RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Digital Map – Business Case

Preliminary issue

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Change history

0.1	01.04.2021	Marco Moos, David Cuesta, Benedikt Wenzel,	Draft Version (internal 1.0) to be reviewed by the other member of the cluster

		Christian Rahmig, Giusy Emmanuele	
0.2	21.05.2021	Marco Moos	Added changes suggested by the review (internal 1.1)
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1.0	20.08.201	Marco Moos	Final Version (internal 3.0), accepted by Digital Map Cluster
1.1	15.10.2021	Gabriele Ridolfi, David Cuesta	Edited version (internal 3.1) incl. comments from Gabriele Ridolfi. Separation between “basic Map Data” describing the infrastructure and additional engineering data
1.2	30.11.2021	Gabriele Ridolfi, David Cuesta	New version after MVP review

1. Introduction

1.1. Release information

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Digital Map – Business Case

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1.3. Scope

This document gives a short overview of the content of the Digital Map and presents its "business case". The cost benefit analysis shows the difference, in terms of cost and benefits, between a predefined base case and the "fully evolved" RCA system. The "fully" evolved RCA system is chosen, as it is intended to represent the "future" state of the art within railway CCS Systems. The benefit of the Digital Map, described in chapter 5, relies as much as possible on the RCA business case [1]. Where this is not possible, the sources are clearly stated and listed in the list of sources in chapter 8.

1.4. Target audience

The target group consists of members of the RCA/OCORA.

1.5. Structure

The document is structured in the following way:

- Chapter 2 gives a short overview of the current situation
- Chapter 3 will explain the assumptions made for the considerations in the following chapters
- Chapter 4 is describing the assumed occurring costs
- Chapter 5 explains the (potential) benefits of the Digital Map
- Chapter 6 shows a small numerical example
- Chapter 7 presents a conclusion

1.6. Terms and Abbreviations

For abbreviations and definitions, please refer to the Glossary [2], and the Digital Map concept document [3].

2. Current situation

Nowadays, a lot of rail systems make use of infrastructure data to determine the position of different assets, these rail infrastructure elements can be summarised as “Map Data” [3], e.g. a rail control system or the TMS planning system. Besides such “operating” applications, the whole engineering process has also a wide need in different Map Data.

Nevertheless, current railways target is to improve the performance of the rail operations and to reduce the associated costs. To achieve this ambitious aim, it is important to count with a standardised architecture to avoid vendor locking situations and the harmonisation of operational procedures. In this line, several initiatives like RCA and OCORA, which are defining a reference architecture for the complete trackside and on-board respectively, were born. One of the important features to standardised is the functionality provided by a “Digital Map”. An overview of its definition and scope is shown in the Digital Map concept document [3].

The remaining part of this document describes and lists the associated costs and benefit of the Digital Map comparing a predefined base case and the fully evolved RCA system as presented in chapter 3..

3. Assumptions

As mentioned in the previous chapter, the use of Map Data within the CCS systems is not new. A basic set of data is already available and different functions and/or processes for creating, updating and maintaining that data is also existing. The following two sections define the regarded base case and describe the fully evolved RCA system. The base case is assumed to represent the current state of the art for most or even all rail Infrastructure Managers within Europe. Map Data, and processes to maintain it, is available but does not have a level sufficient enough to fulfil the requirements coming from consuming systems within RCA or OCORA.

3.1. Base Case

3.1.1. (Basic) Map Data

- A track level node-edge model of the rail network, including the length of the edges, is available
- Attributes (type, location, etc) of objects within the track field are known (signals, switches, …)
- Geometric track information is known (curve radius, gradient, cant, …)
- Track properties are known (allowed speed, electrified areas, …)

3.1.2. Processes

- Processes to create, validate, update and maintain Map Data are available
- There is no a complete digitised/automated tool chain covering all engineering and distribution phases of data (fragments of the tool chain are available, but not the whole process)
- Process time (create => validate => update) is not fast enough and not standardised (reliability)
- Data validation for safety-related data is not available for all type of data, in a sufficient manner for the systems and goals within the RCA context, i.e. in terms of efficiency, GoA, accuracy, maintainability....

