RCA

Reference CCS Architecture

An initiative facilitated by the ERTMS Users Group and the EULYNX consortium

Cost – Benefit Analysis for the Track Occupancy Concept

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Disclaimer

This issue is a preliminary version of this document. The content of this document reflects the current ongoing specification work of RCA. Requirements management and change management will be introduced in future iterations. The content may be unfinished, will likely contain errors and can be changed without prior notice.

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1. Introduction

1.1. Purpose of the document

This document comprises a cost-benefit analysis (CBA) for the track occupancy concept paper written as part of the RCA's vision for a digitalized and automated railway operation. The document is written to provide a top-down approach overview on how track occupancy, as pictured on the RCA framework, can show a beneficial business case.

1.2. Scope

This document aims at providing a short overview of the track occupancy principle, whose concept is developed in [RCA.Doc68].

The scope of the present document is to present a cost-benefit analysis when comparing an initial scenario for determining the occupancy of the tracks to the RCA target scenario.

The final target is framed in the context of RCA. To reach this situation a migration strategy needs to be defined. This transient scenario is not in the scope of this document nor the migration strategy.

The document will provide a qualitative and, where possible, a quantitative analysis of the costs and benefits provided by the target track occupancy concept in comparison with the current systems in place.

The scope is to describe the CBA methodology to be applied to the TO concept and to perform the analysis by taking as examples different scenarios for different countries.

1.3. Use of the document

This document can be used for getting an overview of the different economic benefits and additional costs introduced by the RCA Track Occupancy Concept and, once consolidated, to drive possible choices for implementing the new TO concept.

1.4. Target group

This document is intended for the RCA and OCORA members. It is the basic information for the System Pillar.

1.5. Related documents

Document	Remarks	Version number
RCA – Track Occupancy Concept	RCA Doc 68	1.0
RCA – System Architecture	Poster	
RCA plateau migration approach	RCA.Doc.28	1.2
CR1368	Economic Justification	
EUG-LWG Remit		
RCA mains concepts and goals		
Subset 026 ETCS SRS	SS026	3.6.0
LOC OB System Definition and Operational Context	22E126	1.0

1.6. Terms and abbreviations

AC	Axle counter
BCR	Benefit-cost ratio
CAPEX	Capital expenditure
CBA	Cost-benefit analysis
GHG	Greenhouse gases
GNSS	Global navigation satellite system
LOC-OB	Localisation on-board
NPV	Net present value
OPEX	Operational expenditure
RCA	Reference CCS architecture
TC	Track circuit
TDS	Train detection system
TMS	Traffic management system
TO	Track occupancy

1.7. Structure of the document

The document is based on the Track Occupancy Concept [RCA.Doc68] and is structured as follows:

- Chapter 2 offers an overview of the track occupancy function which varies from the initial scenario based on a trackside-centric approach for detecting elements on the tracks, to the target scenario based on a train-centric approach
- Chapter 3 explains the methodological approach followed to derive the cost-benefit analysis examples
- Chapter 4 describes the economic model used
- Finally, chapter 5 presents the conclusions of the analysis

2. Scenarios

2.1. Initial Track Occupancy scenario (baseline scenario)

Determination of track occupancy is extremely important to guarantee the safety of the rail operation. Track occupancy management is the cornerstone of the safety management of rail operation, which prevents two trains from collision.

Track occupancy determination is based nowadays on track detection devices that are activated when they detect any kind of rolling stock in the area they are monitoring. These hardware elements physically detect when a trackbound object is occupying a certain area of the network they are monitoring.

These elements, due to their technological principles, are reliable but do not provide an optimised output of the section of the track that is occupied by vehicles. The “occupied” status is given for the whole length of the track circuit, while only a part of it is occupied by the train. This leads to a loss of capacity.

On top of that loss of capacity, trackside elements constitute additional costs derived from their installation and maintenance.

This document assumes in the initial scenario a situation where track occupation is only determined by these trackside detection devices and any other additional elements to determine train position under ETCS (European Train Control System). Most of the networks use track circuits and/or axle counters to determine track occupancy.

Track circuits are continuously proving that the section they are monitoring is not occupied, while axle counters keep the section occupied when they determine that a certain number of axles have entered the block and not all of them have left it.

Both technological approaches have their benefits and drawbacks, but both represent an investment cost for installing the devices and block the track during the installation time and later in operation result in maintenance costs to monitor their performance and fix any malfunction.

The supervision of the safety of the system and the execution of the operational plan is done according to the information provided by these elements.

