administration and the Swedish Road Administration, as well as certain activities that were undertaken by the Swedish Maritime Administration and the Swedish Institute for Transport and Communications Analysis.

The Swedish Transport Administration employs around 6,500 people. The headquarters are located in Borlänge, and there are regional offices in Eskilstuna, Gävle, Gothenburg, Kristianstad, Luleå and Stockholm. The Swedish Transport Administration also has local offices at several locations across the country.

When the Swedish Transport Administration was formed on 1 April 2010, the Swedish Rail Administration, the Swedish Road Administration and the Swedish Institute for Transport and Communications Analysis were phased out.

The new authorities cooperate with LFV (the LFV Group - Swedish Airports and Air Navigation Services), the Swedish Maritime Administration and the Swedish Transport Agency in order to simplify everyday travel by sea, road, air or rail.

- The Swedish Transport Agency stipulates rules and monitors how they are followed, grants permission (driver’s licenses and certificates) registers change of ownership and manages congestion and vehicle taxation.
- The Swedish Transport Administration is responsible for long-term planning of the transport system for road, rail, maritime and air traffic, as well as for building, operating and maintaining public roads and railways.
- Transport Analysis reviews bases for decisions, assesses measures and is responsible for statistics.
- LFV is responsible for air traffic control.
- The Swedish Maritime Administration is responsible for safety and navigability.

The Swedish ERTMS Programme is responsible for the introduction of the new ERTMS traffic management system in Sweden. In accordance with EU Directive 2001/14/EG on the allocation of infrastructure capacity, the levying of fees and charges for use of the infrastructure and the issue of safety certificates, as well as the Railway Act (2004/519), Trafikverket hereby publishes a description of the railway network, or Network Statement, which is administered by Trafikverket.
The purpose of the Network Statement is to provide all stakeholders intending to apply for infrastructure capacity or operate rail services on the Swedish railway network with basic information on the prerequisites for this, with an emphasis on that part of the railway network which is administered by Trafikverket. The Network Statement therefore contains information on:

- Requirements to be met by applicants and principles governing the right to operate traffic, licences, safety certificates, operation agreements, etc.
- Infrastructure, i.e. stations, halts, track gauges, loading profiles, axleload, gradients, electrification, speed, communication systems, etc.
- Regulations governing applications for infrastructure capacity, as well as principles and criteria for capacity allocation
- Fee system including fees and charges for certain individually specified services

ERTMS is a traffic management system that is common to Europe, and is aimed at creating cross-border rail traffic. A system with fewer components and keener competition is expected to lead to reduced costs of both installation and maintenance. ERTMS also enables speeds higher than 200 km/h.

5.2. Network context analysis – TRAFIKVERKET ERTMS migration strategy

The main strategy for ERTMS in Sweden is Level 2

Level 2 offers a larger number of functions and is a more flexible system than Level 1. Among other things, scope is available for reducing the distance between signal points, which results in increased capacity. Moreover, Level 2 is more effective in disturbed situations, such as track circuit faults.

The fact that Sweden is introducing Level 1 at a number of places is mainly because today’s GSM-R cannot manage to handle all of the information needed at stations in which we have very many vehicles at the same time, such as Stockholm C, Malmö C and Hallsberg.

ERTMS Regional, a Level 3 application, is a cost-effective system for lines with low traffic intensity. It is introduced on the present sections of track without line blocking.

Figure 45: ERTMS Regional a first step for ERTMS Level 3
5.2.1. Vehicle strategy

The vehicle strategy forms the basis of the implementation of ERTMS in Sweden and implies that all vehicles using the sections that will be equipped with ERTMS need to be equipped with a special on board equipment. This equipment, consisting of ETCS (European Train Control System), GSM-R and STM (Specific Transmission Module), allows use of lines with the existing ATP system as well as new ERTMS lines.

When ERTMS is implemented on junctions with interregional traffic, almost all vehicles intended for interregional freight and passenger traffic will have to be equipped with ERTMS equipment. Not until then, the upgrading of the infrastructure will commence.

The vehicle strategy has the advantage that when the vehicles concerned have been upgraded, also the infrastructure can be upgraded from a traffic optimization point of view and other criteria implying that the implementation is carried out where the greatest possible benefit can be utilized. With this strategy, new lines do not have to be dual equipped.

The disadvantage with the strategy is that there will be a gap in time between the time when the railway companies have to invest in new vehicle equipment and the time when the companies can benefit from the ERTMS implementation in the infrastructure. On account of this gap in time between costs and benefits, financial support from the European Union is expected.

*Figure 46 Trafikverket regional train in Stockholm*
5.2.2. Infrastructure strategy

The strategy for implementation of ERTMS in the infrastructure can be summed up as follows and in the following order of priority:

1. **New and/or essential route or line upgrades**

   ERTMS will be implemented according to valid requirements when a new railway is built or when existing railways are upgraded to a considerable extent. On special occasions, there may however be relevant to apply for exception to these requirements. In those cases, preliminary work, e.g. implementation of widely spread interlocking system technology, shall obviously be carried out even though ERTMS is not installed. A reason for applying for exception may be in short line sections, which if equipped with ERTMS, cause that a considerable number of vehicles need be equipped with ERTMS at an earlier stage than economically justified.

