OCORA

Open CCS On-board Reference Architecture

Economic Model

Discussion paper, towards a cost assessment methodology: Approach, first results, needs for further development

Gamma Release

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0.01	Initial release	JBS	2020-10-30
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0.03	Additional comments JH	JH	2020-11-27
1.00	Editorial work, final version for Gamma Release	RM	2020-12-04

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References

The following references are used in this document:

[1] OCORA-10-001-Gamma – Release Notes

[2] ERTMS Coordinator Work Plan, May 2020

[3] The ERTMS business case on the 9 core network corridors – Second release", European Commission, June 2019

[4] Decision authorising the use of unit contributions to support ERTMS deployment under the Connecting Europe Facility (CEF) - Transport sector, Ref. Ares(2019)1025126 - 19/02/2019

1 Introduction

This chapter describes 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.

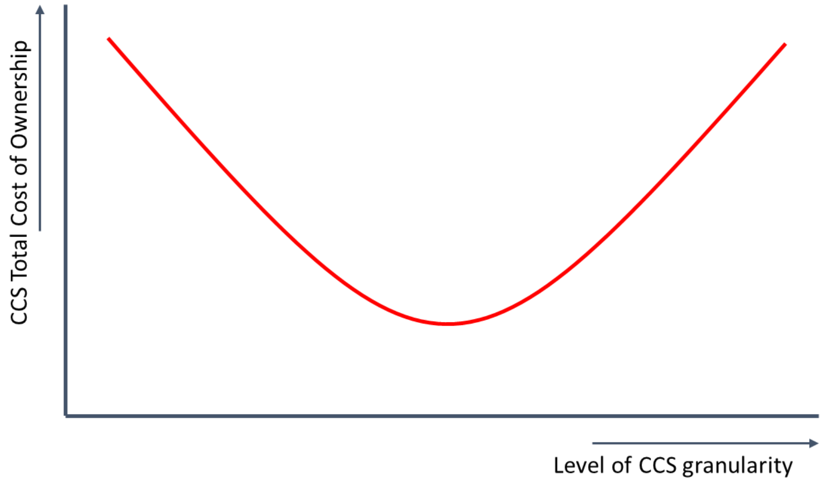

Figure 1: Tentative relation between CCS TCO and level of granularity

1.1 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.

1.2 Objectives of OCORA economic modelling

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

1. 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.
2. 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 and stability has to be properly handled.
3. Defining guidelines for establishing the economically viable level of granularity for the on-board CCS system. An optimal level of granularity will allow fleet owner 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.
4. CCS evolution (risk) management assessment by individual RU's and rolling stock 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.

1.3 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 toolbox 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.

1.4 Document context and purpose

This document is published as part of the OCORA Gamma release, together with the documents listed in the release notes [1]**Error! Reference source not found.**. It is the first release of this document and it is still in a p reliminary state.

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.

1.5 Why should I read this document?

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.

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. 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:

1. 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;
2. 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).

