OCORA

Open CCS On-board Reference Architecture

Economic Model Introduction & Overview

Towards a cost assessment methodology: Approach, first results, needs for further development

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Management Summary

The economic justification for the OCORA raison d'être and tooling that support OCORA technical decision making is presented. Essential precondition for this document is that it represents the fleet owner point of view, but with a keen eye on business interests of the supply industry and on infrastructure manager's needs. The model aims to provide analytic tools that help to satisfy common business objectives.

This document introduces the economic modelling approach enabling a quantitative assessment of the benefits of OCORA. It is the foundation for developing a more extensive reasoning on an open architecture approach and therefore shall embrace various dimension, at various level of abstraction.

Revision history

Version	Change Description	Initial	Date of change
0.00	Gamma Release as a starting point	NPA/SCA	08.06.2021
0.01	Comments following BWS06 internal review	NPA/SCA	17.06.2021
0.02	Version for OCORA Coreteam review	NPA/SCA	23.06.2021
1.00	Official version for OCORA Delta Release	NPA/RM	30.06.2021

Table of contents

Table of figures

Table of tables

References

Reader’s note: please be aware that the numbers in square brackets, e.g. [1], as per the list of referenced documents below, is used throughout this document to indicate the references to external documents. Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). OCORA always reference to the latest available official version of the SUBSET, unless indicated differently.

[1] OCORA-BWS01-010 – Release Notes

[2] OCORA-BWS01-020 – Glossary

[3] OCORA-BWS01-030 – Question and Answers

[4] OCORA-BWS01-040 – Feedback Form

[5] OCORA-BWS03-010 – Introduction to OCORA

[6] OCORA-BWS04-010 – Problem Statements

[7] OCORA-BWS06-020 – Economic model

[8] OCORA-BWS09-010 – Acceptance of Global Standards

[9] OCORA-TWS01-030 – System Architecture

1 Introduction

1.1 Purpose of the document

The purpose of this document is to support the OCORA argumentation for the modular setup of the ERTMS on-board and the game changers, later to be extended to vehicle level, through economic modelling

This document is addressed to experts in the CCS domain and to any other person, interested in the OCORA concepts for on-board CCS. The reader is invited to provide feedback to the OCORA collaboration and can, therefore, engage in shaping OCORA. Feedback to this document and to any other OCORA documentation can be given by using the feedback form [4].

If you are a railway undertaking, you may find useful information to compile tenders for OCORA compliant CCS building blocks, for tendering complete on-board CCS system, or also for on-board CCS replacements for functional upgrades or for life-cycle reasons.

If you are an organization interested in developing on-board CCS building blocks according to the OCORA standard, information provided in this document can be used as input for your development.

1.2 Applicability of the document

The document is currently considered informative but may become a standard at a later stage for OCORA compliant on-board CCS solutions. Subsequent releases of this document will be developed based on a modular and iterative approach, evolving within the progress of the OCORA collaboration.

1.3 Context of the document

This document is published as part of the OCORA Delta release, together with the documents listed in the release notes [1]. Before reading this document, it is recommended to read the Release Notes [1]. If you are interested in the context and the motivation that drives OCORA we recommend to read the Introduction to OCORA [5], and the Problem Statements [6]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

This document aims at providing the reader a first introduction to the economic justification for the OCORA raison d'être and tooling that support OCORA technical decision making. Essential precondition for this document is, that it represents the fleet owner point of view, but with a keen eye on business interests of the supply industry and on infrastructure manager's needs. The model aims to provide analytic tools that help to satisfy common business objectives.

This document introduces the economic modelling approach enabling a quantitative assessment of the benefits of OCORA. It is the foundation for developing a more extensive reasoning on an open architecture approach and therefore shall embrace various dimension, at various level of abstraction.

The economic model for OCORA should help fleet owners and suppliers to build relevant business cases for CCS On-board migrations with OCORA. It should also help the TSI revision process by providing quantitative and qualitative assessment.

This document sets the ground for a collaborative economic modelling roadmap. It lays down the main hypothesis and objectives for an economic evaluation. It proposes an approach on economic values to be modelled and a first empirical evaluation of expected results.

1.4 Foreword

This paragraph and the following ones describe the scope and objectives of this document that is to be part of the OCORA Economics of Modularity analytic framework, as well as the limitations of the document given the present state of discussion and development. OCORA intends to support its argumentation for the modular setup of the ERTMS on-board and the game changers, later to be extended to vehicle level, through economic modelling. Overall goal is to demonstrate the economic value of modularity from the perspective of users, suppliers and the institutional environment, and to prove that optimization of the level of granularity of CCS and vehicle subsystems enables effective management and control of the total cost of ownership of rolling stock fleet by fleet owners as tentatively indicated in the diagram below.

