OCORA

Open CCS On-board Reference Architecture

Economic Model

Guiding Principles - Assumptions - Assessment Criteria

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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 levels of abstraction.

Revision history

Version	Change Description	Initial	Date of change
0.00	Gamma Release as a starting point	RM	04.12.2020
1.00	Official version for OCORA Delta Release	NPA/ RM	30.06.2021
1.01	• First R1 version for WS review	NPA	29.10.2021
1.02	• Comments following BWS06 review	NPA	10.11.2021
1.03	• Redesign of the document: split into WS documents 10 and 50	JH	23.11.2021
1.04	• Final update and revision	NPA	26.11.2021
1.05	• Final update after coreteam review	NPA	02.12.2021
2.00	Official version for OCORA Release R1	NPA	06.12.2021
2.01	Decoupled document from a specific OCORA release	NPA	10.06.2022
2.11	Reviewed the document to add clarity and correct typos	MR	30.06.2023
2.12	Editorial work in Introduction	LDL	31.01.2025

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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-BWS03-020 – Guiding Principles

[7] OCORA-BWS04-010 – Problem Statements

[8] OCORA-BWS06-020 – Economic Model

[9] OCORA-BWS06-030 – Economic Model – Model Description

[10] OCORA-BWS06-040 – Economic Model – User Manual

[11] OCORA-BWS06-050 – Economic Model – CCS System Life Cycle Costing Scenario Studies

[12] Verband der Bahnindustrie in Deutschland e. V., Die Zukunft Der Schiene Soll Rasch Beginnen, Umfassender Konzeptvorschlag: Aus- und Umrüstung von Schienenfahrzeugen mit ETCS-Bordgeräten, www.bahnindustrie.info.

[13] Second ERTMS Coordinator Work Plan, September 2022

[14] Special Report of the European Court of Auditors, "A single European rail traffic management system: will the political choice ever become reality?", 2017

1 Introduction

1.1 Purpose of the document

The purpose of this document is to reflect 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 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.

This document is part of a larger and growing configuration of documents that envisages to provide the foundation for scenario and sensibility analysis regarding decisions on the implementation of CCS related applications in rolling stock. The reader will find the underlying assumptions, general principles and criteria which OCORA has developed to enable such analysis. Based on these assumptions, a model for cost calculation has been developed that is still in an experimental stage of development. The model is at the moment an Excel application [8], but due to the enveloping complexity, alternative tools are contemplated. For full understanding on both the fundamentals of the model and its concrete application, the reader is referred to this document and the complementary documents on the application of the model proper (manual) [10] and on the algorithmic of the model [9].

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.

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-inspired 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 organisation interested in developing on-board CCS building blocks according to the OCORA design principles, information provided in this document can be used as input for your development.

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.

1.2 Applicability of the document

The document is considered informative. 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 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 reading the Introduction to OCORA [5], and the Problem Statements [7]. 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.

2 Background and approach

Traditionally, a rule of thumb regarding passenger rolling stock is having a 1:2 ratio between CAPEX and OPEX over lifecycle. In other words, for every Euro spent on buying and commissioning a train, two Euro are needed to be spent on maintenance and modifications to keep the rolling stock in operational condition from commissioning unto phasing out. RU procurement strategies are often firmly embedded in this tradition where cost levels and cost structures are primarily dictated by the physical properties of the train. The train protection system, although being a fairly expensive piece of equipment, used to perfectly fit this assumption. Indeed, in most cases it would be installed at the time of construction, last until phasing out, and changes over the life cycle would be few. In fact, many Class B systems are still based on relay technology that easily lasts over the complete life cycle of the vehicle.

Depending on market dynamics and demand levels, legacy Class B systems make up only a minor part of the investment in rolling stock. In Figure 1, the German situation (PZB, PZB and LZB combination) is represented, based on an open ETCS analysis made in 2012 that was derived from an earlier Deloitte & Touche investigation. Similar conditions can be found in other countries.

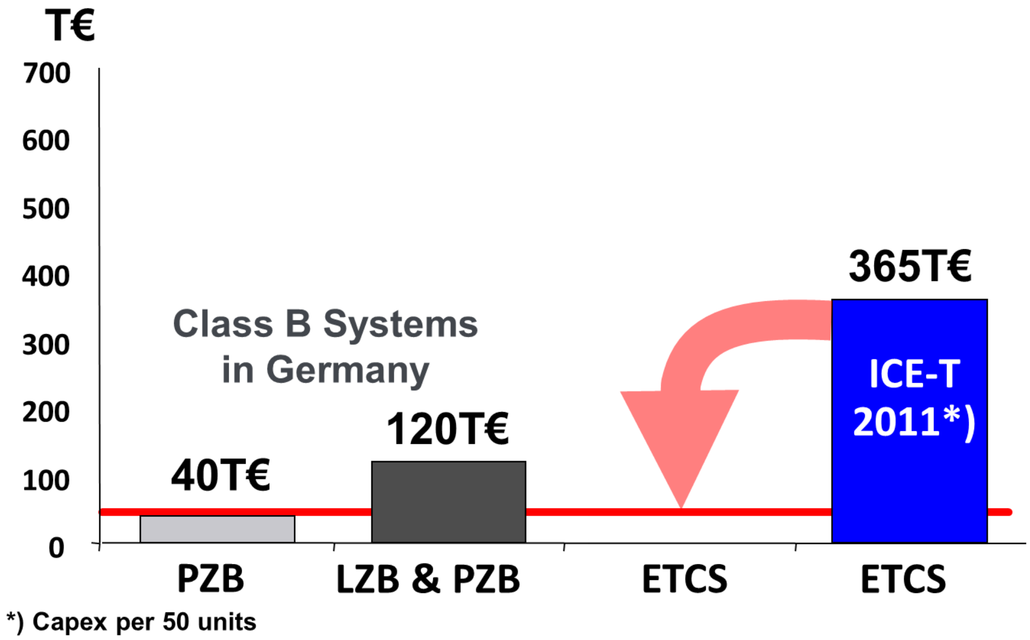

Figure 1 PZB and PZB/LZB versus ETCS capex levels (openETCS analysis, March 2012)

Generally, investment levels considerably increased over time with the advent of state of art IT technology. This is the case for ETCS and Class B systems, as can be witnessed form the example in **Figure 1**. These are caused by three major developments:

1. Sharp increase of CCS system complexity, involving high R&D, integration, certification and approval efforts, and, consequently, costs, requiring extensive engineering, prototyping and testing before serial roll out and commissioning.
2. Sharp decrease of CCS life cycle expectancy from vehicle life cycle equivalence to 5 to 10 years at present (depending on specific situations and conditions) with on average approximately expected 6 years.
3. User requirements expanse that demands integration of new developments and innovations like ATO, incrementally adding complexity to CCS systems.

In the present situation, and corroborated by recent experience, the **CAPEX** involved in equipping a multi car EMU with ETCS can be up to € 1 million [14], given a fleet size of at least 50 vehicles. This cost can rise considerably for smaller numbers of vehicles. Prototyping and integration costs typically are about € 10 million but much higher quotes are known [14].

