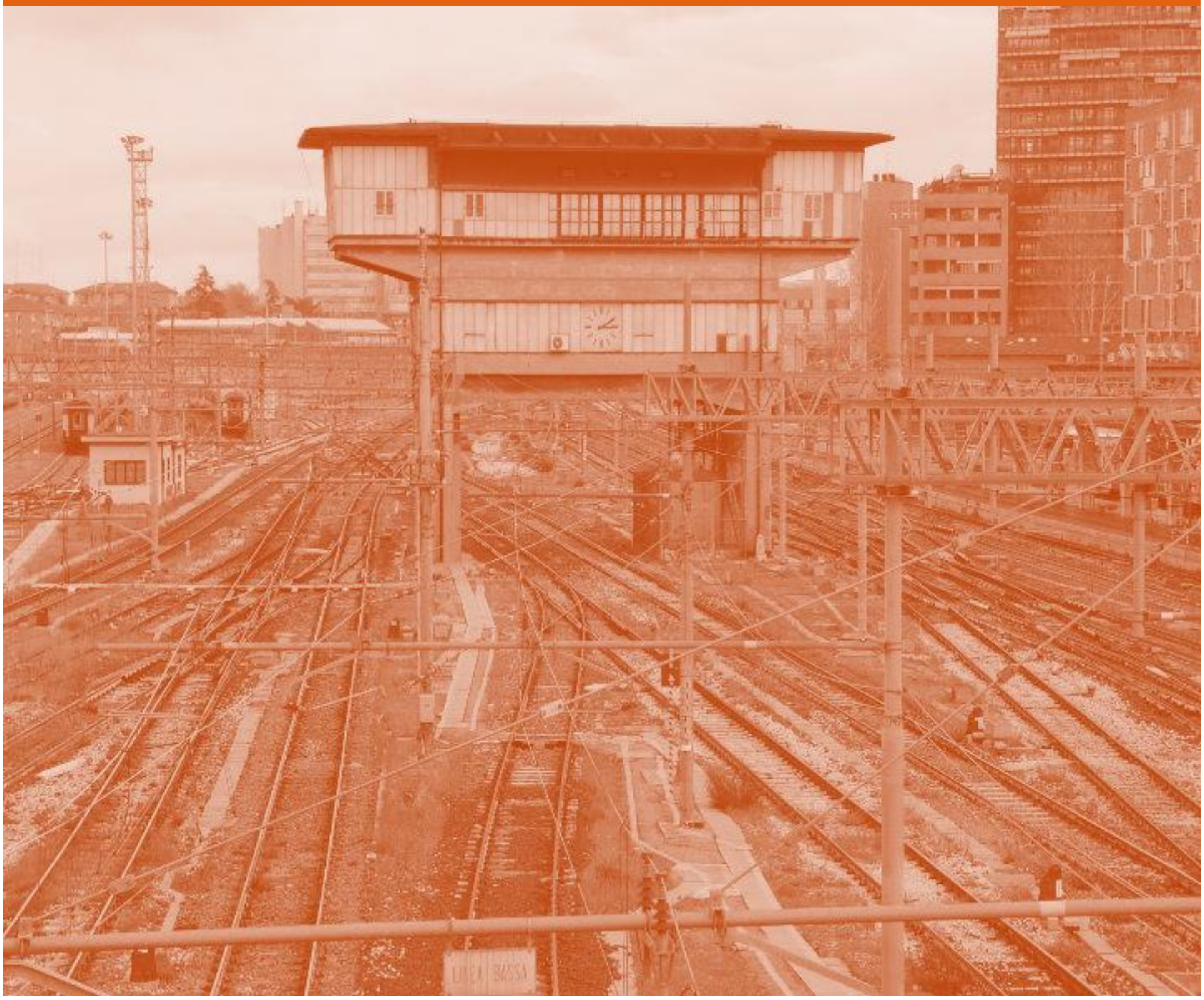
FEASIBILITY STUDY REFERENCE SYSTEM ERTMS

Final Report

Digitalisation of CCS (Control Command and Signalling) and Migration to ERTMS

European Railway Agency - 2017 23 OP



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CONTENTS

EXECUTIVE SUMMARY

Safety is a key issue in rail transport. The backbone for safe train operation is formed by the Control Command and Signalling (CCS) systems. Currently there are more than 20 signalling systems across the European Union, each based on their respective initial rail philosophies and national requirements. Trains used by a national rail company must be equipped with at least one system but sometimes more, just to be able to run safely within that one country. Each system is stand-alone and non-interoperable, and therefore requires extensive integration and engineering effort, driving total delivery costs up, for cross-border traffic. This restricts competition and hampers the competitiveness of the European rail sector vis-à-vis other modes of transport by creating technical barriers to international journeys.

The ERA has launched a study to get an overview of the overall situation of existing interlocking, block systems and traffic management systems, their expected remaining useful life and plans to replace/renew them, as well as of the ambitions of the railways in terms of functionality and architecture for their future CCS-systems (excluding ERTMS). This will assist the ERA in its mid-term and long-term strategic reflection to further improve the conditions for the ERTMS deployment, and on the evolution of the rest of the CCS-system.

As digitalizing CCS- and TMS-systems oftentimes go hand-in-hand with ERTMS-rollout and as the ERA indicated the ultimate goal of the feasibility study was to help the ERA in its mid-term and long-term strategic reflection to further improve the conditions for the ERTMS deployment, it may be considered that this feasibility study was, at least in part, also intended to research whether the non-ERTMS systems (interlocking, block systems, and traffic management systems) posed some sort of impediment to the deployment of ERTMS. Were they (part of) the reason for the slow rollout of ERTMS across the Member States?

Through interviews with a selection of Infrastructure Managers, Operating Companies, and Suppliers, as well as desk research into the current CCS-systems of 10 countries, EU policies and legislation, EU development initiatives, and inspiration from non-rail industry sectors, the following subquestions were researched:

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?
2. What are the relevant future strategies with regard to CCS and TMS?
3. Which actions can be proposed to the ERA that are relevant at EU level in terms of coordination and standardisation activities and beneficial to facilitate the migration to ERTMS, in order to facilitate the objective of the SERA?

The inventory showed a range of country-specific CCS-systems. We have identified digitalisation programmes in all surveyed countries. Some of these have nearly been completed already, others have a farther horizon. The commonalities in these plans include that significant parts of the CCS-system have reached the end of their technical or economic lifespan. All Infrastructure Managers are implementing, have plans to implement, or consider implementation of digital-based CCS-systems, often including the implementation of ERTMS. In order to facilitate interoperability, the current patchwork of country-specific CCS-systems and TMS-systems need to interface. However, as pretty much all (series of) current CCS-components are unique and designed for a specific application in a specific country by the Suppliers that once produced these components and the interfaces between the different components of different Suppliers are tailormade, this means that the interfaces are expensive to specify and build. In short, it is not a technological matter, but an organizational, judicial and consequently an economic issue. In fact, none of the stakeholders mention that non-ERTMS systems (interlocking, block systems, and traffic management systems) in theory pose some sort of impediment to the deployment of ERTMS (or interoperability).

ERTMS and digital CCS-systems comprise a silent revolution in train safety and railway operation. The ICT-based technology commands a different way of thinking. A lack of sufficient knowledge in this CCS-field (as there are too few people skilled in a digital view of its problems and possible solutions) poses difficulties for the Governments and Infrastructure Managers to oversee the risks of implementing completely new, digital CCS-systems. This results in the natural reaction to lean towards 'the safe option' and to continue thinking along the lines of what one knows and can oversee. As a consequence:

- They chose (unwittingly) for a patchwork of quick, short-term solutions. This choice is also based on lower initial costs.
- They translate one-on-one the national, analogue train safety philosophy into ETCS.

Driven by that, it seems hard for governments and Infrastructure Managers to let go of the national, trusted CCS-systems. This again has the following consequences:

- The patchwork of quick short-term solutions hampers the development in the long run. Cheap but fast development may result in troublesome deployment and a shorter than expected lifespan in the long run.
- Instead of one ETCS system, each country develops its own ‘ETCS dialect,’ which is in direct conflict with the goal of swift cross-border traffic of a Single European Railway Area.

As described, currently many choices are made with a short-term focus. Moreover, often they are not made across the entire system of trackside and rolling stock onboard systems, which means that the European Union cannot subsidise the entire system but due to its legislation can fully subsidise public Infrastructure managers for trackside while only partly subsidising private Operating Companies for the onboards. Furthermore, for Operating Companies there is no stimulant pull to gain from other benefits such as cost reduction or capacity increase. This way business cases for these separate onboard and trackside investments will not become profitable and investments are curtailed, averted or postponed.

Finally, all the parties have different drivers for replacing CCS-systems, which generates difficulties to have all head in the same direction towards the same common goal.

In answer to these conclusions, the following recommendations have been discussed in a workshop with amongst others ERA, European Commission, DG Move, UIC, several NSAs, EULYNX, Siemens, TÜV Rheinland, ERTMS Users Group, SBB, and SNCF.

1. Work towards a standardised CCS-system
2. Consider onboard ETCS as part of trackside
3. Support training of workforce
4. Stronger mandates and more resources for ERA

Work towards a Standardised CCS-system
First, it is advised to work towards a standardised CCS-system. The systems known at present in the various countries have evolved over the past decades as a consequence of the possibilities and limitations of the technology of that time. The current state of technology allows for much more. Now may be the right time to revisit this situation and initiate a new signalling and control philosophy, taking into account all these new technological possibilities. This could then be a European philosophy, which could be the future standard. From this standard it follows to ‘configure, not customise.’

A standardized CCS-system consists of 3 elements:

- *A simplified system architecture*.
  Based on all the information gathered and on following the initiatives of EULYNX and the ERTMS User Group (Reference CCS Architecture), it is possible to draw up a theoretically ideal system architecture. This is built on three main principles.
  a. Strict separation between ‘Safety’ and ‘Non-Safety’
  b. Simplify the system architecture
  c. Aim for defining a limited number of interfaces in the simplified system architecture
- *A common (European) set of operational rules.*
  Operational rules in the past have been established based on the current state of the technological possibilities. Given the new possibilities of IT, it is no longer necessary to embed all these rules in hardware, software allows for new and better solutions. It is advised that ERA try to standardise technology, but also harmonise current country-specific processes.
- *And a lingua franca for person-to-person communication.*
  Train safety (through hardware and software, and by communal processes) work fine in standard operation. However, in degraded modes communication between the train dispatchers, train drivers and others become more important. For cross-border transport, this communication will take place between different nationalities. As the aviation industry demonstrates, the safest option is that all staff speak the same lingua franca.

Consider Onboard ETCS as Part of Trackside

The second recommendation is that onboard ETCS should be considered as part of trackside. The deployment of ERTMS serves the higher goal of SERA. However, the fact that Infrastructure Managers and Operating Companies are not a single governmental institution complicate the business case. There is agreement amongst the stakeholders that installing ETCS on a train does not result in a gain in number of passengers or passenger satisfaction. When considering the trackside and onboard as one complete railway system, a sound business case can be made. The example of Switzerland proves that this will in fact result in long-term savings. This in its turn will advance the rollout of ERTMS. As the regulations prohibit subsidies for Railway Undertakings / Operating Companies to finance onboard unit installation, which hinders the rollout of ERTMS, it might be necessary to change European rules and regulations in this regard.

Support training of workforce

As said, the sector is fundamentally changing towards digital leading to a demand for a huge regeneration in skills and knowledge. At present there are educational institutions at national level and some initiatives on international level (e.g. UIC). In order to profit most from these and to ready people for the future needs of the rail sector, a uniform system architecture helps to homogenise the learning process. It helps limit the patchwork not only in technology but hence also in education. ERA can indicate this dot on the horizon, so national training courses can be arranged accordingly, and people will be trained in a future-proof manner. Moreover, in this transformation it is advisable to gain knowledge from other sectors that are experiencing or have undergone a similar movement from analogue technology to a digital basis. ERA can enquire which parties have contributed, where advice was needed, and what regulation was required, i.e. a benchmark study in other industries to acquire lessons learned and best practices. Finally, it is important for ERA to identify together with the Member States whether any training development plans are feasible within the framework of their national personnel and whether they are needed for the timely implementation of ERTMS. ERA can include and provide substance to a training plan in the European Deployment Plans, so that training and rollout continue to be in sync.

Stronger Mandates and More Resources for ERA

Thirdly, it is recommended that there be stronger mandates and more resources for ERA. In order to achieve the first recommendation of a simplified CCS-system a coordinator with authority is needed. The ERA is already set up for this purpose. Within the 4^{th} Railway Package, the framework is already available. However, the ERA is a small agency, with approximately 200 employees and a similarly modest budget. These more ambitious strategies cannot be accomplished within these current resources. Moreover, under the current mandate progress will be slow. Many stakeholders expressed an urgent need for action. However, many parties are involved, all with their own drivers and individual goals, not always matching with goals of the EU / ERA. Decision-making is therefore very slow. A stronger mandate for ERA could speed this up.

At first sight, these recommendations may pose an unrealistic task to achieve. However, this research demonstrates that:

- There is increasingly widespread and growing support from stakeholders to embrace these strategies.
- Though on a smaller scale, the case of Switzerland proves it can be achieved.

An implementation plan, laying out possible steps to achieve such a standardized CCS-system, could be the follow-up study from the conclusions and recommendations of this feasibility study. This should also encompass the relation with current ongoing programs.

1 INTRODUCTION

1.1 EU Context of Feasibility Study

The European Union (EU) is a union of 28 Member States which share political and economic relations. Its main purposes include functioning as a “Single market” through a standardised system of laws that apply in all Member States and ensuring free movement of people, goods & services and capital within its all borders. The free movement of people, goods, and services requires cross border rail traffic (interoperability). Nevertheless, achieving a single European rail market has proven difficult. Europe’s market has been open for rail freight transport since 2007 and for international passenger services since 2010. Directive 2012/34/EU, establishing a Single European Railway Area (SERA), adds important changes to tackle the lack of competition, limited regulation, and low investment observed in the rail market (and interoperability) in the last decade. It applies to the international rail freight and passenger market segments.

One way to achieve this, is having one single rail signalling system in Europe, i.e. ERTMS.[1] Governments / rail Infrastructure Managers have agreed to implementing ETCS trackside on nine Core Network Corridors covering the main transport relations for freight and passenger traffic throughout Europe, as a first step towards eventually substituting all national signalling by ERTMS.

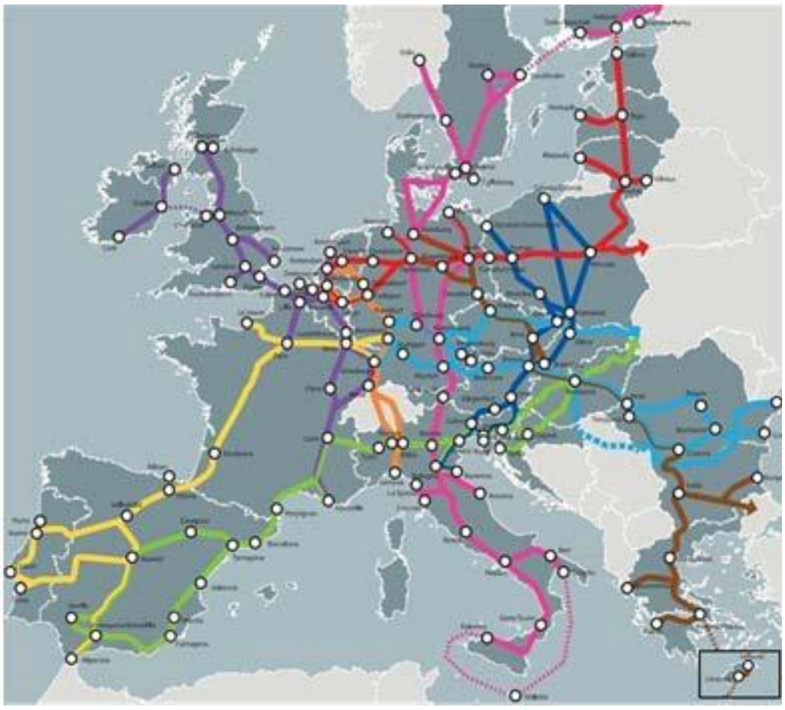


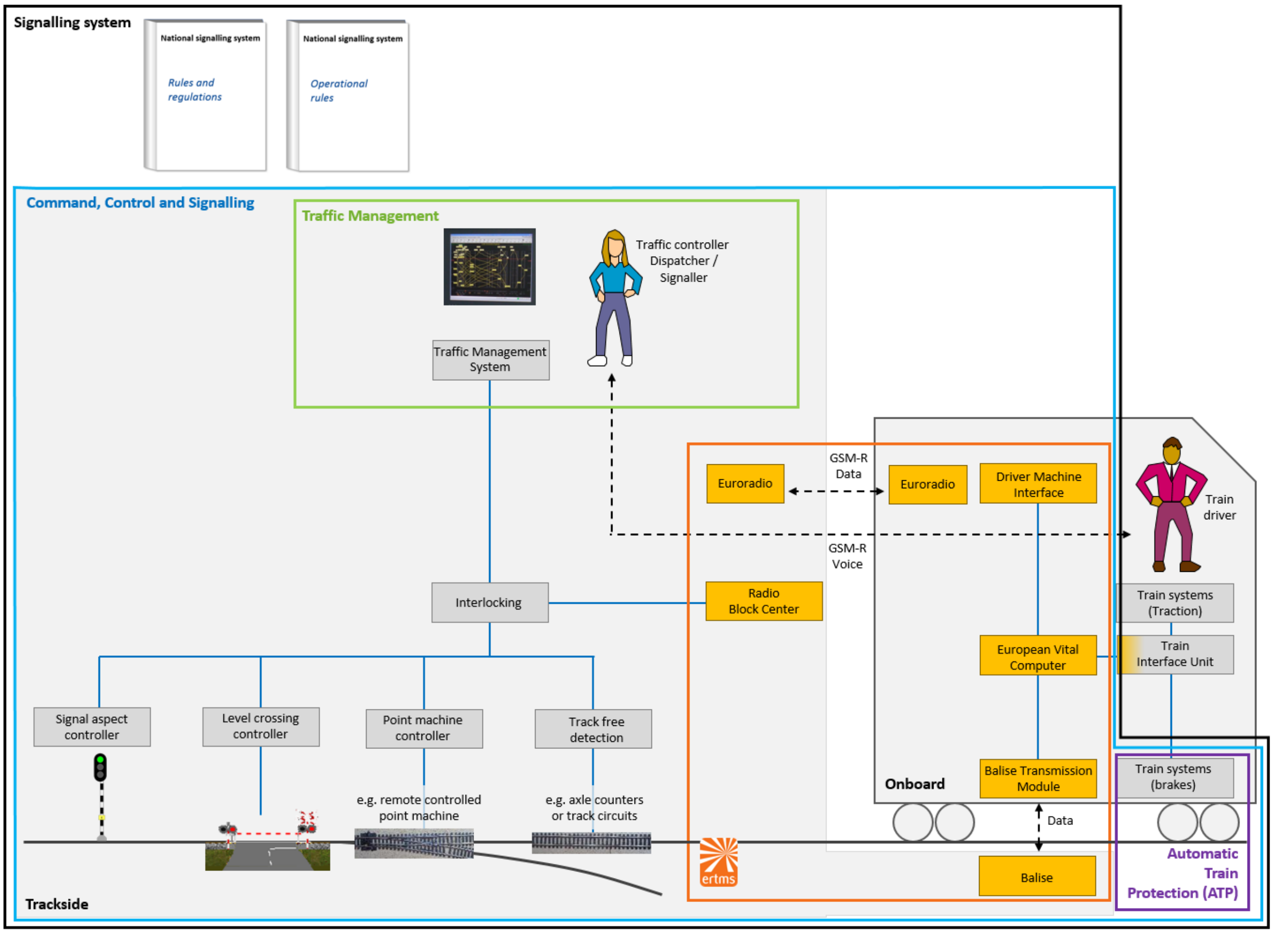
Figure 1 Core Network Corridors for ETCS trackside

1.2 Digitalisation of the Rail Sector

Safety is a key issue in rail transport. Control Command and Signalling (CCS) systems are the backbone for safe train operation. Currently there are more than 20 different signalling systems across the European Union, each based on their respective initial rail philosophies and national requirements. Trains used by a national rail company must be equipped with at least one system but sometimes more, just to be able to run safely within that one country. Each system is stand-alone and non-interoperable, and therefore requires extensive integration and engineering effort, driving total delivery costs up for cross-border traffic. This

[1] According *to ERTMS/ETCS Glossary of Terms and Definitions*, Subset-023, Issue 3.3.0, 13/05/2016, the definition of ERTMS is “Signaling and operation management system encompassing ETCS for the Control Command and GSM-R for voice and data communication. GSM-R is used as radio bearer for ETCS.” We interpret that as a programme and philosophy, for convenience sake. ETCS is “The Control Command part of ERTMS.” We interpret that as the system components, excluding GSM-R. However, the terms are used loosely and sometimes interchangeably in the text, for instance as a result of quoting references or sources.

restricts competition and hampers the competitiveness of the European rail sector vis-à-vis other modes of transport by creating technical barriers to international journeys.



Definition (colours corresponding with squares in figure above)	*Explanation*
Signalling system	*The philosophy (as used by a certain country) to guarantee the safety of train traffic. Specifically, this refers to the systems, design standards, and laws and regulations. In addition to guaranteeing the safety, the signalling system has attained an increasing role in managing and controlling the running of trains.*
Command, Control and Signalling (CCS)	*The CCS is the total of all systems that together guarantee the safety and hence manage the running of trains.*
Traffic Management	*The part within the CCS that manages the running of trains.*
ERTMS	*The position of ERTMS-elements within the CCS.*
Automatic Train Protection (ATP)	*The total of elements and processes that within the CCS ensure that a train is automatically brought to standstill if, for whatever reason, the driver does not respond to the command to reduce speed or to stop. Since the actual functioning of the ATP-system varies per (national) signalling system, it is not incorporated in this figure.*
Track side	*All CCS-elements in the infrastructure or lineside.*
Onboard	*All onboard CCS-elements in the locomotive..*

Figure 2. Schematic overview and legend of definitions

Before the implementation of ERTMS, trains themselves have had at best one basic form of ‘intelligence’ by having an onboard Automatic Train Protection (ATP) System. Nowadays almost all ATP-systems communicate only in one direction – from the infrastructure to the train. The train does not provide feedback to the trackside – not to traffic management nor to other trains. With the implementation of ERTMS Level 2, trains will continuously send actual information like position and speed to the trackside ETCS infrastructure, i.e. the Radio Block Centre (RBC), which makes this data available for traffic management.

The introduction of ERTMS was the first step towards a Single European Railway Area (SERA), both in terms of market and interoperability for trains. However, the harmonised specifications for ERTMS do not cover the systems controlling the conditions of the trackside objects. Moreover, ERTMS must interface with the different interlocking and block systems. This may add complexity and cost as, in a technological sense, the implementation of ETCS-components can be a trigger to renew or replace other parts of the CCS-system, or even make this necessary. This becomes evident from the fact that ETCS-components might not be able to communicate directly with, for instance, the existing variety of interlocking systems. Therefore, the obvious next step – similarly to what is done with ERTMS – is to come to a set of specifications for the non-ETCS-components (at least for the interface) of the CCS-system.

On 20th of June 2017, Commissioner Bulc at the SERA Convention in Brussels presented a draft of the ERTMS Deployment Action Plan which is based on the following objectives:

- Deploying an interoperable and compliant infrastructure;
- Taking the steps to deliver standardised Onboard Unit;
- Driving efficiencies in testing and validation processes;
- Providing focused financial support.

The first bullet supports such possible harmonisation of non-ETCS-components of the CCS-system.

A second motive for focusing on the non-ETCS-components of the CCS-system can be sought in the pervasive digitalisation of the transport sector. All over Europe, railways are investigating and investing in programmes to address digitalisation and big data, for instance Digital Railways in the UK and Digital DB in Germany.[2] ERTMS is based on digital technology and continuous exchange of data. It is probably the first real step in complete digitalisation of CCS-systems. This can be a threat or an opportunity for the railways, and it can represent a driving force for the rail sector to improve its intermodal appeal and competitive position, and to increase its market share.

1.3 Objectives of Feasibility Study

Considering the instigators and context mentioned in the preceding paragraphs, the ERA has launched a study to get an overview of the overall situation. This encompasses the existing interlocking, block systems and traffic management systems, their expected remaining useful life and plans to replace/renew them, as well as of the ambitions of the railways in terms of functionality and architecture for their future CCS-systems (excluding ERTMS). This will assist the ERA in its mid-term and long-term strategic reflection to further improve the conditions for the ERTMS deployment, and on the evolution of the rest of the CCS-system.

As digitalizing CCS- and TMS-systems oftentimes go hand-in-hand with ERTMS-rollout and as the ERA indicated the ultimate goal of the feasibility study was to help the ERA in its mid-term and long-term strategic reflection to further improve the conditions for the ERTMS deployment, it may be considered that this feasibility study was, at least in part, also intended to research whether the non-ERTMS systems (interlocking, block systems, and traffic management systems) posed some sort of impediment to the deployment of ERTMS. Were they (part of) the reason for the slow rollout of ERTMS across the Member States?

1.4 Focus of Feasibility Study

Within the broad context mentioned above, this feasibility study focuses on the CCS-systems and Traffic Management Systems (TMS). It addresses three main questions:

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?

2. What are the relevant future strategies with regard to CCS and TMS?

[2] http://www.digitalrailway.co.uk and https://www.deutschebahn.com/de/Digitalisierung/DB_Digital.

3. Building on the above-generated information, which actions can be proposed to the ERA that are relevant at EU level in terms of coordination and standardisation activities and beneficial to facilitate the migration to ERTMS, in order to facilitate the objective of the SERA?

As the European Union consists of 28 Member States, it would be too extensive a scope to research these questions for all these countries. Moreover, as these questions are not relevant to all Member States, the ERA decided to limit the study to a representative selection of states.

1.5 Report Structure

Chapter 1 describes the background of the study and its objectives. These are translated into a methodology, which is presented in Chapter 2. This chapter describes the scope, methodology, and process followed for the study. Unfortunately, the methodology envisioned at the start of the project did not yield sufficient results. Therefore, the chapter also explains which elements of the methodology were abandoned and how they were substituted.

Chapters 3 presents the overall findings and trends on CCS- and TMS-systems for the various studied states, as distilled from interviews with and documents from Infrastructure Managers. The description of the systems for every Infrastructure Manager are described in more detail in Appendix C.

Chapter 4 presents the general findings from a selection of Operating Companies.

Chapter 5 describes in similar fashion the results for the Suppliers.

Development initiatives, which are developed in a cooperation between an EU institution and a combination of several private parties such as EULYNX and Shift2Rail, are treated in a separate Chapter 6.

Chapter 7 presents sources of inspiration from non-rail industry sectors, where digitalisation has also had extensive impact on development and innovation of products.

It proved impossible to focus on CCS- and TMS-systems in the EU without considering the EU-policies and legislation on interoperability. Chapter 8 elaborates on these.

Chapters 9 and 10 outline the conclusions and recommendations for current and future strategies.

The appendices A and B include a list of abbreviations and references to all the documentation consulted.[3] As mentioned above, Appendix C elaborates on the CCS- and TMS-systems of the Infrastructure Managers in more detail.

[3] Information is based on Arcadis expertise if no in-text reference is provided.

2 SCOPE AND METHODOLOGY

This chapter describes the process that was followed and methodology used to reach our conclusions on the study and its objectives. The outcome of such study generally strongly depends on the cooperation of stakeholders, data that could be retrieved, and flexibility of the team to deal with unforeseen circumstances. From this perspective, the methodology was subject to regular revision and modification on an as need basis. Our expert team have periodically reviewed the current methodology and discussed this with ERA. Within the available timeframe and budget, the mitigating measures were implemented to ensure that the methodology effectively provided answers for the research topics. As a result, the scope and interviewed parties have shifted over the course of the study as well.

2.1 Methodology

As stated in paragraph 1.4, the study consisted of 3 main questions:

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?

2. What are the relevant future strategies with regard to CCS and TMS?

3. Building on the above-generated information, which actions can be proposed to the ERA that are relevant at EU level in terms of coordination and standardisation activities and beneficial to facilitate the migration to ERTMS, in order to facilitate the objective of the SERA?

In order to answer these questions in an adequate manner, the following iterative process was followed. The first steps revolve around gathering information, including various perspectives. This generated much raw data, some of it very relevant to the research questions, others more in a broader context. This can be considered the stage of diverging of the information. From step 4 onwards, the information was funnelled to the most relevant points, in order to draw conclusions and formulate recommendations.

Figure 3: Overview process

Step 1 Start-up

In the start-up phase of the project, there was a Kick-off meeting with ERA. In this meeting, the scope and methodology, as suggested at tender stage, was further refined.

Step 2 Desk Research

In order to answer the first part of Question 1, a desk research was commenced. We used public policy documents and publications for this. As findings in steps 3 and 4 sometimes provided entry to new information and insights, this process step was iterated several times.

The first findings of step 2 were tested and verified within the Arcadis project team in internal workshops and review sessions.

Step 3 Reflection and Verification

To reflect on the information that was gathered in the desk research, to verify this information, and moreover to acquire additional insights and perspectives, a number of stakeholders was interviewed in step 3. The interviews mainly taught us what the problems and bottlenecks of the current system (question 1) were and how future strategies were shaped (question 2).

The interviewed stakeholders were mainly Infrastructure Managers. To develop a broader understanding, Train – and Freight - Operating Companies and other rail institutions were also consulted. The development of questionnaires has assisted in these interviews and served as a guideline during the interviews. The results of these interviews were discussed several times internally at Arcadis through expert sessions.

The interviews repeatedly led to iterations, which led to revision of the researched scope and methodology (step 1), subsequently leading to (additional) desk research (step 2).

Additionally, the gathered information and initial conclusions were verified by sharing these with other parties in the form of hypotheses. For this, a second questionnaire was developed, which was shared with the interviewed parties. Its intention was to, on the one hand, achieve more depth of information and, on the other hand, verify our preliminary insights.

Step 4 & 5 Bringing together of Information & Conclusions and Recommendations

After step 3 the phase of collecting information was complete, all available data, insights and perspectives were brought together. In order to translate our findings, insights, and conclusions from desk research and interviews with stakeholders to solid advice on future policies and strategies, several workshops within Arcadis were held. Based on workshops, both internally with Arcadis' experts and externally with stakeholders, the problems identified in current systems and ideal future strategies were discussed.

> *Example:*
> *From the desk research and the first questionnaire arose the idea that SBB (Switzerland) has an advanced implementation strategy for digital CCS and TMS and a comprehensive digitalisation programme. To make optimal use of the knowledge surrounding this strategy in this study, an additional workshop with SBB and ERA in August was held.*

We discussed the information and issues with representatives of (international) experts within the specific discipline and accompanied them with recommendations.

Moreover, in September 2018 a workshop was held with stakeholders (amongst others ERA, European Commission, DG Move, UIC, several NSAs, EULYNX, Siemens, TÜV Rheinland, ERTMS Users Group, SBB, SNCF) to:

- Verify the gathered information,
- Verify conclusions,
- To test our draft recommendations.

Over the course of the study, several modifications of the list of interviewed stakeholders occurred for various reasons. Moreover, along the way new parties presented themselves. In order to draw broad conclusions and create a solid (information) base, these were added to the research.

2.2 Scope Addition

In order to help the ERA in its strategic reflection to further improve the conditions for the ERTMS deployment, and to involve the rest of the CCS-system, this feasibility study was launched to get an overview of the overall situation of existing interlocking, block systems and traffic management systems, of their expected remaining useful life, of plans to replace/renew them, and of the ambitions of the railways in terms of functionality and architectures for their future CCS-systems (excluding ERTMS).

As stated above, the original scope of this feasibility study excluded ERTMS. However, it proved almost impossible to address non-ETCS components of the CCS-system without considering ERTMS itself. This may have been the result of simple facts such as having to deal with interfaces between ETCS- and non-ETCS components when implementing a migration to ERTMS. Also, the deployment of ERTMS could actually lead to or require replacing some non-ETCS components of the CCS-system. Conversely, necessary replacement of essential components of the CCS-system, for whatever reason, may be an argument to switch to ERTMS.

Therefore, ERTMS and the migration to ERTMS are considered in the following chapters as well.

2.3 Wider Pallet of Interviewed Parties

In line with our initial approach Infrastructure Managers from a selection of 8 countries in Europe were contacted. However, as these did not yield the expected result, the scope was extended to Infrastructure Managers from other countries, Operating Companies, the European Commission, and other (European) development initiatives as well.

2.3.1 Infrastructure Managers

Arcadis and ERA agreed on studying 8 countries initially. These were:

- United Kingdom
- Switzerland
- Germany
- France
- The Netherlands
- Denmark
- Poland
- Romania

In order to interview the Infrastructure Managers from these initial 8 countries, multiple contact persons from our own network and from ERA were contacted at the start of the project. During the stage of performing desk research and obtaining interviews with representatives, the selection of relevant Member States was subject to change. This shift was mainly caused by two reasons:

1. Availability of representatives,
2. and the increased emphasis on the existence of digitalisation projects within the Member State (and more specifically the Infrastructure Managers).

The first change occurred during the kick-off of this study. Both the ERA and Arcadis agreed that Belgium and Australia would be a valuable addition to the scope. Though not a Member State of ERA, Arcadis proposed to include two states in Australia, New South Wales and Queensland,[4] in our investigation for the

[4] Australia, much like the United States of America (USA), has a federal government and independent states. These states can make laws and decisions about what happens within its borders. Australia is divided in six states, each with their own rail managers.

following reasons:

- Australia is a fast growing and young continent, investing significant funds in extending and upgrading their railway networks. In fact, both states are planning to implement ETCS on a broad scale within the next few years and are therefore also having a closer look at their entire CCS-system.
- Both states have their own rail infrastructure, which is even less standardized than in Europe.
- Australia is not bound in any way to European regulations and legislation. Therefore, they are presumably open to new concepts for CCS-systems and TMS.

Henceforth, ERA agreed that it would be interesting to understand the choices made by these states, (as these could conceivably be inspirational to Europe) and worth including in the study.

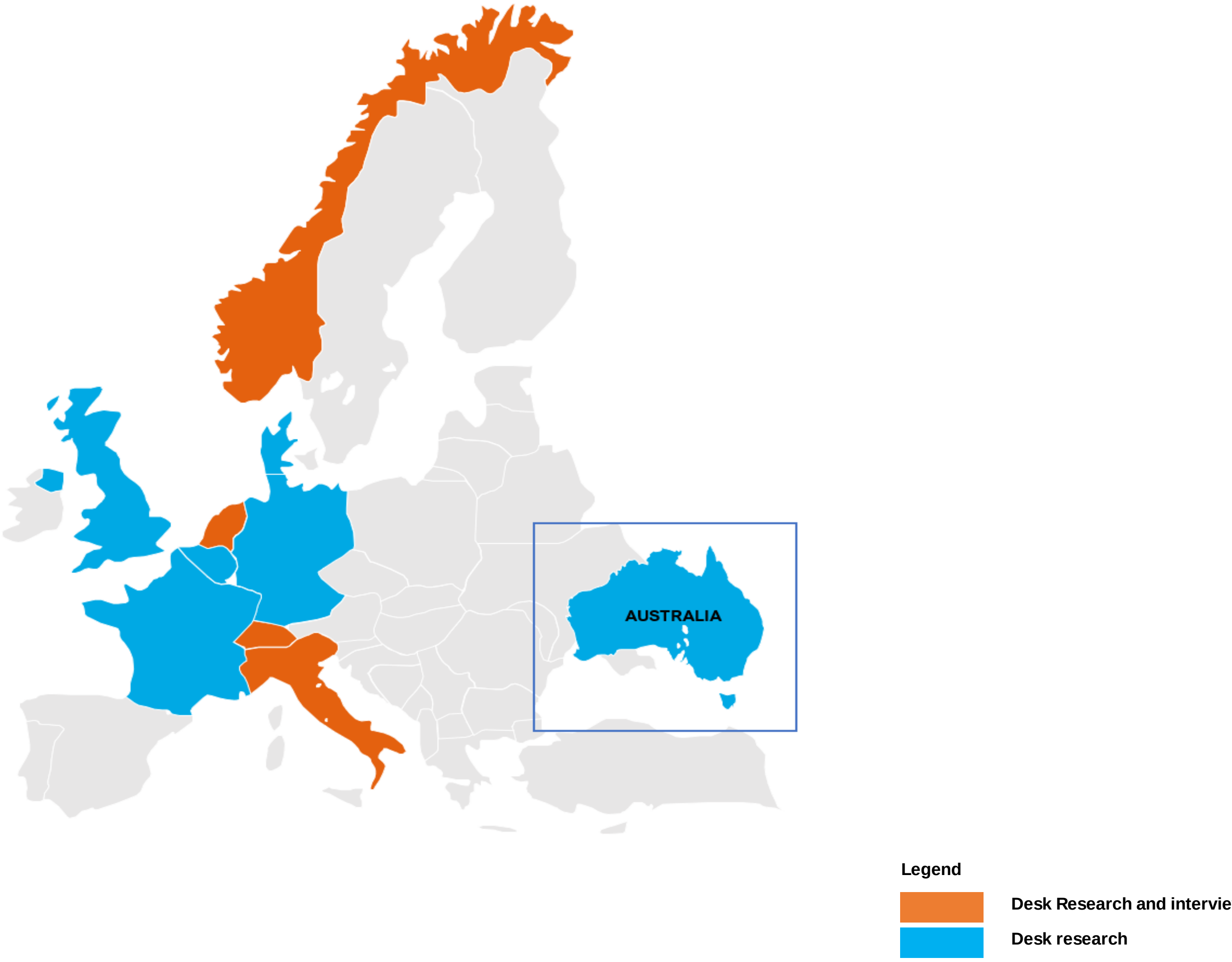


Figure 4: Geographical scope of the study

A second change was necessary after a meeting of the European Infrastructure Managers (EIM) in Brussels on 14 February 2018. Arcadis presented the goals of the feasibility study and asked for cooperation of the various representatives that were deemed the contacts who could answer the study's questions. Although the EIM does not represent all European Infrastructure Managers, the organisation represents the United Kingdom (Network Rail), France (SNCF), the Netherlands (ProRail), Denmark (Banedanmark) and Belgium (Infrabel) from our selected countries.[5] Unfortunately, the EIM members were sceptical about the approach and goal of the study and acted reserved in their cooperation. They requested more information about the goals and (long-term) strategy of the ERA with regard to this feasibility study, ERTMS, and CCS.

[5] Germany (DB Netze), Switzerland (SBB) are not members of the EIM.

Consequently, ERA as well as Arcadis joined the next EIM meeting to answer their questions and again request their cooperation. This yielded the following results:

- The EIM suggested to distribute the questionnaire Arcadis had developed. Based on this questionnaire, the EIM-members could compile initial information and suggest one or more contacts for an interview/workshop elaborating on this information. The questionnaire was forwarded the week after the meeting.
- From the selected countries, ProRail (the Netherlands) and Network Rail (United Kingdom) initially responded positively. Additionally, Bane Nor (Norway) and Adif (Spain) also were positive.
- After the meeting Infrabel (Belgium) and Banedanmark (Denmark) responded that cooperation was not likely due to reorganisations and busy agendas.
- The EIM members pointed out that much information on harmonisation of interlocking, CCS and TMS could also be found at the European development initiatives EULYNX and Shift2Rail.

To compensate the loss of two initially selected countries (Belgium and Denmark) and their Infrastructure Managers, Bane Nor (Norway) and Rete Ferroviaria Italiana (Italy) were added to the study.

Summary of Selection of and Information from Infrastructure Managers

From the start of the feasibility study, a desk study for all relevant countries was undertaken. This would serve as basis for the inventory of the current CCS- and TMS-systems, to be discussed and verified in the interviews with the contacts of the relevant countries. As Arcadis only conducted interviews with a limited number of Infrastructure Managers, the information for some countries is restricted to desk research only.[6] This means that some documentation which originated from unofficial sources could not be used, that the findings from internet sources, other documentation, and knowledge of our experts for those countries have not been verified in interviews, and that the results for those countries are therefore considered to be the view of Arcadis rather than the view of the local Infrastructure Manager. Below the results of the quest for information is summarised in a table.

Country	Infrastructure Manager	Type of information
Australia	TfNSW	Desk research
Australia	Queensland rail	Desk research
Belgium	Infrabel	Desk research
Denmark	Banedanmark	Desk research
France	SNCF Réseau	Desk research
Germany	DB Netze	Desk research
Germany	Bundesministerium für Verkehr und Digitale Infrastruktur	Information received and interview
Italy	RFI	Information received and interview
The Netherlands	ProRail	Information received and interview
Norway	Bane Nor	Information received

Table 1: Overview of Infrastructure Managers

[6] Desk research refers to internet sources, other documentation, and knowledge of rail experts in the various Arcadis‘ offices. See for all consulted documentation Appendix B.

2.3.2 Suppliers

Arcadis identified 9 suppliers of (significant components of) ERTMS and CCS and TMS-systems in total. From a rail perspective, the established names, Alstom, Bombardier, Siemens and Thales are huge players. Hitachi and Ansaldo STS also play a substantial role. Huawei, CAF and AngelStar/Mermec are relatively new to the market. We spoke to the following parties:

Supplier	Type of information
Angelstar/Mermec	Desk research and interview
Bombardier	Desk research and interview
CAF	Interview
Siemens	Desk research and interview
Thales	Desk research and interview

Table 2: Overview of Suppliers

2.3.3 Operating Companies

Though the information provided by the Infrastructure Managers was limited, it did yield some valuable insights with respect to the potential benefits and strategies by Operating Companies regarding the use of ERTMS- and non-ERTMS-systems. In light of this, Arcadis adapted the methodology to include an interview with a passenger and a freight carrier. As a representation of these, one passenger and one freight operating company, as well as one freight transport representative organisation were contacted:

- NS (the main passenger train operating company in the Netherlands)
- DB Cargo (a main freight operating company in Europe)
- RailGood (a lobby organisation representing the rail freight transport sector in the Netherlands)

Country	Operating Company	Type of information
The Netherlands	NS	Information received and interview
The Netherlands & Germany	DB Cargo	Interview
The Netherlands	RailGood	Information received and interview
Other	ERFA	Desk research

Table 3: Overview of Operating Companies

2.3.4 Other Institutions

As mentioned above, the EIM suggested to include research of several European development initiatives. After consultation with the ERA, Arcadis included these in the research.

Moreover, the interview with ProRail also identified a recent study by the European Commission as a relevant report. After consultation with ERA, Arcadis contacted the European Commission as well.

Finally, one of the interviewees suggested a similar development initiative in the automotive and aviation industry, which were looked into.

Other	Type of Information
Railway Industry Development Initiatives	
EULYNX	Desk research
Shift2Rail	Desk research
European Commission - EU DG MOVE	Desk research
Non-Rail Industry	
AUTOSAR	Desk research
IMA	Desk research
ICT	Desk research

Table 4: Overview other institutions

2.4 Timeframes

In this feasibility study, the focus was (initially) on three predefined ‘timeframes’:

- Short term < 5 years
- Middle term ≈ 10 years
- Future and long-term opportunities > 20 years

Over the course of the research, the timeframes proved to be too strictly defined. The interviewed parties did not recognize themselves in these definitions and timeframes. Moreover, the plans and ambitions of the various parties could not always be ascribed to a strict timeframe, often it could be viewed as more of a continuum spreading over more than one category. Thus, these timeframes were demarcated less strictly and adapted their names. In the remainder of the research and in this report, the following definitions have been used:

Current Situation
This timeframe describes the current situation, including already initiated changes / transitions. It has not been taken into account whether these transitions / changes could be realised within a period of 5 years. This timeframe ties in with the first research question.

Plans & Ambitions
Plans concern developments which have already been through the decision-making process and are likely to be executed, but are however not in place yet.

An ambition is a goal on the horizon, something to work towards in the future. These can range from plans that have not been decided on to ideas on how future CCS-systems can be envisioned. These visions may be very conceptual, to give direction to future developments.

This timeframe ties in with the second research question of this study.

3 INFRASTRUCTURE MANAGERS

The Infrastructure Managers purchase, develop, implement and maintain trackside CCS- and TMS-elements. This chapter presents the findings and trends on CCS- and TMS-systems for the various studied states, as distilled from interviews with and documents from the Infrastructure Managers, on both their short-term and longer-term strategies.

3.1 Findings and Trends Infrastructure Managers

Taking inventory of the CCS- and TMS-systems of the Infrastructure Managers, a general trend can be discerned. This trend is described in this chapter. The underlying descriptions of their systems is described in more detail in Appendix C.

Drivers

In order to understand how the current situation emerged and why Infrastructure Managers embrace the plans and ambitions they have, it is important to understand the drivers. The Infrastructure Managers have listed drivers in their ambition for their plans and strategies. Below a small selection:

- Recent technologies enable the possibility to have intelligent conflict/delay identification and can improve the efficiency of TMS. More in general: a new architecture can provide more room for innovative TMS systems, while simplifying safety components.
- Track renewal is a push-factor for replacing CCS-systems. Track layout changes can cause large modifications to the TMS and Interlocking. Not a reason in itself, but it can be an incentive.
- Renewal offers a chance to decrease the variety of existing systems (create a mature, simple reference design) and can thus lower maintenance costs.

Looking at these and other motivations, they all have in common that national Infrastructure Managers wish to reduce their (maintenance) costs and improve their track capacity (more trains per track by avoiding building additional new tracks to meet the demand for more trains). Specifically, for the centralised train control (CTC) centres, ERTMS and digitalisation these translate as such:

- Drivers for ERTMS (in case of Level 2) – Reduction of the amount of trackside equipment and increase of track capacity.
- Drivers for CTC – More efficient traffic management and reduction of the number of staff.
- Drivers for ‘digitalisation’ of CCS components – Reduction of the number of or complete replacement of old, costly, obsolete analogue technology. Moreover, a promotion of ‘state-of-the-art’ equipment to attract young people to join the railway industry (especially dispatchers) in this time of technical staff shortages.

Clearly, these drivers have helped shape the respective Infrastructure Managers’ plans and programmes.

Another driver is dictated by government, an important financial stakeholder of any plans and programmes. The European Commission issued a TSI that obliges Member States to implement ERTMS on (re)new(ed) tracks. The European countries have committed themselves to this. However, implementation of ERTMS itself is not the biggest challenge governments are facing. National governments are also directed by regional and municipal governments and public opinion. The biggest challenge in rail and public transport is to find a solution to the increased traffic demand around the big economic centres. To meet this demand, significant investments are needed. Unfortunately, the new CCS-systems do not automatically lead to more capacity or service to passengers (seats on the train) or to new stations. Moreover, these investments also come hand-in-hand with political demand for more attention to compensate the negative effects of more train traffic, such as the reduction of noise levels. This means that the political climate has significant influence on the extent of the scope of and the speed with which these ERTMS- and CCS-programmes are undertaken.

3.1.1 Current Situation CCS

This paragraph provides an overview of the country-specific situation of existing interlocking, block systems and traffic management systems, and of their expected remaining useful lifetime. Accordingly, these provide the Infrastructure Managers' answer to the first research question of this feasibility study:

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?

Traffic Management Systems (TMS)
Almost all railways have had a multitude of Traffic Management Systems (TMS) to guide trains throughout their infrastructure. The routes are set in various ways – from 'manually set the route for every train by hand' to a completely digital system with automatic route setting.

Manual route setting is generally considered to be out of date. Though this is not a technical but rather an operational or personnel issue, as there is no longer technical support (knowledge and spare parts) available from Suppliers and the knowledge of these older systems is becoming scarce. However, there is a technical relation with the equipment. Manual setting of routes is usually done on equipment which is based on relay or mechanical technology. Considering that the control and safety layers of these systems are usually closely connected, the (remaining) technical lifespan is described below underneath the paragraph Interlocking.

Most Infrastructure Managers are moving towards digitalizing their TMS to cut costs and increase capacity. As shown in the figure below some countries have fully digitalized their TMS and most will be digitalizing their TMS within five years.

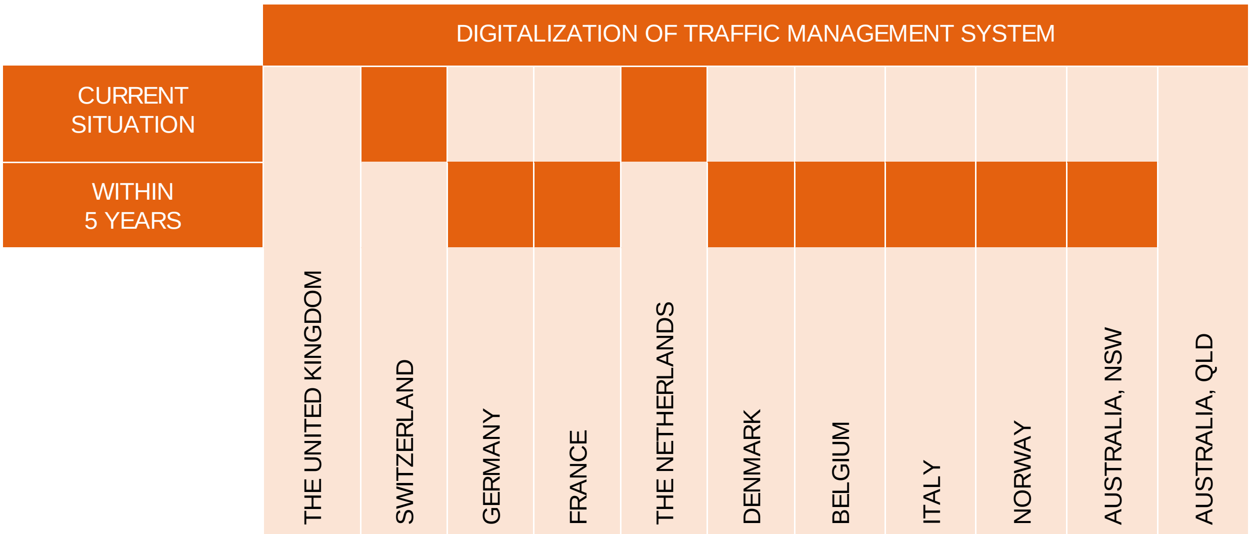


Figure 5: Overview of Digitalization of Traffic Management Systems

Most Infrastructure Managers are traditionally organised in small, decentral traffic control units. In order to gain efficiency, many move to Centralized Traffic Control (CTC) centres. Some countries are down to a limited number of Traffic Control centres like the Netherlands and Queensland, Australia. Most Infrastructure Managers are planning to reduce their Traffic Control centres in the same way in the very near future. Denmark is in the process of rolling this out as part of the ERTMS-roll out.