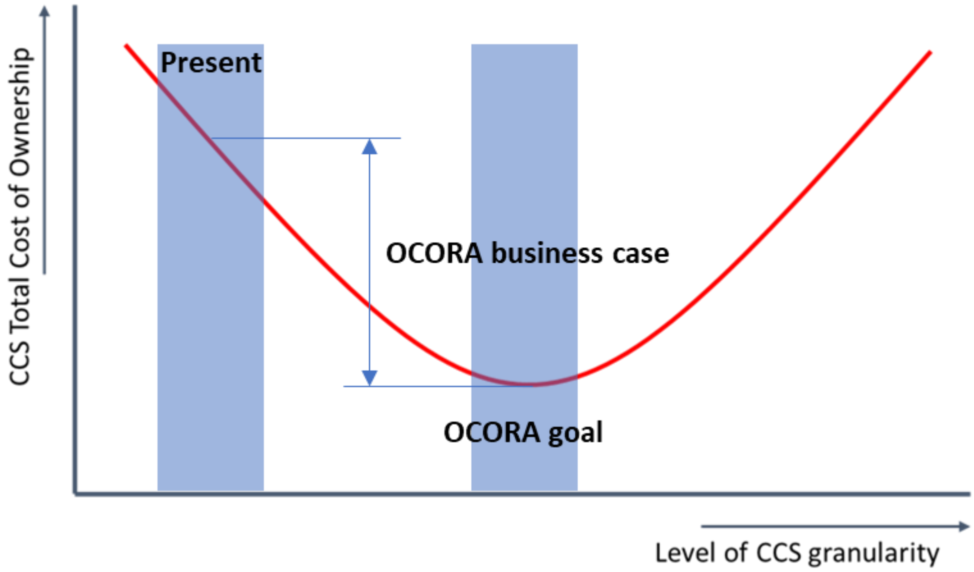

Figure 1 Tentative relation between CCS TCO and level of granularity

1.5 Disclaimer

This document reflects the current state of discussion on the development of analytic tools for demonstrating the added value of the OCORA drive for modularizing the CCS on-board according to the OCORA design principles. It specifically addresses the issue of cost assessment, which is but one aspect of economic modelling. Its major objective is to spark discussion between OCORA and stakeholders, thus enabling validation and verification of the assumptions underlying future economic analysis OCORA is preparing, as well as of the actual calculations.

The calculations and approaches proposed in this document, make use of numbers that were adopted from formal EC reports and analysis. The sources are indicated in the document where relevant.

Assumptions underlying both methodology and calculations, will be specifically indicated to facilitate discussions.

1.6 Objectives of OCORA economic modelling

The development of the OCORA economic model, intends to provide tools for:

- Getting a clear view of the impact of modularization of the on-board on the development of the European CCS market, based on the general assumption that an increase in cost-effectiveness has a positive impact on market volume.
- Enabling a managed evolution of ERTMS (and game changers) implementation that takes account of both user as well as supplier interests, e.g. to define consecutive win – win situations and rapid development steps, taking account of the fact that solutions have to be found in a brownfield situation and that legacy aspects, migration and stability has to be properly handled.
- Defining guidelines for establishing the economically viable level of granularity for the on-board CCS system. An optimal level of granularity will allow fleet owners to optimise and accelerate technical regeneration (equipment, retrofit, maintenance). Alternatively, it will enable manufacturers to enlarge market volumes and consequently offer better prices and quality through increased efficiency of research and development and the maximisation of engineering effectiveness.
- CCS evolution (risk) management assessment by individual RU's and fleet owners, enabling optimization of retrofit programs and of decision taking processes concerning rolling stock fleet strategies
- These objectives are not all fulfilled in this document but should inspire further sector collaboration on, and development of the OCORA economic modelling roadmap, e.g. as a support for setting priorities on collaborative R&I projects or to feed ERA ex ante assessment of TSIs migration and transition provisions.

1.7 Scope of this document

OCORA primarily targets modularization of the CCS on-board, later potentially to be followed by the integral vehicle, by developing an architecture supporting plug and play exchangeability on a *to be defined* level of decomposition. This quest for modularization raises the question among stakeholders on both the general economic rationale for this approach as well on the issue, what the optimum level of granularity of system decomposition would be from an economic point of view. OCORA intends to develop, in a constructive dialogue with its stakeholders and under the scrutiny of independent assessors, tools for economic modelling to be able to answer these questions.

It is clear from the outset, that proposing a diverging preferential technical architecture by the railways must be backed by economic reasoning. And that such economic evaluation would have to include cost and benefit analysis, market assessments, including e.g. market volume expectations and technology road mapping, and a business analytics tool box that allows for scenario assessments, including sensitivity analysis. This certainly will also be true for the final OCORA economic model. But to achieve the ultimate goal, OCORA proposes a stepwise approach towards the final result, to be able to share intermediate results for validation and verification purposes, especially with respect to the basic assumptions that are used.

The single one key issue affecting CSS market development at the moment, is cost development. The requirement of periodically having to replace or modify the on-board at considerable expenditure, causes substantial investment, performance and planning risks that have to be absorbed by RU's and fleet owners. Ultimately, with high cost and a precarious predictability of asset values, the end result is that investments are postponed and the planned implementation of ERTMS and the game changers that pave the way for SERA, is compromised. In other words, higher market efficiency is the necessary condition for large scale deployment but also to reach critical mass of implementations.

For this reason, this first step of the OCORA economic analysis considers the issue of expenditure incurred over the complete life cycle, i.e. investments, operational and maintenance costs and capital costing. It specifically addresses the aspect of the development of ERTMS (including the game changers) total cost of ownership (TCO) over a predefined period for RU's and rolling stock owners (e.g. leasing companies) and the impact of modularisation according to OCORA design principles on this development. As such, it supports the analysis of an OCORA Economics of Modularity survey.