2. **Routes or lines without signal plants, centralized traffic control and ATP systems**

   When a line without a technical safety system shall be equipped with such a system, ERTMS becomes cheaper than the conventional ATP system. Examples of such lines are Ådalsbanan, Haparandabanan’s new and upgraded parts and Västerdalsbanan. For lines with passenger traffic supervised by way of manual train announcement, there are also requirements for increased traffic safety from Järnvägsstyrelsen (the Swedish Rail Agency). ERTMS is Trafikverket’s solution to meet these requirements.

3. **Routes or lines with major reinvestment needs for existing signal plants**

   In spite of the fact that a signal plant has a very long life cycle, provided that sufficient resources for operation are planned, the plants have to be replaced when maintenance no longer is adapted to its purpose, e.g. on account of high maintenance costs, insufficient system reliability or uncertain spare parts supply.

4. **Routes or lines included in the EU ERTMS corridors (particularly used by freight trains crossing borders)**

   ERTMS will be implemented on the Swedish part of corridor B, i.e. the section Öresundsbron – Hallsberg/Stockholm.

5. **The remaining parts of the routes in the TEN network and after the other parts of the railway network have been equipped (points 1-4)**

5.2.3. Swedish ERTMS implementation plan

Trafikverket has presented to the Government a proposal for a revised investment plan up to 2015 including documentation for further discussion and decision. The revised investment plan includes a proposal for ERTMS migration strategy for Sweden.

Sweden participates in the planning of the implementation of ERTMS on the freight corridor B (Stockholm – Naples) pointed out by the European Union. The implementation plan for ERTMS on the Swedish part of corridor B is based on discussions within the scope of the corridor B work, where other parts of the corridor will be equipped with ERTMS prior to the year 2020.
2008 - 2015

During the period 2008 - 2015, the work on the projects included in Trafikverket’s proposal for revised investment plan for the railway is planned to proceed. The projects in question are Citytunneln in Malmö, including Malmö passenger railway yard, Öresundsförbindelsen, Botniabanan, Ådalsbanan, Haparandabanan and Västerdalsbanan, which constitutes the pilot line for ERTMS-Regional.

Another five or six low traffic lines are planned to be equipped with ERTMS-R. Those lines will be specified in a decision later on. In connection with the start of the implementation of ERTMS on the section Malmö – Hässleholm along Södra stambanan, the implementation of ERTMS on Kontinentalan and Malmö freight railway yard is initiated.

Malmö is an important junction for freight and passenger traffic and the installation of ERTMS in the Malmö region is therefore governing for a very large part of the vehicle upgrading. The vehicles which have Malmö as destination have to be equipped with on board equipment able to manage both ERTMS and the existing ATP system. This is valid even though the main part of the services is performed on sections not yet equipped with ERTMS.

2016 - 2019

ERTMS will be implemented on sections where comprehensive upgrading projects or reinvestment needs in the signal plant justify an early implementation (e.g. Malmbanan).

In connection with Citybanan being built, adjacent parts of the railway transport system in Stockholm are proposed to be upgraded to ERTMS as well.

The implementation of ERTMS is proposed to proceed during this period on the remaining part of Södra stambanan (Hässleholm – Hallsberg) and on Västra stambanan (Hallsberg – Järna – [Stockholm]).

The proposal implies that the Swedish part of corridor B will be equipped with ERTMS in 2020.

2020 - 2025

ERTMS will be implemented on the parts of the railway network where the system entails a capacity improvement, on the parts of the network where entirely new railways are built and where implementation is justified by operational reasons. The lines and routes coming into question during this period are principally Västkustbanan, Norge/Vänernbanan (Göteborg – Kornsjö), Västra stambanan (Hallsberg – Göteborg), Södra stambanan (Mjölby – Katrineholm), Ostkustbanan and Arlandabanan.

2026 - 2030

ERTMS implementation is expected to proceed on the remaining lines in of the TEN networks. Finally, other lines in the railway network will be equipped.

The proposed ERTMS implementation plan implies that the major part of the Swedish railway network will be equipped with ERTMS around 2030. GSM-R has already been implemented on the entire TEN networks. On the low traffic lines where ERTMS Regional is implemented, GSM-R will be installed as well.
5.2.4. Global cost overview

The following table shows the global cost overview of the Västerdal Regional Line ERTMS/ETCS Regional implementation project. These costs will be specified in detail in the following chapter. The total costs of implementation of the Västerdal Regional Line add up to 12.3 M€, which is about 92 K€ per km of (single track) line for the new European signalling system over the entire system lifecycle of 20 years.

This value comes close to the benchmark pool of ERTMS/ETCS L1 projects presented in chapter 4.1.

### Table: Global Cost Overview

<table>
<thead>
<tr>
<th>Phase</th>
<th>Category / sub system</th>
<th>Cost element</th>
<th>Description</th>
<th>Nº of units</th>
<th>Net present value 2008 (6% discount rate)= LCC</th>
<th>% of Total LCC</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub total R&amp;D costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,003,333</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Sub total Investment costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8,281,307</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Sub total Operation and Maintenance costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,956,630</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Sub total Disposal costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Total LCC costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12,241,271</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 47 Global cost overview per LCC phase – Västerdal Regional Line

Compared to other ERTMS implementations, this value seems to be very competitive and UIC is therefore very grateful to Trafikverket to share this specific ERTMS Regional case study in this report.

Project Organisation, Timing & Resources

The Project was organized according to Trafikverket’s standard project phasing plan, using a mix of internal and external resources over 115 months (note: System Development and Installation run concurrently).

