# RCA

Reference CCS Architecture

*An initiative of the ERTMS users group and the EULYNX consortium*

# Concept: RCA effects – Business case

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## Version history

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| Gamma.1 | 31.01.2020 | Bernhard Rytz / Jan Göritz | First publication after review RCA core group. |

# 1. Introduction

## 1.1. Purpose of the document

The document “Concept: RCA Effects overview” [RCA.Doc.37] gives a short overview of the main aspects of RCA effects and presents its business case. The overall effects of an RCA-based architecture include cost savings, capacity gains, safety and reliability. This document will focus on the business case (all direct financial effects) of implementing an RCA-based system.

An important point is that RCA is a reference architecture and only a specific implementation plan can be financially evaluated. Therefore, we show in this document:

- the financial evaluation for smartrail 4.0, a concrete implementation plan based on RCA;
- important factors to be able to extrapolate these finding to other situations of other IMs;
- summary of the findings.

**How is the case derived?**

The Swiss signalling programme smartrail 4.0 (SR40) has an existing, detailed evaluation of its business case (including an independent second opinion). Since SR40 contributes to and will be compatible with RCA, we will use it as a “base” business case here. That means wewe will use it to exemplify (extrapolate) the potential business case of applying RCA to other networks.

The document identifies the following main drivers of SR40 saving potentials:

- Reduction of CCS assets
- Reduction of non-CCS assets
- Automation of operations

Based on the “base case” from SR40, the absolute savings (purchasing power parity PPP-adjusted) are extrapolated linearly, based on different scaling factors as well as network characteristics of the infrastructure managers (IMs). These scaling factors are: number of points within the network, main track length and number of operational employees (operational train production). The network characteristics are: CCS complexity, traffic density and degree of automation, respectively. It is shown that for three different IM profiles, the extent of savings per main driver of SR40 differs significantly. Yet, for each IM the overall potential is large enough to justify further individual analysis.

**Overall effects**

Based on SR40, the benefits of a standardised (CCS) architecture on the European level have been estimated with a potential reduction in trackside lifecycle cost (LCC) of € 5 billion p.a. The main aspects of the business case are cost reduction, increased availability, capacity and safety, and a fast migration towards the European Rail Traffic Management System (ERTMS).

**Document structure**

The document is structured as follows:

- Chapter 2.: expected savings, investments and the business case of SR40 are discussed (base case)
- Chapter 3: the approach to estimate the potential benefits of SR40 for other IMs is described (extrapolate on base case)
- Chapter 4: brief conclusion
- Annex: a short description of the architecture and the functions of SR40

**How to apply this work**

IMs within the RCA group may decide on two complementary approaches in estimating the net saving effects:

- Initially, a rough analysis of its scaling factors and its network characteristics will be made, allowing a guesstimate of potential savings (accuracy of ± 50%). This analysis can be done within weeks based on the proposed linear model. A simple calculator will be provided.
- In a second step, a detailed investigation of all aspects of infrastructure cost reductions and migration paths along the different lines is necessary. In addition, the dependency between rolling stock and infrastructure will also need to be considered. This investigation will probably last some months and requires considerable effort. The SR40 experience may facilitate the investigation and reduce this effort.

## 1.2. Related Documents

[1] Concept: RCA Effects overview [RCA.Doc.37]

[2] Concept: RCA Effects - Capacity [RCA.Doc.12] a more in-depth treatment of capacity effects.

## 2. Establishing a base business case

As described in the introduction, we use data from SR40 to establish the base business case. As a reminder: SR40 strives to contribute to and to be compatible with RCA.
After successful implementation of SR40 at SBB[1], a positive nominal delta cash flow (benefit) of approx. 370 million € p.a.[2] will be generated starting around 2040. It compares with the base case "ETCS L1LS conventional" that is currently implemented at SBB. This base case assumes a comprehensive ETCS Level 1 Limited Supervision Baseline 3 with some lines operating ETCS L2 full supervision. The radio data transmission uses the FRMCS standard as soon as it becomes available.

The business case of SR40 at SBB can only realise its full potential when the full programme is implemented as a unified architecture. The business case relies on different contributions to achieve a steady-state yearly net benefit of 370 million € (nominal). The main contributions that benefit the business case, after the migration and national rollout are completed in 2040, are:

- reduction of control, command and signalling (CCS) assets
- reduction of non-CCS assets
- automation of operation

These benefits generate additional costs of 138 million € p.a. The costs are due to the maintenance and renewal of the CCS environment.
The saving potential as well as the additional costs are shown in the following graph. They will be explained in the following sections.

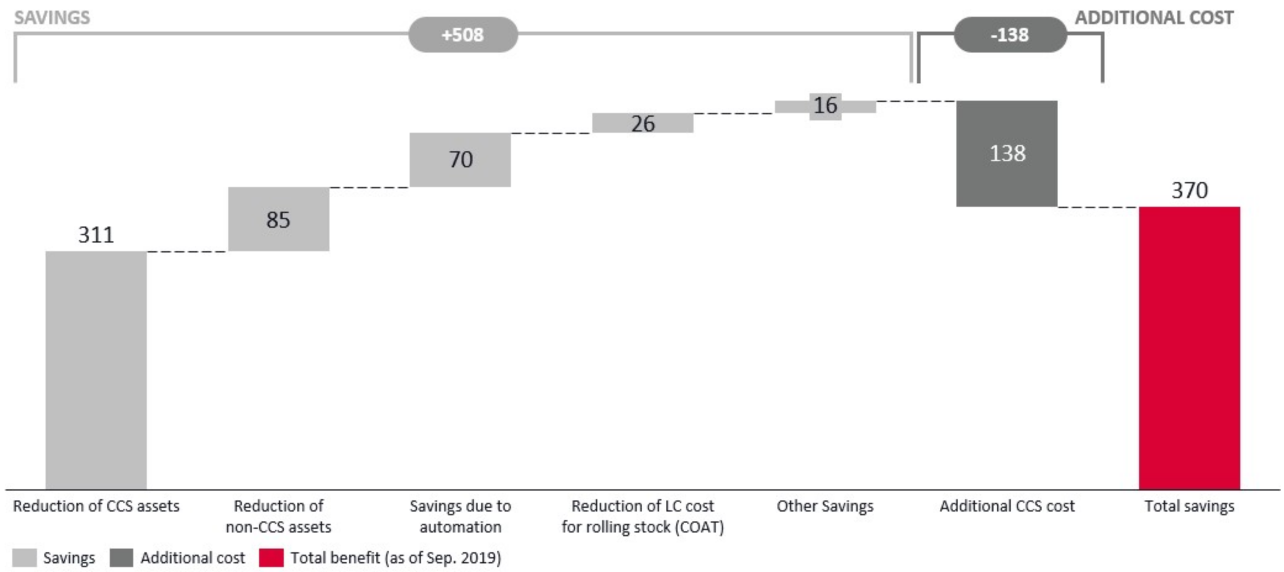



*Figure 1: Main saving potentials of SR40 for SBB as well as additional costs [in million € p.a.; nominal]*