Given a vehicle life expectancy of at least 30 years, up to four retrofits for new ETCS equipped rolling stock could be necessary under current conditions compared to approximately one CCS retrofit in the past. This means that with ETCS rolling stock fleet cost structures have dramatically changed and CCS has become a major corporate cost driver for fleet owners.

Advancing technologies to keep CCS system performance in the time of delivery ‘as is’ state of operation also resulted in cost increases.

OCORA partners have made several operational cost analyses of the current generation of ETCS on boards. These cost cover soft and hardware maintenance, including baseline updates. Based on the aggregate of their experiences total OPEX over the system life cycle (6 years) is between 10% to 20% of CAPEX. As a consequence, effectively managing investments has a much higher impact on CCS cost levels than containing maintenance costs. Still in comparison with the older CCS equipment ETCS presents a serious financial risk for fleet owners.

In the modelling approach and calculations presented in this document mainly pertaining to operations cost of the CCS system and others to investments. Please note that the investment to maintenance cost ratio is expected to be 4: 1, meaning that the impact of the OCORA approach on either CAPEX or OPEX should be appreciated according to this cost distribution. It will be indicated where calculations will specifically target either CAPEX or OPEX cost consequences.

Ultimately, the goal of economic – and more precisely business – modelling is to demonstrate the added value of systematic considerations on e.g. architecture, fleet planning, etc. for the ability of sector partners to facilitate investment decisions. In the end, supplier and customer need to agree on preferably joint development strategies leading to balanced optimisation of costs and benefits. The main underlying assumptions for the OCORA initiative for modelling are graphically represented in Figure 2 below: They will be further elaborated upon in the following chapters.

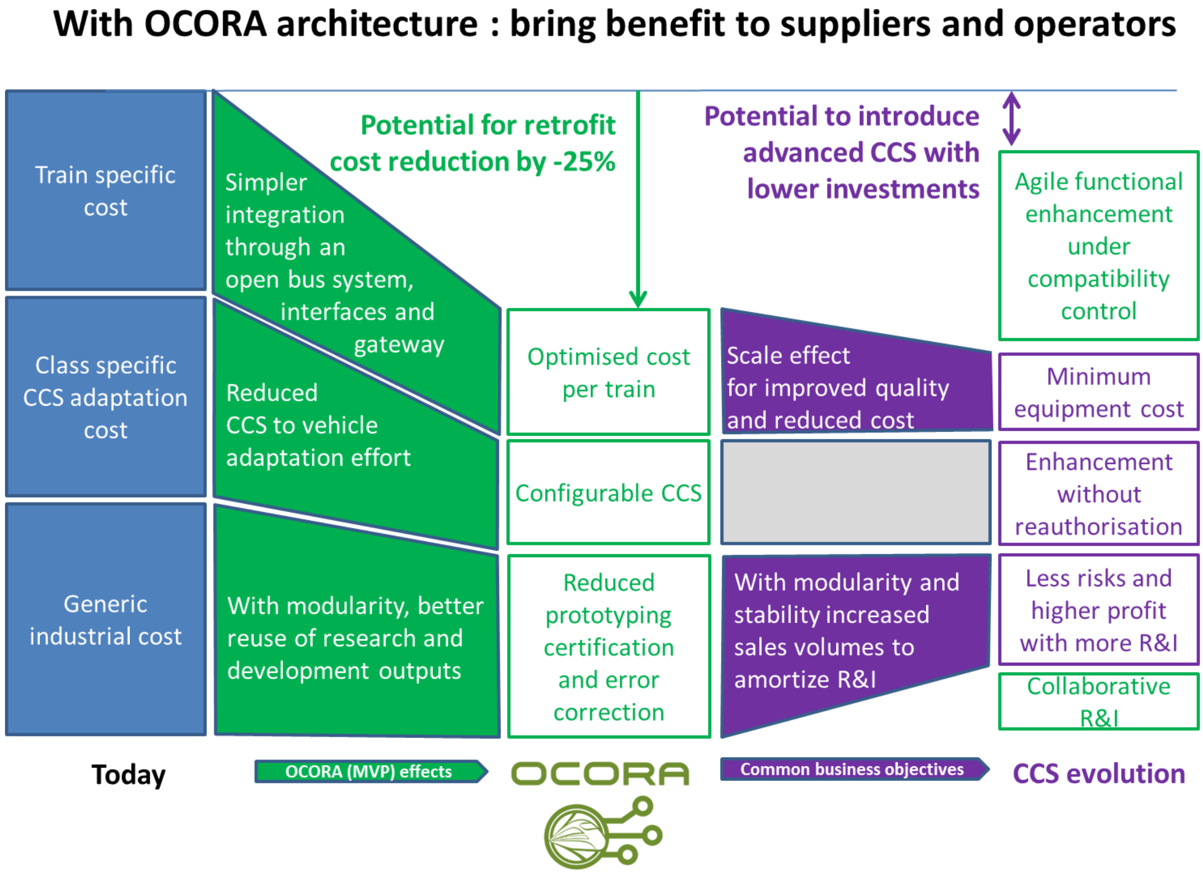

Figure 2 OCORA value proposition to be tested through economic modelling

3 Scope and Objectives

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 goals are to:

- demonstrate the economic value of modularity from the perspective of users, suppliers and the institutional environment;
- prove that optimising the level of granularity of CCS and vehicle subsystems enables effective management and control of the total cost of ownership of rolling stock fleet cf. **Figure 3**.

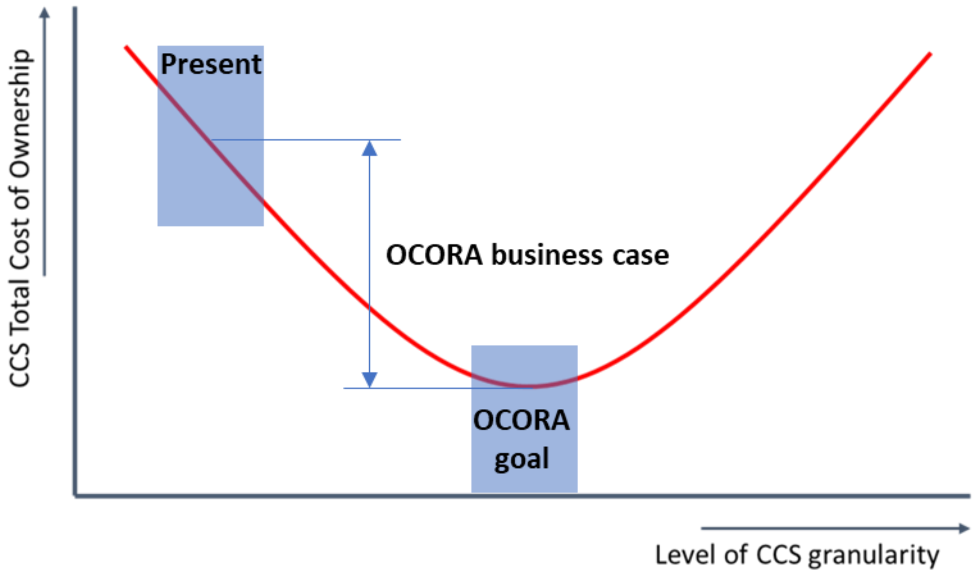

Figure 3 Theoretical relation between CCS Total Cost of Ownership and Level of CCS granularity

3.1 Objectives of OCORA economic modelling

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

- getting a clear view of on-board modularisation impact 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 and supplier interests. For example, it could be defining consecutive win – win situations and rapid development steps while considering that solutions have to be found in a brownfield situation and legacy 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). In parallel, 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;
- assessing CCS evolution (risk) management by individual RUs and fleet owners, enabling the optimisation of retrofit programs and decision taking processes concerning rolling stock fleet strategies.