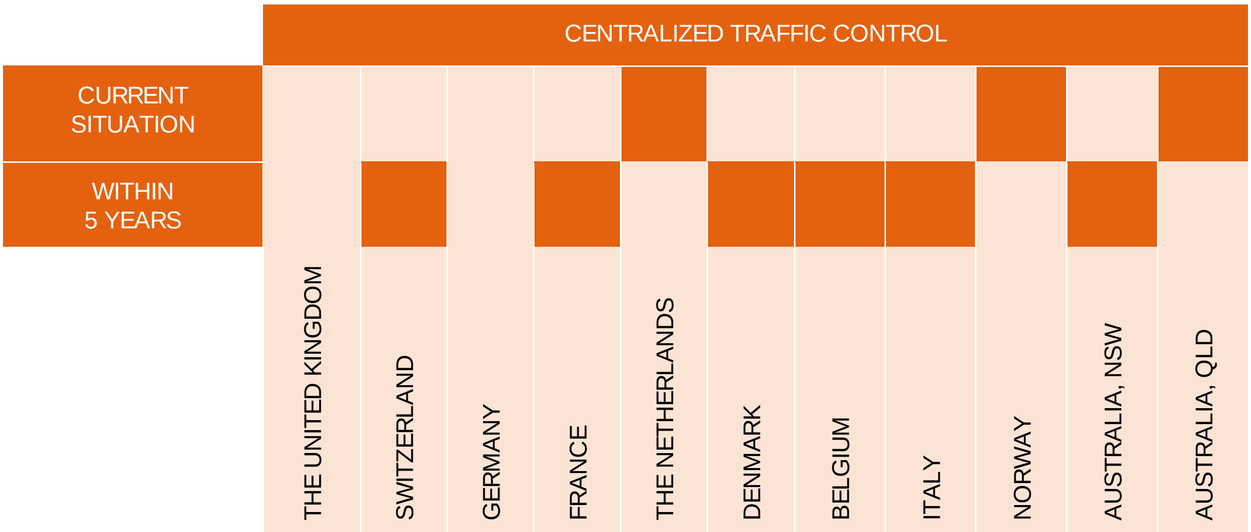


Figure 6: Overview of the Centralization of Traffic Control

Interlocking

In all the countries in this study relay Interlocking is commonplace. In a number of countries mechanical Interlocking is still used. However, the mechanical and relay interlockings are to be replaced by digital systems in all countries. This is regardless of whether they are recently built or adapted relay interlockings with still a theoretical technical lifespan of 50 years. For instance, the most recently built relay-based Interlocking in The Netherlands dates from as recently as 2016 [6.G]. The most commonly found argumentation by Infrastructure Managers for this replacement is that replacement parts of the system are no longer available, and knowledge of the system is becoming scarce. Occasionally the supplier has indicated that they will no longer support the system, both in spare parts and in maintenance staff. Other argumentation states that it is cheaper to no longer adapt the existing Interlocking to changing circumstances, but to adopt the new (digital) technology.

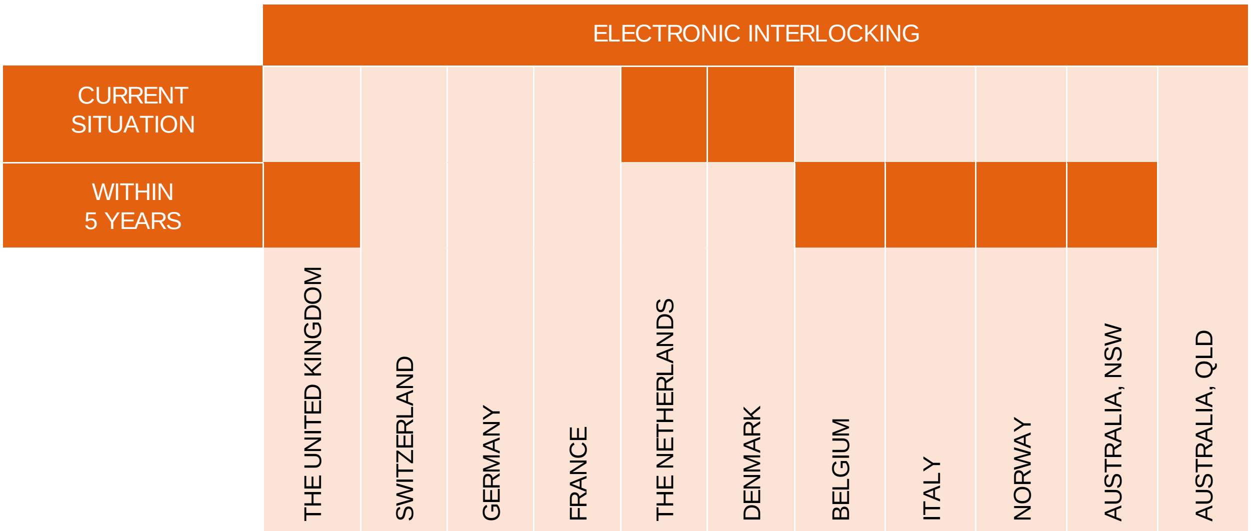


Figure 7: Overview of the rollout of Electronic Interlocking

Block Systems

All countries have signalling based on the division of the infrastructure in fixed blocks with lineside signals. The most common train detection systems are track circuit and axle counters. The trend is to start using axle counters for train detection upon renewal of CCS-systems. None of the Infrastructure Managers make explicit mention of the argumentation for replacing track circuits by axle counters.

Automatic Train Protection (ATP)
As said, almost every country has its own ATP-system. In several cases a country has more than one unique, country-specific ATP-system.

Reasons to abandon current ATP-systems include that the systems are no longer supported by suppliers, the system no longer meets the required safety levels, and there are governmental decisions to convert to ERTMS. However, no estimate can be made regarding the remaining life cycle of ATP systems, as the argumentation differs per system and per country. For instance, in the Netherlands there are no plans to replace their ATB-EG system completely, as ERTMS is only rolled out over part of the Netherlands. Moreover, the ATB-EG system offers sufficient safety levels, provided it is amended with ATB-vv. Finally, ATB-EG (including ATB-vv) only remains on the more remote routes, where capacity is not yet an issue.

3.1.2 Current Situation (Digitalization) Processes

The previous paragraph focused on the various (sub) systems of the CCS. This paragraph elaborates on the processes and issues surrounding the current (digitalization of the) CCS-system.

Steps towards digitalization

We have identified digitalisation programmes in all surveyed countries. Some of these have nearly been completed already, others have a farther horizon. The commonalities in these plans include that significant parts of the CCS-system have reached the end of their technical lifespan. All Infrastructure Managers are implementing, have plans to implement, or consider implementation of digital-based CCS-systems. Traffic management systems are further digitalized. Mechanical and relay interlockings are predominantly replaced by modern electronic interlockings. And axle counters are the most applicable type of trackside train detection system in a new (digital) CCS-system. These renewal programs comprise a substantial investment, and are complicated as well as made more expensive by vendor lock-in situations.

Tailor made solutions and vendor lock-in

Pretty much all (series of) current CCS-components are unique and designed for a specific application in a specific country by the Suppliers that once produced these components. Also, the interfaces between the different components of different Suppliers are tailormade. Most of the Infrastructure Managers mentioned to encounter a type of vendor lock-in in their CCS- and TMS-business. Infrastructure Managers are strongly and sometimes wholly dependent on Suppliers for the implementation of adaptations of the newly bought systems or components into their networks. It is very difficult to break the viscous circle. Solutions are demanded today for issues, which practically can only be done by adaptations to the existing equipment. This in its turn can only be carried out by the Suppliers of (one of) the components. This vendor lock-in is one of the points where Infrastructure Managers feel they can reduce costs and become less dependent on Suppliers.

Co-creation versus legislation

Co-creation of the CCS-system by Suppliers and Infrastructure Managers, by joint design, shared risk assessments and collaboration agreements, are mentioned by several Infrastructure Managers as a necessity for implementing modern CCS-systems. However, they state that co-creation is hampered by legislation. Suppliers that co-create (parts of) the CCS-system have to be excluded from the successive procurement process. Therefore, from a long-term perspective, co-creation is not beneficial to suppliers.

Focus on nodes

Considering the new possibilities of digital technology, the real benefits of the introduction of digital CCS-systems (such as ERTMS) can be found at transport nodes. At the moment, this is where much is still to be gained. However, current national safety (CCS) regulations prevent substantial improvements. Digital technology allows many safety margins to be generated by software, which is an important difference with the current (analogue) situation. According to the current regulations a number of these safety margins must currently be guaranteed by the track layout (overlaps).

3.1.3 Relevant Future Strategies

This paragraph provides an overview of the plans to replace/renew the existing interlocking, block systems and traffic managements systems, and of the ambition of the Infrastructure Managers in terms of functionality and architectures for their future CCS-systems (excluding ERTMS). These provide the Infrastructure Managers' answer to the second research question of this feasibility study:

2. What are the relevant future strategies with regard to CCS and TMS?

Digitalization Strategies

As said, digitalisation programmes have been identified in all surveyed countries. Some of these have nearly been completed already, others have a farther horizon. In addition to the renewal of CCS-systems, the plans embrace ETCS / ERTMS, or DAS/ATO. See the table below for an overview of the countries, programmes and their elements, and their planned horizons.

ATO or at least Driver Advisory Systems is a topic of consideration in many but not all countries. The United Kingdom and the Netherlands are currently involved with ATO pilots. The pilot in the United Kingdom has already yielded ATO operational on ETCS Level 2 on the Thameslink line, but it is still at planning stage for other routes. Norway is awaiting ERA specifications on ATO but has expressed interest.

Country	Programme name	Renewal CCS	ETCS & ERTMS	DAS & ATO	Planned horizon
United Kingdom	Digital Railway		x	x	2014 - 2039
Switzerland	SmartRail 4.0	TMS IXL	x	x	2005 - future
Germany	Digitale Schiene Deutschland		x		
France	Argos innovation partnership	IXL			2018 – 2030
				x	
The Netherlands	ERTMS programme		x		
		TMS		x	
Denmark	ERTMS programme				Due to finish 2028?
Belgium	ERTMS programme	TMS, IXL	x	x	Current – 2035
Italy			x		
Norway	Renewal programme	TMS, IXL OC	x	x	
Australia, New South Wales	Digital Systems Project	TMS, TCS,	x	x	2017 – 2028

		ATP		
			x	
Australia Queensland	Cross River Rail & Inner City Project	IXL		
	Cross River Rail	TMS		x

Table 5: Overview of Digital Programmes

The expectation that implementation of ERTMS in Australia would yield additional and/or different insights compared to the situation in Europe has not materialized. No significant differences in approach have been found, both with respect to ERTMS and to the modernization of the total CCS system.

Digitalization Strategy versus ERTMS Implementation

All countries in this study are moving towards implementing ERTMS. However, not necessarily at the same pace and with the same impact on the digitalisation of CCS- and TMS-systems. Where Switzerland allready has ERTMS L1 on all lines, most other Infrastructure Managers in this study have not reached that stage yet.

Most Countries have opted to first implement ERTMS trackside, often as a parallel system next to the current signalling system, including the current line side signals. This principle is known as dual signalling. Operating Companies will purchase ERTMS onboard equipment at a later stage. These countries are planning a further implementation of ERTMS in the following years.

Conversly, the Netherlands has opted to first equip the fleet with ERTMS onboard. ERTMS trackside is set to be implemented further in the next 10 years.

The United Kingdom, Germany, and France have run ERTMS/ETCS pilots on some lines and have committed themselves to the European Deployment Plan, but have yet to present detailed plans for a full rollout.

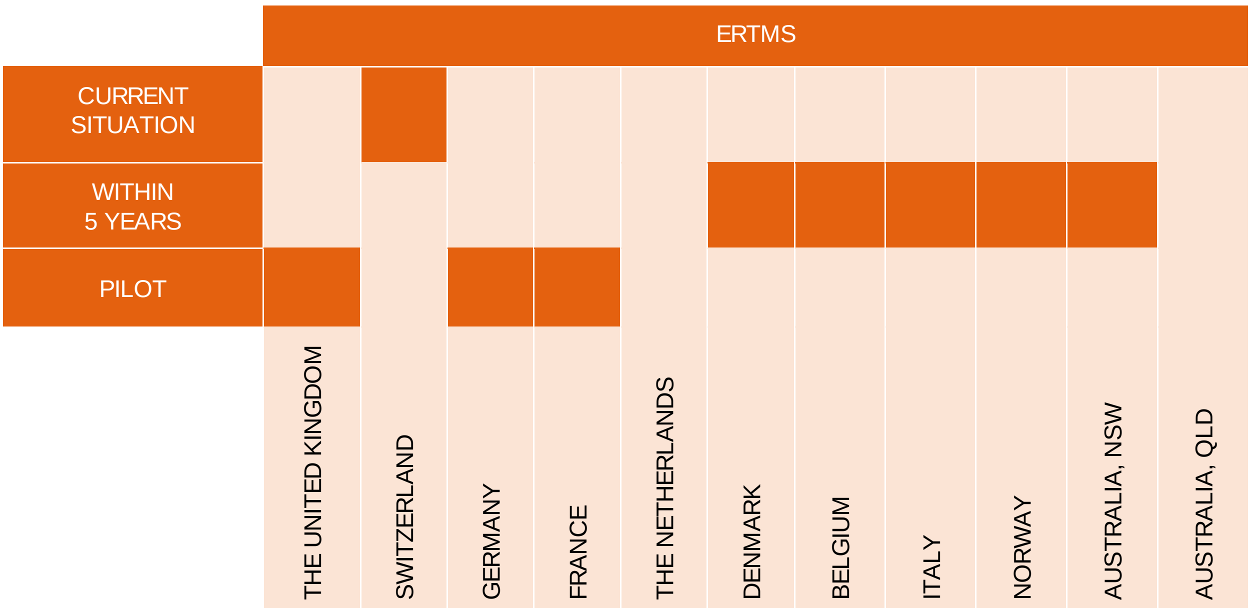


Figure 8: Overview of the rollout of ERTMS

In fact, the European Court of Auditors remarks that deployment of ERTMS today represents a patchwork in systems and planning. Although European countries (the Infrastructure Managers) have agreed to deploy ERTMS on their network, this does not mean that ETCS trackside will be rolled out on the entire national network of each individual country. Hence, there are different approaches in ERTMS deployment. Only a few countries will or already have rolled out ECTS trackside (Level 1 LS, Level 1, Level 2 or a combination) on their entire network. These are:

- Luxembourg
- Belgium
- Denmark
- Norway
- Switzerland

In this decision they considered the remaining lifespan, as well as shortcomings and obsolescence of current national signalling systems. [1.B, 34]

All other European countries plan to only convert parts of their network to ERTMS and keep their legacy Class B[7] system. The Court of Auditors called this 'ERTMS as an add-on software based-system for their national signalling systems'. [1.B, 34] Possible (combined) arguments for this approach are:

- Costs of converting their entire network due to its size.
- Class B systems with long expected lifespan, and currently still meeting (future) requirements for safety and capacity.

As a result of these different approaches to ERTMS deployment, the ways the Infrastructure Managers deal with the various arguments and (proposed) scenarios to accelerate renewal of CCS-systems (including ERTMS and non-ETCS components) differ as well. We illustrate this by elaborating on Banedanmark, ProRail, and SBB, that provide different positions on the spectrum.

Banedanmark (Denmark)

Banedanmark does not only implement ERTMS on the entire network but also simultaneously renews all non-ETCS components. Furthermore, Banedanmark has decided on a very ambitious planning for the implementation. Compared to other countries and their respective approaches, this can be described as a 'big bang' type approach.

For Banedanmark, the main motivation for also renewing the non-ETCS parts was:

- 60% of their signalling system was obsolete (e.g. interlocking systems dating back to mid of 20th century).
- Difficulties on Operation & Maintenance because of rare spare parts and progressive retirement of experienced staff.
- Benefits provided by a complete renewal, which ensures:
  - Better prices due to economy of scale and open market
  - A quantum leap in technology, through standard products
  - Relevant savings on the long run in terms of Operation & Maintenance

[7.C]

ProRail (The Netherlands)

ProRail has decided on a different approach. Only part of the railway network will be equipped with ERTMS. Furthermore, not all parts of the non-ETCS components will likely be replaced. The main reason for not replacing the non-ETCS components is an already very modern CCS-system:

- The entire network is (remotely) controlled from 13 Centralised Traffic Control centres which will be further reduced to 5 in the future.

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[7] Class B systems for the trans-European rail system network are a limited set of train protection legacy systems that were in use in the Trans-European rail network before 20 April 2001. Class B systems for other parts of the network of the rail system in the European Union are a limited set of train protection legacy systems that were in use in that networks before 1 July 2015. The list of Class B systems is established in the European Railway Agency technical documents 'List of CCS Class B systems, ERA/TD/2011-11, version 3.0'.

- Automatic route setting is implemented nationally.
- ATO pilots are planned (2018).
- ProRail developed an interface between the TMS-layer and the interlocking layer (Astris), making the traffic management layer independent from the type of interlocking used (e.g. relay interlocking, Alstom VPI, Hi Max PLC interlocking, Bombardier EBI lock).
- ProRail developed the TMS-system in-company in collaboration with non-rail industry suppliers.
- ProRail replaces all relay-based interlockings by modern open digital interlockings, independent from implementation of ERTMS (however ERTMS compatible).

[6.A, 6.C, 6.G, 6.J]

SBB (Switzerland)

It is important to note that Switzerland is working backwards from their Ambition, SmartRail 4.0. First the Ambition was defined, planned changes to the CCS-system were then derived from the Ambition. With SmartRail 4.0 Switzerland is working towards automated planning, automation of operating centres, fine control train runs and speeds, complete security and full surveillance, new simple technologies, increasing visibility on and around the tracks, automatized remote control of the train, precise train routing/departure and driveway, high radio data capacity for customers and rail traffic, and a reduction of trackside assets by up to 70%.

The highlights of the CCS-migration strategy by SBB comprise the following steps:

1. Fast and simple migration to ERTMS L1LS; Level 2 pilots
2. Single cab system, ERTMS only
3. Roll out SmartRail 4.0 as an integrated program to completely migrate CCS to ‘CCS of tomorrow,’ making maximum use of IT technology.

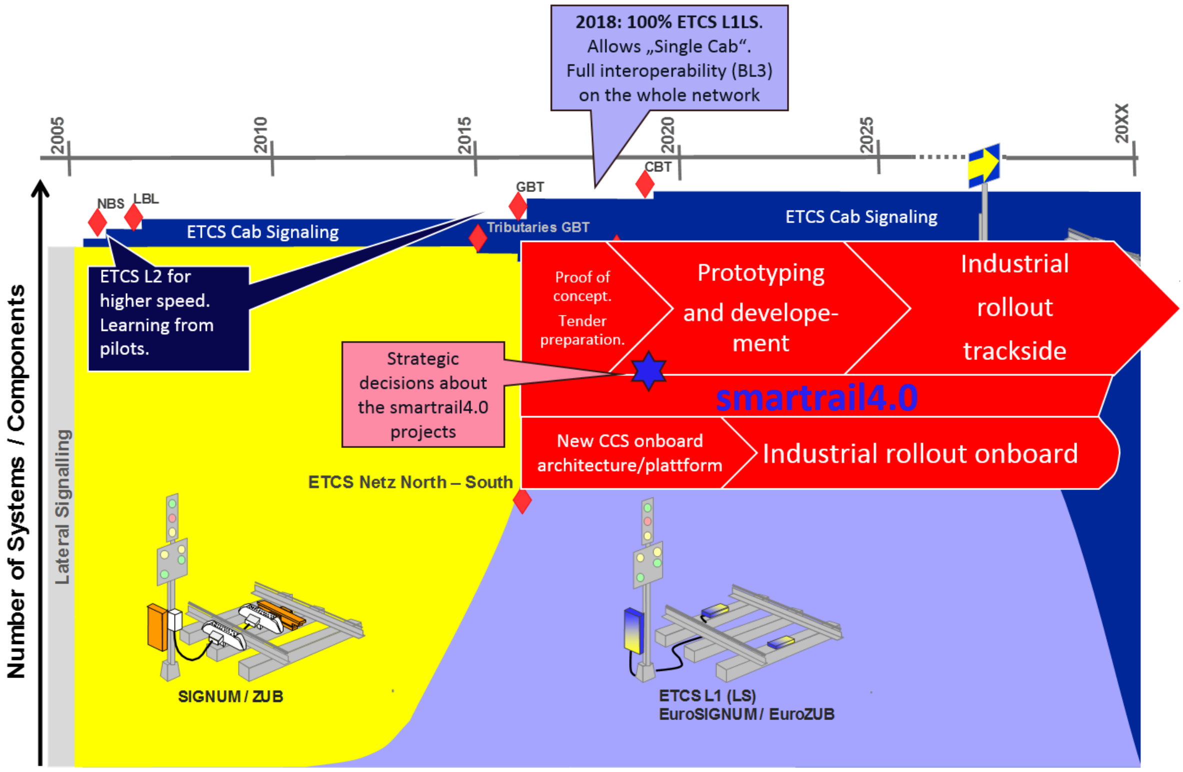


Figure 9 Overview CCS migration strategy SBB [3.N]

The ambition is driven by cost reduction, capacity increase, and a safety increase. If everything succeeds, a cost saving of CHF 400 million per annum is estimated. This includes both Infrastructure manager and Railway Undertaking.

[3.A, 3.I, 3.J, 3.K, 3.N]

3.2 Reasons for Replacing Non-ETCS Components

As stated by the European Court of Auditors, deployment of ERTMS is lagging behind due to insufficient funding, insufficient qualified staff, technical problems, and distrust in the system by national governments. Arguments which are also more or less valid when it comes to renewing the CCS-systems in general. Moreover, without (short-term) benefit or necessity to renew (parts of) the CCS-system, nothing will happen. Yet, it can be observed from the research that the CCS-systems are being renewed and replaced. [1.B]

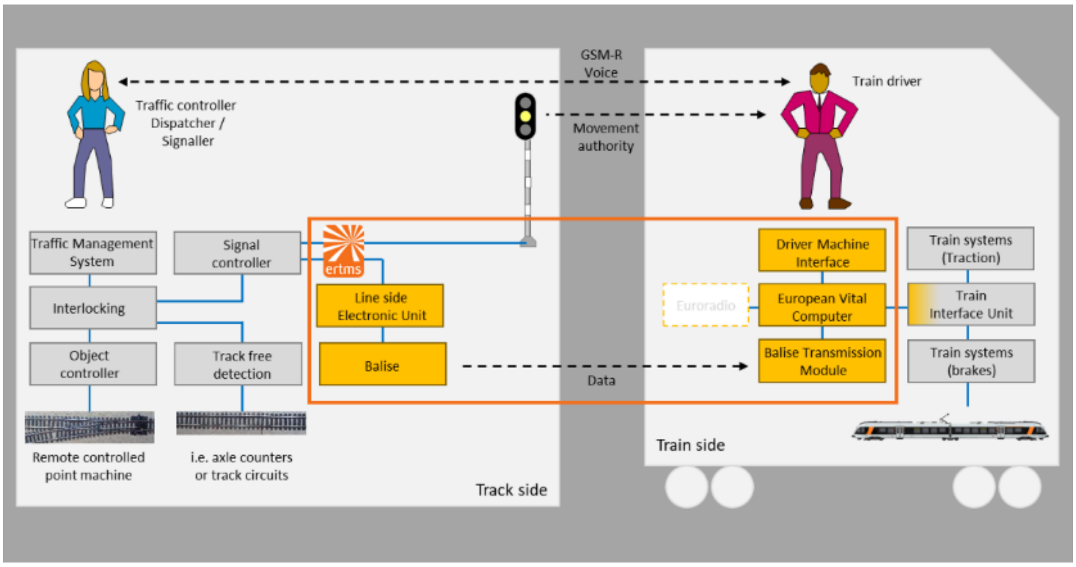
From the desk research and interviews with the Infrastructure Managers the following technical argumentation for Infrastructure Managers to replace non-ETCS components (e.g. Interlockings, object controllers, TMS) in the future could be derived:

1. Driven by implementation of ERTMS trackside
2. Driven by limitations of the current CCS-system (safety)
3. Driven by other arguments (e.g. centralising TMS)

1. Driven by the implementation of ERTMS trackside
There can be technical reasons that are directly related to the implementation of ERTMS, that require the replacement of the CCS-system. The following technical reasons have been identified, specified by the ERTMS Level to be implemented.

1.1 ERTMS Level 1 case

To provide an example for a technical reason, the Signal Controller may not be compatible within economically feasible terms with Lineside Electronic Unit. ERTMS Level 1 is designed to be a relatively simple way of implementing ERTMS since it can be considered as an overlay on the existing Class B system. The only trackside connection between the Class-B system and ERTMS is the Lineside Electronic



Unit (LEU). The LEU can be considered as an interface.

Figure 10: Simplified overview general system architecture ERTMS Level 1

However not all legacy systems can be connected by a LEU, such as mechanical or very rare analogue systems within reasonable effort / costs. Replacement of the CCS-system is then necessary.

1.2. ERTMS Level 2 case

An example for ERTMS Level 2 is provided by the interlocking not being compatible with Radio Block Centre (within reasonable effort / costs). This causes a domino effect – If interlocking is replaced by a modern (e.g. digital) version, it might be necessary to install new 'object controllers'[8] since they in turn are no longer compatible with the new interlocking.

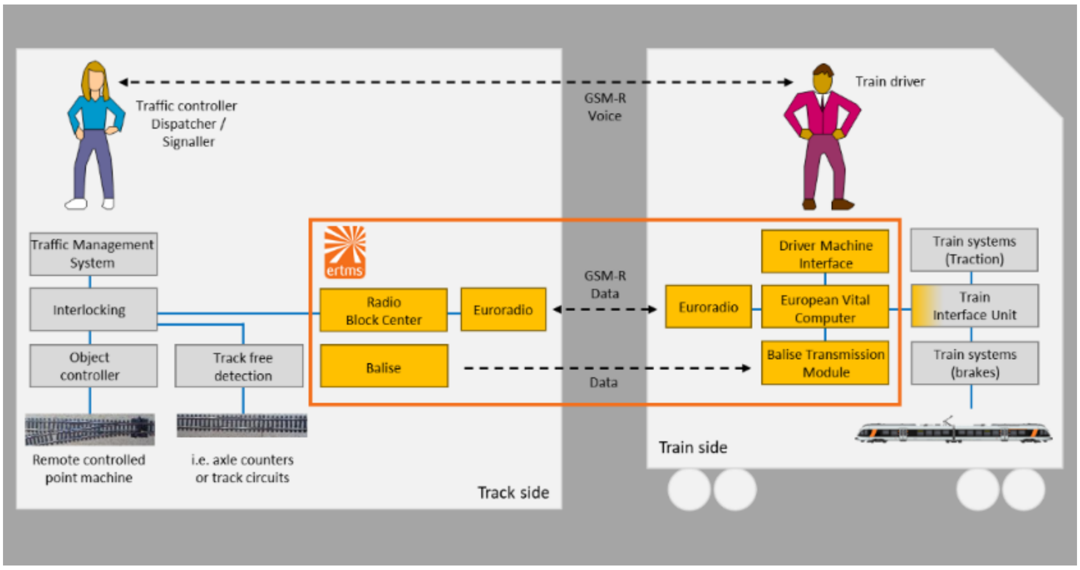
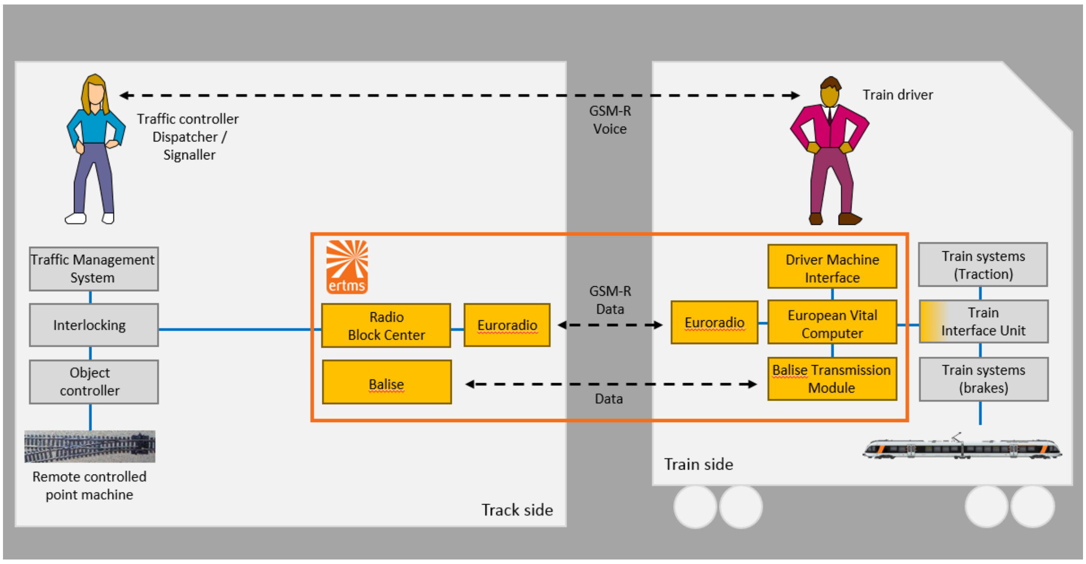


Figure 11: Simplified overview general system architecture ERTMS Level 2

Another consideration can be to centralise interlockings; instead of small(er) interlockings close to objects such as points and signals, one can consider reverting to one interlocking and remote (data line) object controllers.

1.3. ERTMS Level 3 case

In an ERTMS Level 3 situation there is no trackside train detection needed. Therefore, trackside train detection can be removed, requiring a modification of the Interlocking.



[8] Relay type interlockings do not have separate object controllers. Objects like point machines and signals are 'hard wired' to the interlocking.

Figure 12: Simplified overview general system architecture ERTMS Level 3

2. Driven by limitations of the current CCS-system

Limitations of the current CCS-system can be arguments to replace the current CCS-system.

2.1 Safety requirements
- The existing system does not meet the (minimum) specifications for safety (anymore). In most cases this is a lack of an adequate ATP (automatic train protection) system. A trigger for renewal can be imposed by an authority or accident prevention.

2.2 Performance requirements
- The existing system does not meet the requirements for handling today's or tomorrow's number of train movements (capacity).

2.3 Obsolete components
- The existing system is technically at the end of its lifecycle (i.e. it is old and deteriorating).
- The existing system still functions; however, it is becoming harder (and/or expensive) to acquire spare parts (financial argument).
- The existing system still functions; however, the supplier does not support maintenance / upgrades / new installations any longer (qualified staff related).

2.4 Optimisation of process
- ERTMS provides new options. If the legacy / analogue interlocking is not able to transfer traffic information from the RBC to the TMS layer, one cannot provide from the full benefits of ERTMS.

3. Driven by other arguments

Finally, there are other drivers which are related to control, which might drive the replacement of CCS-systems in the future.

3.1 Process optimisation
- There are desired features like automatic route setting which are not compatible with existing route setting devices.

3.2 Centralisation
- The Infrastructure Manager wants to move away from local controlled stations (signal boxes) to CTCs.
- The Infrastructure Manager wishes to (further) reduce the number of CTCs. Arguments for this are further process optimisation and reduction of staff.

Combination of drivers

Of course, any combination of multiple drivers is possible, as visualised in the picture below.

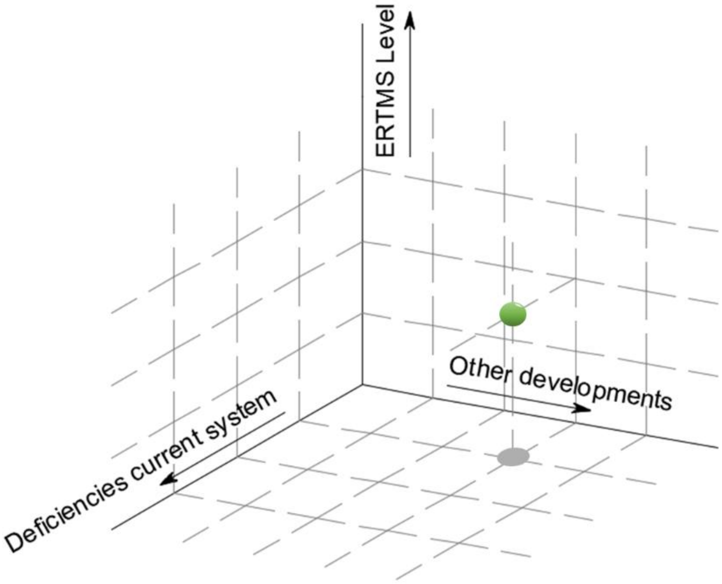


Figure 13: Matrix showing combination of arguments for new CCS

3.3 Short-Term versus Long-Term

From the interviews, the documentation and the workshops it emerged (directly and indirectly) that a shift in thinking is needed, which will have a significant influence on the structural improvement of CCS-systems (including ETCS).

ERTMS and digital CCS-systems comprise a silent revolution in train safety and railway operation. The ICT-based technology commands a different way of thinking. A lack of sufficient knowledge in this CCS-field (as there are too few people skilled in a digital view of its problems and possible solutions) poses difficulties for the Governments and Infrastructure Managers to oversee the risks of implementing completely new, digital CCS-systems. This results in the natural reaction to lean towards ‘the safe option’ and to continue thinking along the lines of what one knows and can oversee. As a consequence,

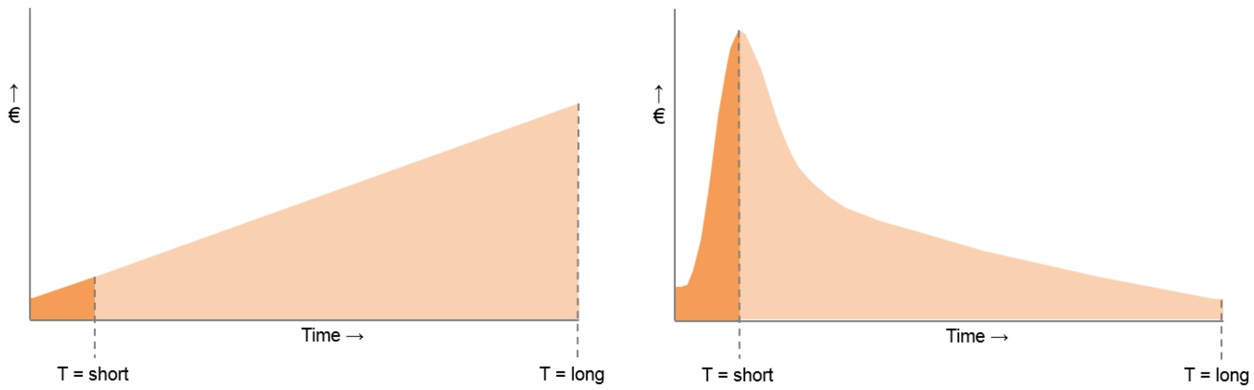


Figure 14 Short-term versus long-term cost arguments

- They chose (unwittingly) for a patchwork of quick, short-term solutions. This choice is also made based on the initial costs, see the figure above. The tailormade solution often involves less investment when looking at a short-term horizon (T = short), especially compared to the initial high investments of a system overhaul for standardized solutions. However, when looking at the longer-term (T = long), several

tailormade solutions will lead to substantially more costs than the initial investment and upkeep of the standardized new solution (the total costs is the surface under the line up to T = long).
- They translate one-on-one the national, analogue train safety philosophy into ETCS. Driven by that, it seems hard for governments and Infrastructure Managers to let go of the national, trusted CCS-systems.

This again has the following consequences:

- The patchwork of quick short-term solutions hampers the development in the long run. Cheap but fast development may result in troublesome deployment and a shorter than expected lifespan in the long run.[9]
- Instead of one ETCS system, each country develops its own 'ETCS dialect,' which is in direct conflict with the goal of swift crossborder traffic of a Single European Railway Area.

As a side note, training the staff to work with digitally enabled processes and tools is a topic of concern in the implementation of digital systems (including CCS- and TMS-systems) and needs to be addressed in the implementation of the digitalisation programmes.

[9] With one exception: in the short-term it might be beneficial to use a type of trackbound 'train detection' for lose wagons on marshalling yards.

4 OPERATING COMPANIES

In the previous chapter the general findings and trends for the various studied countries were presented, as distilled from interviews with and documents from the Infrastructure Managers. However, whereas the Infrastructure Managers have a focus on trackside equipment, Operating Companies have their focus on onboard equipment, and might have different views. This chapter communicates the general findings from a selection of Operating Companies. As a representative of the passenger rail market Arcadis approached the Dutch Railways (NS) and similarly, as a representative of the international freight market, DB Cargo. Additionally, RailGood was interviewed, a lobby organisation that provides the management of external relations to companies in the rail freight transport sector in the Netherlands.

4.1 Dutch Railways (NS)

In an interview with Arcadis, NS described the introduction of ERTMS as the biggest innovation in the railway sector in the last 150 years.[10] However, the rollout takes too long. As a result, the railway sector risks being overtaken by the automotive and aviation sector.

Prolonged ERTMS implementation

NS has identified multiple causes for this elongated rollout.

1. Business case

There is no business case for the introduction of ERTMS. The dual onboard migration strategy in The Netherlands (ETCS + STM class-B ATP) allocates the cost of ERTMS first to the TOC, i.e. NS. However, there are no benefits for the NS until the rollout in infrastructure is complete. See Appendix C for implementation / migration strategy in The Netherlands.

Furthermore, NS only sees limited benefits with the introduction of ERTMS. Benefits are expected in increased line speed and introduction of ATO. However, technically ERTMS is not required for the introduction of ATO. Only a limited increase in capacity is expected. Risk is this effect will be reduced caused by a reduction in timetable stability when additional trains are added to the timetable.

Regarding safety, the current ATB-system already has a high safety level. Although knowledge of the current ATB-system amongst personnel is disappearing, the system can still be maintained.

The main driver of the ERTMS rollout for NS is thus not a valid business case, but a government governed incentive. The government has acknowledged this and subsidizes the procurement and implementation of onboard equipment.

2. Complex System Architecture

The ERTMS equipment is located on the infrastructure (trackside) as well as in the vehicle (onboard). In this respect there is no change in complexity compared to the current situation, which also has trackside and on-board systems. Yet, in other industries such as the automotive industry (self-driving cars), the tendency is to include all ‘intelligence’ in the vehicle itself.

Furthermore, many stakeholders must agree on the strategy and the system specifications. This has resulted in the ERTMS specification facilitating the operational processes of all European railways, making the system specification large and complex.

Furthermore, the current tendency of the railway sector is to fully specify the ERTMS implementation, including all additional wishes that can be included in the CCS-system when implementing ERTMS. Part of

[10] NS is the main Train (passenger) Operating Company (TOC) in The Netherlands

the reason is the safety function of ERTMS. However, it is not possible to fully specify the system implementation without errors. Thus, the ERTMS rollout remains stuck in specifying too much in detail. Rather a type of trial-and-error approach would speed up the implementation process. In this approach the focus would first be on making the primary functions and functionalities work, before moving on to the 'extras'. Looking at other sectors reveals another approach. For example, within the automotive sector the system is not distributed. All of the advanced equipment, such as required for self-driving, is within the vehicle. The infrastructure does not need any equipment. This simple system architecture reduces the number of stakeholders that must agree on specifications, resulting in faster implementation of new technologies.

3. Suppliers

NS has some concerns with the recent merger of Alstom and Siemens, especially in the field of signalling equipment. Combined Alstom and Siemens control approximately 90% of the signalling market. NS fears the reduction in competition might lead to a reduction in the quality of the provided services.

NS would like to have possession of the interface specification of onboard equipment. This would simplify the replacement of peripherals such as odometry units. However, Suppliers do not facilitate this. This results in a vendor lock-in situation. The original supplier is required for each small modification.

Furthermore, suppliers do not provide long-term service agreements. Long-term service agreement would unburden NS, because modifications to the system can be dealt with in the service agreement. For this the railway sector should look to the IT-sector in which long-term service agreements are common practice.

ERTMS onboard procurement strategy

The Dutch ERTMS strategy requires trains to be capable of running on both ERTMS and legacy Automatic Train Protection (ATB-EG). This requires a system Specific Transmission Module for ATB-EG (STM ATB-EG), which converts ATB-EG signals to input for the ERTMS system, and ETCS onboard units.

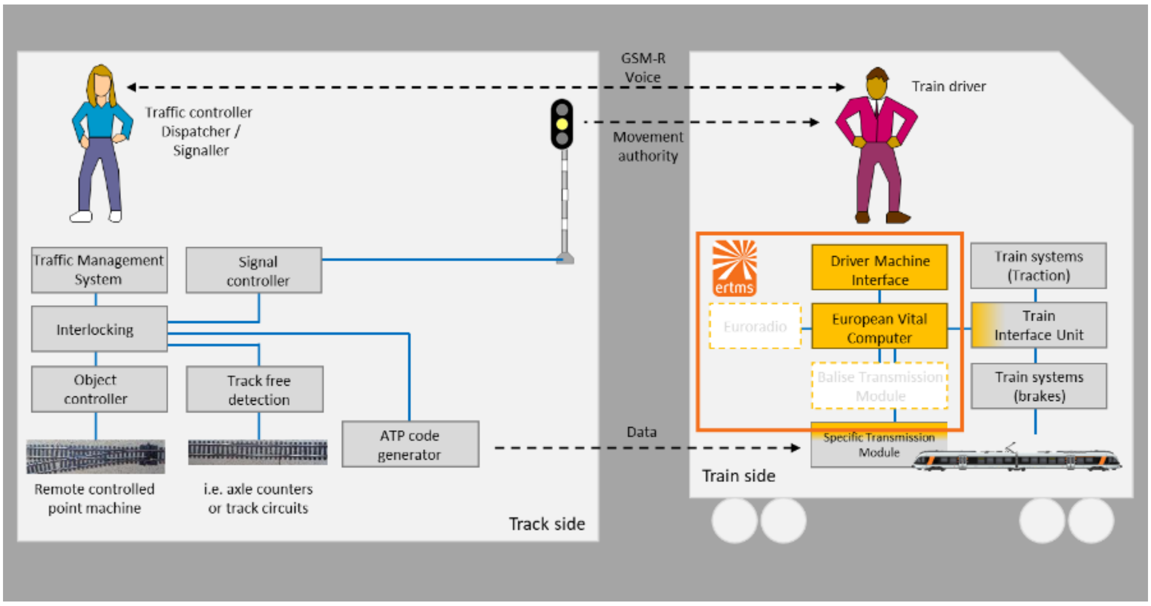


Figure 15 Simplified overview general system architecture STM

In the interview NS indicated that the current ATB-EG STM is based on dated technology. The rail market in general is not investing in ATB-EG STM. For this reason, NS, ProRail and the Ministry of Infrastructure & Water Management, as the 3 parties in the Dutch ERTMS-programme, have started a market consultation in 2017 on this topic. It focused around the following subjects:

- System Requirement Specification STM-ATB-EG
- Planning and milestones

- System integration of STM-ATB-EG with ETCS
- Installation and integration of STM-ATB-EG in the rolling stock
- Maintenance management and support services

This consultation is the first step towards a possible tendering of such a solution.

Automatic Train Operation (ATO)

Automatic Train Operation (ATO) can help to improve the business case of ERTMS. The Dutch railway operating company, NS, is interested in the development of ATO, specifically in GoA3 for its robustness and flexibility benefits. The main driver of NS for the implementation of ATO is the increase in flexibility for staff planning – only one official is needed (the conductor) rather than two (conductor and train driver). In degraded mode the conductor can drive the train.

1. The separation of rail traffic management and running trains disappears

The introduction of GoA4 will most probably be accompanied by a theoretical discussion on the base principles of train operations and responsibilities within those. At the moment there is a clear distinction in responsibility between Infrastructure Manager and Operating Company. The Infrastructure manager clears the train paths. The Operating Company on its turn runs the trains on the cleared paths. The introduction of ATO will remove the distinction between clearing the paths and the running of trains.

Eliminating this distinction can reduce the Operating Company's freedom whether or not to use these train paths. This can mean that the Infrastructure Manager (ProRail in case of NS) as manager and controller of the ATO-system will attain a more direct role in directing the trains, while the focus of the Operating Company will move towards making the rolling stock available. Hence, this development may have effect on the commercial freedom of the Operating Company.

2. Human factors

The concerns of NS about human factors are twofold. First of all, the change in responsibilities of drivers and train guard requires close consultation with labour unions because responsibilities are linked to the payments to drivers. Secondly, the workload of drivers changes. The role of drivers changes from control to supervision. This means that in steady state their role is very passive, only monitoring the computer screen rather than actively responding to signals and other occurrences to be viewed through the front window. However, during calamities or disturbances they suddenly get an active role, having to respond to the system and the outside world. NS is worried how to ensure that drivers are alert for those few moments when they have to switch from a passive monitoring to having to actively intervene.

4.2 DB Cargo

DB Cargo argues that the implementation of ERTMS is the most important innovation for rail freight transport. In time the system can theoretically reduce the obstacle of country borders. However, DB Cargo does remark that until present the goal of SERA has not been reached and that the roll-out of ERTMS has been one of the largest cost items for cargo transport by rail [6.O]. It is the easy crossing of borders which is of primary importance to Freight Operating Companies (FOCs). Over 90% of all transport initiating in the Netherlands, passes at least one national border along the way. [6.P]

DB Cargo mentions that the business case for implementing ERTMS is not beneficial for FOCs and that an effective implementation is impossible. This is caused by an 'intermediate phase', in which a double deployment of safety systems – both the existing and the new system must be operation – is obligatory.

Finally, DB Cargo indicates that the implementation strategy should be streamlined:

- The most important international corridors deserve preference,
- Deploy ERTMS on the alternative rerouting routes. These are often given less attention as these may be unfrequently used routes.

- And it is of importance to tune migration plans with neighbouring countries – in the Netherlands at least with Belgium and Germany.

[6.P]

4.3 RailGood

Inspired by an article suggesting that the cost of the ERTMS-conversion of freight trains are hardly covered, RailGood – a lobby organization providing management of external relations to companies in the rail freight transport sector in the Netherlands – was contacted.

RailGood feels that the conversion of freight trains is too costly, because of the variety of rolling stock types on the Dutch network. For passenger trains (NS) there are usually substantial series of one train type, which has the advantage that all train scan be converted in the same manner and following the same procedure, thus saving costs. However, locomotives for freight trains sometimes number only one to twenty of a single type. Both passenger and freight trains are subsidized by CEF for conversion, but RailGood feels that the costs for NS are fully covered, whereas the higher cost of freight trains are not. Moreover, RailGood believes the Dutch market to be too small to invest in new locomotives. Because of the installation of equipment for specific Dutch railway technical systems and the small order quantities, the purchase of locomotives in the Netherlands are 25% more expensive than in Germany. Consequently, he advises the Netherlands to cooperate with Germany in procurement of ERTMS.
[6.K, 6.L, 6.M]

Concerns

In our interview, RailGood identified several concerns[11] with regard to the wish for interoperability and all the practical consequences following from this political wish.

Return to the basics
RailGood wonders why people adhere to ERTMS as chosen technology to achieve interoperability. ERTMS is a (or one of the) means of promoting cross border rail transport. Interoperability is important for cross border freight rail transport. However, ERTMS is not by definition the solution for train protection in this respect, there are other possible technical solutions as well.

Market economics: Follow the market
Rail Freight Corridors (RFCs) do not always match the routes that emerge from commercial origin to destination paths. For instance, the new relation North Sea to Black Sea runs through Romania.

When procuring ETCS, procure onboard and trackside equipment as one package. This will ensure that the supplier will guarantee correct and reliable interface workings between trackside and onboard. A prime example is how Norway has organized their procurement (see paragraph 13.9.3 Norway / Ambitions).

The German economy is the largest in the European Union. It holds a key position in European rail freight transport, on the one hand being located centrally in Europe and on the other hand housing several of the major ERTMS suppliers. Considering the Netherlands and Germany share borders, it is a very important economy for the Dutch to take into account. Therefore, RailGood advises to follow the Germans in their footsteps, both in (technical) choices and in planning. RailGood illustrates this statement with the example of the baseline to be used for ERTMS-rollout. If Germany and The Netherlands use different baselines, you face the risk of not being interoperable. Moreover, RailGood advises to attain economies of scale by jointly (the Netherlands and Germany) procuring the required technology.

Technology
Only apply proven technology. Learn from experiences on the dedicated rail Freight line the Betuweroute. De

[11] Besides signaling, RailGood mentioned (differences in) traction power supply, load gauge, and axel loads. These topics are outside scope and therefore not mentioned in this report.

Betuweroute is ETCS level 2 only. Consequently, FOCs were forced to equip their locomotives with ETCS onboard. At the time, this was baseline version 2. Currently countries are deploying their infrastructure with a higher baseline version (version 3), which means that these locomotives must be upgraded to this higher baseline as well. Otherwise these locomotives are not allowed on the line. In a relatively short time span this is again a huge investment for the FOCs. Moreover, this investment is hard to explain to financiers and/or shareholders of the FOCs. It results in freight traffic being financially unreliable. And reliability is very important for rail freight transport.

The Dutch train detection system GRS Spoorstroomlopen (i.e. direct-current track detection) frustrates the approval of modern, internationally operating locomotives. Consequently, approval of new locomotives such as the Vectron takes much longer than country-specific approvals elsewhere. Moreover, the use of GRS Spoorstroomlopen system causes lighter locomotives to not be approved for the Netherlands, whereas they are very common elsewhere in Europe. Therefore, RailGood advises to replace all GRS Spoorstroomlopen in the Netherlands by axle counters.