2.2. Target Track Occupancy scenario (project scenario)

In radio-based train supervision the train reports its own position by means of the train position report (TPR) message.

The ETCS Position Report in the target scenario contains at least the following data:

1. Reference location (LRBG)
2. Confidence interval of the train
3. Safe train length and train integrity information
4. Further train data (e.g., speed, ETCS mode, ETCS level).

Please refer to [SS026] chapter 7 for a complete list of ETCS parameters contained in an ETCS train position report.

In order to increase the capacity of the networks, and decrease associated costs to determine track occupancy, the use of new technologies such as GNSS and digital map (among others) need to be included in an interoperable way.

Providing the actual occupation of the tracks, in an accurate and reliable way will allow the trackside to have a complete picture of the situation of the occupancy of the tracks, and the use of trackside TDS could be minimised or even avoided. Additionally, other related processes such as planning, installation, maintenance, etc. of TDS will be positively impacted, as well as the service level for customers.

With this idea in mind, track occupation determination could move from the current trackside-centric approach, where track occupancy is determined by TDS, to a train-centric approach, where the track occupancy is given by relying on train position information.

However, relying on train position information has some constraints that depend on configuration factors:

1. Frequency of TPRs
2. Latency of the communication
3. Frequency of train integrity determination
4. Confidence intervals and inaccuracy

New ETCS functions such as “cab always connected” will facilitate the implementation of the target scenario.

All these factors may contribute to keeping some TDS in certain areas where accuracy plays a more key role to guarantee capacity during rail operation (e.g. stations, level crossings...).

This means that a combined track occupancy model is needed to determine which parts of the network are occupied, with the main goal of reducing the number of TDS, improving the capacity of the network, and keeping the operations safe.

3. TO CBA Methodology

This chapter describes the methodology that has been implemented to build our CBA Model dedicated to the Track Occupancy concept.

3.1. Cost-Benefit Analysis Principles in Rail Projects

The economic assessment of rail investment projects relies on cost-benefit analysis (CBA) principles that can cope with:

- the technical and economic peculiarities of the rail sector which is defined by its capacity to provide fast and regular services to a large number of passengers and freight volumes in a safer way than other modes of transportation (road, air and maritime)
- its capital-intensive construction costs together with significant operation and maintenance costs.

Rail transport is also characterized by very large economies of scale and long-term project expectations. CBA studies also intends to optimize costs induced by such project.

In general, the cost-benefit analysis assesses the economic impact of projects, using a single value (NPV) that provides the main indication of the project's economic performance. The analysis includes some of the following items:

- Economic: Investment costs (CAPEX), change in operating and maintenance costs (OPEX) of the infrastructure and vehicles.
- Capacity changes: Impact of increase of capacity on the current network and impact of avoidance of network extension (CAPEX) resulting in higher network utilisation.
- Indirect effects: for example environmental impacts or social benefits.

In a nutshell, the Track Occupancy concept drives evolutions on track, on-board and system management that can be described in the following figure:

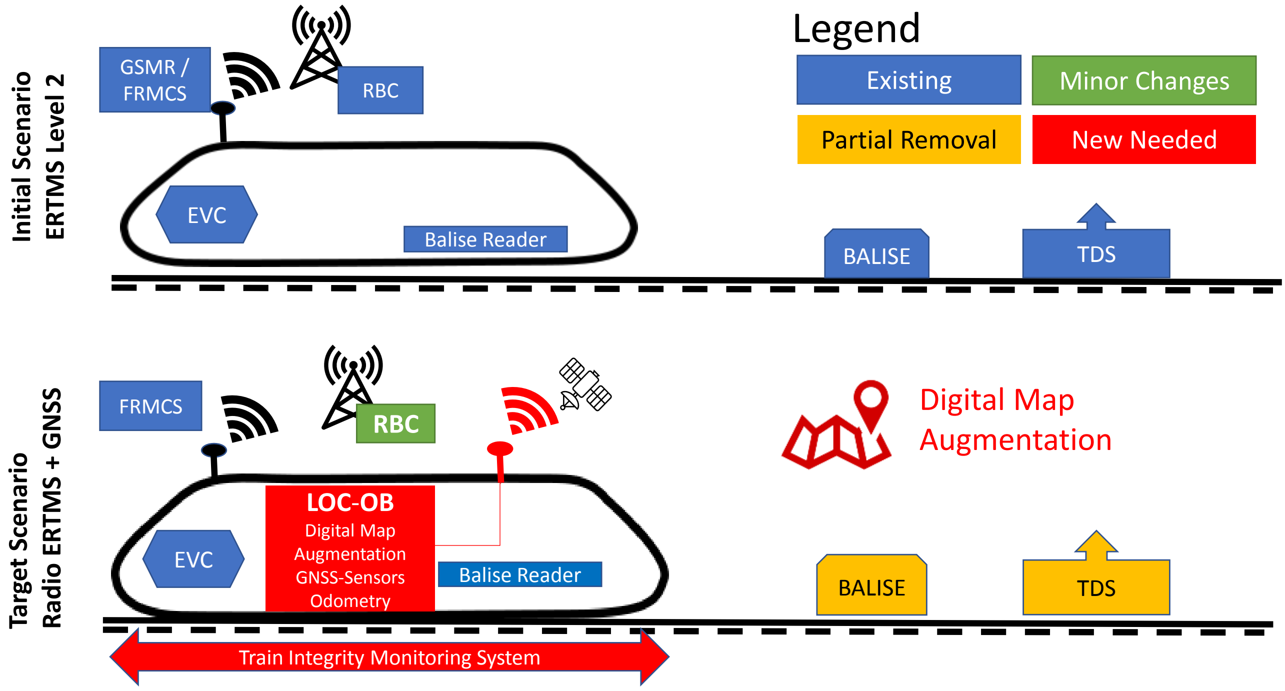

Figure 1: Initial scenario vs target scenario

As depicted in the previous figure, in order to achieve the train-centric approach, the train needs to be equipped with additional devices/sensors to get a reliable and accurate position. The specific identified functions of the LOC-OB are described in [22E126]. This additional equipment represents additional cost to the rolling stock but allows the removal of trackside equipment.

As a preliminary action, the European Guidelines to cost-benefit analysis of investment project (EC 2015), the Railway Project Appraisal Guidelines from the European Investment Bank, which respond to the need for EU-harmonised procedures for the socio-economic and financial appraisal of rail projects following the latest developments in the sector were analysed. We also considered the Return of Experience of many projects or initiatives assessing Rail & GNSS (based on public publications) in Europe.

CBA case	Holders	Program	Date	Document in reference
SR 4.0	SBB – ERTMS User Group – EULYNX consortium	SBB	2020	RCA Business Case for IMs
STARS	UNIFE	H2020	2018	D6.2 Cost Benefit Analysis
Hitachi	Consortium – coordinator	GSA	2020	D1.4 – CBA for Virtual Balise Concept
X2Rail 2	Consortium – coordinator: Alstom France	H2020	2020	D4.5 Cost Benefit Analysis
HPMV	SNCF	SNCF	2017	Rapport d'étude Socio économique
OCORA	DB – SBB – SNCF	Europe's Rail JU	2020	Open CCS On-board Architecture

Table 1: Related CBA documents

Those initiatives represented in Table 1, are very heterogeneous but target a similar objective. Such comprehensive approaches remain very challenging due to the variety of the starting point of scenarios, the processing of transition phases and lack of data for quantitative and qualitative markers allowing for refined global assessment of projects.

Then, a dedicated methodology for the “Track Occupancy CBA” that focuses on the analysis of the TO implementation costs and benefits while transferring the track occupation determination from a trackside-centric approach to a train-centric scenario was created. A diversity of different input parameters and specifics in different countries as well as the availability of data during the exercise were taken into account when developing the model and the strategy to follow. This methodology is presented in the next chapter.

3.2. Track Occupancy: methodology of Cost-Benefit-Analysis

The Track Occupancy concept opens new possibilities for the railway stakeholders’ benefits:

- Contribute to major savings by reducing the need for most of the trackside TDS
- Increase of network capacity
- Improve availability and quality of service
- Facilitate and accelerate the digitalisation of rail, providing scalable solutions for accurate railway positioning, which is essential for safety and better user experience.