These objectives are not all fulfilled in this document but should inspire further sector collaboration 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.

3.2 Scope of the economic analysis

OCORA primarily targets modularisation 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 modularisation raises questions among stakeholders on both - the general economic rationale for this approach and the issue of the optimum level of granularity of system decomposition from an economic point of view. In order to answer these questions, OCORA intends to develop tools for economic modelling in a constructive dialogue with its stakeholders and under the scrutiny of independent assessors.

It is clear from the outset that proposing a diverging preferential technical architecture by the railways must be backed by an economic reasoning. Such economic evaluation would have to include:

- cost and benefit analysis;
- market assessments, including e.g. market volume expectations and technology road mapping;
- a business analytics tool box that allows scenario assessments, including sensitivity analysis.

This certainly will also be true for the final OCORA economic model. To achieve its goal, OCORA proposes a stepwise approach towards the final result. Intermediate results can be shared for validation and verification purposes, especially with respect to the basic assumptions that are used.

The single key issue affecting CCS market development at the moment is cost development. Indeed, 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 RUs and fleet owners. Ultimately, with high costs and a precarious predictability of asset values, investments are postponed and the planned implementation of ERTMS and the game changers that pave the way for the Single European Railway Area (SERA) is compromised. In other words, higher market efficiency is the necessary condition for large scale deployment and to reach critical mass of implementations.

For this reason, this first step of the OCORA economic analysis is to consider the issue of expenditure incurred over the complete life cycle, i.e. investments, operational and maintenance costs and capital costing. In addition, the impact of modularisation according to OCORA design principles on this development is applied. 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. Please note that building blocks themselves can have elements of different life cycles which need attention. Typically, for rail vehicle pertinent TCMS and CCS systems, the connecting bus or network systems have long life cycles (up to 30 years), hardware follow generic technology development, meaning medium life cycles of up to 5 or 10 years, while applications in many cases have much shorter life cycles, sometimes as much as a few months. Life cycle management should be enabled accordingly.
    b. The standardisation of CCS on-board components, 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:

    1. the TCO, for both investments (CAPEX) and the cost of operating the system over its life cycle (OPEX);

    2. the potential costs of adopting new technologies;

    3. the speed and cost of (obsolete) technologies replacement.

    The current model is now able to cover these three changes.

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

    The model, which in this stage allows scenario analysis and sensitivity studies, is not yet equipped to allow in depth analysis of added value of automation of operation. For the moment, 'benefits' addressed in this document pertain only to potential cost savings through modularisation of the CCS system. In the future these benefits should also come from the beneficial 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 the point above, especially since recent market assessments by EC provide solid data for scenario sensitivity analysis. The model uses generic figures found in EC reports. OCORA considers it beneficial if sector working group would be established with the task of defining a set of validated reference values.

6. Market perspective for developing demand and supply scenario, and sensitivity analysis as 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 amortisation 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 as the current model concentrates on three key cost categories (chapter 4.2). 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.

4 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 optimisation. Ultimately, the chain of argumentation leading to cost assessment of the CCS market will be described as well as the parametrisation of cost categorisation that is applied.

Please be aware that in this early stage of development, any values generated by the model do NOT represent monetary values (in Euro) but only allow quantified comparison between scenario outcomes that result from variations in assumptions and parametrisation.

4.1 Modelling methodology: general approach

OCORA economic model main objective is to enable assessment of various conditions or circumstances on CCS cost development as part of RU and fleet owner rolling stock asset management. This is achieved by assessing variations in different scenarios, for which the model has a scenario building approach which is depicted in Figure 4. Scenarios are built on assumptions, which are transferred into assessment criteria, e.g. life expectancy, modularity levels or market specifics. Such criteria (the selection of which is up for debate) are formulated as assumptions that are quantitative and allow parametrisation. The set of assumptions can be adapted according to requirements, new ones can be added and superfluous ones erased.

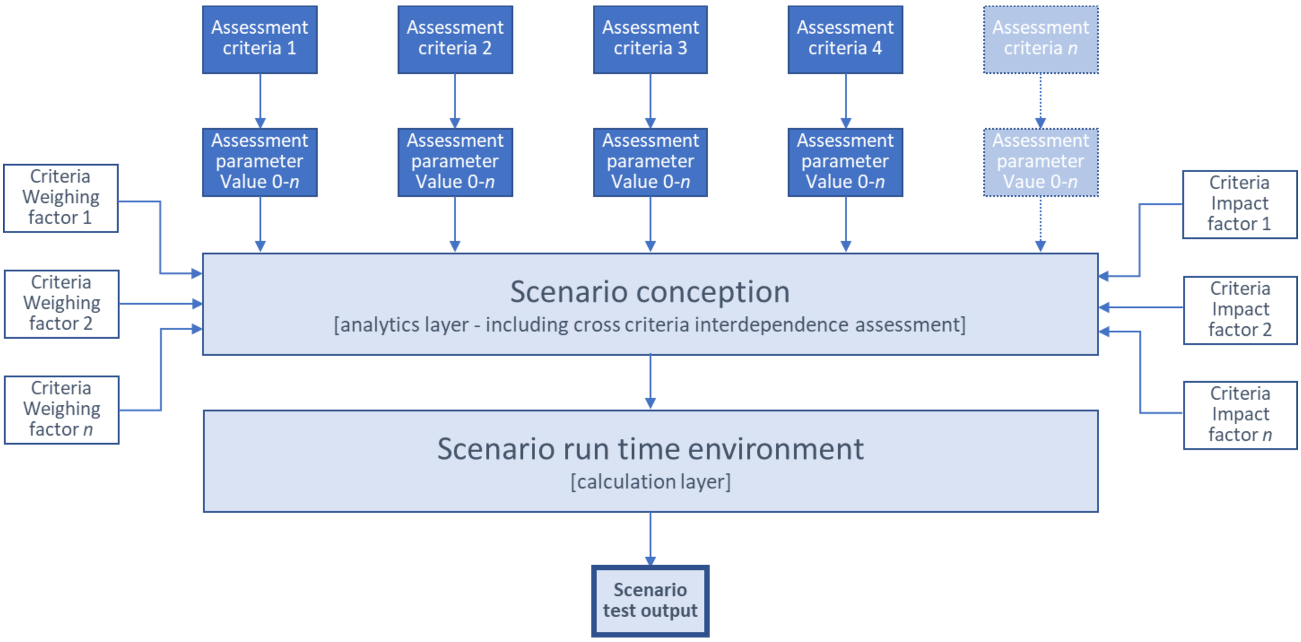

Figure 4 Proposed OCORA CCS cost modelling process

To enable scenario building, one or more assessment criteria can be involved and not all are evenly important. That is why criteria weighing factors are defined and allow prioritization between assessment criteria in a specific scenario. These weighing factors can be adapted according to requirements.