Business case: Investments should be accompanied by yields
When the FOCs profit from the investment, they are willing to cooperate. The FOCs are willing to invest, provided this returns cost efficiency for them within a reasonable timeframe. And provided the investment has a healthy profit margin.

In order to enhance the competitiveness of rail freight transport, there must be a solution for the first and last miles. When an RFC (long haul) is chosen by the EU and the national governments, this will be equipped with ERTMS for the entire corridor. However, this requires that shunting locomotives only operating locally at the first or last mile (in fact yard), which need also be equipped with ERTMS onboard. This is relatively expensive for FOCs. By deploying the public accessible marshalling yards with both ERTMS and the local Class B system (dual signalling) this could be resolved. Unfortunately, this still does not resolve the problem of pushed marshalling under ERTMS, which as of yet does not have a technical solution.

Recommendations to ERA

RailGood recommends the following strategies for ERA:

- *Stop focusing on technology*: Rather focus on the economy and the competitive advantage of the railway industry. Ensure that railway transport can compete with rail transport.
- *Confiscate the role of 'System Integrator'*: Someone needs to take control of the rollout of ERTMS in Europe. Considering that the EU contributes substantially to this rollout by means of subsidies, it seems logical that the ERA should be the prominent 'System Integrator'.
- *Combine onboard and trackside*: Consider financing and or subsidizing onboard equipment jointly with trackside infrastructure. The Infrastructure Manager can then lend, or lease, this onboard equipment to the various TOCs and FOCs.
- *Guarantee interoperability*: Enforce that national solutions are no longer allowed, resulting in a full-on focus on interoperability.

4.4 European Rail Freight Association

The European Rail Freight Association (ERFA) represents 30 private and independent railway companies from across Europe, though these do not include DB Cargo. The association was established in Brussels in 2002 by a handful of new rail freight operators. It was established as the voice of new entrants to support the European vision for a liberalised railway market.

ERFA's main objectives are listed below. Sub bullets provide quotes which are relevant to this research, other subpoints have been ignored:

1. Improve the quality and performance of rail services
   - The EU has long supported investments in the more sustainable modes of transport, with rail as a key beneficiary. In the run-up to the next EU budget framework ERFA calls for an increase or at minimum maintaining the current EU investment levels for rail and better targeting of funding to support better

quality rail services, e.g. accelerating small-scale investments in the rail freight corridors to create seamless rail travel.

2. Reduce the cost of rail
   - A single signalling system for the whole European rail network is a must if rail is to remove the excessive costs linked to crossing national borders and improve economies of scale by reducing product diversity. However, side by side with accelerating ERTMS deployment the lack of a business case for today's railway undertakings, who face the costs, but very little of the benefits of ERTMS must be addressed as a priority.
   - Rail users are not expected to cover the whole costs of rail infrastructure, nor are they expected to cover the costs of state-owned rail operator companies' losses, but lack of transparency in the way charges are passed on to railway undertakings leads to concerns that they are paying too much, undermining rail's ability to grow and attract new customers. New EU rules creating greater transparency, cost efficiency and predictability in access charges must be properly enforced.
3. Remove remaining market access barriers
4. Removing national technical rules
   - ERFA fully supports the work of the European Agency for Railways in removing unnecessary national rules, a legacy of outdated protectionist national rail systems. National technical rules are responsible for increasing the burden and costs for rail companies, without necessarily contributing to a safer railway. Simplifying requirements, while upholding safety, improving cost efficiency of rail operations and unlocking the potential for cross-border operations are the key objectives.
   - Single safety certification and vehicle authorisation - Unnecessary delays to authorisations, additional changes needed to accommodate specific networks, and high costs – all contribute to deterring operators from serving new markets or even entering the market. We count on the new powers of the European Agency for Railways for authorising safety certificates and vehicles to speed up and remove discriminatory practices in accessing the market.
5. Create a level playing field rail versus road
   - Railway undertakings are in competition with road hauliers for customers whose drivers do not face the same stringent language requirements as in rail. If rail is to maintain or even increase traffic levels the language requirements of drivers must be simplified to a level that guarantees the safety of the rail system, while ensuring that the costs involved do not undermine the very existence of rail's business model. The adoption of one single operational language for rail, English, must quickly go ahead. An urgent solution must also be found to simplify language requirements in the short-term for cross-border operations. Here the language requirement should be reversed to the traffic controllers.

[14.J]

4.5 Findings and Trends Operating Companies

Based on Arcadis' experiences and desk research and the interview with NS, DB Cargo and RailGood, the following findings and trends were found.

Drivers

Operating Companies are driven by efficiency and reliability. The major cost components of their business model are wages and rolling stock. Efficiency in their business process means that, for instance, the cost of wages can be reduced. Reliability means that, for instance, less (back-up) rolling stock and personnel is needed to account for delays. However, there is a difference between passenger and freight transport and their respective drivers, which is inherent to their business model as well.

Train Operating Companies (TOC) wish to transport passengers at minimum costs. Strictly speaking TOCs have no preference for any type of CCS-system as long as the timetable is not jeopardised, and safe operation is guaranteed. Operating Companies are pleased if a new CCS-system is implemented which leads to more capacity on the route, as long as it does not lead to higher costs for the TOC.

We currently estimate 90 – 95% of all passenger rail transport to be national. Therefore, interoperability is not an issue for the TOC. Although in theory interoperability might lead to more competition, in practice very few TOCs operate cross-border at present. Costly adaptations to the rolling stock due to traction power requirements, platform height, and safety systems all add to this lack of interest.

Freight Operating Companies (FOC) also wish to transport goods at minimum cost. In theory, FOCs have little interest in the CCS-system. However, as their share in cross-border transport is much bigger compared to passenger traffic, there is a business necessity for interoperability. Moreover, interoperability leads to less delays at the borders - amongst others through fewer locomotive changes (less rolling stock required, but also less human activity related to these changes, and fewer train drivers with knowledge of the various locomotives) - and to cost reduction. Thus, having one CCS-system in Europe is of interest to them, which could explain their inclination for a more positive attitude and willingness to invest in ERTMS.

4.5.1 Current Situation

Due to privatisation in most countries, there is a strict division between Infrastructure Manager (usually a (semi-)governmental agency) and Operating Companies (be it passenger or freight). From the point of view of the TOCs, who account for most of the rail transport, the rollout of ERTMS does not appear to provide a valid business case because:

- Fleet owners have to invest in onboard ETCS equipment, but they hardly benefit from ERTMS. Switching from a class-B system to ERTMS does not lead to more passengers, while investments in onboards are substantial - the equipment itself, especially retrofit, unavailability of locomotives / trainsets while incorporating equipment, and training staff.
- Moreover, the advantages of interoperability are limited when only a small percentage of the trains cross the border.

Thus, implementation of ERTMS remains a government governed incentive rather than internally motivated by the TOC.

As mentioned above, the FOCs have a business necessity for interoperability and a SERA, which drives more willingness to invest in ERTMS. However, a uniform CCS-system is only one of the issues that require international agreements.

Specifically concerning ERTMS, the FOCs fear the relatively high costs for deploying with ERTMS types of locomotives of which they only have a small number. The development of ‘first of class’ approval weigh significantly in their business model.

4.5.2 Future Strategies and Ambitions

Given the driver for cost-reduction and reliability, there is a potential for a (more) positive business case for Operating Companies. A potential cost reducing innovation for both TOC and FOC is Automatic Train Operation (ATO). ATO increases robustness and flexibility of the train service. Furthermore, the responsibilities of the train driver change. Part of the safety responsibility is transferred from the train driver to the ERTMS and the ATO-system.

The introduction of ATO requires some preconditions from the CCS-system. In theory, any digital modern Class B system can accommodate for this, but also ERTMS. Thus, the ambition to introduce ATO contributes to interoperability through ERTMS.

Though only the Dutch Railways (NS) was interviewed, other TOCs are also looking into ATO. The various TOCs are in various stages of this development – for some it is already a trend, for some still an ambition. And as there is no ‘standard’ ATO, every country has their own specific requirements and developments in this field.

5 RAIL INDUSTRY SUPPLIERS

In addition to the Infrastructure Managers and the Operating Companies, the suppliers have a significant role in the Control Command and Signalling system. Suppliers focus on the development, production and installation of CCS trackside and onboard equipment. Given their different focus, their views might differ from that of Infrastructure Managers and Operating companies. This chapter elaborates on the general findings from multiple suppliers.

As some of the Suppliers have indicated to prefer anonymity, all results for all the Suppliers have been anonymised.[12]

5.1 Supplier 1

Concerns
Supplier 1 observes that there is a need for training with regard to digital CCS systems and particularly ERTMS at all levels of education (MSc, BSc, and the more hands-on levels). This training is required to fill the gap in staff. Currently, there is already a shortage of staff and their knowledge, and this will increase as the current staff is aging and will retire in the coming years.

Producing Class B systems (and relay technology in general) becomes less and less beneficial for Supplier 1. This is the case because ‘knowledge’ retires and, as mentioned above, relay technology is no longer part of technical schooling. This means that there are no young people to fill the gap. Additional inhouse training is costly and hence reduces profit margin on these products.

Considering the substantial ERTMS budgets and political importance granted to the implementation by governments should make it understandable that more people work in this field, not only on Supplier-, or ERA-side but in the entire sector. Supplier 1 observes, however, that the staff numbers sectorwide are lower than expected, which can only partly be explained by the lack of qualified staff (both relay technology and digital systems).

It is observed that obsolescence of systems moves faster than renewal. The lifecycle of modern components is much shorter than in the past.

Currently, the EULYNX approach deviates from Supplier 1’s vision. EULYNX focuses on standardizing interfaces within the national architectures, not a common architecture. Therefore, also the rules and functionalities remain national. The Suppliers recommend aiming for a common architecture based on ERTMS Level 3 without Class B equipment, rather than on individual components, thus reducing the number of interfaces.

China produces CCS-systems in high volumes. Due to these high volumes and the political situation they are moving swiftly in the direction of standardization. In fact, Supplier 1 fears that it is just a matter of time before the Chinese standards become a world standard.

Technical and operational diversity is the blocking point for SERA. This is the case because each country gives their unique interpretation to ETCS by including their country specific specials. These ‘ETCS dialects’ make it more difficult for an ETCS-train to cross Europe without problems.

ETCS trackside projects (roll-out) is dictated by national standards rather than one European vision. National standards (i.e. specifications, overlay of European Standards with national add-ons, national interpretation of international standard) dictate the tenders. This lack of uniformity is a cost-driver.

Recommendations to ERA
Supplier 1 recommends the following strategies to ERA, in order to achieve SERA:

- A common (high level) architecture (again future proof and agreed by all members):

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[12] NB As part of the anonymity, they have also not been presented in alphabetical order, but randomly.

- This architecture should be designed with interchangeable components, so a component can be replaced by **a** component (regardless of supplier). This is because of the shorter lifecycle of modern components.
- The use of Hybrid Level 3 is recommended because it is based on a core of operational scenarios and comes closest to a common architecture.
- Get rid of/Stop renewals with Class B systems (waste of resources in old technology). Use one set of common operational rules (i.e. future proof, agreed by all members).

- Homologation on an EU level, i.e. 'One Stop Shop' for Infrastructure (like with vehicles) [14.I]
- Shorten the lead time for procedures.
- Simplify the decision-making process:
  - Define clear work packages
  - Set clear but realistic deadlines
  - Speak only with organizations (one voice) and not with individual stakeholders (multiple voices of one organization)
  - If necessary, apply more political pressure

The benefits of such an approach would be:

- Shorter production time
- More focus on innovation rather than on customizing CCS-components per country.
- Lower prices due to larger volumes (i.e. more signalling per Euro)

In order to achieve this approach, Supplier 1 advises that ERA should have the responsibility for it. That is, ERA should be provided the authority to make the White Paper happen. Moreover, ERA is advised to continue the 'Roadshow' of visiting all Infrastructure Managers.

5.2 Supplier 2

Concerns
Supplier 2 believes that the EULYNX approach will not achieve the ultimate goal of SERA. EULYNX intends to standardize interfaces within national architectures. However, it is not beneficial to develop for each and every type of interlocking a specific interface. It does not strive for a common architecture. Therefore, the rules and functionalities will also remain national.

Supplier 2 feels that automation will be the next step, i.e. ATO over ETCS. Unfortunately, every country is carrying out their own pilot. It feels like this could be coordinated more, thus being more cost-efficient.

Recommendations to ERA
Supplier 2 recommends the following strategies to ERA:

- *Harmonize operational rules*. Currently, every country has its own way of doing things, as there is not one crossborder set of operational rules. ERA should convince the railways to harmonize the operational rules.
- *Focus on ERTMS Hybrid Level 3*. This is recommended because it is based on a core of operational scenarios and comes closest to a common architecture. Supplier 2 proposes to start with demonstrating the maturity of hybrid level 3, preferably first on isolated parts of a railway network. However, the deployment of ETCS Level 2 or Level 2-Overlay should be continued where it fits in with current track-train migration plans. At a certain stage of the ETCS-rollout, the matured ETCS Hybrid L3 can then be deployed on lines where train fleets (equipped with integrity) are ready to bring the benefits immediately.
- *ERTMS implementation strategy*. For the implementation strategy it is suggested to start with ETCS onboard, with the TOCs and/or FOCs being sponsored to counter their initial investments.

This strategy will provide the most beneficial option. More standardization leads to a greater market, which again will lead to lower prices.

5.3 Supplier 3

Concerns
Supplier 3 feels that co-creation, as is wished by several Infrastructure Managers, is not necessary. A proper solution can also be achieved by means of good liaisons on both sides.

Recommendations to ERA
Supplier 3 indicated that the fastest and most cost-efficient way to achieve SERA is to create a ‘Green field’ situation:

- Remove the complete Class B system.
- Make one set of operational rules, which are set by ERA.
- Focus on ERTMS level 3 for all countries.

By doing this, the number of interfaces will be reduced substantially, thus reducing the cost for all players.

5.4 Supplier 4

Concerns
Supplier 4 indicated their concern for the use of Class B systems. These will not benefit an interoperable SERA. In fact, it would be advisable to force railways to stop investing in Class B systems and to remove the current equipment.

The RBC and IXL-systems should be combined to one integrated system. Firstly, because in modern digital systems these become more intertwined anyway. Secondly, this will lead to one less interface issue.

Supplier 4 feels that country-by-country crossborder tests for baseline 3.6.0 (and 3.4.0) should be promoted more vehemently to ensure everything works as it should.

Recommendations to ERA
Supplier 4 recommends the following strategies to ERA:

- *Make a standard architecture for the (wayside) CCS system*. The use of standard architecture should be mandatory for all countries, including common operational rules and open interfaces. A good place to start would be with TMS. It is noted that this will take time and should be carried out step-by-step.
- *Simplify validation process*. ERA should simplify the process of validation without reducing the level of safety because the process of validation is very expensive. Moreover, it is a lengthy process, with occasionally approval being granted when it is already time for renewal of the system. Finally, many players are involved. The added value of some of these players is doubtful, e.g. ISAs and NoBos is doubtful; They never find something that is wrong.

Supplier 4 appreciates the efforts of the ERA. However, they feel the ERA is very ambitious. This leads to goals being set at too short notice, which therefore fail to be achieved. Moreover, though the quality of the ERA-work is good, the ERA does not have the resources (money and staff) to achieve all goals. Therefore, ERA should make a choice:

1. Go in deep: This requires a (minimum) critical mass with more people and more resources.
2. Stay at a high, abstract level: This will in effect then encompass more of a project manager role.

Supplier 4 favours the first option, where ERA should ultimately become the Infrastructure Manager for “Europe” (and of course for rolling stock).

5.5 Supplier 5

Concerns
Supplier 5 feels that technology is never an obstacle. Anything can be developed but requires time and money. Hence, there should be more focus on the business case then on the technology.

That said, Supplier 5 underwrites some improvements on technology:

- There is room for improvement on interfaces, e.g. the interface between IXL and RBC could be standardized and open.
- GSM-R is outdated. Other systems for wireless data communication such as LTE or FRMCS (UIC) could be used.
- Use wireless communication between IXL and objects, which will reduce costs.

Supplier 5 feels that an SLA, as is sometimes requested by Infrastructure Managers for onboard tenders, is not in the market's interest. The authorization process for approving a new baseline is complex (involving many parties), time-consuming and costly. Upgrades of the baseline are dictated externally, which involves high risks for the company and hence high offers to the Infrastructure Managers.

In order to draw new players on the market, the tenders for infrastructure must be split in ETCS-only tenders and Class B tenders. When a mix of ETCS with Class-B (interfaces, removal, adaption etc.) is requested, only the usual companies will tender. This is the case because only they have the knowledge of the Class B systems. Moreover, it is for newcomers not economically advantageous to invest in knowledge of Class B systems.

Recommendations to ERA
Supplier 5 recommends the following strategies to ERA:

- *Discontinue use of Class B systems*. Class B systems frustrate the market and its use should therefore be discouraged.
- *Harmonize operational rules*. A European set of harmonized operational rules should be mandatory for all countries. The development of these requires a role for ERA.
- *Simplify ETCS specifications*. Currently, ETCS comes with too many options. Supplier 5 advises (in lieu with UNISIG) to not make the exception into the standard, e.g. Euroloop and Infill are rarely used so avoid effort in its specifications.
- *Develop a standard for basic STM*. ERA should commission the development of a standard for basic STM for onboards. However, the country-specific features could be left to companies that are familiar with the country-specific Class B ATP.
- *Introduce threshold for retrofit in older rolling stock*. It is very expensive to retrofit older rolling stock (see also Chapter 4 Operating Companies on this). There should be a threshold from where it is no longer beneficial to retrofit ETCS on boards. ERA could play a role in providing help to fleet owners in making this decisions (help with business cases).

These recommendations have one thing in common – they all involve a stronger role for ERA. Supplier 5 feels that the 4th Railway Package offers many opportunities for change, for instance also for the 'One Stop Shop'.

5.6 Findings and Trends Suppliers

The market for CCS- and TMS- equipment (and especially ERTMS-equipment) is relatively complex and regulated by high safety levels, which is therefore dominated by a small group of specialised Suppliers. Moreover, the remaining reliance on national Class B technology retains this status quo – newcomers to the market cannot comply with the requirements and skills involved.

From a rail perspective, the established names, Alstom, Bombardier, Siemens and Thales are huge players. However, from an overall perspective, the rail market is a relatively small part of these supplier's business. These companies all consist of several smaller branch companies or divisions, focusing on a specific technology (e.g. rail, aviation, aerospace, military / defence). Even within rail, signalling is only one of the branches in addition to for instance rolling stock.

Drivers

Suppliers, being commercial companies, are basically driven by the need for turnover and profits. In general, the highest profit margins are attained by selling large quantities. The rail market is a relatively small part of these supplier's business.

Infrastructure Managers are dependent on this relatively small group of suppliers. As there is no open standard or wide-spread standardisation in the market and components, different Suppliers are not compatible. Once an Infrastructure Manager has purchased a system from a Supplier, it is difficult to change Suppliers. Moreover, developing new CCS-systems requires a substantial investment, which may not weigh against the expected profits, considering the size of the market.

5.6.1 Current Situation

Infrastructure managers state that Suppliers are not innovative, are driven by the need for turnover and profits and they sense a low level of service. Suppliers state in return that they want to innovate. However, from their point of view they just deliver what the client requests. In this case tailormade systems that meet national requirements (often Class B or Class B related). As a result, they need to mobilise their scarce resources to meet the demands of delivering nation specific services, instead of using them for innovations.

Regarding 'low level of service', from the interviews with Suppliers it becomes apparent that the Infrastructure Manager's sense of low level of service may be caused by other factors than a drive for profit margin:

- There is a sector wide shortage of staff with knowledge about Class B systems (and relay technology in general). Yet, all countries still adhere to the application of these systems. This means that supply and demand do not meet and therefore may be thin-spread to meet only basic demand (i.e. basic service level).
- Suppliers do not object to co-creation.
- Suppliers do not object to SLAs per se. However, as the decision-making process and external factors surrounding baselines are so obtuse, they are forced to include these risks in their offers. Therefore, the offers are higher than the market requests. This begs the question whether a different type of tender, with less risks for the Supplier, would reap a lower offer.

5.6.2 Future Strategies

All of the Suppliers would applaud more standardisation and a new designed common (high level) architecture including common operational rules, future proof and agreed by all stakeholders. This architecture should be designed with interchangeable components, so **a** component can be replaced by a component (regardless of supplier). This is because of the shorter lifecycle of modern components.

In addition, the use of Hybrid Level 3 is recommended because it is based on a core of operational scenarios and comes closest to a common architecture.

Regarding process it is advised:
- Homologation on an EU level, i.e. 'One Stop Shop' for Infrastructure (like with vehicles)
- Shorten the lead time for procedures.
- Simplify the decision-making process:
- Define clear work packages
- Set clear but realistic deadlines
- Speak only with organizations (one voice) and not with individual stakeholders (multiple voices of one organization)
- If necessary, apply more political pressure

The benefits of such an approach would be:

- Shorter production time
- More focus on innovation rather than on customizing CCS-components per country.
- Lower prices due to larger volumes (i.e. more signalling per Euro)

And there is an argument for standardisation coming from outside Europe. China produces CCS-systems in high volumes. Due to these high volumes and the political situation they are moving swiftly in the direction of standardization. It is feared that it is just a matter of time before the Chinese standards become a world standard.

All Suppliers see a role for the ERA in these strategies. In fact, the majority of the Suppliers envisage a stronger role for ERA to coordinate these processes and achieve these strategies. This involves mandate, more resources and accordingly a higher budget.

6 RAILWAY INDUSTRY DEVELOPMENT INITIATIVES

EULYNX and Shift2Rail are rail industry spanning initiatives, which could influence future strategies surrounding CCS- and TMS-systems. Within these initiatives Infrastructure Managers, the rail industry, and the European Union work to reduce the cost of the railway system. EULYNX aims to achieve this goal by standardising the interlocking interfaces, Shift2Rail by supporting research. However, they do have different timeframes associated with their goals:

- The EULYNX initiative works on the current strategy as it has already resulted in specifications.
- The Shift2Rail initiative works towards the goals of the Transport White Paper of the European Commission [13.A]. This is a future strategy with goals set for 2030 to 2050.

6.1 EULYNX

EULYNX is an initiative of 12 European Infrastructure Managers[13] to standardise interfaces and elements of the signalling systems. The goal of the EULYNX project is to reduce the lifecycle cost of the control and command system. Standardisation reduces cost of engineering, testing and regulatory approval. Secondly, it prevents vendor lock-in. [12.B]

The EULYNX project builds on work done in the Euro-Interlocking project and the INESS project [12.B]. Both the Euro-Interlocking project and the INESS project have a similar goal and method as the EULYNX project.

Within the Euro-Interlocking project 18 European railways participated in the project. The aim of the project was to reduce the lifecycle cost of interlockings by standardisation of the interlocking interfaces. This can create an open procurement market, simplify validation and approval and increase efficiency of planning and commissioning. [12.C]

The Euro-Interlocking project was followed by the INESS project. Within INESS, UNIFE and UIC agreed to continue the work of the Euro-Interlocking project. The aim of this project is to reduce the lifecycle cost of future interlockings. This was to be achieved by defining a common functionality of subsystems and standardisation of the subsystem interfaces. [12.D]. Figure 11 presents the timeline of interlocking standardisation projects.

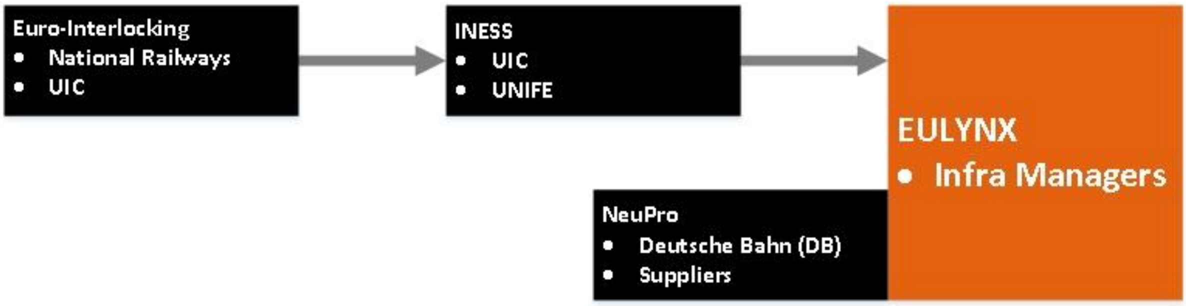

Figure 16 Timeline of interlocking standardisation projects.

The EULYNX project also builds on the results of European standardisation and national development projects such as NeuPro from DB Netze. However, the focus has shifted from standardising products to standardising interfaces between subsystems. [12.E]

The EULYNX project is divided into different cluster projects. The project management coordinates the activities and supports the change process. Each cluster project is undertaken by one Infrastructure Manager and concerns a single interface (e.g. Interlocking-TMS, Interlocking-RBC). The figure below presents an overview of the EULYNX project. It presents all subsystem interfaces EULYNX is standardising.

[13] Not to be confused with European Infrastructure Managers EIM, which is a partnership of 15 Infrastructure Managers.

Within each cluster, core requirements are specified using the system engineering approach. The core requirements are supplemented with national requirements to ensure these are included in the standard.

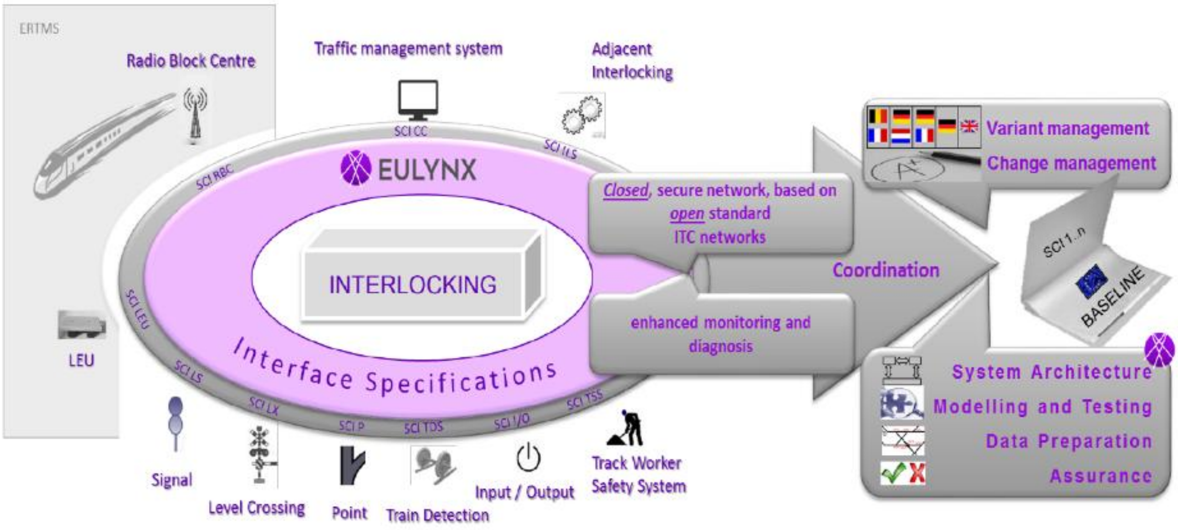

Figure 17. Overview of the EULYNX project [12.E].

On the 15th December 2017 EULYNX released baseline 2. This completes the activities of the project organisation. The project organisation is to be transformed into a standing organisation that maintains the standards. Error corrections, new interfaces and additional national implementations will be handled by the standing organisation. [12.E]

Standard interfaces allow the CCS to be divided into subsystems. This provides new possibilities:

- *Independent lifecycle of subsystems.*
  TMS, interlockings, object controllers and objects can be replaced independently. Lifecycles can be tailored to the specific subsystem. Preventing subsystems to be replaced before end of life.
- *Improved market access for new suppliers*.
  It is no longer required to supply the full CCS-system. Suppliers can specialise in a subsystem, for example only suppling switches or train detection systems.
- *Prevention of lock-in.*
  The standard interface allows supplier independent replacement of subsystems.
- *Prepare for ERTMS.*
  CCS can be replaced using the standardised interfaces retaining new interlocking built according to the EULYNX standard.

However, the new possibilities are threatened by:
- *Suppliers not supporting the new interfaces*.
  Suppliers do not have an incentive to support the standard interface. Currently suppliers can vendor-lock-in Infrastructure Managers, thus reducing the threat from other competitors. A standard interface is not in the suppliers' interest, because a standard interface allows supplier-independent replacement of subcomponents, opening up the modification market to competition.
- *More interfaces*
  The downside of decomponating systems in several subsystems is that this gives rise to more interfaces.

Shifting the focus from standardising products to standardising interfaces proves to be useful. The EULYNX standard is already being used by Infrastructure Managers. For instance, Norway, Luxemburg and Germany currently use the EULYNX standard in contracts.

6.2 Shift2Rail

Shift2Rail Joint Undertaking is a public private collaboration between the European rail sector and the European Union. It provides, as part of Horizon 2020, a platform to smart and sustainable growth through its actions to foster research and innovation in the European railway sector. Research and innovation carried out under the Horizon 2020 initiative develops the technology to complete the Single European Railway Area.

Shift2Rail is funded by the Horizon 2020 initiative. Funds are only available when the rail industry commits an additional contribution. The X2Rail-1 project is an example of an innovation project in CCS which is funded by both Shift2Rail and the rail industry. [13.D]

Shift2Rail supports the key goals set out by the European Commission in the Transport White Paper [13.C]. A number of these goals relate specifically to rail passenger, freight transport, while others relate more generally to urban mobility, with a direct impact on rail. [13.A]. The most relevant are listed below.

For passenger rail

- Triple the length of existing high-speed rail network, and to outpace the increase in aviation for journeys up to 1000km.
- Connect all core network airports to the rail network, preferably high-speed.
- Establish the framework of a European multimodal transport information, management and payment system.

For freight

- To increase the cargo transport by rail for transport over 300km
- Deployment of ERTMS on the European Core Network
- Connect all seaports to the rail freight system
- Establish rail as the backbone of the EU freight transport system

For urban mobility

- To replace the use of ‘conventionally-fuelled’ cars in urban transport.
- Achieve essentially CO2-free city logistics in major urban centres
- Establish the framework of a European multimodal transport information, management and payment system.

Research & Innovation Programme (R&I Programme)

The R&I Programme of Shift2Rail works towards achieving these key goals. Achieving these goals requires different types of activities, including:

- Demonstration of activities
- Research and technological development activities
- Other supporting activities

On top of the activities mentioned here, that are funded and conducted directly by the Shift2Rail. The members of Shift2Rail will be required to conduct additional activities leveraging the effect of the R&I activities undertaken within Shift2Rail. These activities do not receive any financial support by the S2R undertaking but contribute directly to the objectives set out in the S2R master plan.

Demonstration of activities

Demonstration of new technologies allows an assessment of the potential for improvement to the national EU transport networks and SERA. The main focus of Shift2Rail is therefore on these Technical Demonstrators. To assess and provide guidance on the most efficient combination of these new and existing technologies.

These activities are considered as being the last non-commercial stop to demonstrate the operation performance and reliability of the deliverables from the technology demonstrators.

Research and technological development activities

Shift2Rail will also manage collaborative research activities consisting mainly of applied research. These research and technological development activities can be of the following types:

- Dedicated research projects on the development of specific technologies and concepts to fill the gaps in innovative technologies, and in business, organisational and logistic solutions
- Strategic studies, such as for instance deriving the future demand for rail services from long-term trends.
- Projects addressing cross-cutting activities supporting the successful take-up of technological innovations

Other supporting activities

Shift2Rail is also tasked with carrying out other activities in support of research and demonstration activities. These activities include:

- Management activities, over and above technical management linking together the project components, as well as setting up monitoring, evaluation and quality assurance processes.
- Pooling, reviewing and commenting user requirements and proposing interoperability standards
- Conducting activities to communicate and disseminate research results and prepare for the implementation, including knowledge management, communications and activities directly related to protection of results.
- Liaising with relevant stakeholder and establishing links with related European, national and international research and innovation in the rail technical domain.

Innovation Programmes

The research conducted within the R&I Programme is structured in 5 Innovation Programmes, each focusing on a specific asset-specific innovation.

Though there are also contributions from other Programmes, mainly Innovation Programme 2 covers the CCS-system, aiming to take further advantage of the possibilities of ERTMS. However, a key challenge is to ensure the ERTMS core is not impacted. Backwards compatibility with ERTMS protects investments in mainline and urban railways. [13.D]

Eleven Technical Demonstrators are included in innovation programme 2, including:

- *TD 2.1 Development of a new Communication System*
  Development of an adaptable train-to-ground communications system. Using packet switching/IP technology. Providing enhanced throughput, safety and security.
- *TD 2.2 Automatic Train Operation*
  Development and validation of ATO over ETCS. Providing a grade of automation of 3 or 4.
- *TD 2.3 Moving Block*
  Development of moving block technology compatible with ERTMS.
- *TD 2.4 Safe Train Positioning*
  Development of fail-safe onboard train positioning. Reducing the need for trackside train detection.
- *TD 2.5 Train Integrity*
  Specification and prototyping of a train-tail localisation system. Providing train integrity for freight and locomotive hauled trains.
- *TD 2.6 Laboratory Test Framework*
  Develop simulation tools and testing procedures to minimise on-site testing.
- *TD 2.7 Standardised Engineering and Operational Rules*
  Creation of an open interface and a functional ETCS description model.
- *TD 2.8 Virtual Coupling*
  Enable trains to run within absolute braking distance.
- *TD 2.9 Traffic Management System*
  Aiming to improve traffic management operations, automating processes of data exchange with other rail business services.

- *TD 2.10 Smart Radio-Connected All-in-All Wayside Objects*
  Development of smart equipment able to connect to control centres, trackside objects and onboard units.
- *TD 2.11 Cyber Security*
  Optimal level of protection against any significant threat to the signalling and telecom system.

Innovative new technologies help the railway sector to improve competitiveness. Technical Demonstrators such as TD 2.6, TD 2.7 and TD 2.10 can help to reduce the life-cycle cost of the railway transport system. Either by reducing the cost of individual components or by reducing the validation cost. Furthermore, Technical Demonstrators such as Automatic Train Operation (TD 2.2) and Moving Block (TD2.3) can increase the capacity of the railway network, reducing the need for large and expensive infrastructure investments.

However, Shift2Rail is a research programme. All technologies are still under development and have not yet yielded practical results. Given the long-term focus of Shift2Rail, in the short-term practical applications are not expected.

6.3 Findings and Trends Railway Industry Development Initiatives

We have identified two relevant rail industry spanning initiatives which could influence the future strategies surrounding CCS- and TMS-systems.

EULYNX is an initiative of 12 European Infrastructure Managers with a main focus on interfaces and signalling, with regard to this study focusing on interlocking interfaces between current system elements. Standardisation of the interlocking interface would reduce the lifecycle of CCS by:

- Allowing independent lifecycles for subsystems.
- Improving market access for new suppliers that focus on specific subsystems.
- Preventing lock-in with CCS-systems.
- Allowing new infrastructure to be prepared for ERTMS.

The EULYNX standards are already in use, hence having a short-term emphasis. For instance, Norway, Luxemburg and Germany currently use the EULYNX standard in contracts. However, currently the EULYNX approach deviates from the recommendations of Suppliers described above. EULYNX focuses on standardizing interfaces within the national architectures, not a common architecture. Therefore, also the rules and functionalities remain national. The Suppliers recommend aiming for a common architecture of ERTMS Level 3 without Class B equipment, rather than on individual components, thus reducing the number of interfaces.

Shift2Rail Joint Undertaking is a public private collaboration between the European rail sector and the European Union. Shift2Rail aims at achieving the reduction of lifecycle cost by supporting innovative new technologies and product improvement, for the rail industry in the broadest sense.

- Introduction of standardised testing, standardised engineering and operational rules reducing the cost of validation.
- Wireless trackside technology reducing cost of individual components.
- Automatic train operation and moving block technology over ERTMS improving the capacity of railways, without the need for infrastructure investments.

Shift2Rail has a long-term focus (2030-2050).

These two initiatives demonstrate that on the one hand there is need for the standardisation of interfaces. On the other hand, the demand for (national) specific interfaces results in the decomposition of systems into smaller subsystems, which create more interfaces. These two trends seem contradictory. However, there are examples in other industries, in particular ICT, that demonstrate that a good standard interface allows for a wide variety and diversity of components. We will elaborate on these examples in the next chapter.

The activities of Shift2Rail are complimentary as they aim at improving and/or innovating components themselves. Provided this is accomplished by using standard interfaces, these activities can progress autonomously.

7 NON-RAIL INDUSTRY SOURCES OF INSPIRATION

The railway industry is dictated by safety. This also causes the industry to be a conservative and traditional industry – slowing innovation, which needs to be well-thought-out, and extensively tested. Whereas in the railway industry digital standardisation and common interfaces are uncommon or still in the spring of their development, other industries that hold safety in the highest regard digital standardisation and shared interfaces have succeeded in this direction. To draw from their experiences, aviation and automotive industries were looked into. Additionally, the ICT-sector could provide inspiration as most modern CCS-systems are increasingly ICT-based.

7.1 Automotive: AUTOSAR

The AUTOSAR (AUTomotive Open System Architecture) partnership was mentioned in the course of the feasibility study as an example for the rail industry. It pursues the objective of creating and establishing an open and standardised system architecture and interface for automotive Electronic Control Units (ECUs). The rail industry can learn lessons from the partnership for the standardisation of CCS.

The AUTOSAR partnership is an alliance of vehicle manufacturers, suppliers, service providers, and other companies active in the automotive sector. The partnership has been established in 2002 by German automotive companies, but the number of participants has since increased to over 190 partners. Interesting to note is the absence of Road Infrastructure Managers in the AUTOSAR partnership, their absence is possible because all intelligence is centred in the vehicle. [15.B]

Approach

The ultimate goal of AUTOSAR is to increase the flexibility for product modifications, upgrades, and updates and increase the use of “Commercial off the Shelf” hardware and software components. This resulted in the objective to standardise the basic system architecture and interfaces of in vehicle ECUs. ECUs are specialised control units controlling individual electronic subsystems such as: the door lock systems, the engine control systems, and the brake system.

The AUTOSAR system architecture facilitates specialisation of ECUs and the separation of hardware and software. The AUTOSAR Methodology describes functions and information exchange between different ECUs. The AUTOSAR Platform describes the ECU system architecture and distinguishes three software layers: [15.C]

- *Application Layer*
  Hardware independent software layer. This layer provides suppliers the possibility to write supplier specific software, enabling competition between suppliers.
- *Basic Software Layer*
  Hardware dependent software layer, that performs specific predefined functions enabling the functional part of the Application Layer.
- *Runtime Environment Layer*
  The Runtime Environment Layer provides the interface between the Application Layer and Basic Software layer. Furthermore, the Runtime Environment Layer provides the interface between different ECUs.

This approach shows the ICT-way of thinking on systems. The onboard system is divided into highly specialised subsystems, connected with standardised interfaces. Furthermore, hardware and software are separated, allowing functional software to be developed hardware independently. An illustrative example is the 2006 Citroën C6 automobile. 27 specialised onboard computers (approx. 3 main units and 24 ‘object controllers’) control various car functions, communicating with standard interfaces in distinctly separated safe and non-safe circuits.

Organisation

The AUTOSAR partnership differentiates between different memberships. The contribution of different partners depends on the membership of the partner. The following memberships are defined: [15.D]

- *Core Partners*
  Core partners influence overall strategy, establish the roadmap, set budgets, and manage admissions of new partners.
- *Core Partners, Premium Partners, and Development Partners*
  Core, Premium, and Development Partners specify and develop the AUTOSAR Platform.
- *Core Partners, Premium Partners, Development Partners, and Associate Partners*
  The developed standards are available for use by all partners of the AUTOSAR partnership.

Differentiating between partnerships simplifies the management of a large number of different stakeholders.

7.2 Aviation: IMA

Integrated Modular Avionics (IMA) is the onboard system architecture concept of the aviation sector. Contrary to the railway and automotive sector, no standardisation of organisation of onboard systems exits in aviation. Thus, IMA is not a standard or set of standard components, it is a concept.

The goal of the IMA concept is to reduce the number of onboard computers, saving weight of the aircraft. The approach taken is to separate hardware and software, allowing one onboard computer to run multiple applications. The result is a reduction in the number of onboard computers and the use of standard non-system specific computers. However, the computers are aircraft/supplier specific. [14.F]

7.3 ICT-Sector

The ICT-sector is a sector with a high pace of innovation and many different highly specialised suppliers. Furthermore, many standards exist in ICT to ensure compatibility of the components of the many suppliers. The combination of a high pace of innovation and many standards is interesting, the railway sectors can learn lessons from the ICT sector for the digitalisation and standardisation of CCS.

ICT way of thinking

The ICT way of thinking is known for separating the system architecture of a computer system into different layers. For each layer it functions are specified. The two main layers are the software layer and the hardware layer. Moreover, the software layer is further separated into applications and software controlling specific hardware. The result is independence between hardware and software, allowing software developers to easily develop software independent from different hardware configurations.

Furthermore, the separation in layers allows suppliers to specialise in hardware and specific software while still using the common platform.
[15.K]

Standardisation in ICT

The ICT-sector is made up of many highly specialised suppliers. To ensure compatibility between the specialised components many development initiatives exist within the ICT-sector. This paragraph discusses some of the development initiatives in IT.

USB-IF

One of the most commonly known interfaces in ICT is USB (Universal Serial Bus). USB is developed and maintained by the USB Implementers Forum (USB-IF). USB-IF was formed in 1995 by, among others, HP, NEC, Microsoft, Apple, and Intel.

The main goal of USB has been to develop a connector which can connect many different devices to a computer. Before the USB standard different types of devices where connected with different connectors. This resulted in the need for computers to have many different connectors available. The USB standard has addressed this.

The design of the first USB connector was finalised in 1996. Since then, the standard has been maintained resulting in a higher data transfer and smaller connectors. The newest USB standard is made up of multiple different standards which can be combined to create a USB connector:

- *Connector Standard*
  The connector standard prescribes the physical shape of the connector. This allows suppliers to choose a connector that fits their device, from large type A connectors on laptops to small type micro or C on mobile devices.
- *USB Communication Standard*
  The Communication standard is the main part of the USB standard and prescribes how information is transmitted on a USB connection. The USB standard contains different communication standards, ranging in data throughput.
- *Power Delivery-protocol*
  The Power Delivery-protocol (PD) prescribes how power is transmitted over a USB connection. Multiple different PD profiles are specified. Different PD profiles allow devices with different power needs to be supplied with power over a USB connection. For example, a laptop needs more power than a mobile phone.
- *Alternate modes*
  To make the USB standard even more powerful and flexible other communication standards such as HDMI (for video output), Ethernet (for internet), and PCI-e (for graphics cards etc.) can use a USB connector.

[15.J]

The modularity and flexibility of the standard allows many different devices to be equipped with USB in a cost-effective way. For example, a simple computer mouse is most likely to be equipped with the most common connector, the lowest data communication standard, and a low power delivery protocol. This allows for the use of low cost cables and communication chips. Contrary, a powerful external graphics card is likely to be connected with a faster alternate mode communication standard, and a higher power delivery protocol. This requires higher cost cables and chips, which is logical given the use case. The computer these devices are connected most likely support the full range of the USB standard, allowing it to connect to many different devices.

Institute of Electrical and Electronic Engineers Standards Association (IEEE-SA)

IEEE-SA is the organisation with IEEE responsible for developing and maintaining standards in a broad range of fields, among which IT. Notable standards include the Ethernet and WI-FI standards.

IEEE-SA develops standards according to a 6-step process:

1. Initiating the Project
2. Mobilising the Working Group
3. Drafting the Standard
4. Balloting the Standard
5. Gaining Final Approval
6. Maintaining the standard

Standards are developed by working groups made up out of individuals/entities with a specific interest in the field of the respective standard. The aforementioned process ensures a standard which is widely supported by the various stakeholder. Furthermore, the process does not end after the initial standard is completed. Errors in the standard and innovations in the field of the standard require the standard to evolve. Modifications of the standard are again made by the working group to ensure the standard remains supported.

[15.L]

Proprietary standards

However, some parties have made the decision to develop their own proprietary standards. For example, Apple does not use the de-facto standard USB connection on their phones. The main reason for the use of proprietary standards is the ability to control the 'eco-system' of products. The proprietary standards can only be used if a licence has been acquired form Apple, giving them the power to licence only those products which comply to Apples' quality standards. Furthermore, the use of proprietary standards is made possible by the large number of especially iPhones Apple ships. These large volumes offset possible additional development cost.
[15.N]

7.4 Findings and Trends Non-Rail Industry Sources of Inspiration

With regard to standardisation and interfacing, the railway sector can learn from the AUTOSAR approach and IMA concept. The separation of software and hardware allows software to run on hardware independently. This concept facilitates both highly specific subsystems (AUTOSAR) and running multiple applications on standard computers (IMA). Moreover, it allows for suppliers that specialise in subsystems. The standardised interface in the AUTOSAR approach ensures that subsystems of different suppliers work together. This way of thinking on systems is not yet common in the railway sector.

The railway sector can look for inspiration on how to approach standardisation towards the ICT-Sector. Standards in ICT are often made up of sub-standards. This has the following advantages:

- *Separation of hardware and software*
  The separation of hardware and software allows software to be developed independently of hardware.
- *Standards made up out sub-standards*
  Sub-standards can be combined in different ways depending on the specific cases. This allows one standard to be useful for many use cases.
- *Highly specialised suppliers*
  Without standards it would not be possible to create supplier independent compatibility. Thus, standardisation enables highly specialised suppliers.
- *Inclusion of wide group of stakeholders in the standardisation process*
  Working groups which develop the standard are often made up out of a large group of stakeholders. This ensures a widely supported standard. Furthermore, it ensures the standard is adopted by the various stakeholders which is the goal of the standardisation process.

Conclusion

One commonality of many of these development initiatives is their focus on interfaces, with the USB being the most prominent example of this. As in the railway industry digital standardisation and interfaces are uncommon or still in the spring of their development, this begs the question how the railway industry differs from these successful industries. Our observation tells us that in the cases of AUTOSAR, IMA, and ICT-sector the various stakeholders all had the same driver in the long-term, whereas the drivers for Infrastructure Managers, Suppliers, and Operating Companies differ from one another.

8 EUROPEAN UNION

All interviewed parties have referred to European Union strategy, policy, subsidies, or legislation that may have an impact on the conditions for ERTMS deployment and the evolution of the rest of the CCS-system. This chapter investigates these into more detail.

8.1 EU DG Move

The European Commission (EC) is an institution of the European Union, responsible for proposing legislation, implementing decisions, upholding the EU treaties and managing the day-to-day business of the EU. The Commission operates as a cabinet government, with 28 members of the Commission (one member per member state). The term Commission is variously used, either in the narrow sense of the 28-member College of Commissioners or to also include the administrative body of about 32,000 European civil servants who are split into departments called directorates-general and services. The Directorate-General for Mobility and Transport (DG MOVE) is the Directorate-General of the European Commission responsible for transport within the European Union. In addition to developing EU policies in the transport sector and handling dtate aid dossiers, DG MOVE manages the Connecting Europe Facility funding programme for the Trans-European Transport Networks and technological development and innovation.
[14.B]

At the workshop in September 2018 DG MOVE presented her perspective on the deployment of ERTMS. There is a positive business case for it, however, this depends on the achieved coordination in the implementation of ERTMS. This is supported by the findings presented in the report of the European Court of Auditors. The deployment is mainly challenged by the standardisation of the On-board Unit (OBU). This eases retrofit which is currently lagging. An innovative approach is taken on OBU financing by broadening the focus to include OBU's. However, ERTMS must deliver from a political point of view to ensure financing can be given in the future.
[14.C]

8.2 ERA

The Directorate-General for Mobility and Transport (DG MOVE) is made up of five Directorates plus a shared Directorate with DG Ener and several agencies across Europe. The European Union Agency for Railways (ERA) is one of those agencies [14.D]. The objective of the Agency is to:

- Promote a harmonised approach to railway safety
- Devise the technical and legal framework in order to enable removing technical barriers, and acting as the system (design) authority for ERTMS and telematics applications. In that respect, it must establish a transparent process to manage, with the contribution of the sector's representatives, any system changes.
- Improve accessibility and use of railway system information
- Act as the European Authority under the 4th Railway Package issuing vehicle (type) authorisations and single safety certificates, while improving the competitive position of the railway sector.
  [1.H]

At the workshop in September 2018, the ERA presented her vision on the railway system of the future. The ERA stated that other transport modes are much faster to absorb technology, leading to a competitive disadvantage of rail. Rail must overcome its limitations (fragmentation), in order to become the backbone of the multimodal transport chain. This requires securing the opportunities for innovation in rail.

The ERA has a long-term vision on autonomous trains. The introduction of onboard intelligence and power allows for the introduction of fully autonomous trains. All safety logic will be moved from trackside to onboard, with trains directly controlling track assets. The trackside system will only consist of switches, level crossings, and a network wide traffic management system. The new system will consist of three layers/ loops of control:

1. Individual vehicle: intelligence and safety system is concentrated here
2. Collective: real-time communication between vehicles about location and speed, input for safety system in layer 1.
3. Network wide traffic management system

A large issue will be cybersecurity, which is a topic which must be addressed.

Furthermore, making the railway the backbone of an intermodal system will require global standardization. For example, one TMS language. Standardization on a global level is common practice in aviation and the maritime sector.

Concerning the lack of common operational rules, the following was discussed:

- A fundamental issue is the issue of one operational language. Currently, initiatives are developed to standardize the operational language in rail.
- To standardize the operational rules on a European level some parts of the TSI OPE are taken out and moved to the TSI CCS. Further standardizing operational rules is needed.
- Shunting is not standardized yet.
- Currently there are different processes for re-authorisation. However, ERA is working on a flowchart on when and when not to re-authorize a train. When finished, the flowchart will be shared with all stakeholders.
- ERA feels that it needs to keep an eye on what happens outside of Europe. Europe can learn from the lessons learned elsewhere, for example the lesson of PTC interoperability or the growth of railways in China because of the single railway area.
  [14.E].

