OCORA

OCORA

Open CCS On-board Reference Architecture

Economic Modelling Series

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

Revision history

Version	Change Description	Initial	Date of change
0.00	▪ Initial draft	NPT	19.05.2022
0.01	▪ Revised draft including all results from LH and PV	NPT	03.06.2022
0.02	▪ Revised draft including further results	NPT	09.06.2022
1.00	1st release version	NPT	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-BWS04-010 – Problem Statements

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

[8] 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

[9] ERTMS Coordinator Work Plan, May 2020

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 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 by different OCORA members in this document, using the economic model [7], make use of numbers that were adopted from formal reports and analysis from EC or other sources. 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 compliant CCS building blocks, for tendering complete on-board CCS system, or also for on-board CCS replacements for functional upgrades or for life-cycle reasons.

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

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

2 The fleets investigated

2.1 Introduction

Several fleets have been considered to perform the sensitivity analysis. Different sizes and distributions have been chosen, in order to have a large panel of cases.

2.2 The European fleet

European fleet level analysis is based on the Ruete report [9], figures as depicted below in **Figure 1**. The Ruete report has elaborated two scenarios for fleet development in the years 2020 – 2030: a high bound and a low bound scenario. From this report, the total European fleet to be equipped by 2030 is estimated between 27.500 and 38.500 vehicles.

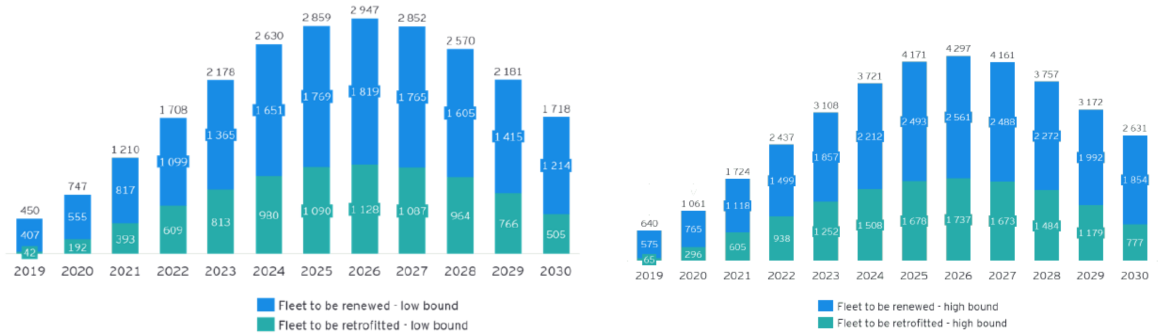

Figure 1 Ruete high (left) and low (right) bound scenario for rolling stock to be renewed or retrofitted

The figures considered for the acquisition and retrofit of vehicles are the following ones:

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 na	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	0

Table 1 European scale (low bound) deployment scenario

2.3 The VDB fleet

This simulation task aimed to have a realistic overview of the ETCS-retrofit plan for the German fleet. Basis of this calculation was the VDB study published in [8] which is freely available.

The study made deep investigations in specifying the process of ETCS retrofitting according to the German roll-out plan. The first indicative numbers used in our simulation were the numbers of vehicles divided into the years from 2022 to 2030. The next relevant indicator was the defined equipment cluster. In total, three different equipment clusters were presented, and only one of them was suiting the OCORA requirements: The fully integrated solution with TCMS. That cluster includes the following specifications:

- Digital interface of the ETCS/ATO OBU to the vehicle through TCMS
- Implementation of comfort functions, e.g. vehicle diagnostics, processing of track conditions
- DMI functionally and mechanically integrated in driver's cab
- During integration/conversion, the OEM must be fully involved

The VDB study also divided the number of total vehicles into the three clusters. The next step was to calculate the number of vehicles per year by the ratio of the vehicles of that relevant cluster. After that was done, the third indicator was mentioned: the different vehicle types. In total, six different vehicle types are mentioned in the VDB study: ICE, e-locomotive, d-locomotive, EMU, DMU & H2 and track construction and special vehicles. Dividing the number of relevant vehicles per year to the ratio of these vehicle types, the final table was calculated.