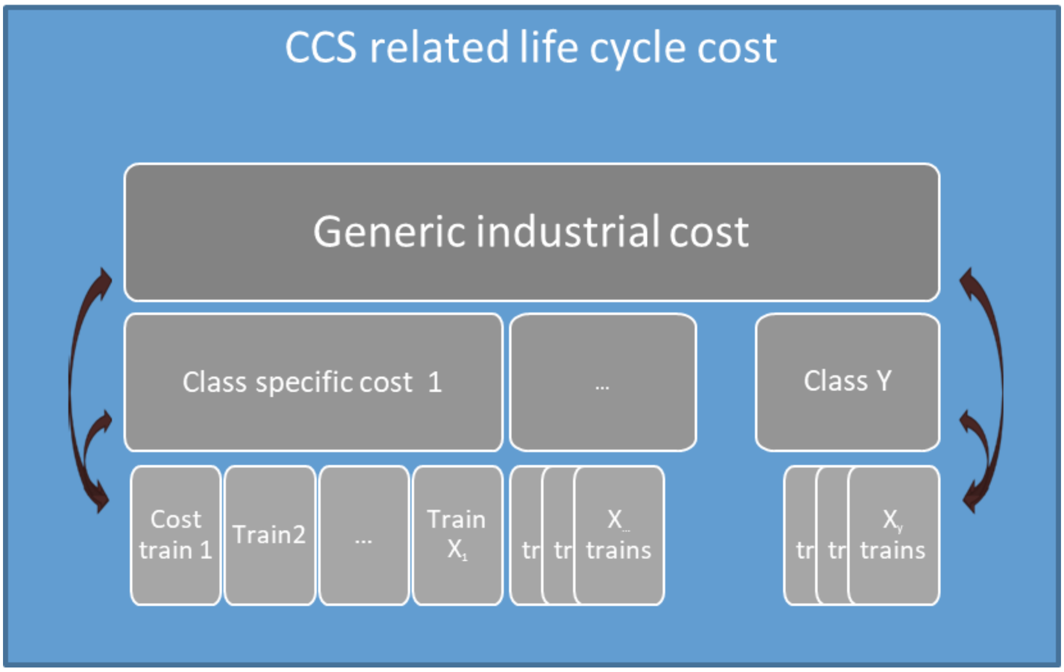

Figure 1 - CCS cost aggregation levels

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 life time 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
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 - CCS system cost categorisation: example with some cost elements indicated

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 in order 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.

2.2 Scope of the model

Product development starts with designing a product concept that is fit for industrialisation, i.e. ready to be manufactured and sold to satisfy customer requirements. In the CCS domain, user requirements are currently usually specified for specific projects, e.g. the retrofit of a train type or class. Suppliers are incurring costs for the development of baseline products ('platforms') that can be fine-tuned for specific implementations or elaborated into a product range. The development costs of the product concept (which could include e.g. engineering, prototyping, testing, approval and certification and development of a production line for manufacturing), have to be amortised over the cumulative number of products of this specific platform that are sold over the platform life cycle (that means: from the perspective of the supplier). Once a platform is economically or technically outdated, there is no more market for such product design.

The initial OCORA model calculations are based on one single “non-recurrent industrial cost”, meaning the cost the supplier is incurring for developing, maintaining and disposing of one single product concept design or platform, including the part of the fixed organisation cost (cost category 1a above) that can be allocated to that platform, in relation to the sales volume of products that belong to that platform. Platform specific product sales volumes are consequently related to platform life cycle cost which results in an amortization parameter (total platform life cycle costs / platform sales volume). Of course, this approach is based on the assumption that the supplier is able to forecast platform sales volumes, or at least, sales potential, and has precise knowledge of its cost structure. In reality, the railway supply industry, being a heterogeneous oligopoly with inherent uncertainty on sales volumes, the supplier will try to recover the platform development cost largely or entirely in the first order.

In future versions of the OCORA economic model, the approach could be more refined and other, more detailed industrial cost categories could be distinguished to allow for a more precise analysis. Elements that might drive industrial costs could be:

- Developments related to ERTMS as a stable but nevertheless gradually evolving European standard.
- Adaptations to standard platforms provided by the industry because of national or network specific requirements.
- Customization of such standard platforms because of changing or deviating user requirements.

The current model does not cover the last two points as separate categories because it is complicated to apportion such cost elements in the current model to specific projects or even single platforms; they are “hidden” in the overall platform development cost. Future upgrades of the economic model should investigate these specific adaptations since they undermine the RU drive for cost and risk management while their elimination can offer an effective mitigation strategy.

In addition to generic industrial cost, the model identifies specific cost categories per vehicle type or class and per train. A good example is the one-off cost for safe integration, requiring a prototype for each specific vehicle type or class. This is one of the major cost drivers that is impacted by OCORA design. Installation costs will also be affected when OCORA compliant modularity of the CCS system will be achieved.

The current aggregation level of the model result in a number of specific cost categories not being identifiable in the model; they are included in aggregates of a higher order. Examples could be specific maintenance activities, software debugging, obsolescence handling, etc.

The cost aggregates applied in the current version of the model are listed in chapter 2.4 below.

2.3 A scenario based model

At this stage, four scenarios are developed and analysed. Scenarios are intended to capture and understand the major impact of OCORA on CCS product value propositions. Differentiation of cost scenario depends on sets of:

- Assumptions for costs that relate to implemented technology (e.g. study cost, testing, fitting work…).
- A set of parameters related to implementation projects and life cycles.
- KPIs that can be calculated from assumptions and parameters : KPIs are today build as Key cost indicators, further KPIs (e.g. migration speed, technical risk/readiness) may be covered in subsequent releases of the model

The four scenarios that were developed, are:

1. *0-scenario,* providing an estimate of actual cost structures, built with values deducted from EC reports [9], [10] and [11]. It provides a standard scenario on which to perform sensitivity analysis. This reference scenario may be tuned over OCORA releases to ensure better traceability and coverage towards actual cost for ERTMS B3 fitting.
2. *Minimum Viable product (MVP) scenario*: introduction of an ERTMS compliant with OCORA. To analyse the cost and benefit of OCORA, it is essential to first understand the economy of the OCORA proposition, mirroring the same functional characteristics as the actual ERTMS products analysed in the 0-scenario. The MVP scenario encompasses standardised train interface and UVCC bus enabled retrofits.
3. A *Full OCORA Platform scenario* is established to measure the economic effects of the implementation of a modular architecture that is compliant with OCORA design principles (e.g. with respect to exchangeability). Detailed modules are not isolated in the model but addressed through specific functional enhancement costs.
4. An *EU Digital CCS scenario* is proposed to investigate the effects of technology and market on a modular architecture. It build on the full OCORA platform scenario and allow to assess impact of shorter serve to analyse economic sensitivity of faster renewal and larger project size.

2.4 Economic parameters

Since precise reference cost information is missing, any CCS related economic model will have to rely on a certain level of abstraction and more generic cost overviews that are backed by expert analysis. The assumptions and parameters used, will obviously be adapted if falsified by the incumbent parties themselves, provided that such information is properly substantiated by traceable and verifiable evidence.

At this stage, there are 3 kinds of parameters managed by the model:

- Development cycle (number of years between platform renewal):
  - SW renewal in case of new software versions (e.g. baseline change).
  - HW renewal in case a new baseline requires changing the computing platform or EVC.
  - System renewal is about the complete exchange of the system technology, requiring a fresh integration of the new on-board in the vehicle
- Amortization parameters (to consolidate KPIs with different cost categories):
  - One off cost per class are spread over the average number of trains per class under consideration in an economic scenario.
  - One off industrial cost are spread over an amortization parameter that covers several classes to be retrofitted (i.e. a generic version is to be instantiated in several class).
- Scenario (to consolidate KPIs according different investment point of views: see section 2.1)
  - In the first scenario, (estimated actual cost) the renewal rate is calculated in line with ERTMS coordinator work plan [2]
  - The value of 30 years between system renewal is defined in line with generic rolling stock life cycle figures: the retrofit and specific TCMS adaptation may occur only once in the life cycle of a rolling stock (this may however change with advanced ATO functionalities: see last scenario).
  - Average vehicle class volume is 20, i.e.the mean value used for the number of train per class according to [4]
  - As a basic modelling assumption, 500 trains are considered to be the average volume of platform specific product sales to establish the industrial cost amortization parameter. This assumption is based on the fact that a generic ERTMS version is rarely developed for a single class of train but may be implemented in various retrofitted and new built train.

Current assumptions used to calculate the first findings, are represented in Table 1

parameters		Hy	Estimated a	MVP	OCORA	Digital CCS
para	#years SW renewal		10	10	10	4
para	#years HW renewal		15	15	15	10
para	#years system renewal		30	30	30	15
para	#years per year (for calculation)		1	1	1	1
para	#train		20	20	20	20
para	#class		1	1	1	1
para	#train to amortize industrial cost		500	500	2000	2000

Table 2 - General parameters used in the model

Comparison of scenarios based on aggregated cost per train

Scenarios are used to calculate cost related KPIs and therefore analyse economic drivers for OCORA. KPIs allow 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.

KPIs are calculated for one train, using the amortization parameter to break down industrial costs and costs per class (e.g. cost for a class will be divided by the number of vehicle in the considered class). For the average cost over 30 years, development costs for the different building blocks are taken several time into account, depending on technology cycles (e.g. with 5 years renewal period for a software, for the life cycle cost, the study, certification, authorisation and installation of this software are taken into account 6 time). With the identification of scenario per actor, the model should allow to analyse different investment perspective (e.g. user, CCS supplier, rolling stock supplier, system integrator…).

KPI(one configuration)= R&I_cost + class adaptation + component cost

KPI(30 years) = sum (KPI(configuration**s**) x technology lifespan)

2.5 Economic assumptions

Table 2 below provides an overview of assumptions used in each scenario and for each cost category.