### 2.1. Benefits of SR40

In this chapter, the three main saving potentials of SR40 – the reduction of CCS assets, the reduction of other, non-CCS-related assets and the automation of operations – will be illustrated for the SBB business case by breaking down the components and the gross savings of each aspect. Further savings potential, including the

[1] SR40 is a joint programme of SBB, BLS, SOB, RhB and TPF. The financial numbers in the considered case only refer to SBB. Each partner has their own business case.

[2] Throughout this paper, a conversion rate of 1 CHF = 0.9 EUR is used. The 370 Mio € correspond to 411 Mio CHF. In earlier communications a target of 450 Mio CHF has been stated. The 411 Mio CHF correspond to the currently validated effects.

implementation of FRMCS (5G), ATO, Energy savings and increased safety, will also be quantified for SBB, but will not be extrapolated to other IMs. For SBB, a separate business case has been developed to analyse the profitability of equipping the rolling stock with a CCS onboard application platform of trackside related functions (COAT, see also section 2.1.4). This analysis will also not be extrapolated in this paper.

### 2.1.1. Reduction of CCS assets

The main contribution to the savings generated by SR40 is through the reduction of CCS-related trackside assets during their whole lifecycle. In the case of SBB, the saving potential of 311 million € p.a. is derived from the following analysis:

**Reduction of interlocking replacements**
With the migration to SR40, the number of interlockings and trackside installations, such as signals and axle counters, that need to be operated, maintained and renewed is greatly reduced by 65%. The asset reduction is expected to generate average savings of 121 million € p.a. for SBB compared to the base case.

**Reduction of extension investments in train protection systems**
With SR40, SBB's trackside installations for train protection systems will be reduced by around 65%. As a result, savings of up to 100 million € p.a. will be achieved regarding upcoming investments in the current train protection systems that will be installed in the coming network extension phases over the next decades.

**Reduction of maintenance costs for train protection systems**
The reduction of the installations and investments in train protection systems will automatically reduce the maintenance costs of these systems. Here, the cost reduction amounts to 38 million € p.a.

**Benefit of automatic warning system (AWAP)**
Railway construction sites need to be safely secured. An automatic warning system (AWAP - Automatisierung Warnprozesse) directly linked to the interlocking warns the site workers in case of incoming trains. Thus, the increased safety and the reduction of safety personnel will generate expected savings of 30 million € p.a.

**Reduction of costs for further development of interlocking systems**
The existing interlocking systems (SIMIS W, Elektra 2 and ILTIS) currently in operation at SBB will be further developed in the base case. The development costs of these systems are higher than the costs of further development of the SR40 interlocking components. The difference amounts to approximately 22 million € p.a.

**Additional CCS costs**
Contrary to the benefits generated through the reduction of CCS-related assets, additional costs of 138 million € p.a. arise due to the maintenance and renewal of the SR40 CCS environment after the rollout. These costs need to be subtracted from the savings explained above, to obtain the net savings of 173 million € p.a. through the reduction of CCS assets.

### 2.1.2. Reduction of non-CCS assets

The total saving through the reduction of non-CCS-related assets is estimated at 85 million € p.a. in the steady state. This is composed of avoided or postponed network extensions and the savings related to flank protection as well as rail joints.

**Avoidance of network extensions**
With the successful implementation of SR40 from 2040 onwards, the existing network will be used more efficiently. Current estimations assume a capacity increase of 15 – 30% with SR40. From 2040, SR40 offers the possibility to use this additional network capacity in order to avoid construction work aimed at augmenting the capacity during the period under review. To determine the possible avoided network expansion costs in the SR40 case, it is assumed that an average of 1 expansion step can be omitted or that the construction

contained therein can be postponed far into the future after 2100. This leads to an expected savings potential due to avoided extensions of 60 million € p.a.

**Flank protection**

Starting in 2030, the derailment devices for flank protection will be gradually dismantled and SR40 will also eliminate the need for protective points. This results in expected cost reductions of approximately 6 million € p.a.

**Rail joints**

With the partial removal of trackside installations and the elimination of rail joints, the maintenance of the track is easier, leading to a reduction in renewal costs for the isolation joints by a factor of 8. Savings of 19 million € p.a. can be realised in railway-track maintenance.

### 2.1.3. Automation of operations

The benefits of automation with SR40 provides the third largest savings of around 70 million € p.a. These savings are due to the introduction of an integrated Traffic Management System (TMS) and the phase-out of the existing timetable planning tool (NeTs) and the train control systems (RCS and ILTIS).

**Traffic Management System (TMS)**

The new TMS platform should be available in the train-control centres as a leading planning and control system from around 2023.The benefits of TMS are based on implementing new efficient operational processes. Even though the current processes are mostly automated, an improvement in the automation is achievable. It will result in a reduction of timetable planners and network operators, leading to savings of around 63 million € p.a. In addition, the replacement of the functionalities of the existing IT systems through TMS will increase the savings by up to 7 million € p.a.

### 2.1.4. Reduction of life-cycle costs for rolling stock and other savings

According to the base case, the CCS maintenance effort for the rolling stock at SBB (passengers, freight and infrastructure) is divided into personnel expenses, IT costs and material costs. This maintenance is cyclic and is necessary during the whole lifecycle of the rolling material. In addition, a loss of income is generated while the trains are being refitted. With the platform COAT (CCS onboard application platform of trackside related functions) of SR40, CCS monitoring and maintenance updates will be done remotely, thus reducing the overall lifecycle costs. Expected savings of up to 26 million € p.a. are planned for the rolling stock in the business case.