	ICE	Lok E	Lok D	EMU	DMU, H2	Track construction etc.
2022	0	4	1	3	2	2
2023	1	19	5	16	10	10
2024	8	154	36	127	81	81
2025	13	250	59	206	131	131
2026	16	307	72	253	161	161
2027	16	317	74	261	166	166
2028	16	317	74	261	166	166
2029	16	317	74	261	166	166
2030	16	317	74	261	166	166
Total:	102	2000	470	1650	1050	1050

Table 2 Number of relevant vehicles per year to the ratio of the vehicle types from the VDB report.

2.4 A typical regional fleet

A typical regional fleet of 100 vehicles is also considered, with all the vehicles being equipped the first year.

2.5 A distributed fleet

For this fleet a combination of several types of vehicles has been considered, to illustrate a typical program of combining ETCS on-board equipment (retrofit and upgrade) on existing vehicles and newly built vehicles. The goal of this distribution is to find and understand any potential differences in the model's outcomes introduced by varying in size (ranging from 50 – 200) and type of ETCS project (upgrade – retrofit – newbuilt).

For the retrofit fleets, a remaining lifecycle of 18 years has been considered. After this period the vehicles will be taken out of consideration. For retrofitted and new built vehicles an introduction rate of 50 per years has been considered.

The Table 3 gives the figures for the resulting fleet of 1500 vehicles.

1500 vehicles	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																														
Upgrade_1	100	100																												
Upgrade_2	100	50																												
Upgrade_3	100																													
Upgrade_4		50																												
Retro_1	50	50	50	50															-50	-50	-50	-50								
Retro_2	50	50	50																-50	-50	-50									
Retro_3		50	50																	-50	-50									
Retro_4				50																		-50								
New_1			50	50	50	50																								
New_2			50	50	50																									
New_3				50	50																									
New_4						50																								

Table 3 Number of relevant vehicles per year for the distributed fleet.

3 The parameters investigated

3.1 Cost variation

For the first three fleets, three scenarios have been investigated, with cost variation:

a. Baseline case: EVC product vs pre-OCORA product

b. WBS case: variation of the class parameter in the Work Breakdown Structure for the class value in specification/industrialization tasks (with pre-OCORA product)

c. PBS Commissioning case: decrease of the cost parameter value for the commissioning costs, with the pre-OCORA architecture

	Product	**WBS Specification & industrialization values for Class**	**PBS Commissioning cost**
Baseline	**- EVC** **- Pre-OCORA**	0.50	Core CCS = 5 MCG (GSM-R, FRMCS) = 5 Train Loc. = 10
WBS case	Pre-OCORA	**- 0.25** **- 0.50**	Core CCS = 5 MCG (GSM-R, FRMCS) = 5 Train Loc. = 10
Commissioning case	Pre-OCORA	0.50	**Core CCS = 2** **MCG (GSM-R, FRMCS) = 2** **Train Loc. = 2**

Table 4 Summary of cases investigated for the three fleets: European fleet, VDB fleet and regional fleet, with varying parameter in blue.

The accompanying roadmaps are the following ones, for both EVC and pre-OCORA products.

Products PBS ROADMAP

CCS Subsystem Component	EVC	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
On-board CCS	x				TSI					TSI						TSI					TSI					TSI							TSI				
Core CCS	x																																				
Core CCS - ATP (ETCS Core)	x					Upgrade (SW)					Upgrade (SW)		HW obs	Upgrade (SW)			Upgrade (SW)					Upgrade (SW)					Upgrade (SW)							Upgrade (SW)			
CCS addon - NTC-STM																																					
CCS addon - ATO																																					
CCS addon - other functions/services																																					
Communication and interfaces	x																																				
I/O Ports	x												Obso (HW)			Obso (HW)																					
Functional Vehicle Adapter (FVA)																																					
UVCC	x																																				
Gateway																																					
MCG (GSM-R, FRMCS…)	x												5G(HW/SW)								6G (HW/SW)												7G (SW)				
Sensing	x																																				
ETCS Sensing (eg Odo, BTM, LTM)	x															Obso (HW)																					
Train Loc (GNSS, Inertial…)																																					
Perception sensoring (other sensors)																																					
DMI	x															Obso (HW)																					
Tools																																					
Testing tools (eg test bench, simulator)																																					
Maintenance tools																																					
Training tools																																					