Following issues have been considered when developing the economic model:

1. Modularity supporting plug and play exchangeability of individual parts of the CCS system, is the main objective of the OCORA architecture. Exchangeability should support:

    a. Independence of CCS and train building block configuration life cycles, and the standardisation of the CCS building block configuration independently from the type of vehicle. This requires e.g. a standardised but flexible approach to the vehicle interface.

    b. The standardisation of CCS on-board constituents, enabling functional expansion of the CCS annex train functionality (e.g. migration to ATO GoA 3/4). This requires a functional distribution framework, including an open bus system and standardised interfaces on the applicable OSI levels.

This document primarily seeks to substantiate the above statements since their verification provides solid support for the OCORA claim that plug and play modularity at large satisfy common sector business objectives.

2. The decomposition of the CCS system in a specific number of single building blocks and the function(s) allocated to such building blocks, shall be the result of an impact assessment of:

    a. Life cycle costs and benefits for given levels of decomposition;

    b. Life expectancy;

    c. Performance requirements;

    d. Physical location in the vehicle;

    e. Hardware requirements;

    f. Procurement requirements, e.g. with respect to the desired level of complexity, planning issues or operational requirements.

    This document specifically addresses the first assumption.

3. Changes in the selected level of system decomposition for the OCORA architecture, have an impact on:

    a. Total Cost of Ownership;

    b. The potential for and cost of adopting new technologies;

    c. The speed and cost of (obsolete) technologies replacement.

    The current state of the model allows for the first assumption to be verified; the final model support covering all these elements.

4. Establishing plug and play exchangeability of the CCS system as part of the vehicle, will already have a decisive impact on cost efficiency of ERTMS implementation and allow for substantial savings: it therefore is or should be an absolute priority for the rail industry.

    The model does not (yet) allow analysis of added values of automation proper. ‘Benefits’ addressed in this document, for the moment pertain only to potential cost savings through modularisation of the CCS system and not (yet) to potential beneficial effects of implementation of ERTMS or any of the game changers on a rail industry level. Future enhancements will demonstrate whether the model will allow such macro-economic research.

5. Cost assessment will primarily target the impact of (4) above, especially also since recent market assessments by EC provide solid data for scenario sensitivity analysis.

    The model is using generic figures found in EC reports. OCORA considers it beneficial if sector working group would be established with the task of defining a set validated reference values.

6. Market perspective (for developing demand and supply scenario and sensitivity analysis)

    The model can handle varying market perspectives. Model analytics use a set of assumptions on market drivers (e.g. number of trains to be retrofitted and amortization parameters) that is not exhaustive and needs to be further refined. Basic parameters that structure and drive market development have to be included in subsequent versions (e.g. number of suppliers, overall market size).

7. Cost and benefit structures

The current model concentrates on three key cost categories. Benefits are not addressed by the model: the objective is not to go for a pricing model but benefit for an accelerated railway automation may be covered in subsequent version of the economic model.

2 Cost modelling approach

This chapter will describe how the aspect of 'cost' will be analysed, defined and parametrised to be used as key element in the OCORA Economic Model [7]. Both the perspective of the supplier and the user will be included, providing arguments and concepts for market cost optimization. Ultimately, the chain of argumentation leading to cost assessment of the CCS market will be described as well as the parametrisation of cost categorization that is applied.

2.1 Cost categorisation

CCS cost assessment methodology has to take account of the fact that costs:

- Are generated in subsequent phases of the product life cycle, e.g. costs for concept development, design, engineering, manufacturing, installation, operation (incl. maintenance) and disposal;
- Can be allocated on different product aggregation (or abstraction) levels, like life cycle costs for single products or units, for unit types or for product ranges.

Be aware that the term 'product' can have different meanings in this context, e.g. a concept design ready for industrialisation, a single, manufactured unit based on that concept design or the installation of that unit in its designated environment (which in essence is a 'service).

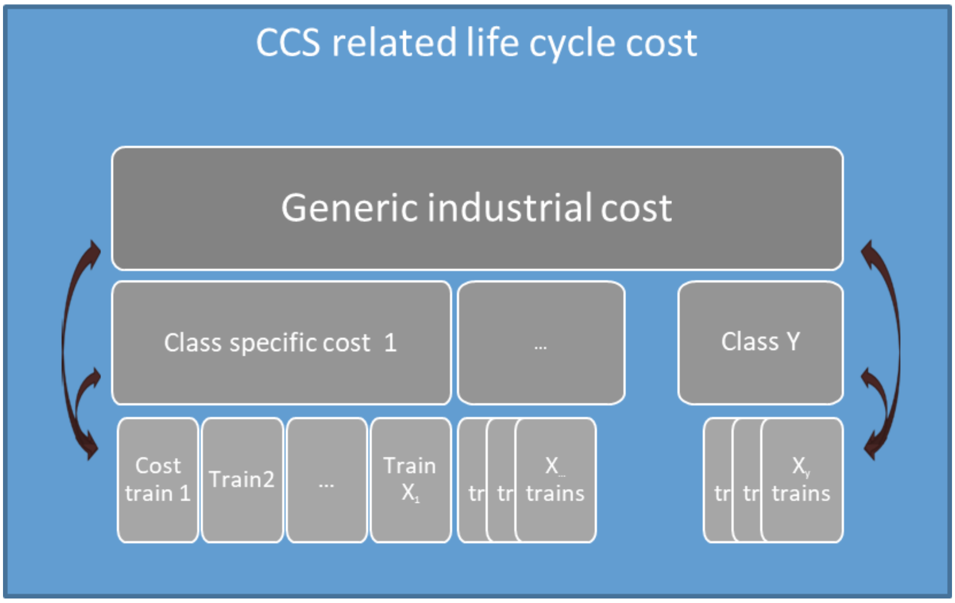

Figure 2 CCS cost aggregation levels

As for cost aggregation levels, Figure 2 indicates the layering typical for CCS systems:

1. The more or less fixed industrial cost for cyclical development of a (range of) generic CCS application(s), is a prerequisite to 'stay in business'. A better word might be a 'product concept' or 'platform' design, hence, 'platform development cost'. It is typically a design that can be adapted and parametrised for specific purposes or projects, according to user requirements. The costs for developing, maintaining and recycling or disposing of a continuous range of product cycles by a commercial enterprise (e.g. ERTMS level 2 consecutive baseline products and their upgrades), can be differentiated in:

    a. More or less fixed expenditure made to ensure the continuity of prime function of the enterprise proper, the capacity and capability to market CCS products. Such costs that are sometimes indicated with the term 'overhead', include the permanent organisation cost, an installed base of competent staff, the costs of facilities and assets (buildings, plants, laboratories) to support e.g. product development, manufacturing and marketing and sales, and pay for capital costs.

b. Partly fixed, partly variable program of project-oriented development costs for product concepts that provide the basic approach towards a concrete and marketable consumer product or product range. In these cases, specific tooling, engineering, equipment, qualified staff, development environments and testing facilities have to be provided that last over the lifetime of that specific platform. In general, companies are scalable over such specific program or project-oriented domains; they can be started or stop whenever the market dictates necessities.

2. The non-recurring cost for adapting a design to prepare it for production and delivery according to customer requirements to make it fit for manufacturing and installation are henceforth called 'product development cost'. Given the fact that the product must be tested and certified for serial production and installation, usually implies prototyping.

3. The recurrent cost of manufacturing and installing a predefined number of units in the vehicle environment in compliance with contractual and legal requirements, termed 'product unit cost'.

Of course, cost generation can be perceived from the point of view of both the supplier as of their customers, resulting in a cost categorisation like the one in **Table 1**, below.

	Generic / Industry		**Product type / class**		**Single product**	
	Supplier	User	Supplier	User	Supplier	User
Specifications				Evolution		
Design	Innovation					
Engineering	R&D / tools		Integration	Mock Up		Documentation
Manufacturing	Test tools		Production		Material	Unit
Installation	Certification		Approval	Project	Assembly	Acceptance
Operation	Maintenance		Maintenance			Maintenance
Marketing	Sales		Tender	Procurement		
Disposal						Demolition

Table 1 Example of a CCS system cost categorisation

OCORA intends to analyse a substantial subset of CCS on-board life cycle costing at the one hand but does not claim an exhaustive approach on the other (e.g. repair of broken parts or company, network or country specifics requirements on development are not addressed). The main objective is to find a level of abstraction on CCS economy that will allow economic reasoning and output assessment in relation to established reference values.

This approach allows to parametrise KPI's embedded in the model in order to develop different scenarios according to the following preconditions:

- A scenario is a consistent set of economic assumptions for a retrofit case;
- A KPI will combine the different values of a scenario: this allow comparison between scenario and help sensitivity analysis within a scenario.

Economic argumentations applied to develop scenarios are making use of this and other relevant information categories to allow various analytic perspectives. In the current model, these are more specifically:

- The tripartite cost aggregation level: industrial cost, cost per class, platform or product range and cost per train;
- CCS life cycle and obsolescence management, dictating the rate with which CCS systems or their building blocks – either hardware or software - have to be replaced;
- The actors involved: more specifically RU's (operators and rolling stock owners), and suppliers of CCS systems and rolling stock.

The cost categorisation is based on a breakdown structure for both:

- the CCS system itself: Product Breakdown Structure (PBS), see **Figure 1** below;
- the different tasks to be performed: Work Breakdown Structure (WBS), see **Figure 2** below.

For the current modelling, four types of “products” are considered, corresponding the foreseen evolutions of the CCS on-board system from the existing architecture to the pure digital CCS system (see [5]):

- EVC as is solution: current architecture
- pre-OCORA Minimum Solution: solution with OCORA architecture without new functionalities/peripheral, which could be considered as an enabler for a first industrialisation and deployment step. This is the solution enabling the decoupling of the CCS on-board and the vehicle for the most imminent retrofit projects: the interface between the proprietary CCS system and the fully integrated proprietary vehicle environment is isolated, enabling exchange of the CCS environment without affecting the vehicle and vice versa, hence simplifying obsolescence issues
- OCORA Full Modular Solution: OCORA architecture with the comprehensive integration of all functions though modules. This solution consists in the decomposition of the CCS on-board into individual building blocks, connected by open interfaces and an open bus system allowing exchangeability between the building blocks without affecting either the vehicle or other CCS constituents
- Digital CCS: Full OCORA architecture within a full digital environment: The core CCS functions will be organised on a generic platform that enables adding, removing or changing functional applications without affecting the computing platform or runtime environment on which they are installed or the state of approval of non-affected parts of the system. This will facilitate fast and easy software updates and upgrades of only necessary applications.

The phasing of the different levels of modularity will be further described.

CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is solution	pre-OCORA Minimum Solution	OCORA Full Modular Solution	Digital CCS
CCS	On-board CCS	x	x	x	x
CCS Core	Core CCS	x	x	x	x
CCS Core	Core CCS - ATP (ETCS Core)	x	x	x	x
CCS Core	CCS addon - NTC-STM				
CCS Core	CCS addon - ATO			x	x
CCS Core	CCS addon - other functions/services			x	x
CCS peripherals	Communication and interfaces	x	x	x	x
CCS peripherals	I/O Ports	x	x	x	x
CCS peripherals	Functional Vehicle Adapter (FVA)		x	x	x
CCS peripherals	UVCC	x	x	x	x
CCS peripherals	Gateway		x	x	x
CCS peripherals	MCG (GSM-R, FRMCS…)	x	x	x	x
CCS peripherals	Sensoring	x	x	x	x
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)	x			
CCS peripherals	Train Loc (GNSS, Inertial…)		x	x	x
CCS peripherals	Perception sensoring (other sensors)				
CCS peripherals	DMI	x	x	x	x
CCS tools	Tools				
CCS tools	Testing tools (eg test bench, simulator)				
CCS tools	Maintenance tools				
CCS tools	Training tools				
RST	Rolling Stock CCS related components	x	x	x	x
RST	TCMS	x	x	x	x
RST	JRU	x	x	x	x
RST	Train networks interfaced to CCS (eg ECN)		x	x	x
RST	STM				
RST	Specific STM network				
RST	CCS related RST parts (bogies, cabinet…)	x	x	x	x
RST	Other CCS related devices & sensors			x	x

Table 2 Product Breakdown Structure

WBS
Specification & Design
Specification (functional, interfaces, performances…)
Design (SW/ HW & architecture)
Industrialization
Production process, configuration mngt, associated tools
Integration, Verification & Validation
Product integration & validation
HW qualification
Class specific integration & validation
Certification
Reliability, Availability, Maintainability, Security, Safety - RAMSS & Cyber
Product (eg GASC)
Class specific (eg SASC)
Configuration studies and production
Installation & Commissionning
Commissionning (customer)
Supply (HW)
Install Integrate CCS (HW&SW) with RST (manpower)
Removal of CCS (HW&SW) from RST
Study train modification
TCMS evolution/adaptation
Adapt Rolling Stock (except. TCMS)
Immobilize train for modification
Maintain CCS (HW & SW)

Table 3 Product Breakdown Structure

2.2 Deployment scenarios

In addition to the cost assumptions, the modelling needs the assessment of the deployment scenarios of CCS on-board equipment with the different foreseen products, accompanying the roll out or ERTMS over the rail networks, together with the possible decommissioning of Class B systems.

Those deployment scenarios are considered either at European scale or at national scale, for given fleets of rolling stock. They indicate over 30 years the number of vehicles to be equipped each year, while distinguishing the new build and retrofit situations, and taking into account the industrial capacity to perform the corresponding works.

Those scenarios will be established according to the following template:

SCENARIO WITH:	OCORA (insert above product name		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
Fleet to equip/retrofit		Type																														
Fleet 1	EMU/DMU Class 1	new build	10	40														50														-50
Fleet 2	EMU/DMU Class 2	retrofit	40	40	40	40																			-160							
Fleet 3	HS	new build				20																										
Fleet n	Loc	new build									30																					
	Total fleet		50	80	40	60	0	0	0	0	30	0	0	0	0	0	0	50	0	0	0	0	0	0	-160	0	0	0	0	0	0	-50

Table 4 Example of deployment scenario

2.3 Life cycles and Scenario based approach

Scenarios are used to calculate costs (WBS/PBS related) and therefore allow analysing economic drivers for OCORA. This scenario approach allows to consolidate an economic value for:

- Deploying one configuration of the system.
- The average life cycle cost related to CCS over 30 years, being the theoretical life expectancy of rolling stock.

As described above, costs are calculated for “fleet-based scenarios” (using the amortization parameter to break down industrial costs, as well as costs per class and costs par train).

For cost estimation, scenarios are calculated over 30 years allowing to consider the whole life cycle of the CCS: either the whole system (e.g. TSI driven upgrades, functional enhancement…) is driving updates, or the hardware of each PBS artefact requests updates (e.g. obsolescence, technological induced upgrade), or the software requests updates (e.g. obsolescence, SW upgrades induced by system upgrades…).

This approach allows to take into account for the different building blocks the different technology cycles.

For a building block with e.g. 5 years renewal period for a software, the life cycle cost (study, design, certification, authorisation and installation of this software) considers 5 upgrades. The calendar of these upgrades can be adjusted for each scenario (and individualized for each PBS artefact on the PBS basis – see table hereunder).

Lifecycle		Products				PBS ROADMAP																																
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is solution	pre-OCORA Minimum Solution	OCORA Full Modular Solution	Digital CCS	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
						First HW and SW release																																
CCS	On-board CCS	x	x	x	x						TSI						TSI					TSI					TSI							TSI				
CCS Core	Core CCS	x	x	x	x																						HW obs											
CCS Core	Core CCS - ATP (ETCS Core)	x	x	x	x							SW up						SW up					SW up					SW up							SW up			
CCS Core	CCS addon - NTC-STM																																					
CCS Core	CCS addon - ATO			x	x																																	
CCS Core	CCS addon - other functions/services			x	x																																	
CCS peripherals	Communication and interfaces	x	x	x	x																																	
CCS peripherals	I/O Ports		x	x	x																						HW obso											
CCS peripherals	Functional Vehicle Adapter (FVA)		x	x	x																						HW obso											
CCS peripherals	UVCC		x	x	x																						HW obso											
CCS peripherals	Gateway		x	x	x																						HW obso											
CCS peripherals	MCG (GSM-R, FRMCS…)	x	x	x	x									FRMCS (HW/SW)								6G (SW)												7G (SW)				
CCS peripherals	Sensoring	x	x	x	x																																	
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)	x																																				
CCS peripherals	Train Loc (GNSS, Inertial…)		x	x	x																						HW obso											
CCS peripherals	Perception sensoring (other sensors)																																					
CCS peripherals	DMI	x	x	x	x																						HW obso											
CCS tools	Tools																																					