Then, assessment criteria have a potential impact on other, e.g. decomposition levels and component life expectancies. The interference or interdependency need to be operationalized as well, for which the model proposes criteria impact factors. During the modelling development process, this approach needs to be validated by scenario testing.

The model will be refined experimentally in a learning-by-doing approach. This includes regular and rigorous assessment of the modelling approach itself.

Of course, scenario assessment output will be reused to refine the model by e.g. adding or removing assessment criteria, detailing parameters and assessment factors, improving the analytics layers and scrutinising and debugging the algorithms.

4.2 Cost categorisation

OCORA 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).

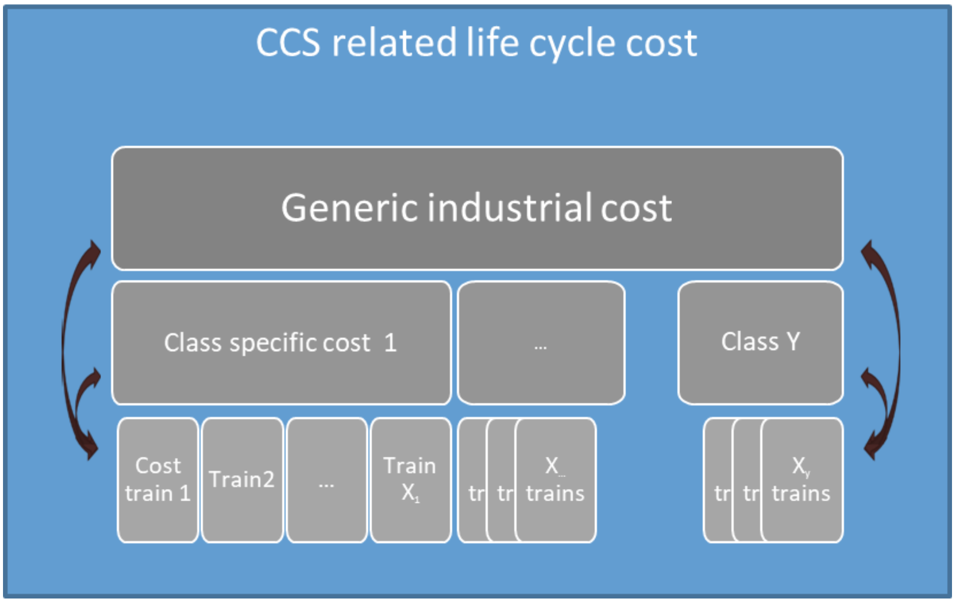

Figure 5 CCS cost aggregation levels

As for cost aggregation levels, **Figure 5** indicates the layering typical for CCS systems.

1. The industrial cost for cyclical development of a range of generic CCS application(s) is a prerequisite to ‘stay in business’. It can also be referred as a ‘product concept’ or ‘platform’ design, hence, ‘platform development cost’. It is 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. fixed expenditure made to ensure the continuity of prime function of the enterprise proper, the capacity and capability to market CCS products. Such costs, 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 for production and delivery according to customer requirements regarding manufacturing and installation, henceforth called ‘product development cost’. Given the fact that the product must be tested and certified for serial production and installation, it usually implies prototyping;
3. the recurring 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 and their customers, resulting in a cost categorisation like 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

On one hand, OCORA intends to analyse a substantial subset of CCS on-board life cycle costing. On the other hand, the initiative does not claim an exhaustive approach (e.g. repair of broken parts as well as 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. The plausibility of which should ultimately be verified by sector partners.

This approach allows to parametrise Key Performance Indicators 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 allows comparison between scenarios and help sensitivity analysis within a scenario.

In order to allow various analytic perspectives, economic argumentations applied to develop scenarios are based on the current model. In the current model, these perspectives are:

- The tripartite cost aggregation level - industrial cost, cost per train, and cost per class, platform or product range;
- 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 RUs, rolling stock owners, and suppliers of CCS systems and rolling stock.

The model considers costs to be the combined result of activities to be performed to generate constituent products of the integral product configuration. The cost categorisation is, thus, based on a breakdown structure for both categories:

- the CCS system itself: Product Breakdown Structure (PBS), see **Table 2**;
- the different tasks to be performed: Work Breakdown Structure (WBS), see **Table 3**.

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

- EVC 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 OB 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.

4.3 Cost breakdown structure

The OCORA economic model is based on a breakdown of the CCS system in core system elements and peripheral or external system elements. Core elements are the functions encapsulated in hard- and software artefacts or operational processes that enable safe movement of the train using ERTMS. Other elements indicate auxiliary functions or processes, including operating a train in Class B environments. The breakdown is periodically validated in accordance with cost calculations made by OCORA partners and studies for ongoing and imminent retrofit, development and demonstrator projects. An overview is presented in **Table 2** where cost elements are related to the scenarios described in the previous chapter.

CCS Product Break Down (PBS)		Features			
Topology	Object description	EVC	Pre-OCORA	Full OCORA	Digital CCS
CCS		X	X	X	X
CCS Core	Core CCS	X	X	X	X
	Core CCS – ATP (ETCS Core)	X	X	X	X
	CCS Add on – NTC - STM				
	CCS Add on – ATO			X	X
	CCS Add on – other functions, services			X	X
CCS Peripherals	Communication and interfaces	X	X	X	X
	I/O Ports	X	X	X	X
	Functional Vehicle Adapter		X	X	X
	UVCCB	X	X	X	X
	Gateway		X	X	X
	MCG (GSM-r, FRMCS)	X	X	X	X
	Sensoring	X	X	X	X
	ETCS sensoring (e.g. Odo, BTM, LTM)	X			
	Train localisation (GNSS, Inertial, etc.)		X	X	X
	Perception sensoring (other sensors)				
	DMI	X	X	X	X
CCS Tools	Tools				
	Testing tools (e.g. test benches, simulator)				
	Maintenance tools				
	Training tools				
Rolling stock (rail vehicle)	Rolling stock CCS related components	X	X	X	X
	TCMS	X	X	X	X
	JRU	X	X	X	X

CCS Product Break Down (PBS)		Features			
Topology	Object description	EVC	Pre-OCORA	Full OCORA	Digital CCS
	Train bus / network systems interfacing with CCS (e.g. ECN)		X	X	X
	STM				
	Specific STM Network				
	CCS related rolling stock parts (e.g. bogies, cabinets)	X	X	X	X
	Other CCS related devices and sensors			X	X

Table 2 Product Breakdown Structure

The first column allocates single cost drivers to the domain of either core, peripheral or external parts of the CCS system. The second identifies the relevant elements of the system which can be single objects or integrated in larger single system components.

The breakdown has in this stage a rather pragmatic approach that is derived from standard practice. OCORA fully acknowledges the need for a harmonised CCS system ontology. In a later stage, terminology will be refined, aligned with ongoing architecture work and properly defined in the OCORA Glossary, and remaining ambiguities will be eradicated. Any suggestions for improvement will be duly accepted and processed.

Additionally, OCORA discerns a number of life cycle stages in which certain costs are incurred to identify and define the periodicity of life cycle costs, cf. **Table 3**. These allow to define costing cycles that affect both supplier and fleet owner business processes. In this case too, further refinement is expected in subsequent versions of the OCORA economic modelling investigation.