8.2.1 4th Railway Package

As said above, the ERA acts as the European Authority under the 4th Railway Package. The 4th Railway Package is a set of 6 legislative texts designed to complete the single market for Rail services (Single European Railway Area). Its overarching goal is to revitalise the rail sector and make it more competitive vis-à-vis other modes of transport. It comprises two 'pillars' – a Governance and a Technical Pillar.

The Governance or market pillar will complete the process of gradual market opening started with the 1st railway package. It establishes the general right for railway undertakings established in one Member State to operate all types of passenger services everywhere in the EU, lays down rules aimed at improving impartiality in the governance of railway infrastructure and preventing discrimination and introduces the principle of mandatory tendering for public service contracts in rail. Competition in rail passenger service markets will encourage railway operators to become more responsive to customer needs, improve the quality of their services and their cost-effectiveness. The competitive tendering of public service contracts will enable savings of public money. The market pillar is expected to deliver more choice and better quality of rail services for European citizens, these being the overriding objectives.

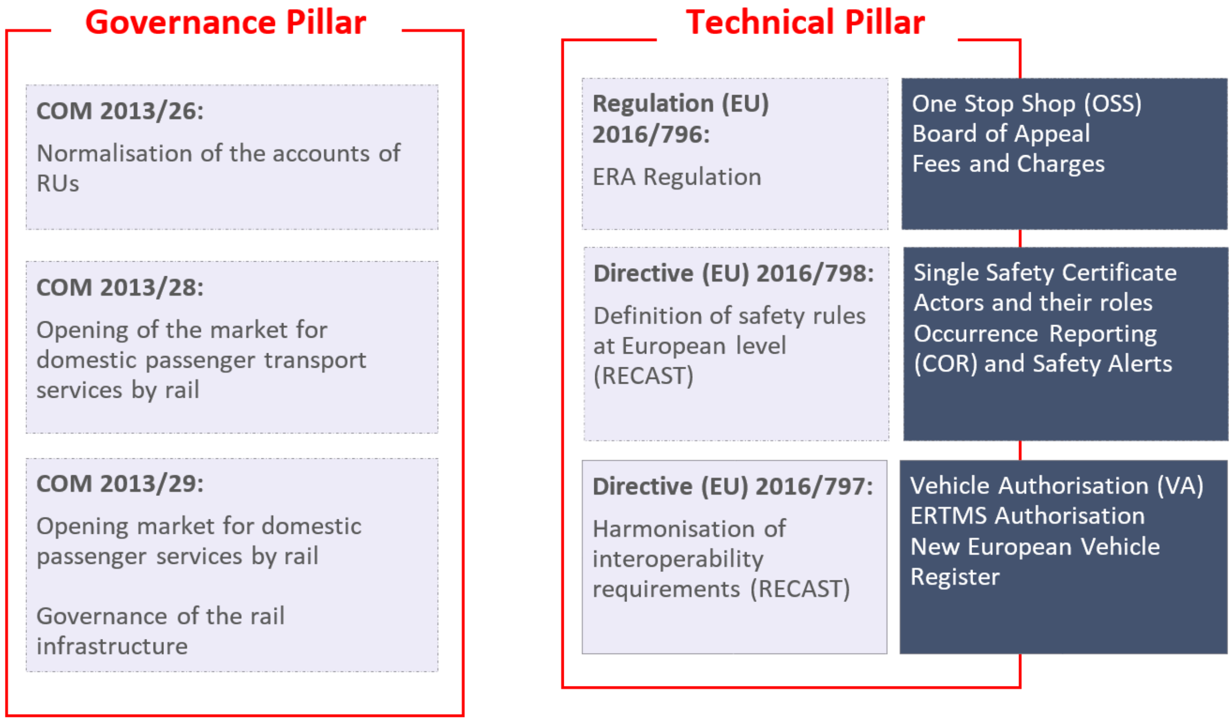

Figure 18 4th Railway Package.
Source: https://www.uiprail.org/index.php/dossier-menu/policy/activity-4th-railway-package (consulted 1 October 2018)

The Technical pillar is designed to boost the competitiveness of the railway sector by significantly reducing costs and administrative burden for railway undertakings wishing to operate across Europe. In particular, it will:

- save firms from having to file costly multiple applications in the case of operations beyond one single Member State. ERA will issue vehicle authorizations for placing on the market and safety certificates for railway undertakings, valid throughout the EU. So far, railway undertakings and manufacturers needed to be certified separately by each relevant national safety authority.
- create a "One stop shop" which will act as a single entry point for all such applications, using easy, transparent and consistent procedures.
- ensure that European Rail Traffic Management System (ERTMS) equipment is interoperable.
- reduce the large number of remaining national rules, which create a risk of insufficient transparency and disguised discrimination of new operators.
  [14.F]

After adoption by the Council in October 2016, the European Parliament formally approved the final element of the package in December 2016.

8.2.2 ERTMS Implementation Planning

As said above, the ERA acts as the system (design) authority for ERTMS, establishing a transparent process to manage, with the contribution of the sector's representatives, any system changes. Member States have agreed to equip at least 30-40% of the tracks of the nine European Core Network Corridors with ERTMS by 2023. In 2030 all track should be equipped with ETCS trackside. [1.A] However, this is already a revised planning. The original dates were respectively 2015 and 2020. Unfortunately, these dates were not met or were deemed as impossible to meet due to lack of money, lack of qualified staff, technical problems and distrust in the system by national governments.

At the moment, there are indications that the new deadlines will not be accomplished either. See for instance the article of 30 May 2018 below on the delay of the deployment of ERTMS in the Netherlands. The governmental decision is delayed as the costs of implementation are expected to be higher than expected.

As a result, fewer corridors will be equipped with ERTMS and the first two corridors will not be implemented until 2026-2028.

Kosten uitrol ERTMS hoger dan verwacht, programmabeslissing uitgesteld

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De Nederlandse overheid zal dieper in de buidel moeten tasten voor de uitrol van het beveiligingssysteem ERTMS. Uit een voortgangsrapportage van het Programma ERTMS blijkt de spoorsector met het huidige budget slechts zeven tot acht baanvakken met het Europese systeem uit kan rusten. Eerder werd gedacht dat de financiering de ombouw van twaalf baanvakken zou dekken.

Minder baanvakken

Staatssecretaris Stientje van Veldhoven meldt in de begeleidende brief bij de voortgangsrapportage dat minder baanvakken kunnen worden aangepast, omdat de directe kosten hoger zijn dan eerder verwacht. Er komen kosten bij vanwege 'het opzetten van een testlab, het aanpassen van twee bestaand[illegible] van machinisten en extra budget voor beheer en onderhoud die niet in de rami[illegible] en meegenomen'.

Daarnaast wordt duidelijk dat de programmabeslissing [illegible] Europese s[illegible] steld naar volgend jaar. Deze stond eerder gepland [illegible] jaar. Het uitstel betekent volgens het programmabureau ook dat 'de indienststelling van de eerste twee baanvakken naar achte[illegible]n schuift'. Die kunnen volgens de nieuwe plannin[illegible] tussen 2026 en 2028 in gebruik worden [illegible]nomen. Het ui[illegible] van de programmabesli[illegible] heeft te maken [illegible] complexiteit van het project en de [illegible]inge afhan[illegible]en binnen het pro[illegible] 2018 zal vo[illegible] Veldhov[illegible] in het teke[illegible]etsen [illegible]mali[illegible]

Figure 19 Article about ERTMS deployment in the Netherlands published in ezine SpoorPro 30 May 2018. [6.F]

In 2017 the European Court of Auditors reported on an audit of a single European traffic management system. Their conclusions on the planning of the ERTMS migration are in line with the (more recent) news reports in the Netherlands. Moreover, they are also critical on the realisation of a Single European Railway Area:

> "V. So far, deployment in the EU is at a low level and represents a patchwork, despite the fact that the ERTMS concept and vision to enhance interoperability is not generally questioned by the rail sector. The current low status of ERTMS deployment may mainly be explained by the reluctance of many Infrastructure Managers and railway undertakings to invest in ERTMS equipment due to the expense entailed and the lack of an individual business case for many of them. EU funding, even if better managed and targeted, can only cover a limited amount of the overall cost of deployment.
>
> VI. This puts not only the achievement of the deployment targets set for 2030 and investments made so far at risk, but also the realisation of a single railway area as one of the major Commission's policy objectives. It may also adversely affect the competitiveness of rail transport as compared with road haulage." [1.B]

Considering the remaining lifespan of their current non-ETCS systems, the various Member States have chosen different strategies for the deployment of ERTMS on initially the Core Network routes and subsequently on their rail network. However, the European Deployment Plan does not include a strategy or deadline for decommissioning national system in the Member States. The absence of such a strategy and deadline pose a significant obstacle in any decisions or long-term investment planning relating to systems interfacing with ERTMS, including the non-ETCS systems interfacing with the ETCS-systems.

8.2.3 ERTMS Users Group

The ERTMS Users Group is a European Economic Interest Grouping formed in 1995. The members of the ERTMS Users Group are railway companies with large investments in ERTMS (typically more than €250 million). The ERTMS Users Group works closely together with the European Union Agency for Railways (ERA), UNISIG (the international association of signalling companies in the railway industry), the Railway Operational Communications Industry Group, (the providers of railway telecommunication systems) and the independent laboratories involved in the testing of ERTMS equipment. The ERTMS Users Group offers a platform for railways peers to share experiences and to consolidate their views. Also, the ERTMS Users Group advises the Community of European Railways (CER), the European Rail Infrastructure Managers (EIM), the European Rail Freight Association (ERFA) and the European Passenger Train and Traction Lessors' Association (EPTTOLA), together with the International Union of Railways (UIC). Finally, the ERTMS Users Group also advises the European Core Network Corridor organisations in the deployment of ERTMS on their rail freight corridors.

Its members are:

- Adif, Spain
- Banedanmark, Denmark
- Deutsche Bahn Ag/DB Netz Ag, Germany
- Infrabel, Belgium
- Bane Nor, Norway
- Network Rail, United Kingdom
- ProRail, The Netherlands
- SNCF Réseau, France
- RFI, Italy
- SBB, Switzerland
- Trafikverket, Sweden

[14.G]

The ERTMS Users Group together with EULYNX presented their view on a Reference CCS Architecture (RCA) at the workshop in September 2018. They stated that the implementation of ERTMS in combination with legacy CCS is too expensive and does not bring sufficient benefits. It is estimated that RCA brings significant life cycle cost reductions. The starting point for the RCA is a greenfield situation, as a reference architecture starting from the legacy situation results in too much complexity. From the onboard perspective it is only necessary to have the train equipped with ERTMS. This includes ATO. The most important parts of the RCA are:

- System Architecture
- Requirements
- Data Model

The next steps for RCA are:

- Come to an agreed decomposition of the CCS system.
- Define interfaces to develop.

SmartRail 4.0 is basically a starting point of RCA.

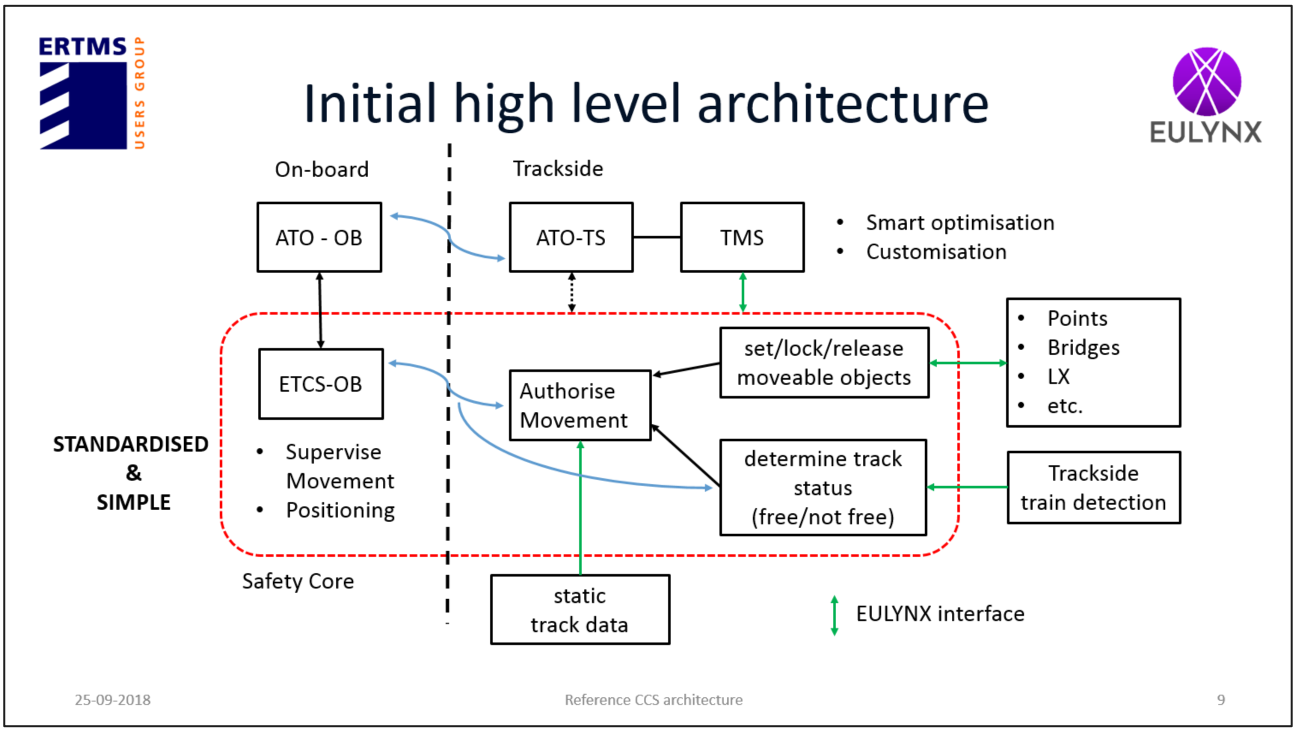

Figure 20. Screenshot proposed high level architecture presentation RCA [14.H]

The biggest identified risk is members not agreeing on an RCA. Another risk is that there is no scenario for migration of RCA yet. The migration will differ for each country depending on the legacy systems and the drivers. Some countries will migrate quick and other countries will migrate slow.
[14.H]

8.3 EU Legislation

The European Union (EU)/ European Agency for Railways (ERA) aims to increase the competitiveness of rail versus road and air traffic by establishing a Single European Railway Area (SERA). One of the means of attaining this goal is the implementation of ERTMS. However, despite the efforts of the ERA and the available subsidies for the implementation of ERTMS, the goal has not yet been reached. With regard to this goal several legislative challenges were mentioned in the interviews with the various stakeholders:

- EU Procurement legislation
- EU Subsidies
- TSIs

8.3.1 EU Procurement Legislation

The interviews with Infrastructure Managers showed that they would prefer longstanding work relations with their suppliers. An important condition to enable those relationships is a fully open and transparent cooperation between IM and suppliers. This avoids conflicts with European legislation. According to European legislation and jurisdiction, participating in collaboration with the Infrastructure Manager will exclude them from the next project phase(s) when having an unfair advantage in knowledge in relation to competitors.

Opting for longer projects is not an option either. Throughout the development of a product, significant scope changes could occur. According to European legislations, when these scope changes occur, a new tender would have to be put on the market, halting progress of the development.

8.3.2 EU Subsidies

At the workshop in September 2018, it is found that there is consensus on the statement that installing ERTMS onboard a train does not result in a passenger and freight increase, nor an improvement of passenger satisfaction). This makes it unappealing for the Operating Companies to invest in ERTMS. This is particularly the case for smaller Operating Companies, as they cannot rely on economies of scale. Contrarily, Infrastructure Managers can rely on public funding.

In fact, the regulations in the Railway Guidelines[14] state that private parties such as Operating Companies may only be partly subsidised by the EU (channelled through the Member State) for the implementation of onboards with regard to interoperability on the Trans-European transport network:

> Considerable support for ERTMS deployment has been offered through the TEN-T and CEF programmes since 2007, with over EUR €1.2 bn having been committed to date. In addition, the cohesion policy (currently ESIF) funds have been used extensively to support ERTMS in cohesion Member States and regions.
> Future EU-level funding support is likely to be constrained and needs to be targeted more effectively. EU funding support beyond grant funding, for example through blending, deployment funds, or increased use of private finance, should be considered more actively by the rail industry.
> Work through the ERTMS business case has identified that RUs, in particular those operating in international environments, have difficulties obtaining a positive business case for deployment as retrofitting costs can be high, and benefits (seen at system level) are difficult to capture in a competitive environment. Additionally, crossborder infrastructure will continue to be an important EU priority in order to drive technical solutions between two different Member States.
> …
> In the broader picture, Member State support will continue to be vital to deliver ERTMS deployment. There are considerable opportunities to support RU deployment to a significant extent, assisting in deploying ERTMS more quickly. In general, for interoperability measures, Member States can provide support up to 50% of eligible costs. This threshold can be exceeded if Member States demonstrate the need and proportionality of the measures in question. For example, as part of a broader investment package, the Czech Republic can potentially provide significant support for an on-board retrofitting programme, with potential support of up to 85% of (all) eligible costs.
> [1.A]

However, the interviews with the Operating Companies in Chapter 4 indicate that a sponsoring of 50% (and in exceptional cases up to 85%), especially for smaller Operating Companies, does not weigh against the investments. The remaining 50% (or in exceptional cases 15%) are not enough to enable a profitable return-on-investment.

As limiting these subsidies in order to finance installation of onboards hinders the rollout of ERTMS, it might be necessary to change rules and regulations in this regard to support migration to ERTMS. Alternatively, it could be considered to find a way around these Railway Guidelines to avoid subsiding Operating Companies.

8.3.3 Technical Specifications for Interoperability (TSI)

The Technical Specification for Interoperability (TSI) are specifications drafted by the European Railway Agency and adopted in a Decision by the European Commission, to ensure the interoperability of the Trans-European rail system. The interoperability issues apply to the lines within the Trans-European Rail network.

[14] Commission Guidelines on State aid for railway undertakings, Official Journal of the European Union, 2008/C 184/07.

TSIs specify by which means each subsystem or part thereof is covered to meet requirements and to ensure interoperability within the European rail network. [1.D] They are legally binding for European Union Members and apply when upgrading or renewing assets. [1.E] The TSIs further state that Infrastructure Managers must modify their systems, when upgrading or renewing, based on equipment owned by other Infrastructure Managers.

> **COMMISSION REGULATION (EU) No 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union**
> *Article 2*
> *Scope*
> 1.The TSI shall apply to all new, upgraded or renewed 'infrastructure' of the rail system in the European Union as defined in point 2.1 of Annex I to Directive 2008/57/EC.
> 2.Without prejudice to Articles 7 and 8 and point 7.2 of the Annex, the TSI shall apply to new railway lines in the European Union, which are placed in service from 1 January 2015.
> 3.The TSI shall not apply to existing infrastructure of the rail system in the European Union, which is already placed in service on all or part of the network of any Member State on 1 January 2015, except when it is subject to renewal or upgrading in accordance with Article 20 of Directive 2008/57/EC and Section 7.3 of the Annex.
>
> **COMMISSION REGULATION (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union**
> *Article 2*
> *Scope*
> 1. The TSI shall apply to all new, upgraded or renewed 'trackside control-command and signalling' and 'on-board control-command and signalling' subsystems of the rail system as defined in points 2.3 and 2.4 of Annex II to Directive 2008/57/EC.
> 2. The TSI shall not apply to existing 'trackside control-command and signalling' and 'on-board control-command and signalling' subsystems of the rail system already placed in service on all or part of any Member State's railway network on the day this Regulation enters into force, except when the subsystem is subject to renewal or upgrading in accordance with Article 20 of Directive 2008/57/EC and Section 7 of the Annex.
>
> *Article 8*
> *Class B systems*
> Member States shall ensure that the functionality, performance and interfaces of the Class B systems remain as currently specified, except where modifications are needed to mitigate safety-related flaws in those systems.
>
> *Article 9*
> *EU-funded projects*
> 1. ETCS shall be installed in railway infrastructure projects receiving financial support from European funds when:
> (1) installing the train protection part of a CCS subsystem for the first time; or
> (2) upgrading the train protection part of a CCS subsystem already in service, where upgrading changes the functions or the performance of the subsystem.
> 2. The Commission may grant a derogation from the obligation laid down in the paragraphs above when signalling is renewed on short (less than 150 km) and discontinuous sections of a line and provided that ETCS is installed before the earlier of these two dates:
> — 5 years after the end of the project,
> — the date on which the section of the line is connected to another ETCS equipped line.
>
> **COMMISSION IMPLEMENTING REGULATION (EU) 2017/6 of 5 January 2017 on the European Rail Traffic Management System European deployment plan**
> *Article 2*
> 5.Member States may decide to keep the existing Class B systems, as defined in point 2.2 of the Annex to Regulation (EU) 2016/919. However, by the dates set out in Annex I, the vehicles referred to in point 1.1 of the Annex to Regulation (EU) 2016/919 which are equipped with ERTMS in a version compatible with the track-side equipment, shall be given access to those lines and to the infrastructure components as referred to in Article 11 of Regulation (EU) No 1315/2013 without requiring them to be equipped with a Class B system.

However, these TSIs do leave room for Member States to not abandon their Class B systems:

- TSI CCS article 2 states that it only applies to new, upgraded or renewed rail system. This leaves room to avoid improvements in order to avoid having to replace the Class B system towards ERTMS.
- TSI CCS article 8 makes an exception for safety-related issues.
- TSI CSS article 9 says that a derogation may be granted for renewals of less than 150km, for a period of maximum of 5 years until ERTMS is applied.

Moreover, national rules may be applied in addition to European rules only under certain conditions, as defined in Directive (EU) 2016/797 and in Directive (EU) 2016/798, when they relate to:

- the placing on the market or placing in service of structural subsystems,
- the operation of the Union rail system,
- the role of the actors,
- the safety certification,
- the safety authorisation
- and the accident investigation.

However, national rules, which are often based on national technical standards, are gradually being replaced by rules based on common standards, established by Common Safety Methods (CSMs) and TSIs. In order to eliminate the obstacles for interoperability, the volume of national rules, including operating rules, is expected to be reduced as a consequence of extending the scope of the TSIs to the whole of the Union rail system and of closing open points in the TSIs. [14.L]

Also, the text from Commission Delegated Decision[15] supplementing the TSI for Interoperability provides the Infrastructure Managers with room for maintaining their legacy CCS-systems:

> (13) Article 4(3)(h) of Directive (EU) 2016/797 allows TSIs to include provisions applicable to existing subsystems and vehicles, in particular in the event of their upgrading and renewal. Those provisions can give rise to legal uncertainty in case of authorisations which are already issued, therefore there should be particular attention to the preliminary analysis of the related costs and benefits and to the definition of the modification works which require an application for a new authorisation.
> [1.E]

The development of TSIs is in principle a collaborative effort between the ERA and the Infrastructure Managers. Depending on the topic, TSIs are discussed in various gremia, for instance the CCS Working Party or the ERTMS Users Group. The TSIs are decided upon by the European Commission. However, the Infrastructure Managers feel it is no longer a collaborative effort. Infrastructure Managers have indicated by means of EIM that initially TSIs were (also) initiated on their initiative but currently they are only passively asked to respond and review the TSIs as put forward by ERA. Moreover, they feel that some TSIs are too detailed and are stifling innovation while others are still missing despite their requests, e.g. the RBC – RBC interface. [14.N, 14.O] It is unclear where this feeling stems from. It could be the case that not all Infrastructure Managers are involved in the CCS Working Party or ERTMS Users Group but only a selected representation? Or that the Infrastructure Managers feel the final TSI does not fully incorporate their views? However, as it is outside of the scope of this study, this is mere speculation and warrants further research.

As a final point, NS pointed out that there is a fine line between standardisation and innovation. Too strict standardisation hampers innovation. Thus, ERA in cooperation with all shareholder must find a balance between standardisation and innovation.

[15] Commission Delegated Decision (EU) 2017/1474 of 8 June 2017 supplementing Directive (EU) 2016/797 of the European Parliament and of the Council with regard to specific objectives for the drafting, adoption and review of technical specifications for interoperability (notified under document C(2017) 3800), 08/06/2017.

8.4 European Regulation on Lingua Franca in Railway Sector

Directive 2007/59/EC on the certification of train drivers operating locomotives and trains on the railway system in the Community States that all train drivers must have B1 language skills for each country they drive through. This requires extensive and hence expensive language training for many crossborder freight drivers.

The European Rail Freight Association (ERFA) requests that this requirement for B1 language skills be dropped. The ERFA proposes to use English as lingua franca to improve the flexibility, reliability and efficiency of European rail traffic. In addition, ERFA proposes to draw up a list of keywords and commands for train dispatchers and train drivers, for use in emergency situations demanding direct action. ERFA proposes that at the long-term the B1-requirement be dropped and English becomes the common language used on all European rail networks. [14.K]

At the workshop in September 2018 a common language was also discussed. ERA suggested that, as part of global standardization, one TMS language could be a backbone. Standardization and common language is common practice in the aviation and maritime sector. She suggested that currently initiatives are developed to standardize the operational language in rail.
[14.E]

8.5 Findings and Trends European Union

All interviewed parties have referred to European Union strategy, policy, subsidies, or legislation that may impact the conditions for ERTMS deployment and the evolution of the rest of the CCS-system. To summarise the previous chapter, the following points were found to have an influence.

Standardised system architecture

There is interest and support within the EU for a standardized architecture for the entire CCS-system. This could look like what the ERTMS Users Group and EULYNX propose as Reference CCS Architecture.

Lingua Franca

To attain a SERA there is more needed than agreements on technology. Human communication between train driver and train dispatcher will remain needed in case of disruptions and when driving in degraded modes. Currently, this is organized by certification of train drivers with B1 language skills for every country they drive through. However, several parties have remarked that one operational language would be preferred.

ERTMS

At the moment ERTMS deployment of the entire network is carried out in Luxembourg, Switzerland, Belgium, Norway and Denmark. All other European countries plan to only convert parts of their network to ERTMS, while keeping their legacy Class B system as well. The European Court of Auditors found that deployment so far is at a low level and represents a patchwork, despite the fact that the ERTMS concept that seeks to enhance interoperability is not generally questioned by the rail sector. Infrastructure Managers and Railway Undertakings are reluctant to invest due to the expenses entailed and the lack of a positive outcome for their individual business case (for example in the Member States with well performing national systems and significant remaining lifetime). Moreover, there is no deadline for the decommissioning of the national signalling systems in the Member States.

The long-term practice does not demand harmonisation of the CCS-systems within the ERTMS framework, when considering the digitalisation trends and when differentiating between safety levels for various functions. The European Commission emphasises that ERTMS can become a cornerstone in the digitalisation of the rail sector (…). [1.C, 7] As ERTMS rollout has a strong link with the replacement of CCS-systems, it may be concluded that this constitutes a patchwork of CCS-systems across the Member States as well.

Legislation

Another reason the patchwork of systems remains in place is due to legislative reasons. On the one hand, European procurement legislation does not facilitate long working relations between Infrastructure Managers and suppliers, which includes product development and innovation. On the other hand, there is the feeling that, amongst Infrastructure Managers and Operating Companies, the TSIs covering harmonisation of systems are too detailed and stifle innovation. This while TSIs requested by the rail industry, such as describing RBC – RBC interface, are still lacking. Despite the main purpose of the TSIs, being harmonisation, national exceptions may be made. This complicates the SERA.

Finally, European legislation also dictates which institutions are eligible for EU subsidies, i.e. that Operating Companies can only receive limited subsidies, which hinders ERTMS rollout.

9 SUMMARY AND CONCLUSIONS

The ERA's objective for this study was to get an overview of the overall situation of existing interlocking, block systems and traffic management systems, of their expected remaining useful life, of plans to replace/renew them, and of the ambitions of the railways in terms of functionality and architectures for their future CCS-systems (excluding ERTMS). For this reason, Infrastructure Managers, Operating Companies, and Rail Industry Suppliers were consulted and desk research was carried out. Firstly, the following two sub-questions were researched:

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?
2. What are the relevant future strategies with regard to CCS and TMS?

It proved nearly impossible to answer these questions without also looking at ERTMS, as digitalizing CCS- and TMS-systems oftentimes go hand-in-hand with ERTMS-rollout. Moreover, the ERA indicated the ultimate goal of the feasibility study was to help the ERA in its mid-term and long-term strategic reflection to further improve the conditions for the ERTMS deployment, and on the evolution of the rest of the CCS-system.

Based on this, it may be considered that this feasibility study was, at least in part, intended to research whether the non-ERTMS systems (interlocking, block systems, and traffic management systems) posed some sort of impediment to the deployment of ERTMS. Were they (part of) the reason for the slow rollout of ERTMS observed so far across Member States? In order to answer this question, the findings of surveying the 3 main stakeholders – Infrastructure Managers, Operating Companies, and Suppliers – and the force field analysis between them are summarized. These are set against the European Union's strategy, policy, subsidies, and legislation aspects which may influence these.

9.1 Infrastructure Managers, Operating Companies, and Suppliers

Infrastructure Managers

All surveyed Infrastructure Managers have plans or are in the process of renewing their CCS-systems. The most important drivers for this exercise are cost reduction and more capacity on the existing infrastructure. The higher European goal of SERA – a single market for rail services with its overarching goal to revitalise the rail sector and make it more competitive vis-à-vis other modes of transport – is barely a stimulus. This is logical, considering the limited number of trains (passenger and freight) that are cross-border (less than 5-10% of the total number of trains within a Member State) and the societal (political) pressure to increase capacity around urban conglomerates with more (passenger) trains.

Interlocking

In many countries the interlockings and control systems are aging. Relatively many countries still own mechanical controls and accompanying interlockings. Spare parts for these systems are no longer available and knowledge about these systems is dying out as well. However, this also applies to younger systems based on relay technology. In several cases the suppliers have indicated to no longer support these systems by means of spare parts nor do they educate or retrain their engineers for support. This is an argument for transferring to digital interlockings.

Another argument to transfer to a new generation of digital interlockings is large-scale adaptation or expansion of the infrastructure. Based on a cost-benefit-analysis it can be beneficial to choose deployment of a fully new (digital) interlocking rather than major adaptations of existing (analogue) interlockings. This argument also applies to routes planned to be ERTMS-equipped. In principle, an interface to any type of interlocking, whether modern or 'old school', can be developed, but this might not be the most cost-efficient solution.

Traffic Management System (TMS)

For the old analogue TMS similar arguments apply as to interlocking – outworn, no spare parts, knowledge dying out, and expensive in case of changes or modifications.

At the same time many countries are reorganizing their traffic management. In order to reduce costs and to improve operational processes, they are vacating local train management locations. The functions are then combined in centres which serve large parts of the country. These centres are equipped with the most modern apparatus.

This modern equipment allows for the introduction of automated processes such as automatic route setting and, in the longer term, automatic driving trains.

Finally, employing new train dispatchers is mentioned as an argument for changing over to modern technology – these job vacancies have historically been difficult to fulfil. For younger professionals, these are only appealing when they can work with 'state-of-the-art' equipment. Or contrarily, it is impossible to find employees wanting to work with mechanical equipment.

Digital programmes/ambitions

We have identified digitalisation programmes in all surveyed countries. Some of these have nearly been completed already, others have a farther horizon. The commonalities in these plans include that significant parts of the CCS-system have reached the end of their technical lifespan. All Infrastructure Managers are implementing, have plans to implement, or consider implementation of digital-based CCS-systems. Moreover, often these plans include the implementation of ERTMS. Finally, several of these plans consider ATO or at least Driver Advisory Systems.

ERTMS

All countries in this study are moving towards implementing ERTMS. The argumentation for the implementation of ERTMS differs per Member State. It varies from 'because we agreed with the EU' to sound business cases for the deployment of ERTMS Level 2.

Several countries implement ERTMS in several phases, meaning first ERTMS Level 1 and later a transfer to ERTMS Level 2. ERTMS Level 3 hybrid is considered an interesting development for capacity reasons.

Other European countries plan to convert only parts of their network to ERTMS and keep their legacy Class B system. The Court of Auditors called this 'ERTMS as an add-on software based-system for their national signalling systems'.

As a result of these different approaches to ERTMS deployment, the ways the Infrastructure Managers deal with the various arguments and (proposed) scenarios to accelerate renewal of CCS-systems (including ERTMS and non-ETCS components) differ as well.

Operating Companies / Fleet Owners

Whereas the introduction of ERTMS, with or without whole or part modernization of the other components of the CCS-system, can lead to a sound business case for Infrastructure managers, this does not apply to Operating Companies (fleet owners). Specifically, national passenger TOCs may not pull in additional customers with ERTMS while being confronted with significant costs for ETCS onboard equipment. Especially when retrofitting older, current rolling stock.

Freight Operating Companies are interested in SERA, as they operate internationally almost by definition. However, a uniform CCS-system is only one of the elements that require international agreements. Others may be electrification, axle load, etc. For smaller FOCs the costs of ERTMS are relatively high, as they need to install it in locomotive series of which they only have small numbers. This makes the development and approval cost of 'first of class' weigh significantly on the other locomotives of the series.

Suppliers

The market for CCS- and TMS- equipment (and especially ERTMS-equipment) is relatively complex and regulated by high safety levels, which is therefore dominated by a small group of specialised Suppliers. Moreover, the remaining reliance on national Class B technology retains this status quo – newcomers to the market cannot comply with the requirements and skills involved (weighing the investment in schooling against the market gain), according to the interviewed Suppliers.

Suppliers, being commercial companies, are basically driven by the need for turnover and profits. In general, this can be attained by standardisation and a common architecture. The use of Hybrid Level 3 is recommended because it is based on a core of operational scenarios and comes closest to a common architecture. The benefits of such an approach would be:

- Shorter production time,
- More focus on innovation rather than on customizing CCS-components per country,
- Lower prices due to larger volumes (i.e. more signalling per Euro),
- And it allows newcomers to the market.

Relation Infrastructure Managers – Suppliers

The Infrastructure Managers and Suppliers currently seem to keep each other mutually trapped in a stalemate which neither actually wants. There are historical reasons to this situation, but both parties have indicated a wish for change over the course of this research.

Historically, Infrastructure Managers have focused on tailormade systems that meet national (safety) requirements (often Class B or Class B related). This has frequently resulted in purchasers automatically having a long-lasting relationship with Suppliers who develop these for them, so called ‘vendor lock-in.’ As the volumes of these sold systems yielded substantial profits, there was no instigation for Suppliers to change this.

Currently, although often considered as such, for Infrastructure Managers vendor lock-in may not be a negative, provided that:

- There is healthy competition between Suppliers in the procurement phase,
- And there can be a long-term Service Level Agreement with the supplier.

Nevertheless, for the time being, this situation does not seem to occur. The argumentation used by both Infrastructure Managers and Suppliers is that Suppliers cannot foresee the risks of future system modifications and therefore include these risks in their offers, which then overrun the budget that the Infrastructure Manager had foreseen.

Conversely, the Suppliers are still trying to meet client requests by delivering and supporting these tailormade systems, but they would rather deploy their scarce resources to focus on innovation and standardisation. There is a sector wide shortage of staff with knowledge about Class B systems (and relay technology in general). Yet, all countries still adhere to the application of these systems. This means that supply and demand do not meet and therefore may be thin-spread to meet only basic demand (i.e. basic service level).

Suppliers foresee standardisation and new digital solutions in the future, which may be given a giant push by products from China. Standardisation and common architecture yields opportunities for more volume and hence profits. Therefore, they would prefer to look forward to these new ERTMS- and digitised systems than look backward to Class B systems. Yet, since Suppliers deliver what clients ask for, they feel that in the end only the clients can change the market, by changing demand.

Railway Industry Developments

These different drivers and horizons of Infrastructure Managers and Suppliers have also given rise to two different railway initiatives, EULYNX and Shift2Rail. EULYNX is an initiative of 12 European Infrastructure Managers with a main focus on interfaces and signalling, with regard to this study focusing on interlocking interfaces between current system elements. EULYNX has a nearer horizon, with baseline 2 implemented at the end of 2017 .

Shift2Rail Joint Undertaking is a public private collaboration between the European rail sector, amongst which Suppliers, and the European Union. Shift2Rail aims at achieving the reduction of lifecycle cost by supporting innovative new technologies and product improvement, for the rail industry in the broadest sense. These include standardisation, and automatic train operation and moving block technology over ERTMS. Shift2Rail has a long-term focus (2030-2050).

Though both are valuable initiatives, considering that neither has a sectorwide approach may play a role in their lack of substantial success in contributing to SERA so far.

Lessons Learnt from Non-Rail Industries

As in the railway industry digital standardisation and interfaces are uncommon or still in the spring of their development, this begs the question how the railway industry differs from these successful industries. For instance, standardisation to overcome interfaces in the ICT-world is common practice. The most striking example is the USB (Universal Serial Bus), which enabled a wide range of apparatus of an equal wide range of suppliers to be connected to one another or to a computer. Our observation tells us that in the cases of AUTOSAR, IMA, and ICT-sector the various stakeholders all had the same driver in the long-term, whereas the drivers for Infrastructure Managers, Suppliers, and Operating Companies differ from one another.

Relation Infrastructure Managers – Operating Companies

Due to privatisation in most countries, there is a strict division between Infrastructure Manager (usually a (semi-)governmental agency) and Operating Companies (a commercial company, be it passenger or freight). National Infrastructure Managers are responsible for the trackside equipment. Their respective governments assess their performance based on costs and track capacity. Therefore, Infrastructure Managers are driven by a need to reduce (maintenance) costs and improve track capacity (i.e. more trains per track to prevent building new tracks to meet an increased demand for more trains). ERTMS (Levels 2 and 3) aid in this by reducing the amount of trackside equipment and enlarging track capacity.

Operating Companies are driven by efficiency and reliability. The major cost components of their business model are wages and rolling stock. Strictly speaking TOCs have no preference for any type of CCS-system as long as the timetable is not jeopardised, and safe operation is guaranteed. Operating Companies are pleased if a new CCS-system is implemented which leads to more capacity on the route, as long as it does not lead to higher costs for the TOC. Freight Operating Companies (FOC) also wish to transport goods at minimum cost. As their share in cross-border transport is much bigger compared to passenger traffic, there is a business necessity for interoperability. Thus, having one CCS-system in Europe is of interest to them.

The rollout of ERTMS involves a trackside and an onboard component. Usually, the trackside investments are covered by the national Infrastructure Manager, who in turn receive the funds from their governments. Contrarily, the FOCs receive limited sponsoring and have to carry a substantial part of the investment for interoperability themselves. Specifically concerning ERTMS, the FOCs fear the relatively high costs for deploying a range of types of locomotives with ERTMS. The development of ‘first of class’ approval weigh significantly in their business model, due to lack of economies of scale. A business model which includes both the trackside and onboard components seems to circumvent any issues with EU subsidy guidelines.

9.2 Role European Union

DG MOVE is a Directorate-General of the European Commission responsible for transport within the European Union. The Directorate-General is made up of five Directorates, amongst which the ERA. It is ERA’s mission to:

- Devise the technical and legal framework in order to enable removing technical barriers, and acting as the system authority for ERTMS and telematics applications

- Act as the European Authority under the 4th Railway Package issuing vehicle (type) authorisations and single safety certificates, while improving the competitive position of the railway sector.

ERA presents a vision of railway being the backbone of an intermodal system. This will require global standardization, including a global TMS language. Standardization on a global level is common practice in the aviation and maritime sector. These modes are much faster to absorb technology – leading to a competitive disadvantage of rail. Innovation in the railway sector is hindered by fragmentation. Rail must overcome its limitations (fragmentation) in order to become the backbone of this multimodal transport chain.

This fragmentation is partly caused by the historically national (safety) focus by the various Infrastructure Managers. Therefore, the ERTMS Users Group (consisting of a group of Infrastructure Managers working closely with the ERA) in combination with EULYNX presented a vision of a Reference CCS Architecture (RCA). Implementation of ERTMS in combination with legacy CCS is too expensive, if not unaffordable, and does not bring sufficient benefits. It is estimated that RCA brings significant life cycle cost reductions. Switzerland's SmartRail 4.0 is seen by the ERTMS Users Group / EULYNX as a starting point of RCA. The biggest risk that they foresee is that the various members cannot be lined up and agree on a common RCA.

The ERA represents the European, overarching goal. This may at times be incongruent with the Member States 'national governments' interests, which are represented by the Infrastructure Managers. The Suppliers appreciated the work of the ERA and her efforts to attain a common market, but showed concern that the ERA does not have the resources (money and staff) to achieve its goals. The Suppliers feel that the 4th Railway Package provides a good framework to achieve these goals. Many Suppliers in fact favour a stronger role of the ERA to achieve these goals by means of standardization and a common architecture.

The patchwork of systems remains in place due to legislative reasons as well. On the one hand, European procurement legislation does not facilitate long working relations between Infrastructure Managers and Suppliers, which includes product development and innovation. On the other hand, the TSIs covering harmonisation of systems are felt to no longer be a collaborative effort between the ERA and the Infrastructure Managers, resulting in TSIs which are too detailed and which stifle innovation, or TSIs requested by the rail industry still lacking. Despite the main purpose of the TSIs, being harmonization, national exceptions may be made. This complicates the SERA.

European legislation also dictates which institutions are eligible for EU subsidies. Because Operating Companies are private parties, they cannot be granted 100% EU subsidies to facilitate the implementation of ERTMS onboards. This is one of the underlying reasons for the lack of a sound business case for ERTMS – the Infrastructure Managers can rely on public funding, whereas the Operating Companies are forced to invest themselves to a certain extent without having a prospect to achieve a positive business case.

Though the ERA envisioned one global language, the European Union is based on the postulation that all European languages are equal. Currently, this results in the directive 2007/59/EG that at present all train drivers must have B1 language skills for each country they drive through, which requires extensive and hence expensive language training for many crossborder freight drivers. In aviation and the maritime industry, English is used as lingua franca, including a set of common commands. Adoption of such a linga franca would be favoured by Freight Operating Companies as well.

9.3 Conclusion

Looking across the board, none of the stakeholders mention that non-ERTMS systems (interlocking, block systems, and traffic management systems) in theory prevent a swift rollout of ERTMS. It is not a technological matter; all interfaces can be built. However, considering the patchwork of national CCS- and TMS-systems, all these interfaces are unique. This means they are expensive to specify and build. Moreover, they are very much Supplier-dependent. Meaning the interface provides a short-term solution but not a long-term solution. As a result, this patchwork dictates the possible migration strategies towards ERTMS, often favouring the more complex and hence expensive and lengthy strategies.

ERTMS and digital CCS-systems comprise a silent revolution in train safety and railway operation. The ICT-based technology commands a different way of thinking. A lack of sufficient knowledge in this CCS-field (as there are too few people skilled in a digital view of its problems and possible solutions) poses difficulties for the Governments and Infrastructure Managers to oversee the risks of implementing completely new, digital CCS-systems. This results in the natural reaction to lean towards ‘the safe option’ and to continue thinking along the lines of what one knows and can oversee. As a consequence:

- They chose (unwittingly) for a patchwork of quick, short-term solutions. This choice is also based on lower initial costs.
- They translate one-on-one the current (national) train safety philosophy to ETCS. However, this philosophy is still based on the technological possibilities (or rather limitations) of the (analogue) systems of the previous century.

Driven by that, it seems hard for governments and Infrastructure Managers to let go of the national, trusted CCS-systems. This again has the following consequences:

Considering the new possibilities of digital technology, the real benefits of the introduction of digital CCS-systems (such as ERTMS) can be found at transport nodes. The interconnecting corridors between nodes are no longer indicative for the capacity of a corridor. The nodes (large stations) will become the new bottlenecks in capacity. Hence, this is where much is still to be gained. However, current national safety (CCS) regulations prevent substantial improvements. Digital technology allows many safety margins to be generated by software, which is an important difference with the current (analogue) situation. According the current regulations, a number of these safety margins must currently be guaranteed by the track layout (overlaps).

As described above, currently many choices are made with a short-term focus and not across the entire system of trackside and onboard. Moreover, this also means that the European Union cannot subsidise the entire system but due to its legislation can only support the government owned parts of the system. This way business cases for these separate onboard and trackside investments will not become profitable and investments are curtailed, averted or postponed.

The most important conclusion is that all the parties have different drivers for replacing CCS-systems, which generates difficulties to have all head in the same direction towards the same common goal.

10 RECOMMENDATIONS

From the inventory of the current situation and the future strategies of Infrastructure Managers, Operating Companies, and Suppliers regarding non-ERTMS CCS- and TMS-systems, it follows that the major impediment to a speedy ERTMS- deployment across Europe is the lack of standardisation (and consequently the number of interfaces between the systems and the cost involved of building and maintaining these). This chapter proposes which actions the ERA can take into consideration that are relevant at EU level in terms of coordination and standardisation activities and beneficial to facilitate the migration to ERTMS, in order to facilitate the objective of the SERA? The following three top recommendations have been discussed in a workshop with amongst others ERA, European Commission, DG Move, UIC, several NSAs, EULYNX, Siemens, TÜV Rheinland, ERTMS Users Group, SBB, and SNCF:

- Work towards a standardised CCS-system
- Consider onboard ETCS as part of trackside
- Stronger mandates and more resources for ERA

A fourth recommendation was added after the workshop:

- Support training of workforce.

10.1 Work towards a Standardised CCS-System

The systems known at present in the various countries have evolved over the past decades as a consequence of the possibilities and limitations of the technology of that time. The current state of technology allows for much more. Now may be the right time to revisit this situation and initiate a new signalling and control philosophy, taking into account all these new technological possibilities. This could then be a European philosophy, which could be the future standard. From this standard it follows to 'configure, not customise.'

When history is not carried into the future of new systems, this will be beneficial to all stakeholders. No longer requiring customised systems, the volumes to be produced will be bigger. Economic laws dictate that increased demand will decrease the costs per unit. With standardisation, wider experience across the European sector will yield better quality over the course of time. Moreover, standardization will also enable newcomers to the market. This will not only bring economic benefits, but probably will also be accompanied by a surge of innovations. Finally, the specials in CCS take up valuable staff capacity, so standardization is the key to free up capacity.

A universal interface would make one independent of product and/or supplier. A rudimentary form of ERTMS, such as ERTMS L1LS as developed by SBB, is a good example of this. Unfortunately, though it meets all the demands of ERTMS-compatibility with the trackside infrastructure, it does not provide the ideal solution to all parties. For instance, it does not provide the Infrastructure Manager with additional track capacity. Moreover, considering the remaining (conventional and digital) trackside equipment, the maintenance costs do not decrease either. Hence, the solution must not be sought in a standard interface, but in a standardized system. A standardized CCS-system consists of 3 elements:

b. A simplified system architecture,
c. A common (European) set of operational rules,
d. And a lingua franca for person-to-person communication.

At first sight, this may seem an unrealistic task to achieve. However, this research demonstrates that:

- There is increasingly widespread and growing support from stakeholders to embrace these strategies.
- Though on a smaller scale, the case of Switzerland proves it can be achieved.

An implementation plan, laying out possible steps to achieve such a standardized CCS-system, could be the follow-up study from the conclusions and recommendations of this feasibility study. This should also encompass the relation with current ongoing programs.

10.1.1 A Simplified System Architecture

Based on all the information gathered and on following the initiatives of EULYNX and the ERTMS User Group (Reference CCS Architecture), it is possible to draw up a theoretically ideal system architecture. This is built on three main principles.

1. Strict separation between ‘Safety’ and ‘Non-Safety’

A strict separation between Safety and Non-Safety must be translated into the requirements of the specific parts of the CCS-system. If this division is strictly adhered to, it is possible to guarantee safety at the core of the CCS-system. This provides freedom and flexibility to incorporate innovative and high-qualitative applications in the non-safety layer of the CCS system; the Traffic Management Layer. This can be done in stages and can be adapted to new requirements in the future.

As there will be no stringent demands on the non-safety level, it is possible to hire engineers or suppliers that are not part of the traditional suppliers.

More importantly, a digital non-safety level for TMS offers the possibility to develop a range of apps that will not need to adhere to strict safety requirements.

2. Simplify the System Architecture

A modern CCS-system in essence consists of only a limited number of components:

- The core of the CCS-system, which guarantees the safety. In this philosophy this combines the functions of an interlocking with a Radio Block Centre.
- A control layer, which incorporates all the applications to deal with the daily train running in a highly automated manner.
- An aligned carrier for wireless, continuously safe data communication between train and trackside.
- A group of infrastructure elements, such as:
    - A point switch
    - A lineside train detection system
    - A level crossing
    - A ‘latch’ (i.e. safety switch) between the CCS-system and other systems, for instance an operated rail bridge or a manual point switch

Crucial when designing a simplified architecture is finding the balance between on the one hand logically combining components with the goal of reducing the number of complex interfaces, and on the other hand deconstructing system parts into smaller components in order to create a broader market for specialised companies. A good example of the former is combining the Interlocking with the Radio Bock Centre. Together they will form the core of the Safety part of the simplified system architecture.

In order to reach a theoretical optimum, the first two can be combined with a third principle.