To better assess those benefits, the “TO CBA” Methodology falls into 6 main phases:

2

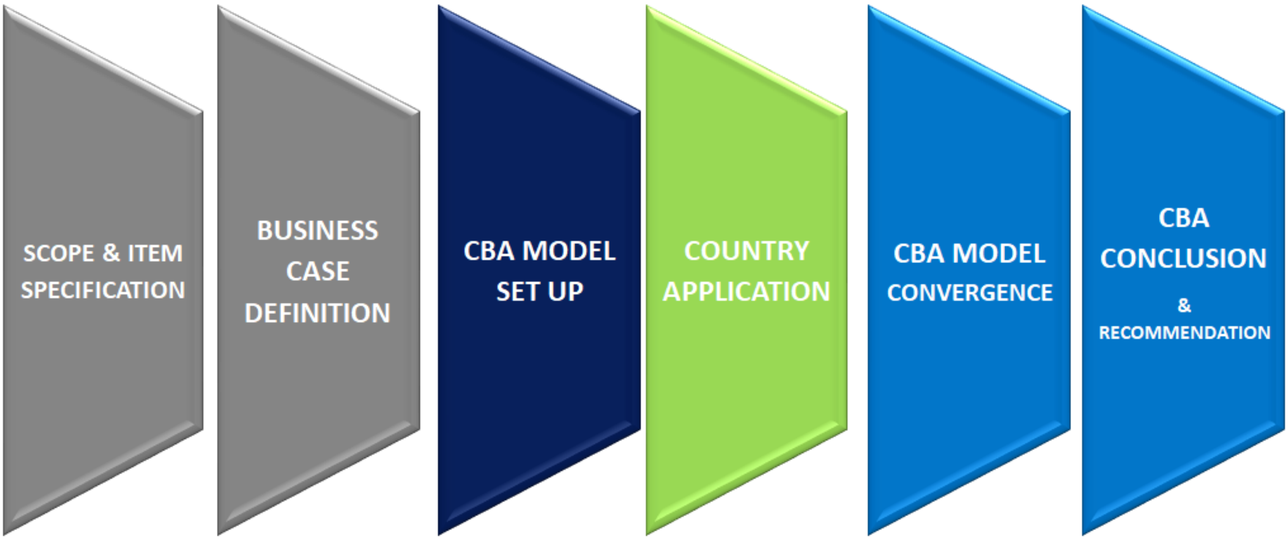

Figure 3: Methodology workflow

Each phase is described in detail in the following chapters.

3.2.1. Phase 1: Scope & Item Specification

Due to the expected development of the onboard localisation systems in the context of RCA to provide reliable localisation information with the focus set on the target scenario, the economic impact on the trackside needed to be considered. For this reason, items with a direct or an indirect impact on the CBA calculation, as well as other qualitative inputs, were included in a list to facilitate the decision-making process and the analysis itself.

The item description refers to the following characteristics:

- **Type:** Trackside, on-board or system depending on the asset usage
- **Stakeholders:** IM (infrastructure manager),RU (Railway Undertaker), depending on who will carry the cost or collect the benefit.
- **Impact:** Cost and/or benefits depending on the impact of the items in the CBA calculation. Both are possible if it entails a cost during a period and a benefit for another period.
- **Type of cost:** CAPEX meaning an impact on investment and OPEX meaning recurrent annual impact on Profit & Loss.
- **Contribution:** Representative of the part of the impact directly linked to the Track Occupancy (TO) concept and the part of the impact shared with others initiative. We classified this contribution into 4 groups:
  - Group 1 enhanced LOC-OB and train integrity: Items that are directly linked to the change in train localisation processes within the TO concept. 100% of the costs/benefits can be linked to Train Localisation technological choices.
  - Group 2: CCS-assets (devices – e.g. track circuit- and related activities): that are closely linked to train localisation (train tracking (track circuit, AC), safe train separation (L3)) that benefit from train localisation developments. Not 100% of the costs/benefits can be linked to Train Localisation technological choices. As a first rough assumption, 30% of the benefits related to localisation choices can be allocated to these items. This has to be confirmed once the model is implemented.
  - Group 3: Train operation: other CCS- and Traffic management-related items that are linked to train localisation and benefit from train localisation technological advancements (e.g., ATO accuracy, traffic regulation, energy savings, ...). As a first rough assumption, 10% of the benefits can be allocated to these items. This has to be confirmed once the model is implemented.
  - Group 4 social benefits: all other items that benefit indirectly (social impact of a better transportation offer): not explicitly studied and considered in this analysis.