Table 5 Product roadmap – Lifecycle table

The scenario approach differentiates the cost related to the CCS from those related to the vehicle adaptations. Therefore, the model should allow to analyse different investment perspective (e.g. user, CCS supplier, rolling stock supplier, system integrator…), and to introduce the technology roadmap (e.g. the game changers: ATO, FRMCS, L3…)

2.4 Economic assumptions

2.4.1 Generic costs vs Class specific costs

In this approach, we need to take into account, apply and distribute the « generic cost vs class specific cost" vs "train specific cost" in the scenarios.

Following assumptions are considered in the economic model (some can be adjusted by parameters) :

- A cost is estimated in the PBS/WBS cost matrix (for a given product-solution) with no distinction of "generic" or "class"
- When a WBS activity is tagged as "generic" only, then it applies only once and is spread over all train classes (divided by the n train classes from the scenario).
- When a WBS activity is tagged as "class" only, then it is applied to each train class from the scenario.
- When a WBS activity is tagged as "generic" and "class", then 50% of it is considered as "generic" and 50% as "class" and the rules above apply for the scenario. This parameter can be adjusted.
- When a WBS activity is tagged as "train specific" only, then it is applied to each train from the scenario.

WBS	Generic costs (Product Dev R&I)	Class specific (Adapt to train class)	Train specific
Specification & Design			
Specification (functional, interfaces, performances...)	x	x	
Design (SW/ HW & architecture)	x	x	
Industrialization			
Production process, configuration mngt, associated tools	x	x	
Integration, Verification & Validation			
Product integration & validation	x		
HW qualification	x		
Class specific integration & validation		x	
Certification	x	x	
Reliability, Availability, Maintainability, Security, Safety - RAMSS & Cyber			
Product (eg GASC)	x		
Class specific (eg SASC)		x	
Configuration studies and production		x	
Installation & Commissionning			
Commissionning (customer)		x	x
Supply (HW)			x
Install Integrate CCS (HW&SW) with RST (manpower)			x
Removal of CCS (HW&SW) from RST			x

Table 6 Generic vs class vs train specific cost allocation matrix principle

2.4.2 Product and railway system roadmaps induced costs

We shall estimate the induced costs from the PBS product roadmap (those costs induced by hardware upgrade due to obsolescence, software upgrades, TSI alignment...) with 3 different perspectives:

- System (eg TSI) upgrade:
  - The induced costs within the scenario are estimated within the software and hardware upgrades (see below): the PBS roadmap is therefor used to choose in the scenario if there is a software upgrade only or both a software and a hardware upgrade. In addition, the PBS roadmap allows to select the PBS artefacts (i.e. the blocks) that are affected by this system evolution.

- Software upgrade:
  - The induced costs within the scenario (either simple product upgrade due to obsolescence, functional enhancement, Change Request, or TSI) are estimated at xx % (xx is a configurable parameter) from overall “generic costs”.
    This has to be applied once for all trains.
  - There is also a need to upgrade the system already deployed (on trains): the associated cost is “Install Integrate CCS (HW&SW) with RST (manpower)“ has to be applied for each train.
  - If for the scenario, we don’t want to apply these costs (no software upgrade, keep the system as it is…): simply cancel “SW upgrade” cell in the product roadmap
- Hardware upgrade (obsolescence):
  - The induced costs within the scenario (either simple product upgrade due to obsolescence, enhancement, TSI adaptation...) are estimated at yy % (yy is a configurable parameter) from overall “generic costs”. This has to be applied once for all trains
  - There is also a need to upgrade the system already deployed (on trains): the associated cost is “Install Integrate CCS (HW&SW) with RST (manpower)“ has to be applied for each train.
  - If for the scenario, we don’t want to apply these costs (no hardware upgrade, keep the system as it is…) : simply cancel “HW upgrade” cell in the product roadmap

2.4.3 Costs estimations for raw WBS/PBS activities or devices

At this stage of the project, a first attempt to estimate the costs is a “base 10” approach, i.e. not economic evaluation in euros but a relative estimation of costs of the WBS and PBS (0 is the min i.e. no associated cost, 10 is the max):

- For a given PBS artefact: the relative weight of WBS activities related to this artefact
- For a given WBS activity: the relative weight between the different PBS artefacts.