- Phase 0: Concept to System Definition 2003-2005 16 months 8M SEK/833 K EUR (100 % internal): 2 FTE
- Phase 1: Risk Analysis to System Requirements 2005-2008 45 months 22M SEK/2.3 M EUR (10 M SEK/1.1 M EUR internal); 4 FTE
- Phase 2: System Development 2007-2011 54 months 170 M SEK/17.7 M EUR (130 M SEK/13.5 M EUR external) (6 FTE)
- Phase 3 Installation 2007-2011 86 M SEK/8.95 M EUR (external 40 M SEK/4.2 M EUR)
- Phase 4 Operation & Maintenance TBD
- Phase 5 Disposal TBD

Some specifications on labour costs:

- Standard Labour rate = 450 SEK/46.9 EUR per hour including 1.45 social costs multiple (salary only), assuming 8 hour days/ 40 hour workweek, excluding all overheads & business equipment (excluding VAT 25 %) → 3 600 SEK/375 EUR per man day, 18 000 SEK/1 875 EUR per man week, 72 000 SEK/7 500 EUR per man month, 864 000 SEK/90 000 EUR par man year
- External consultant rate 900 SEK/94 EUR per man hour or 7 200 SKE/750 EUR per man day
5.2.5. Research and Development costs

The development costs of the Regional were the following:

- 68 K€ for programme management costs (mix of internal/external resources)
- Development, test, engineering costs of 2 M€

![Figure 48 R+D costs Västerdal Regional Line](image)

R&D Costs for the Västerdal Regional Line are apportioned on a per line basis. There are currently 10 ERTMS Regional Line projects, so the Västerdal R&D costs represent 10 % of the total R&D costs. For the 130 km Västerdal Regional single track line the R&D costs are about 16 K€ per km of line and track, or 17 % of the total LCC costs.

### Table: Distribution of R&D Costs

<table>
<thead>
<tr>
<th>Phase</th>
<th>Category / sub system</th>
<th>Cost element</th>
<th>Description</th>
<th>No of units (€)</th>
<th>Net present value 2008 (6% discount rate) = LCC (€)</th>
<th>% of Total LCC</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and Development</td>
<td>Development, prototypes</td>
<td>Program Management cost</td>
<td></td>
<td></td>
<td>67,708</td>
<td>1%</td>
<td>Mix of internal and external system supplier resources, R&amp;D costs apportioned to Västerdal Line on a per line basis (10% of total R&amp;D costs)</td>
</tr>
<tr>
<td>Research and Development</td>
<td>Development, prototypes</td>
<td>Equipment development and test cost</td>
<td></td>
<td></td>
<td>2,015,625</td>
<td>15%</td>
<td>Unable to split costs. Covers development verification, validation and system acceptance of ERTMS Regional Gerenci product (GP) and Gerenci Application (GA), R&amp;D costs apportioned to Västerdal Line on a per line basis (10% of total R&amp;D costs)</td>
</tr>
<tr>
<td>Research and Development</td>
<td>Design and test study</td>
<td>Development and test cost</td>
<td></td>
<td></td>
<td>2,015,625</td>
<td>15%</td>
<td>Unable to split costs. Covers development verification, validation and system acceptance of ERTMS Regional Gerenci product (GP) and Gerenci Application (GA), R&amp;D costs apportioned to Västerdal Line on a per line basis (10% of total R&amp;D costs)</td>
</tr>
<tr>
<td>Sub total R&amp;D costs</td>
<td></td>
<td>Engineering design and test cost</td>
<td></td>
<td></td>
<td>2,083,333</td>
<td>17%</td>
<td></td>
</tr>
</tbody>
</table>

5.2.6. Investment costs

The investment costs of some 8.3 M€ (64 K€ per km of line) represent about 67 % of the total LCC of the ERTMS/ETCS Regional system of the Västerdal Line. The following table shows the distribution of investment costs according to the predefined cost structures defined by the UIC ERTMS Benchmark Study 2008 Working Group.
Figure 49 Investment costs of ERTMS/ETCS Regional system Västerdal Regional Line (L3application)
General costs and engineering

With 19% of the total investment costs the general costs and engineering costs sum up to some 1.6 M€ (12 K€ per km).

The engineering costs were split up to the following elements:

- General engineering and system design costs of the supplier (centralised and decentralised field elements);
- Engineering costs and data preparation for interlockings;
- Engineering and software design for RBC’s;
- Engineering costs for Balises and other field elements;
- Engineering for cabling;
- Engineering for power supply;
- Certification and Quality Assurance

<table>
<thead>
<tr>
<th>Category / sub system</th>
<th>Cost element</th>
<th>Description</th>
<th>No of units</th>
<th>Net present value 2008 4% discount rate) - LCC</th>
<th>% of Total LCC</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>General costs and engineering costs</td>
<td>Project management by supplier (coordination, assistance, risk analysis, etc.)</td>
<td>€ 115,021</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project management by Trafikverket (personnel costs involved in the Regional line project)</td>
<td>€ 751,042</td>
<td>9%</td>
<td>Mix of Trafikverket employees and consultants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>General engineering and system design costs of the supplier (centralized and decentralized field elements)</td>
<td>€ 396,979</td>
<td>6%</td>
<td>Mostly external resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Data preparation and engineering of the interlocking (DIL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineering and software design (general engineering, data preparation, system construction cost, etc.) for RBC’s</td>
<td>€ 429,167</td>
<td>6%</td>
<td>Independent 3rd parties (ISa and Nizpo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineering for Balises and other field elements (points, trackcircuits, signals, other field objects)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineering for cabling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineering for power supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Certification costs/Quality assurance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub sub total: total general costs - investment phase</strong></td>
<td></td>
<td></td>
<td>€ 1,577,188</td>
<td>19%</td>
<td>% of investment costs</td>
<td></td>
</tr>
</tbody>
</table>