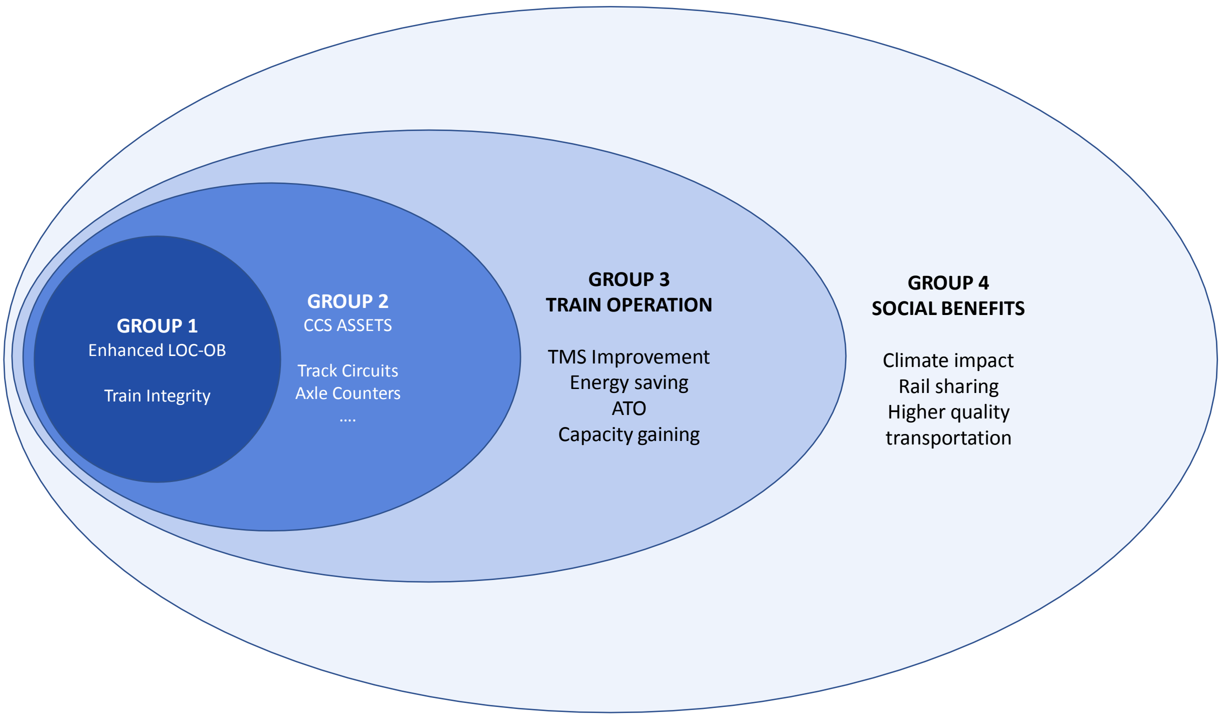

Figure 4: Contribution classification

Inputs from several countries have been used as examples for this CBA. These examples have been studied, benchmarked and challenged.

The following assumptions apply:

1. Rolling stock on-board communication equipment costs are not explicitly considered because they are partially included in the LOC-OB and partially shared with other on-board functions, which already need communication devices in the initial TO scenario.
2. A new dedicated radio infrastructure is not needed to implement the TO train-centric approach because it is already needed in the initial TO scenario.

A list of 17 items has been identified for the scope of this TO CBA. They are summarized in the following table.

TYPE	ITEMS	STAKEHOLDER	IMPACT	NATURE	CONTRIBUTIO
					GROUP
Track	Balise	IM	Benefits	CAPEX / OPEX	1
Track	Axle Counters	IM	Benefits	CAPEX / OPEX	2
Track	Track Circuit	IM	Benefits	CAPEX / OPEX	2
Track	Field Connection	IM	Benefits	CAPEX / OPEX	2
System / data	Digital Mapping Services	IM	Cost	CAPEX / OPEX	1
System / data	GNSS augmentation services	IM	Cost	CAPEX / OPEX	1
Board	LOC-OB	RU	Benefits / Cost	CAPEX / OPEX	1
Board	TIMS device (Train Integrety & Lenght)	RU	Benefits / Cost	CAPEX / OPEX	1
TMS	Capacity Increase	IM + RU	Benefits	OPEX	2
TMS	Network Extension saving	IM	Benefits	CAPEX	2
TMS	Energy Savings	IM + RU	Benefits	OPEX	3
TMS	Improved Track Management Services	IM	Benefits	OPEX	3
TMS	Improved Fleet Management Services	RU	Benefits	OPEX	3
TMS	New Passengers Services	RU	Benefits	OPEX	3
TMS	Social Benefits	RU	Benefits	OPEX	4
TMS	Demographic change	RU	Benefits	OPEX	4
TMS	Less Polution	RU	Benefits	OPEX	4

Table 2: Items considered in the CBA

The main costs and benefits are detailed below:

<table>
<tr><th>TRACK</th><th></th></tr>
<tr><td>Balise deployment costs (CAPEX) and associated OPEX savings</td><td>The proportion of balises dedicated to train localisation that can be decommissioned (or not installed) by using TO concept.
The following components shall be considered for balises:
CAPEX

