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The technical challenges of monitoring ERTMS systems & use of a value engineering approach to increase capacity & reduce costs for the rail sector

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The technical challenges of monitoring ERTMS systems and use of a value engineering approach to increase capacity and reduce costs for the rail sector.

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Abstract

This paper evaluates the role of ERTMS signalling and telecoms systems-wide monitoring and the use of 'value engineering' approach, compared to the more traditional 'fix on failure'. The first part examines the ERTMS components, the errors that can occur and the costs of testing in relation to the product lifecycle. The second part uses 5 case studies to demonstrate how using analytical tools can predict and plan systems maintenance (value engineering) to realise some of the positive cost benefits associated with ERTMS for rail infrastructure operators, vendors and contractors.

1 Introduction

This paper evaluates the role of ERTMS signalling and telecoms systems-wide monitoring and the use of 'value engineering' approach, compared to the more traditional 'fix on failure'.

Rail infrastructure companies across the globe are modernizing to increase capacity, improve safety and reliability, reduce costs and enhance the passenger experience. In Europe and elsewhere, this is facilitated by the deployment of ERTMS (the European Rail Traffic Management System).

ERTMS systems control train compliance with speed restrictions and signalling status using three components partly installed wayside, beside the track, and partly on-board trains. These components are:

- GSM–R rail telecommunications
- ETCS signalling networks
- Interlocking (IXL) systems
- EVC – European vital computer

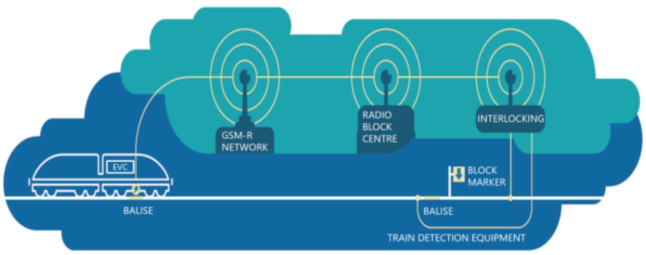

Figure1: The ERTMS environment [1].

1.1 ERTMS failure examples

Failures in any one or more of the telecoms, signalling or interlocking systems can prevent the train from moving. This can trigger delays, passenger dissatisfaction, increased unplanned maintenance work and also incur penalties when SLAs are not met. For example, according to the data of a tier 1 railway operator in Europe, every minute late beyond the agreed tolerance level, corresponds to a 6000 € fee.

These are just a few of the errors that can occur:

- GSM-R coverage, handover, interference, transmission errors, congestion, authentication failures and equipment malfunctions
- ETCS signalling, MSC-RBC communication errors, RBC-EVC protocol stack issues, software bugs in RBC firmware, RBC-RBC interoperability problems,
- IXL misreading, mis-alignments, switch issues, track occupation issues
- EVC malfunctioning, wrong identification, drivers' mistake

With such a diverse range of potential issues, finding the root cause of a problem can be both time consuming and frustrating for signalling and telecoms engineers, and expensive for the train operators or infrastructure providers when it comes to unplanned maintenance and penalty payments. In addition, as a GSM-R network is used considerably less than a typical mobile network, it is impractical to rely on statistical data to measure quality of service.

Furthermore, in addition to the continuous on-board monitoring of signalling and communications systems, the ability to monitor other asset components such as track, wheel and brake performance can significantly increase the volume of data being generated on-board, which can impact data storage and impede traditional analysis capabilities.

These provide the potential for systems errors but at the same time, the opportunity for improved knowledge and understanding with regards to asset management, as well as the potential for time and cost savings when it comes to identifying the source of issues and troubleshooting.

2 Fix on failure and the product lifecycle

Using an example life cycle cost diagram of time vs. stage of deployment, the period from concept to production and test is half of the lifetime cost. The other half is taken up with the operations.

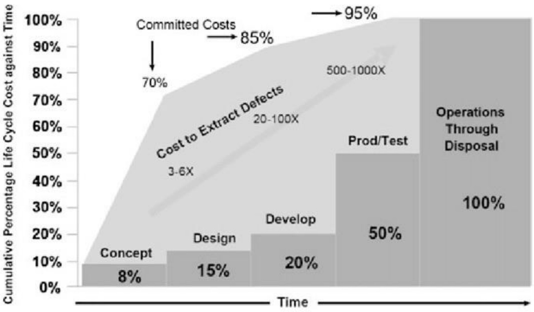

Figure 2. Cumulative percentage lifecycle cost vs time [2].