Other savings that are not directly related to the CCS platform have been identified at SBB. The savings are generated from 1) an improvement in connectivity with the introduction of the FRMCS standard that will provide an efficient, reliable and available communication bandwidth; 2) a better and more accurate real-time localisation of moving objects through tagging; 3) a further development of ATO grade of automation and 4) a large energy reduction. Analysis shows that these savings amount to a reduction of around 16 million € p.a.

## 2.2. Investment cost of SR40 and business case at SBB

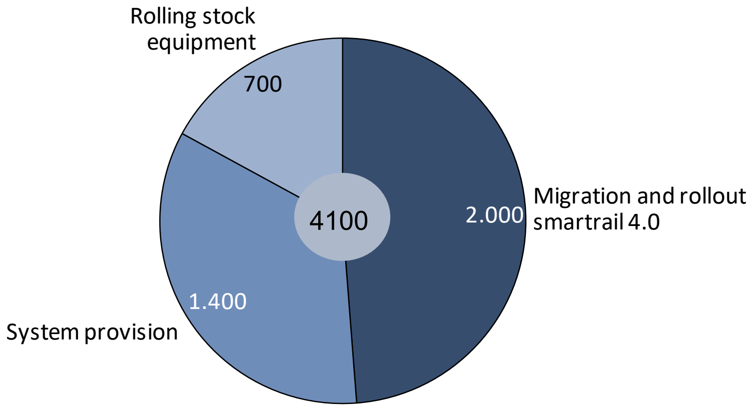
To realise these benefits, the total investment volume required for the overall SR40 programme up to 2040 at SBB amounts to approximately 4.1 billion €. Differentiated by type of cost, the investment is segmented as follows:

- System provision costs 1.4 billion € (project planning, testing and transformation)
- SR40 migration and rollout until 2040 contributes 2 billion €
- Investments for the equipment of rolling stock of SBB Passengers, Cargo and Infrastructure divisions amount to 0.7 billion €.

A different view of the total investment volume at SBB is provided through a differentiation by programme as outlined in Chapter 3. The costs per programme include the deployment and the rollout and are as follows:

- ETCS Interlocking (ES) – 1 200 million €
- Localisation/Connectivity and Security (LCS) – 1 150 million €
- CCS onboard application platform of trackside related functions (COAT) – 860 million €
- Traffic Management System (TMS) – 390 million €
- Automatic Train Operation (ATO-GoA2) – 170 million €
- Programme management – 330 million €

The graphic in Figure 2 shows the total investment volume of SR40 at SBB differentiated by type of cost and per programme.



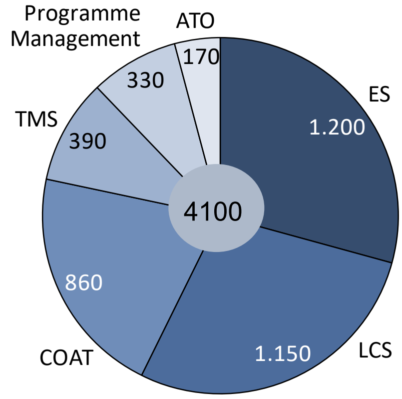




*Figure 2: Total investment of SR40 by type of cost (left) and by programme (right) [in million €; nominal]*

After successful implementation of SR40, a nominal positive cash flow delta (benefit) of approximately 370 million € p.a. compared to the base case "ETCS L1LS conventional" will be achieved from around 2042 onwards. This is illustrated by the navigator [I] in Figure 3. The necessary investment volume for the overall SR40 programme amounts to approximately 4.1 billion € up to 2041, shown by [II] in Figure 3. Of this total, approximately 1.4 billion € will be spent on the SR40 system provision (including project planning, testing and transformation) and approximately 2.7 billion € on the SR40 rollout. The latter includes approximately 0.7 billion € for the conversion of the SBB fleet (Passenger, Cargo, and Infrastructure fleet). Compared to the base case "ETCS L1LS conventional", SR40 leads to an additional investment of 1.4 billion € (nominal) until 2034, shown by [III] in Figure 3. From 2034 onwards, more benefits will be generated annually than the funds required. In a nominal view, the payback will be achieved after 21 years (from 2019) in 2040. In a dynamic view (inflation 1.5%, discount factor 2.5%), the payback is reached one year later in 2041 [IV]. The NPV amounts to 13 billion € in the selected observation period up until the year 2100.
The graphic below shows the total nominal investment for SR40 and the delta free cashflow compared to the base case ETCS L1LS at SBB.

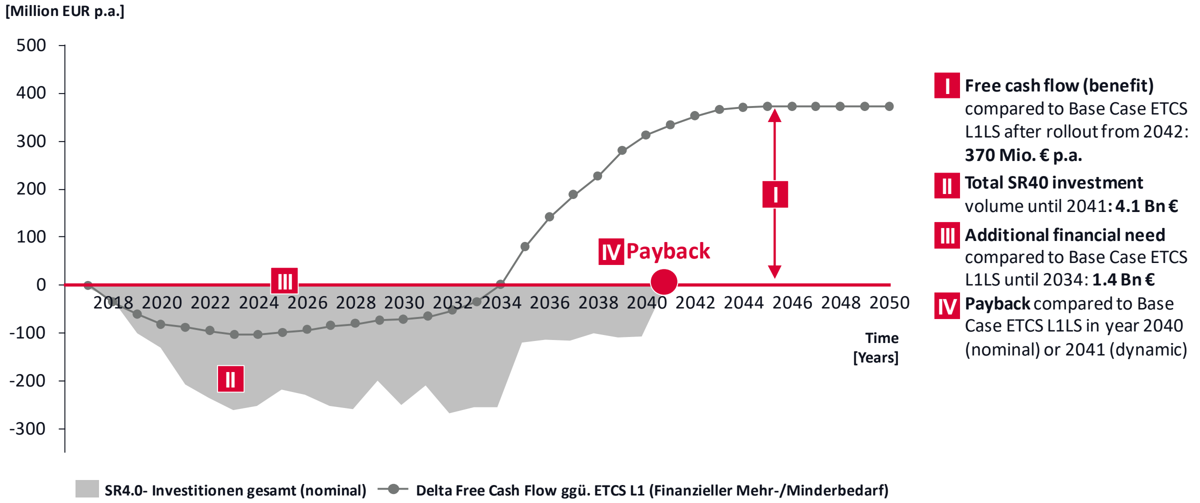



*Figure 3: Illustration of the SR40 business case at SBB.*

# 3. Extrapolation of the base business case

In this chapter, an approach to estimate the savings for other European IMs based on the base business case of the previous chapter is described. The aim is to demonstrate how the three main savings potentials of SR40 can be extrapolated to other IMs. To recall, these are the reduction of CCS assets, the reduction of non-CCS assets and automation through TMS.