Figure 2 PBS roadmap for the EVC product

Lifecycle

Product: PBS ROADMAP

CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is 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							TSI						TSI					TSI					TSI							TSI				
CCS Core	Core CCS		x																							HW obs											
CCS Core	Core CCS - ATP (ETCS Core)		x								Upgrade (SW)						Upgrade (SW)					Upgrade (SW)					Upgrade (SW)							Upgrade (SW)			
CCS Core	CCS addon - NTC-STM																																				
CCS Core	CCS addon - ATO																																				
CCS Core	CCS addon - other functions/services																																				
CCS peripherals	Communication and interfaces		x																																		
CCS peripherals	I/O Ports		x																							Obso (HW)											
CCS peripherals	Functional Vehicle Adapter (FVA)		x																							Obso (HW)											
CCS peripherals	UVCC		x																							Obso (HW)											
CCS peripherals	Gateway		x																							Obso (HW)											
CCS peripherals	MCG (GSM-R, FRMCS…)		x										FRMCS (HW/SW)								6G (SW)												7G (SW)				
CCS peripherals	Sensing		x																																		
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																																				
CCS peripherals	Train Loc (GNSS, Inertial…)		x																							Obso (HW)											
CCS peripherals	Perception sensoring (other sensors)																																				
CCS peripherals	DMI		x																							Obso (HW)											
CCS tools	Tools																																				
CCS tools	Testing tools (eg test bench, simulator)																																				
CCS tools	Maintenance tools																																				
CCS tools	Training tools																																				

Figure 3 PBS roadmap for the pre-OCORA product (for European, VDB and regional fleets)

3.2 Roadmap variation

The update frequency of the CCS system has been investigated for the distributed fleet, with a variation of 2 years, from 2 to 10 years and finally as a reference no updates at all. he following figures show the different PBS roadmaps considered; all being used with the pre-OCORA product.

Lifecycle		Products PBS ROADMAP																																			
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is 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							TSI						TSI					TSI					TSI							TSI				
CCS Core	Core CCS		x																							HW obs											
CCS Core	Core CCS - ATP (ETCS Core)		x								Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrade (SW)		Upgrac
CCS Core	CCS addon - NTC-STM																																				
CCS Core	CCS addon - ATO																																				
CCS Core	CCS addon - other functions/services																																				
CCS peripherals	Communication and interfaces		x																																		
CCS peripherals	I/O Ports		x																							Obso (HW)											
CCS peripherals	Functional Vehicle Adapter (FVA)		x																							Obso (HW)											
CCS peripherals	UVCC		x																							Obso (HW)											
CCS peripherals	Gateway		x																							Obso (HW)											
CCS peripherals	MCG (GSM-R, FRMCS...)		x										FRMCS (HW/SW)								6G (SW)												7G (SW)				
CCS peripherals	Sensoring		x																																		
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																																				
CCS peripherals	Train Loc (GNSS, Inertial...)		x																							Obso (HW)											
CCS peripherals	Perception sensoring (other sensors)																																				
CCS peripherals	DMI		x																							Obso (HW)											
CCS tools	Tools																																				
CCS tools	Testing tools (eg test bench, simulator)																																				
CCS tools	Maintenance tools																																				
CCS tools	Training tools																																				

Figure 4 PBS roadmap for the distributed fleet – 2 years frequency for upgrade

Lifecycle		Products PBS ROADMAP																																			
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is 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							TSI						TSI					TSI					TSI							TSI				
CCS Core	Core CCS		x																							HW obs											
CCS Core	Core CCS - ATP (ETCS Core)		x								Upgrade (SW)				Upgrade (SW)				Upgrade (SW)				Upgrade (SW)				Upgrade (SW)				Upgrade (SW)				Upgrade (SW)		
CCS Core	CCS addon - NTC-STM																																				
CCS Core	CCS addon - ATO																																				
CCS Core	CCS addon - other functions/services																																				
CCS peripherals	Communication and interfaces		x																																		
CCS peripherals	I/O Ports		x																							Obso (HW)											
CCS peripherals	Functional Vehicle Adapter (FVA)		x																							Obso (HW)											
CCS peripherals	UVCC		x																							Obso (HW)											
CCS peripherals	Gateway		x																							Obso (HW)											
CCS peripherals	MCG (GSM-R, FRMCS...)		x										FRMCS (HW/SW)								6G (SW)												7G (SW)				
CCS peripherals	Sensoring		x																																		
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																																				
CCS peripherals	Train Loc (GNSS, Inertial...)		x																							Obso (HW)											
CCS peripherals	Perception sensoring (other sensors)																																				
CCS peripherals	DMI		x																							Obso (HW)											
CCS tools	Tools																																				
CCS tools	Testing tools (eg test bench, simulator)																																				
CCS tools	Maintenance tools																																				
CCS tools	Training tools																																				

