ETCS: The foundation for efficient and attractive railways

Dr. Felix Laube
Felix.Laube@emchberger.ch
Emch+Berger AG
CH-3001 Bern
+41 79 610 63 68

Andrew Nash
andy@andynash.com
GreenCityStreets.com
1070 Vienna
Austria

ABSTRACT

The European Rail Traffic Management System (ERTMS) consists of the European Train Control System (ETCS), GSM radio communications for railways (GSM-R) and advanced traffic management. ERTMS is designed to improve European railway service by replacing different national-based train control systems with a single interoperable system. ERTMS also increases safety by providing full supervision of train movement and increases capacity by reducing train headways.

A significant benefit of ERTMS is the development of detailed digital data on railway infrastructure and operations. This data, coupled with improved technologies for managing staff and resources, provides the foundation for developing an advanced traffic management system (TMS) that can significantly improve railway efficiency and attractiveness.

Banedanmark is developing an advanced TMS to achieve this goal. Banedanmark's TMS takes a fresh approach to railway operations by creating Production Plans consisting of precisely defined tasks to be carried-out in operating the railway. Production plans are developed based on a very clear definition of customer needs called Service Intentions. Banedanmark's approach integrates planning and operations by using the same algorithms and data. It improves the precision of planning and provides updated Production Plans quickly enough to significantly reduce the impact of delays and disturbances. This article provides an overview of ERTMS and Banedanmark's new TMS.

Key Words

Railways, Traffic Management, Scheduling, Rescheduling, ETCS, Denmark

1. Introduction: ERTMS

The European Railway Traffic Management System (ERTMS) is a specific approach for providing movement authority and permitted speed information to railway train drivers. It is designed to enable trains to operate throughout Europe using the same signalling equipment and train protection. ERTMS is a key element in the European Commission's effort to improve interoperability and thereby increase railway sector competition. The ERTMS consists of three elements:

- European Train Control System (ETCS) – a standard for the interface between trackside and on-board signalling equipment;
- Global System for Mobile communication for Railway (GSM-R) – a GSM frequency reserved for railways; and,

- European Traffic Management Layer (ETML) – not yet developed in detail.

ETCS is designed to increase safety by providing full supervision of train movement (all speed limitations of any kind and all stopping locations are supervised) and installing signals inside the cabs (where they are easier for drivers to see). Ultimately ETCS will reduce operating costs by allowing railways to remove line-side signals. There are three levels of ETCS:

- ETCS Level 1 – Overlay to existing signal system: Movement authorities provided to the train cab from Eurobalises (balise transmits signal information to driver cab by radio). Train integrity and position information are provided by track occupancy detection. Existing wayside signals can be removed, but most implementations keep them.
- ETCS Level 2 – Permitted speed information sent to trains via GSM-R radio signal. Trackside signals are often removed. Train position detected by train occupancy detection.
- ETCS Level 3 – Permitted speed information <u>and</u> train position data sent by GSM-R radio. Train integrity is checked using onboard systems.

ETCS Level 3 is also referred to as "moving block" because the block of space that provides train separation moves along with the trains and therefore can be the minimum necessary (thus maximising line capacity). However, Swiss experience shows that ETCS Level 3 capacity benefits can be achieved using ETCS Level 2 with short block lengths. Therefore ETCS L3 must be justified based on less expensive technologies.

2. ERTMS implementation in Europe

The European Commission (EC) strongly supports ERTMS through research and financing but national railway infrastructure owners are responsible for implementation. As of September 2013 approximately 19,900 kilometres of track are equipped with ERTMS in Europe. The EC would like to see more rapid progress especially on key international corridors. It has identified significant political, technical and financial challenges in ERTMS implementation and is acting to address these challenges. One key action has been appointing corridor managers responsible for advancing implementation of international projects.

National railway infrastructure owners have two possible approaches for implementing ERTMS:

- Migrate: install ERTMS on new lines and when existing equipment reaches the end of its service life. Examples include Austria's Westbahn, Switzerland's high speed line, Loetschberg Tunnel and Gotthard Tunnel, and German projects.
- Replace: completely replace signalling system for an entire country with state-of-the-art ERTMS. Examples include Denmark, Norway, and the UK (sector-based).