Work Breakdown Structure (WBS)		
Category	Sub-category	Remarks
Specification and Design	Specification	Functional, interfaces, performance, etc.
	Design	Hard- and software, Architecture
Industrialisation	Production process structuring	Incl. of configuration management, tooling
Integration, validation, verification	Production integration & validation	
	Hardware qualification	
	Class specific integration & validation	
	Certification	
RAMS and cyber security	Product level	E.g. GASC
	Class level	E.g. SASC
Configuration management	Studies and production	
Installation & commissioning	Commissioning	Customer responsibility
	Product supply (HW)	
	Safe integration in vehicle	Hardware, software, staffing
Maintenance	Routine HW & SW maintenance	Preventative and corrective
Rolling stock maintenance and modifications	(Vehicle) modification studies / preparation	
	TCMS evolution, adaptation	
	(Vehicle) modifications (except TCMS)	
	Rolling stock standstill	
Removal & disposal	Hardware & software	

Table 3 Work Breakdown Structure

5 Scenario configuration principles

For building comprehensive scenarios to evaluate decisions with respect to CCS implementation, it is imperative to differentiate life cycle costing of the CCS system proper. The expected life cycle of the CCS systems differ from life expectancy of the vehicle itself. Where legacy CCS system life cycles have been similar to that of its carriers, this is no longer the case with state of art, IT based, CCS systems.

Expected life cycle duration of modern CCS systems (both as a whole and as a configuration of multiple constituent elements) are shorter than that of its carrier, the rail vehicle. Therefore, principal constituent elements of the CCS systems need to be periodically replaced before the end of the life cycle of its carrier, e.g. because of hardware obsolescence, baseline upgrade or implementation of one or more game changers.

Periodical replacement of (parts of) the on-board CCS system has become an important element of vehicle and fleet life cycle management, involving repeated investments in equipment, engineering, prototyping, integration, certification and commissioning. Given the frequency of replacement and the investment volumes involved, CCS OB has become an important cost driver for fleet owners and operators. Its business impact is gradually becoming a key issue in fleet and rolling stock life cycle management.

Then, over the life cycle of the CCS system, it needs to be maintained. Maintenance costs are depending on a number of factors, specifically the life expectancy of the system and its constituent elements, the level of granularity of those systems, and a number of other aspects. The prime benefit of OCORA is that replacing or upgrading and updating a single constituent element will not necessarily affect others, depending on the level of granularity of the CCS system decomposition.

The experience demonstrates that CCS life cycle expectancy is between 5 and 10 years, meaning replacement and, therefore, a new investment cycle. Residual vehicle life expectancy is a relevant parameter in determining investments needs. As a reference, OCORA proposes a portfolio approach for defining main scenarios for business analysis by differentiating:

1. non recurrent costs, being usually categorised as asset investments (CAPEX) and recurrent costs, normally considered asset operations or maintenance costs (OPEX);
2. aggregation level, indicating whether the assessment is made from the point of view of fleet composition, vehicle type or the singe vehicle.

The approach enables a general scenario categorisation as presented in **Figure 6**.

Each main category allows multiple specific scenarios where assumptions are tested on their effects. Important parameters include fleet size, fleet age, life expectancy of the CCS system and its building blocks, and level of system decomposition. Portfolio based scenario development can be applied for assessment of investment decisions for each of the main categories represented back in **Figure 4**. Single scenario studies will indicate to what category they pertain and what assessment criteria are put to the test. In the following sections, the approach will be exemplified by combining critical assessment parameters of life expectancy, level of granularity and impact of interface standardisation.

5.1 Fleet size and rolling stock life expectancy

For establishing fleet size, OCORA uses publicly available data from elaborated sources like the 2020 and 2022 report of the ERTMS coordinator for the European Commission and the Ruete Work Plan [13]. The reason OCORA considers such documents as 'raw material' has to do with the fact that they contain important business intelligence and processed data and information which can be disputed. For instance, it is clear from the Ruete report that demand figures are based on the assumption that there is no difference between vehicle and CCS systems life expectancy.

For modelling purposes, a reference life cycle of 30 years for rolling stock is assumed, even if there are numerous examples of rolling stock that remain operational for much longer times. For advanced modelling, a life expectancy bandwidth of between 30 and 40 years would be more appropriate.

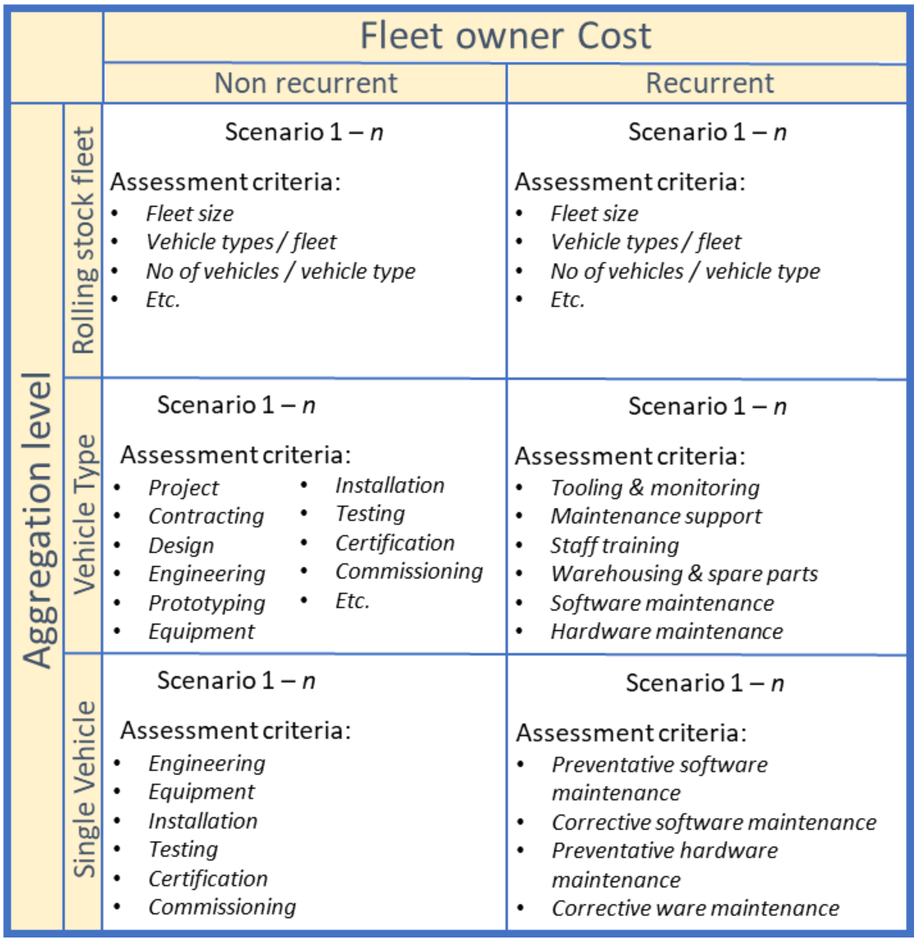

Figure 6 Main development portfolio for scenario building and categorization

Operator and fleet owner experience of the last decades is that the life expectancy of the on-board ERTMS CCS system is between 5 and 10 years, depending on e.g. network characteristics. Thus, for new rolling stock the amount of CCS exchanges over the life cycle would be between 2 (best case, update at 10 and 20 years of age) and 7 (worst case, upgrade at 5, 10, 15, 20, 25, 30 and 35 years of age).