<u>Examples:</u>

Cost estimation for EVC “as is” in the “Base 10” approach (based on WBS/PBS approach) (illustration):

Cost assumptions "as is"		Products																					
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is solution	pre-OCORA Minimum Solution	OCORA Full Modular Solution	Digital CCS	Specification (functional, interfaces, performances…)	Design (SW/ HW & architecture)	Production process, configuration mngt, associated tools	Product integration & validation	HW qualification	Class specific integration & validation	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissioning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) with RST	Removal of CCS (HW&SW) from RST	Study train modification	TCMS evolution/adaptation	Adapt Rolling Stock (except. TCMS)	Immobilize train for modification	Maintain CCS (HW & SW)
CCS	On-board CCS	x				5													5			0,5	
CCS Core	Core CCS	x																					
CCS Core	Core CCS - ATP (ETCS Core)	x					5	1	5	5	5	5	5	5	10	1	1	1		2	1		
CCS Core	CCS addon - NTC-STM																						
CCS Core	CCS addon - ATO GoA2																						
CCS Core	CCS addon - other functions/services																						
CCS peripherals	Communication and interfaces	x																					
CCS peripherals	I/O Ports	x					2	1	2	2	1	2	2	2	2	0.5	0.5	0.5			1		
CCS peripherals	Functional Vehicle Adapter (FVA)																						
CCS peripherals	UVCC	x					2	1	1	1	1				2	0.5	0.5	0.5			1		
CCS peripherals	Gateway																						
CCS peripherals	MCG (GSM-R, FRMCS…)	x					5	1	5	5	1				10	1	1	1			1		
CCS peripherals	Sensoring	x																					
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)	x					5	1	5	5	1	5	5	5	10	1	1	1			1		
CCS peripherals	Train Loc (GNSS, Inertial…)																						
CCS peripherals	Perception sensoring (other sensors)																						
CCS peripherals	DMI	x					2	1	2	2	1	2	2	2	2	0.5	0.5	0.5			1		
CCS tools	Tools																						
CCS tools	Testing tools (eg test bench, simulator)																						
CCS tools	Maintenance tools																						
CCS tools	Training tools																						

Table 7 EVC "As is" cost assumptions draft (in "base10" approach)

Cost estimation for the "pre-OCORA" product in the "Base 10" approach (based on WBS/PBS approach) (illustration):

Cost assumptions "pre-OCORA"		Products																					
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is solution	pre-OCORA Minimum Solution	OCORA Full Modular Solution	Digital CCS	Specification (functional, interfaces	Design (SW/ HW & architecture)	Production process, configuration r	Product integration & validation	HW qualification	Class specific integration & validatic	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissioning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) wit	Removal of CCS (HW&SW) from RS	Study train modification	TCMS evolution/adaptation	Adapt Rolling Stock (except. TCMS)	Immobilize train for modification	Maintain CCS (HW & SW)
CCS	On-board CCS		x			5													5			0,5	
CCS Core	Core CCS		x																				
CCS Core	Core CCS - ATP (ETCS Core)		x				5	1	5	2	2	5	2	2	10	1	1	1		2	1		
CCS Core	CCS addon - NTC-STM																						
CCS Core	CCS addon - ATO GoA2																						
CCS Core	CCS addon - other functions/services																						
CCS peripherals	Communication and interfaces		x																				
CCS peripherals	I/O Ports		x				2	1	2	2	1	2	2	2	2	0.5	0.5	0.5					
CCS peripherals	Functional Vehicle Adapter (FVA)		x				2	1	2	2	1	2	2	2	2	0.5	0.5	0.5		1			
CCS peripherals	UVCC		x				1	0,25	0,25	0,25					2	0,25	0,25	0,25					
CCS peripherals	Gateway		x				2	0,25	0,25	0,25	0,5				2	0,25	0,25	0,25			1		
CCS peripherals	MCG (GSM-R, FRMCS…)		x				5	1	5	5	1				10	1	1	1			1		
CCS peripherals	Sensoring		x																				
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																						
CCS peripherals	Train Loc (GNSS, Inertial…)		x				5	1	5	5	1	5	5	5	10	1	1	1			1		
CCS peripherals	Perception sensoring (other sensors)																						

Table 8 "pre-OCORA" cost assumptions draft (in "base10" approach)

<u>Relative comparison of some WBS/PBS activities between EVC As is and pre-OCORA :</u>

- On these draft assumptions, many items are considered to be very equivalent between the two solutions in this first approach (eg hardware for ECU and other building blocks - eg Train localisation devices – are considered at equivalent cost)
- Those considered to be less expensive in the OCORA approach:
  - Class integration
  - re-certification (eg after SW upgrades)
  - vehicle impact