Denmark provides a case study on the benefits of full nation-wide signal system replacement. In the late 1990s service quality on Denmark's railway network was falling while demand was increasing due to economic growth and a desire to improve environmental sustainability by shifting traffic from road to rail. Delays were growing significantly and over 50% were caused by signal failures. Furthermore, the signalling system's maintenance costs were increasing rapidly, and old infrastructure could not be used to optimise processes.

In 2005 Banedanmark, Denmark's railway infrastructure manager, prepared a strategic study on signalling system replacement. The study concluded:

- Total replacement would be more economic than piecemeal replacement because it would reduce costs by eliminating the need for creating provisional interfaces and providing economies of scale, even though some existing signalling equipment would be written off early.
- Total replacement would provide larger benefits much earlier, especially in terms of improving the quality of railway operations and lowering maintenance costs (including costs due to loss of know-how for maintaining legacy signalling assets).

On the basis of this study Denmark decided to install an ERTMS Level 2 signalling system nationwide. The project's expected cost is 3.2 billion Euro and illustrates why more railways do not embrace total replacement: despite the clear economic benefits, it is difficult to raise such large sums of money.

The Banedanmark Signalling Programme began with a multi-year tender development process. Contracts were signed with the ERTMS suppliers in 2012. Tender results confirmed the economic advantages of total replacement. The system design is being completed; testing and implementation are underway. The project is on schedule to be fully implemented by 2021.

During the tender development process, the designers realised that complete signalling system replacement could also provide the foundation for creating an advanced railway traffic management system (TMS) that could significantly improve the quality of railway operations. Banedanmark decided to develop such a TMS. The rest of this paper describes Banedanmark's TMS and how it will transform railway traffic management.

3. Advanced traffic management for attractive and efficient railway service

ERTMS is designed to improve the safety and efficiency of railway traffic. The focus to date has been on developing a standardized approach to safety, but ETCS and GSM-R also provide a strong foundation for building a traffic management system to significantly improve the quality of railway service.

The key problem facing developers of traffic management systems is the lack of accurate data. Railway networks are very large and have grown incrementally over the past 100 years. Therefore, digital data on infrastructure and operations is often unavailable and sometimes no data is available at all.

Complete signalling system replacement addresses this problem because high quality digital data is needed to design and implement ERTMS, and sensors must be installed to provide real time digital information (e.g., data on train location, infrastructure status, etc.). While it's possible to create an advanced TMS without completely replacing the signalling system, it can be difficult and expensive to collect the necessary data. In other words, complete signal system replacement provides the digital data needed to feed an advanced TMS.

Once the data is available, the next question becomes how should an advanced TMS be designed? There are many examples of advanced TMS in closed systems such as metros, but these are generally small, self-contained networks that use a single type of rolling stock and a simple operating pattern. The design of advanced TMS for large, heterogeneous, international railway networks is just beginning and Banedanmark's TMS is a pioneer.

Given the project's pioneering nature, Banedanmark started the design effort by re-considering railway operations and management. This effort focused on three closely interrelated questions:

1. What are railways selling?
2. How do railways produce service?

3. How do railways manage their business?

The following sections summarise how Banedanmark answered these questions.

3.1 What are railways selling?

The process started by asking: “What are railways selling?” for two reasons. First, businesses often lose sight of these types of fundamental questions – especially older businesses like railways. Second, the question focuses on customers. This is especially important in Europe, where infrastructure owners and train operating companies have been separated. Today the railway network’s first line customer is a train operating company rather than an end customer (passengers or shippers).

Banedanmark’s main finding was recognising that railways provide services. On the simplest level this means that railways provide transport for travellers (they provide other services to other users). Yet, most railways are not organised and managed based on services, but rather on the basis of moving trains around. Travellers don’t (really) care about trains; they care about getting where they are going comfortably and efficiently.

A simple example is a traveller who needs to be somewhere for a meeting that starts at 11:00. This traveller doesn’t care if the train arrives at 10:48 or 10:51 but only that the trip is relatively fast and the train is comfortable – in contrast with the railway which is very concerned with precise arrival times of trains. In other words, the quality measure used by the railway is not the same as the quality measure used by the customer.