Another issue lies when the CCS system specifics have to be determined i.e. when preparing the tender specifications at the moment of contracting or at commissioning. Since rolling stock procurement lead times cover up to 10 years or longer, a requirement to specify CCS system version and characteristics during the tendering phase is needed. Of course, this can be prevented when standardised interfaces allow integrating the CCS system at delivery, indicating the interdependency between scenario parameters.

The scenarios used are based on the number of vehicles to be equipped each year over a period of 30 years. The scenarios distinguish newly built trains to be delivered including ETCS as well as retrofit situations and take into account of the estimated industrial capacity to perform the corresponding works. Such scenarios can be established according to the template shown in **Table 4**, where negative figures indicate decommissioning and disposal of rolling stock).

Fleet to equip/retrofit	(insert above product n	Type	Product used	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 1	EMU/DMU Class 1	new build	OCORA	10	40														50														-50
Fleet 2	EMU/DMU Class 2	retrofit	OCORA	40	40	40	40																			-160							
Fleet 3	HS	new build	OCORA				20																										
Fleet n	Loc	new build	OCORA									30																					
	Total fleet			50	80	40	40	0	0	0	0	0	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

European fleet level analysis is based on the Ruete report figures as depicted in **Figure 7**. The Ruete report has elaborated two scenarios for fleet development in the years 2020 – 2030 with high and low bound scenarios. From this report, the total European fleet to be equipped by 2030 is estimated between 27.500 and 38.500 vehicles.

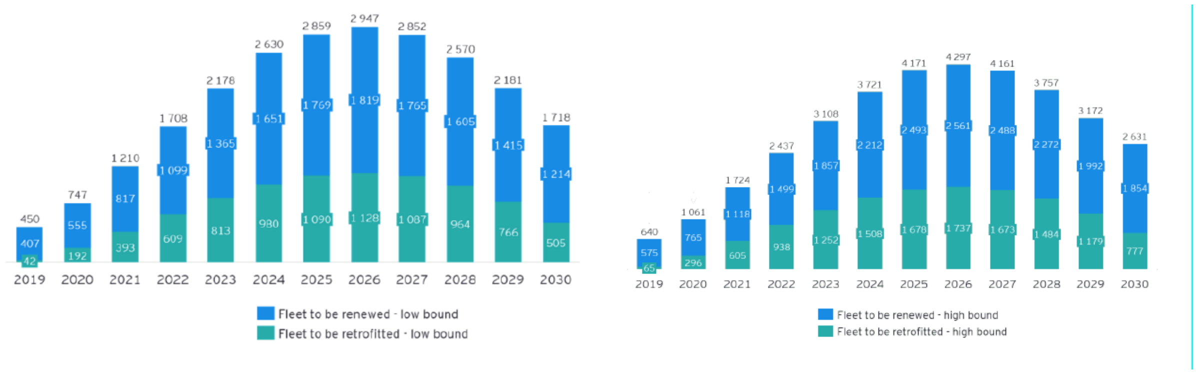

Figure 7 Ruete high (left) and low (right) bound scenario for rolling stock to be renewed or retrofitted

From an OCORA perspective, vehicle types are rolling stock technically identical from a perspective of CCS integration, i.e. rolling stock that would require only one single process of design, engineering, prototyping, installation, testing, certification, approval and commissioning to integrate a specific CCS application. It should be noted that even in a same rolling stock production series or rolling stock class there can be technically different build types because of e.g. variances in delivery dates causing change in applied technology solutions or as a consequence of modifications/evolution and maintenance.

From that perspective, a 'fleet composition' would be composed as follows:

$$Fleet\ composition = \sum_{i=1}^{N} n_i * VehicleType_i$$

With:

N the number of different vehicle types in the fleet;

n_i the number of vehicles of type i in the fleet;

$VehicleType_i$ the type of vehicle i.

Without standardising the interfaces every upgrade cycle would involve renewed integration efforts per vehicle type, significantly hampering life cycle management optimisation. Interface standardisation specifically the one between CCS system and vehicle will therefore allow migration from life cycle management per vehicle type to fleet level, whether the fleet aggregate relates to company level (operator, vehicle owner, lease company), satisfying company business requirements or national or/and European level, satisfying transportation policy needs.

Fleet composition is an essential assessment criterion for economic modelling since 'fleet' can have various levels of aggregation, and therefore consist of some or a multitude of vehicle type. The Ruete calculation of implementation of ERTMS on the European rolling stock fleet from 2020 to 2030 [13] estimates the number of prototypes delivered to be between approximately 385 and 850. According to the "Umfassender Konzeptvorschlag: Aus- und Umrüstung von Schienenfahrzeugen mit ETCS-Bordgeräten" [12] the VDB expects that the roll-out of ERTMS in Germany alone will affect approximately 260 different vehicle types.

However, it seems the Ruete figures are based on the assumption that only one single integration effort per vehicle is necessary over its complete life cycle, where experience demonstrates that periodical upgrade is inevitable. In reality the demand for prototyping will be much higher if no solution is found regarding the multitude of proprietary incompatibilities, barring plug and play exchangeability.

5.2 CCS life expectancy

CCS life cycle determines the need for cyclical investment in rolling stock and maintenance cost. In **Figure 8** the case is illustrated with three different life cycles for a system, e.g. an EVC that requires regular short and long cycle software adaptations.

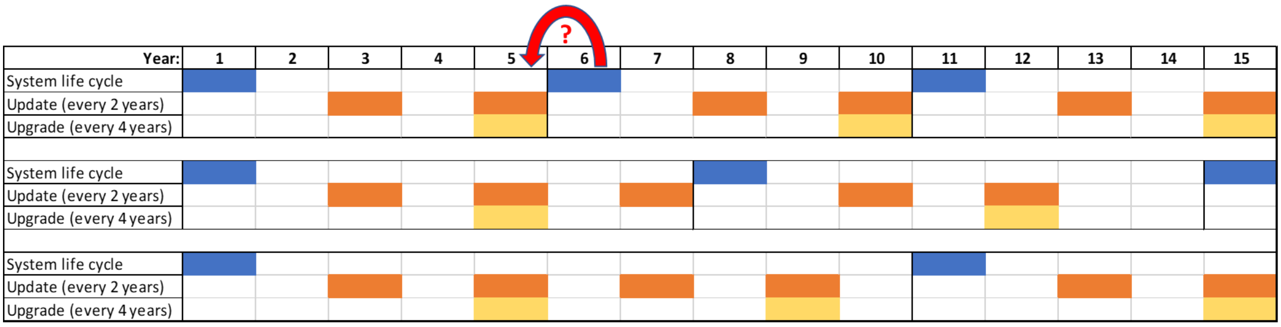

Figure 8 Impact of life expectancy on maintenance: example

The figure demonstrates certain dilemmas that occur because of different life cycles. For example, in case the system lasts 5 years, the question of postponing a software upgrade to save the cost arises. Alternatively, there is the possibility to advance the retrofit by one year to save the extra software updating and upgrading costs. Such decision would heavily depend on other features like the level of granularity and interface standardisation. In case the software maintenance cost would equal or exceed the cost of the system itself and its safe integration in the vehicle, or the larger CCS environment, the option to retrofit the system earlier becomes more probable.