3. Aim for Defining a Limited Number of Interfaces in the Simplified System Architecture

Inspired by the USB-standard as developed in the ICT-world, the system architecture should revolve around only four interfaces. For these interfaces both the connector and the manner of data exchange will be defined. The relevant interfaces are the numbered 1 to 4 in the figure below:

1. TMS ↔ IXL / RBC
2. IXL / RBC ↔ IXL / RBC
3. IXL / RBC ↔ objects
4. IXL / RBC ↔ Wireless data Communication system

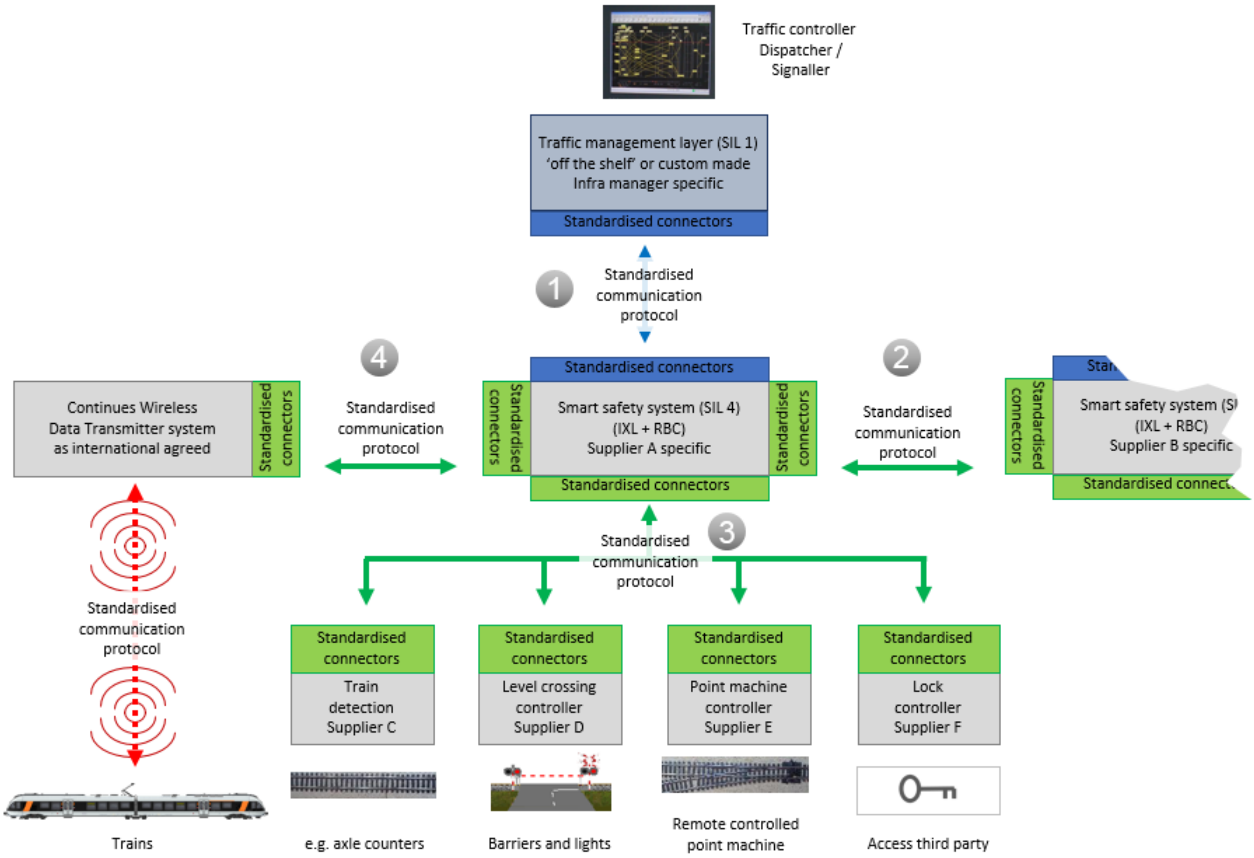

Figure 21. Reference optimum system architecture

The connection itself is not described but could be a glass fibre network. Whether it is a public or closed network can be determined later.

It should be noted that within the scope of this study only a description of the system architecture on the infrastructure side is provided. There is a similar need for a simplified system architecture for onboard systems.

4. Use of Non-Rail Technologies

A standardized system offers opportunities to introduce the use of non-rail technologies in rail.

Localization
Precise and rail time train localization with the use of multiple technologies combined on one platform (e.g. GNSS satellite, Fibre Optic Sensing, 5g High accuracy enhanced positioning) [3.C]

Communication
Use of public open 5G network instead of dedicated bandwidths. [3.C]

10.1.2 A Common (European) Set of Operational Rules

With a simplified system architecture, the safety processes are guaranteed. However, how to operate cannot be guaranteed by a system or its architecture. This is written down in Operational Rules. Problem is these operational rules are currently country-specific. And have in return effects on the system architecture.

Most differences in interpretation occur in degraded modes like ‘Shunting’, ‘On Sight’ and ‘Staff Responsible’. To provide two examples of these types of operational rules:

- Shunting in the Netherlands is done with 30 km/h and in France it is allowed with 40km/h.
- In using the mode 'On Sight', in The Netherlands flank protection by switches is guaranteed, in Denmark not.

Generally, the methodology of train traffic and control within Europe is comparable. However, within this framework there are still differences. Operational rules in the past have been established based on the current state of the technological possibilities. Given the new possibilities of IT, it is no longer necessary to embed these rules in hardware, software allows for new and better solutions. It is advised that ERA try to standardise technology, but also harmonise processes. Aviation is a good example. In aviation flight paths are communicated and handed-over between ground controls in an identical manner no matter where on earth, both handled by software and oral communication processes between flight dispatchers.

However, some hurdles have been identified as threatening to the standardisation of operational rules:
- In order to harmonise and enforce standard operational rules, a stronger role is required for ERA. The number and range of operational rules that need to be harmonised within a foreseeable future cannot be accomplished by the limited resources of the ERA.
- Currently not all facets of the operation are considered. For example, rules governing shunting are left to the member states. How can operational rules be standardized if certain facets are excluded? Furthermore, excluding certain facets is a threat to a fully interoperable system.

We realize that letting go of national Operational Rules in favour of European Operational Rules is not done overnight. It will take time and diplomacy to achieve this. However, the 4th Railway Package, moving block, and ATO offer opportunities to start the discussion.

10.1.3 Lingua Franca for Person-to-Person Communication

Train safety cannot only be guaranteed by hardware and software, nor by communal processes. These work fine in standard operation. However, in degraded modes communication between the train dispatchers, train drivers and others become more important. This is less of an issue for communication within one country, as all speak the same language. However, for crossborder transport, this communication will take place between different nationalities. As the aviation industry demonstrates, the cheapest but also the safest option is that all staff speak the same lingua franca – aviation English.[16] A specialised code, based on the English language, used by pilots and air traffic controllers working in international civil aviation, and having standards, phrases, and levels of proficiency established by ICAO. Standard phrases must prevent misinterpretation and hence ensure safety. The pronunciation is developed in such a way that anyone, no matter what his or her native language must be able to pronounce and understand the words clearly.

A FEW EXAMPLES OF AVIATION ENGLISH[17]

AFFIRM: When pilots mean 'yes,' with a pronunciation of "AY-firm"
CLEARED: Authorized to proceed under the conditions specified
DISREGARD: Consider that transmission as 'not sent
NEGATIVE: No, permission not granted, or that is not correct
SAY AGAIN: Repeat all, or the following part of your transmission
WILCO: I have received your message, understood, and will comply with it

For the FOCs it means all staff will be trained in only one foreign language, saving on education costs. Moreover, the incident of the two-months shutdown of the key Rhine-Alpine Gateway one year ago demonstrated that the language requirement for the countries the trains were rerouted through, made it very hard to find qualified train drivers. Such economic costs would also be avoided. Finally, miscommunication was the cause of several air accidents and the reason of the use of aviation English. Also, for rail, a shared communication will ensure less miscommunication in case of emergencies and ensure a safer railway.

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16 https://en.wikipedia.org/wiki/Aviation_English
17 https://www.news.com.au/travel/travel-advice/flights/the-300word-language-that-senior-air-crew-must-speak-whatever-their-nationality/news-story/18d742358ba3512c2914731569064636

10.2 Consider Onboard ETCS as Part of Trackside

The deployment of ERTMS serves the higher goal of SERA. However, the fact that Infrastructure Managers and Operating Companies are not a single governmental institution complicate the business case. There is agreement amongst the stakeholders that installing ERTMS on a train does not result in a gain in number of passengers or passenger satisfaction. When considering the trackside and onboard as one complete railway system, a sound business case can be made. The example of Switzerland proves that this will in fact result in long-term savings. This in its turn will advance the rollout of ERTMS.

Secondly, having onboard and trackside in one hand, might mean fewer compatibility issues. It has been known to happen that there were software differences between onboard and trackside, being commissioned by two different parties (e.g. Betuweroute when launched in 2004). Theoretically, with only one commissioner compatibility issues such as these will occur less frequently, will be spotted earlier and hence will have less impact.

Finally, having onboard and trackside in the hand of the Infrastructure Manager, this leaves more freedom in migration strategies for ERTMS rollout. Theoretically, there are the following alternatives, with the arrows indicating the moment in time:

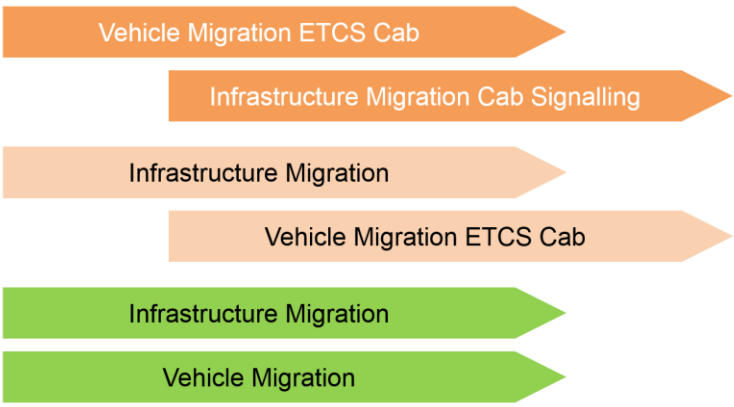

Figure 22. Migration strategies

The green arrows are only considered to be applicable in a greenfield situation. Practically, having the two subsystems in the hand of the Infrastructure Manager may open up new migration strategies.

Moreover, having the onboard and trackside in one hand, the regulations restricting subsidies of onboard installation to Railway Undertakings can be avoided altogether.

10.3 Support Training of Workforce

As said, the sector is fundamentally changing towards digital. As a consequence, there is a demand for a huge regeneration in skills and knowledge. The development of the technology moves faster than the 'workforce' can keep up – both in terms of technology and volume.

At present there are educational institutions at national level and some initiatives on international level (e.g. UIC). In order to profit most from these and to prepare people for the future needs of the rail sector, a uniform system architecture helps to homogenise the learning process. It helps limit the patchwork not only in technology but hence also in education. Which in its turn means that knowledge is better exchangeable internationally. ERA can indicate this dot on the horizon, so national training courses can be arranged accordingly, and people will be trained in a future-proof manner.

In this transformation it is advisable to gain knowledge from other sectors that are experiencing or have undergone a similar movement from analogue technology to a digital basis. ERA can enquire which parties have contributed, where advice was needed, and what regulation was required, i.e. conduct a benchmark study in other industries to acquire lessons learned and best practices.

Finally, it is important for ERA to identify together with the Member States whether any training development plans are feasible within the framework of their national personnel and whether they are needed for the timely implementation of ERTMS. ERA can include and provide substance to a training plan in the European Deployment Plans, so that training and rollout continue to be in sync.

Currently there is no ready training for CCS, TMS or ERTMS that can be applied across the board, it does help to draw up a blueprint of the situation. Currently, development of expertise usually occurs by means of general vocational schooling (e.g. ICT, electrical engineering), with 'add-ons' of sector specific training (Rail Centres) and learning on the job within the companies. For future needs, two approaches can be discerned to train the workforce for the digital transformation:

- (Re)training existing staff
- Educating new talents

Where a gap will be identified between current training and future required knowledge and steps will need to be taken in recruiting or educating suitable staff, the ERA and the Member State can follow the diagram below to identify how to proceed.

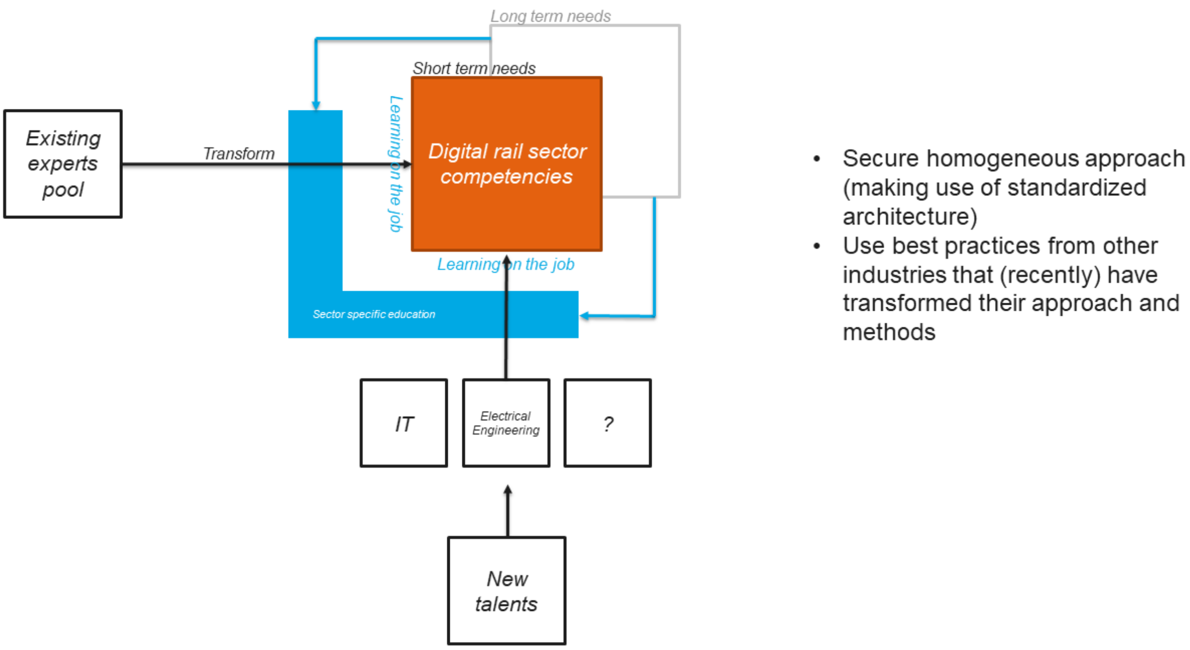

Figure 23 Diagram for identifying focus on training

ERA's role thus is using the existing platforms, make an inventory of available training course supply, and possibly identify and support (harmonization) possibilities for the future. A solid and logical architecture of the system as well as accompanying logical operational rules will lead to relatively less demanding education requirements for all parties (i.e. Infrastructure Manager, Operating Company, etc.) and for all end users (dispatchers, drivers).

10.4 Stronger Mandates and More Resources for ERA

Though strictly speaking outside of the scope of this study, one more recommendation emerged from it frequently and only for that reason alone is worth mentioning. Many stakeholders mentioned that a stronger role for ERA is needed. Words used were 'Project Director', 'System Integrator' and 'the Infrastructure Manager of Europe'.

Furthermore, in order to achieve the first three recommendations a coordinator with authority is needed. The ERA is already set up for this purpose. Within the 4th Railway Package, the framework is already available. However, the ERA is a small agency, with approximately 200 employees and a similarly modest budget. These more ambitious strategies cannot be accomplished within these current resources.

Moreover, under the current mandate progress will be slow. Many stakeholders expressed an urgent need for action. However, many parties are involved, all with their own drivers and individual goals, not always matching with goals of the EU / ERA. Decision-making is therefore very slow. A stronger mandate for ERA could speed this up.

Today the ERA has two options to achieve goals on a European level that are not matching with national goals:

- By convincing stakeholders of the high level benefits
- By ‘seducing’ them with sponsoring

However, if the ERA has a mandate to enforce, this knowledge gives the ERA a stronger position in negotiations. Even if this mandate will never be used.

Therefore, a stronger role for ERA to coordinate these processes and achieve these strategies involves a stronger mandate, more resources and accordingly a higher budget.

As part of this new role, the ERA can consider the introduction of ATO as a future area of special interest. The introduction of ATO will be accompanied by a shift in interests and responsibilities of the various stakeholders. This will also offer new opportunities to standardise and promote rail transport, towards the ultimate goal of a Single European Railway Area (SERA).

11 APPENDIX A LIST OF ABBREVIATIONS

Abbreviation	Explanation
ACEI	Italian route setting device
AMS	Advanced train control Migration System
ARS	Automatic Route Setting
ASD	Automated System Development
ASA	Asset Standards Authority. This is an independent unit of Transport for New South Wales (Australia)
ASTRIS	Aansturing en Statusmelding van de Railinfrastructuur (Control and status reporting of the rail infrastructure)
ATB-EG	Automatische Trein Beïnvloeding – Eerste Generatie (First Generation). A Dutch ATP-system.
ATB-NG	Automatische Trein Beïnvloeding – Nieuwe Generatie (New Generation). A Dutch ATP-system.
ATB-vv	Automatische Trein Beïnvloeding – verbeterde versie (evolved version). A Dutch ATP-system.
ATB-EG	Automatic Train Control First Generation, a Dutch ATP-system
ATB-NG	Automatic Train Control New Generation, a Dutch ATP-system
ATB-vv	Automatic Train Control Evolved version, a Dutch ATP-system
ATC-2	Norwegian type of line side signalling
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATRICS	Advanced Train Running Information Control System
AUTOSAR	AUTomotive Open System Architecture. A worldwide development partnership of automotive interested parties pursuing the objective of creating and establishing an open and standardised software architecture for automotive electronic control units (ECUs).
AWS	Automatic Warning System
BACC	Blocco Automatico a Correnti Codificate, Italian ATP system
BDK	Banedanmark (Rail Net Denmark)
BIM	Building Information Modelling
BRIO	Belgian Railway Infrastructure Objectives
BSA	BELGOSIGNAL, consortium of Alstom and Siemens
bSI	buildingSMART
CAF	Construcciones y Auxiliar de Ferrocarriles

CCS	Command, Control & Signaling
CDAS	Connected Driver Advisory Systems
CEF	Connecting Europe Facility
Class-B	National Train Control System: Class B systems for the trans-European rail system network are a limited set of train protection legacy systems that were in use in the trans- European rail network before 20 April 2001. Class B systems for other parts of the network of the rail system in the European Union are a limited set of train protection legacy systems that were in use in that networks before 1 July 2015. The list of Class B systems is established in the European Railway Agency technical documents ‘List of CCS Class B systems, ERA/TD/2011-11, version 3.0’.
CP"x"	Control Period x
CS	Cab Signaling
CTC	Centralised Traffic Control
DANISH ATC	Danish ATP system
DAS	Driver Advisory Systems
DB	Deutsche Bahn
DBM	Design, Build and Maintain
DCTC/ATNS	Type of Danish Traffic Management System
DG MOVE	Directorate-General for Mobility and Transport. A Directorate-General of the European Commission responsible for transport within the European Union.
DICS	Type of Danish Traffic Management System
DMI	Driver Machine Interface
DO	Swiss type Relay-Based Interlocking
DR	Digital Railway
DSP	Digital Systems Project
DTRS	Digital Train Radio System
EBICAB	Norwegian ATP system
EBI Lock	Type of electronic interlocking manufactured by Bombardier
EBS	Type of digital interlocking manufactured by Siemens
EBS+	Type of digital interlocking manufactured by Siemens
EBP	Type of route setting device manufactured by Siemens
ECI	Early Contractor Involvement
ECRG	ERTMS Change Review Group
ECU	Electronic Control Unit (automotive)
EDP	ERTMS European Deployment Plan

EFTA	European Free Trade Association
EIM	European Rail Infrastructure Managers
ELEKTRA ½	Type of electronic interlocking manufactured by Thales
EOI	Expressions of Interest
ERA	European Union Agency for Railways
ERFA	European Rail Freight Association
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
EU	European Union
EUROSIGNUM	Swiss ATP system
EUROZUB	Swiss ATP system
EULYNX	EULYNX is an European initiative by 12 Infrastructure Managers to standardise interfaces and elements of the signalling systems
EVC	European Vital Computer
FOC	Freight Operating Company
FS	Full Supervision
GN	Guidance Notes
GNT	Geschwindigkeitsüberwachung Neigetechnik. German ATP system which enables to rise the speed of tilting trains until 30 % above the limits for conventional trains.
GoA	Grade of Automation
GRS – track circuit	Type of Dutch train detection system
GSM-R	Global System for Mobile Communications - Rail
H/V - signals	German type of line side signals
HI - signals	German type of line side signals
HVI	Type of Transport for New South Wales train detection system
ICMP	Intelligent Congestion Management Program
IECC	Integrated Electronic Control Centre
IFC	Industry Foundation Classes
ILTIS	Integrale Leit- und Informationssystem. Swiss traffic management system
IM	Infrastructure Managers
IMA	Integrated Modular Avionics
INESS	INtegrated European Signaling System

IP	Internet Protocol
IXL	Interlocking
JADE	Jointless Audio-frequency Detection, by Alstom
KISA	Kommunikationsinfrastruktur für sicherheitsrelevante Anwendungen. System which encrypts the data communication between subsystems
Ks	German type of line side signals
L1	Level 1
L1LS	Level 1 Limited Supervision
L2	Level 2
L3	Level 3
LEU	Line side Electronic Unit
L type	Swiss type of line side signals
LZB	Linienzugbeeinflussing. German type of Automatic Train Protection
MAS	Multiple Aspect Signaling
N - type	Swiss type of line side signals
NeTS	Netzweites Trassen-System. Swiss Traffic Management system
NIC	National Infrastructure Commission
NS	Dutch Railways, the main passenger train operating company in the Netherlands
NSA	National Security Agency. An NSA has a duty to authorise, and in the case of rolling stock keep a register of, new and changed components of the railway, ensuring relevant technical specifications for interoperability (TSIs) are met. The NSA is also required to develop a safety regulatory framework, including a system of national safety rules, and to produce an annual safety report to ERA.
NSW	New South Wales
NX PANEL	eNtrance-eXit panel. Switch/button type of route setting device
NeuPro	Neue Produktionsverfahren. New Production Processes
NEXTEO	French type of Automatic Train Protection system specifically designed for the Paris RER rail network
OCDN	Operations Critical Data Network
ONRSR	Office of the National Rail Safety Regulator
OS	Operational System
PAI	Poste d'Aiguillage Informatique. French electronic interlocking controlled by a digital route setting device
PLC interlocking	Programmable Logic Controller. Open source Interlocking
PRIME	Parsons' Railway Integrated Modelling Environment

PRCI	Poste tout Relais á commande informatique. French type of relay-based interlocking controlled by a digital route setting device
PZB	Punktförmige Zugbeinflussing. German type of Automatic Train Protection
R&I Programme	Research & Innovation Programme
RBC	Radio Block Centre
RFC	Rail Freight Corridor
RCS	Rail Control System. Traffic management system developed in-house by SBB
RCS-Dispo	Core of the Rail Control System
RCS-ADL	Calculates energy-optimised driving profiles
RCS-HOT	Automatic conflict detection and resolution
RCS-ARS	Automatic route Setting
RCS-ALEA	Incident information management
RFF	Réseau ferré de France
RFI	Rete Ferroviaria Italiana. Infrastructure Manager for the Italian railway network
ROC	Rail Operating Centre
RSSB	Rail Safety and Standards Board
RSx Codici	Italian Automatic Train Protection system
RTM	RailTopoModel
RTCT	Danisch type of relay pushbutton Route setting device
RVO	Rail Vehicle Owners
S-Bahn	German metro like transport system based on train technology
SCMT / SSC	Sistema Controllo Marcia Treno. Italian Automatic Train Protection system
S2R	Shift2Rail
SERA	Single European Railway Area
SIL	Safety Integrity Level
Simis	Type of electronic Interlocking manufactured by Siemens
SLA	Service Level Agreement
SoM	Start of Mission
SNCF	Société Nationale des Chemins de fer Français, the main operating company in France
SPAD	Signal Passing at Danger
SpDrs	Swiss type of relay based Interlocking

SSB	Schweizerische Bundesbahnen / Swiss Federal Railways
SSI	Solid State Interlocking
ST	Sydney Trains
STM	Specific Transmission Module
TBL 1	Transmissie Baken-Lokomotief. Belgian Automatic Train Protection system
TBL 1+	Belgian Automatic Train Protection system which uses Eurobalises
TBL 2	Belgian Automatic Train Protection in use on the high speed line
Ten-T	Trans European Transport Network
TDs	Technology Demonstrators
TfNSW	Transport for New South Wales
TI21	Type of audio frequency train detection system in use by Transport for New South Wales
TMC	Transport Management Centre (TMC) Systems
TMS	Train Management System
TOC	Train Operating Company
TPWS	Train Protection & Warning System
TPWS+	Improved version of Train Protection & Warning System
TSI	Technical Specifications for Interoperability
TVM	French family of Automatic Train Protection systems
UIC	International Union of Railways
UNIFE AND UIC	Union des Industries Ferroviaires Européennes. UNIFE is representing the European rail manufacturing industry
UM71	Type of audio frequency train detection system in use by Transport for New South Wales
UK	United Kingdom
USB	Universal Serial Bus
VPI	Vital Processor Interlocking
ZUB 123	Type of Danish Automatic Train Protection system
ZUB SIGNUM ATP	Type of Swiss Automatic Train Protection system

12 APPENDIX B REFERENCES

General Information

Nr. 1	Source
1.A	European Commission, Deployment Action Plan (2017), https://ec.europa.eu/transport/sites/transport/files/2017-ertms-deployment-action-plan.pdf (consulted 15-03-2018)
1.B	European Court of Auditors (03/10/2017), A single European rail traffic management system: will the political choice ever become reality?, https://www.eca.europa.eu/Lists/ECADocuments/SR17_13/SR_ERTMS_RAIL_EN.pdf (consulted 30-05-2018)
1.C	Council of the European Union (29-01-2018), Outcome of Proceedings (Council conclusions on European Court of Auditors' Special Report No 13/2017: "A single European rail traffic management system: will the political choice ever become reality?"), http://data.consilium.europa.eu/doc/document/ST-5584-2018-INIT/en/pdf (consulted 30-05-2018)
1.D	ERA, Technical specifications for interoperability, http://www.era.europa.eu/core-activities/interoperability/pages/technicalspecifications.aspx (consulted 04-06-2018)
1.E	Commission Delegated Decision (EU) 2017/1474 of 8 June 2017 supplementing Directive (EU) 2016/797 of the European Parliament and of the Council with regard to specific objectives for the drafting, adoption and review of technical specifications for interoperability (notified under document C (2017) 3800), https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32017D1474 (consulted 08-06-2017)
1.F	Programmabureau ERTMS (2017), Informatiebijeenkomst STM ATB-EG, https://www.tenderned.nl/tenderned-tap/aankondigingen/120544;section=2 (consulted 31-05-2018)
1.G	Programmabureau ERTMS (2017), Openbaar verslag 4e marktconsultatie (STM-ATBEG), https://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjSgoSUyKXcAhVBaVAKHSoQCoQQFggoMAA&url=https%3A%2F%2Fwww.ertms-nl.nl%2Faanbesteding-%2Ben%2Bcontracteringstrategie%2Fmarktconsultaties%2Fmarktconsultatie%2B4%2Fhandlerdownloadfiles.ashx%3Fidnv%3D799870&usg=AOvVaw2PqleuOBhsnaT3LH1rrxdq, (consulted 31-05-2018)
1.H	European Union Agency for Railways Policy, 15/06/2016, POL_IOM_001 V 3.0, https://www.era.europa.eu/sites/default/files/agency/docs/european_union_agency_for_railways_policy_en.pdf
1.I	UIC, Worldwide Railway Organisation, ERTMS, What is ERTMS, 3. ETML, https://uic.org/ertms (consulted 19-10-2018)
1.J	Verkeersleiding, https://nl.wikipedia.org/wiki/European_Rail_Traffic_Management_System (consulted 19-10-2018)
1.K	Railway Talents, https://uic.org/railway-talents (consulted 29-10-2018)
1.L	Minor Railway Technology, Co-operation between industry & education, Evaluation Pilot 2012 – 2015 https://www.slideshare.net/AndrvanEs/presentation-uic-minor-railway-technology (consulted 29-10-2018)

United Kingdom

Nr. 2	Source
2.A	Arriva, Cambrian Level 2: In-service experience, http://www.irse.org/knowledge/publicdocuments/6_CPH%20ERTMS%20P%20Leppard.pdf (consulted 08-02-2018)
2.B	Association of Train Operating Companies (2015), ATOC Guidance Note - Level 2 ETCS Principle Considerations for Driver Training, https://www.rssb.co.uk/rgs/oodocs/atocgn%20ertms%20002%20iss%201.pdf (consulted 08-02-2018)
2.C	Balfour Beatty (October 2017), Fast Track to Digital Railway, https://www.balfourbeatty.com/media/316903/digital-railway-paper.pdf (consulted 07-02-2018)
2.D	Department for Transport (2016), Recommendations on Government Policy for a Digital Railway Programme and accelerated deployment of digital signaling technology, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664516/digital-railway.pdf (consulted 08-02-2018)
2.E	Digital Railway (2015), ETCS: Infrastructure Changes, http://digitalrailway.co.uk/wp-content/uploads/2015/11/RDG-Education-Day-040817-Handout-Part-2.pdf (consulted 06-02-2018)
2.F	Digital Railway (2015), Rail Delivery Group, http://digitalrailway.co.uk/wp-content/uploads/2015/11/RDG-Education-Day-040817-Handout-Part-1.pdf (consulted 06-02-2018)
2.G	Digital Railway (2015), ETCS: Infrastructure Changes, http://digitalrailway.co.uk/wp-content/uploads/2015/11/RDG-Education-Day-040817-Handout-Part-2.pdf (consulted 07-02-2018)
2.H	Digital Railway (December 2016), Delivering Digital Train Control Technology Efficiently, http://digitalrailway.co.uk/wp-content/uploads/2016/12/Early-Contractor-Involvement-Report-Dec-16.pdf (consulted 06-02-2018)
2.I	Digital Railway (12 January 2017), Digital Railway Suppliers Conference, http://digitalrailway.co.uk/wp-content/uploads/2017/02/Digital-Railway-Suppliers-Conference.pdf (consulted 07-02-2018)
2.J	Digital Railway (31 March 2017), ETCS Onboard Assembly - Baseline 3 - National Onboard Subsystem Requirements Specification, https://www.rssb.co.uk/Library/improving-industry-performance/2014-05-19-specification-etcs-onboard-system-baseline-3.pdf (consulted 06-02-2018)
2.K	Network Rail (2018), Network Rail Infrastructure Limited – Network Statement 2018, https://cdn.networkrail.co.uk/wp-content/uploads/2016/12/2018-Network-Statement.pdf (consulted 05-03-2018)
2.L	Rail Safety and Standards Board (2017), CCS Standards Committee Chairman's presentation, https://www.rssb.co.uk/Library/groups-and-committees/2017-03-21-iscc-appendix-1.pdf (consulted 06-02-2018)
2. M	Network Rail (15-11-2011), Cambrian: In service experience – an Infrastructure Manager's perspective, http://www.irse.org/knowledge/publicdocuments/5_IRSE%20ERTMS%20Seminar%20Cambrian%20151111v3.pdf (consulted 08-02-2018)
2.N	Transport research Laboratory (2010), ERTMS Level 3 Risks and Benefits to UK Railways, https://trl.co.uk/media/773946/cpr798_-_ertms_level_3_risks_and_benefits_to_uk_railways.pdf

	(consulted 08-02-2018)
2.O	Mitchell, I. (2003), Signaling Control Centres Today and Tomorrow. IRSE Proceedings 2002-2003, http://www.irse.org/knowledge/publicirseproceedings/IRSEProceedings2002-2003.pdf (consulted 16-04-2018)
2.P	RSSB. (2015). AWS and TPWS Handbook, https://www.rssb.co.uk/rgs/rulebooks/RS522%20Iss%203.pdf, (consulted 2-8-2018)
2.Q	International Railway Journal. (2018). Automatic Train Operation takes to the main line, http://www.railjournal.com/index.php/technology/automatic-train-control-takes-to-the-main-line.html, (consulted 2-8-2018)

Switzerland

Nr.3	Source
3.A	Email ERA CCS study (08-01-2018), Arnold Trümpi and Steffen Schmid. Answers to questionnaire.
3.B	SBB CFF FFS (2018), Network Statement 2018, https://company.sbb.ch/content/dam/sbb/de/pdf/sbb-konzern/sbb-als-geschaeftspartner/angebote-fuer-evus/onestopshop/grundlagen-netzzugang/Network_Statement_2018_E.pdf.download.pdf. (consulted 05-03-2018)
3.C	SBB CFF FFS, BLS, SOB, RhB (2017), SmartRail 4.0
3.D	SBB CFF FFS, NeTS – Network-wide Track Management System and RCS – Rail Control System, https://company.sbb.ch/content/dam/sbb/de/pdf/sbb-konzern/sbb-als-geschaeftspartner/RCS/I-UE-VK_Broschuere_NETS_und_RCS_Innotrans_en.pdf (consulted 13-06-2018)
3.E	Siemens, Controlguard Itlis N, https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/rail-solutions/rail-automation/operations-control-systems/controlguard-iltis-n-en.pdf (consulted 13-06-2018)
3.F	SBB CFF FFS (October 2007), ORR Best Practice Study, http://orr.gov.uk/__data/assets/pdf_file/0014/5261/wbps-rail-switzerland.pdf (consulted 13-06-2018)
3.G	Siemens (2012), ETCS Level 1 Limited Supervision for a Fast and Cost Effective Migration of Legacy Train Control Systems to ETCS, http://www.irse.nl/resources/ETCS_LS_IRSE_Wildenrath-V2.pdf (consulted 11-06-2018)
3.H	IRSE Swiss Section (2014), ETCS Rollout, Siemens's Rollout of ETCS L1 Limited Supervision on SBB, http://www.irse.org/nearyou/publicdocuments/Veranstaltung%202014%2004%20IRSE%20News_ETCS%20L1LS.pdf (consulted 11-06-2018)
3.I	SSB CFF FFS (31-08-2017), <<SmartRail 4.0>>, (consulted 28-01-2018)
3.J	SBB CFF FFS (February 2018) SmartRail 4.0 Jahresbericht 2017, https://smartrail40.ch/content/dam/internet/smartrail/2017-Jahresreporting.pdf (consulted 20-06-2018)
3.K	Email. SBB review conclusions (28-06-2018) Steffen Schmidt. Answers SBB review conclusions.
3.L	SBB CFF FFS, The Swiss Way to Capacity Optimization for Traffic Management. https://www.sbbrcs.ch/fileadmin/user_upload/bilder/broschuere/RCS_Whitepaper_en.pdf (consulted 10-07-2018)
3.M	ERTMS National Implementation (NIP) Plan of Switzerland, Summary, 20 September 2017

	https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)
3.N	Presentation on SmartRail 4.0; Boosting migration, by Steffen Schmidt, SBB AG, CCS migration workshop, 25 September 2018, Lille

Germany

Nr.4	Source
4.A	Deutsche Bahn (2018), The Track Access Charges 2018 of DB Netz AG, https://fahrweg.dbnetze.com/resource/blob/1367430/7976d965d38a386f350dfd7f533a96f4/tpsbroschuere2018_en-data.pdf (consulted 05-03-2018)
4.B	DB Netze. (2016, February). Themendienst Vom Stellhebel Zum Mausklick: Wie die Bahn in Ihrem Schiennennetz täglich 40.000 Züge Stuert. https://www.deutschebahn.com/resource/blob/1295806/b424db51a0b9a4d51226c1e424b17297/2015-07-Themendienst-Stellwerke-data.pdf (Consulted 11-04-2018)
4.C	Elsweiler, B. (SD). EULYNX A strategic project for DB. [presentation] http://www.irse.org/knowledge/public/seminarconferencepapers.aspx (Consulted 11-04-2018)
4.D	SBB. (SD). DB Netz AG introduces RCS (Consulted 11-04-2018)
4.E	SBB. (SD). RCS Whitepaper. (Consulted 11-04-2018)
4.F	Global Railway Review. (16 October 2017) Equipped for the future with an Integrated Control System https://www.globalrailwayreview.com/news/63003/equipped-for-the-future-with-an-integrated-control-system/ (Consulted 12-04-2018)
4.G	Hans Leister. (8 September 2017). ETCS und Digitale Technologie für Stellwerke.
4.H	EULYNX. (12 December 2017). EULYNX on track towards digital railways. https://eulynx.eu/index.php/documents/presentations-given/164-20171213-irse-nl (Consulted 12-04-2017)
4.I	EULYNX. (25 January 2017a). Workshop Industry. https://eulynx.eu/index.php/documents/presentations-given (Consulted 12-04-2018)
4.J	DB. (2015). Zukunft Bahn. https://www.deutschebahn.com/file/de/12819522/U7iLPXszVcfW1Dzv9Vs_mDk5O14/11870318/data/Zukunft_Bahn.pdf. (Consulted 12-04-2018)
4.K	Stellwerke.de. (2006). Signalsystem Deutschland. http://www.stellwerke.de/signal/deutsch/ks.html. (consulted on 5-7-2018)
4.L	ERA. (2010). Electromagnetic Compatibility Requirements Germany. http://www.era.europa.eu/Document-Register/Documents/The%20Demonstration%20of%20Electromagnetic%20Compatibility%20in%20Germany.pdf. (consulted 5-7-2018).
4.M	Aktuelle Trends von IT/TK und LST in Eisenbahnprojekten; Digitale LST, NeuPro, KISA, bbIP. https://www-docs.b-tu.de/fg-eisenbahn/public/Lehre/LV/Kolloquium/2017/LST_ITK_Bahn.pdf. (consulted 5-7-2018)
4.N	McKinsey&Company. (2018), Feasibility study Zukunft Bahn (ETCS/NeuPro)

4.O	Bahnblogstelle. (2015). Betriebssteuerung RB Süd: Ein Blick in die Betriebszentrale München. https://bahnblogstelle.net/2015/10/29/betriebssteuerung-rb-sued-ein-blick-in-die-betriebszentrale-muenchen/, (Consulted 2-8-2018)
4.P	Thales. (2018). Traffic Management Systems. https://www.thalesgroup.com/en/countries/europe/germany/transportation/traffic-management-systems. (consulted 2-8-2018)
4.Q	Siemens. (2018). Operations Control Systems and Rail-IT solutions. https://www.mobility.siemens.com/mobility/global/en/interurban-mobility/rail-solutions/rail-automation/operations-control-systems-and-rail-it-solutions/planning-and-disposition/Pages/planning-and-disposition.aspx (consulted 2-8-2018)
4.R	DB Netze. (2017). Die LZB wird durch ETCS abgelöst. https://fahrweg.dbnetze.com/fahrweg-de/kunden/nutzungsbedingungen/etcs/etcs_migration/lzb_abloesung-1369708. (Consulted 2-8-2018)
4.S	National ETCS Implementation Plan, 11 December 2017, Version 1.11 https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)
4.T	DB Netz, Stefan Bode, CCS migration, German approach/topics, e-mail 12 October 2018

France

Nr.5	Source
5.A	SNCF Réseau (2018), Network Statement of the National Rail Network – 2018 Timetable, https://www.sncf-Réseau.fr/en/drr_telechargement/2018/chapitre/complet (consulted 05-03-2018)
5.B	SNCF Réseau (2016), RER E – Soon One Train Ahead Thanks to NEXTEO, https://www.sncf-Réseau.fr/en/reportages/nexteo. (consulted 4-7-2018)
5.C	SNCF Réseau (2018), Parenariat D'Innovation Argos, https://www.sncf.com/sncv1/ressources/cp_argos.pdf. (consulted 10-7-2018)
5.D	EPSF (2017), Les signaux, http://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0ahUKEwj3gdT6yqXcAhXPEVAKHV_xBYQQFgg8MAI&url=http%3A%2F%2Fwww.securite-ferroviaire.fr%2Fsites%2Fdefault%2Ffiles%2Fusers%2Freglementations%2Fpdf%2Fdocumentpedagogique-lessignaux-lesregimesdexploitationdeslignes-lessystemesdespacementdestrains.pdf&usg=AOvVaw14Rc5j99fa-VBXW9SBQet1, (consulted 10-7-2018)
5.E	SNCF (2018), The autonomous train, 1st UIC Global Conference on Signalling
5.F	RFF (2-10-2012), ERTMS Strategy – RFF, http://lyonturin.eu/documents/docs/Mosmann_RFF_ERTMS_Helsinki_Oct2013%20modane%20rfc6%20corridor%20d.pdf (consulted 17-07-2018)
5.G	ATOS. (2014). Atos signs contract with Réseau Ferré de France to develop and implement the new centralized command/control rail management system: MISTRAL NG. https://atos.net/en/2014/press-release/deals-contracts-press-releases_2014_06_26/pr-2014_06_26_02. (consulted 6-8-2018)
5.H	IRSE. (2016). Commissioning Strasbourg "PAI". http://irse.org.hk/newsletter/Issue%2032%20August%202007.pdf. (consulted 6-8-2018)
5.I	Document De Référence Du Réseau Ferré National, Horaire de service 2019, Version 1.1 du 15 mars 2018
5.J	Regulation (EU) 2016/919 from the Commission of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling subsystems' of the railway system in the European Union, National implementation plan for France, Version as of 27 June 2017 https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)

The Netherlands

Nr.6	Source
6.A	Ministry of Infrastructure and Environment (2013), ERTMS Railway Map – Version 1.0 – Start Decision, https://www.government.nl/binaries/government/documents/reports/2013/12/10/railway-map-ertms-1-0/railmap-ertms-version-1-0.pdf (consulted 20-02-2018)
6.B	Ministry of Infrastructure and Environment (2013), Railway Map ERTMS – Version 2.0 – State of play regarding research in the Exploratory Phase, https://www.government.nl/binaries/government/documents/reports/2014/01/08/railway-map-ertms-2-0/railway-map-version-2-0-eng-2.pdf (consulted 20-02-2018)
6.C	Ministry of Infrastructure and Environment (2013), Railway Map ERTMS – Version 3.0 – Memorandum on Alternatives, https://www.government.nl/binaries/government/documents/reports/2014/04/01/railway-map-ertms-version-3-0-memorandum-on-alternatives/railmap-3-0-engels.pdf (consulted 20-02-2018)
6.D	ProRail (2018) Network Statement 2018, https://www.prorail.nl/sites/default/files/network_statement_2018_prorail_version_1.0.pdf (consulted 05-03-2018)
6.E	Rail center. (SD). Plannen, be-bijsturen en beveiligen van treinenloop.
6.F	SpoorPro (30-05-2018), Kosten uitrol ERTMS hoger dan verwacht, programmabeslissing uitgesteld, https://www.spoorpro.nl/spoorbouw/2018/05/30/kosten-uitrol-ertms-hoger-dan-verwacht-programmabeslissing-uitgesteld/?utm_source=newsletter&utm_medium=email&utm_campaign=Nieuwsbrief%20week%202018-22 (consulted 30-05-2018)
6.G	Questionnaire as input for interview ERA feasibility study Digitalisation of CCS and migration to ERTMS (25-04-2018), Henri van Houten and Maarten van der Werff, Utrecht - De Inktpot.
6.H	ERA studie interview NS (08-05-2018), Henk de Boer, NS main office Utrecht.
6.I	SpoorPro. (2016). 250 miljoen uit het ERTMS-budget gaat naar station Schiphol. https://www.spoorpro.nl/spoorbouw/2016/06/23/250-miljoen-uit-het-ertms-budget-gaat-naar-schiphol/, (consulted 6-8-2018)
6.J	National Implementation Plan of ERTMS in The Netherlands https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)
6.K	SpoorPro (19 juli 2018), Kosten ombouw goederetrein naar ERTMS nauwelijks gedekt, https://www.spoorpro.nl/goederenvervoer/2018/07/19/kosten-ombouw-goederentrein-naar-ertms-nauwelijks-gedekt/ (consulted 6-8-2018)
6.L	Brief van de Staatssecretaris van Infrastructuur en Waterstaat aan de Voorzitter van de Tweede Kamer der Staten-Generaal Den Haag, 19 juni 2018 https://www.tweedekamer.nl/kamerstukken/brieven_regering/detail?id=2018Z11727&did=2018D34651 (consulted 6-8-2018)
6.M	Allianz Pro Schiene (2017). Überblick: Masterplan Schienengüterverkehr https://www.allianz-pro-schiene.de/themen/aktuell/ueberblick-masterplan-schienengueterverkehr/ (consulted 25-06-2018)
6.N	ProRail Beheerplan 2018, December 2017
6.O	DB Cargo (2016). Position paper d.d. 20 september 2016 – Position paper DB Cargo Nederland t.b.v. hoorzitting/rondetafelgesprek ERTMS-uitrolstrategie d.d. 28 september 2016. (consulted 13-9-2018)
6.P	Interview DB Cargo (13-9-2018), Heinrich Wehrmeyer, Jelle Rebbers, DB Cargo office Utrecht

Denmark

Nr.7	Source
7.A	Banedanmark (2018), Network Statement 2018), https://uk.bane.dk/en/Railway-Undertaking/Network-Statements/Network-Statement-2018 (consulted 24-04-2018)
7.B	Banedanmark (2013), The Danish Signaling Programme. http://www.railcopenhagen2013.transport.dtu.dk/material (consulted 24-04-2018)
7.C	Banedanmark (2012), A Case study from Denmark, http://www.irse.org/knowledge/publicdocuments/10_IRSE%2030032012%20presentation%20BA%20AM.pdf (consulted 24-04-2018)
7.D	Bassano, D. (2018), The Danish Signaling Programme, deployment of a complete network upgrade and related authorisations processes. 1st UIC Global Conference on Signaling Milan 2018.
7.E	Lundsten, (SD). Danish Signaling, an introduction. http://www.lundsten.dk/dk_signaling/dksignal.html (consulted 5-7-2018)
7.G	Ello Weits, (2013). Signalling Programme en Fjernbane East in Denemarken, http://www.irse.nl/resources/130828-Alstom-F-Bane-slides-for-IRSE-v2.pdf. (consulted 11-7-2018)
7.H	Thales (2014). LockTrac 6151 ESTW L90 5, http://thalesgroup.com.au/sites/default/files/database/d7/asset/document/05_p184753_thales_leaflet_locktrac6151_en.pdf. (consulted 11-7-2018)
7.I	Frauscher (2015). Signalling system renewal Bandedanmark. https://www.frauscher.com/assets/media/CaseStudies/2013 BaneDanemark/EN_Frauscher_Case-study_10_Banedanmark-Denmark.pdf. (consulted 11-7-2018)
7.J	Eelco Schrik (2015). ERTMS realisatie Denemarken, https://www.kivi.nl/uploads/media/564988f992253/Presentatie%20ERTMS%20realisatie%20Denemarken%20KIVI%20_%20Strukton%20E.%20Schrik.pdf, (consulted 11-7-2018)
7.K	Atkins, (2017). Learning lessons form a national ETCS roll-out. https://www.atkinsglobal.com/en-GB/media-centre/features/national-signalling-programme-denmark, (consulted 3-8-2018)
7.L	ERTMS_Factsheet_19_ERTMS_deployment_in_Denmark http://www.ertms.net/wp-content/uploads/2014/09/ERTMS_Factsheet_19_ERTMS_deployment_in_Denmark.pdf (consulted 20-8-2018)

Belgium

Nr.8	Source
8.A	Infrabel (2018), Network Statement, https://www.infrabel.be/sites/default/files/documents/ns_2018_20171208.pdf (consulted 05-03-2018)
8.B	Infrabel (2016), New Traffic Management, https://uic.org/forms/IMG/pdf/09_infrabel_tms_das_ws_uic_160210.pdf, (consulted 9-05-2018)
8.C	NMBS Groep (2012), Investeringsplan 2013-2025, www.belgianrail.be/nl/corporate/onderneming/beheer/~/media/3996D263BDC249118D4684770638E805.ashx (consulted 9-05-2018)
8.D	Infrabel (2018), Het ETCS systeem, https://www.infrabel.be/nl/etcs (consulted 9-05-2018)

8.E	Infrabel (2015), ETCS Master Plan, https://www.spoorpro.nl/wp-content/uploads/2016/03/Infrabel_ERTMS-Conference_Brochure.pdf, (consulted 9-05-2018)
8.F	Alstom, (2008), ERTMS/ETCS on Belgian High-Speed Lines L3 and L4
8.G	Infrabel, (2006), Facts & Figures 2005-2006, http://ecms.infrabel.be/DMS/ds/en/396355. (consulted 5-7-2018)
8.H	Infrabel, (2018), Siemens, Infrabel's Deficient Supplier, Responsible for Major Network Disruption, https://www.infrabel.be/en/press/siemens-infrabel-s-deficient-supplier-responsible-major-network-disruption. (consulted 5-7-2018)
8.I	B-Signal, (2017), Het Belgisch seinwezen – De basis, http://www.b-signal.thesignalpage.nl/basis.php. (consulted 5-7-2018)
8.J	Alstom. (2009). EBPPLP 1299 Frame contract. http://irse.nl/verslagen/page29/page30/files/EBPPLP1299%20-%20sept%2009.pdf. (consulted 9-7-2018)
8.K	Infrabel, Developing safety systems, https://www.infrabel.be/en/about/safety/developing-safety-systems (consulted 12-07-2018)
8.L	National ETCS implementation plan, 08/06/2017 https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)
8.M	Nationaal Implementatieplan ETCS + Annex https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)

Italy

Nr.9	Source
9.A	Rete Ferroviaria Italiana (15-11-2017), Innovation solution for a decommissioning strategy of the class B: the Italian path, http://www.era.europa.eu/Document-Register/Documents/05%20ERA%20conference%20RFI_02.pptx (consulted 26-03-2018)
9.B	Interview 27-03-2018, Fabio Senesi, UIC conference on signalling, Milan.
9.C	1st UIC Global Conference on Signalling, Milan (26,27,28-03-2018) presentation 1.1 ERTMS in the world: The Funding Challenges
9.D	RFI (19-09-2017), RFI experience for the application of satellite technologies to ERTMS signalling system, https://business.esa.int/sites/default/files/spacemoves2017/RFI%20-%20Presentazione_Berlino_05.pdf (consulted 13-06-2018)
9.E	ECM, With the conception of an architecture that contemplates HMR9® technology as the core of the signalling system, ECM has developed a completely integrated, flexible, scalable and modular solution, http://www.ecmre.com/en/hmr9.php (consulted 13-06-2018)
9.F	UIC (28-11-2017), Italy: Trials begin for ERTMS Level 3 Regional System – a new way of developing railway operations beyond the digitalisation of signalling, https://uic.org/com/uic-e-news/573/article/italy-trials-begin-for-ertms-level-3-regional-system-in-italy-a-new-way-of?page=iframe_enews (consulted 13-06-2018)
9.G	Questionnaire as input for interview ERA feasibility study Digitalization of CCS and migration to ERTMS (27-03-2018), Fabio Senesi.
9.H	National implementation plan of ERTMS https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)