As a result of this question, Banedanmark realised that customer needs must be re-examined and that it was critical to develop a systematic approach for expressing the needs of all customers (e.g., passengers, shippers, train operating companies, railway maintenance organisations, station owners, connecting public transport operators, local governments, etc.) using a common language that could be used to optimise railway service. This language is called ***Service Intentions*** and it forms the basis for Banedanmark’s TMS.

3.2 – How do railways produce services?

The second question focuses on how railways think about producing their services. In the past railways have thought about running trains. This makes sense when data is scarce and analysis is slow – but today the situation is reversed: data is abundant and analysis is fast.

Thinking in terms of running trains is problematic because it is precise in ways that don’t particularly matter for customers and is imprecise in describing how to actually operate railways. The preciseness is outlined above: customers don’t especially care if the train arrives at 10:48 or 10:51, but railways do – creating a mismatch that reduces the ability of the TMS to focus on customer satisfaction.

The imprecision problem is that timetable-based information (train departs at 10:15 and arrives at 10:48) does not provide sufficient information directly to those actually implementing the service. Many specific activities necessary to “run a train” are not described. For example, consider the train guard responsible for locking the doors before departure. Does the guard lock the doors at 10:15:00? If so the train won’t be able to depart until 10:15:15 (since it takes time for the driver to prepare the train and react). Has the infrastructure been reserved from 10:15:00 resulting in wasted capacity? Today no one really knows.

As a result of this question, Banedanmark realised that the railway production process needed to be split-up into very specific tasks and that these tasks needed to be very precisely planned. All the tasks that are needed to provide the desired services are combined into a ***Production Plan***. The Production Plan:

- Precisely describes all tasks needed to provide service;
- Assigns tasks to "task owners" (people and systems);
- Allocates resources (e.g. track sections) to tasks;
- Uses tolerance bands to define task performance; and,
- Provides real-time task updates in case of divergences.

Here again, it's only possible to develop a Production Plan-based approach because of today's advanced information technology and digital data availability. It would be impossible to manage and analyse so much data without precise information and effective technology.

3.3 – How do railways manage their business?

There are two main elements in managing a railway: planning and operations. Today planning and operations are separate: planners develop timetables and analyse investment decisions, while dispatchers manage railway operations in real-time. While both perform similar activities, they use different tools and different data.

In contrast, Banedanmark's TMS provides an integrated approach to railway planning and operations. Planners and dispatchers use the same database, functions and applications. This makes planning more accurate, makes operations more customer oriented (including faster recovery from disruptions), and increases the efficiency of both.

Today a typical planning process starts with a high level analysis of general concepts and gradually increases the level of detail depending on the analysis purpose. The process uses different types of planning tools, but these are simplified due to the complexity of operational-level planning and lack of detailed data.

For example, consider the question of building an additional track in a heavily congested area. Today planners use techniques including simulation to obtain information about the impact of the new track. However, most simulations do not capture the full complexity of operational scenarios and therefore the results are not conclusive. In contrast, the Banedanmark TMS uses the same scheduling algorithm and detailed data used to create actual Production Plans to precisely analyze the impacts of the new track. The new TMS enables planners to understand exactly how the new track will work, thus improving the quality of their recommendations.

Similarly, when planners use the Banedanmark TMS to consider different service concepts (e.g., can a shorter interval of service be provided), the analysis is based on an operational-level Production Plan rather than simplified methods. In other words, if it is feasible to shorten the interval, the TMS will create a Production Plan with this update that is ready for implementation. This is a significant improvement over today's schedule planning process where schedules are gradually taken from the conceptual to operational level.

Banedanmark's TMS has similar benefits on the railway operating side. Today dispatchers receive information on delays and then develop action plans to get the trains back on schedule. In contrast, the TMS receives information on disruptions immediately (the system automatically reports any tasks not accomplished within its tolerance level – well before a train might be recognised as delayed) and the scheduler can re-plan services based on current system conditions (train positions, staff availability, and infrastructure status). Importantly the TMS develops an updated Production Plan for the entire network – today, in contrast, even the best dispatchers can only focus on relatively small areas of the network.

