

OCORA

Open CCS On-board Reference Architecture

Economic Model

CCS System Life Cycle Costing Scenario Studies

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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 provides the results of first test runs, assessing life cycle impact on CCS LCC as a means to demonstrate the plausibility of the modelling approach.

The test runs prove, that life cycle expectancy of the CCS system, have a direct impact on life cycle costing, as might be expected. Based on that result of the scenario assessment, the modelling output demonstrates that the model provides predictable output.

These initial test runs also demonstrate that the model must be further developed for which recommendations are made.

Revision history

Version	Change Description	Initial	Date of change
1.00	Official version for OCORA Release R1	JH/NPA	03.12.2021
1.01	Decoupled document from a specific OCORA release	JH/NPA	10.06.2022

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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-BWS06-010 – Economic Model – Guiding Principles - Assumptions - Assessment Criteria
- [9] OCORA-BWS06-020 – Economic Model
- [10] OCORA-BWS06-030 – Economic Model – Model Description
- [11] OCORA-BWS06-040 – Economic Model – User Manual
- [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] ERTMS Coordinator Work Plan, May 2020

1 Introduction

1.1 Purpose of the document

This document reports on the output of only one specific, out of a multitude of possible modelling scenarios, i.e. the impact of life cycle expectancy on the recurrent life cycle cost of the EVC core of the ERTMS based CCS system. This scenario study has no intention to present definite conclusions on such cost, it is to be understood as a mere attempt in a series of many, to test the plausibility and scalability of the OCORA economic model and its methodology. Therefore, any conclusions are to be understood as assumptions that could support further investigation.

The purpose of this document is to reflect first results of the development of a scenario based approach that supports sensitivity to analyse and measure the effects of applying various assumptions and their different parametrisation in economic evaluations. The goal of testing different scenarios in this phase of development of the OCORA economic model, is primarily to test and improve the methodology and substantiate underlying assumptions and their parametrisation through trial and error and discussions with stakeholders. As such, this document mirrors a 'work in progress' state of affairs and needs to be judged as such. It is specifically intended first of all, to spark discussion.

For any background information, we refer the reader to the general introduction [8], the model description [10], and the applied algorithms for cost calculation [9].

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.

1.2 Applicability of the document

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

1.3 Context of the document

This document is published as part of the OCORA Release R2, together with the documents listed in the release notes [1]. Before reading this document, it is recommended to read the Release Notes [1]. If you are interested in the context and the motivation that drives OCORA we recommend to read the Introduction to OCORA [5], and the Problem Statements [7]. The reader should also be aware of the Glossary [1] 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 Scenario description

In the first test runs of the model, the objective is to test if the model provides 'feasible' results. 'Feasible' is defined as output that does not appear counterfactual from an expert point of view. Obviously, this is a subjective assessment criteria but nevertheless demonstrates that the model does not generate any 'funny' results: the output can be explained in objective terms. This is an important step since it gives confidence that the further development process will provide credible output. Nevertheless, next steps include rigorous analysis, assessment and testing of both underlying assumptions and the applied algorithms. The model currently enables analysing the effects of life cycle expectancy of CCS costing profiles (see specifically [16], and [18] and [19] for details). Two situations are considered and compared:

1. The Pre-OCORA situation, representing the actual market situation;
2. The OCORA situation, reflecting the impact of establishing the OCORA architecture.

Then, considering the CCS configuration, the model differentiates between:

1. The EVC to be part of the delivery of new rolling stock;
2. The EVC to be part of retrofit of existing rolling stock

Based on the following assumptions, test runs were executed with the model [9].

Two fleet scenarios have been considered:

1. European scale (2020 Ruete report [13] low bound figures)
2. National scale – One 100 vehicles fleet

Based on an assumed state of art CCS life expectancy variation between 5 to 10 years, test runs were made, based on an assumed CCS average life expectancy of 5, 7 and 10 years. The resulting BPS roadmaps for the five-year scenario is in Figure 1. For the seven-year and ten-years scenario, see respectively Figure 2 and Figure 3.