3.2. Fully evolved RCA system

- The most recent RCA release [1] is meant to be the fully evolved RCA system
- The effects and benefits of the fully evolved RCA system are described in [1] [6]
- The Digital Map has no “stand alone” benefits. It is responsible for providing Map Data to the RCA systems and enables functions, which then cause the benefits of the RCA business case [1].
- Costs related to the definition/engineering of virtual/logical elements (e.g. engineering of virtual balises, new reference points, APS Drive Protection Sections) in the Digital Map Data are not considered in this document because they have to be allocated to the consumers which needs them.

[1] RCA Baseline 0 Release 2

4. Cost of the “Digital Map”

To simplify the calculation of the occurring cost, the cost will be separated and divided into the three different parts: “Data Preparation”, “Map Development and Map Implementation” and “Operational Use”.

Figure 1: Separation of the different parts of the Digital Map

4.1. Data Preparation

The part “Data Preparation” contains every action from the collection of the data until the data is validated, converted and correctly inserted in the track database. The cost to consider is only the additional cost compared to the base case. This excludes all cost concerning the asset design and planning, converting, entering and updating of the data in the database and also the *“surveying, if the data is still valid”*. What remains is the cost for currently not available data, the amendment of current data (if needed) and the improvement of the current data acquisition and validation process (maintain data quality and make sure all data is available in a digital form).

Comparing the above defined base case with the Fully evolved RCA system and the current[2] OCORA architecture, there is no need for additional (not available) basic Map Data[3] apart from those virtual/logical elements not existing on tracks (e.g. virtual balises, new reference points, Drive Protection Section [5] for APS) that must be engineered and may be used as additional information points for localisation, train protection, automatic train operation or other possible map data consumers. What could be required is an initial digitalisation campaign (get all Map Data into a digital and proper usable form) and an amendment of current data (e.g. outdated data or only low granularity of data is available). These costs are declared as *initial cost*. They occur

[2] Gamma Release – Update 12/2020 (03/2021 Cyber Security)

[3] Assumption: While the basic Map Data contains the description of the infrastructure (track axes, nodes/edges, elements), it does not include the additional engineering data like logical and virtual elements (e.g. routes or train detection areas of legacy systems or Drive Protection Section for APS). For a complete set the basic Map Data must be enriched by an engineering process, which adds the logical/virtual data.

at the beginning and should only appear once. These costs will be expressed in €/Linekm[4]. Note: The data acquisition and validation process need to provide all data in a digital and machine-readable format.

In addition to the initial cost, continuous costs appear during the maintenance of the data quality. The maintenance has to make sure that the available data is always up-to-date, reliable, complete and ready to use. This implies all changes have to be validated and implemented in the database as soon as possible (e.g. engineering data is changed due to an insertion or removal of a switch) and inconsistencies, between database and real network, have to be detected and reported. These *continuous costs* are expressed in €/map update, €/Linekm or €/database.

4.2. Map Development and Map Implementation

The part "Map Development and Map Implementation" considers all occurring costs after entering the engineering data into the database until they are accessed by distributing/consuming systems. This includes the development/implementation and maintenance costs of the storing infrastructure (hardware) as well as the cost of the operational system (software)[5].

Comparing the base case with the fully evolved RCA system, it is reasonable to assume that the storing infrastructure does not have to be procured, as well as parts from the current software can be adopted. Similar to the cost within the Data Preparation, there are initial costs (development of the needed software) and continuous costs (running the system). They are expressed in €/software system and €/year.

4.3. Operational Use

Operational Use describes the actual usage of the information, from accessing the database until its final use in the consuming system.

As the availability and accessibility of the data is already considered in the previous sections, these costs are neglected in further consideration. Additionally, the consumption itself does also not cause any cost for the Digital Map. Thus, the transmission of the data is the only part, which has to be considered. Compared to the base case, it is assumed6 that there is no additional infrastructure needed to transmit the data from the database to the consuming systems. Therefore, and based on the fact that there is already a transmission/data exchange of Map Data between the consuming systems, there won't be any additional cost in the part Operational Use7.

4.4. Rollout of the system

Not specifically considered in the above sections is the rollout cost of the system. In general, there are two different cost which occur when such a system is introduced. The two kinds are briefly explained below.

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[4] A Linekm is assumed to contain 2 km of track, on average

[5] The Digital Map ensures the data is accessible. It does not cover the data provision/distribution. This is assumed to be done by another system like DCM. In addition, the case with different, dedicated map servers is not considered.

[6] The assumption is made according to the fact that it is currently not foreseen to develop a dedicated Digital Map Data way of transmission.