Typ	Cost category parameters	Hy	Estimated a	MVP breakthrough	MVP	OCORA breakthrough	OCORA	Digital CCS breakthrough	Digital CCS
			Typical values per config						
One off cost per train									
One	train modification work		50k€	simpler integration with bus/gateway	25k€		25k€		25k€
One	UVCC supply and instalation			easy to instal standard gateway	5k€		5k€		5k€
One	gateway supply and instalation			easy to instal standard gateway	10k€		10k€		10k€
One	ETCS sensoring		50k€	simplificaiton	40k€	scale effects	32k€		32k€
One	advanced sensoring				0k€	plug & play sensors	20k€		20k€
One	DMI		20k€	standardised HMI	16k€	advanced HMI with simplified instal	20k€		20k€
One	CCS hardware supply		50k€		50k€	standardised off the shelf multivendor	25k€		25k€
One	system integration and testing		20k€	autotest and autoconfiguration	10k€		10k€		10k€
One	train immobilisation for retrofitting		20k€	simpler upgrade with modularity	5k€		5k€		5k€
One	SW update on train		5k€		5k€	remoted software maintenance	0k€		0k€
One	train immobilisation for version upgrade		1k€		1k€	remoted software maintenance	0k€		0k€
One off cost per class									
One	retrofit project management		150k€		150k€	modularity as a new routine	120k€		120k€
One	Development TCMS version		500k€		500k€	learning curve for train mnaufacturer with gateway	400k€		400k€
One	Train modification study		200k€		200k€	learning curve for train mnaufacturer with gateway	160k€		160k€
One	*Financing*							Enhanced CEF lumpsum	-500k€
One	CCS hardware baseline integration		200k€	use of CCS generic hardware	100k€		100k€		100k€
One	CCS specific software version integration		200k€	use of CCS generic configuration connected to gateway	100k€		100k€		100k€
One	Gateway and train interface configuration			CCS / train netork configuration	100k€		100k€		100k€
One	CCS prototype, train test and autorisation		100k€	minimized field test	50k€	Full autoconfiguration and lab testing capabilties	25k€		25k€
One	HW test and autorisation		100k€		100k€	HW portability to minimize reauthorization cost	50k€		50k€
One	SW test and autorisation		200k€	SW upgradability to minimize reauthorization cost	100k€		50k€		50k€
One off industrial cost									
One	R&I for CCS system		20 000k€	synergy through collaboration			20 000k€		20 000k€
One	Test tools for system and modules		5 000k€	developped advanced virtual validation	5 000k€		5 000k€		5 000k€
One	*Financing*							opportunity to boost through S2R2	-15 400k€
One	Development gateway			need for MVP	2 000k€	high performance gateway	5 000k€		5 000k€
One	Industrialisation CCS hardware platform		5 000k€	source off the shelf platform	2 000k€		2 000k€		2 000k€
One	Development CCS computing platform baseline					invest in platform and/or Middleware	5 000k€		5 000k€
One	development Bus			alliance with other sector	2 000k€	high performance train networks	5 000k€		5 000k€
One	advanced sensoring					develop new capabilities	10 000k€		10 000k€
One	remoted maintenance					develop new capabilities	5 000k€		5 000k€
One	Development generic CCS software baseline		10 000k€	through modularity better reuse of development	2 000k€		2 000k€		2 000k€
One	Prototyping generic CCS HW configuration		5 000k€	less field test more lab	2 000k€		2 000k€		2 000k€
One	Prototyping generic CCS SW configuration		5 000k€	less field test more lab	2 000k€		2 000k€		2 000k€
One	development advanced functionalities					ATO, etc…	10 000k€		10 000k€
Annual recurring cost									
Ann	Software maintenance		5k€	Software maintenance to cover SW generic development	5k€		5k€		5k€
Ann	CCS Maintenance cost								

Table 3 - Detailed quantitative assumptions

For this iteration of the economic model, values have been established according following process:

1. General cost information that can be found in EC reports and their break down in different cost categories through expert judgement (e.g. split between hardware, software and immobilization cost)
2. On each of the cost categories, OCORA effects have been analysed, new values have been defined, and traced to the “estimated actual cost”; these were consequently subjected to critical checks.
3. Sensitivity analysis have been performed to establish a set of coherent assumptions within a scenario and between scenario (e.g. keep KPIs on study related costs as much as possible stable).