Lifecycle		Product: PBS ROADMAP																																			
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as solution	pre-O.	OCORA Full Modular Solution	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																																			
CCS Core	Core CCS	x																																			
CCS Core	Core CCS - ATP (ETCS Core)	x																																			
CCS Core	CCS add-on - NTC-STM																																				
CCS Core	CCS add-on - ATO																																				
CCS Core	CCS add-on - other functions/services																																				
CCS peripherals	Communication and interfaces	x																																			
CCS peripherals	I/O Ports	x																																			
CCS peripherals	Functional Vehicle Adapter (FVA)	x																																			
CCS peripherals	UVCC	x																																			
CCS peripherals	Gateway	x																																			
CCS peripherals	MCG (GSM-R, FRMCS...)																																				
CCS peripherals	Sensoring	x																																			
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																																				
CCS peripherals	Train Loc (GNSS, Inertial...)	x																																			
CCS peripherals	Perception sensoring (other sensors)																																				
CCS peripherals	DMI	x																																			
CCS tools	Tools																																				
CCS tools	Testing tools (eg test bench, simulator)																																				
CCS tools	Maintenance tools																																				
CCS tools	Training tools																																				

Figure 1: PBS roadmap for a 5-years CCS system life expectancy

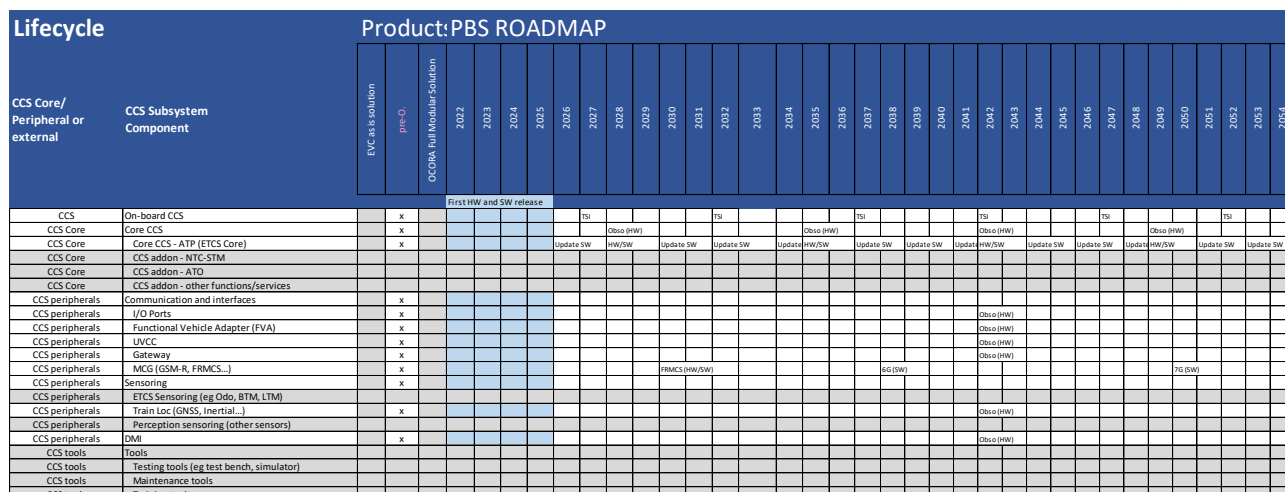


Figure 2: PBS roadmap for a 7-years CCS system life expectancy

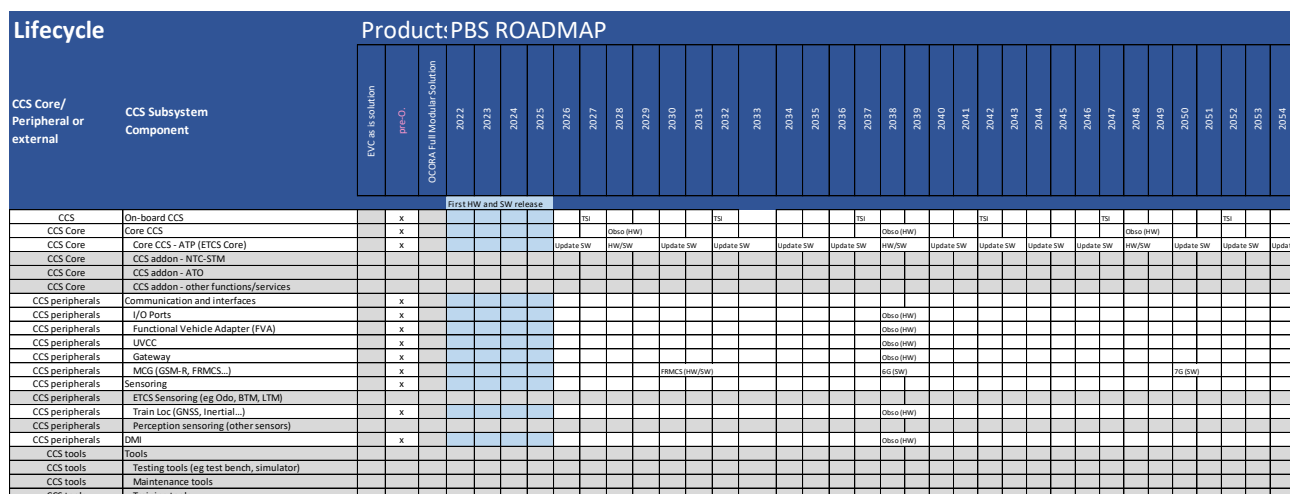


Figure 3: PBS roadmap for a 10-years CCS system life expectancy

Please note: the scenario that are tested here, address the effects of OCORA only on fleet level and do NOT differentiate fleets into vehicle types. As remarked in the guiding principles, main assumptions and general assessment criteria document [16], integration costs are dominated by fleet composition rather than fleet size

3 Test run findings

The first test runs have analysed and calculated the effects of OCORA in the previously described scenarios as far as operations costs OPEX are concerned.

The scenarios have been performed by the tool previously as described in [10].

Scenarios were performed for this 1.0 release with the model / tool adapted (as introduced in [9]).

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