Project management costs were split into external project management costs and TRAFIKVERKET internal project management costs. The mentioned certification costs do not include GSM-R related certification costs.
5.2.6.1. ETCS equipment
The hardware costs for the signalling elements of the trackside subsystem of the ERTMS/ETCS Regional implementation on the Västerdal Regional Line add up to some 5.6 M€ (68% of total LCC costs and 43 K€ per km). The main part of these costs is related to construction of the environment around the ERTMS system of about 3.9 M€ (30 K€ per km).

5.2.6.2. GSM-R costs
The GSM-R costs for the Västerdal Regional Line are minimal (3 755 €) and only related to the additional RBC cards for data transmission.

5.2.6.3. Taking into service
This phase represents the last phase of the investment phase. Activities like testing, training of personnel, documentation and other transitional costs are presented in this chapter.
Some 482 K€ were spent on functional tests being the most important cost element of this phase followed by some 268 K€ for education and training. Taking into service represents 13 % of the total investment costs of the system.

5.2.7. Operation and Maintenance costs

In order to calculate the net present value of the future operation and maintenance payments we have taken the following economic boundary conditions into consideration:

- Yearly increase of future payments by 3 % (being 2008 the basis year T0);
- 20 future payments (20 years lifetime of the system);
- 6 % discount rate that represents the time value of money: it reflects the opportunity cost of capital or what it can be expected to earn if the capital is placed on other investments of equivalent risk.

All contractual costs arose in 2005 and were calculated to a 2008 value in order to make cost comparisons between different case studies possible.

![Figure 53 O&M costs of ERTMS/ETCS Regional system Västerdal Regional Line](image)

As we can see from the table above, the total LCC (net present value 2008) of the operation and maintenance phase adds up to some 1.9 M€ (more than 1.8 M€ of which are maintenance costs) representing 16 % of the total LCC.

5.2.8. Phase out

No costs could be identified for this late phase of the life cycle.
## 6. Outlook for the Benchmark study 2011

By the end of 2010, UIC came up with a concrete proposition of activities of the UIC ERTMS Benchmark Working Group throughout 2011 and beyond. The following table presents the Work Streams that have been identified by the UIC ERTMS Working Group and gives an outlook on:

- the main activities to be carried out in each Work Stream,
- the potential timing of realization of each Work Stream
- the possible dates for the ERTMS work group meetings in 2011.

<table>
<thead>
<tr>
<th>N°</th>
<th>Work Stream</th>
<th>Main activities</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On-going project management, coordination and communication</td>
<td>- Project follow ups, Meeting minutes, Press releases, Project presentations</td>
<td>01-12/2011</td>
</tr>
</tbody>
</table>
| 2  | Continuation of the data collection with new implementers within and outside of Europe to enhance the number of datasets (minimum 6 case studies planned) | - Launch of a call for interest in participating in new case studies upon existing WG members, UIC members that are not yet members of the Benchmark Project, non-European ERTMS implementers and evt. non-UIC members having implemented ERTMS (ex. Railway Rolling Stock leasing companies for on-board equipments):  
  - Preparation and coordination of the new case study data collections  
  - Participation and facilitating of the data collection meetings and documentation of the results  
  - Elaboration of the case study reports and integration of the results to the database  
  - Hypothesis of new 6 case studies | 01-06/2011   |
| 3  | In-depth data analysis of all existing and new case studies: “Lessons learned” meetings and deepening of the understanding of costs of all phases of the system life cycle (including explanation of cost differences) | Organize specific meetings for ERTMS/ETCS L1, L2 and on-board equipment with the case study developers in order to discuss the obtained results in a confidential setting and develop strategies in order to lower the total system costs for future implementations:  
  - Preparation of dedicated meetings for the 3 benchmark pools (3 dedicated meetings for ERTMS L1 and L2, 2 dedicated meetings for On Board)  
  - Participation and facilitating of the 3 dedicated meetings in order to  
    ◦ Present the obtained case study results among the peers,  
    ◦ Better understand cost differences and performances  
    ◦ Exchange in a confidential setting on strategies to adopt in order to improve cost/performance situations  
    ◦ Adjust the case study data sets according to necessary harmonization (to make them even more comparable) | 04-12/2011   |
<table>
<thead>
<tr>
<th>N°</th>
<th>Work Stream</th>
<th>Main activities</th>
<th>Timing</th>
</tr>
</thead>
</table>
| 4  | UIC ERTMS Benchmark Workshop 2011 in order to give an update on the results and exchange on the latest developments within the railway sector (October 2011) | - Workshop agenda and invitation, Presentation slides for the workshop  
- Workshop minutes and press release | 10/2011 |
| 5  | Analysis of best ERTMS implementation practices with a focus on project organization, procurement practices, maintenance organization, contracting, organization of knowledge transfer, ... | Documentation of the experiences made by the different railways in terms of ERTMS via the elaboration of a best practice report on ERTMS implementation:  
- Analysis of ERTMS procurement strategies and practices via  
  ◦ the elaboration of a detailed online survey  
  ◦ focused interviews with ERTMS implementers  
- Documentation of the obtained results and elaboration of a comprehensive report on best practices of ERTMS projects | 07-12/2011 |
| 6  | Finalization of the ERTMS Signalling Equivalent Unit Concept for the UIC ERTMS Benchmark Project | The objective of this concept is to shift from cost ratios expressed in €/km to a more accurate €/SEU comparisons  
This concept is very important to give the added value to our analysis. Nevertheless UIC Rail system department thinks that, concerning the ERTMS Benchmark working group, it is better to leave the development of this topic to the signalling experts work groups, and to take into account this concept when it will be defined and recognized by all railway signalling experts’ community | 07-12/2011 |
Figure 54: UIC ERTMS Benchmark Project activities 2011