This approach has been used for fictive as well as real IMs other than SBB, which have been anonymised and possess various network sizes and characteristics. Different scaling factors are used to measure the network size from the corresponding saving's perspective. The savings are further defined through specific network characteristics that determine how high the potential of each aspect is. These characteristics illustrate the network complexity, the network usage and the degree of operational automation.
To simplify the analysis, a linear modelling approach was developed for each savings potential. The model considers the scaling factors as main variables and the network characteristics as parameters for the marginal savings. By differentiating each network characteristic into three levels (high, middle, low), the robustness of the model is enhanced. The model is visualised by plotting a line per level for each savings potential against the scaling factor. This results in three graphics that will be presented in the following sections.
The analysis focuses on the benefits of the programme in the steady state after the full implementation of SR40 as a delta view with respect to the base case, which is IM specific.
The savings are shown as net savings to guarantee that the running costs generated through SR40 are considered. However, these additional costs will vary considerably between different IMs and require a detailed individual analysis for a more reliable calculation. To ensure comparability between IMs, the net savings are normalised to the average European price level, as shown in Figure 4.

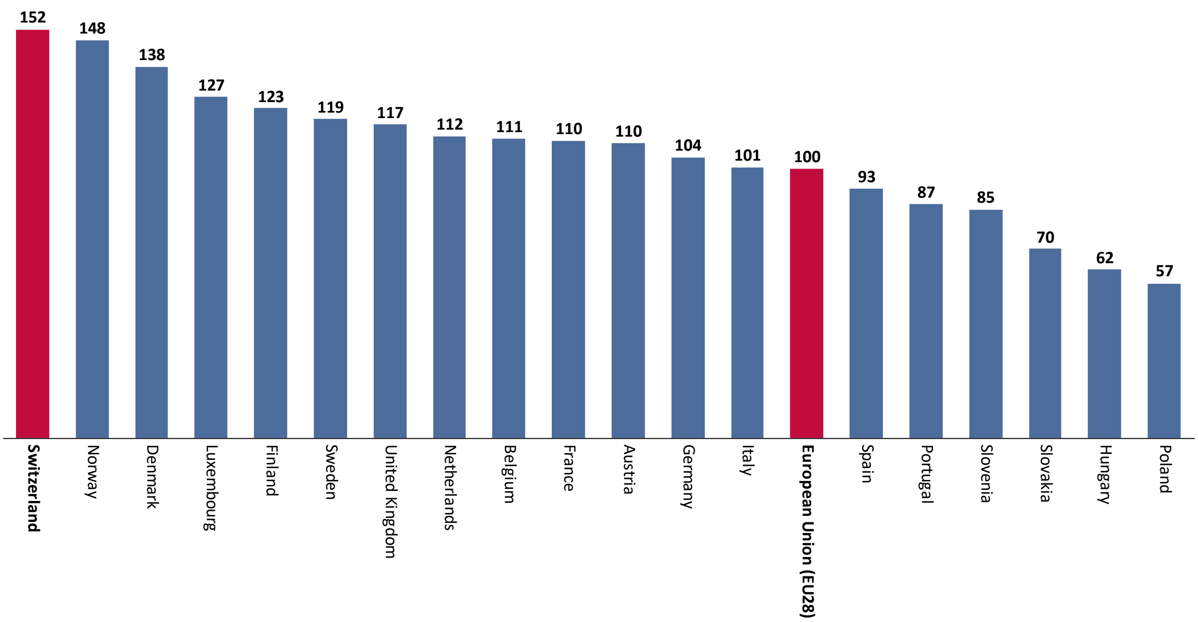



*Figure 4: Comparative price levels based on consumer prices for 2018[3]*

## 3.1. Reduction of CCS assets

The main driver of savings are CCS assets that are either being standardised, omitted or replaced as part of the implementation. This leads to a simpler system architecture, which results in a reduction in lifecycle costs. CCS assets are signals, trackside detection devices (axle counters and track circuits), shunting signals, train protection devices and level crossings.

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[3] ; Source: Eurostat (https://ec.europa.eu/eurostat/databrowser/view/tec00120/default/table?lang=en, retrieved on 12/11/2019 at 10:20 am).

As explained above, the basic idea of the extrapolation is to use a scaling factor to extrapolate the savings from the base business case to other networks. In the case of CCS assets, the scaling factor is the number of points within the network. The number of points is a suitable scaling factor, as points have a predefined number of required CCS assets that is relatively similar across different networks.
To determine the marginal benefit of reducing CCS assets, the relative reduction potential of elements per point is used as the defining network characteristic: the more existing elements can be omitted per point, the higher the marginal saving.
Consequently, the absolute saving is defined as the combination of the number of points as scaling factor and the possible relative reduction of CCS elements as savings rate per point. In other words, the higher the number of points and the higher the relative reduction of CCS assets, the higher the savings potential.

It is assumed that a critical number of points is required to benefit to the same extent from the implementation of RCA with respect to the reduction of CCS assets, as shown in this analysis. Therefore, the trajectories shown in Figure 6 are to be confirmed for very small IMs.

In the case of SBB, the reduction of CCS assets through SR40 is expected to have the following effects:

- Elimination of signals (currently 1.1 signals per point)
- Reduction of trackside train detection devices from 1.8 per point to 0.3 per point
- Elimination of shunting signals (currently 1 per point)
- Elimination of train protection devices (currently 1.5 per point)
- No effect on level crossings (0.4 per point)
- Additional 0.7 localisation devices per point

In total, the number of point-related assets (including the point itself) decreases from 6.8 to 2.4 per point (reduction of 65%). The number of points in the network of SBB is approximately 13.000 and the PPP-adjusted annual net savings generated by the reduction of CCS assets for SBB are estimated to be around 115 million € (nominal 173 million € p.a.).