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

The two scenarios aim at showing the impact on the implementation of the pre-OCORA architecture, in comparison with the existing EVC architecture.

3.1 Scenario 1: European scale / low bound figures

For this scenario, the figures considered for the acquisition and retrofit of vehicles are listed in Table 1:

SCENARIO WITH: OCORA				2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
Fleet to equip/retrofit		(insert above product n: Type		Product used																													
Fleet 1	EMU/DMU Class 1	new build	EVC	407	555	817	1099	1365	1651	1769	1819	1765	1605	1415	1214																		
Fleet 2	EMU/DMU Class 2	retrofit	EVC	42	192	393	609	813	930	1090	1128	1087	964	766	505																		
Fleet 1	EMU/DMU Class 1	new build	pre-O.	407	555	817	1099	1365	1651	1769	1819	1765	1605	1415	1214																		
Fleet 2	EMU/DMU Class 2	retrofit	pre-O.	42	192	393	609	813	930	1090	1128	1087	964	766	505																		
Total fleet				449	747	1210	1708	2178	2581	2859	2947	2852	2569	2181	1719	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 1: Ruete low bound scenario ERTMS on-bord roll out figures, newly built and retrofit [30]

As remarked in the introductory document [16], this European fleet is constituted of a multitude of technically different vehicle types. In this test run, no account is taken of this aspect.

In the next table, the results are presented for fleet development as represented in Table 1.

		CCS Costs			
5 years	New Build	1 360 055	Fleet 1	EMU/DMU Class 1	EVC
		747 427	Fleet 2	EMU/DMU Class 2	EVC
	Retrofit	925 817	Fleet 1	EMU/DMU Class 1	pre-O.
		509 058	Fleet 2	EMU/DMU Class 2	pre-O.
	Total	2 107 483	Fleet 1	EMU/DMU Class 1	EVC
-32%		1 434 875	Fleet 2	EMU/DMU Class 2	pre-O.
7 years	New Build	1 466 708.84	Fleet 1	EMU/DMU Class 1	EVC
		807 102.13	Fleet 2	EMU/DMU Class 2	EVC
	Retrofit	977 699.40	Fleet 1	EMU/DMU Class 1	pre-O.
		537 792.25	Fleet 2	EMU/DMU Class 2	pre-O.
	Total	1 970 262	Fleet 1	EMU/DMU Class 1	EVC
-33%		1 316 077	Fleet 2	EMU/DMU Class 2	pre-O.

10 years	New Build	1 180 513.20	Fleet 1	EMU/DMU Class 1	EVC
		647 189.28	Fleet 2	EMU/DMU Class 2	EVC
	Retrofit	789 439.34	Fleet 1	EMU/DMU Class 1	pre-O.
		433 709.67	Fleet 2	EMU/DMU Class 2	pre-O.
	Total	1 827 702	Fleet 1	EMU/DMU Class 1	EVC
-33%		1 223 149	Fleet 2	EMU/DMU Class 2	pre-O.

Table 2: Results for the European scale (low bound) deployment scenario, for the three CCS life expectancies

Conclusion:

- The model provides plausible results for those considered scenarios
- This scenario demonstrates the impact of extended life expectancy on the expenditure on fleet level. Substantial savings are feasible when CCS life expectancy can be extended.