The testing phase before ERTMS deployment is very important and helps considerably in identifying and preventing the issues that could be fixed on failure at this stage. This explains why the railway industry rightly focuses on extensive testing.

However, as the rail environment is very complex, there is no way to test all the possible variables in it - at least, not all together. In the GSM world, the impossibility to test everything in lab is nowadays commonly agreed and the same applies for the ERTMS environment. Therefore, testing in situ is just as important as the initial lab tests.

2.1 Tests and standardisation

The tests required to meet the ERTMS radiopath standards are extensive. Two examples are shown in Table 1 below.

Test	*KPI*	*Referenced Standard*
Short repetitive voice calls	• Connection establishment delay • Connection establishment failure	ERTMS–Class 1
Data connection in circuit switch mode	• Maximum break during HO • Network registration delay • Transfer delay • Connection loss rate • Transmission interference	ERTMS–Class 1 SUBSET-093 UIC 0-2475

Table 1: Example ERTMS standards [3].

However, the lab tests can only go so far. For example, the interoperability test described in UIC 0-2475, Subsets -110, -111 and -112 relates to the laboratory testing of the actual Train EVC or Onboard Unit (OBU) against the actual trackside implementation Subset cannot be exhaustively defined when it comes to make the equipment working in the real environment. Therefore, whilst lab testing is very important, it does not necessarily prevent interoperability issues, such as the deadlock in ETCS protocol that recently happened to one of the major railway European operators.

2.2 The impact of errors

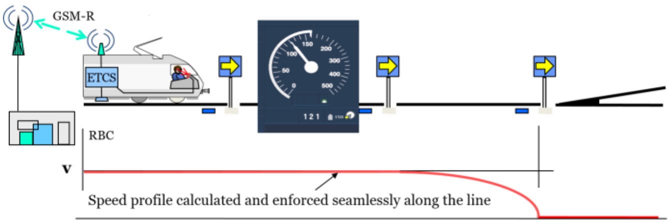

Figure 3. ETCS level 2 diagram [4].

In this case, the entire high-speed line was paralyzed for more than 10 minutes because of a protocol error. A message sent by the OBU (sequence number 129) got lost. This meant that the Radio Block Centre (RBC) did not send back any acknowledgement as it had not received the message. The OBU then neither solicited an acknowledgment nor retransmitted the message. Both the RBC and OBU simply kept the communication alive using standard messages such as the 24-General Message and the 146 – Acknowledgement. It is not crystal clear if the message was sent by the OBU because there is no evidence on the RBC logs and the OBU was not monitored.

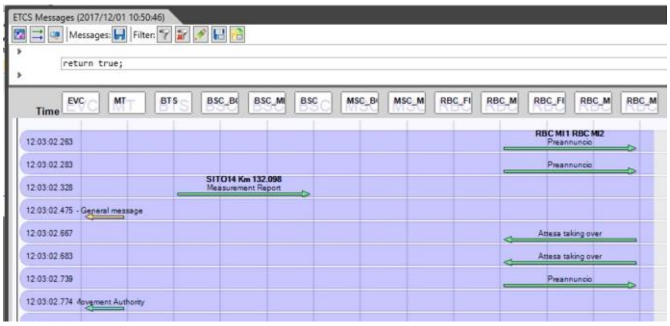

Figure 4. ETCS message string [5].

Cases like this are hard to identify via laboratory testing and therefore cost money in the form of penalties to the railway operator and time to analyse the issue.

That brings us two considerations. Firstly, despite all the testing made on ETCS protocol and in every other element of the system, odd cases might still happen. Secondarily, when we are not monitoring all the players in the game, when something odd occurs, we are blind. Therefore, it is important to not only to test, but also to monitor all the systems in the live environment.

2.3 The benefits of systems monitoring

Monitoring all the interfaces and units involved is fundamental. Today's operational data management infrastructure in the railway sector is built on traditional systems and platforms, based on relational databases. When considered within the context of low bandwidth data collection, and the tendency for siloed operations (where many databases are deployed across the enterprise, each with only a subset of the data), the result is a failure to make use of significant amounts of useful data.

The railway industry is not alone in this regard. Until recently all industries were similar. However, recent advances in IT, IoT architectures, wireless and sensor technology means increasing volume of high velocity data can be processed effectively and efficiently. In general, IT and data analysis benefits arise as the result of two main functions: from the continuous integration of real-time data, and from the ability to extract analytics from the data, and to react to the results, in a timely manner.