Norway

Nr.10	Source
10.A	Email. Questionnaire as input for interview ERA feasibility study Digitalisation of CCS and migration to ERTMS (02-04-2018) Kjell Holter. Answers Questionnaire Bane NOR.
10.B	Bane NOR (03-03-2015), ERTMS National Implementation, http://www.banenor.no/en/startpage1/Projects/ERTMS-National-Implementation/ (consulted 13-06-2018)
10.C	Bane NOR (12-04-2018), Norway builds Europe's most modern railway: Bane NOR goes digital for 20 billion, http://www.banenor.no/Prosjekter/prosjekter/ertms/innhold/2018/norway-builds-europes-most-modern-railway-bane-nor-goes-digital-for-20-billion2/ (consulted 13-06-2018)
10.D	International Railway Journal (12-07-2016), ERTMS in Norway: escaping the "burning platform", http://m.railjournal.com/index.php/signalling/ertms-in-norway-escaping-the-burning-platform.html (consulted 13-06-2018)
10.E	Email. Bane NOR review conclusions (25-06-2018) Kjell Holter. Answers Bane NOR review conclusions.
10.F	LOVDATA (2008), Forskrift om togframføring på det nasjonale jernbanenettet. https://lovdata.no/dokument/SF/forskrift/2008-02-29-240/KAPITTEL_9#KAPITTEL_9, (consulted 26-7-2018)
10.G	National Signalling Plan, upgrading of, and investment in, railway signalling equipment Introduction of ERTMS, November 2015 https://ec.europa.eu/transport/modes/rail/interoperability/interoperability/ccs-tsi_en (consulted 22-8-2018)
10.H	Norway awards ERTMS onboard contracts to Alstom, International Railway Journal, https://www.railjournal.com/signalling/norway-awards-ertms-onboard-contracts-to-alstom/ (consulted 12-6-2018)

Australia

Nr.11	Source
11.A	Transport for New South Wales (2017), Automated Systems Phase 1 – Market Briefing, https://tenders.nsw.gov.au/?event=public.rft.showArchived&RFTUUID=0D57E4B6-0491-652D-510072720A853CE2, (consulted 15-03-2018)
11.B	Transport for New South Wales (2017), Automated Systems Project, https://tenders.nsw.gov.au/?event=public.rft.showArchived&RFTUUID=0D57E4B6-0491-652D-510072720A853CE2, (consulted 15-03-2018)
11.C	Transport for New South Wales (2017), Transforming the Sydney Rail Network using New Signaling and Rail System Technologies, (consulted 15-03-2018)
11.D	Sydney Trains (2016), PL S 44000 Signaling and Control Systems Strategy, https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/PL-S-44000-Signaling-and-Control-Systems-Strategy.pdf (consulted 26-03-2018)
11.E	RailCorp (2010), Signaling System Future Capacity Plan and Asset Condition Programs, https://www.parliament.nsw.gov.au/committees/DBAssets/InquirySubmission/Body/52288/Sub5%20-%20100226%20-%20RailCorp%20Signaling%20Strategy.pdf (consulted 26-03-2018)
11.F	Forrest, J. (2015), Rail Operatin Centre, (consulted 26-03-2018)
11.G	Scheck, M. (SD), Strategies for Train Control Within Queensland Rail. http://atrf.info/papers/1993/1993_Scheck.pdf (consulted 05-04-2018)
11.H	Queensland Government (2010), Independent review – Failures of QR universal traffic control (consulted 05-

04-2018)

EULYNX

Nr.12	Source
12.A	EULynx (2014-2018), Baseline 1 through 5, https://eulynx.eu/index.php/documents/project-description (consulted 27-02-2018)
12.B	Van der Werff, M., Heijen, F., Blazic, M., (2015), EULYNX: The Next Generation Signaling Strategy, http://www.irse.org/knowledge/public/seminarconferencepapers.aspx (Consulted 16-04-2018)
12.C	UIC, (1999), EURO-INTERLOCKING: Project Declaration, https://uic.org/cdrom/2008/04_euro-interlocking2/docs/general/project_declar_v2.1.pdf (consulted 16-04-2018)
12.D	UIC, (2009), INESS Project (INtegrated European Signaling System), https://uic.org/com/uic-e-news/142/article/iness-project-integrated-european?page=thickbox_enews (Consulted 16-04-2018)
12.E	EULYNX, (2017), EULYNX: On track towards digital railways, http://www.irse.org/knowledge/public/seminarconferencepapers.aspx (Consulted 16-04-2018)
12.F	EULYNX, (2017), Baseline 2 released, https://eulynx.eu/index.php/home2/30-baseline-2-released, (Consulted 16-04-2018)

Shift2Rail

Nr.13	Source
13.A	Shift2Rail (2015), Shift2Rail Strategic Master Plan, https://ec.europa.eu/transport/sites/transport/files/modes/rail/doc/2015-03-31-decisionn4-2015-adoption-s2rmasterplan.pdf (consulted 23-04-2018)
13.B	Shift2Rail (27-10-2017), Shift2Rail Joint Undertaking (S2R JU), Annual Work Plan & Budget, https://shift2rail.org/wp-content/uploads/2017/11/Decision-6-2017_-AWP2018_Annex.pdf (consulted 23-04-2018)
13.C	European Commision (2011), Transport White Paper,, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0144, (consulted 04-06-2018)
13.D	Shift2Rail (2017), R&I Programme, Innovation Programme 2, https://shift2rail.org/research-development/ip2/, (consulted 04-06-2018)

European Union

Nr.14	Source
14.A	ERA/UNISIG/EEIG ERTMS USER GROUP(13-05-2016), Glossary of terms and abbreviations, www.era.europa.eu/Document-Register/Documents/SUBSET-023%20v330.pdf (consulted 21-05-2018)
14.B	Directorate-General for Mobility and Transport, https://en.wikipedia.org/wiki/Directorate-General_for_Mobility_and_Transport and https://ec.europa.eu/info/departments/mobility-and-transport_en (consulted 27-09-2018)
14.C	Presentation EC activities in the field of ERTMS roll out and CCS migration – Ian Conlon (EC – DG Move),

	CCS migration workshop, 25 September 2018, Lille
14.D	European Agency for Railway, https://www.era.europa.eu/, (consulted 27-09-2018)
14.E	Presentation The Railway System of the Future and how it will be operated - Josef Doppelbauer (ERA), CCS migration workshop, 25 September 2018, Lille
14.F	4th Railway Package, https://ec.europa.eu/transport/modes/rail/packages/2013_en (consulted 27-09-2018)
14.G	ERTMS Users Group, https://ertms.be/ (consulted 27-09-2018)
14.H	Presentation EEIG/Eulynx "White paper reference CCS architecture based on ERTMS" (Michel Ruesen/Robert Dijkman –EEIG), CCS migration workshop, 25 September 2018, Lille
14.I	DECISION n° 159 of the Management Board of the European Union Agency for Railways adopting the technical and functional specifications for the establishment of the One-Stop Shop (OSS) https://www.era.europa.eu/sites/default/files/agency/docs/decision/decision_n159_technical_and_function_specifications_oss_en.pdf (consulted 12-10-2018)
14.J	European Rail Freight Association, http://erfarail.eu/ (consulted 12-9-2018)
14. K	ERFA, Input paper on simplification of language requirements, http://erfarail.eu/uploads/ERFA%20Language%20input%20paper-1529938627.pdf (consulted 27-9-2018)
14.L	National Rules, https://www.era.europa.eu/activities/national-rules_en (consulted 27-9-2018)
14.M	State aid SA.44621 (2016/N) – Czech Republic – Individual subprograms for ensuring interoperability in railway transport, C(2017) 2222 final, 7 April 2017
14.N	Presentation at meeting European Infrastructure Managers (EIM), (14-02-2018), EIM office Brussels
14.O	Meeting European Infrastructure Managers (EIM), (14-03-2018), EIM office Brussels

Other

Nr.15	Source
15.A	Huawei (2015), Huawei In Transportation, Case Studies, https://e.huawei.com/en/material/onLineView?materialid=94e9012a1eb14920aec8ebbb3e7c4152, (consulted 06-06-2018)
15.B	AUTOSAR (2018), History, https://www.autosar.org/about/history/, (consulted 06-06-2018)
15.C	AUTOSAR (2018), Classic Platform, https://www.autosar.org/standards/classic-platform/, (consulted 07-06-2018)
15.D	AUTOSAR (2018), Organization, https://www.autosar.org/about/organization/, (consulted 06-06-2018)
15.E	Airbus (SD), A380 Integrated Modular Avionics, http://www.artist-embedded.org/docs/Events/2007/IMA/Slides/ARTIST2_IMA_Itier.pdf, (consulted 07-06-2018)
15.F	International Railway Journal (2018), Stadler and Mermec form AngelStar ETCS joint venture, http://www.railwaygazette.com/news/business/single-view/view/stadler-enters-the-signalling-market.html. (consulted 18-7-2018)
15.G	Angelstar (2018), Angelstar. http://www.angelstarcompany.com/. (consulted 18-7-2018)
15.H	Mermec (2018), Mermec Company Profile. http://www.mermecgroup.com/mermec-incorso/images/File/About/companyprofile/MERMEC%20Company%20Profile_EN0516.19.pdf (Consulted 18-7-2018)

15.I	Stadler (2018), About Us, https://www.stadlerrail.com/en/about-us/. (consulted 18-7-2018)
15.J	Tweakers. (2016). De veelbelovende warboel van usb-c; Eén kabel die vrijwel alles kan. https://tweakers.net/reviews/4647/de-veelbelovende-warboel-van-usb-c-een-kabel-die-vrijwel-alles-kan.html, (consulted 7-8-2018)
15.K	Google Developers. (2018). Platform Architecture. https://developer.android.com/guide/platform/. (consulted 8-8-2018)
15.L	IEEE Standards Association. (2018). Develop Standards. http://standards.ieee.org/develop/index.html. (consulted 8-8-2018)
15.M	Wikipedia. (2018). Zigbee. https://en.wikipedia.org/wiki/Zigbee, (consulted 8-8-2018)
15.N	iMore. (2013). Pulling back the curtain on Apple's Lightning connector licensing program. https://www.imore.com/mophie-pulls-back-curtain-lightning-accessories, (consulted 8-8-2018)
15.O	CAF (2018). Sistemas ERTMS. https://www.caf.net/en/productos-servicios/senalizacion/sistemas-ERTMS.php (consulted 12-9-2018)
15.P	Interview Thales Group (09-2018), Klaus Mindel, Innotrans Berlin
15.Q	Interview Bombardier (09-2018), Thomas Hromadka, Innotrans Berlin
15.R	Interview CAF Signalling (09-2018), Jose Antonio Quintano Rodriguez, Innotrans Berlin
15.S	Interview Mermec Group (09-2018), Inzirillo Francesco, Innotrans Berlin
15.T	Interview Siemens (09-2018), Ruediger Brandt, Ralf Kaminsky, Innotrans Berlin
15.U	https://en.wikipedia.org/wiki/Bombardier_Transportation and https://rail.bombardier.com/ (consulted 18-10-2018)
15.V	https://en.wikipedia.org/wiki/Construcciones_y_Auxiliar_de_Ferrocarriles and https://www.caf.net/en/compania/index.php (consulted 18-10-2018)
15.W	https://www.thalesgroup.com/en/ (consulted 18-10-2018)
15.X	https://mobilitymatters.siemens.nl/road-city/noord-zuidlijn-terugblik/ https://www.createglobalmobilityplayer.com/ https://nl.wikipedia.org/wiki/Siemens_AG https://electricitymatters.siemens.nl/overig/nasa-mars/ https://www.mobility.siemens.com/mobility/global/en/interurban-mobility/rail-solutions/rail-automation/train-control-system/european-train-protection-system/pages/european-train-control-system.aspx (consulted 18-10-2018)
15.Y	Siemens and Alstom sign rail merger deal to compete with China, https://www.dw.com/en/siemens-and-alstom-sign-rail-merger-deal-to-compete-with-china/a-43113411 (consulted 18-10-2018)
15.Z	https://www.thalesgroup.com/en/activities/ground-transportation https://www.thalesgroup.com/en/worldwide/transportation/press-release/norway-relies-thales-develop-its-digital-railways-all-over https://www2.thalesgroup.com/asset/transport/ground-transportation/?_ga=2.186033198.664693956.1539849059-1179095776.1539849059#page=7 https://www.thalesgroup.com/en/security https://www.thalesgroup.com/en/aerospace (consulted 18-10-2018)

13 APPENDIX C INVENTORY INFRASTRUCTURE MANAGERS

In chapter 3 of this report, the main trends and findings regarding Infrastructure Managers were noted. In the following appendix, the more detailed information and findings will be presented for all studied (Member) States.

Each paragraph answers two of three main research questions for a country.

1. What is the current situation surrounding interlocking and TMS? Which problems are encountered with regard to these systems and what is done to solve these?
2. What are the relevant future strategies with regard to CCS and TMS?

For all countries/paragraphs the first section will answer the first question, i.e. the current situation. Next the plans and ambitions further on the horizon are described in two sections. The final section describes the Lessons Learnt, in order to answer the subquestion “Which problems are encountered with regard to these systems and what is done to solve these?’

For all countries, the research concentrates on the most common systems, which means that occasionally the more obscure systems will have been ignored. However, this does not change any of the conclusions across the board, as described in Chapter 3.

13.1 United Kingdom

Network Rail is the responsible Infrastructure Manager for the British railway network.

13.1.1 Current Situation

In the current situation the legacy systems are largely determined by the architecture of the British Traffic Management System. Aside from existing relay Interlocking systems mechanical interlockings are still operational. The Operating Centres are organized decentrally.

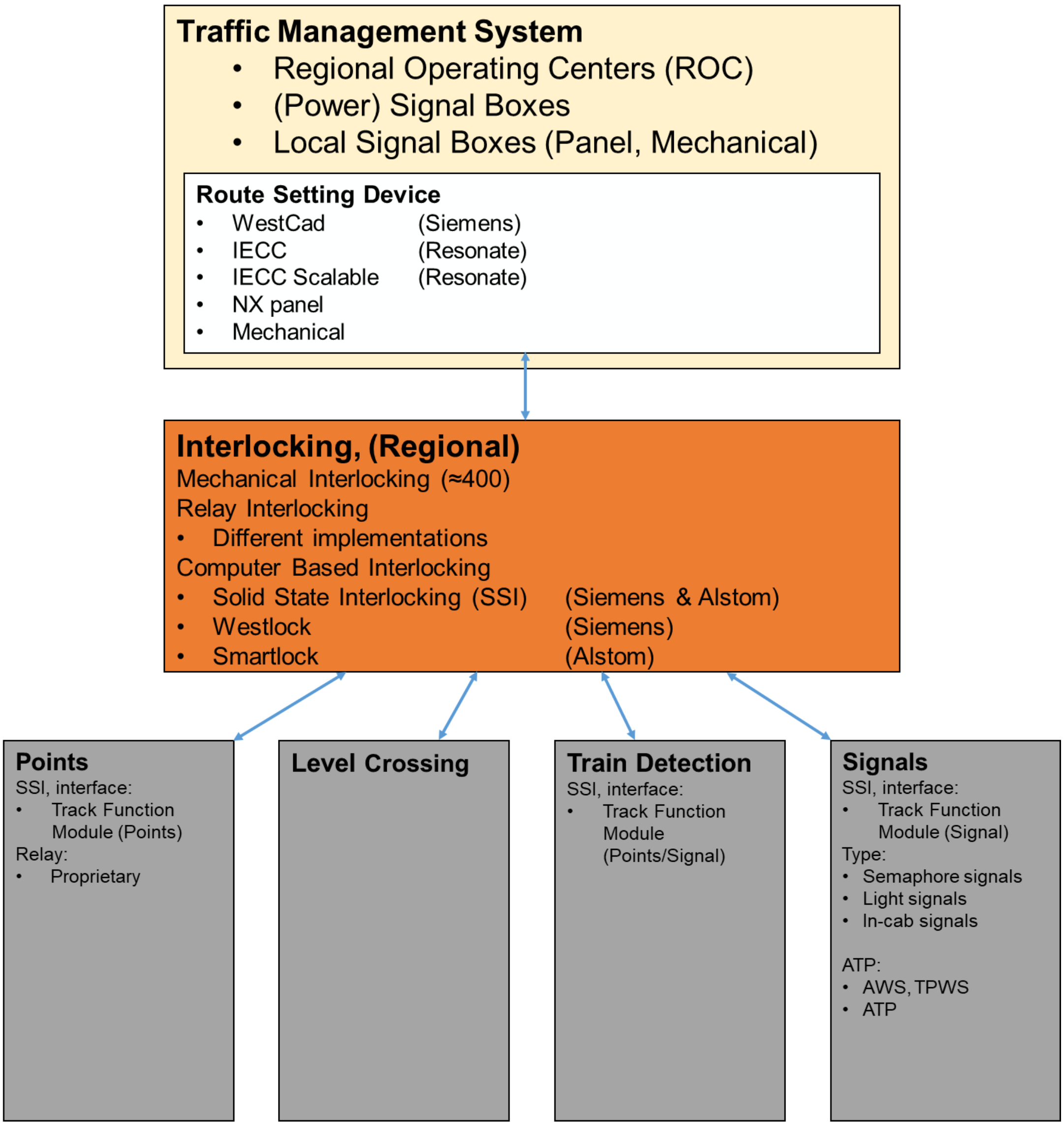

Figure 24: System architecture Network Rail [2.O].

Traffic Management Systems (TMS)
Traffic management in the United Kingdom is moving towards centralised traffic control. Traffic management system development is ongoing, including the introduction of intelligent conflict/delay identification and resolution. The system also interfaces with crew management systems and rolling stock management.

In the current situation the following forms of traffic management exist:
- *Regional Operating Centres (ROC)*
  Centralised traffic control centres
- *(Power) Signal Boxes*
- *Local Signal Boxes (panel, mechanical)*

Route setting device
- WestCad (Siemens)
- IECC (Resonate)
- IECC scalable (Resonate)
- NX panel
- Mechanical

Automatic Route Setting
- ARS (often integrated in control system)

Expected Remaining Useful Life
IECC is no longer maintained. Other operating systems are to be renewed either during re-signalling or re-control. During re-signalling either track layout changes requiring a large modification to the TMS and interlocking. Or the TMS and interlocking is one-on-one replaced, both resulting in full replacement of the CCS-system.
During re-control signalling boxes are integrated int ROC's, interlockings are not changed with re-control.

Plans to Replace/Renew
A new traffic management system will be introduced under the Digital Railway programme. The new traffic management system (TMS) will introduce more intelligence in timetable management. This includes automatic conflict detection and resolution.

Interlocking
Mechanical and relay interlockings are progressively replaced by electronic interlockings during large re-signalling projects. Replacement will be accelerated under the Digital Railway programme for the 7 routes on which the Digital Railway is currently planned to be rolled out.

Mechanical Interlocking
The United Kingdom still has approximately 400 mechanical interlockings in use. Alterations are executed mainly by Network Rail themselves.

[2.O]

Relay Interlocking
There are different implementations, such as geographical and free-wire logic.

Electronic Interlocking

Interlocking	Supplier
Solid State Interlocking (SSI)	Siemens & Alstom, (hardware no longer available)
Westlock	Siemens
Smartlock	Alstom

Table 6: Overview of electronic based interlocking in the UK [2.O]

The table above presents the suppliers of the various electronic interlockings in use on the United Kingdom railway network. Additionally, other parties can make data changes to the electronic interlockings. These parties can also provide other services around the electronic interlockings such as Testing and Commissioning. However, hardware is only provided by the aforementioned suppliers.

Expected Remaining Useful Life
SSI and mechanical interlockings are end of life. SSI hardware is no longer available.

Certain relay interlockings are end of life (geographical interlockings).

Plans to Replace/Renew
Replacement of SSI, relay and mechanical interlocking occurs only when an area is re-signalled. In case of minor changes, current installations are slightly altered or updated. Major changes may result in full replacements of the interlocking installation. What constitutes a minor or major change depends on the type of interlocking installation – for instance a mechanical interlocking, which is older, will more likely be replaced, while an SSI will be altered.

Block Systems

The railway network of the United Kingdom is fitted with a fixed block system equipped with trackside train detection. Both track circuits and axle counters are present on the British railway network.

Signalling
The British railway network is equipped with a route signalling system. Signals are of the colour light aspect type.

Expected Remaining Useful Life
The remaining useful life depends on the interlockings used. SSI, certain relay, and mechanical interlockings are end of life.

Plans to Replace/Renew

The block system is replaced with re-signalling projects.

Automatic Train Protection (ATP)

TPWS / TPWS+ (Train Protection & Warning System) is the most widely used train protection system in Britain although on some routes Automatic Train Protection (ATP) is used.

Expected Remaining Useful Life
As the replacement of TPWS with ERTMS will be gradual and take several years, the rail industry looks at how TPWS can be maintained on the network until the implementation of ERTMS.

Plans to Replace/Renew
In line with European directives, the national network is now committed to a migration plan that will replace TPWS with ERTMS. This will provide a higher level of train protection whilst helping the railway towards a more cost-efficient signalling system.

13.1.2 Plans

Modernisation of the CCS-system is performed under the Digital Railway programme. This programme sets out long-term ambitions for the railway. These ambitions are presented in paragraph 3.3. In this paragraph the concrete plans and actions for the next 5 to 10 years are presented.

The Digital Railway programme has commissioned members of the global supply chain to explore whether, and how they could drive a more cost-effective and outcome-focused approach for rail customers. These Suppliers, supported by the Rail Supply Group, looked at the targeted deployment of digital technology which claims to deliver capacity and performance benefits on the rail network.

This new approach to early contractor involvement has already resulted in the development of new ideas and potential solutions. A business information tool has also been used to provide immediate and real asset performance data. This has empowered Suppliers to develop the right solutions which could bring significant benefits for customers of the railways.
[2.C, 2.D, 2.F]

A review of the ETCS Reference Design by suppliers is performed during early contractor involvement. The ETCS reference design describes how ETCS will be used in the United Kingdom. It has been written by Network Rail with extensive stakeholder input. A mature and reviewed refence design results in the following benefits:
- Provides a centralised document for managing current and future requirements
- Ensures a common source for all projects
- Drives operational consistency
- Enables suppliers to Identify & scope modifications
- Ensures a deliverable set of requirements

[2.I]

The review of the ETCS reference design by suppliers resulted in the follow remarks:
- The reference design has not yet reached the required level of maturity
- Effective review of the reference design requires people with extensive knowledge in diverse fields:
    - ETCS specifications

- ETCS application
- Suppliers’ own ETCS products and systems
- Suppliers’ international experience
- UK signalling principles and operation practices

Thus, further reviews and modifications are required. However, individuals who possess the required expertise are in short supply. The following steps are proposed:

- Undertake a workstream to harmonise Supplier views on where the issues are in each document
- Decide how to proceed with review/update
- Implement configuration management process

[2.I]

The Digital Railway programme is moving towards the rollout of the Digital Railway. Seven routes are being explored:

- South East Route – Need of capacity and performance increase.
- East Coast Main Line – Signalling to be renewed.
- Anglia – Introducing Traffic Management and Connected Driver Advisory Systems (C-DAS) on the Anglia Route and ETCS on Great Eastern main Line.
- Great Western Route – Digital Railway Programme has teamed up with Network Rail’s Western Route and the British signalling and train control specialists, Resonate, to trial the ‘Luminate’ Traffic Management System to boost performance on train journeys between London Paddington and Bristol Parkway.
- Trans-Pennine – Development fund of up to £5 million to scope how digital technology could be embedded into the trans-Pennine route to deliver Britain’s first digitally controlled intercity main line railway.
- West Coast Main Line – Addressing performance issues for Euston, constrained during HS2 construction, through TM and also capacity around Crewe using ETCS for HS2 trains.
- South East and East London Line (with Transport for London) – Addressing capacity and performance through the East London Line tunnel and linking into the south-east network.

Further engagement is required with those already involved in the Early Contractor Involvement (ECI) programme, and with other parts of the supply chain who have not yet been involved. Working with the Rail Supply Group, the Digital Railway programme will continue the ECI programme to further develop evidence in support of the initial finding and embed those into the targeted set of business cases. [1.D]

The findings will also inform the work the Digital Railway programme is doing to develop an integrated industry plan. This will be in conjunction with key stakeholders across the rail industry and government to ensure that digital deployment is aligned with rail re-franchising and re-signalling schemers planned in the coming years. [1.D]

<u>ATO on ETCS</u>

ATO (Automatic Train Operation) in combination with ETCS is being investigated. Initial implementation on Thameslink in core route section has recently been commissioned. Thameslink is the testbench for Shift2Rail ATO GoA2[18] over ETCS. Results of this test bench are used in drafting the specifications. The aim is to include ATO in the CCS TSI in 2022.
[2.Q]

<u>ERTMS Level 3</u>

Successful trials of hybrid ERTMS Level 3 have taken place. Consideration is being given to whether this should be given preference above ERTMS Level 2.

<u>Outcomes-led programme</u>

[18] GoA2 Grade of Automation 2 or Semi-automatic train operation. Starting and stopping is automated. Train driver operates the doors, drives the train if needed and handles emergencies.

New Signalling and Control Systems: These need to be installed alongside existing conventional systems, before decommissioning. The new technology will require investment as well as re-skilling the workforce. For example, training operational and maintenance staff to work with digitally enabled processes and tools.

13.1.3 Ambitions

The main ambition on the United Kingdom railway network is to increase line capacity, without adding more tracks.

Digital Railway
Digital Railway is a rail industry-wide programme, launched in 2014, which encompasses a complex 25-year package of digitally enabled interventions which aim to improve the way systems work together. To accomplish this, it will modernise train command, control and signalling systems designed in a pre-digital age, faster than they would otherwise be upgraded. The intention is to significantly increase capacity at a much lower cost than new line construction. At the heart of the programme is the adoption of modern signalling technology that will allow trains to run closer together, achieving higher network utilisation and reducing the amount of infrastructure and associated maintenance and renewal cost. Similar technology has been successfully deployed internationally on projects such as the new French TGV line between Tours and Bordeaux and is being pioneered in the UK through central London’s Thameslink core lines.
[2.C]

Government Involvement
Rail Safety and Standards Board (RSSB) is continuously reviewing and updating the guidance on safety requirements (GN).

The Secretary of State for Transport, the Rail Minister and the Minister for Industry from BEIS hosted representatives from the rail supply chain and wider technology innovators at two round table events. They discussed the current ambitions and concerns of the supply chain including how to remove any potential barriers to entry into the market by new Suppliers. [2.D]

Ministers were particularly interested in promoting innovation and establishing the UK as a leader in the application of new technology to the railway:

- There is an appetite for new approaches and a preparedness to discuss and evaluate the implications for franchises, existing commercial models and funding arrangements and the role of Network Rail in these new approaches.
- There needs to be a greater understanding of the key programme risks and how they might be mitigated. Participants reiterated that this would not just be a technology programme but would involve wider change in the industry with implications for existing processes, skills and training and development.
- Any programme for the delivery of digital signalling technology must be delivered with cross-industry integration and collaboration. Of interest was the way in which disruption to the network from its enhancement could be managed better with less impact to the travelling public.
- There is a role for Government in supporting and championing a long-term plan for the introduction of digital signalling technology. The industry needs confidence to invest, to encourage innovation and to drive better value through economies of scale.
- There was a recognition that industry needed to explain better how working effectively with government would guarantee lower costs, confident delivery schedules and the development of the UK’s expertise.

[2.D]

The Group was also aware of the Government’s broader ambitions for the railway and, the emphasis being given to:

- Ensuring that the passenger or user is at the heart of everything that we do. Investment by the government or by any party must deliver real and demonstrable benefits.
- Bringing the track and train closer together. This means ensuring that the railway operates as a more effective whole by removing the friction and disconnects between those responsible for the railway infrastructure and those who use it. Those tensions have so often resulted in inconvenience for the user. Digital Railway is itself an integrative set of technologies, between track and train, requiring a cross-industry approach as reflected by the cross-industry Digital Railway team, its membership and governance.

- Encouraging greater levels of private sector financing. The government believes that it has not made the most of the potential of the market to improve the efficiency and cost of the railway.
- Establishing the UK rail industry as a global leader. The government is clear that it wants an industry strategy that is fit for the next decades and that the industry should seize this opportunity to put itself at the forefront of global thinking and development.

[2.D]

13.1.4 Lessons Learnt

The following lessons learnt have been identified in the United Kingdom.

<u>Expertise</u>

- Need for a team of operators (infrastructure and trains) and engineers (infrastructure and trains)
- More critical understanding of the operational concept before commencing engineering design
- Understanding that minor changes to trackside can have a significant impact to the operability/drivability of the train
- Need to understand the managing of reliability growth from a systems perspective with a comprehensive Defect Recording and Corrective Action System

[2.A, 2.M]

<u>Radio Block Centre (RBC)</u>

Problems are encountered with the current use of ERTMS. Equipment gets ‘confused’ because of several reasons:

- Line speed changes which are ‘too frequent’
- 2 trains in the same platform both seeking movement authorities
- Crossing trains at loops ‘too quickly’
- Trains shunting from the running line into the depot
- Mixture of mile hr-1 and km hr-1
- Lack of incorporation of automatic level crossings into ERTMS
- Degraded-mode maximum speed
- Permanent speed restrictions have become too restrictive
- 2 Different certifications

[2.A, 2.M]

13.2 Switzerland

SBB (Schweizerische Bundesbahnen / Swiss Federal Railways) is the responsible Infrastructure Manager for the Swiss railway network.

13.2.1 Current Situation

The Swiss railway network is equipped with a modern and up to date traffic management system. Many components have been developed in-house by SBB, ensuring the capability for further development and long-term maintenance of the applications. Furthermore, traffic management is in the process of further centralisation.

Relay interlockings are to be replaced with electronic interlockings. The migration plan will depend on the decision made concerning the SmartRail 4.0 plan.

Two signalling systems currently exist side by side in Switzerland, a route signalling system and a speed signalling system. The route signalling system is progressively replaced by the speed signalling system. The Swiss railway network is already equipped with an ETCS L1LS ATP-system.

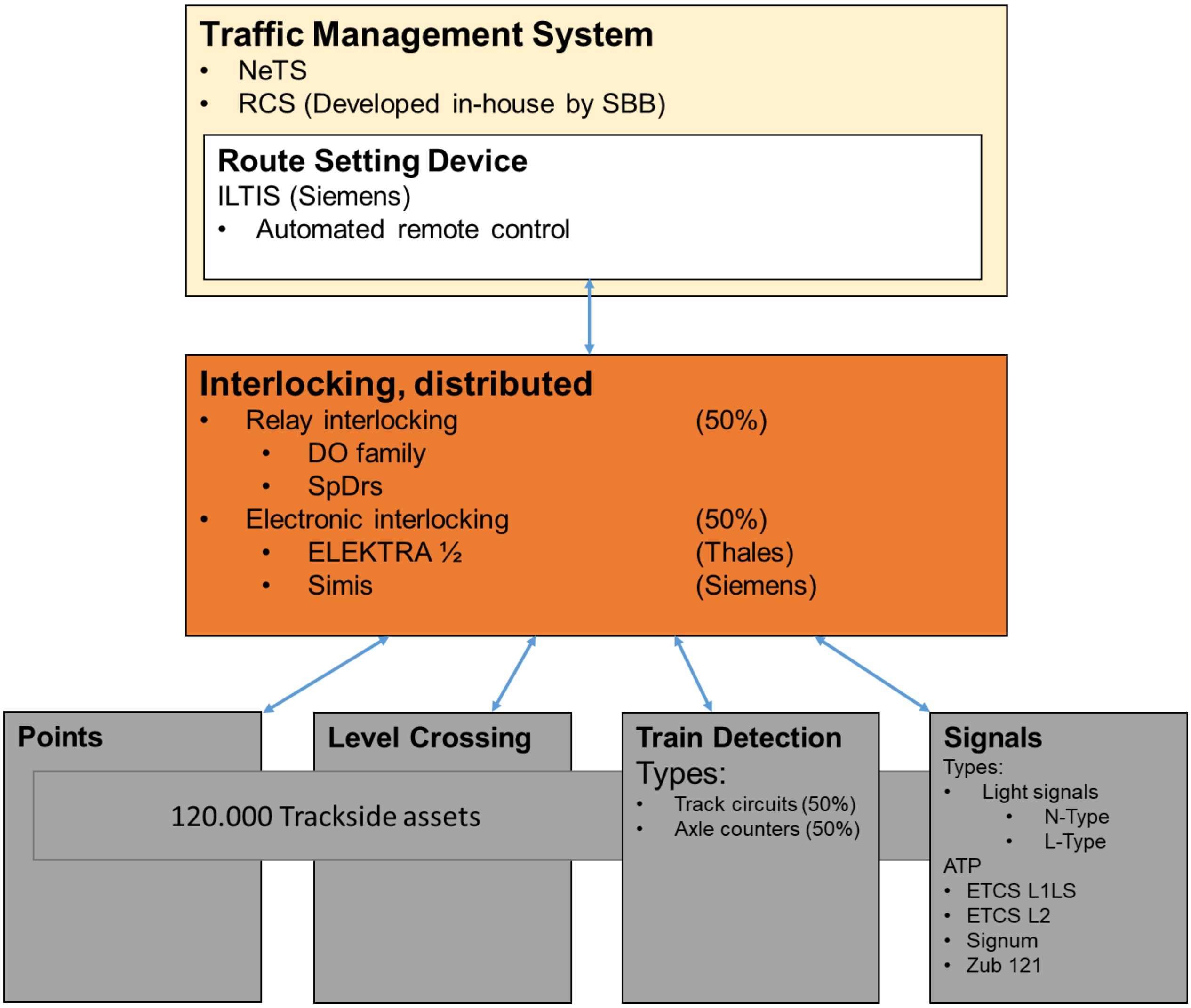

Figure 25: System architecture SBB

Traffic Management Systems (TMS)

The traffic management layer of SBB consists of three ‘components’:
- NeTS
- RCS
- ILTIS

NeTS
NeTS (Netzweites Trassen-System) integrates all rail network planning activities: annual and daily planning, line and junction planning, closures and reduced speed sections in addition to the entire workflow for train path allocation. Specific data and services such as topology data, the calculation of travel times, rolling stock, authentications, and authorisations are all provided through defined interfaces.

RCS
The Rail Control System (RCS) traffic management system is completely developed in-house by SBB, as a precisely constructed group of applications which cover needs from route management and topology data management to the presentation of operational status and rail control. Thanks to its open architecture, all applications are highly integrated and deliver data and services to over 200 additional systems. It features automatic route setting, conflict detection, and conflict resolution. The result is automatic route setting even with delays present.

Route Setting Device
The route setting device ILTIS (Integrale Leit- und Informationssystem) is developed and maintained by Siemens.
[3.D, 3.E]

Expected remaining useful life
Thanks to the flexible and open architecture of NeTS, the capability for further development and long-term maintenance of the applications is ensured.

SBB cannot share information regarding expected remaining useful life, because this is relevant for public procurements or part of contracts.
[3.K]

Plans to replace/renew
In 2005 the SBB launched a project to centralise and merge rail control as a whole into four central locations. By 2016, due to the level of automation achieved, most of the rail traffic was being controlled from these four train-control centres. There are some secondary lines that are being served locally. The full centralisation is scheduled for completion in 2019.
[3.L]

The plans to replace/renew the traffic management system will be made within the programme SmartRail 4.0. The final decision will be made in the upcoming years.
[3.A]

Interlocking

Interlocking consists mainly of electronic and relay interlocking. Both account for approximately 50% of the network. However, some mechanical interlockings are still present. The interlockings control approximately 120,000 trackside objects.

Relay Interlocking
- DO family relay-based interlockings (Do55, Do67, Do69 etc.)
- SpDrs (relay)

[3.A, 3.G, 3.H, 3.K]

Electronic Interlocking
- ELEKTRA ½ (Thales)
- Simis C, Simis-IS, Simis-W (Siemens)

[3.A, 3.G, 3.H, 3.K]

Expected remaining useful life
In general, the lifespan of all systems is balanced and acceptable. However, because of the introduction of N type signals (see 'Signalling' hereafter), relay-based interlockings like Do55 and SpDrs are no longer compatible and must be replaced.
[3.A]

Plans to replace/renew
SBB intends to replace all relay-based interlockings. The migration plan will be decided according to the programme SmartRail 4.0, which will be decided in the upcoming years.
[3.A, 3.K]

Block systems

Systems in use:
- Trackside train detection
- Track circuits (50%)
- Axle counters (50%)

Application of track circuits and axle counters are nearly equally divided. The share of axle counters is increasing.
[3.K]

Signalling
Switzerland has two types of lineside light aspect signals: The L type, which is most widespread in the country and is based on route signalling principles. And the N (numérique) type, based on speed signalling principles. The N-system was developed for the Rail 2000 project.

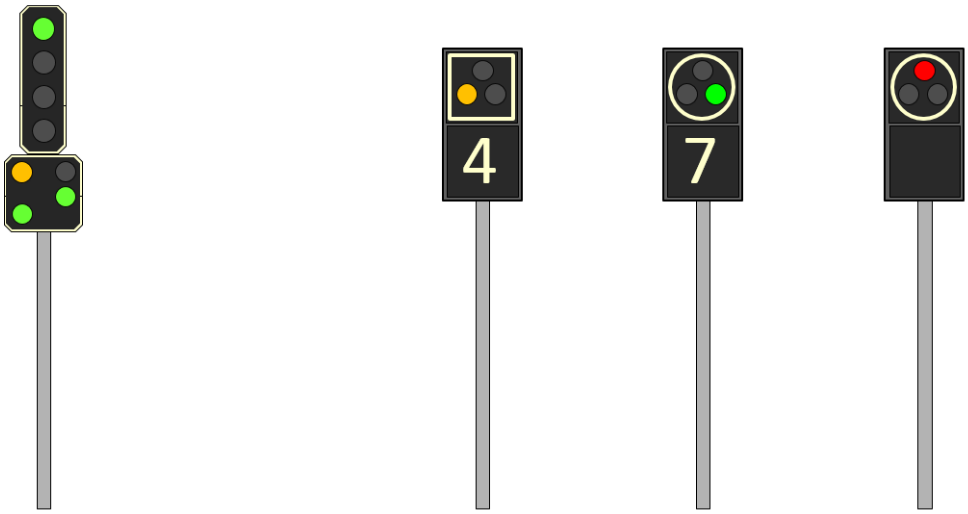

Figure 26: Simplified examples of the Swiss L (left) and N type signals (three on the right)

For speeds over 160 km/h cab signalling is required.
[3.A, 3.G]

Plans to replace/renew
SBB is progressively replacing L type signals by N type signals, because N type signals are more complete, better adapted to high-speed operation (>140 km/h), allowing greater fluidity and thus increasing capacity.
[3.G, 3.H]

Automatic Train Protection (ATP)

Systems in use:
- ETCS L1LS
- ETCS L2
- EUROZUB
- EUROSIGNUM

[3.K]

Expected remaining useful life
ZUB SIGNUM ATP equipment was obsolete. ZUB magnets were replaced by ETCS balises. However, they are programmed with ZUB and SIGNUM data as a migration step towards ETCS. Such installations are called: EuroZUB and EuroSIGNUM.

Plans to replace/renew
The ZUB SIGNUM ATP-system is replace by ETCS L1LS. This is the first step of the migration to ERTMS, providing a fast and cost-effective migration of legacy train control systems to ETCS. For the long-term SBB is looking at SmartRail 4.0.
[3.A]

13.2.2 Plans

The plans of SBB for the future CCS-system follow from the ambition of SBB. This Ambition is SmartRail 4.0 and is presented hereafter. A decision will be made on the plans resulting from SmartRail 4.0 in the coming years.
It is important to note that Switzerland is working backwards from their Ambition. First the Ambition is defined, planned changes to the CCS-system are then derived from the Ambition.

13.2.3 Ambitions

The Switzerland is working towards SmartRail 4.0. Starting from scratch, using all high-end basic technologies form all sectors, using a very slim and cheap architecture, and using senior expertise of the system architecture. The result is a system with the highest performance, lowest complexity, easiest migration and simplest lifecycle, usable for mainline, regional and metro. This is not a “long-term” ambition but a goal that Switzerland wants to try and achieve as fast as possible. Because the technological CCS-situation today is not acceptable as it is not affordable and manageable by the railway system. However, proof of concepts for all projects in the programme are not yet finalised.

With SmartRail 4.0 Switzerland is working towards automated planning, automation of operating centres, fine control train runs and speeds, complete security and full surveillance, new simple technologies, increasing visibility on and around the tracks, automatized remote control of the train, precise train routing/departure and driveway, high radio data capacity for customers and rail traffic, and a reduction of trackside assets by up to 70%.

The highlights of the CCS-migration strategy by SBB comprise the following steps:
1. Fast and simple migration to ERTMS L1LS; Level 2 pilots
2. Single cab system, ERTMS only
3. From here on big technology jumps

The ambition is driven by cost reduction, capacity increase, and a safety increase. If everything succeeds, a cost saving of CHP 400 million per annum is estimated. This includes both Infrastructure manager and Railway Undertaking.
[3.A, 3.I, 3.J, 3.K, 3.N]

13.2.4 Lessons Learnt

Lessons learnt from presentations given by Swiss representatives on ERTMS, the questionnaire from Arcadis, and the CCS migration workshop in Lille:

- Patchwork (short fast solutions) kill in the long run. It is necessary to clean patchwork up and to use a good architecture of processes and systems.
- Not enough work is being done to create a powerful standard CCS architecture in Europe (like AUTOSAR or IMA). The job is left to the industry who cannot fix this themselves, they just create puzzle pieces and proprietary dependencies.
- The ongoing process of adding new component types in a steady flow, without a standardised architecture and without a prepared lifecycle, is increasing the costs and risks.
- Cheap and fast but bad development means a very bad deployment and very bad lifecycle. But, the cost comparison is 1:10, so it makes sense to use adult and well automated systems and high-quality architectures.
- To get adult systems and architectures means that the market fragmentation must be stopped, and components must be smaller and exchangeable (modular).
- No product developer will make large/good developments for a small market. Large markets resulting from a homogenous interface will attract new players.
- No industrial company will or can do the integration, migration, and architecture job of an infrastructure provider. The Infrastructure Managers must do it themselves, if they can.
- Infrastructure Managers have lost the ability to develop or specify systems themselves. This makes them dependent on Suppliers.
- Since the European Deployment Plan forces many countries to invest a lot of money in a short time, tender volumes and prices go up fast. This is either a threat and an opportunity. A threat when it comes to budget versus offers and an opportunity for new players to enter the market.
- The location of trains will be determined by trains. A continuously improving state of the technology (location by satellite, improved odometry, sensor technology) will result in there not being any facilities in the track in the future. Even further in the future, all ‘objects’ on the tracks can be detected.
- In the short-term it might be useful to equip marshalling and classification yards with a type of trackbound ‘train detection’ for loose wagons.
- It is probably that eventually newcomers will enter the market. This will probably be the companies that are currently working for the major Suppliers as subsupplier of (ICT) technology.
- Only clients can change the market.

Recommendations can be drawn from these Lessons Learnt:

- Considering the new possibilities of digital technology, the real benefits of the introduction of digital CCS-systems (such as ERTMS) can be found at transport nodes. The long track sections between nodes are no longer indicative for the capacity of a corridor. The nodes (large stations) will become the new bottlenecks in capacity. Hence, this is where much is still to be gained. However, current (CCS) regulations prevent substantial improvements. Digital technology allows many safety margins to be generated by software, which is an important difference with the current (analogue) situation. According the current regulations a number of these safety margins must currently be guaranteed by the track layout (overlaps).
- Avoid any choices that are made with a short-term focus and not across the entire system of trackside and onboard
- Only a relatively modest number of people are involved in the modernization of CCS (including ERTMS), while this is of huge influence on the functioning of the rail system and financially huge investments are involved. Therefore, more resources (people and budget) must be made available for the development of CCS (including ERTMS).

- Realise that approximately 70% of the turnover of the current Suppliers can be lost when implementing modular, modern systems, which will be supplier-independent when making use of a universal interface.

[3.A, 3.I, 3.N]

13.3 Germany

DB Netze is the responsible Infrastructure Manager for the German railway network.

13.3.1 Current Situation

The German railway network has recently been equipped with a new traffic management system, the Swiss RCS system. Different signalling systems exist currently on the German railway network. Currently, the Ks speed signalling system is progressively deployed on the network. The LZB ATP-system is end of life due to diminishing industry support, LZB will be replaced by ERTMS.

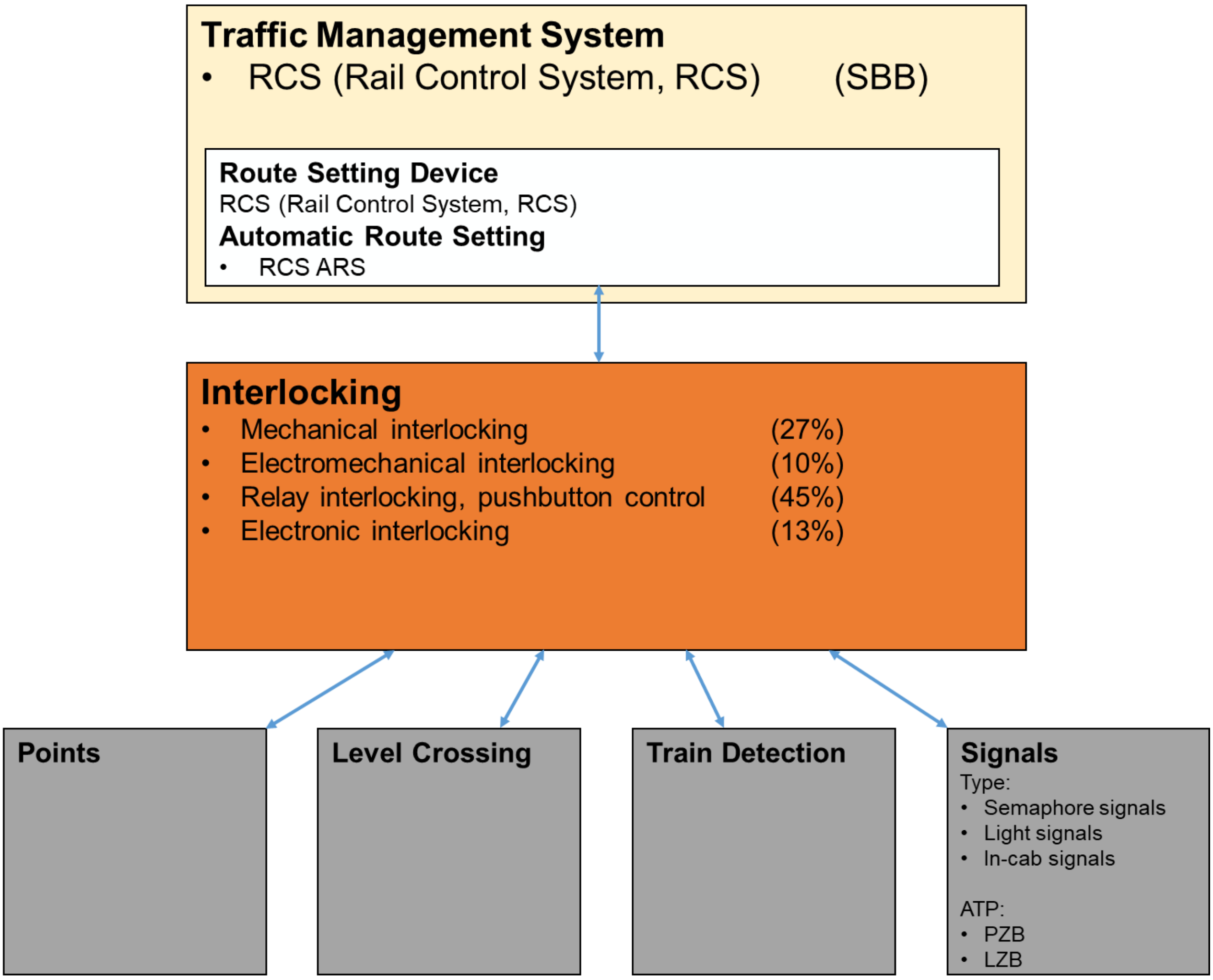

Figure 27: System architecture DB Netze [4.B], [4.D], [4.E], [4.F], [4.J].

Traffic Management Systems (TMS)

The German railway network is controlled from 7 regional control centres. Thus, TMS is highly centralised in Germany.
[4.O]

Route setting device

The German railway network is equipped with multiple different route setting devices. The following systems are, among others, currently installed:

- Vicos (Siemens)
- NetTrac 6613 ARAMIS (Thales)
- NetTrac 6616: Train Describer (Thales)

[4.P, 4.Q]

Automatic route setting

Automatic route setting is present on the German railway network. The following systems are, among others, currently installed:

- NetTrac 6614 (ZL L2000) (Thales)

[4.P]

Expected remaining useful life

The current traffic management system, being replace by RCS, will reach the end of its lifecycle in 2019. [4.F]

Plans to replace/renew

The existing traffic management systems will be replaced with the swiss Rail Control System (RCS) by 2020. The RCS is a traffic management system is developed by the SBB.
The RCS system consists of a core functionality (RCS-Dispo) which can be combined with additional modules. The core functionality presents information from trains and infrastructure. Based on this information forecasts are made to support the conflict resolution. The following modules can be added to the core functionality:

- RCS-ADL Calculates energy-optimised driving profiles
- RCS-HOT Automatic conflict detection and resolution
- RCS-ARS Automatic route Setting
- RCS-ALEA Incident information management

[4.E, 4.F]

Interlocking

The railway network of DB Netze is controlled by over 3,000 interlocking installations. These mainly (82%) consist out of conventional analogue and electronic interlockings [4.B]. The table below gives an overview of the installation base of interlocking types. It has to be kept in mind that a single modern electronic interlocking can control larger parts of the network than an individual mechanical, electromechanical, or relay interlocking.