[7] There might be an increase of the transmitted data volume between track and train. But it is assumed, that such an increase can be handled by the existing infrastructure and does not cause additional cost.

Installation

Installation cost occur when a new system or a new hardware needs to be installed and connected with the surrounding systems. This cost is already included in the initial costs of the "Data Preparation" and the "Map Development and Map Implementation" and therefore does not to be mentioned in further considerations.

Introduction

Introduction considers all cost during empowering the (human) users. These actions include training to perform and update of the internal processes associated to the Digital Map. As these costs are rather small, compared to the overall cost, they will be neglected in further considerations.

Maintenance

xxxx

4.5. Cost: Data Preparation

As mentioned above, the Data Preparation contains three different costs to be considered. The parts below give a short summary of the cost and a rough estimate about their size.[8]

1) *Digitalisation campaign*
   The aim of the digitalisation campaign is to make sure that all information is available in a digital and proper usable form. This is mandatory for the future use. It allows other systems to easily access the data later on and allows a simple data handling. These costs appear only once as initial cost.
   This cost should be considered together with the amendment and acquisition process. The total costs of these two parts are estimated around 2K€/linekm – 4K€/linekm, depending on the amount of necessary work.
2) *Amendment of current data and its acquisition process*
   Although there is no additional railway infrastructure data (basic Map Data) needed, compared to the current available, an amendment of the data might be (partly) necessary. The current data might be outdated or not available in the desired granularity, e.g. a denser point cloud is required by consuming systems. In case certain data is used for safety related applications or not all data are gathered and stored in a proper digital form, an improvement of the data acquisition process is also required. These costs appear only once as initial cost.
   This cost should be considered together with the digitalisation campaign. The total costs of these two parts are estimated around 2K€/linekm – 4K€/linekm, depending on the amount of necessary work.
3) *Maintenance of data quality*
   To maintain the data quality might be the most important part of the Digital Map. It ensures that all changes and updates in the engineering data are implemented promptly and remain reliable and ready to use[9]. The occurring cost is determined by the optimisation and improvement of the current data update process. It is estimated to be around 1K€-2K€/linekm. As these costs describe a process, it is expected that the cost will slightly decrease during the first few years.

[8] Estimations were collected from the input of different IM's experiences.

[9] Excluding small changes due to maintenance work. This work is done to recover the original state. No changes and updates should be necessary

4.6. Cost: Map Development and Map Implementation

As mentioned above, the Map Development and Map Implementation contains two different costs to be considered. The parts below give a short summary of the cost and a rough estimate about their size.

1) Software development
   The software development contains the cost of the software to store, structure and to make the data accessible. These costs appear only once as initial cost.
   a. 10-40Mio € (to be shared between the IMs) [4]
   b. 1Mio€ for the first few installations (to be shared between the IMs) [4]

2) Running the system
   The yearly occurring cost consider the software maintenance and possible upgrades. They are estimated with about 5-10% of the development cost.
   a. 2mio € / year (open: can this be shared between IMs?) [4]

4.7. Cost: Operational Use

As mentioned above, there is no addition cost in terms of Operational Use.

4.8. Cost: Rollout of the system

As mentioned above, there is no addition cost in terms of rollout of the system.

5. Benefit of the “Digital Map”

The Digital Map does not have a direct financial benefit apart for being the unique reference system where the infrastructure data is stored, opposite to what happens nowadays, where generally each system manages its own infrastructure data in an isolated way. This may represent a saving in the development of other applications and their data management, but these savings are not to be imputed to the Digital Map itself.

This means that the Digital Map is required to enable and optimise current and future applications, which guarantee a safe and optimised rail traffic. The financial benefit of these applications is mentioned below and, if possible, the part which explicitly requires a Map Data is highlighted.

5.1. Benefits in the RCA and OCORA environment

5.1.1. Localisation (VL, MOL, PSL)

Within the RCA environment the enhanced on-board localisation is the map consuming application with the most potential of reducing current costs. It’s Economical Justification [4] states its main benefits in the area of reducing track CCS assets and increasing the capacity. These cost reducing benefits identify a saving potential[10] of about 8’8K€/switch[11] and 6K€/Linekm[12][13] per year. The Economic Justification especially states the requirement of a Digital Map service. Hence, it is proper to assume that the total benefit of the localisation would be reduced or even vanishing without a Digital Map.