Given the size of the fleet, non-recurrent integration costs, specifically the need for prototyping, etc., can be reimbursed over a huge fleet, so they will have little impact on overall cost. For this and other reasons, the scenario only minor relevance for cost - benefit assessment of the OCORA and non-OCORA condition.

In Annex 1, graphical outputs of the test scenarios have been visualized. The graphs show the relative values for replacement, soft- and hardware costs relevant to their life cycle. As explained above, they reflect cost developments for both newly built and existing rolling stock (retrofit) in a 'non-OCORA' and 'OCORA' environment. Consolidated, the results are reflected in Figure 4, below.

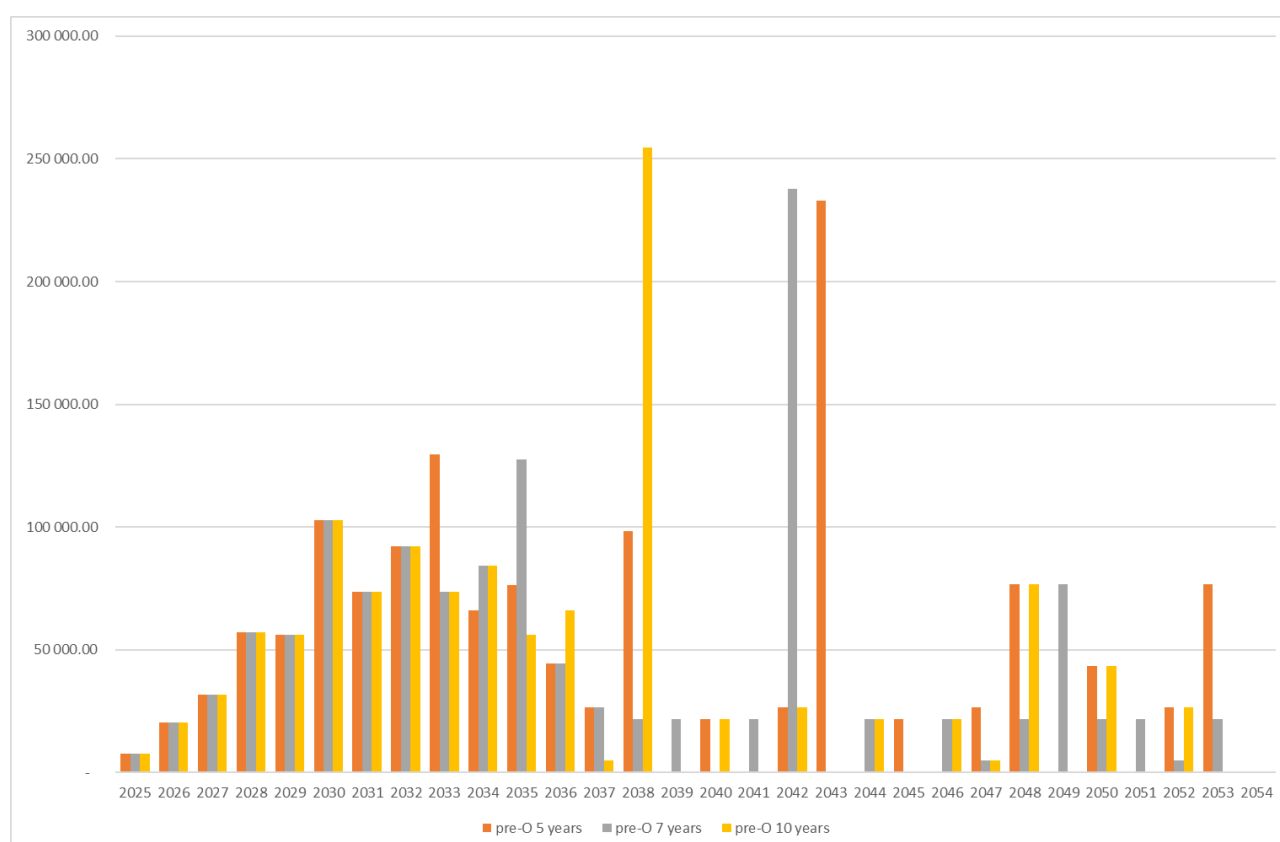


Figure 4: Scenario 1 – costs distribution for the pre-O product and the three 5-, 7- and 10-years CCS life expectancies

For this deployment scenario, the introduction of the OCORA architecture, with the 1st step being the pre-OCORA product, leads to a reduction of 30% of the CCS OPEX for both considered fleets (fleet 1 – renewed vehicles, fleet 2 – retrofitted vehicles) over the whole life cycle of the vehicles.