Interlocking type	Number of installs	Percentage of total
Mechanical interlocking	839	27 %
Electromechanical interlocking	339	10 %
Relay interlocking	1397	45 %
Electronic interlocking	424	13 %
Remainder	91	2 %

Table 7: Overview of interlockings installed on DB Netze railway network [4.B].

Expected remaining useful life

The mechanical, electromechanical, and relay interlockings are to be replaced with electronic interlockings. This will be carried out under the NeuPro, based on EULYNX standards.

Plans to replace/renew
The current strategy of DB Netze is to replace the current interlocking system with electronic interlockings. This replacement is carried out under the “Digitale Schiene Deutschland” programme. This programme incorporates the replacement of interlockings and the rollout of ERTMS. Interlockings will be rolled out according to the EULYNX specification. The EULYNX strategy is to standardise the interfaces between the traffic management, interlocking, and object controllers. DB Netze started this in the NeuPro programme in cooperation with interlocking Suppliers. Currently, the programme has been incorporated in EULYNX.

The new generation of interlockings will communicate digitally with trackside objects, removing the need for an individual cable to each object. A reduction in cables necessary results in a cost reduction.
[4.G, 4.H, 4.J]

Block systems

The German railway network uses a fixed block system equipped with trackside train detection. Train detection is performed both by track circuits and axle counters.
[4.L]

Signalling
The German railway network is equipped with different types of lineside signals. The main types are:

- *H/V-Signals*
  The H/V-Signals are the oldest signals in use on the German railway network. The signals can be implemented both as semaphore signals or colour light aspects. The light signals present the night aspects of the semaphore signals. The H/V signal system is based on speed signalling principles.
- *HI-Signals*
  Within East Germany the HI-signal system was implemented. The HI-signal system uses colour light aspects. The HI signal system is based on both route signalling and speed signalling principles.
- *Ks-Signals*
  After the reunification of Germany, a new common signal system was designed for both East and West Germany. The Ks-signal system is a speed signalling system using colour light signals.

Furthermore, in-cab signalling is used on railway lines equipped with the LZB signalling and ATP-system.
[4.K]

Figure 28: Semaphore signals S-Bahn Hamburg (2015)

Figure 29: Accompanying signal box (2015)

Expected remaining useful life
Since mechanical and electromechanical interlockings are to be replaced, it can be assumed H/V signals, especially the semaphore signals, are at the end of life.

Plans to replace/renew
New signals are mainly of the Ks-Signal system.

Figure 30: New Ks type signals

Automatic Train Protection (ATP)

Two ATP-systems are in use on the German railway network:
- Punktförmige Zugbeinflussing (PZB)
  - *GNT*
    modification to the PZB system to allow tilting trains to operate (Safely) at higher than line speeds.

- Linienzugbeeinflussing (LZB)
  - *Basic LZB system*
    The basic LZB system is no longer supported by its supplier.
  - *CIR ELKE-I extension*
    Improvement of the basic LZB system to allow for shorter blocks and more flexible speed changes.
  - *CIR ELKE-II extension*
    Increase of maximum speeds and gradients, allowing 300 km/h operation on the Cologne-Frankfurt high-speed line.
  - *AFB*

[4.M, 4.R]

Expected remaining useful life
The industry is eliminating old LZB technology approximately between 2027-2030, thus replacement is required.

Plans to replace/renew
As of yet no concrete plans have been defined for the replacement of LZB. Decisions regarding the replacement are pending.

13.3.2 Plans

The German government is currently making steps towards a decision on plans regarding the CCS-system. This will include a decision on the rollout of ERTMS.

Two implementation scenarios are taken into consideration:
- *Scenario A*
  The nationwide rollout of digital technology for railway control centres. ERTMS will be rolled out networkwide. Traffic management and interlockings will be replaced with digital technologies, allowing for a reduction in the number of control centres. During the migration trains will be equipped with both the legacy system and ERTMS.
- *Scenario B*
  ERTMS as a second system next to PZB, thus replacing the LZB system by ERTMS. Minimal investments will be made to ensure compliance with EU regulation. This is driven by the elimination of LZB and EU-mandated ERTMS migration.

The following criteria have been set for the new traffic management and interlockings systems:
- *Safety*
  Equal safety level to existing system
- *Interoperability*
  Simplification of cross border traffic
- *Reliability*
  Reduction in equipment faults
- *Upgrade potential industry*
  Compatibility with future technologies as ATO, 5G communication system, and adoption of new standards
- *Delivery Capacity*
  Ensured availability of the chosen technology, easy replacement on component level.
- *Benefits in use and maintenance*
  Reduction of operating cost by reducing the commissioning time, reduction of maintenance cost by reducing the number of installations.
- *Reduction of investment*
  For example, by reducing the reinvestment cost
- *Capacity increase*
  Improve capacity of network without the need for new tracks, for example with moving block technology.

Currently Scenario A is seen as the most economical scenario, because the need to support both the old and new systems is reduced. Furthermore, new technologies can reduce the number of traffic control centres. This mitigates the effects of a reduced appetite of young people work in traffic control. Furthermore, the number of staff required can be reduced.

The rollout strategy of the specific railway lines will be based on the following considered criteria:
- Traffic criteria:
  - Ten-T corridors
  - Importance of railway line in the traffic network
  - Border crossings
- Infrastructure criteria:
  - Remaining useful lifetime of systems
  - Diversity of interlocking systems
  - ETCS compatibility of current systems
  - Presence of the LZB ATP-system
  - Importance of railway line in infrastructure network

To ensure a fast rollout of ERTMS system in Germany the following is required:
- One baseline, stable for at least 5 years
- Long-term availability of financing
- Acceleration of the certification of train types – certification currently by ERA
- Centrally managed rollout of ERTMS

13.3.3 Ambitions

The ambition of DB Netze is to reduce the cost of the railway infrastructure. The following steps are taken to attain this ambition.

TMS and interlockings are digitalised and further automated. This allows for the reduction in the number of traffic management and interlocking locations (from approximately 3,000 to approximately 200). Furthermore, the number of different technologies used (mechanical, relay, etc.) is reduced to only electronic technology. This allows for easier, more efficient maintenance and a reduction in time needed for training.

Furthermore, DB Netze will change the system architecture of the CCS-system. Currently DB uses proprietary networks to connect the different subsystems in CCS. Moreover, different networks are used to connect different subsystems i.e. TMS and interlocking are connected using a different network compared to interlocking and objects. The new system architecture allows the use of open networks to connect the different subsystems. Furthermore, all subsystems communicate via one network.

The security of the connection is ensured by KISA, this system encrypts the data communication between the subsystems.

The interfaces between the different subsystems will be standardised according to the NeuPro/EULYNX standard. Open standards aid competition, reducing the cost of subsystems.
[4.M]

13.3.4 Lessons Learnt

Cost of on-board migration and upgrading during lifecycle (e.g. to replace an obsolete radio bearer system) can become the showstopper for ETCS deployment and in general for railway digitalization. Modular, interoperable, upgradeable, interchangeable and open system architecture is a mandatory condition to achieve sustainability. In the past, many investment decisions governing ETCS, were based on untested assumptions. A new approach is need based on total cost of ownership over the life cycle.

The following two aspects are crucial for a sustainable modular system:

1. Apply principles of modular system architecture to onboard architecture
2. Make international standards applicable for safety relevant railway systems

[4.T]

13.4 France

SNCF Réseau is the responsible Infrastructure Manager for the French railway network.

13.4.1 Current Situation

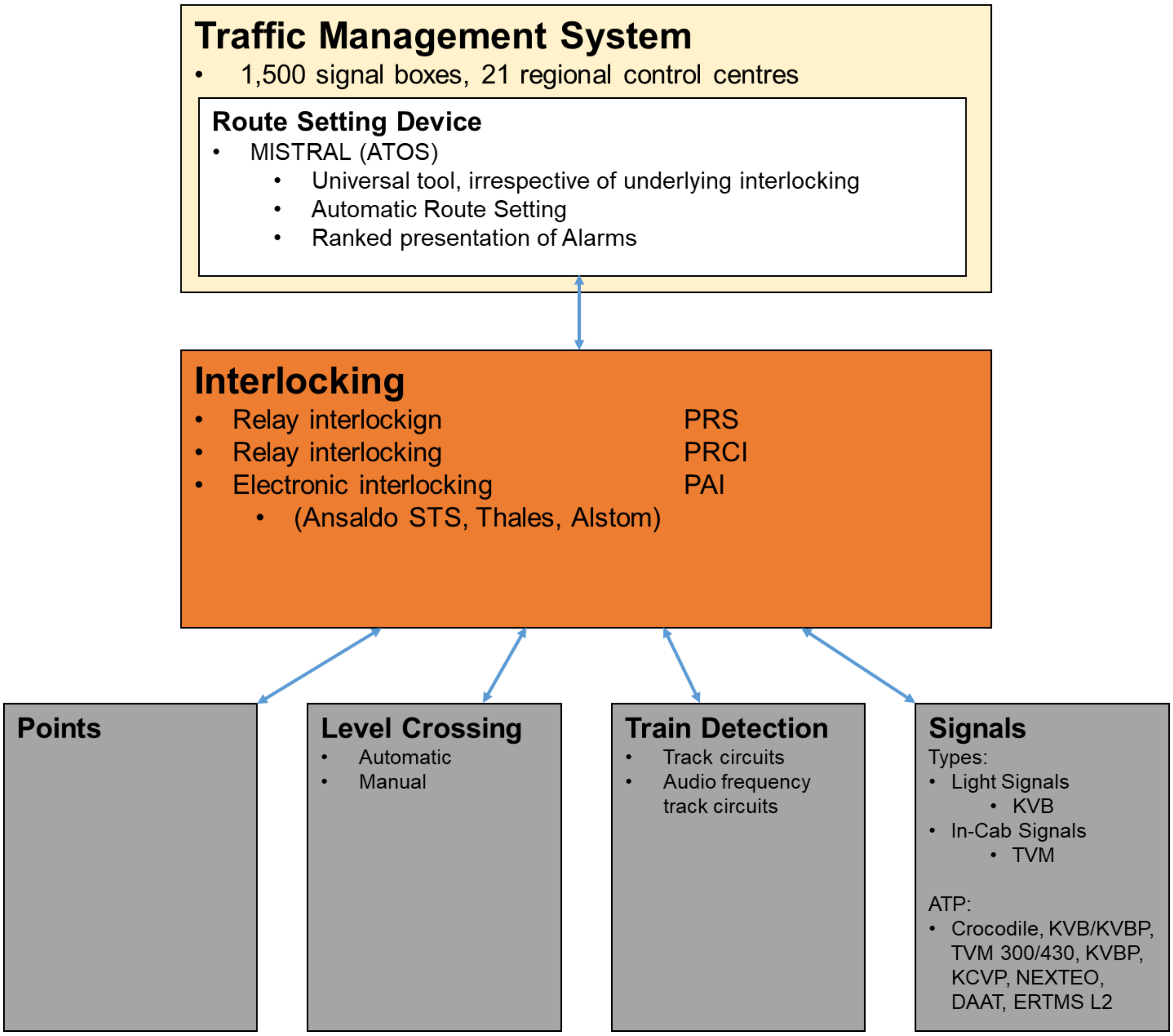

Figure 31: System architecture SNCF [5.A]

<u>**Traffic Management Systems (TMS)**</u>

The majority of the French railway network is currently controlled from 1500 signal boxes, overseen by 21 regional centres for traffic control.
The French Command, Control, and signalling system makes a distinct separation between home signals and intermediate block signals. Home signals are found in station areas with an interlocking. The dispatcher controls the signals. Intermediate block signals are found on the open track and are automatically controlled by an automatic block system.

<u>Route setting device</u>
The main route setting device is MISTRAL, a digital traffic management system. This system is installed in over 50 signal boxes and manages over 15,000 routes of the network, including both conventional and high-speed lines. MISTRAL provides the following functions and advantages over previous systems:
- Universal route setting tool, irrespective of the underlying interlocking technology
- Simplified interventions

- Automatic route setting
- Better responsiveness in the event of a network disruption
- Assistance with diagnosis of problems
- Consolidation and ranking of alarms delivered to the operators
- Improved safety
- Simulator for training of dispatchers

The MISTRAL system has been developed by Atos in 1998 under a framework contract from SNCF. Atos is a large software development company active in the international market.
[5.G, 5.H]

Furthermore, some relay-based route setting devices are still present in the network.

Automatic Route Setting
The MISTRAL system provides automatic route setting.
[5.H]

Expected Remaining Useful Life
The MISTRAL system is currently 20 years old and does not make use of the latest technologies. Therefore, it will be replaced by a new version of MISTRAL, i.e. MISTRAL NG.

Plans to Replace/Renew
France is currently in process of centralising traffic management, going from 1,500 signal boxes and 21 regional control centres to 16 regional control centres and 1 national control centre.

The MISTRAL route setting device will be replaced by a new generation, MISTRAL NG. This is again performed by Atos under a 30-year programme and will see an 8-billion-euro investment. The main objective of MISTRAL NG is to allow for the centralisation of signal boxes. Furthermore, the man-machine-interface will be reviewed and redesigned, making use of the full possibilities of today's computers.
[5.H]

Interlocking

Different interlocking systems are in use on the French railway network, including mechanical interlocking, electromechanical interlocking, relay interlocking, and electronic interlocking. In total 2,200 interlockings are present on the French railway network. The following three generations of interlockings are present:

1. *Poste tout Relais á transit Souple (PRS)*
   A relay interlocking controlled by a relay-based route setting device.
2. *Poste tout Relais á commande informatique (PRCI)*
   A relay-based interlocking controlled by a digital route setting device.
3. *Poste d'Aiguillage Informatique (PAI)*
   An electronic interlocking controlled by a digital route setting device. PAI interlockings can be supplied by three suppliers: Ansaldo STS, Thales, and Alstom.

Currently all new interlockings are PAI interlockings. SNCF has selected the suppliers for PAI based on a tender in which the specifications where set out. Ansaldo STS, Thales, and Alstom all have systems that fulfil the specifications. However, fewer investments than originally planned have been made in PAI interlockings due too poor maintainability. The costs of maintenance and modifications, even for minor modifications, are large.

Expected remaining useful life
It is expected that current interlockings generations are replaced by a new generation of electronic interlockings.

Plans to replace/renew
SNCF Réseau is in the process of replacing mechanical and relay interlockings with electronic interlockings. The Electronic interlockings will be based on a new generation to be developed under the ARGOS innovation partnership.
[5.C]

Block systems

The French railway network uses an automatic fixed block system called Block Automatique Lumineux (BAL). Multi-track railway lines are generally signalled uni-directional, i.e. the line is signalled in only one direction. Track occupation is determined by trackside train detection, which is performed by:
- Track circuits
- Audio frequency track circuits

Signalling
The French signalling system is based on speed signalling principles. The signals are of the colour light aspect type.
[5.E]

Expected remaining useful life
It is unknown what the remaining useful life is of the current block system.

Plans to replace/renew
As of yet no replacement plans are known.

Automatic Train Protection (ATP)

Multiple, different ATP-systems are used on the French railway network. The following types are present or under development:
- *KVB, KVBP*
  These ATP-systems are present on the conventional network and provide automatic train protection using trackside balises. KVBP is an improvement of KVB. With KVBP the balise is placed further from the signal, allowing for more flexibility.
- *TVM 300, TVM430*
  The ATP-system for High-speed railway lines in France and the Channel Tunnel. The TVM system was developed in 1981 and has since been improved continuously.
- *NEXTEO*
  The NEXTEO ATP-system is an in-cab signalling and ATP-system for the RER-E in Paris. KVB is used as a fall-back system for NEXTEO equipped railway lines. This system has been specifically designed for the Paris RER rail network, it is expected that other lines (RER D, B) are also equipped with NEXTEO. ERTMS has not been chosen for the Paris RER network due to the insufficient capacity of ERTMS Level 2.
- *ERTMS Level 2*
  Recently constructed high-speed railway lines are equipped with an ERTMS overlay over conventional ATP and signalling systems (LGV Est, Ansaldo; LGV Sud Europe Atlantique). This allows both trains equipped with Class-B systems and ERTMS to operate on the railway line.
  [5.B, 5.I]

Expected remaining useful life
The decision to implement KVB was back in 1981. The system boasts a high reliability and availability. Obsolescence is not expected before 2030.

TVM, installed in 1981, has a high level of reliability and availability. TVM's expected remaining useful life is until at least 2030.
[5.F]

Plans to replace/renew
As of yet no replacement plans are known for the ATP-system.

13.4.2 Plans

SNCF Réseau is currently in the process of developing a new generation electronic interlocking. SNCF Réseau has launched the Argos innovation partnership in 2018. Argos has three main objectives:
- 15 % reduction in procurement, maintenance and future modernisation cost.
- Reduction of commissioning impact to reduce required possession time
- Improve the performance of the interlocking installation

The Argos partnership consists of SNCF Réseau and 4 industrial partners:
- Alstom
- Ansaldo STS, Systra, and Eiffage
- Siemens, SafeRail, and Est Signalisation (Siemens is a new player on the French signalling market)
- Thales, Engie Ineo and Vossloh

The experts of each industrial partner work together with experts from SNCF Réseau to develop the new generation of electronic interlockings. The goal is to develop a prototype by spring 2019, a selection of partners is made based on the prototype. In 2020 the selected partners finalise their designs. It is expected that significant innovation is required to allow for the easy modification of SIL 4 interlocking system.

The aim is to commission the new generation electronic interlocking by 2023, allowing 30 new interlockings to be commissioned each year by 2030.

The signalling replacement programme has a budget of roughly € 7 billion, of which € 1 billion is available for the Argos partnership.
[5.C]

13.4.3 Ambitions

The introduction of Automatic Train Operation (ATO) on the French railway network is an ambition of SNCF. The following grades of automation (GOA) are considered by SNCF:
- High-Speed Trains — GOA 2
- Commuter Train — GOA 3 and GOA 4
- Cargo Train — GOA 4

The goal of SNCF is to implement ATO technology using an ATO standard box. The ATO standard box contains the technical subsystems required for ATO. The goal is to make the ATO standard box plug-and-play for new and existing trains. Furthermore, the standard will be an open standard removing the risk of vendor lock-in. The ATO standard box is connected to the train using a train specific interface.
[5.D]

13.4.4 Lessons Learnt

Regarding ERTMS corridors, the following lessons are learned:
- Due to lack of experience with ERTMS the tender took longer than expected
- Insufficient expertise on the change from legacy systems to ERTMS caused misunderstanding between the RFF and the supplier, this caused significant delays.
- STI modifications created some delays
- The declination of so called “off-the-shelf” products almost led to specialised, more expensive, products due to:
  - Complex specifications and requirements
  - Development of interfaces with legacy signalling technologies
  - Large number of different signalling cases on the French railway network
- Scarcity of human and technical resources caused problems in the planning
- ERTMS knowledge and expertise was slow to be diffused among SNCF installers and maintainers
- Increasing costs of tests on a network in operation

[5.F]

13.5 The Netherlands

ProRail is the responsible Infrastructure Manager for the Dutch railway network.

13.5.1 Current Situation

In general, the CCS-system of ProRail functions quite well. ProRail is able to run a large number of trains per track (one of the highest in the world) in a mixed traffic situation with the use of the current traffic management system, existing interlockings, and the speed signalling system NS '54. The combination of the ATB-EG and ATB vv ATP-systems ensures meeting high safety standards.
[6.A, 6.B, 6.C, 6.G, 6.H]

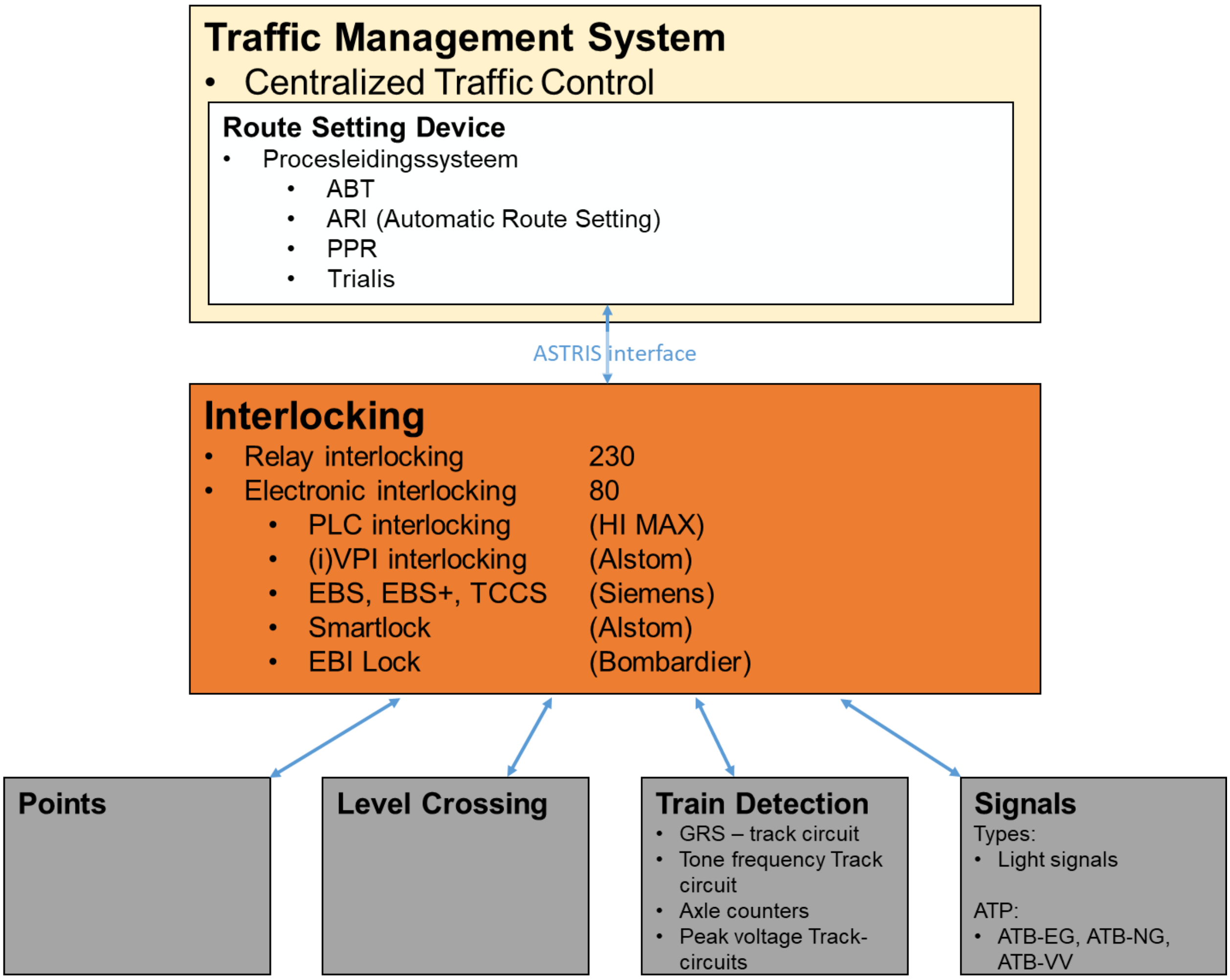

Figure 32: System architecture ProRail. [6.E]

Traffic Management Systems (TMS)

ProRail has developed her entire TMS-system in-house with help of non-traditional rail industry suppliers. . Furthermore, a distinct separation is made between the management layer and the safety layer. The ASTRIS interface allows for uniform presentation of information originating from the interlockings. [6.N]

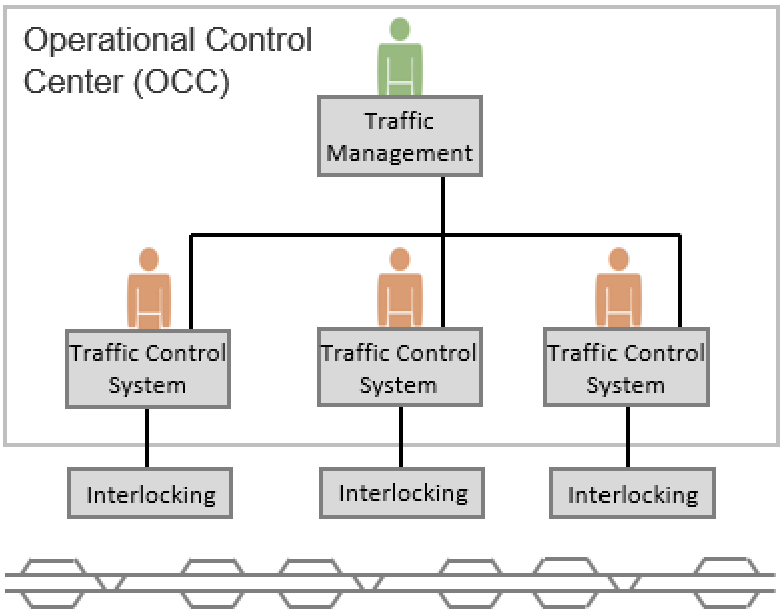

Figure 33: Centralised Traffic Control (CTC) with additional separated Traffic management.

ProRail has centralised all in traffic management in 13 (Centralised Traffic Control) CTC-centres. From here dispatchers control all main corridors and tracks in the Netherlands. There is one additional national traffic management centre to supervise traffic regulation and decides about measures to be taken in case of disturbances, incidents or accidents with a (protentional) superregional impact. The national traffic management centre does not make use of dispatchers.

Expected remaining useful life
The expected life of the current TMS is “endless” because it is running on COTS hardware and the software is developed in an open market.

Interlocking

Relay Interlocking
The Dutch railway network is equipped with 230 relay interlocking installations based on B-relays.

Electronic interlocking
The Dutch railway network is equipped with 80 electronic interlocking installations.
- Alstom VPI
- Hi Max PLC Interlocking
- Siemens, EBS, EBS+, TCSS
- Alstom Smartlock
- Bombardier EBI lock

Expected remaining useful life
Based on ‘end of life’, the last B-relay interlocking will be replaced by approximately 2065 – 2070, since the last new-built B-relay interlocking was delivered in 2016 / 2018 and lifespan of the equipment is 50 years. The first generation of ‘digital’ interlocking, i.e. EBS (Siemens), is close to the end of the technical life-cycle and will be replaced sooner since Siemens announced to no longer support this (first) generation of EBS.

Plans to replace/renew
The strategy of ProRail is to eventually replace all B-relay interlocking by modern digital based interlockings. In 2017 ProRail started a programme called "Programma Vervanging Treinbeveiliging". This programme concerns the replacement of relay-based interlockings by modern open-system interlockings. The main argument for this operation is the end of life of signal posts, cables, and the interlockings themselves. Most of the replaced components are aged 50 – 60 years.
[6.A, 6.B, 6.C]

Signalling
The Dutch railway network is equipped with signalling systems based on speed signalling principles with lineside light aspect signals (NS '54).
On the High -Speed Line South and Betuweroute (dedicated freight line) ERTMS L2 is installed.

Block systems

The Dutch railway network is equipped with a fixed block system with trackside train detection. Train detection systems in use:
- AC Track circuits (former General Railway Signal Company)
- Axle counters (Thales, Siemens)
- JADE (Jointless Audio-frequency DEtection) (Alstom)

Plans to replace/renew
On tracks where ERTMS is deployed, track circuits are replaced by axle counters.
[6.A, 6.B, 6.C]

Automatic Train Protection (ATP)

All main tracks in the Netherlands are equipped with ATP. The most common used system is ATB-EG (Eerste Generatie = first generation), a system developed in the 1960s. The implementation programme took almost 40 years. Over the years a new variant of this ATP-system has been developed. ATB-NG (Nieuwe Generatie = new generation) . ATB-NG can more or less be compared to ETCS L1.
ATB vv (verbeterde versie = improved version) was developed as an addition to ATB-EG to fill the safety gap in ATB-EG (no ATP brake reaction of speed below 40 km/h, which makes it possible to pass a signal at low speed without the ATP-system reacting).
[6.A, 6.B, 6.C]

Expected remaining useful life
Further development of ATB-NG was stopped because of agreements related to ERTMS.

13.5.2 Plans

Where implementation of ETCS is planned, the philosophy of ProRail is to have a contract covering the whole life-cycle for the complete safety layer of the CCS system with "open engineering" and maintenance in competition. The development is foreseen in close relation with the supplier(s) because none of the stakeholders involved is able to design and build a well-functioning CCS-system based on ERTMS by themselves. Not the suppliers, not the engineering firms, not the Infrastructure Managers have the knowledge, the experience and the amount of (qualified) staff to achieve this.

The foreseen risks however are industrial partners have no incentive to go for a co-creation concept before a large ERTMS implementation contract. Two reasons mentioned:

1. The co-creation scenario is not beneficial to suppliers. According to European legislation, participating in collaboration with the Infrastructure Manager will exclude them from other biddings due to an advantage in knowledge in relation to the competitors.

2. Since suppliers cannot oversee the consequences of future adaptions / configurations, they are not keen in having a long-term relationship with built-in guarantees from the start. For them it is more beneficial and less risky to stick to 'design and build' and tender again if (re)configuration is needed. [6.G]

Concerning the implementation of ERMTS the Dutch government made two major decisions:
- Only part of the infrastructure will be equipped with ETCS trackside (level 2);
- The migration starts with converting the rolling stock first.

Although several billion euros are labelled to implementation of ERTMS, the ERTMS programme is competing with other investments for funding. A recent transfer of 250 million Euro from the ERTMS programme to a project for necessary improvements of Schiphol Amsterdam International airport station indicates ERTMS is not top priority.
[6.I]

13.5.3 Ambitions

Traffic Management Systems
ProRail plans to further centralise traffic management, by reducing the number of 13 CTC-centres today to eventually 5. For this there is no timeframe yet.

Automatic Train Operation
ProRail has indicated an ambition to introduce ATO (GoA2) on the Dutch Railway network.

This year (2018) ProRail starts two pilots with Automatic Train Operation (ATO), in both cases Grades of Automation (GoA) 2.
[6.G, 6.H]

13.5.4 Lessons Learnt

It is possible to develop, build and maintain high quality TMS-systems with the help of non-traditional railway industry suppliers (especially ICT-firms).

13.6 Denmark

Banedanmark is the responsible Infrastructure Manager for the Danish railway network.

13.6.1 Current Situation

Banedanmark, the state-owned rail network Infrastructure Manager in Denmark has committed to an ambitious and radical planned upgrade of its total main line network. In a first ever decision by a national Infrastructure Manager to modernise its total network (currently amounting to more than 3245 route-km, 307 stations and 750 level crossings) the vision is to see this modernisation completed by around 2024. This decision was facilitated by the Danish Parliament in January 2009.
[7.L]

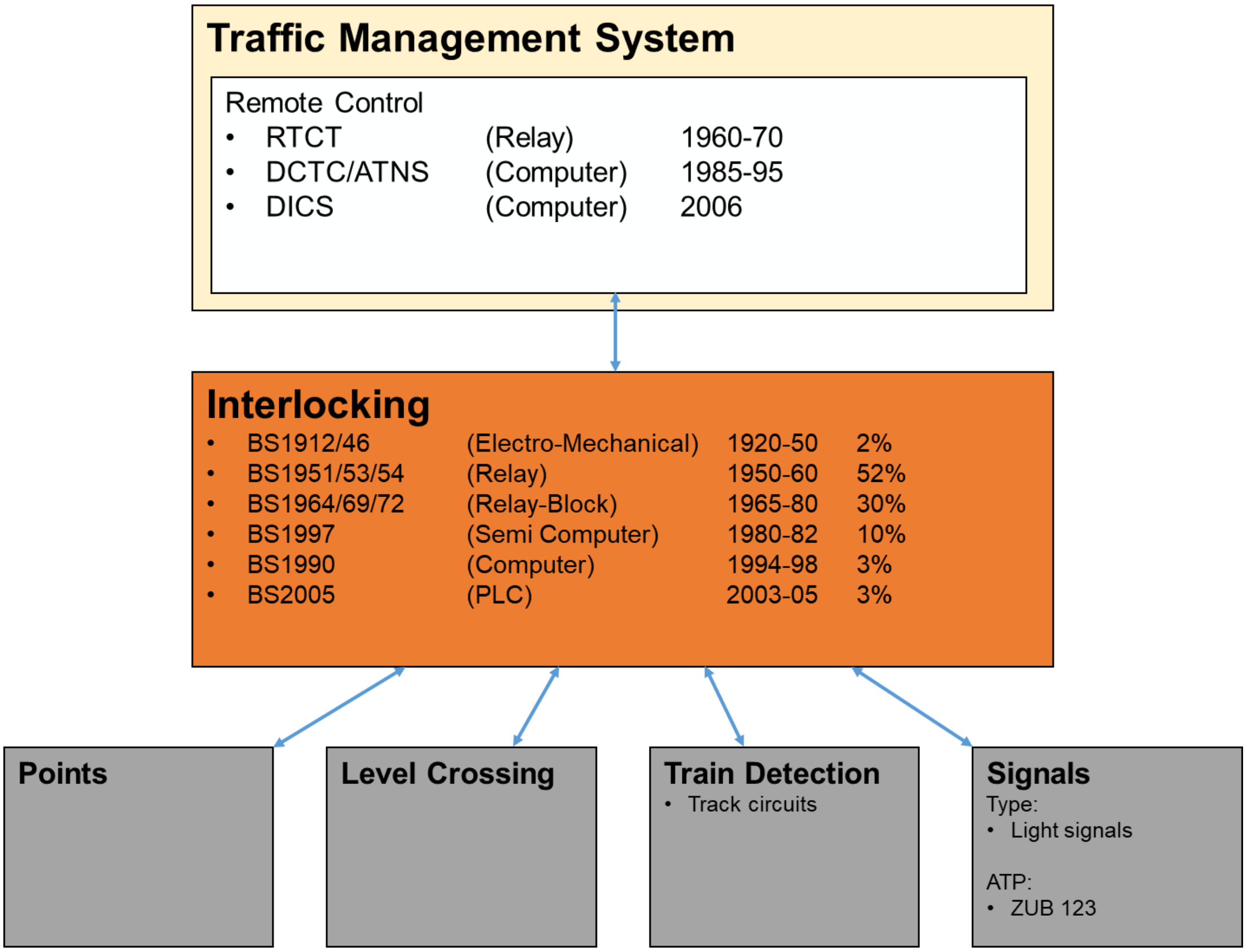

Figure 34: System architecture Banedanmark. [7.B], [7.C].

<u>Traffic Management Systems (TMS)</u>

<u>Route setting device</u>
RTCT: Relay pushbutton
DCTC/ATNS: computer-based
DICS: computer-based

<u>Automatic route setting</u>
Automatic route setting is present on the Danish railway network.

Expected remaining useful life

TMS	Type	Year installed
RTCT	Relay	1960-1970
DCTC/ATNS	Computer	1985-1995
DICS	Computer	2006

Table 8: Overview of current TMS used in Denmark [7.B], [7.C].

The table above provides an overview of the current Banedanmark Train Management Systems. Most of these systems have been built over 20 years ago and are rapidly approaching the end of life their useful life.

Plans to replace/renew
The current strategy of Banedanmark it to completely renew their traffic management system. Full renewal reduces the cost of implementation due to the scale of the project and competition. Furthermore, the new traffic control will be further centralised and automated, resulting in a reduction of staff.
[7.B]

Interlocking

The following table summarises the interlockings currently present on the Danish railway network. For each interlocking system the type, installation year, and approximate coverage is indicated.

Interlocking	Type	Year installed	Coverage
BS1912/46	Electro-mechanical	1920-1950	2%
BS1951/53/54	Relay	1950-1960	52%
BS1964/69/72	Relay-Block	1965-1980	30%
BS1997	Semi-Computer	1980-1982	10%
BS1990	Computer	1994-1998	3%
BS2005	PLC	2003-2005	3%

Table 9: Overview of Danish interlockings [7.B], [7.C].

The majority of the interlockings within Denmark are installed over 50-years ago. These interlockings are based on electromechanical and relay technology. Only 16% of interlockings are based on modern (semi)-computer technology.
[7.B]

Expected remaining useful life
Within 15 years, 60% of the interlockings installed on the Danish railway network will be end of life.
[7.B]

Plans to replace/renew
The current strategy of Banedanmark is the full rollout of ERTMS on the Danish mainline railway network, including the complete renewal of the interlockings. The Danish mainline railway network is split up in 2 geographical areas, East and West. Alstom is responsible for the eastern area. Thales is responsible for the western area.

Alstom has equipped the eastern part of the Danish railway network with the Smartlock 400 GP + Smart IO electronic interlocking system. The RBC-system is integrated in the interlocking hardware.

Thales has equipped the western part of the Danish railway network with 16 LockTrac electronic interlocking systems.
[7.G, 7.H]

Block systems

Fixed block system with trackside train detection:
- Track circuits (100%)

Signalling
The Danish signalling system uses both speed signalling principals and route signalling principles. The signals are colour light aspects.
[7.E]

Expected remaining useful life
The current block system is end of life.

Plans to replace/renew
The current strategy of Banedanmark to completely renew the CCS-system includes the replacement of the block system. ERTMS Level 2 in-cab signalling provides the new signalling system on the Danish railway network.

Track circuits are replaced by axle counters. Alstom has equipped the eastern part of the Danish railway network with the Frauscher FAdC axle counting system and 3,000 Frauscher RSR123 wheel sensors. Thales has equipped the western part of the Danish railway network with circa 3,500 axle counters.
[7.I, 7.J]

Automatic Train Protection (ATP)

The current ATP-system is Danish ATC, also known as ZUB 123.

Expected remaining useful life
The current ATP-system is end of life in 2020.
[7.B]

Plans to replace/renew
Complete renewal: ERTMS Level 2 baseline 3 replaces the current Danish ATP-system.

Banedanmark has chosen for ERTMS baseline 3, as managed by ERA. The main reason for this is the backwards compatibility of trains fitted with baseline 3, i.e. trains with baseline 3 can run on baseline 2 infrastructure, while trains with baseline 2 cannot run on baseline 3 infrastructure. Thus, giving BDK more flexibility where their trains can travel.

Other reasons for baseline 3 are:
- Bigger nodes/stations
- Radio capacity/ETCS over GPRS/EDGE
- Cold movement detection-SoM
- Braking Curves
- Online key management
- Backwards compatibility to 2.3.0d trackside (first Swedish lines)
- Finishing test specifications baseline 3 (certification of Onboard)
- SP will be maturing part of the ERTMS specifications

[7.B]

Command Control and Signalling Replacement and ERTMS Rollout Strategy

Banedanmark is the owner of DK railway infrastructure responsible for replacement, maintenance, and operation of the Danish railways. In 2006 Banedanmark concluded that 60% of all signalling equipment would exceed absolute final service life within 21 years (2027), life of DK-ATC expires in 2020, and it would take up to 10-12 years to renew all signalling assets. The age of the systems on the Danish railway network already results in more breakdowns, currently, half of the train delays in Denmark are ascribed to signalling failures.

The same year, the Danish parliament decided that a total renewal strategy was the best option, work began on a detailed plan and budget for total replacement. Early 2009 the final political decision was made and in February of the same year procurement began and finished in 2012. In 2012 the contracts have been awarded.

The involvement of the Danish government highlights the importance of the Government as a stakeholder in the digitalisation of CCS. Furthermore, the delay in the signalling programme has led to the Danish Government to revise priority for rail investments, e.g. prioritising electrification in the planning.
[7.C, 7.D]

Reasons for total renewal

- *Better prices*
  By making large project available to a large market Banedanmark hoped to get products and services at a discount. The project was tendered on the global market to increase competition. Furthermore, the renewal project was divided into large chunks to let the same company do large parts of the railway to make them work faster as they went due to the learning curve effect (models of the learning curve effect and the closely related experience curve effect express the relationship between equation and efficiency or between efficiency gains and investment in the effort).
- *Savings on operations and uniform safety*
  By procuring a new system to replace the failing one Denmark hoped to cut maintenance costs. No longer would delays have to be fixed fast and at inflated prices. With uniformity of safety across the network simpler and safer operational rules could be implemented, this would also mean fewer traffic management sites and a reduction in staff, cutting costs further.
- *Quantum leap in technology*
  The introduction of ERTMS will result in standard components, redundancy of central components, and higher availability. Furthermore, Banedanmark will also need fewer safety approvals and fewer interfaces.

Contract strategy

The full ERTMS rollout is tendered out to market into five tenders. The tenders prescribed Design, Build, and Maintain contracts. The first two tenders covered main and regional lines, with the network divided into two lots: East and West. The third tender covered the installation for ETCS onboard equipment for main and regional rolling stock. The fourth tender covered the rollout of GSM-R. Finally, a fifth tender covered the S-bane. All these contracts were awarded within its target budget.

Collaboration philosophy

Collaboration with the market plays a big part in de Banedanmark strategy. This is to mitigate risks and reduce disputes. By joint design, co-location, collaboration agreements, and shared risk assessments BDK hopes to reduce possible risks significantly. The following tools and ideas are implemented to collaborate with the market:
- Relocated together
- Joint risk work
- Joint design meetings
- Systematic approach: collaboration agreements
- Evaluate the common work, evaluate each other, management feedback
- Joint change management, joint contract management
- Joint steerco's
- Clear mandates
- Clear structures and processes

However, this strategy poses a risk as it might make roles and responsibilities unclear. This might result in neither party wanting to take responsibility when possible problems arise. [7.B, 7.C, 7.D]

13.6.2 Plans

Banedanmark is implementing their future strategy now with a full replacement of the CCS-system and the full rollout of ERTMS.

13.6.3 Ambitions

The full ERTMS replacement plan helps Banedanmark to implement the ambition of increasing train frequencies on the railway network.

Furthermore, the Traffic Management System will be further centralised into two Centralised Traffic Control Centres.

13.6.4 Lessons Learnt

The following lessons learnt have been published by Banedanmark:

- *Integration is key*
  The contracts for the rollout of the new CCS and ERTMS have been split up in two geographical infrastructure contracts and an onboard contract. Thus, Banedanmark has taken the role of System Integrator to ensure whole system thinking.
- *Lab testing*
  Lab testing allowed for off-site system integration test, this reduced on-site train free periods required for tests.
- Connecting IT and legacy systems is a challenge, especially in the field of cybersecurity.
- The new digital technologies require a shift in skills and processes for Banedanmark.

13.7 Belgium

Infrabel is the responsible Infrastructure Manager for the Belgium railway network.

13.7.1 Current Situation

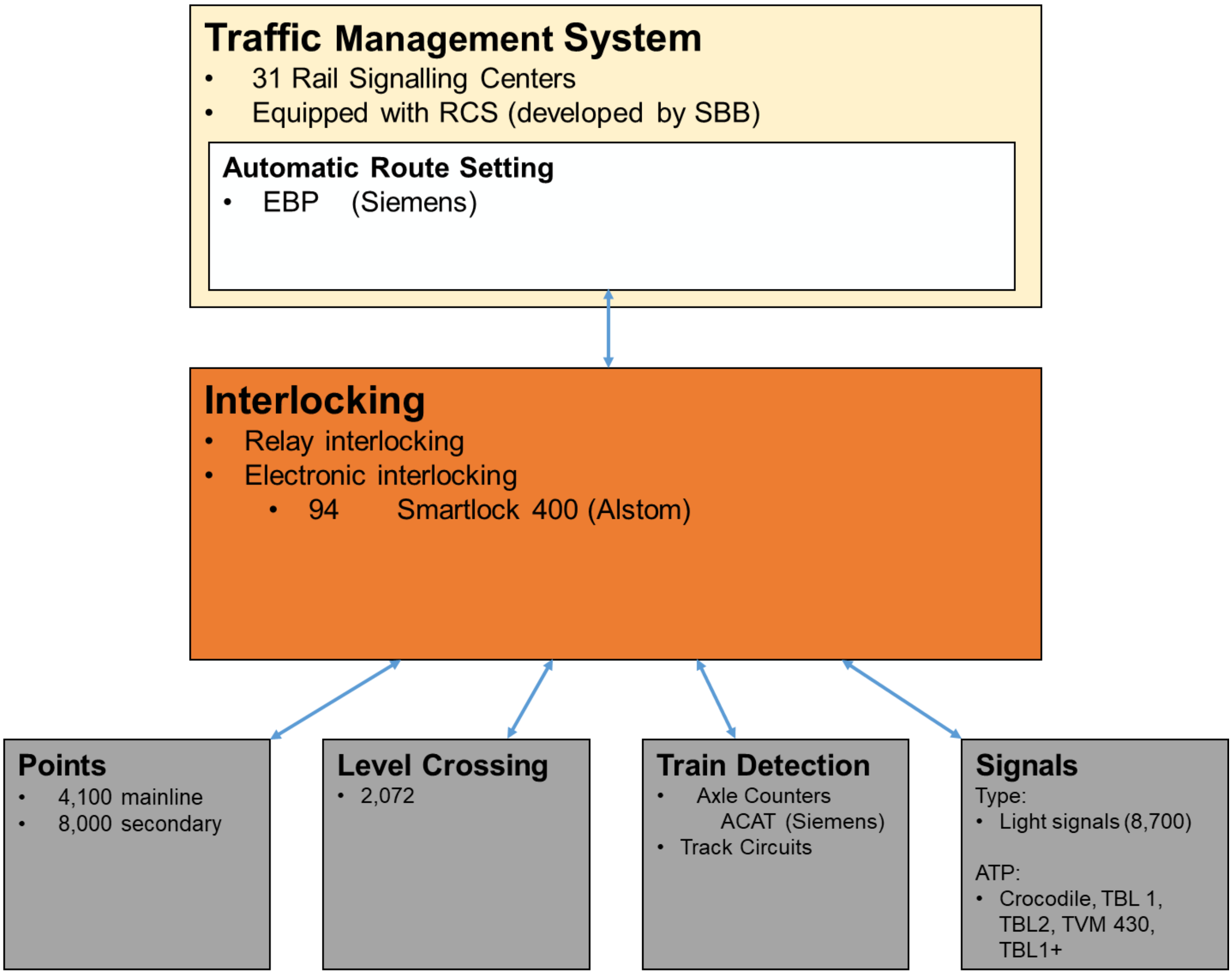

Figure 35: System architecture Infrabel. [8.B], [8.C]

Traffic Management Systems (TMS)

Infrabel has divided its railways in 31 regions. Every region has its own Rail Signalling Centre. Infrabel opted for the Swiss RCS (Rail Control System). With the help of the Swiss SBB the RCS was launched in late 2013. SBB drew on its own system and experience to support Infrabel where required. Mid-November 2016 the implementation of RCS was successfully completed. Infrabel now uses RCS to manage all trains that operate across the Belgium rail network.
[3.L]

Route setting device
Automatic Route Setting by means of the RCS-system.

Expected remaining useful life
Our contact at the SBB cannot share information regarding expected remaining useful life, because this is relevant for public procurements or part of contracts.

Plans to replace/renew
The Belgian traffic management system will be further centralised from 31 signal boxes to 10 rail operating centres (ROC). The ROCs use the Swiss RCS traffic management system. This system allows the traffic managers to work more proactively.
[8.B]

Interlocking

Two types of interlockings are present on the Belgian railway network, relay interlocks and electronic interlockings. The electronic interlockings are of the Smartlock 400 type, supplied by Alstom.

Expected remaining useful life
The relay interlockings do not support the further centralisation of the traffic management system into 31 Rail Signalling Centres. Because of this incompatibility the relay interlockings are at the end of their useful life.

Plans to replace/renew
The remaining relay interlockings will be replaced by modern electronic interlockings, under the Belgian Railway Infrastructure Objectives (BRIO) programme. The electronic interlockings support the implementation of the New Traffic Management System. Furthermore, it allows the implementation of ERTMS Level 2 in the future.

The contract for the replacement of the interlockings and traffic management system is a framework contract. The framework contract has been awarded to the BELGOSIGNAL (BSA) consortium in 2007. The BSA consortium consists of Alstom and Siemens.

Alstom is contracted for the installation and maintenance of the technical shelters, the Smartlock 400 interlockings, and the object controllers.

Siemens is contracted for the installation and maintenance of the EBP route setting device and ACAT axle counters. The EBP system runs on Stratus Computers.
[8.C, 8.F]

Block systems

The Belgian railway network is equipped with a fixed block signalling system. Track occupation is determined by:
- Track circuits, among which JADE track circuits
- Axle counters, among which ACAT (Siemens)

[8.F, 8.H]

Signalling
The Belgian signalling system is based on speed signalling principles. The signals are a combination of colour light aspects and position light aspects.
[8.I]

Expected remaining useful life
Automatic block systems build upon relays are end of life.
[8.C]

Plans to replace/renew

The block systems based upon relays are replaced with block systems based on electronic technology.
[8.C]

Automatic Train Protection (ATP)

The following ATP-systems are in use on the Belgian railway network:
- Crocodile
- TBL 1, TBL 1+
- TBL 2
- TVM 430

Expected remaining useful life
Since a decision is made to implement ERTMS on the entire Belgium network, obsolescence is no issue any longer.

Plans to replace/renew
Crocodile and TBL 1 will be replace with TBL 1+. Thereafter, TBL 1+ will be transformed to ERTMS Level 1.

13.7.2 Plans

The ERTMS implementation of Infrabel consists of four phases.

- *Phase 1*
  In phase one the implementation of TBL1+ is accelerated. TBL1+ is an automatic train protection system that uses eurobalises. The system can be transformed to an ERTMS Level 1 system with minor adjustments.
- *Phase 2 (2015-2022)*
  In this phase the TBL1+ system is transformed to an ETCS system.
- *Phase 3 (2025)*
  From 2025 onwards ETCS will be the technical standards for operators in Belgium. All trains must be equipped with ETCS.
  ETCS has, so far, been installed on:
  - The Brussels North – Leuven Line;
  - The Schaerbeek – Mechelen line;
  - The Diabolo rail link (to and from Brussels National Airport);
  - The Mechelen – Leuven line, between Hever and Wijgmaal.
- *Phase 4 (2030-2035)*
  In this phase the network will be transformed form ERTMS Level 1 to a homogenous ERTMS Level 2.

Improvements in safety level and punctuality are the main drivers for the implementation of the new TMS, new Interlocking, and ERTMS.