As mentioned in the introduction, the respective network characteristic is classified into three levels. Based on the analysis of SBB, an anonymised IM and a fictive large-scale IM, the classification of the relative reduction of CCS assets is as follows:

- The reduction by two thirds realised by SBB determines the **high level**
- The reduction by one half as estimated for the anonymised IM sets the **medium level**
- The **low level** of reducing CCS assets, as assumed for the fictive large-scale IM, is set to roughly one third

For the determination of the potential reduction of CCS assets per point, it is assumed that all elements that can be eliminated at SBB can also be eliminated in other networks. Elements that are simply reduced and not eliminated are expected to decrease to the same number as for SBB. Moreover, it is assumed that the number of CCS elements per point cannot fall below a minimal threshold. The exact threshold must be determined in a deeper analysis.

The graphic in Figure 5 shows the expected reduction in CCS assets comparing the current mode of operation (CMO) to the future mode of operation (FMO) with SR40 for different reduction levels of CCS assets.

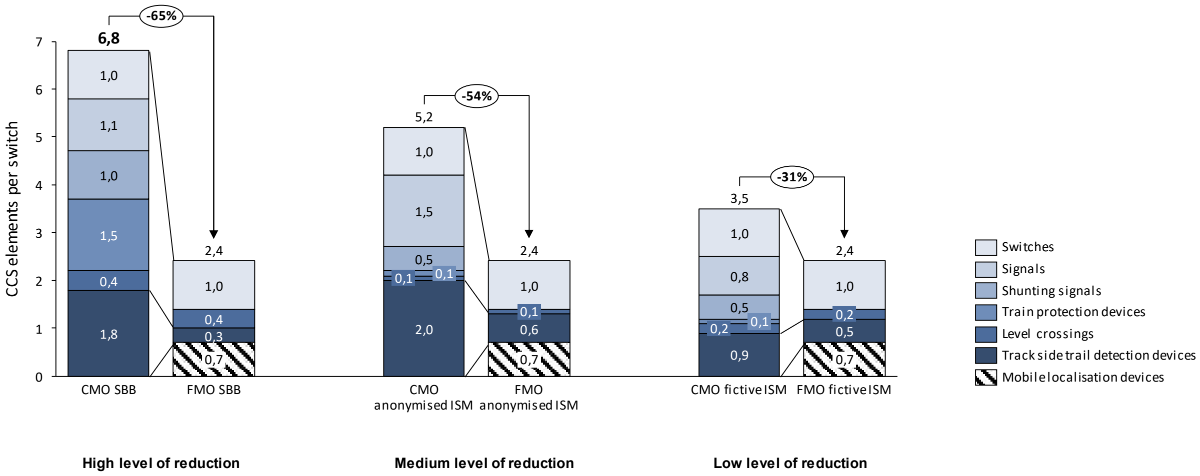


*Figure 5: Reduction of CCS assets for different IMs based on the three reduction levels*

Figure 6 shows the simplified linear extrapolation of possible savings through the reduction of CCS assets.

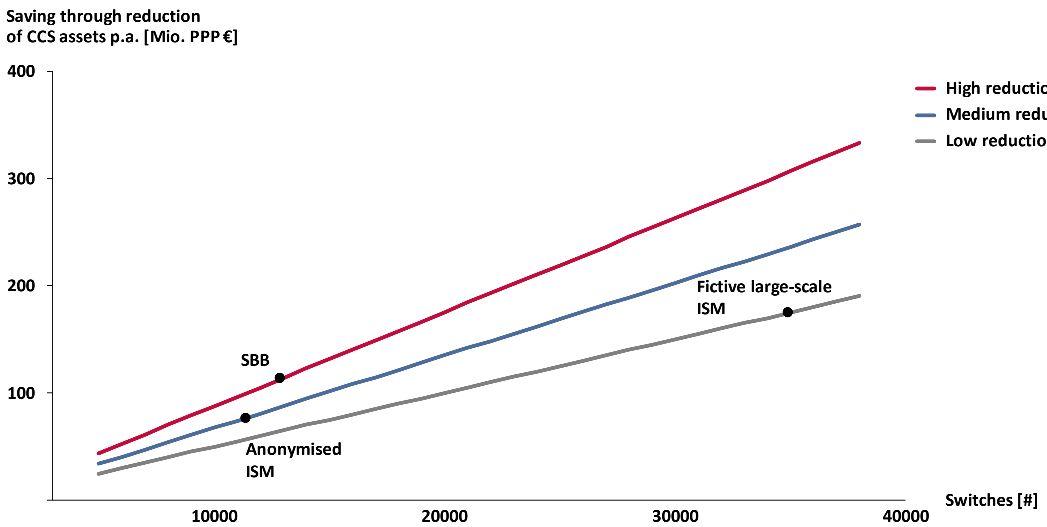


*Figure 6: Linear model for savings through reduction of CCS assets based on number of points and relative reduction of CCS assets*

## 3.2. Reduction of non-CCS assets

There is an impact on assets other than CCS assets as well. The main drivers are avoided or postponed extensions of the infrastructure network. In addition, the number of protective points and rail joints is reduced. Overall, this reduces the maintenance and renewal expenditures for non-CCS assets, from which other departments of the IM, such as superstructure, can also benefit.

Again, a scaling factor is needed to extrapolate the expected savings due to SR40 at SBB with respect to the reduction of non-CCS assets to other rail networks. In this case, the network size is measured by the main track length. It is assumed that the possible savings in terms of the reduction of non-CCS assets induced by SR40 increase linearly with the main track length of the network.
As required for the modelling approach, a network characteristic is used to determine the marginal savings rate per main track kilometre. Given that the biggest part of potential savings originates from avoided extensions, a suitable network characteristic is the traffic density. This is measured by the average annual number of train movements per main track kilometre. With a higher traffic density on the network, there is a greater need for extensions, which will be postponed or even avoided through SR40.

The absolute savings are obtained by combining the network size in terms of main track kilometre with the average traffic density. The larger the network and the higher the traffic density, the more savings can be realised through the reduction of non-CCS assets.
It is assumed that a critical network size is required to benefit to the same extent from the implementation of SR40 regarding the reduction of non-CCS assets as shown in this analysis. The assumed linearity cannot be applied to very small networks. Therefore, the trajectories shown in Figure 7 are to be confirmed for very small IMs.