1. System studies: balise positioning design (schematic plans for installation), balise content determination
2. Installation studies: the balises
3. Procurement: purchase of balise and its mounting device
4. Intervention: interruption of operation, track access/track protection, staff
5. Installation: programming and mounting of balise,
6. Post-installation check out testing (balise reading and checking of balise content)
7. “as built” schematic plans update (after installation)

OPEX

1. Failure detection: possible analysis to identify the balise in failure</td></tr>
</table>

TRACK	
	2. Replacement after failure: purchase of balise and its mounting device and possible individual components such as cabling 3. Intervention: interruption of operation, track access/track protection, staff 4. Re-installation (in case it is needed): programming and dismounting/re-mounting of balise 5. Repeated Post-installation check out testing (balise reading and checking of balise content)
Deployment costs (CAPEX) and associated OPEX savings for other CCS track assets	The proportion of trackside CCS (track circuits and axle counters) used for block occupancy supervision that can be decommissioned (or not installed) by using TO concept. The following components shall be considered for track circuit (TC) and axle counter (AC): CAPEX 1. System studies: TC/AC positioning design (schematic plans for installation) 2. Installation studies: survey prior to studies e.g., for checking possible constraints on track 3. Procurement: purchase of TC/AC devices (for TC: emitter/receiver, cables, power supply; for AC: counter, mounting device, cables, power supply) 4. Intervention: interruption of operation, track access/track protection, staff 5. Installation: mounting of devices 6. Post-installation check out testing (tuning) 7. “as built” schematic plans update (after installation) OPEX 1. Failure detection: possible analysis to identify the TC/AC in failure 2. Replacement after failure: purchase of TC/AC devices (emitter/receiver, cables, power supply) 3. Intervention: interruption of operation, track access/track protection, staff 4. Re-installation (in case it is needed): dismounting/re-mounting of devices Repeated Post-installation check out testing (tuning, reset)
Deployment costs (CAPEX) and associated OPEX savings for track assets connection	For some business cases, the total removal of trackside assets will also reduce the need for connectivity and power supply along the track, providing further savings.

Table 3: Track-related elements description

SYSTEM / DATA	
Trackside digitalisation	TO concept requires a mapping of the entire rail network with an initial collection campaign and regular updates. Updates will also be requested upon track evolution. This will generate CAPEX and OPEX costs for the digital map generation, storage, and transmission to trains. Nevertheless, this digitalisation is already needed to support other functions (ref Digital Map - System Definition, RCA.Doc.59). Thus, our CBA will consider only a percentage of this cost. This

	percentage will be frozen during the CBA set-up, based on conclusions on RCA group dealing with Digital Map.
Ground and satellite transmission system deployment and maintenance	Radio-based train supervision (ETCS Levels 2/3) requires new technologies for train localisation. GNSS augmentation reception and dissemination system (deployment and maintenance) is deemed necessary to achieve the enhanced LOC-OB and will then be a cost for the CBA.

Table 4: System-related description

ONBOARD	
Rolling stock onboard localisation system equipment (LOC-OB), installation and development	TO concept implies a major upgrade of the OBU (balise reader, precise odometer, various other sensors …) and further important evolution (digital mapping processor, multi-source GNSS receiver and processor, augmentation information, possibly other future technologies) that will be developed with an efficient on-board CCS modularity.
TIMS (train integrity and length)	Onboard device providing train integrity data and potentially train length in a safe way. Train integrity provided by the on-board is necessary to determine the safe train length and hence implement ERTMS L3 application, which is in the target TO scenario. [RCA.Doc68]

Table 5: Onboard-related descripction

TMS	
Capacity increase	ETCS L3 will improve traffic capacities for a given track line without the need for an expensive, complex, and timely infrastructure extension and then generate revenue when this capacity can be commercialised.
Network extension savings	See capacity increase.
Reduction of resources	The TO target scenario, will drive transportation towards some environmental savings (less resources to produce, operate, store and dispose of).
Improved track management services	Track digitalisation will also improve track maintenance operation as well as rolling stock availability, potentially leading to savings in new train CAPEX engagement.
Social and environmental benefits	Making railways a more efficient, punctual and reliable transportation system will have an impact on passengers' satisfaction. This encourages people and industries to use it in a wider way, migrating to a greener and more efficient way of transport for goods and people.