The overall KPIs that are consolidated, and values that are used, are probably quite moderate when compared to experience so far with ERTMS (e.g. UIC benchmark, specific figures out of EC reports).The cost variance that is used here, has been established for modelling purposes, acknowledging the fact that:

- Amortization of R&D studies is involving much more complex strategic and commercial mechanisms than just one parameter.
- The boundary between generic and specific applications is not just about a handover process. The cost for adapting a single class may increase when deep changes are to be done in e.g. the TCMS and cabling.
- The scope of this model is about generic cost and not pricing. From the existing model, some first deduction can be made on the mode from project to product and from product to service oriented market. Further sensitivity analysis will be need on those aspects, without necessarily for developing a comprehensive price model for CCS supply.

3 Preliminary results

Based on the information that was discussed in the previous chapter, an analytic model was built in Excel. This approach is sufficient for the current stage of work and the basic algorithmic that is applied, but in later stages of the development of the model, more sophisticated tooling will be necessary. As is well known to those that are experienced with the Excel spreadsheet tool, validation and verification of both the algorithms as well as the outcome is of vital importance. The results of the calculations presented below, were executed with the utmost care. Nevertheless, OCORA cannot guarantee for a full 100% that no errors were made in modelling and calculating. OCORA experts checked plausibility, however. The OCORA team invites other stakeholders as well to scrutinize both the model and its outcomes, inclusive of the underlying assumptions, since that will enable the team to improve its economic model.

3.1 Overview on the economic model and its results

OCORA architecture brings benefit to suppliers and operators.

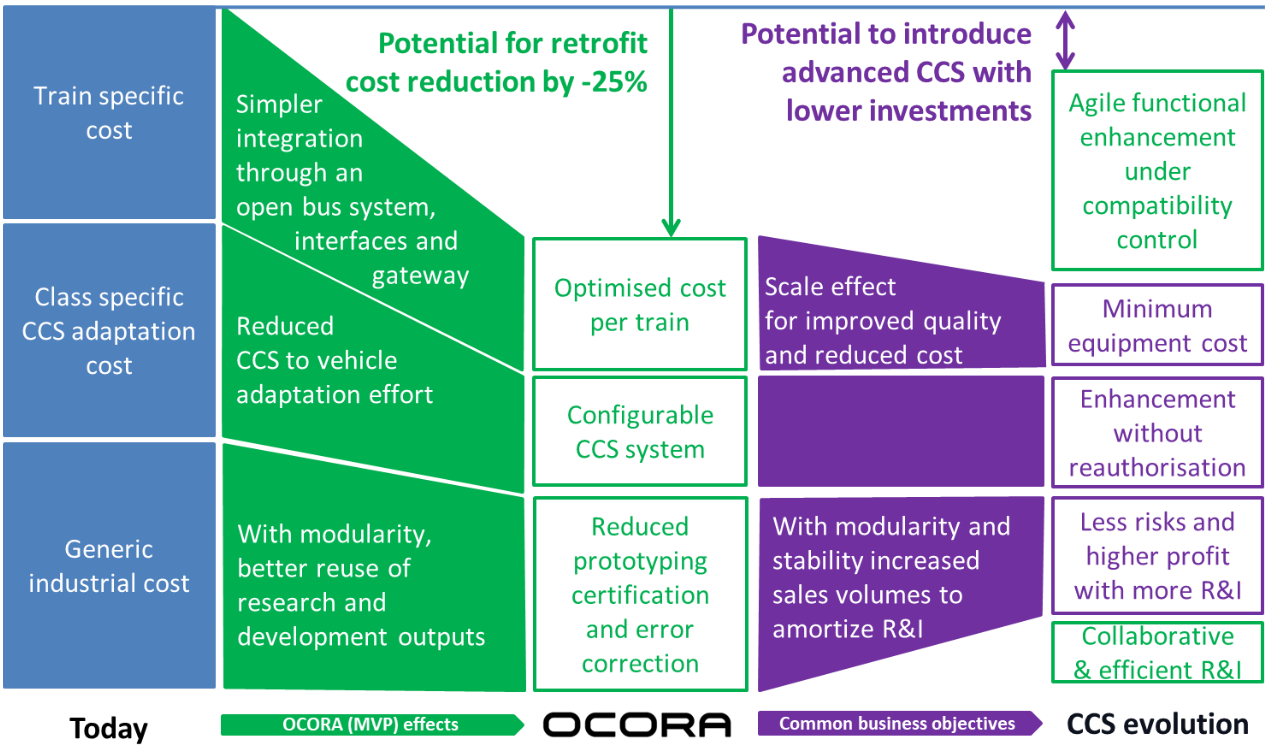

Figure 2 - Overview of the OCORA economic model

3.2 Test run findings

Achieving modularity in accordance with OCORA design criteria results in enhancing the utilization of previous investments in R&D and a reduction of CCS equipment cost by an estimated **25%** (e.g. due to standardisation, simpler retrofits, etc.). On the other hand, the business case for the supply industry will only be moderately affected from both a regional and a wider, European perspective. At the same time, the industries' innovation potential will be considerably enhanced, which would offer the European suppliers a competitive edge on the global market.