With the new traffic management Infrabel is able to introduce DAS (Driver Advisory Systems) and ATO. [8.B, 8.C, 8.E, 8.K]

13.7.3 Ambitions

ERTMS Level 1 will be further upgraded to ERTMS Level 2 from 2030-2035.

13.7.4 Lessons Learnt

No specific lessons learnt were identified during this research.

13.8 Italy

Rete Ferroviaria Italiana (RFI) is the responsible Infrastructure Manager for the Italian railway network.

13.8.1 Current Situation

The RFI currently manages over 16,000 km network and over 24,000 km of track, of which 700 km is equipped with ERTMS.
[9.C, 9.G]

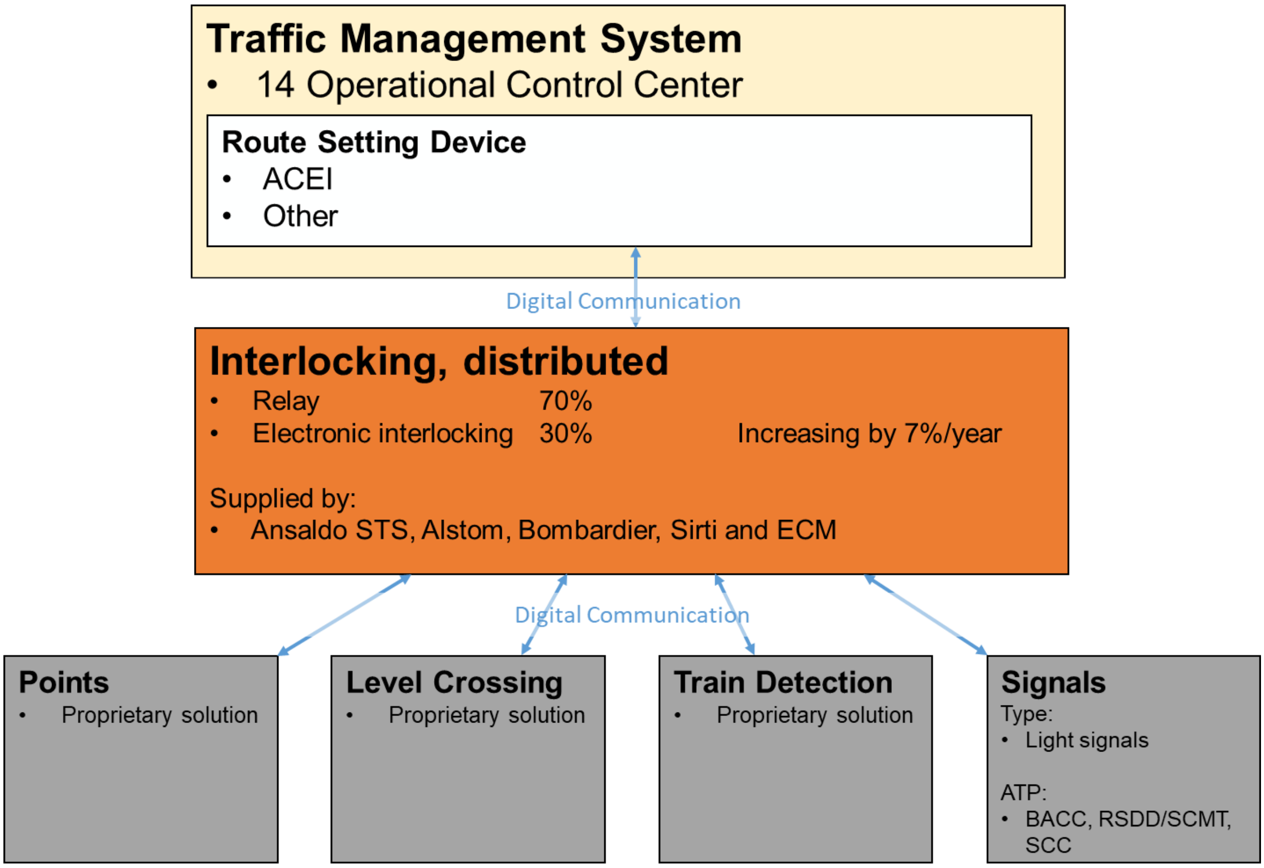

Figure 36: System architecture RFI [9.G]

<u>Traffic Management Systems (TMS)</u>

The RFI network is controlled from 14 local/regional Operational Control Centres (CTC) and one national traffic management centre for integrated management of rail traffic. Some rural lines are controlled based only on mutual communication between station managers or supervised by a centralised dispatcher stationed in one of the 14 CTC-centres.

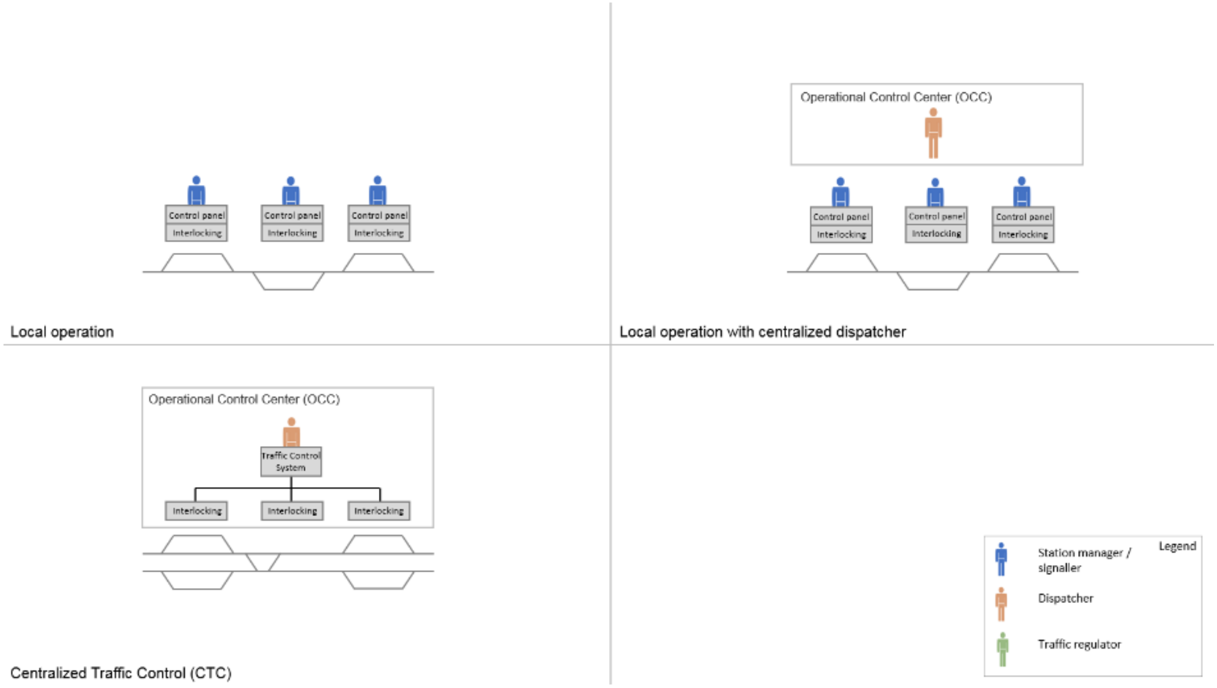

Figure 37: Types of traffic control centres maintained by the RFI.

<u>Route setting device</u>
Different route setting devices are used on the Italian railway network, amongst which:
- ACEI (relay-based)
- Computer-based (type unknown).

<u>Expected remaining useful life</u>
No specific information provided.

<u>Plans to replace/renew</u>
The ACEI (pushbutton) route setting device and other existing traffic management systems will be replaced in the next 20 years.

<u>Interlocking</u>

The railways in Italy are mostly covered by relay interlocking (approximately 70%). The other 30% is electronic interlocking. The following systems are in in use:
- Ansaldo STS
- Alstom Smartlock 400
- Bombadier
- Sirti ACC-M
- ECM (Elettromeccanica CM), SCMT, SSC, HMR9 (New ERTMS-compatible computer-based interlocking)

[9.G]

<u>Expected remaining useful life</u>
Relay interlockings are reaching the end of their useful life.

<u>Plans to replace/renew</u>
Relay interlockings are being phased out in favour of electronic interlockings. The latest plans by the RFI anticipate that all relay interlockings will be replaced in 10 years.
[9.G]

Block systems

Fixed block system equipped with trackside train detection by means of:
- Track circuits
- Axle counters
- Audio frequency track circuits (high-speed lines)
- Treadles (level crossings)

Signalling
The Italian signalling system is based on speed signalling principles:
- Lineside signals
- Cab signalling (high-speed lines)

Expected remaining useful life
No specific information provided.

Plans to replace/renew
No specific information provided.

Automatic Train Protection (ATP)

In Italy three families of ATP-systems are used:
1. RSx Codici
2. SCMT / SSC
3. ETCS

RSx Codici
- RS4 Codici (Ripetizione Segnali a 4 codici) cab signaling system
- RS9 Codici (Blocco Automatico a Correnti Codificate, BACC) RS9 Codici is an extension of RS4 Codici which also continuously monitors the train speed and computes braking curves according to the train's length, mass, and braking ability.

SCMT / SSC
The Italian Rail Traffic Management System Sistema Controllo Marcia Treno (SCMT) is the most common ATP-system used on the majority of the Italian Railway Network.

Some of the CTC-lines have an additional application: SSC (Sistema Supporto Condotta). This is purely an informational drive aid system. Its function is to provide a comprehensive set of visual helps to the driver, about block signalling, speed limits and temporary limitations. The system is rated for speeds up to 150 km/h, thus making it useful on most of the Italian network.

ETCS
More than 700 kilometres of the in total approximately 1,000 kilometres of high-speed line is equipped with ETCS Level 2.
[9.A, 9.B, 9.F]

13.8.2 Plans

Regional programme of RFI
The “Regional” programme of RFI, aiming to significantly reduce the costs of the operation and maintenance of regional lines, belonging to both RFI and to second Infrastructure Managers in Italy.
To achieve this a combination of innovative ideas is not only proposed, but already tested. Such as:
- ERTMS Level 3 tested on the line Avezzano – Roccasecca in central Italy
- Use of virtual balises by satellite technology (Galileo)
- Use of public telecom as bearer for Euroradio as an alternative for GSM-R.

[9.B]

13.8.3 Ambitions

Ambitions of the railways in terms of functionality and architectures for their future CCS-systems
RFI is working towards ERTMS Level 2 systemwide. To aid in this transition RFI has 2 scenarios.

In the first scenario, quick migration, RFI would line their whole fleet with ETCS. After the trains are able to communicate with ERTMS the decommissioning of Class B systems can begin. This scenario would lower the operational cost as there is no longer a need to have or manage light signals.
Advantages of this scenario are the economical convenience for Infrastructure Managers as cost of ownership decreases interoperability and innovation maximising performances for all CCS not only for ETCS.

The second scenario means a slower migration to ERTMS. With lower investment cost up front not all of the fleet would be fitted with ETCS. This in turn means that the legacy systems must be maintained as not all trains would benefit from the implantation of ERTMS.
No economical convenience for Infrastructure Managers is gained or even increase cost due to fitting the infrastructure with two systems on the same track.
[9.B, 9.C, 9.F]

To significantly reduce the cost of low traffic regional lines, RFI proposes the implementation of ERTMS Level 3. Furthermore, innovations such as virtual balises and the use of public telecom as bearer of EURORADIO can further reduce costs.

13.8.4 Lessons Learnt

No specific lessons learnt were identified during this research.

13.9 Norway

Bane NOR is the responsible Infrastructure Manager for the Norwegian railway network.

13.9.1 Current Situation

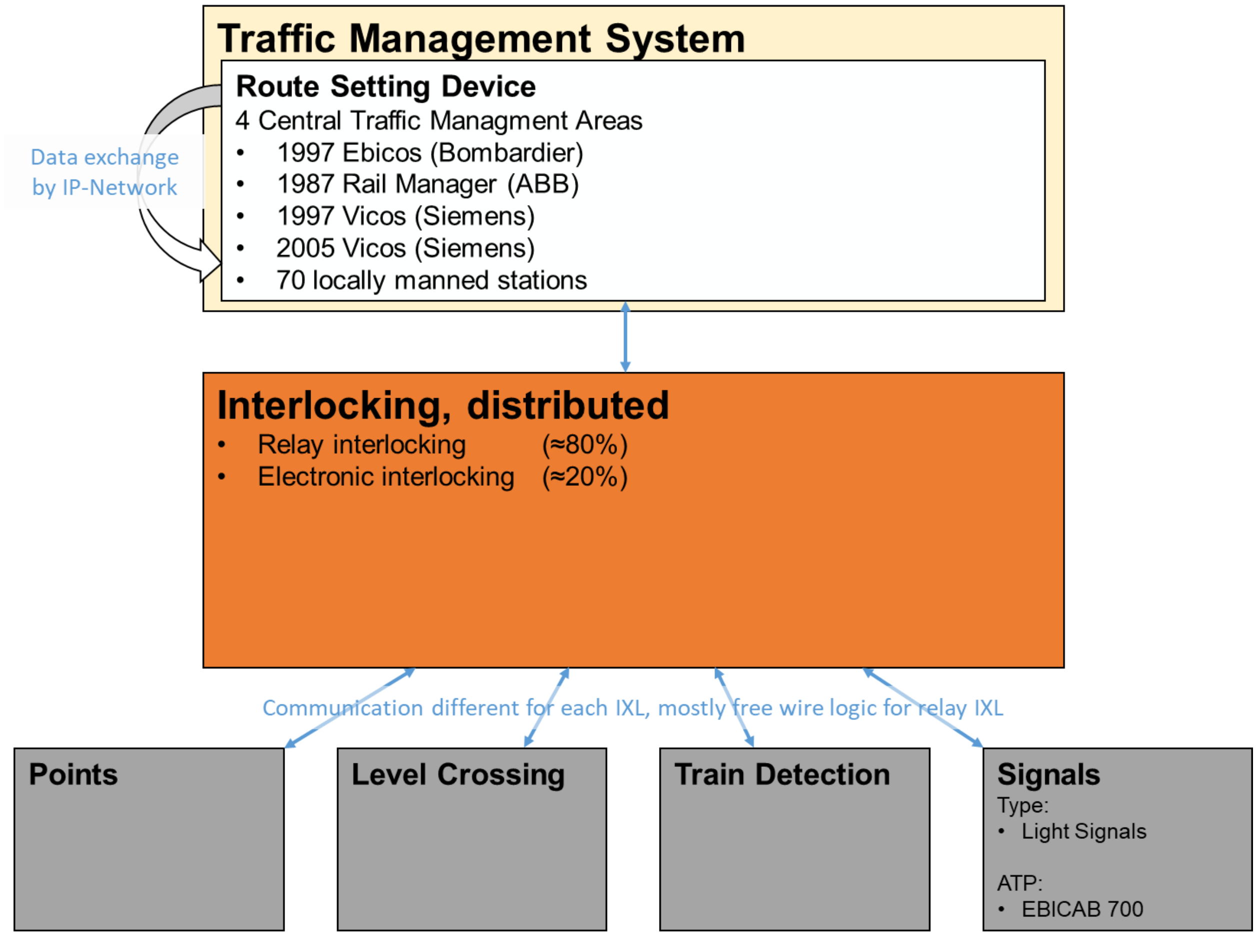

Figure 38: System architecture Bane NOR, [10.A].

Traffic Management Systems (TMS)

There are 4 CTC-centres and around 70 locally manned stations.

TMS	Supplier	Year installed
Ebicos	Bombardier	1977
Rail Manager	ABB	1987
Vicos	Siemens	1997
Vicos	Siemens	2005

Table 10: Traffic management systems in Switzerland [10.A]

The TMS are separated but some of them can communicate with each other by either IP or fixed network communication.

Expected remaining useful life
Most TMS are at end of life and need to be replaced. One new system for the complete network will provide one common interface for operation and a much higher grade of automation. This will provide possibilities for more efficient use of staff.

Plans to replace/renew
Norway has laid out a strategy to replace TMS in 2005. The new TMS is planned to be taken into operation from 2019 forwards and will at the end control the complete railway networks ERTMS L2 signalling systems. The new TMS contract has been awarded to Thales, including maintenance for up to 25 years.
[10.A, 10.E]

Interlocking

Bane NOR's interlocking is in total covering 336 sites and more than 15 different systems, of which:
- Relay interlocking (≈ 80%)
- Electronic interlocking (≈ 20%)

Expected remaining useful life
Most of the relay-based interlockings date back to the late 1950s, meaning they are now at the end of life, especially since the relay supplier has decided to close their factory. In addition, existing relay and early computer technology is no longer taught in schools and therefore it is harder to hire skilled people. Furthermore, Bane NOR needs to increase safety by eliminating railway sections without interlocking or block systems.

Plans to replace/renew
The decision to replace all interlockings was made in 2005, as well. Bane NOR is part of the EULYNX cooperation which standardises requirements for interfaces. The hope is that in the future Bane NOR can buy more freely from different suppliers, based on the standardised IP-based interfaces. Furthermore, standardisation of interfaces means it would be easier to replace small parts rather than the whole systems when one part fails, further reducing costs.
[10.A, 10.E]

Block systems
Relay-based line block system connects the interlocking systems. Bane Nor has the following systems in use:
- Trackside train detection
- Track circuits.

Signalling
Lineside light aspect signals (ATC-2). The signal system is based on route signalling principles

Expected remaining useful life
Block systems will be replaced with the implementation of computer-based interlocking systems and ERTMS Level 2. Remaining useful life of equipment for existing block systems is equal to the life time of relay-based interlocking systems (uses the same basis technology).

Plans to replace/renew
In relation to implementation of new computer-based interlockings and ERTMS Level 2 baseline 3, existing track circuits will be replaced by axle counter systems. With this approach existing relay-based block systems will be removed. Lineside signals are to be removed since Bane NOR chose to implement ERTMS Level 2 only.
[10.A, 10.B, 10.E]

Automatic Train Protection (ATP)

System in use:
- Ebicab 700.

Expected remaining useful life
In 2005 the Ebicab 700 was foreseen to be at it expected end of life from around 2015. The expected increase in implementation of ERTMS will speed up the need for replacement of the Ebicab system.

Plans to replace/renew
Correspondingly, the decision to replace all existing ATP (Ebicab 700) was made in 2005. Based on Bane NOR's strategy from 2005 and several feasibility studies done thereafter, in 2008 and 2011, the government has stated that all future signalling shall be based on ERTMS. This has been made clear to both the Infrastructure Manager and the train operating companies. In 2015 Bane NOR showed their government that ERTMS worked at the Pilot ERTMS L2 Line. In 2016 the programme was financially secured. The new trackside signalling systems ERTMS L2 has been awarded to Siemens.
[10.A, 10.E]

13.9.2 Plans

Bane NOR will work towards a single TMS for the complete network. This is to increase safety, efficiency, and to reduce costs that come with the operation of multiple TMS-systems.

EULYNX is regarded as an immense help in terms of cutting costs. Object controllers and other interfaces are going to be ordered according to the EULYNX common requirements, Baseline 2.

Furthermore, one of the most important issues Bane NOR is dealing with in their signalling strategy is to clean up the multitude of TMS, interlockings, and object controllers they have today, which is costly both in terms of parts and competences required. The way Bane NOR is going to resolve this problem is to do an all-over clean up.

As part of the renewal programme Bane NOR will introduce a test of DAS/ATO, based on the ERA requirements when they are available. The objective of the test will be to learn and adapt to the future with the aim to reduce power consumption, increase capacity, and reduce track maintenance.

13.9.3 Ambitions

Norway has decided to implement ERTMS Level 2 baseline 3 on their entire network. In line with this decision, they decided to standardise the non-ETCS components of the CCS-system. Arguably, without significant standardisation the implementation of ERTMS is more expensive.

The strategy that all future signalling shall be based on computer-based interlockings with IP-based communication to trackside objects and ERTMS L2. This will realise a digital signalling platform for the complete Norwegian railway network and it will pave the way for future technologies such as ATO, satellite-based positioning and ERTMS L3. The entire network will be lifted into the digital age, as partial replacement/implementation would make it hard to enter the digital world for CCS.

Onboard units rolling stock
Bane Nor negotiated the delivery of ETCS onboard equipment on behalf of 14 Norwegian vehicle owners and awarded contracts to Alstom to equip the country's entire mainline train fleet of 467 trains of 55 different types with ERTMS and maintain it for up to 25 years.
This approach to procuring onboard systems generates economies of scale and ensures all operators pay the same price for the equipment they are purchasing.

The onboard delivery is divided in three different contracts comprising:
- General-application contract covering the development and testing of onboard equipment and installation in three test trains;
- Specific application contact for the conversion of Bane NOR's maintenance machines, and;
- A contract to coordinate the onboard equipment of trains with the commissioning of ERTMS on individual lines to ensure sufficient trains are available.

[10.A, 10.B, 10.E]

13.9.4 Lessons Learnt

Bane NOR has run into problems regarding the lack of CCS-standardisation. This relates both to interfaces and functionality. ERTMS is partially standardised and Europe is still struggling because harmonised engineering rules or operational rules are not in place.

Current suppliers for TMS support are available. However, the supplier systems can only be supported by the supplier themselves. Due to lack of or limited competition and poorly handled contracts the supplier can demand any price they want. This also makes it difficult to benchmark whether prices are at the right level. Still, with the new TMS Thales will be Bane NOR's contract partner for the foreseeable future. The question should be whether it is better with one or several monopolists. Bane NOR has evaluated the situation in such a way that one supplier provides best value for money.

A different situation relates to interlockings and object controllers. Bane NOR only has supplier support for 4 out of the over 10 different signalling systems, the rest must be served in-house. In those cases where supplier support is available, only the original supplier can support it. Leading to the same situation as described for TMS.

Bane NOR is not considering doing business with non-rail suppliers as it is difficult for an Infrastructure Manager to ensure that new systems will have a safety rating, e.g. SIL 4. Added functionality to systems is often integrated into systems with a SIL 4 rating, making the SIL 4 supplier the 'master'.

Bane NOR has had several discussions on whether the trackside delivery (ERTMS) should be provided by one or more suppliers. Due to the fact that it even today is limited standardisation of signalling systems (ERTMS is the exception) related to national interlocking functionality, Bane NOR find it feasible to have only one trackside contract for ERTMS. Two or more different contracts would only result in several monopolists instead of one, for the lifetime of the systems.

For the interlockings and object controllers that Bane Nor does in-house, suppliers have long disappeared from the market. Due to governmental regulation Bane NOR shall "not earn money". This makes it difficult to recoup costs from in-house solutions to keep the legacy systems running. This also makes it difficult to check whether the work can be done cheaper or more efficiently.

Bane NOR would like to see a common requirement standard for the full CCS-system. A standard set of requirements would ensure the right services and products from suppliers. The requirements should be governed by the Infrastructure Managers themselves or an overarching body, ensuring the needs of Infrastructure Managers are incorporated in the standard.

Two organisations are currently involved in the standardisation of CCS – the ERTMS User Group (ERA) and EULYNX (Infrastructure Managers). The focus of each party is on a different part of the CCS-system, resulting in the Infrastructure Manager carrying the sole responsibility for standardisation of interlocking requirements. Bane NOR would like to see more parties involved in the standardisation of interlocking requirements. Without a standardised interlocking functionality, interoperability could be influenced / jeopardised at the end.

In order to facilitate the transition to ERTMS and reduce the economic impact on Rail Vehicle Owners (RVOs), the Norwegian government has introduced a financial aid scheme for the implementation of ERTMS on rolling stock. The aid scheme is approved by the EFTA (European Free Trade Association).

Railway interoperability already exists between Norway and Sweden, by the use of Ebicab 700 in both countries. Norway's implementation of ERTMS shall be synchronised with the current Swedish ERTMS plan in order to ensure continued interoperability.

In contrast with the Danish programme, the rollout of ERTMS in Norway will not be accompanied by a complete overhaul of the operating rulebook. Bane NOR carried out an analysis of the rulebook and one option was to copy-and-paste the Danish rule, but there are differences between the two networks. The Norwegian railway network is 95% single track and the analysis showed that an adaptation of the existing Norwegian operating rules would be preferred.
[10.A, 10.B, 10.E]

13.10 Australia, New South Wales

Transport for New South Wales (TfNSW) is a statutory authority of the New South Wales Government that was created on 1 November 2011 to manage the transport services in the state of New South Wales, Australia. It is the leading transport agency of the state. The authority is a separate entity from the New South Wales Department of Transport.

TfNSW is responsible for improving the customer experience, planning, programme administration, policy, regulation, procuring transport services, infrastructure, and freight.

13.10.1 Current Situation

Transport for New South Wales (TfNSW) has conventional signalling systems based on trackside signals, train detection, safety information, and block interlocking. These systems are close to the end of their lifecycle and are costly to install.

With newer technologies on the market, that could increase capacity, TfNSW is looking for more modern technology to replace their 6,000 track circuits and 3,000 signals on the network. To make this possible TfNSW invited interested parties to take part in a market sounding in 2017. The goal of this market sounding was to inform the development of a delivery strategy for ATO. TfNSW has been seeking input, views, and new ideas from industry leaders in delivering technical integration, business integrations, traffic management systems, and trackside assets.

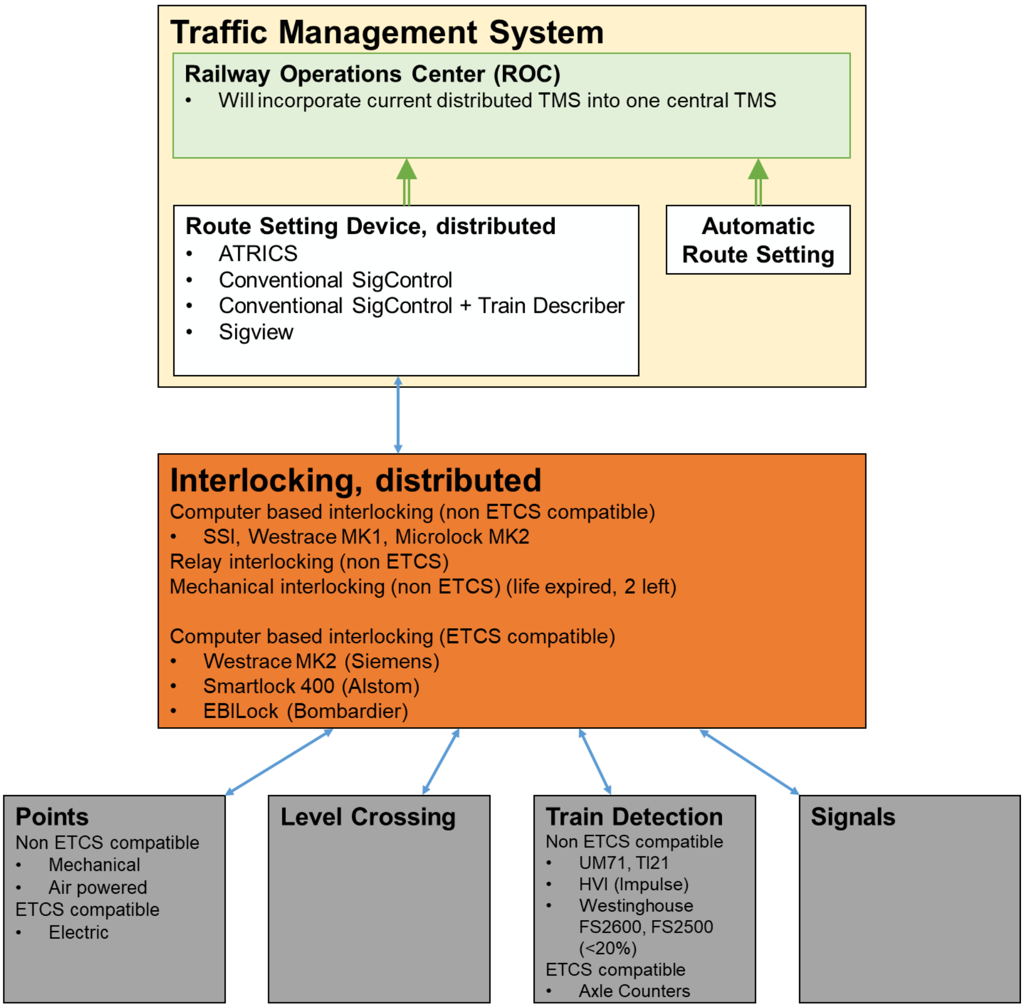

Figure 39: System architecture TfNSW. [11.D], [11.E], [11.F].

Traffic Management Systems (TMS)

Different commercial traffic management systems are present on the TfNSW network. Traffic management is currently distributed.

Route Setting Devices
Like traffic management systems there are different route setting devices used across the state. These are the systems used:
- ATRICS
- Conventional SigControl
- Conventional Sigcontrol + Train Describer
- Sigview
- Automatic route setting

Expected Remaining Useful Life
The expected remaining useful life of the traffic management system on the TfNSW network is until 2020.

Plans to Replace/Renew
Sydney Trains is currently implementing the new combination of centralised signalling control with their rail traffic management centre in a building called the ROC. The scope of the ROC will include systems which will minimise delays and ensure that customers will receive better and faster information when a delay occurs. The ROC will modernise how Sydney's rail network is controlled by incorporating multiple systems and changing the approach to managing trains.

This project provides a platform for the introduction of a Train Control System that would provide the following functions:

- Operation of signal controls to execute the train timetable
- Resolving train conflicts and setting routes
- Dynamic planning and re-planning of timetables in response to incidents and other types of delays.
- Reducing secondary delays and allowing faster service restoration.
- Optimisation of ATO train movements to improve greater consistency in overall train performance and running times while making the network more energy efficient. [11.C]

The traffic management system will be renewed under the Digital Systems Project (DSP). However, as of yet no decision has been made on the type of system to be installed. The new TMS will be put out to tender.

Interlocking

Computer-based interlocking, relay interlocking, and mechanical interlocking are present on the network. None of the currently installed interlockings are compatible with ETCS. Interlockings compatible with ETCS are not yet installed on the network.

Non-ETCS Compatible Interlocking

Interlocking	Type
SSI	Computer-based
Westrace MK1	Computer-based
Microlock MK2	Computer-based
Relay interlocking	Relay
Mechanical interlocking (expired, 2 left)	Mechanical

Table 11: Overview of TfNSW non-ETCS compatible interlocking [11.D], [11.E], [11.F].

ETCS Compatible Interlocking

Interlocking	Supplier
Westrace MK2	Siemens
Smartlock 400	Alstom
EBILock	Bombardier

Table 12: Overview of TfNSW ETCS compatible interlocking [11.D], [11.E], [11.F].

Expected Remaining Useful Life
Mechanical interlockings present on the TfNSW railway network are end of life.

Relay interlockings on the core of the network are end of life. However, relay interlocking on the edges of the network, interfacing with other networks, remain in operation.

The computer-based interlockings are not yet at the end of their useful life. However, the current computer-based interlockings are not compatible with ETCS.

Plans to Replace/Renew
Mechanical interlockings are to be replaced as soon as possible.

Relay interlockings at the core of the network will be replaced.

The computer-based interlockings are only replaced when ETCS is installed on the network.

Block Systems

The TfNSW railway network uses a fixed block system. Trackside train detection by means of both track circuits (approximately 6,000) and axle counters:
- UM71, TI21 (audio frequency)
- HVI (impulse)
- Westinghouse FS2600, FS2500 (,20%)
- 50 HZ AC
- Axle counters

Signalling
The TfNSW railway network is equipped with (approximately 3,000) light signals of a three-aspect colour light type. The signals work according to route signalling principles.

Figure 40: Signals at Katoomba station

Expected Remaining Useful Life
The block system and signals have an expected remaining useful life of 10 years.

Plans to Replace/Renew

The signalling system will be replaced under the "More Trains, More Services" project. Digital systems (ETCS Level 1 limited supervision) will replace the signalling ATP-system.

Automatic Train Protection (ATP)

Currently some areas of the TfNSW railway network are equipped with the ETCS Level 1 limited supervision ATP-system. Until 2019 ETCS Level 1 limited supervision will be rolled out on the remainder of the network.

Expected Remaining Useful Life
The expected remaining useful life is not yet known as the system is still being installed.

Plans to Replace/Renew
The ETCS ATP-system is currently under installation in the "More Trains, More Services" project. ETCS L1LS reduces the need for trackside equipment as not each signal has to be equipped with a LEU (Lineside Electronic Unit).
An Automatic Tran Protection using ETCS L1LS provides:
- Rapid improvement in safety
- Commence ETCS fitment of rolling stock fleets
- Enabler of future ETCS Level 2 deployment

[11.A]

13.10.2 Plans

TfNSW hopes to roll out ATO and a new Train Management System (TMS) before 2028. The rollout is part of the Digital Systems Project (DSP). The goal of DSP is to move the Sydney Trains network to a modern, automated railway. The project includes the following elements:
- A move from lineside signalling to cab signalling, based on ETCS Level 2 (which provides ATP)
- Simplified trackside signalling, without signals and use of axle counters for train detection
- Adoption of traffic management for more effective day-to-day operational management
- Deployment of Automatic Train Operation (ATO), Grade of Automation 2, with a driver.

The final goal is to optimise functionality and performance with automated systems. The following objectives for the DSP project have been defined:
- Enable the network to meet projected growth
  - Improve reliability up to 20 trains per hour
  - Increase capacity up to 24 trains per hour
- Enable dynamic systems so that disruptions and incidents can be managed faster
  - Reduction of delays caused by network incidents and disruptions
- Provide more accurate service information
  - Availability of real-time customer info
- Facilitates financially sustainable maintenance and operations of the network
  - Reduce whole life cost to maintain signalling technology
  - Reduce incidence of signalling assets failure
  - Optimise energy consumption
- Replace end-of-life assets in a way that minimises costs and disruption
  - Minimise cost of replacing assets (Reduce operational costs)
  - Minimise the need for and impact of possessions

- Improved safety
    - Reduced need to be trackside
    - Stronger controls for possession

[11.A, 11.B]

The DSP includes the deployment of technology, people and process elements to achieve these goals. these elements include new safe working rules, definition of new roles, training of staff, and the operational and maintenance readiness activities to bring the system into service. Technology, people and the process must work together to achieve the goal of the TfNSW to modernise the railway system.
[11.C]

'No regrets' Initiatives
- Utilise analytics to optimise customer journeys, routes and interchange.
- Create the blueprint for automated and fully digitised mass-transit networks.

[11.A]

Technology
- Cab signalling (ETCS Level 2)
- Simplified trackside using axle counters
- Traffic Management System
- Automatic Train Operation (GoA2, with driver)
- Diesel interoperability

People
- Mindset/values/culture
- Skills and competencies
- Learning, training and development
- Roles and organisational structure

Process
- Normal operation
- Degraded modes of operation
- Mixed-network operation
- Access to track

[11.A, 11.B]

In 2018 TfNSW will start with preparing to roll out Automatic Train Operation. Information is gathered to prepare for designing the new system. During this process they will train their personnel to get them familiar with the new Cab signalling design and incorporate feedback in the designs. First deployment of the new cab signalling systems is expected to start in the last quarter of 2019. Testing this is set to conclude in early 2022. [11.B]

In parallel, TfNSW starts with the design and deployment of ATO in 2020. Personnel will be trained for the new operational process during this process. TfNSW plans to have ATO available in 2024.

During cab system design, TfNSW will also start development on a new Train Control System. Including training this new Train Control System is set to be deployed together with the availability of ATO in 2024.

The key justification for new ERTMS and ATO technology is to support higher train frequencies. As the main operational constraint with existing CCS and TMS is the train speed variability. With more modern systems the trains follow-up times can become shorter thus increasing capacity. The use of ETCS Level 2 with ATO GoA2 specifically enables greater increases in capacity without incurring the increased cost and disruption to the network that deployment of other systems would necessitate. [11.B]

Philosophy of the Digital Systems Project
Automated Systems is a generational change to how the railway will operate:
- Shift in ways of thinking and doing
- Use of standardised equipment rather than bespoke development

- Configured – not customised
- Develop Operating Rules from international standard
- Leverage international expertise

[11.C]

Principles of Assurance & Standards
- The existing suite of TfNSW Standards relate to the current systems in use across the network.
- The Automated Systems project is seeking to procure and implement a new system onto the network.
- The existing standards are not necessarily relevant to this new system but contain a large volume of informative material.
- It is anticipated that a new set of standards will be required to support introduction and operation of the new system.
- It is anticipated that the new set of standards will be proven and internationally recognised.
- ASA, the Automated Systems project and Suppliers will work together to identify and if required develop appropriate standards.
- The assurance process will focus on approval of the overall system, rather than type approval of system components.

[11.A]

13.10.3 Ambitions

TfNSW's vision is to: "drive transport transformation through innovation and enabling technology". They plan to deliver and manage smart technology solutions for safe and efficient transport services. The ambition of TfNSW is to centralise traffic control into the Railways Operations Centre, introduce ETCS Level 2 on the network, and introduce ATO. These ambitions have been translated into plans by TfNSW, the plans have been presented in previous paragraph.

13.10.4 Lessons Learnt

Industry Engagement and Collaboration
TfNSW has not enough experience with these systems in-house and this project is significant for NSW and Australia. Because of this, there is a huge emphasis on a 'co-design' approach. TfNSW works closely with industry and other stakeholders to ensure that an appropriate delivery model is implemented. [11.B]

Key Challenges
System integration: The need to have multiple work packages will mean that effective integration between all suppliers will be a key issue to ensure a functional system. Interfaces and accountabilities will need to be clearly defined and managed.
- *Business change:* Deployment of Automated Systems will impact over 3000 personnel across the network. TfNSW, Sydney Trains and other operators will require effective planning and deployment of business change activities to support and drive the adoption of change and new ways of working.
- *Configure not customise:* TfNSW is seeking, as far as possible, to adopt existing systems. Understanding the nature and implications of existing systems will be critical to ensure an informed choice can be made. TfNSW is determined to avoid customisation and preferential engineering.
- *Supplier interoperability:* A successful project will require at least two ETCS trackside suppliers delivering systems working to the same operational rules, interoperating with at least four onboard products (including ATO) and controlled using a separate supplier's TMS.
- *No disruption*: Deployment of the system must be achieved in a brownfield environment without disruption to operations. Use of axle counters will assist. TfNSW is also interested in testing and integration approaches that minimise on-track work.

[11.B]

13.11 Australia, Queensland

Queensland Rail is the responsible Infrastructure Manager for the Queensland railway network, owned by the Queensland Government. Queensland Rail operates suburban (Citytrain network) and long-distance (Travel network) trains in Queensland. Furthermore, Queensland rail manages 6,500 km of track.

13.11.1 Current Situation

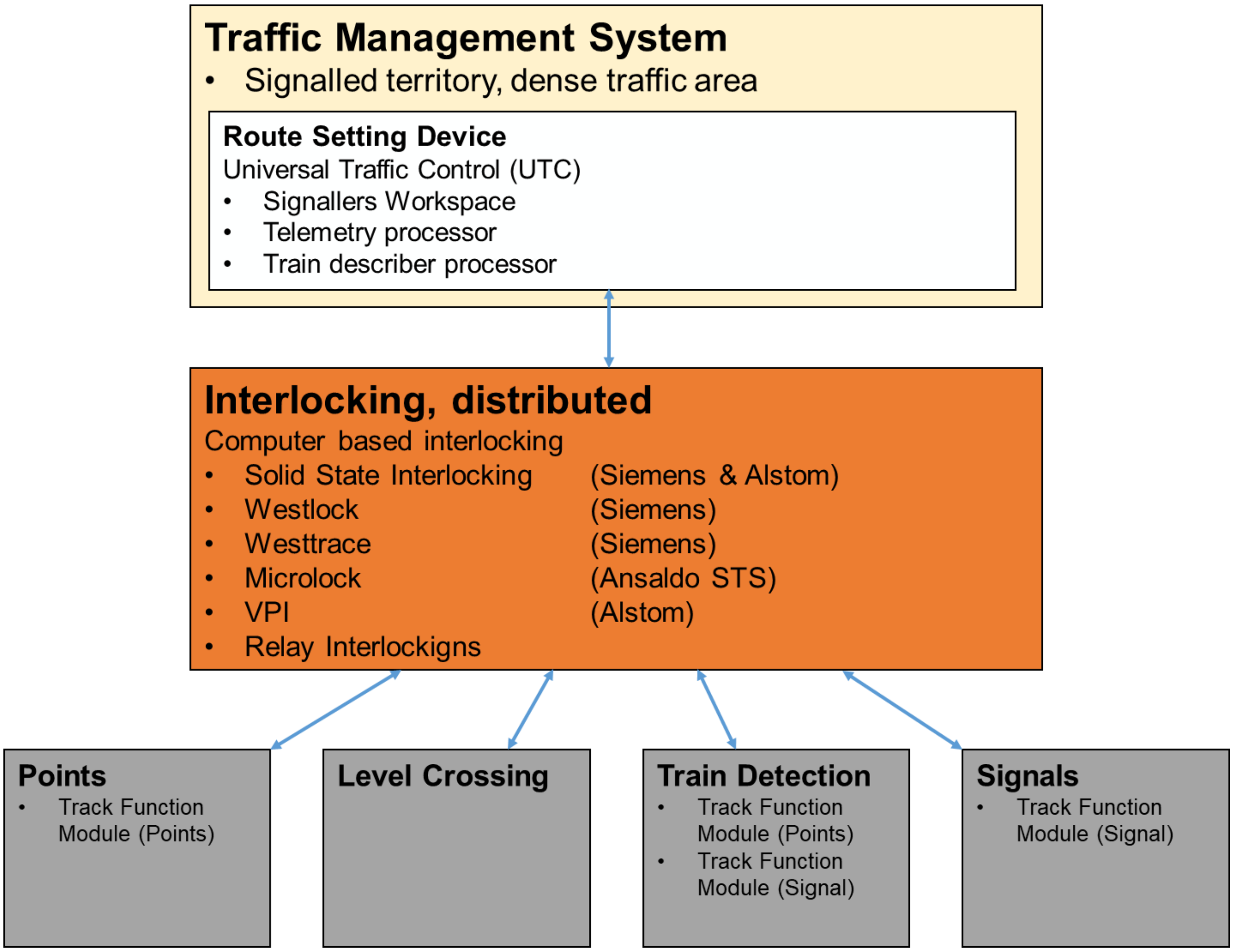

Figure 41: System architecture Queensland rail. [11.G], [11.H].

__Traffic Management Systems (TMS)__

The Queensland rail suburban network is controlled from the Queensland Rail Control Centre. As such, the Centralised Traffic Control is present on the suburban network in Queensland. From this location train movements are governed remotely.

Route setting device
Universal Traffic Control (UTC)
- Signallers Workspace
- Telemetry processor
- Train describer processor

Automatic Route Setting
ARS is present on the Queensland rail network.

Expected Remaining Useful Life
The TMS-system is life expired.

Plans to Replace/Renew
The TMS-system will be replaced as part of the Inner City project. The renewal of the TMS is not yet put out to tender, thus no information is available of the new TMS-system.

Interlocking

Interlocking	Type	Supplier
Solid State Interlocking (SSI)	Computer-based Interlocking	Siemens & Alstom
Westlock	Computer-based Interlocking	Siemens
Westtrace	Computer-based Interlocking	Siemens
Microlock	Computer-based Interlocking	Ansaldo STS
VPI	Computer-based Interlocking	Alstom
Relay Interlocking	Relay Interlocking	

Table 13: Overview of Queensland Rail interlocking

Expected Remaining Useful Life
A large portion of the interlockings installed on the Queensland Railway network are life expired.

Plans to Replace/Renew
Replacement of the interlockings is taking place under the are taking place under the Cross River Rail Project and the Inner City Project. Interlockings replaced under the Inner City project will be compatible with ETCS Level 2.

Block Systems
The Queensland railway network is equipped with a fixed block signalling system. Trackside train detection is provided by means of track circuits and axle counters.

Signalling
The Queensland railway network is equipped with light signals of the three aspect colour lights type. The signals work according to route signalling principles.

Expected Remaining Useful Life
The block system and signalling system of Queensland have an expected remaining useful life of 10 years.

Plans to Replace/Renew

Under the Inner City project, the block system and signalling system will be replaced on the core of the Queensland railway network.

Automatic Train Protection (ATP)

The North Coast railway line of the Queensland railway network is equipped with the Westec ATP-system. Other railway lines are not equipped with ATP.

Expected Remaining Useful Life
The Westec system is end of life.

Plans to Replace/Renew
The Westec ATP-system on the North Coast line is currently being replaced by ETCS Level 2.

13.11.2 Plans

The current plans are the result of the future strategy. Thus, a large overlap is present between the ambitions and current strategies.

13.11.3 Ambitions

The following future strategies are identified:
- Introduction of a fully integrated ETCS Level 2 throughout the Brisbane suburban network.
- Replacement of interlockings by ETCS Level 2 compatible interlockings.

The main driver for the introduction of ETCS is an increase in capacity, enabling a 20 percent capacity increase on the Northern and Western lines. The automatic train protection features of ETCS allows trains to safely run closer together.

The Cross River Rail project delivers a new railway line through the Brisbane CBD (Central Business District). The Cross River Rail line will be equipped with Automatic Train Operation (ATO), allowing for the installation of platform edge doors.

13.11.4 Lessons Learnt

Queensland rail is currently planning the introduction of ETCS on the railway network. Therefore, as of yet no lessons learnt can be formulated regarding the replacement of TMS, interlockings, or the introduction of ETCS.

14 APPENDIX D BACKGROUND SUPPLIERS

14.1 AngelStar (Mermec & Stadler)

Recently Mermec and Stadler formed the AngelStar joint venture. The joint venture is specialised in the design, development, and supply of ETCS onboard equipment. AngelStar develops and supplies a range of ETCS onboard equipment under the Guardia brand. The developed systems are currently undergoing tests. [15.F, 15.G]

Mermec is an Italian company active in the fields of rail inspection, signalling and industrial inspection systems. The company delivers legacy Italian signalling and ATP-systems, and ERTMS Level 1 and Level 2 solutions. Mermec is a member company of Angel, active in high-tech sectors railway, aviation, space, and internet of things. [15.H]

Stadler is a Swiss manufacture of rolling stock. Stadler's products range from light rail and trams to high-speed trains. The focus of Stadler is on smaller orders, delivering trains based on common platforms.

Up until now Stadler has purchased ETCS onboard equipment from other suppliers, many of which are active in the rolling stock market as well. The planned merger of Siemens-Alstom has driven Stadler to develop its own ETCS onboard solution, due to the large market share of Siemens-Alstom. The components developed by AngelStar reduce the reliance of Stadler on these competitors for vital train components. [15.I, 15.F]

Stadler partnered with Mermec due to the high complexity and standardisation of the ETCS system. This presents a high barrier to Therefore, Mermec will bring in the expertise and experience with ETCS. [15.F]

14.2 Bombardier

Bombardier is a Canadian manufacturer of airplanes and trains founded in 1974. The Transportation branch of Bombardier is currently operating in more than 60 different countries and employs around 39.850 people. Their main challenges consist of making a reliable, safe, and sustainable transport available for everybody. Ways to achieve this is by the manufacturing of, for example, a full battery driven train, or by receiving a new order as Siemens's partner and supplier in the expansion of Deutsche Bahn's ICE 4 fleet.

Besides the manufacturing of rolling stock, Bombardier also focusses on the implementation of the different levels of ERTMS. For example, Bombardier already supplies ERTMS level 1 solutions in Europe and Asia, was the first to commission an ERTMS level 2 system for commercial operations in Switzerland in 2002, and is implementing the moving block ERTMS level 3 in major lines in countries such as Algeria, Brazil, Chile, and Netherlands.
[15.U]

14.3 CAF

Construcciones y Auxiliar de Ferrocarriles (CAF) or in English; Construction & Other Railway Services, is a worldwide manufacturer in rolling stock, and railway equipment and components. This more than 100 year old company employs more than 7000 employees and is missioned to supply comprehensive transit solution for sustainable mobility. With 11 factories in countries such as Spain, Brazil, and Mexico, they provided the manufacturing of trains for companies as RENFE (a large Spanish railway operator) and rolling stock for the metro system in Madrid and Barcelona. Furthermore, they delivered trains and metros in countries such as the United States, Mexico, Argentina and the Netherlands.

CAF have developed their own solution for ERTMS and ensures high performance solutions for ERTMS level 1 and 2. Furthermore, CAF offers an integrated onboard system platform which provides modular solutions for level 1 and 2 ETCS which allows interoperability beyond boarders.
[15.O, 15.V].

14.4 Siemens and Siemens Alstom

Siemens is a 170 year old German company that employs about 350.000 people and is active in around 190 countries across the globe. This company is specialized in activities such as energy management, Building technologies, Digital factory, Mobility, and process industry. Projects that characterize Siemens include Siemens' design and simulation software that contributed to the development of the Mars rover Curiosity, which is perceived as the most complex project of the space agency up until now.

Recent developments include the agreement of the business combination of Siemens and Alstom regarding the proposed combination of siemens' mobility business with Alstom's rail traction drive business. This combination (Siemens Alstom) will then consists of about 65.000 employees and will be active over 60 different countries. In the mobility field, Siemens delivered for example the central control system and the platform systems for the new North-South metro line in the Netherlands, that opened in July 2018. With regards to ERTMS, Siemens already impressively demonstrated the real-life interoperability of its on-board equipment in different combinations with other manufacturers. Furthermore, they provide GSM-R and TETRA radio systems for the ETCS for rail projects worldwide.
[15.X, 15.Y]

14.5 Thales

Thales is a well-known French company, specialized in aerospace, defence, information technologies, and ground transportation all over the world. Large projects include the development of radar systems, GPS-systems, airport security systems for example in Dubai, Doha, JFK in New York, and provides about 40% of world's aerospace managed by Thales air traffic control centre. In the transportation branch, they focus on network & operations management, passenger information and connectivity solutions, and different type of signalling systems, Route control systems, Field equipment and Traffic management systems. Thales offers ERTMS products and has been awarded for example a 25 year deal from Norway, to rollout ERTMS in a service contract, including support and maintenance. Furthermore, Thales is currently powering rolling stock manufactured by companies such as Alstom, Ansaldo-Breda, CNR, Mitsubishi, CAF and Bombardier.
[15.Z].

COLOPHON

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