The TMS can develop these comprehensive plans because it has very precisely defined all tasks needed to operate services and it has a clear understanding of customer desires (Service Intentions). When there is a disturbance the TMS scheduler algorithm attempts to create a new feasible Production Plan that meets the objectives of the Service Intentions. If a feasible Production Plan is found, the system sends the updated Production Plan tasks to all affected personnel and resources in real time. If a feasible Production Plan cannot be found, then service intentions will be updated until a feasible Production Plan can be found. An important benefit of this approach is that it is done easily, so the problem can be contained before it escalates. Furthermore the changes can be fed directly into the passenger information system so that they are also informed immediately and correctly.

Finally, the TMS also keeps a record of history. This allows planners to identify recurring problems and develop ways of addressing these problems in the future.

4. Banedanmark TMS: Building the future of railways

Banedanmark's TMS is more than just a new tool to improve railway planning and operations; it is designed to provide a foundation for revolutionizing the railway business. Banedanmark's TMS will:

- Increase railway capacity by precisely managing resources to increase efficiency;
- Improve service quality by providing tools for more effective disruption management and accurate customer information;
- Facilitate innovation by introducing Service Intentions – a structure for re-imagining railway services;
- Reduce costs by more accurately analyzing investment impacts; and,
- Increase control of railway operations by precisely defining production tasks.

However, achieving these benefits depends on how deeply TMS is integrated into the railway's organisational DNA. Put simply, the full railway organisation – and our customers – must fully embrace the new approach and must actively implement it, if it is to be the foundation for a revolution in railway operations. Two examples serve to illustrate the potential difficulties.

First, the TMS is based on a shared library of high quality data. To be fully effective this database must be maintained and improved by the individual railway departments. Today, however, many railway departments have their own databases. In the long run departments will have better data and lower costs with the shared database, but this means changing established processes.

Second, to take full advantage of the TMS, all needs must defined in terms of Service Intentions. This is a significant change because Service Intentions require taking a different angle to describing trains. This runs against established habits. (Note that this is the essence of the problem TMS is trying to solve: words are too imprecise to use as optimisation criteria for railway operations so a new language is needed.) Again, in the long run, using Service Intentions could fundamentally increase railway competitiveness by helping support more customer-focused transport services – but there will be a steep learning curve.

Consider one of the most problematic railway markets: fresh produce. Today few growers would send their produce by rail because a delay might mean total loss due to spoilage and there is no efficient way for railways to specify special needs efficiently. Using Service Intentions shippers could designate specific service qualities (i.e., delivery window for a specific wagon). The TMS would include this Service Intention in its optimisation process and be able to find the produce wagon needle in the marshalling yard haystack, sending it on its way within the desired parameters. In other words, by more precisely describing the desired services, the TMS can expand the railway market, but this means embracing a new way of thinking about railway operations.

In summary, Banedanmark's TMS represents a departure from business as usual and therefore will be difficult to operationalise. Therefore, Banedanmark is using a highly developed change management process to help develop and implement its advanced TMS. This program includes:

- Comprehensive stakeholder involvement – the design team is working closely with end users and suppliers to understand needs, create usable functions and interfaces, and to develop effective communications and training programs;
- Phased implementation – TMS will be gradually introduced and features will be added over time; and,
- Attractive and efficient HMIs (human machine interfaces) and support applications are being developed to smooth implementation.

Banedanmark believes that this process will be fundamental to the ultimate success of the TMS.

5. Conclusions

Banedanmark's TMS is an advanced traffic management system to precisely plan and provide railway service for railway customers. It is based on three key ideas (paradigm changes):

- Focus on customer needs: services not trains;
- Precise control of operations; and,
- Integrate planning and operations.

The TMS uses a new concept called Service Intentions to describe customer needs in a precise and systematic manner. It fully considers all the tasks carried out by people and resources needed to successfully provide railway services. These tasks are precisely defined, assigned to specific people and resources, and monitored in real time. Finally, the TMS improves the efficiency of railway management and quality of service by using the same data and functions to plan and operate railway services. Step change in railway operations is necessary to achieve the full benefits of this advanced railway traffic management system.