Dates for the data analysis meetings per Benchmark Pool

- ERTMS On Board Tuesday 10 May 2011
- ERTMS L2 Wednesday 11 May 2011
- ERTMS L1 Tuesday 7 June 2011

Possible dates for further meetings of the UIC ERTMS Benchmark Project

- Tuesday 13 September 2011
- Tuesday 8 November 2011

Annual Workshop:

- Tuesday 4 October 2011 or Thursday 29 September 2011
Agreed cost structures, in the three different pools, which have been used for all case studies developed.

### ERTMS/ETCS L1
**Trackside subsystem cost table**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Category/sub system</th>
<th>Cost element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research and Development</td>
<td>1.1 Research and Development studies, system integration, prototypes and tests</td>
<td>1.1.1 Program Management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2 Equipment development and test cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.3 Adaptation of the existing signalling system</td>
</tr>
<tr>
<td>1.1.1 Program Management</td>
<td></td>
<td>1.1.4 Development and study cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.5 Engineering design and data cost</td>
</tr>
<tr>
<td>2. General costs</td>
<td>2.1 General costs</td>
<td>2.1.1 Project management (coordination, assistance, risk analysis, etc.)</td>
</tr>
<tr>
<td>2.1.1 Project management</td>
<td></td>
<td>2.1.2 Engineering and System design (general engineering, data preparation, signalling engineering, system construction cost, etc.)</td>
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<tr>
<td></td>
<td></td>
<td>2.1.3 Certification costs</td>
</tr>
<tr>
<td>2. Track side subsystem</td>
<td>2.2 Track side subsystem</td>
<td>2.2.1 Eurobalises</td>
</tr>
<tr>
<td>2.2.1 Eurobalises</td>
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<td>2.2.2 Fixed balises</td>
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<tr>
<td></td>
<td></td>
<td>2.2.3 Switchable balises</td>
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<tr>
<td>2.2.3 Switchable balises</td>
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<td>2.2.4 Euroloop</td>
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<td></td>
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<td>2.2.5 Euroradio radio-Infill unit</td>
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<td>2.2.5 Euroradio radio-Infill unit</td>
<td></td>
<td>2.2.6 LEU and interfacing of interlockings</td>
</tr>
<tr>
<td>2.2.6 LEU and interfacing of interlockings</td>
<td></td>
<td>2.2.7 Centralised Command System for Level 1</td>
</tr>
<tr>
<td>2.3 GSM-R for VOICE incremental costs</td>
<td>2.3 GSM-R for VOICE incremental costs</td>
<td>2.3.1 Network planning</td>
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<tr>
<td>2.3.1 Network planning</td>
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<td>2.3.2 Frequency planning</td>
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<tr>
<td>2.3.2 Frequency planning</td>
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<td>2.3.3 Site-acquisition</td>
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<tr>
<td>2.3.3 Site-acquisition</td>
<td></td>
<td>2.3.4 Power supply</td>
</tr>
<tr>
<td>2.3.4 Power supply</td>
<td></td>
<td>2.3.5 Civil works (BTS sites, cables, etc.)</td>
</tr>
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<td>2.3.5 Civil works (BTS sites, cables, etc.)</td>
<td></td>
<td>2.3.6 Negotiation with frequency authority and public operators</td>
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<td>2.3.6 Negotiation with frequency authority and public operators</td>
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<td>2.3.7 Defining Railway Specific</td>
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<td>2.3.7 Defining Railway Specific</td>
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<td>2.3.8 Overlapping border areas</td>
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<td>2.3.8 Overlapping border areas</td>
<td></td>
<td>2.3.9 Definition of handover-areas</td>
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<tr>
<td>2.3.9 Definition of handover-areas</td>
<td></td>
<td>2.3.10 GSM-R Network QoS Tests and other tests</td>
</tr>
<tr>
<td>2.4 Taking into service / Commissioning Trackside subsystem</td>
<td>2.4 Taking into service / Commissioning Trackside subsystem</td>
<td>2.4.1 Functional tests</td>
</tr>
<tr>
<td>2.4.1 Functional tests</td>
<td></td>
<td>2.4.2 Education of any personnel involved in ERTMS</td>
</tr>
<tr>
<td>2.4.2 Education of any personnel involved in ERTMS</td>
<td></td>
<td>2.4.3 Testing tools, equipment</td>
</tr>
<tr>
<td>2.4.3 Testing tools, equipment</td>
<td></td>
<td>2.4.4 Documentation</td>
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<tr>
<td>2.4.4 Documentation</td>
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<td>2.4.5 Transitional costs (incl. removal costs of old systems)</td>
</tr>
<tr>
<td>2.4.5 Transitional costs (incl. removal costs of old systems)</td>
<td></td>
<td>2.4.6 Other costs (insurances, hidden costs, etc.)</td>
</tr>
<tr>
<td>3. Operation and Maintenance</td>
<td>3. Operation and Maintenance</td>
<td>3.1 Operation</td>
</tr>
<tr>
<td>3.1.1 Operation of the system</td>
<td></td>
<td>3.2 Maintenance</td>
</tr>
<tr>
<td>3.2 Maintenance</td>
<td>3.2.1 Inspection and diagnostics of the hardware elements and maintenance activities for hardware elements</td>
<td>3.2.1 Inspection and diagnostics of the hardware elements and maintenance activities for hardware elements</td>
</tr>
<tr>
<td>3.2.2 Inspection and diagnostics tools</td>
<td></td>
<td>3.2.2 Inspection and diagnostics tools</td>
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<tr>
<td>3.2.3 Maintenance activities for software applications</td>
<td></td>
<td>3.2.3 Maintenance activities for software applications</td>
</tr>
<tr>
<td>3.3 Modification</td>
<td>3.3.1 System modifications (software upgradings)</td>
<td>3.3.2 System modifications (hardware upgradings)</td>
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<td>3.3.2 System modifications (hardware upgradings)</td>
<td></td>
<td>4. Phase out, disposal</td>
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<tr>
<td>4. Phase out, disposal</td>
<td>4.1 Disposal</td>
<td>4.1.1 Disposal cost</td>
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<td>4.1.1 Disposal cost</td>
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<td>4.1.2 Cleaning cost</td>
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<td>4.1.2 Cleaning cost</td>
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<td>4.1.3 System residual value</td>
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<td>4.1.3 System residual value</td>
<td></td>
<td>4.1.4 Regeneration/Recycling cost</td>
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<tr>
<td>4.1.4 Regeneration/Recycling cost</td>
<td></td>
<td>4.1.5 Removal of the existing national system</td>
</tr>
</tbody>
</table>