The three life expectancies lead to the same decrease of the costs, when comparing the two products EVC and pre-O.

(As a reminder: the input data are based on a base-10 approach, the quantitative results shall not be seen as representative figures).

The graphs above show a different distribution of costs over years, with similar costs for the yearly regular updates, and much lower costs for the upgrades, due to the modularisation introduced.

Comparing to the 5-years life expectancy results, the 7-years and the 10-years results bring decreases of 8% and 15% respectively. Those results were predictable given restricted scope of the scenarios involved and restricted articulation of the underlying assumptions and parameters. Since the goal was to find out if the test runs could provide unexpected outcome, the results give confidence that the general approach is valid.

3.2 Scenario 2: National scale – One 100 vehicles fleet

In the next table, the results are presented for a fleet of 100 vehicles. Here too, in reality this could be somewhere between 1 and 5 vehicle types as explained in [16].

	CCS costs	
5 years		
Total	7 635	EVC
-38%	4 740	pre-O.
7 years		
Total	7 463	EVC
-38%	4 644	pre-O.
10 years		
Total	7 119	EVC
-37%	4 454	pre-O.

Table 3: Results for the 100 vehicles fleet deployment scenario, for the three CCS life expectancies

Here too, we can see that life cycle costs diminish with an increase in system life expectancy, although less pronounced as the previous scenario.

The consolidated scenario test output is represented in Figure 5 below.

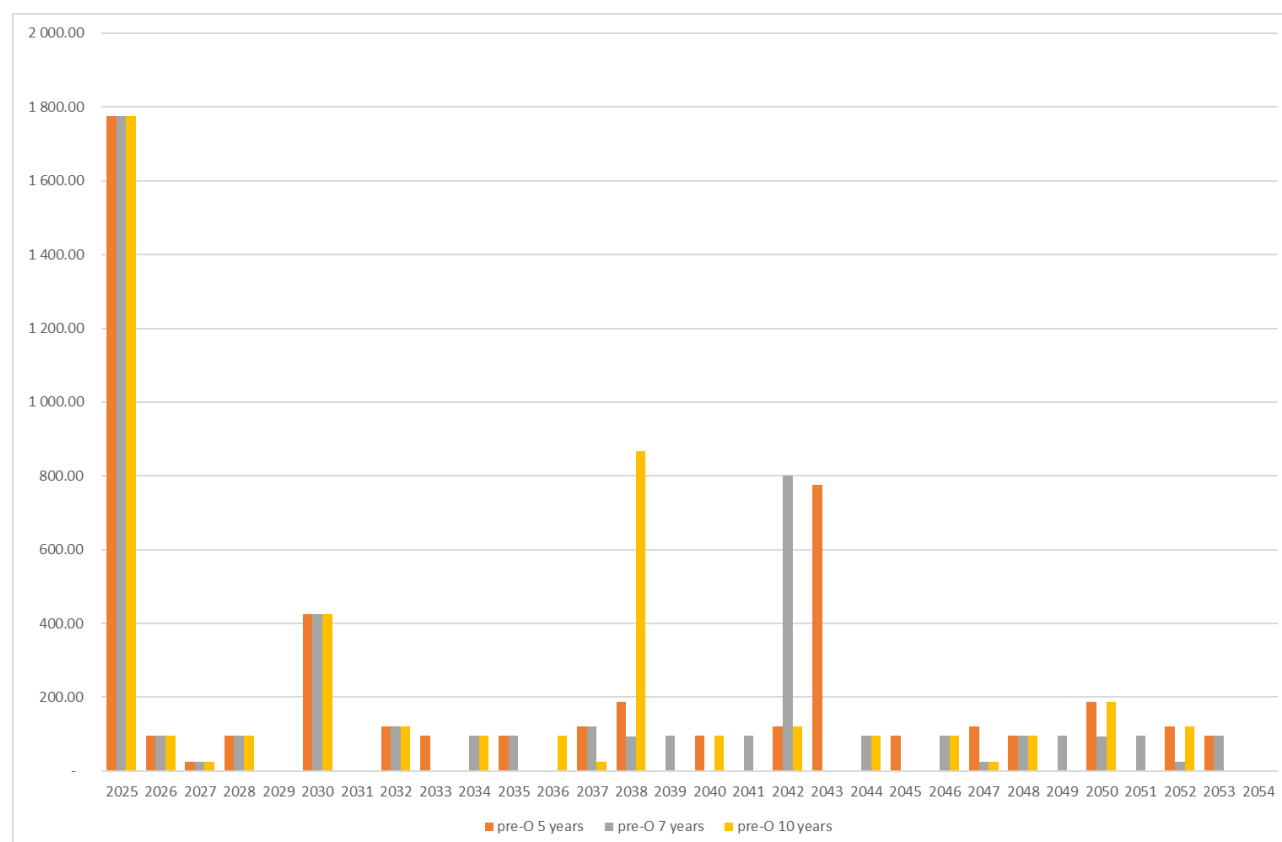


Figure 5: Scenario 2 – costs distribution for the pre-O product and the three CCS life expectancies

In this example, the impact of the introduction of the OCORA architecture is even more significant, with a larger reduction of the costs.