Cost calculations are based on fleet size assumptions (chapter 5.2) using life expectancy pertinent amortisation parameters to break down industrial costs, costs per train class and costs per train. For cost estimation, scenarios are calculated primarily over the reference vehicle life expectancy of 30 years, allowing to consider varying life cycle characteristics of the constituents of CCS configurations. These are, notably:

- the integrated system, life expectancy of which is determined by e.g. TSI driven upgrades, functional enhancement, etc.;
- interface layers like bus and network systems that typically last for decades (e.g. Profibus, MVB, Ethernet) and their protocols;
- medium life expectancy constituents like most hardware's, APIs and some operating systems which last for 5 to 10 years, depending on global technology cycles and equipment availability;
- short cycle applications, specifically application software which need to be upgraded at a frequent rate of a few months to a few years.

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

The model provides for scenario analysis, calculating the effects of parametrising life cycle characteristics of e.g. the CCS system itself, and short cycle (updates, e.g. debugging, enhancements) and medium cycle (upgrades, e.g. additional functionality, functional improvements) renewal rates for its embedded software. The periodicity of these upgrades can be adapted for each scenario and individualized for each product breakdown structure, PBS artefact on the product brake down roadmap like in **Table 5** below.

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 OCORA economic model product roadmap template– life cycle table

As explained above, the scenario approach differentiates CCS related cost and modifications of the vehicle proper. Consequently, the model should allow analysing different investment perspectives (e.g. user, CCS supplier, rolling stock supplier and system integrator) and calculating the effects of technology road mapping (e.g. inclusion of game changers implementation like ATO, FRMCS, Level 3).

5.3 Level of granularity

Decomposing the CCS system as part of the rail vehicle allows effective life cycle management on a 'component' level. The question was already raised in the introduction of Chapter 3 to what level the CCS system should be divided in single, marketable products to suit both customer and supplier requirements. As a general assumption, decoupling system building blocks should support:

- execution of system functions according to functional and non-functional requirements;
- effective life cycle management from the user point of view (cost, performance, risk and operations);
- effective development, engineering and manufacturing from the supplier point of view (return on investments, resource requirements and production capacity).

A principal driver from all points of view is the spatial distribution of system constituents over the vehicle or, alternatively, the CCS system and the building block life expectancy. In other words, the CCS and CCS to train architecture should drive to a large extend the identification of functions and auxiliary services to be clustered in concrete marketable products.

First of all, CCS systems contain parts that need to be physically divided into multiple, single constituents because system building blocks are located at different areas or locations of the system environment (e.g. antennas, encoders).

Then, it is feasible to divide systems in single parts when they consist of multiple single components or functions that have different life expectancies. Maintenance and investment costs can be optimised when single constituents can be exchanged while others remain in operational service (a main driver for e.g. division of hard- and software). This can be ensured by finding the optimum level of decomposition, where the portfolio depicted in **Figure 9** can be used for scenario analysis. Setting off life expectancy variance and spatial distribution of system elements, range finding can be executed on an a priori basis, indicating promising scenarios from a business perspective.

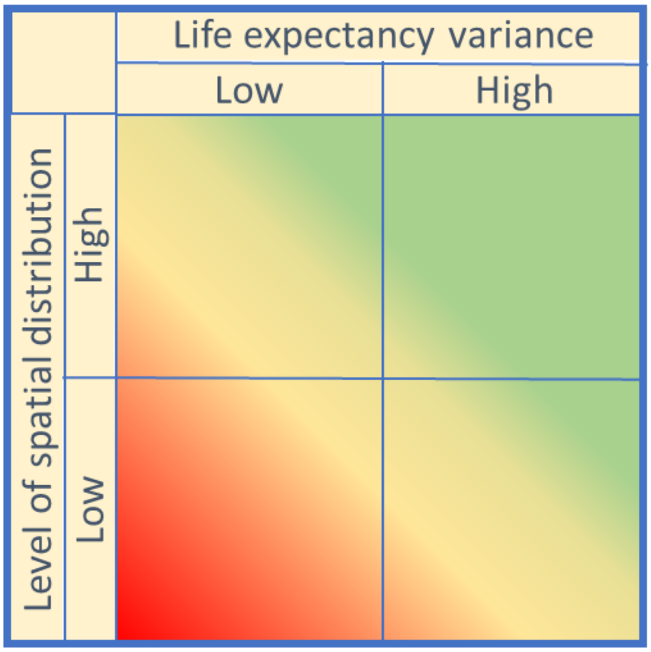

Figure 9 Level of granularity scenario assessment portfolio

5.4 Level of granularity versus interface standardisation level

Modularisation of a system, in effect, means extending system life expectancy by enabling unrestricted replacement of its constituent parts with a lower life expectancy than the system itself without affecting the integrity of the system. Of course, this only works when upgrading and replacing the system can be achieved in relation to cost and performance level optimisation, requiring an open market for CCS products and a level playing field for procurement.

One of the key points of OCORA architecture is the optimisation of CCS system decomposition into single, vendor independent products. Indeed, there is a strong relation between the level of standardisation of the interfaces between such single building blocks and the level of granularity. This perspective in scenario building is represented in **Figure 10**.

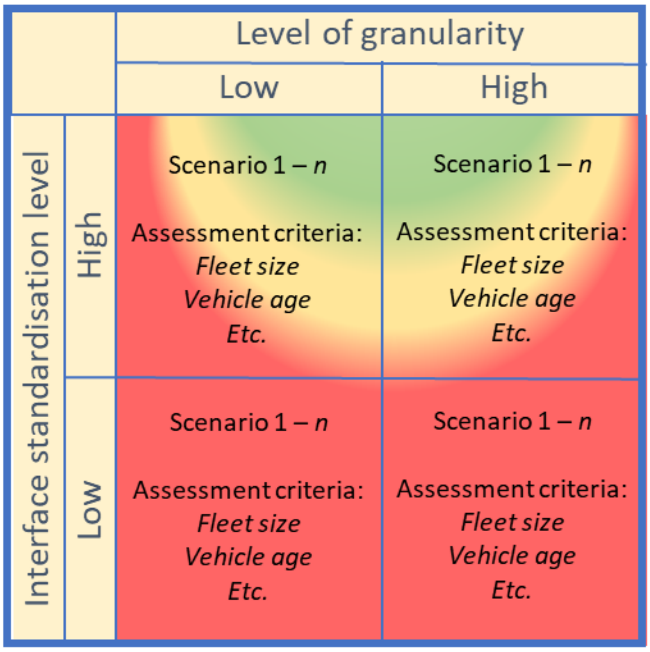

Figure 10 Level of granularity to level of interface standardisation scenario development portfolio

5.5 Conclusion

The examples presented in the previous sections demonstrate that life expectancy, life cycle management, and decomposition and standardisation levels are important parameters. These together enables investment analysis and decisions. They also indicate that effective life cycle management according to OCORA Modularisation Principles enables rapid replacement and innovation cycles by e.g. easing the burden of safe integration. Moreover, adaptive scenario development may exclude certain options because they simply do not comply with either OCORA or supplier requirements, increasing the effectiveness of the economic model.