The traffic density is defined by three levels based on the values of the real and fictive IMs that have been analysed. The categorisation is as follows:

- The traffic density of SBB with around 28’000 annual train rides per track kilometre defines the **high level**
- The traffic density of the fictive large-scale IM with around 22’000 annual train rides per track kilometre defines the **medium level**
- The traffic density of the anonymised IM with around 16’000 annual train rides per track kilometre defines the **low level**

The expected savings through the reduction of non-CCS assets are based on the three effects described in Chapter 2.1.2: avoided or postponed extensions, reductions of flank protections and rail joints (see Section 2.1.2). For the determination of the potential savings, it is assumed that the effects that are expected at SBB can be realised in other networks as well. In this analysis, a first approximation is made based on a simple extrapolation of the expected effects at SBB. In order to have a more reliable calculation for other IMs, further evaluations of the three effects on their networks are required.
Based on this approach of calculating the savings through the reduction of non-CCS assets, Figure 7 shows the simplified linear extrapolation of possible savings through reduction of non-CCS assets based on network size and on the three levels of traffic density

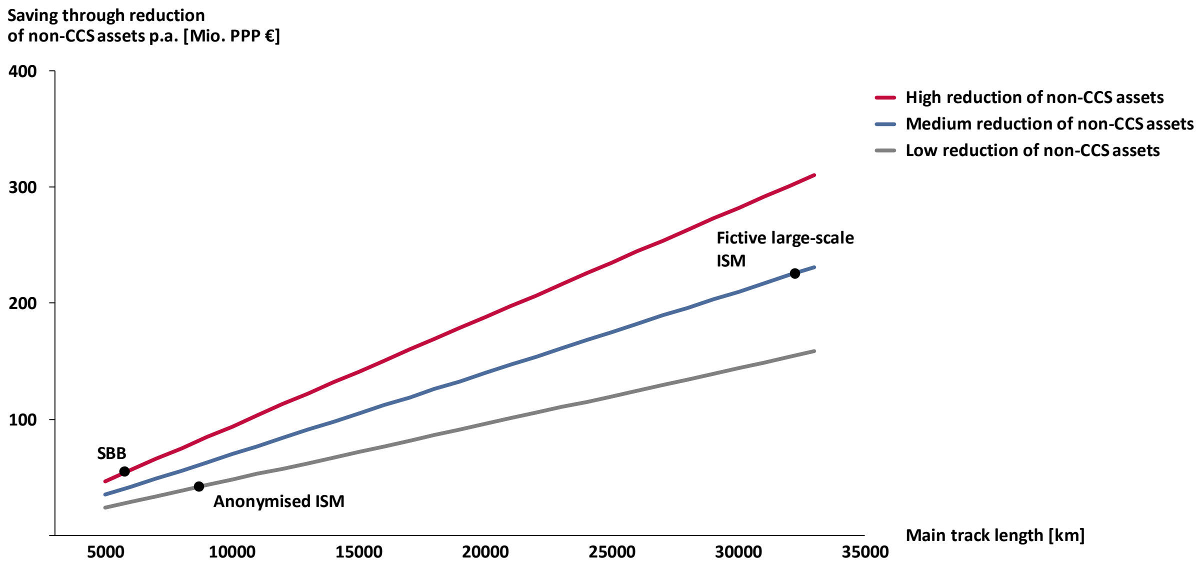


*Figure 7: Linear model for savings through reduction of non-CCS assets based on main track length and traffic density on the network*

## 3.3. Automation of operations

The third aspect considered in this analysis is the automation of train operations through TMS.
The scaling factor that is relevant for this aspect is the current number of employees operating the network, measured in full-time equivalents (FTEs). It is assumed that the savings through automation increase linearly with the current number of FTEs in train operations (operational train production).

The degree of automation (DoA) is used as the network characteristic, because it is a good approximation of the possible increase in automation.
In our model, the DoA is differentiated into four levels, which are defined as follows:

- **DoA 1**: 0% automation. Manual operation of interlockings – staff is operating the interlockings on site;
- **DoA 2**: 45% automation. Semi-automatic control of interlockings – remote control of interlockings or interlockings with predefined operation procedures;
- **DoA 3**: 76% automation. Automatic management of deviations – central operation centres with centralised control systems which can handle small deviations automatically;
- **DoA 4:** 82% automation. Almost fully automated operations (target state for SR40).

By increasing the level of automation to control train operations, less staff is required to handle the same amount of traffic, leading to a cost reduction. A railway with a low DoA today, has therefore a greater potential for savings through automation. Of course, the size of the railway (number of employees) is the second factor driving potential savings. It is assumed that there is a minimal operational staff size required to benefit from the implementation of RCA regarding the automation of operation, as shown in this analysis. Therefore, the assumed linearity cannot be applied to very small IMs.

The current mode of operation (CMO) at SBB corresponds to DoA 3, the CMO of the anonymised IM corresponds to DoA 2 and the CMO of the fictive large-scale IM corresponds to DoA 1. The expected savings are generated through a network operation at target level DoA 4. It is supposed that the analysed IMs can operate with a DoA 4.

Figure 8 shows the simplified linear extrapolation of possible savings through automation of operations based on the number of operational employees as well as the current DoA.

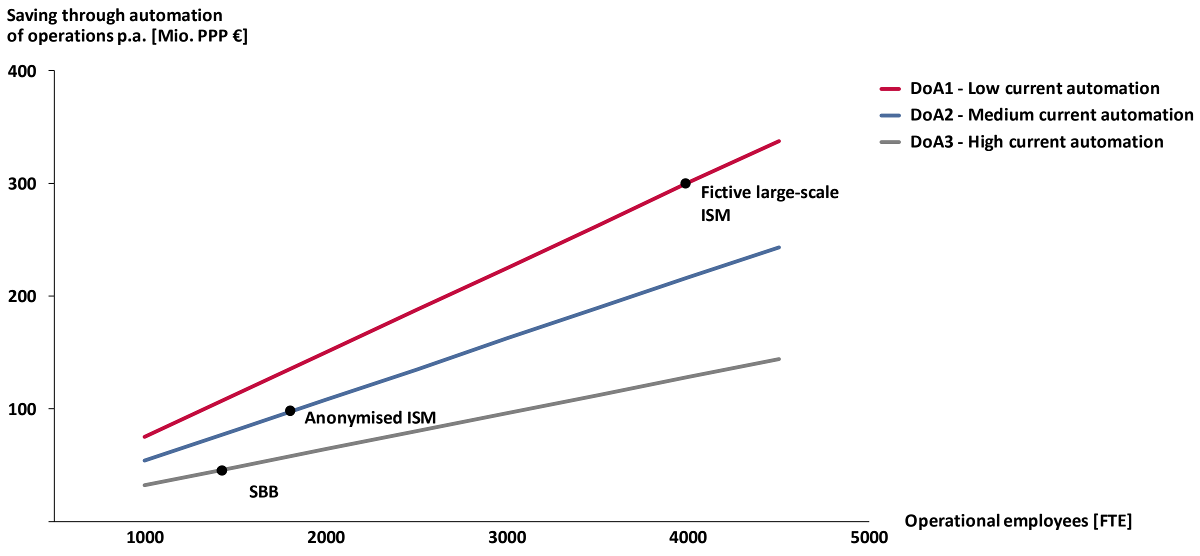


*Figure 8: Linear model for savings through automation of operations based on number of operational employees and current DoA*