3 Preliminary results

3.1 Overview on the economic model and its results

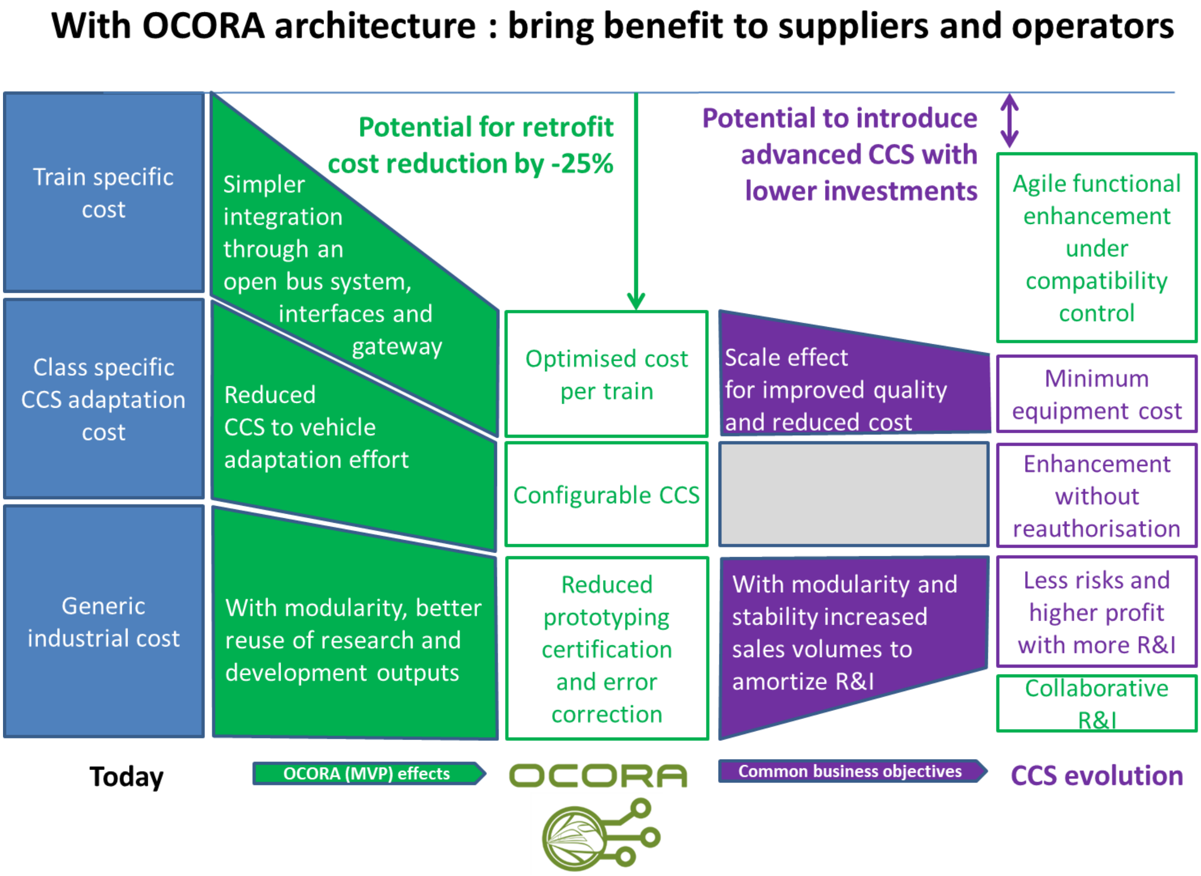

Table 9 Overview of the OCORA economic model

3.2 Test run findings

For the present delta release of this document, the scenarios have not yet been performed on the tool (under construction) (for preliminary results, please see the gamma release).

Scenarios will be performed for the 1.0 release with the model / tool adapted (as introduced in chapter 2).

In particular the “delta costs” (between the different solutions and the EVC “as is”) will be evaluated with a “Life Cycle” perspective (different product PBS roadmaps scenarios):

- for a “software adaptation”
- for a “hardware adaptation”
- for a “system evolution”

The work is still in progress. The results will be available in the 1.0 release.

3.3 Economic indicators

The economic indicators are based on the scenarios.

Here again, for the present delta release of this document, the scenarios have not yet be performed on the tool (under construction) (for preliminary results, please see the gamma release).

The work is still in progress. The results will be available in the 1.0 release.

3.4 Further steps

The next development steps consist in:

- finalizing the model and its associated tool, including the assessment of the costs (in euros),
  - Reinforcement of the description and basic assumptions pertaining to OCORA;
  - Refinement of modelling assumption down to technology choices aligned with OCORA architecture principles. The objective should be for the model to trace in an exhaustive way the effects of implementing the OCORA breakthrough (e.g. technical proposals, design requirements).
  - Enhance the model with parameter costs: all the costs, including the maintenance costs (preventive, curative, repair).
- identifying several scenarios (fleets, roadmaps…):

  The deployment scenarios to help understand cash flows for different stakeholders involved.

  This will require developing deployment and industrialisation scenarios as well as considerations on the capability of the sector to deliver the needed quantities within the different scenarios and for given deployment roadmaps.
- running them using the tool.

In addition, following issues may have to be considered:

- Include and refine the effects of public funding and financing mechanisms.
- Elaborate specific amortization parameters, taking account of variances in one off industrial costs.
- Sensitivity analysis of the feasibility of the OCORA breakthrough. For each of the breakthrough, the impact must be refined and better quantified, the likeliness to deploy each OCORA breakthrough is to be analysed depending on its investment/benefit ratio.
- Enable distinction between cost structures pertaining to vehicle types, e.g. differences in one off cost per train between locomotives and EMU / DMU (not doing so creates a bias for all values and has effects on the final cost calculation). This means that, currently, the model is valid for simulation reasoning purposes only.
- Extend the scope to include relevant elements like specific or detailed building blocks, STMs, recycling, etc.

Although the first results of the OCORA Economic Model (see gamma release) tentatively indicates the added economic value of OCORA for both railways, institutional partners and supply industry, they need to be validated and verified by experts, involving railway undertakings and industrial partners. Specifically the points to be addressed are as follows:

- Quantitative benefit of modularity (direct added value from R&D, instead of routine adaptation for retrofit purpose).
- Rationale for adopting new architecture that enable system upgrade (more value through collaboration).
- Risk of continuing with today's cost distribution function (CCS will become unaffordable and adoption of new functions or technologies will further slowdown.

OCORA intends to involve the sector in further developing this model.

The model is enabling enhanced analysis potential to quantitatively identify and validate common business objectives for stakeholders. S2R and its successor are natural places for further improving the modelling approach and values. OCORA considers the EC ERTMS Deployment Management Team to probably be an appropriate source for a set of (or range for) reference assumptions and parameters.