Overall, the test runs confirm that there is a positive relation between system life expectancy and system life cycle costs, which supports the assumption that the model generates valid results.

On the other hands, the test runs do not allow any conclusions on the equation between OCORA and non-OCORA conditions.

4 Further steps

The scenario studies were but a first exploration of the possibilities of economic modelling. The model will be further refined by the OCORA team. Next development steps include (non-limitative):

- Refining the model and its associated tool, including the assessment of the costs (in euros),
 - Rigorous review and (quality) assessment of underlying assumptions;
 - Regular (quality) check of algorithms and model;
 - Migration from Excel to an appropriate calculation tool;
 - Reinforcement of the description and basic assumptions pertaining to OCORA;
 - Refinement of modelling assumptions down to technology choices aligned with OCORA architecture principles. The objective should be for the model to trace in an exhaustive way the effects of implementing the OCORA breakthrough (e.g. technical proposals, design requirements);
 - Enhance the model with parameter costs: all the costs, including the maintenance costs (preventive, curative, repair);
 - Explore other methods for cost assessment, e.g. by application of a target costing approach, that could be used as e.g., an add-on to check results against each other.
- Identification of a library of relevant scenarios (fleets, roadmaps...):
 - Develop deployment scenarios to help understand cash flows for different stakeholders involved.
 - Ditto regarding deployment and industrialisation scenarios as well as considerations on the capability of the sector to deliver the needed quantities in the different scenarios and for given deployment roadmaps;
 - Evolving scenario development requirements as a result of running scenarios using the tool.

In addition, following issues may have to be considered:

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

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

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

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

The model is enabling enhanced analysis potential to quantitatively identify and validate common business

objectives for stakeholders. S2R and its successor are natural places for further improving the modelling approach and values. OCORA considers the EC ERTMS Deployment Management Team to probably be an appropriate source for a set of (or range for) reference assumptions and parameters.