Table 6: TMS-related description

3.2.2. Phase 2: Business case definition

A CBA looks at project benefits that accrue to both direct users (e.g., rail passengers or freight rail shippers) and non-users (e.g., society at large), as well as the costs required to achieve a project's expected outcomes. Benefits could also include societal and environmental factors, while costs should include the capital, operating, and maintenance expenses necessary to deliver the project benefits.

The systematic process of identifying, quantifying, and comparing expected benefits and costs helps decision-makers organize information about, and evaluate trade-offs among, alternative transportation investments. A CBA compares the anticipated benefits that accrue from a target scenario to the anticipated costs of an initial scenario over a specified period of time.

In this section, the business cases, in which the model will process the above items, are characterised. Within the framework of track occupancy, the business cases can be very diverse including high-speed lines, regional lines, local lines, passengers and/or freight traffic, starting from very different modernisation status. A flexible approach is required to include various cost-benefit analyses, depending on the different partner networks, organisations, and data availability. The following cost-benefit analysis characterisation is defined:

CHARACTERISATION	DEFINITION
NAME	Present the name/label under which the CBA has been published
SCOPE	Define the scope (Network, Rolling stock, traffic...) of the CBA Study
INITIAL SCENARIO	Define the scenario in reference before the project implementation
TARGET SCENARIO	Define the scenario to be implemented during the project
TIME FRAME	Define the time frame taken into account for the scenario comparison

Table 7: Business case characterization

The business case scope needs both stakeholders, infrastructure manager and railway undertaker, prospective reporting the length and type of tracks, the number of stations, when available, due to the fact they have additional safety requirement, the rolling stock sizing and generic economic data. The table below gives a comprehensive list of parameters, although they might be limited to track and rolling stock data in the majority of business cases.

BUSINESS CASE SCOPE		BUSINESS CASE SPECIFICATION	
NATURE	DEFINITION	BC1	
		INITIAL SCENARIO ETCS L1	TARGET SCENARIO (TO CONCEPT)
TRACK	Single	KM	KM
	Dual	KM	KM
ROLLING STOCK	ROLLING STOCK	QTY	QTY
	TRAIN CAPACITY	SEAT / TRAIN	SEAT / TRAIN
STATION	NUMBER OF STATIONS	QTY	QTY
TRAFFIC	TRAIN	TRAIN / DAY	TRAIN / DAY
	PASSENGERS	PASSENGERS / TRAIN	PASSENGERS / TRAIN
	FREIGHT		

Table 8: Element comparison

The scenario will be equivalent to the different cost-benefit analyses, enabling later comparison and benchmarking. Specifically, two scenarios (initial and target) have been identified (see 2).

- **Initial Scenario:** Track occupancy using trackside detection devices under ETCS (European Train Control System) Level 1/2.
- **Target Scenario:** Track occupancy using radio-based train supervision with the train reporting its own safe and continuous position and integrity via onboard equipment.

Other initial scenario (i.e. with no ETCS standard) are considered as out of scope of this study as the CBA focuses on the contribution of the track occupancy evolution and must assessed the benefits of the installation of ERTMS with LOC OB to ERTMS without LOC OB.

The time frame must be consistent with the economic lifetime of the main assets and is relevant to calculate an NPV and take into account OPEX and benefits occurring over time. Although the investment horizon is often indefinite, in a project analysis it is convenient to assume reaching a point in the future when all the assets are in place. It is at that point that it will be possible to judge whether the investment was a success. A **20-year reference time horizon** is applied**, being in the average of the upper limit of equipment life span.**

3.2.3. Phase 3: CBA model set-up

This economic calculation will point out differences between the target scenario and the initial scenario within the project timeframe. For the proposed model, the following considerations apply:

- The Track Occupancy concept CAPEX differences, meaning the additional CAPEX required onboard and the CCS track CAPEX savings for the completion of the system migration.
- The exploitation phase of OPEX differences during 20 years of network operation between the 2 scenarios
- No costs/savings during the migration time have been considered since no migration scenario has been modeled; only the final stages of each scenario have been compared. Implementing country-specific migration scenarios would provide an even more realistic view but would require the will to really implement the TO concept in the specific country.

For each item, the CBA will specify the unit CAPEX, the annual expenses per unit and per year and the quantified differences between both scenarios.