*Figure 55: ERTMS/ETCS L1 - Trackside subsystem cost table*
<table>
<thead>
<tr>
<th>Phase</th>
<th>Category / sub system</th>
<th>Cost element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research and Development</td>
<td>1.1 Research and Development studies, prototypes and tests</td>
<td>1.1.1 Program Management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2 Equipment development and test cost (including costs for system requirements)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.3 Development and study cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.4 Engineering design and data cost</td>
</tr>
<tr>
<td></td>
<td>2.1 General costs and engineering costs</td>
<td>2.1.1 Project management from supplier (coordination, assistance, risk analysis, etc.)</td>
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<td></td>
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<td>2.1.2 Project management from Infrastructure Manager (personnel costs involved in the project management)</td>
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<tr>
<td></td>
<td></td>
<td>2.1.3 Engineering and System design (general engineering, data preparation, signalling engineering, system construction cost, engineering for adaptation of adjacent interlockings, etc.) for interlockings</td>
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<tr>
<td></td>
<td></td>
<td>2.1.4 Engineering for adjacent interlockings (extra costs)</td>
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<tr>
<td></td>
<td></td>
<td>2.1.5 Engineering and software design (general engineering, data preparation, system construction cost, etc.) for RBCs</td>
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<td>2.1.6 Engineering for Balises</td>
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<td></td>
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<td>2.1.7 Certification costs/Quality assurance</td>
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<tr>
<td></td>
<td>2.2 Track side subsystem - hardware material costs</td>
<td>2.2.1 Vital ETCS related Management System (vital part of supervisory system)</td>
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<td></td>
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<td>2.2.2 Radio Block Centres</td>
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<td>2.2.3 Interlocking costs</td>
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<td>2.2.4 Adaptation of adjacent interlockings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2.5 Eurobalises</td>
</tr>
<tr>
<td></td>
<td>2.3 GSM-R for DATA incremental costs (precondition: voice network available)</td>
<td>2.3.1 Network planning (including definition of RBC, RBC numbering)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3.2 Frequency planning</td>
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<tr>
<td></td>
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<td>2.3.3 Site-acquisition</td>
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<tr>
<td></td>
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<td>2.3.4 Extension of the central network</td>
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<tr>
<td></td>
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<td>2.3.5 Extension of BTS and tunnel equipment including civil works, cabling (including project management)</td>
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<td></td>
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<td>2.3.6 Transmission links</td>
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<td></td>
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<td>2.3.7 Power supply</td>
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<td></td>
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<td>2.3.8 Site integration</td>
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<td></td>
<td></td>
<td>2.3.9 SIM card</td>
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<td></td>
<td></td>
<td>2.3.10 Acceptance testing ETCS (QoS tests)</td>
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<td></td>
<td>2.4 Taking into service / Commissioning Trackside subsystem</td>
<td>2.4.1 Functional tests</td>
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<td>2.4.2 Education of any personnel involved in ERTMS</td>
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<td></td>
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<td>2.4.3 Testing tools, equipment</td>
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<td></td>
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<td>2.4.4 Documentation</td>
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<td></td>
<td></td>
<td>2.4.5 Transitional costs (incl. removal costs of old systems)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4.6 Other costs (insurances, hidden costs, etc.)</td>
</tr>
<tr>
<td>3. Operation</td>
<td>3.1 Operation</td>
<td>3.1.1 Operation of the system (key management centre activities)</td>
</tr>
<tr>
<td>3. Operation and Maintenance</td>
<td>3.2 Maintenance</td>
<td>3.2.1 Inspection and diagnostics tools</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.2 Inspection and diagnostics of the hardware elements and maintenance activities for hardware elements</td>
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<td></td>
<td>3.2.3 Helpdesk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.4 Maintenance activities for software applications (configuration management)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.5 Key management activities by industrial supplier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.6 Operational costs for GSM-R</td>
</tr>
<tr>
<td></td>
<td>3.3. Modification</td>
<td>3.3.1 System modifications (software upgradings)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3.2 System modifications (hardware upgradings)</td>
</tr>
<tr>
<td>4. Phase out, disposal</td>
<td>4.1 Disposal</td>
<td>4.1.1 Disposal cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.1.2 Cleaning cost</td>
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<tr>
<td></td>
<td></td>
<td>4.1.3 System residual value</td>
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<tr>
<td></td>
<td></td>
<td>4.1.4 Regeneration/Recycling cost</td>
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<tr>
<td></td>
<td></td>
<td>4.1.5 Removal of the existing national system</td>
</tr>
</tbody>
</table>