Other conclusions that can be drown, are:

- Given the upgrade and replacement cycle of state of art IT products, ERTMS being one of those, the resulting shortening of product life cycles and the accelerating need to accommodate new functionalities like the game changers, requires system and specification stability to be properly managed in order to manage migration risks (cost, performance, planning). Transparency regarding the main CCS cost drivers can help to mitigate the risk of ERTMS implementation cost spiralling out of control. OCORA calculations suggest that optimization of fixed one off cost amortization, based on OCORA principles and supported by effective public funding schemes, could reduce actual CCS costs by an estimated 38%. If this claim were to be substantiated, it would become feasible to accelerate software upgrades and hardware replacement to continuously adopt and apply innovations and add value to basic CCS functionality (ERTMS) that supports automation and digitalisation, without increasing actual life cycle cost.

- Using a gateway and a universal bus system is estimated to result in a 15% decrease of class retrofit non-recurrent cost on the short term, where on the long run it would result in drastically reducing the cost for software upgrades.
- With more transparency on amortization parameters driving industrial cost (e.g. large scale deployment enabled by agile retrofitting and compatibility management), LCC could be reduced by 33% (through e.g. standardisation of building blocks, increased effectiveness of research and development efforts and EU funding). This will provide an incentive for faster deployment of new functionalities and new industry standards.

3.3 Economic indicators

Economic indicators are consolidated, based on detailed assumptions and following the economic modelling approach described in section 2.5.

The results are presented in Table 3 below.

KPIs	Estimated actual cost	MVP	OCORA	EU migration to Digital CCS
Cost per configuration				
retrofit SW	46,0k€	30,0k€	16,0k€	16,0k€
retrofit HW	151,0k€	114,0k€	93,0k€	93,0k€
retrofit syst	398,5k€	271,0k€	243,8k€	211,1k€
new build	245,0k€	165,0k€	158,5k€	158,5k€
Mean cost per year/train (mean over 30 years)				
CCS related LCC	24,9k€	18,8k€	16,8k€	24,6k€
CCS equipment	21,0k€	16,3k€	14,6k€	20,3k€
Study	9,9k€	5,7k€	4,5k€	9,5k€

Table 4 - Key cost indicators measured in the model

NOTE: the absolute value of the indicators is hardly comparable to contracting experience. In today’s project, on top of the scope considered in the model, national specificities are necessary (e.g. integration of class B), TCMS modification or train immobilization may also be much more expensive than the considered assumptions. The cost ratio between scenario is still an important indicator that can help to measure the OCORA added value without entering (yet) in a deep return of investment analysis.

3.4 Further steps

Although the test runs of the OCORA Economic Model 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, specifically the:

- 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 slow down.

Further development step (within OCORA) will notably address:

- Reinforcement of the description and basic assumptions pertaining to the effects of OCORA in the current model and document, addressing the following issues
    - Substantiation of the assumptions regarding cost category estimates now used in the scenarios MVP, Full OCORA and Digital CCS.
    - 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.
    - Refinement of modelling assumption down to technology choices (e.g. ATO GoAx instead of advances automation, perception / localisation instead of advanced sensors, trace interface development cost, define development / equipment effort on building block level). 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).
    - Substantiation of amortization parameters by a study addressing retrofit and new build market volumes.
- Extend the modelling approach, to:
    - Enhance the model with 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.
    - Elaborate specific amortization parameters, taking account of variances in one off industrial costs.
    - Include and refine the effects of public funding and financing mechanisms.
    - Maintenance costs (preventive, curative, repair).
    - Extend the scope to include relevant elements like specific or detailed building blocks, STMs, recycling, etc.
    - 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.

OCORA intends to involve the sector in further developing this first, basic model. The model is enabling enhanced analysis potential to quantitatively identify and validate common business objectives for stakeholders. S2Rand 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.