ITEMS	DEFINITION	BUSINESS CASE			
		CAPEX	OPEX	INITIAL SCENARIO	TARGET SCENARIO
Track	Balise	€/unit	€/unit/year	QTY / KM or total QTY	QTY / KM or total QTY
Track	Axle Counters	€/unit	€/unit/year	QTY / KM or total QTY	QTY / KM or total QTY
Track	Track Circuit	€/unit	€/unit/year	QTY / KM or total QTY	QTY / KM or total QTY
Track	Field Connection	€/unit	€/unit/year	QTY / KM or total QTY	QTY / KM or total QTY
System / data	Augmented GNSS	TBD	TBD		QTY / KM or total QTY
System / data	Digital Mapping Services	€/KM	€/KM		
Board	ROLLING STOCK			QTY	QTY
Board					
Board	LOC-OB	€/unit	€/unit/year		QTY / TRAIN
Board	TIMS	€/unit	€/unit/year		QTY / TRAIN

Table 9: Main track and onboard elements

3.2.4. Phase 4: Country application

The CBA is intended to be applied to different input parameters provided by RCA members. Since the input numbers for individual items comprise a different scope for each country (see list of items and individual components in 3.2.1), this results in a challenging situation to reach a comparable outcome. The members have to collect reference data for the business case and check their consistency. Thus, in the final quantification of the CBA, it needs to be made clear that the results rather provide a certain trend or direction of the outcome instead of a precise CBA result.

3.2.5. Phase 5: CBA model convergence

The Phase 5 will have 2 objectives:

- **Objectives N°1**: Compare common values such as CAPEX & OPEX on the different items

ITEMS	DEFINITION	BUSINESS CASE	Business CASE 1	Business CASE 2	Business CASE 3	Business CASE 4
		OPEX	OPEX	OPEX	OPEX	OPEX
Track	Balise	€/unit/year				
Track	Axle Counters	€/unit/year				
Track	Track Circuit	€/unit/year				
Track	Field Connection	€/unit/year				
System / data	Augmented GNSS	TBD				
System / data	Digital Mapping Services	€/KM				
Board	LOC-OB	€/unit/year				
Board	TIMS	€/unit/year				

Table 10: Comparison of different elements for different countries

- **Objectives N°2**: Compare Net Present Values of the CBA, reported in a €/KM scale

3.2.6. Phase 6: CBA conclusion & recommendations

The last phase of the process consists of formalising the conclusions and recommendations of the TO CBA application, such as:

- Average value for items considered that could be described as reference values
- Possible estimation of the CAPEX/OPEX for the LOC-OB and TIMS devices in order to achieve a positive business case (target price analysis, since actual price of described components can currently not be precisely estimated)
- Main conclusion on the financial appraisal of the Track Occupancy Concept for the various potential business cases
- Main recommendations for decision markers for the optimisation of the deployment of the Track Occupancy Concept

4. TO CBA Model Set up

The model considers an instant system replacement. The delta CAPEX will be considered spent during the first year after which it considers the OPEX for an exploitation period of 20 years. Each cash flow is weighted by the group contribution as defined in 3.2.1.

The ∆CAPEX sums all the costs associated to equipment and their installation in both scenarios (both are negative because represent spending). To simplify the inputs, our model considers that the value of decommissioned equipment is fully recovered. That's why the whole initial scenario is then subtracted to the actual one.

$$\Delta \text{CAPEX} = \text{CAPEX}_{Target} - \text{CAPEX}_{Initial}$$

An OPEX value is calculated for each item based on actual prices given as inputs. The model then considers the relative OPEX: a device that doesn't need/needs less maintenance brings in a positive OPEX whereas new items to maintain bring negative OPEX. All of those are summed up to obtain the global reference OPEX. This reference is then updated each year with an inflation rate given as input, which is considered as a constant for the 20-year exploitation period.

Finally, the net present value is calculated based on the following formula:

CBA formula = Delta CAPEX + Net Present Value of Delta OPEX for 20 years.

$$NPV = \frac{\sum OPEX}{(1+i)^t}$$

Where ***t*** represents the time of the cash flow and ***i*** is the discount rate.

This formula uses a **discount rate i** derived from the "Guide to cost-benefit analysis of investment projects" of the Directorate General Regional Policy of the European Commission and is **fixed at 3.5 %.**

5. Conclusions

5.1. Version 1 of the document

The version 1 of the document provides the description of the reference business cases to consider, the methodology, the business case model, the list of items to be considered for the model and their meaning to ensure a homogeneous collection of data.

Since phase 5 (CBA model convergence) of the methodology is still ongoing starting from data provided by, DB, Infrabel, RFI, SBB, SNCF, results coming from the implementation of the model cannot be made public yet. This is intended to be the objective of the next version of the document.