*Figure 56: ERTMS/ETCS L2 - Trackside subsystem cost table*
<table>
<thead>
<tr>
<th>Phase</th>
<th>Category / sub system</th>
<th>Cost element</th>
</tr>
</thead>
</table>
| 1. Research and Development | 1.1 Research and Development studies, prototypes and tests | 1.1.1 Program Management  
1.1.2 Equipment development and test cost (including costs for system requirements)  
1.1.3 On-board system integration/prototyping  
1.1.4 Development and study cost  
1.1.5 Engineering design and data cost |
| | 2.1 General costs                                          | 2.1.1 Project management (coordination, assistance, risk analysis, etc.)  
2.1.2 Engineering and System design (general engineering, data preparation, signalling engineering, system construction cost, etc.)  
2.1.3 Certification costs |
| | 2.2 Trainborne subsystem                                   | 2.2.1 EVC (European Vital Computer) = Kernel plus embedded software  
2.2.2 TIU (Unit for information exchange management)  
2.2.3 JRU (Juridical Record Unit)  
2.2.4 Balise Antenna (BTM)  
2.2.5 Loop Antenna (LTM)  
2.2.6 Odometer  
2.2.7 DMI (Driver-Machine-Interface)  
2.2.8 Fitting costs including interfacing  
2.2.9 Specific transmission module (STM) |
| | 2.3 GSM-R for ON-BOARD (incremental costs)                 | 2.3.1 Antenna  
2.3.2 Cabling  
2.3.3 MRM unit on-board  
2.3.4 Install radio (and Euroradio for Level 2)  
2.3.5 Upgrade software ETCS (for Level) |
| | 2.4 Taking into service / Commissioning                    | 2.4.1 Functional tests  
2.4.2 Education of any personnel involved in ERTMS including simulator  
2.4.3 Preparation of maintenance activities  
2.4.4 Documentation  
2.4.5 Other costs (insurances, hidden costs, etc.) |
| 2. Investment |                                                    |                                                                                |
| 3. Operation and Maintenance                               | 3.1 Operation                                                               | 3.1.1 Operation of the system (including the inspection and diagnostics costs) |
| | 3.2 Maintenance                                             | 3.2.1 Maintenance activities for hardware elements                          |
| | 3.3 Modification                                            | 3.3.1 System modifications (software upgradings)                            |
| | 4. Phase out, disposal                                      | 4.1 Disposal                                                                | 4.1.1 Disposal cost  
4.1.2 Cleaning cost  
4.1.3 System residual value  
4.1.4 Reproduction/Recycling cost  
4.1.5 Removal of the existing national system |
| 4. Phase out, disposal                                      | 4.1 Disposal                                                                | 4.1.1 Disposal cost  
4.1.2 Cleaning cost  
4.1.3 System residual value  
4.1.4 Reproduction/Recycling cost  
4.1.5 Removal of the existing national system |
APPENDIX 2 – ERTMS O&M Questionnaire

UIC ERTMS Benchmark Study 2010

TASK FORCE on Operation and Maintenance Costs of ERTMS

Questionnaire

June 2010
Questionnaire

Objectives of the Task Force on O&M costs of ERTMS

These questions shall help the Task Force to define a common goal to be achieved as general objective through the activities carried out by the Task Force.

Q1. Can you define the main goal for the UIC task force on ERTMS O&M in terms of cost savings, better understanding of the ERTMS system requirements, maintenance activities, etc.?

Q2. To what extent has your company set objectives in terms of efficiency or productivity gains (cost savings) regarding ERTMS (for LCC, investment, O&M)?

Q3. If yes, have these efficiency/productivity objectives been quantified? How are they defined?