## 3.4. Further possible analyses

There are two further savings aspects of the SR40 business case that have not been addressed in this analysis. They are the CCS onboard application platform for trackside-related functions (COAT/OCORA) and the energy consumption. These aspects are very specific to the IMs as well as to the railway companies and require a detailed analysis. In this chapter, a possible approach of analysing these savings will be outlined.

### 3.4.1. COAT (based on OCORA)

As described in Chapter 2.1.4, the rolling stock platform COAT aims to shift CCS elements from trackside to train side. Different aspects must be considered for the analysis of COAT. The analysis starts with assessing the lifecycle and the current CCS equipment of the existing rolling stock. Different migration scenarios need to be elaborated in alignment with the migration of trackside CCS equipment.
As an example, SBB differentiates the following migration scenarios for implementing COAT:

- **Migration scenario 1:** Rolling stock without ETCS equipment decommissioned before 2038 and never used on ETCS L2 or higher until then
- **Migration scenario 2:** Rolling stock with ETCS equipment decommissioned before 2038
- **Migration scenario 3:** Rolling stock without ETCS equipment (Baseline 0) being upgraded for SR40
- **Migration scenario 4:** Rolling stock with ETCS equipment (Baseline 2) being upgraded for SR40
- **Migration scenario 5:** Rolling stock with ETCS Baseline 3 (ETCS Only) being upgraded for SR40
- **Migration scenario 6:** New vehicles from 2025 onwards equipped directly with SR40 functionalities

Furthermore, the costs of refurbishing the rolling stock with on-board units in terms of engineering and homologation as well as downtime opportunity cost need to be determined.
Two aspects play an important role for the unit costs of on-board units. On a European level, an economy of scale can be achieved by defining COAT as a European standard and as an integral component of future rolling stock procurement. As of today, this assumption is not ensured. On a company level, the diversity of rolling stock types is crucial regarding the fix costs of system provision for COAT. As shown in the case of SBB, the current rolling stock portfolio needs to be analysed in detail for every IM to determine the rollout cost.

### 3.4.2. Reduction of energy consumption

The determination of savings through the reduction of energy consumption with SR40 mentioned in Chapter 2.1.4 depends strongly on the current mode of operation. Based on today’s measures to use energy more efficiently, the savings potential can vary substantially. Further information about existing assistant systems for train drivers to optimise train rides and speed as well as holistic approaches to enhance the timetable with respect to energy consumption is required from the IM. Based on these, the possible savings estimated for SBB can be extrapolated to other IMs.

## 4. Conclusion

The SR40 architecture follows the RCA (as well as EULYNX and OCORA). Therefore, the SR40 business case can be considered as a first approximation (base case) for the evaluation of an RCA business case.
It has been shown that, even though the SR40 business case has been developed for SBB and the Swiss railway infrastructure, other IMs may also profit from the implementation of a comparable architecture based on RCA. The aim of this paper was to explain the main drivers of the SR40 business case at SBB and to provide an approach for estimating the net savings effects at other IMs. The approach abstracts the varying key characteristics of the network and allows an extrapolation of the saving effects to other IMs. For the sake of simplicity, a linear model is used to obtain these savings. In Figure 9, the underlying scaling factors and network characteristics are illustrated and quantified for the analysed IMs regarding the three savings aspects.

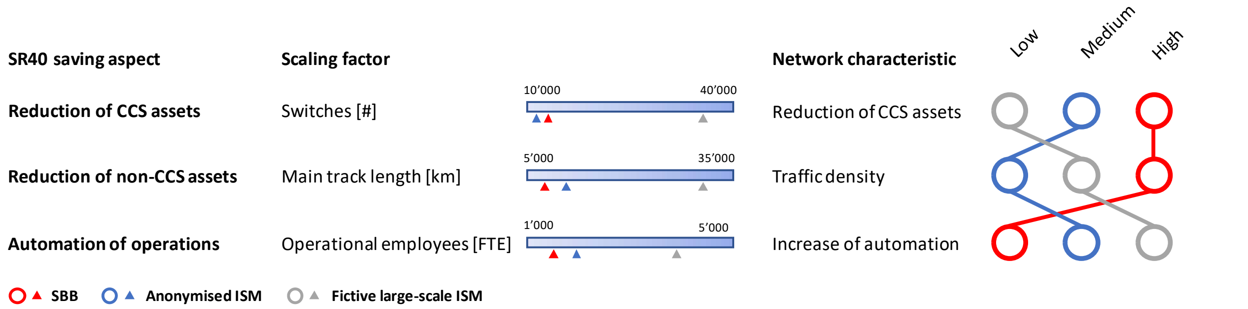


*Figure 9: Overview of network characteristics and scaling factors of the evaluated IMs, used for the model elaboration.*

As shown in Figure 9, the three exemplary IMs vary in terms of size and show different network characteristics. Nonetheless, all three IMs can realise net savings through the implementation of SR40, as summarised in Table 1. SBB, with a complex CCS system, generates the highest savings through the reduction of CCS assets. IMs with a high traffic density extend their network often. Extensions can be reduced by increasing the network capacity through SR40. This translates into high savings through a reduction of non-CCS assets for these IMs. IMs with a low current DoA benefit the most through an increase in automation through TMS.

| *[savings p.a. in million € PPP]* | **Reduction of CCS assets** | **Reduction of non-CCS assets** | **Automation of operations** |
|---|---|---|---|
| **SBB** | 115 | 55 | 45 |
| **Anonymised ISM** | 75 | 40 | 100 |
| **Fictive large-scale ISM** | 175 | 225 | 300 |

*Table 1: Annual savings through different SR40 aspects from the SBB business case and estimated for other IMs.*

As illustrated in Chapter 5, the total savings through SR40 at SBB amount to 370 million € p.a. (nominal). PPP-adjusted, this results to 245 million € p.a. In addition to the saving shown in Table 1, the business case of SR40 at SBB also includes benefits from the platform COAT (17 million € PPP p.a.) and a reduction in energy consumption and other savings (11 million € PPP p.a.). For other IMs, these aspects require a more detailed analysis.