From reference, it also can be established that the parameters mentioned in the example are strongly interlinked, which increases the complexity of a scenario assessment. The portfolio approach, however, enables unambiguous identification and definition of scenarios. The OCORA Economic Model can be developed step by step by testing ever more detailed scenarios and allowing ample room for introducing new parameters. Scenarios can be swiftly tested and assessed on plausibility and credibility with industry partners. Tested scenarios will, in their turn, provide the raw material for further refinement and improvement of the model.

6 Cost accounting principles

This chapter will explain the assumptions made with respect to costing principles. The algorithms underlying the model itself as well as the application of the model itself are explained in documents [9] and [10]. Interested readers should refer to these documents for more detailed information.

6.1 Generic costs versus class specific costs

Developing, engineering, certifying, manufacturing, implementing and using a fresh generation of CCS systems involves the generic development cost of the application and the project specific integration of those systems in new or existing rolling stock. Typically, the generic technology generation development costs will be covered in the specific implementation projects. And then, project wise, costs need to be covered for e.g. product manufacturing, safe integration, maintenance and so forth.

The OCORA model differentiates these two principal categories to be able to assess the relation between market volumes. In this approach, the proposal is to take into account, apply and distribute "generic cost" versus "class specific cost" and "train specific cost" in the scenarios.

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

1. a cost is estimated in the product breakdown structure, PBS / work breakdown structure, WBS cost matrix (for a given product-solution, chapter 4.2) with no distinction of "generic" or "class";
2. 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);
3. when a WBS activity is tagged as "class" only, then it is applied to each train class;
4. when a WBS activity is tagged as "generic" and "class", then 50% of it is considered as "generic", 50% as "class" and the rules above (1, 2 and 3) apply too. This parameter can be adjusted;
5. when a WBS activity is tagged as "class" and "train specific", then 50% of it is considered as "class" and 50% as "train specific" and the rules above (1, 2, 3 and 4) apply for the scenario. This parameter can be adjusted;
6. when a WBS activity is tagged as "train specific" only, then it is applied to each train.

Work Breakdown Structure (WBS)		Cost allocations principle			Hard- or software?
Category	Subcategory	Generic	Class	Train	
Specification and Design	Specification	1	0.5		HW/SW
	Design	1	0.5		HW/SW
Industrialisation	Production process structuring	1	0.5		HW/SW
Integration, validation, verification	Production integration & validation	1			HW/SW
	Hardware qualification	1			HW
	Class specific integration & validation		1		HW/SW
	Certification	1	1		HW/SW
RAMS and cyber security	Product level	1			HW/SW
	Class level		1		HW/SW
Config management	Studies and production		1		SW
Installation & commissioning	Commissioning		0.5	0.5	HW/SW
	Product supply (HW)			1	HW
	Safe integration in vehicle			1	HW/SW
CCS Maintenance	Routine HW & SW maintenance			1	HW/SW
Rolling stock maintenance and modifications	(Vehicle) modification studies and preparation		1		
	TCMS evolution, adaptation		1		
	(Vehicle) modifications (except TCMS)		0.5	0.5	
	Rolling stock standstill			0.5	
Removal & disposal	Hardware & software			1	HW/SW

Table 6 Generic versus class and train specific cost allocation matrix principle

6.2 Migration cost assessment

CCS cost structure is heavily influenced by the need to adapt or renew all, or part of the installations, be it Hardware, Software or both. Migration can be necessary by one or a combination of the following events.

1. Technology development and obsolescence. IT technology applications develop at a rapid pace, rendering both Hardware and Software obsolete in different but invariably relative short time cycles when compared to the rail vehicle. Where bus and network systems, including interfaces with connected systems or components, typically could survive up to 30 years, telecom and IT hard- and software technology generations can last from a few months to about 10 years, depending on e.g. operational requirements and the need for adapting new technologies to satisfy user requirements.
2. Institutional developments, involving e.g. changes in norms, regulations and European and national law. An important driver for migration is the TSI change management process that has demonstrated to cause substantial volatility in system life expectancy.
3. Evolving user requirements. Railways and fleet owners increasingly need to venture towards higher levels of automation and digitalisation to satisfy changing operational requirements and the expanding needs of their customers.

To cope with migration and its related cost, the model considers the above event drivers for assessing product life cycle horizons from the perspective of the need for replacement of the CCS system or parts of it. The main assumption of the approach is that replacement is a major cost driver in the current situation since it usually involves engineering, integration, testing and certification costs and, hence all of those being time consuming activities, standstill costs.

The PBS structure as represented in **Table 2** will be used as a reference for cost estimation, where the following cost drivers are identified:

1. system replacement, indicating the need to integrally replace constituents of the CCS system or parts of it because of one of the events listed above. In these cases, both Hardware and Software are simultaneously exchanged;
2. function extension, the expenditure incurred by adding new functions to an existing system, e.g. adding ATO functionality to an existing ETCS on-board. In this case, all the costs needed to make this extension available need to be considered, as well as the functional extension could have an impact of the future cost profile of the entire CCS system;
3. Hardware replacement, where the CCS system or its constituents remain in place. This would mainly be applicable to maintenance or renewal e.g. of the TCMS or CCS bus system if interfaces remain stable;
4. medium cycle Software upgrades, e.g. for absorbing TSI baseline updates that do not require hardware exchange;
5. short cycle Software updates, e.g. for debugging, minor improvements of functionality or error corrections.

6.2.1 Software upgrades and updates

Cost effects of scenario parametrisation can be e.g., simple product upgrade due to obsolescence, functional enhancement, changes following TSI changes, and are estimated at xx % of overall “generic costs”, where xx is a configurable parameter, applied on fleet level. The parameters appear in the model in the sheet “Parameters”, together with the Hardware upgrade, as represented in **Table 7** below.

Product	HW update (coefficient applied to the costs)	SW update
EVC	0.5	0.3
pre-O.	0.5	0.3

Table 7 Software upgrades and updates costing impact parameters (xx and yy parameters here put at 0.3 and 0.5 respectively)

There is also a need to upgrade the systems which are already deployed on trains: the associated cost, labelled "Install Integrate CCS (Hardware and Software) with RST (manpower)" will be applied to each train. In case no software upkeep costs are applied in a scenario, the "Software (SW) upgrade" cell in the product roadmap should be disabled.

6.2.2 Hardware upgrades (obsolescence)

As with Software upkeep costs (see previous section), cost effects of scenario parametrisation are estimated at yy % of overall "generic costs", where yy is a configurable parameter, applied on fleet level, see **Table 7**.

There is also a need to upgrade the system already deployed on trains: the associated cost, labelled "Install Integrate CCS (Hardware and Software) with RST (manpower)" will be applied to each train. In case no Software upkeep costs are applied in a scenario, the "Hardware (HW) upgrade" cell in the product roadmap should be disabled.

6.2.3 Costs estimations for raw WBS/PBS activities or devices

At present, a first attempt to estimate the costs is a "base 10" approach, i.e. the results of the economic evaluation executed in scenarios do not represent a monetary value, expressed in Euros, but an equation of scenario analysis results relative to each other, expressed in 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.