5.1.2. Automatic Train Operation (ATO)

Automatic train operation can be divided into different grades of automations (GoA). They reach from level 1 (automatic train protection) to level 4 (driverless and unattended operation). The amount of data needed to perform ATO depends directly on the GoA. The higher the level, the bigger the amount of needed data. In terms of the Digital Map, there is a basic dataset which is required for all levels of automation, but depending on the specific level, the amount of data needs to be extended (e.g. the current collector has to be lowered at certain positions, identify denied stopping areas, etc.). Compared to the consumer “Localisation”, the Digital Map does not only optimise the ATO function, it also enables it to function.

In terms of financial benefit, the amount of savings is very hard to determine. It highly depends on the difference between the current and the future GoA used. In addition, the size of the network and the traffic density play a significant role. The RCA Business Case [1] includes the benefits from ATO in the section “… and other savings”. Together with FRMCS which is not part of RCA and it’s taken as a precondition, the mobile object locator and an overall energy reduction, its benefit is calculated at about 16 M€ per year, for the SBB particular analysis.

[10] These values refer to an IM with high level saving potential. All values are PPP adjusted.

[11] Reducing CCS assets at switches

[12] 10’8K€/km (Assumption: 1Linekm contains 1.8km of track, on average)

[13] Reducing maintenance work and non-CCS assets, release of capacity, postpone expansion steps

5.1.3. Traffic Management System (TMS: PAS, PE)

Compared to the current used traffic management systems the RCA TMS is not supposed to use more map information. Therefore, the usage of Map Data does not create an additional financial benefit. The only benefit to this system comes from the management of the data for the TMS itself.

5.1.4. Advanced Protection System (APS: SL, SM, OA, MT, MOT, FOT)

Compared to the current used train protection systems, the APS does not need additional infrastructure data/ (basic) Map Data, apart from those virtual/logical elements not existing on tracks (e.g. virtual balises, new reference points...) that may be used by these systems thanks to the deployment of the Digital map. While the usage of Map Data enables the APS functionality, it will allow a more granular management and control of the network..

5.1.5. Vehicle Supervisor (VS)

The VS implements the supervision part of the ETCS On Board Unit. This functionality is already covered in today's ETCS on-board unit. The usage of Map Data does not create an additional financial benefit.

5.1.6. Diagnostics and monitoring

Diagnostics and maintenance processes would already benefit from the Map Data in the base case scenario. Deployment of Digital Map in the RCA environment would not create additional financial benefit.

5.2. Benefits outside the RCA and OCORA environment

5.2.1. Improvement of project planning/scheduling

Depending on the current availability of Map Data, the Digital Map could improve the data handling and the reliability of the available data. This could reduce project planning time and improve the overall performance of the planning and data preparation process. To address this benefit with a number is very hard and highly depending on the project and the current data availability and reliability. Using a very rough estimate, the benefit could be around 1Mio € per month project time reduction for big maintenance projects and about 10Mio € per Month project time reduction for projects starting from scratch.

6. Example Scenario

This chapter gives a numerical example of the cost / benefit comparison. The assumed infrastructure is close to the one from SBB, as the original RCA Business Case is based on this infrastructure manager (IM). As only the benefit for the localisation is available including an educated guess, it is the only one considered in the scenario.

The infrastructure and the migration are the following:

- Total Line kilometre: 3'000
- Total number of switches: 13'000
- Time until the whole 6'000€/Linekm benefit takes place: 10 years (300km per year)
- Time until the reduction of CCS assets is done at all switches [4]: 13 years (1'000 switches per year)
- Cost for data preparation: 4'000€/Linekm (initial) and 2'000€/Linekm (continuous)
- A 5% decrease for the first 5 years is assumed to take place in the continuous data preparation cost, due to optimisations in the data process.
- Cost for map development and implementation: 25Mio € (initial) and 2Mio € (continuous)
- The cost of the development and implementation is assumed not to be shared between IMs
- The time needed to develop the Digital Map (software) and to install the server is summarized in the year 0. The migration, which leads to the benefits, is started in year 1.

Figure 2 gives a brief overview of the occurring cost and the resulting benefits. Although there is a certain investment needed at the beginning ~27Mio€ the resulting benefits compensate the total cost after 4 years (only switch) or after 12 years.