Finally, the business case of SR40 at SBB will achieve its full potential when the whole programme is implemented as a unified architecture. Based on the experience of SBB, the implementation of SR40 requires a large amount of analytical and conceptual work over many years. SR40 will be implemented on an existing operational network.

Infrastructure managers within the RCA group may consider following the next steps to estimate the net savings effects of an RCA implementation:

- First, a discussion of the described approach to estimate the expected RCA savings for other European IMs based on the SR40 business case is necessary
- The described approach should be implemented in a simplified business-case calculator

- In a third step, a rough analysis of its scaling factors and its network characteristics allowing a guesstimate of potential savings (accuracy of ± 50%) will be made. This analysis can be done within weeks based on the proposed linear model.
- In a fourth step, a detailed investigation of all aspects of infrastructure-cost reductions and migration paths along the different lines is necessary. In addition, the dependency between rolling stock and infrastructure will also need to be considered. This investigation will probably last some months and requires a considerable effort. The SR40 experience may facilitate the investigation and reduce this effort.

## 5. Annex: SR40 architecture

This chapter is provided to help understand the business case of the previous chapters. SR40 strives to contribute to and to be compatible with RCA. For more information, see www.smartrail40.ch.

SR40 can be seen both as an efficiency-enhancement programme as well as an innovation programme: Through extensive digitisation and automation in the core of railway production – and the associated cost-reduction potential – the performance of the railway system and its competitiveness with other modes of transport should be increased.

With the SR40 programme, the Swiss railway operators are designing an overall architecture for realising the automation and optimisation potential in the areas of interlockings, command & control technology, trackside installations, vehicle architecture, radio data transmission and traffic management systems. The architecture follows the Technical Specifications for Interoperability (TSI) and the recommended CCS architecture (RCA) as well as OCORA (Open CCS Onboard Reference Architecture) in the domain of control command and signalling (CCS) for on-board and trackside subsystems. In addition, new technological developments, such as localisation and automatic train operation (ATO), will also be integrated.

The strategic goals defined for SR40 are as follows:

- Reduction of annual overall system costs in rail production by 370 million € (only SBB, infrastructure and rolling stock)
- Increase of track capacity by 15% to 30%.
- Increased safety, especially when shunting and on construction sites
- Increased availability of safety assets
- High mobile data transmission capacity for customers

The SR40 architecture is made up of five programmes that are described in the following.

**APS (Advanced protection system)**

SR40 pursues a comprehensive approach to the automation of rail production. This approach considers not only the "classic" trains, but also all types of moving objects, track-guided and non-track-guided, which can influence a safe rail production. Safety concepts such as “movement authority” and “danger area” are implemented directly in the interlocking to protect moving objects from collisions or from unauthorised track changes. Thus, it is responsible for checking whether movement authorities and danger areas are created, modified or cancelled. Other safety-relevant issues, such as requests for change of object states for points and barriers, are also controlled by the interlocking. Its functions have been consistently reduced to safety-critical assessments. In addition, a "Safety Manager" checks the operating status of the entire network for safety-relevant patterns that may occur due to unexpected events. It then initiates the necessary activities to ensure the integrity of the network. The ETCS interlocking is the basic element of the SR40 control command and signalling (CCS) architecture.

**Traffic Management System (TMS)**

The Traffic Management System (TMS) creates a uniform system for central planning and controlling railway operations, optimising timetables and informing customers. These activities are performed today by systems that are not seamlessly integrated with each other, such as NeTs (timetable generation), RCS and ILTIS (control system and disposition). The aim of SR40 is to achieve optimal and consistent planning over all time horizons of the timetable, and to increase and improve the level of operational automation.

The main goals of the TMS are:

- Automation and standardisation of today's partly manual processes
- Higher utilisation of the network (more trains, shorter train sequences)
- Continuous timetable generation across all time horizons for optimum use of available capacities
- Optimum replacement measures in the event of short-term malfunctions
- Realtime customer information

Even though TMS is not part of the RCA Architecture, it will use the platform-independence approach proposed in the architecture.

**Localisation/Connectivity and Security (LCS)**

In the future, trains should be located precisely, continuously (i.e., without fixed block spacing) and safely (including train integrity). This allows a more precise control of train movements (leading to more capacity) and a dismantling of the trackside detection devices (less costs).

A prerequisite for optimised control is efficient and secure radio data transmission. To this end, the programme is relying on the upcoming FRMCS standard to replace GSM-R (which will be based on an end-of-life 2G technology) because of additional bandwidth requirements. The FRMCS will use the same technologies as the public mobile radio systems. In addition to 4G, the focus is particularly on the future 5G.

**Automatic Train Operation (ATO-GoA2)**

Based on an integrated system of train control and automatic driving system, a (fully) automated operation in subways and enclosed railway systems has been operating successfully for decades. However, these systems cannot be applied to today's railway systems with different train control systems Class-B (ZUB, LZB, KVB...) and ETCS (L1LS, L1FS, L2...) and the non-discriminatory access of railway undertakings to the different infrastructures.

In order to calculate, implement and apply a time- and/or energy-optimised driving profile across countries (interoperable) as required, a standard for all interfaces of an Automatic Train Operation (ATO) system is being developed on the European level. SR40 is based on a complete monitoring by ETCS (Full Supervision). Its planned ATO solution will use the GoA2 (Grade of Automation level 2) interfaces currently specified under Shift2Rail, which will be part of the TSI in 2022. In this configuration, the driver remains responsible for the safe operation of the train.

**CCS onboard application platform for trackside related functions (COAT)**

The aim of the rolling stock platform COAT is to develop a train-bound on-board solution that enables a supplier-independent integration with the whole SR40 system. It is based on an open and published architecture. This platform should specify updates, extensions and adaptations to the interfaces. The implementation of these changes should be centralised and can be remotely downloaded to the rolling stock.