As a result, it is important to have access to a platform and tools that can get access to all the data, collect them and make those available for analysis when this kind of issue happens. Once we have this, we have a well-designed Fix on Failure system; able to react to issues, understand the root causes of issues and can figure out possible solutions. However, this can be costly.

3 Asset management and value engineering

The lifecycle cost diagram in Figure 1 [1] illustrates that it takes up to 50% of the spend to maintain the asset while in the operational phase. So the next questions are: "Could we cut this cost? What if we change perspective looking at the data before failures happen? Could we be able to prevent most of them?"

The answer them all is positive. Once we monitor all the data and we can match those we have all the elements for identifying degradation patterns on coming issues – using Asset Management.

Asset management comprises all systems, methods, procedures and tools to optimise costs, performance and risks for the complete rail infrastructure life cycle. The aim is to find, together with your stakeholders, the best 'value for money'. Without asset management, you may end up being considered either too expensive or not good enough. Finding a balance between the requirements and the overall (lifecycle) cost by applying risk management and consequently linking activities to the companies' objectives.

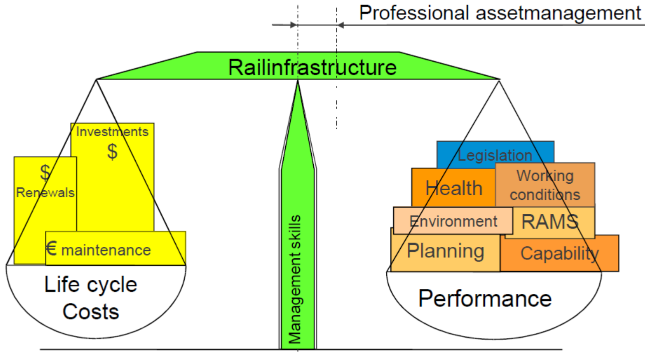

Figure 5. Balancing asset management [6].

If we look to the issue described earlier from a different perspective, the correlation between messages collected from the OBU and data collected from the network elements (such as BSC, MSC, RBC, etc.) can show possible delays and lost messages. Looking that information from a statistical perspective might point out possible reason behind that issue.

If we want to consider the degradation of a single variable and we have enough data stored, we can use trend analysis. That then requires the user's judgment and competence to understand when the degradation of a single issue might jeopardise the systems' end-to-end functionality.

If a visual check looks too questionable, mathematical functionalities such as deviation standard, can be put in place to quantify the degradation before that causes a failure (such as GSM-R. signal strength, for example). However, user competence is still needed to define the threshold which triggers the predictive maintenance before the failure.

The third way is pattern recognition using machine learning. This requires a pretty big CPU power and large amount of data, which can make it difficult or impractical. On the other hand, this can be the only approach to find a pattern when more variables are involved or correlated.

3.1 The benefits of value engineering

Let's consider some cases where a Value Engineering approach would bring benefit and prevent failure compared to using a standard Fix on Failure approach.

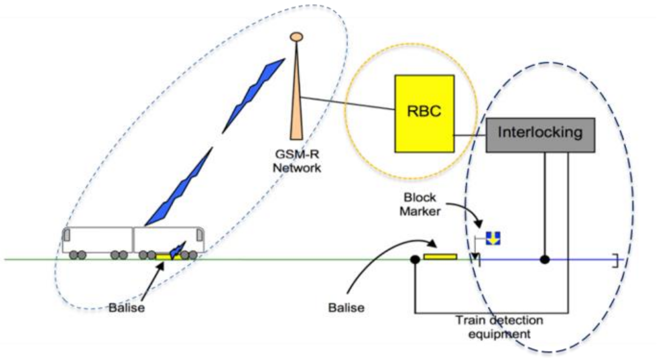

Figure 6. Rail telecoms connectivity monitoring [7].

Case 1 – Interlocking failure. When the interlocking patterns are not properly developed, the train goes into an Emergency Stop. That may happen because of switch failure, ice, faulty sensors, etc. Collecting a consistent amount of data would allow to use the statistics to understand which switches (track points) have more failures and why, we can plan proactive maintenance and prevent unexpected failures.

Case 2 – Balise failure. In an ETCS line, a balises is an electronic beacon or transponder placed between the rails of a railway as part of an automatic train protection. Balises are often set in group of 2-3 units, with two consecutive groups of balises as redundancy measure. When a single balise fails it is not normally a problem because others should be working.