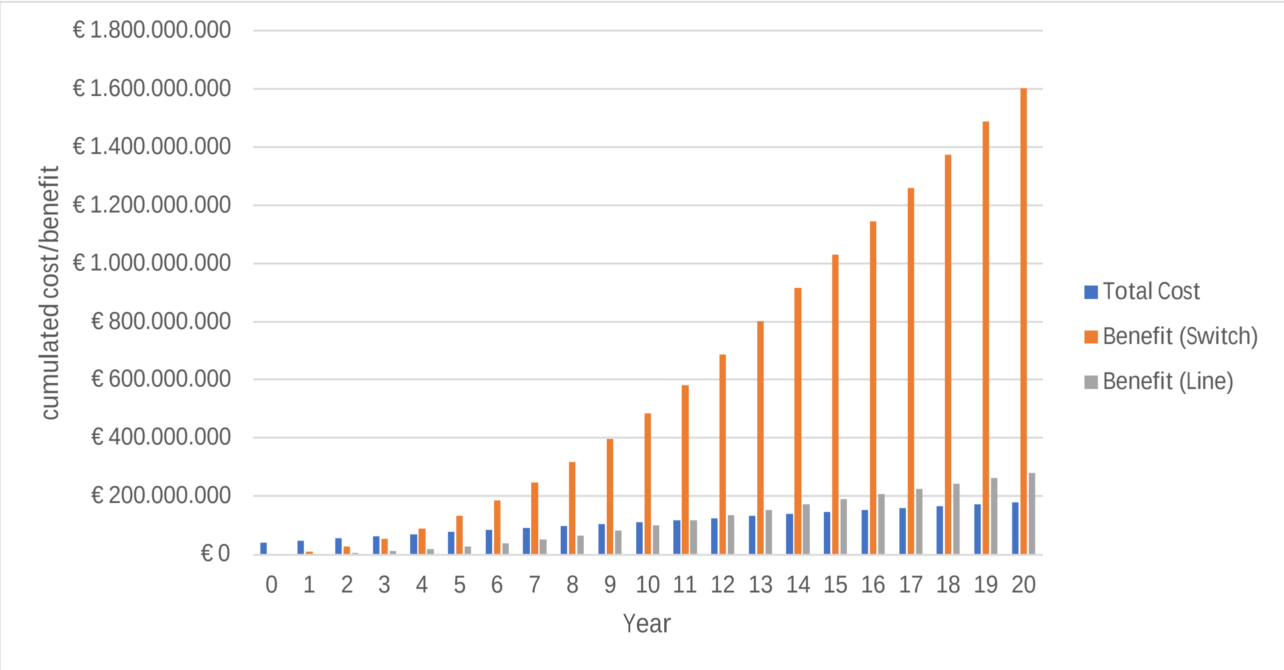

Figure 2: Cost / Benefit of the proposed scenario

7. Conclusion

This document defines a base case and compares the cost caused by the Digital Map between this base case and the "Fully evolved RCA" system. These costs are divided into 4 different types and described shortly. Although it is not easy to get an educated guess for the occurring costs, a rough estimate is shown. In case of a specific project, they may be used as a starting point, but a more detailed calculation, according to the individual circumstances, might be needed.

In addition to the occurring cost, the potential benefits of the introduction of the Digital Map are described. As the Digital Map itself does not create a benefit, the cost reduction caused by consuming systems and the improvement of processes is addressed instead. These values are either in line with the RCA business case [1] or they are based on inputs from different IMs.

In conclusion, the Digital Map shows a positive Business Case although the true and final cost and benefits cannot exactly be determined. In addition, a few assumptions had to be made and there are also still a few open questions (e.g. are there several dedicated map servers or only one, how is the Map Data transferred to the train, etc.) which have to be answered in the near future. Nevertheless, it is agreed, that there are some applications which rely on a detailed and trustworthy Digital Map. In case the Digital Map would only be partly available or not fulfilling all requirements properly, it is likely to have a negative impact on the overall RCA Business Case.

8. References

The following documents provide related references:

[1] RCA Concept: RCA effects – Business Case (Version Gamma.1): [RCA.Doc.10].
[2] RCA Glossary [RCA, Doc.14]
[3] RCA: Digital Map - Concept: [RCA doc. 46]
[4] Economic Justification of Accurate Onboard Localisation [20E084]
[5] RCA Domain Knowledge, Preliminary Issue [RCA.Doc.18]
[6] RCA Goals (Check – whitepaper/conceptual doc)