Q4. Do you consider that the work of the Task Force can help to improve the efficiency of ERTMS maintenance among the Task Force Members?
   a. Yes
   b. No
   c. Other statement: _________________________

Q5. Which objective in terms of cost savings do you consider reasonable within 5 years?
   a. No cost savings possible
   b. 5-10 %
   c. 10-15 %
   d. 15-20 %
   e. 20-25 %
   f. More than 25 %
Interest/Importance of contents of the Task Force on O&M costs of ERTMS

These questions are designed to help us to understand the main fields of interest of the Task Force Members. The results shall help us to prepare the next meetings and set up a working program for the Task Force.

Q6. Please rank the following items from 1 to 5 in terms of importance/strategic interest (1 = very important; 5 = not important).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Ranking (1 = very important; 5 = not important)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERTMS system requirements (expected availability and performance of the system, expected quality of service)</td>
<td></td>
</tr>
<tr>
<td>ERTMS system engineering (engineering rules, functional requirements, redundancies, etc.)</td>
<td></td>
</tr>
<tr>
<td>ERTMS system operation and monitoring (supervision activities, observed quality of service, remote monitoring systems, etc.)</td>
<td></td>
</tr>
<tr>
<td>ERTMS maintenance organization and strategy (importance of the maintenance function in ERTMS, outsourcing vs. in-house, Service Level Agreements, organization of maintenance activities, etc.)</td>
<td></td>
</tr>
<tr>
<td>Maintenance activities (detailed analysis of preventive, corrective, condition-based maintenance activities, performance measurement and indicators of maintenance realisation, management of maintenance teams, logistics, etc.)</td>
<td></td>
</tr>
<tr>
<td>Human resources for ERTMS O&amp;M (competencies, working hours, labour costs, etc.)</td>
<td></td>
</tr>
<tr>
<td>Cost drivers (for operation and maintenance)</td>
<td></td>
</tr>
</tbody>
</table>
**Operation and maintenance regimes**

*These questions shall give first indications on how operation and maintenance of ERTMS is organized among the Task Force Members.*

**System requirements / Availability**

**Q7.** Which level of system availability (standard system requirements) has been set as an objective of your ERTMS system performance for

a. ERTMS/ETCS L1

b. ERTMS/ETCS L2

c. ERTMS/ETCS On-board

**Q8.** What is the impact of non-availability of the system on the rail traffic?
ERTMS system engineering

Q9. What are the main engineering solutions of your ERTMS system that have been applied (redundancies, backup of components, position and n° of LEUs, position and n° of balises, etc.) in order to optimize the balance between the defined system requirements (Q6) and the efficiency of maintenance activities (costs, MTTR, etc.)?

ERTMS system operation and monitoring

Q10. Do you have a monitoring system in place for the trackside subsystem? For the On-board subsystem? A monitoring system that integrates the system components of the on-board and track-side equipment? How is the remote monitoring access to the relevant systems organized?
ERTMS maintenance organization and strategy

Q11. Please describe your ERTMS maintenance strategy in terms of the following aspects:

a. In-house realisation of maintenance vs. outsourcing (to industrial suppliers or maintenance contractors)

b. ERTMS maintenance procurement strategy

c. Development of ERTMS maintenance competencies

d. Software version management

e. Other aspects
### ERTMS maintenance activities

**Q12.** Could you please provide us with the information on the following maintenance activities:

<table>
<thead>
<tr>
<th>Component/Subsystem</th>
<th>Preventive Maintenance</th>
<th>Corrective Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid maintenance</td>
<td></td>
<td></td>
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<tr>
<td>RBC</td>
<td></td>
<td></td>
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<tr>
<td>Balises</td>
<td></td>
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<tr>
<td>Train detection</td>
<td></td>
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<tr>
<td>LEU</td>
<td></td>
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<tr>
<td>Points</td>
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<tr>
<td>On-Board equipment (EVC)</td>
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<tr>
<td>Others</td>
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</tbody>
</table>
Q13. What is the impact of ERTMS on your maintenance manuals and procedures?

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Q14. Do you consider that the ERTMS safety case has an impact on the organization and strategy of maintenance activities? If yes, how did it affect your decisions with regard to ERTMS maintenance?

................................................................................................................................................

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................................................................................................................................................
Organisation of the Task Force on O&M costs of ERTMS

These questions shall help us to understand the group’s objectives or needs in terms of working approach and methodology.

Q15. How do you wish to work together with your peers in this Task Force? Please give us a short statement with your expectations in terms of working approach and methodology.

................................................................................................................................................
................................................................................................................................................
................................................................................................................................................

Q16. Should this task force take a permanent character or should it be a one-time initiative
   a. Permanent
   b. One-time initiative

Q17. If permanent, how often do you consider that this task force should meet per year?
   a. 1 meeting per year
   b. 1 meeting per semester
   c. 1 meeting per trimester
   d. 1 meeting per month

Q18. What kind of managers should attend the task force meetings? Which profiles do you consider valuable contributors to this task force (please specify the types of profiles)?
   a. Maintenance engineers
   b. Procurement experts
   c. ERTMS system engineers
   d. Economic experts
   e. Others: ___________________

Q19. Do you think that field visits are needed in order to better understand the organisation of operations and maintenance of ERTMS?
   a. Yes, absolutely, only what you see with your own eyes can be really understood.
   b. No, field visits are not absolutely necessary to get a better understanding.
APPENDIX 3 – ERTMS O&M List of public presentations

- OM SURVEY RESULT – meeting of 14 of September 2010
- ITALCERTIFER-ON-BOARD-meeting of 8 of February 2011
- ITALCERTIFER-TRACKSIDE-meeting of 8 of February 2011