When a balise fails, the ETCS message relays that we have a balise issue but not if it involves a single balise or more than one. If this had been the only balise in the set that was working, its failure now means circulation paralysis. The train cannot trigger or send the position report and cannot reset the odometer error for an emergency stop. Needless to say, this failure would cause big delays to the entire circulation from that line. If we have the right information about which balise is faulty from the OBU data, this would allow us to plan maintenance and set the right level of priority, to not risk blocking the railway line.

Case 3 - Resetting the tachometer. While the train runs, more likely it is to have a measurement error in over-reading or under-reading error in the distance run. Those errors are reset at any balise group, when the train's supposed position is realigned with the real one. When a tachometer is not working well, one of these errors can occur and train's supposed position might fall onto the wrong track circuit. When that happens, the ERTMS system has discordant information. From the interlocking, we see one track circuit occupied but train could be saying that is not 'me'. If that is the case, we still something in the way, so the train must perform an emergency stop and cause delays. Being aware of tachometry over-reading and under-reading errors and proactive monitoring would allow them to be fixed before this kind of issue can occur.

Case 4 - Radio degradation. Nothing lasts forever, including rail telecoms and wayside signalling equipment. When you start seeing a degradation in the radio pattern, you can plan proactive maintenance. For example, you can check radio network coverage in case of BTS failure, so you won't eventually face the block or serious slowdown of train circulation in that area.

Looking things from this point of view might help as well in case of extra system interference issue: such as radio problems caused by a third-party. In this case, KPIs related not only to drop and failed calls but to intra-cell handover and handover failure can tell a lot about a radio issue on a specific area. This means you have the chance to analyse and fix them before that becomes a failure on an operational train.

Case 5 - the Radio Block Centre (RBC). This 'black box' item of equipment is supplied by the signalling vendor and means that a rail operator can't really test it as each signalling vendor has its own standard. Monitoring RBC performance enables an alert to be sent to the right person before it becomes a serious problem The same can happen with the OBU and radio installed on the train. As soon as you have data indicating that one piece of equipment fails more than the others, you can analyse it properly and fix it before it fails in the field.

It might appear this approach of Value Engineering is just about changing the timing of fixing and maintenance, but it is much more. Firstly, when you can plan a maintenance activity it costs less than when you have to fix something in emergency situation. Secondly, if you can do this in time to prevent a failure in live circulation, it saves money (remember the 6000 € per minute fee cited earlier).

4 The value of data sharing

Having the data available it is very important as it is to share the befit of the predictive analysis to all the stakeholder in the railway area. Considering the tendency for siloed operations in this environment that is a kind of challenge.

That why is important to give access to the right people a platform analysis matching the data coming from all sources, but it is very important as well to give the maximum visibility of the top layer results perhaps with a web platform that could be enquired by the most in the industry.

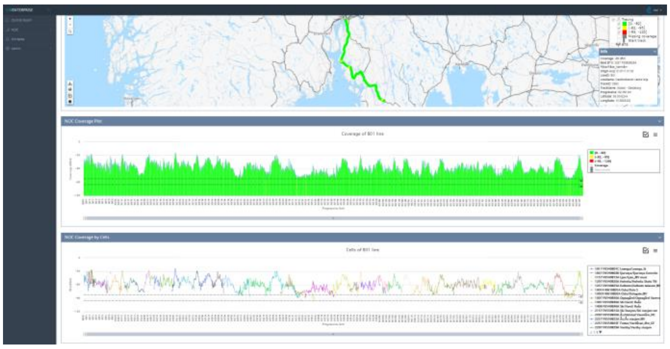

Figure 7. Example data reporting [8].

Existing standard Open System Architecture for Condition-Based Maintenance (OSA-CBM) systems used in the military and navy sectors could be used by rail to reduce cost and enable co-operation between third-party vendors etc.

5 Conclusions

The challenge for rail sector engineering is the evolution from a traditional fix on failure approach to value engineering. Doing so can help to deliver a scalable real-time streaming architecture that integrates sensor and other data with existing siloed, offline, and manual systems, and to deliver real-time information that can be acted on with confidence across all operational divisions.

Continuous integration also enables duplicated systems, databases, and data historians to be rationalized, and with fewer systems, organizations can operate with lower costs yet operate a more effective IT platform.

Detecting an event as it happens is important, but of greater importance is the ability to predict in advance and take avoiding actions. Today's streaming analytics platforms have the capacity to monitor operations in real-time, and ultimately, to take the next step, towards avoidance and real-time predictive analytics, and the possibility of preventative maintenance and intervention.

Preventative maintenance is therefore key to reducing the operational cost represented by urgent intervention and incurred penalties for late or cancelled trains.

Acknowledgements

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