Annex 1: Test scenario output in graphs

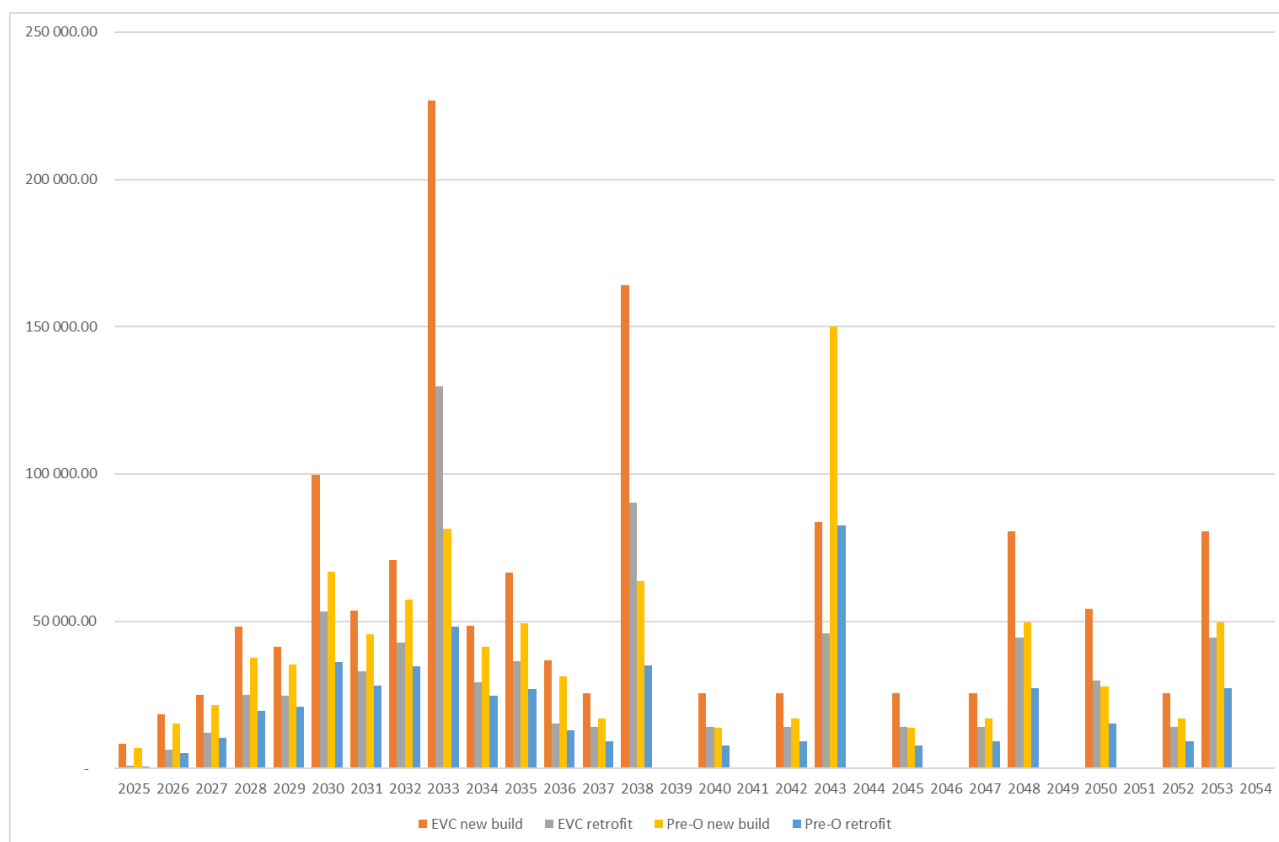


Figure 6: Scenario 1 – costs distribution for EVC and pre-O product for the 5-years CCS life expectancy

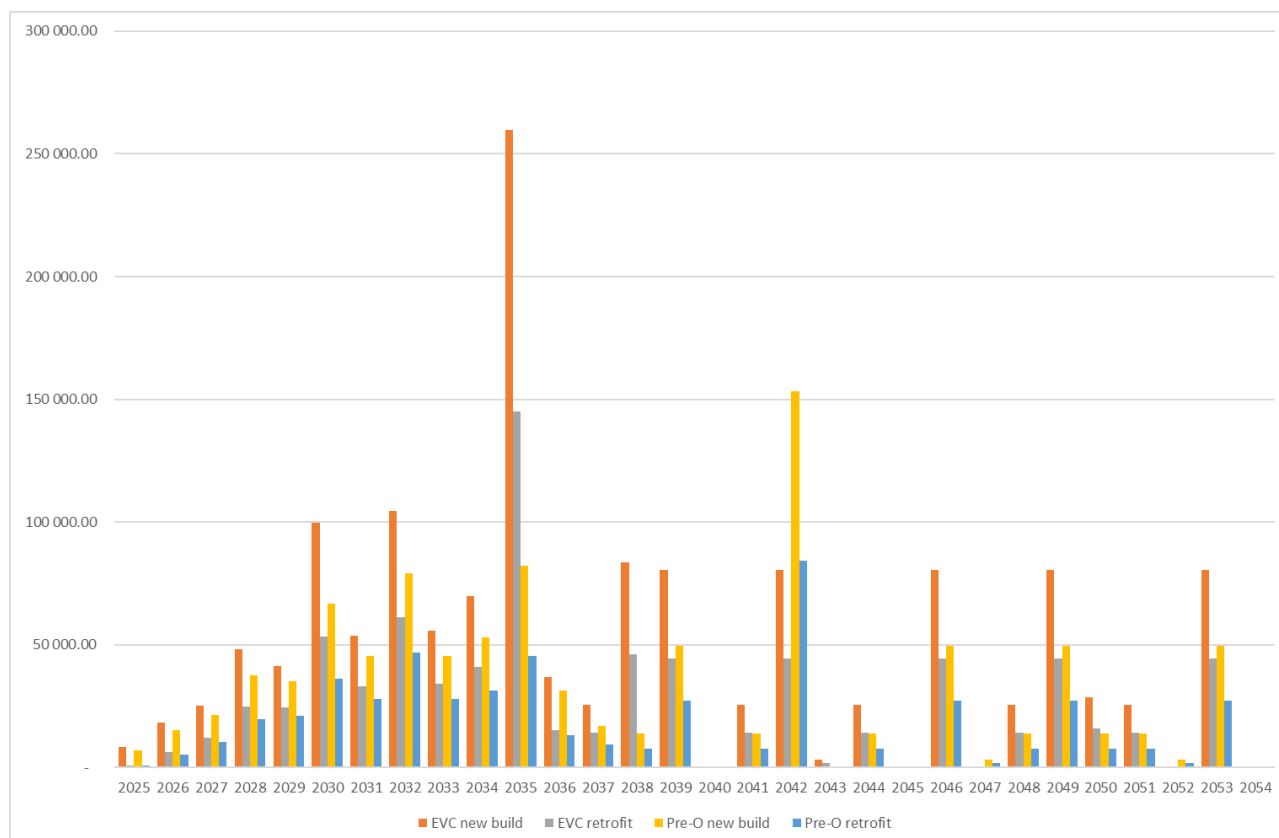


Figure 7: Scenario 1 – costs distribution for EVC and pre-O product for the 7-years CCS life expectancy

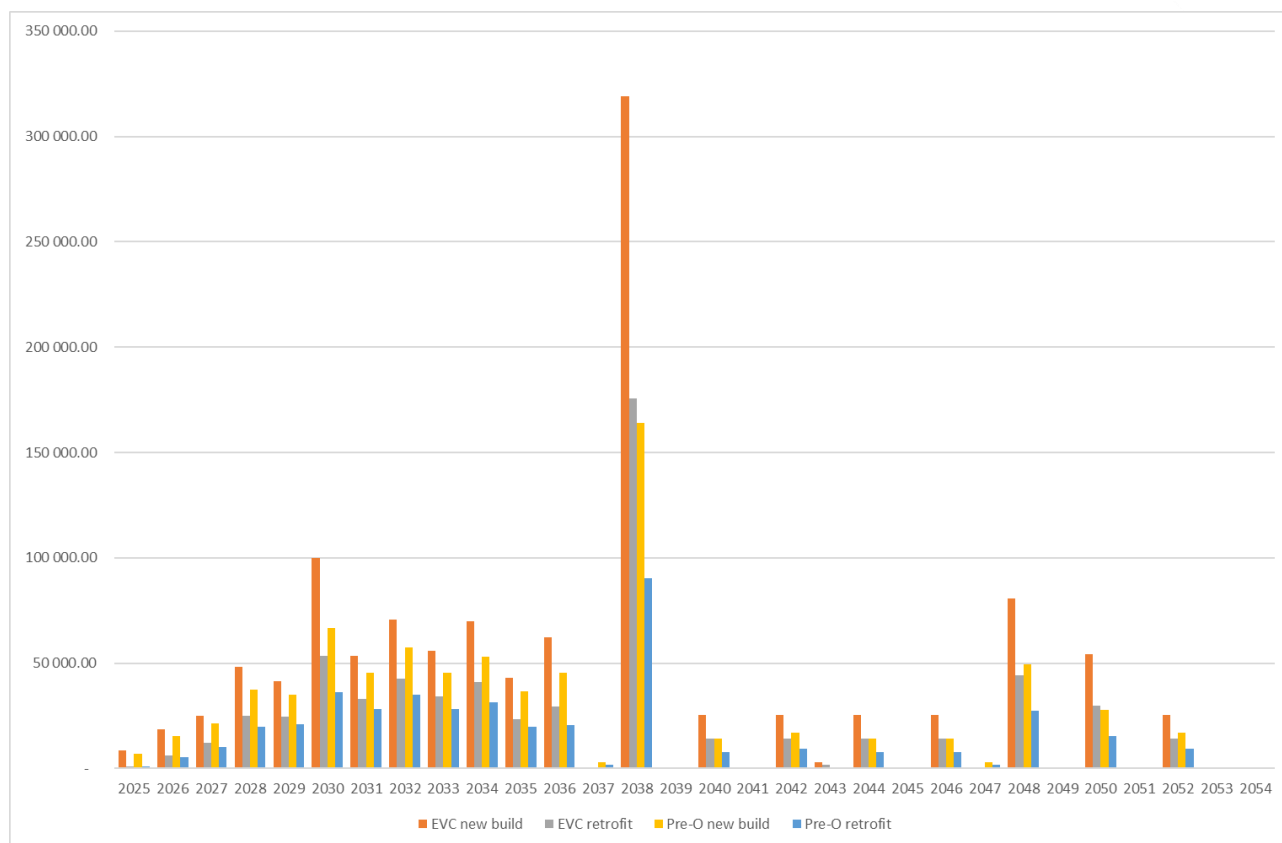


Figure 8: Scenario 1 – costs distribution for EVC and pre-O product for the 10-years CCS life expectancy