Figure 5 PBS roadmap for the distributed fleet – 4 years frequency for upgrade

Lifecycle		Products PBS ROADMAP																																			
CCS Core/ Peripheral or external	CCS Subsystem Component	EVC as is 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							TSI						TSI					TSI					TSI							TSI				
CCS Core	Core CCS		x																							HW obs											
CCS Core	Core CCS - ATP (ETCS Core)		x								Upgrade (SW)						Upgrade (SW)						Upgrade (SW)						Upgrade (SW)						Upgrade (SW)		
CCS Core	CCS addon - NTC-STM																																				
CCS Core	CCS addon - ATO																																				
CCS Core	CCS addon - other functions/services																																				
CCS peripherals	Communication and interfaces		x																																		
CCS peripherals	I/O Ports		x																							Obso (HW)											
CCS peripherals	Functional Vehicle Adapter (FVA)		x																							Obso (HW)											
CCS peripherals	UVCC		x																							Obso (HW)											
CCS peripherals	Gateway		x																							Obso (HW)											
CCS peripherals	MCG (GSM-R, FRMCS...)		x										FRMCS (HW/SW)								6G (SW)												7G (SW)				
CCS peripherals	Sensoring		x																																		
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)																																				
CCS peripherals	Train Loc (GNSS, Inertial...)		x																							Obso (HW)											
CCS peripherals	Perception sensoring (other sensors)																																				
CCS peripherals	DMI		x																							Obso (HW)											
CCS tools	Tools																																				
CCS tools	Testing tools (eg test bench, simulator)																																				
CCS tools	Maintenance tools																																				
CCS tools	Training tools																																				

Figure 6 PBS roadmap for the distributed fleet – 6 years frequency for upgrade

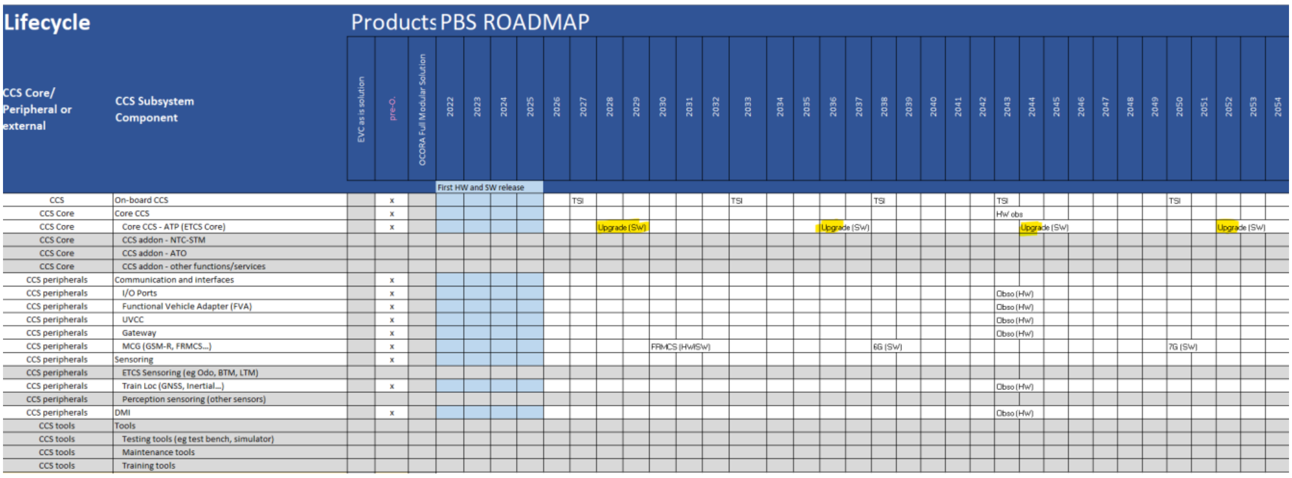

Figure 7 PBS roadmap for the distributed fleet – 8 years frequency for upgrade

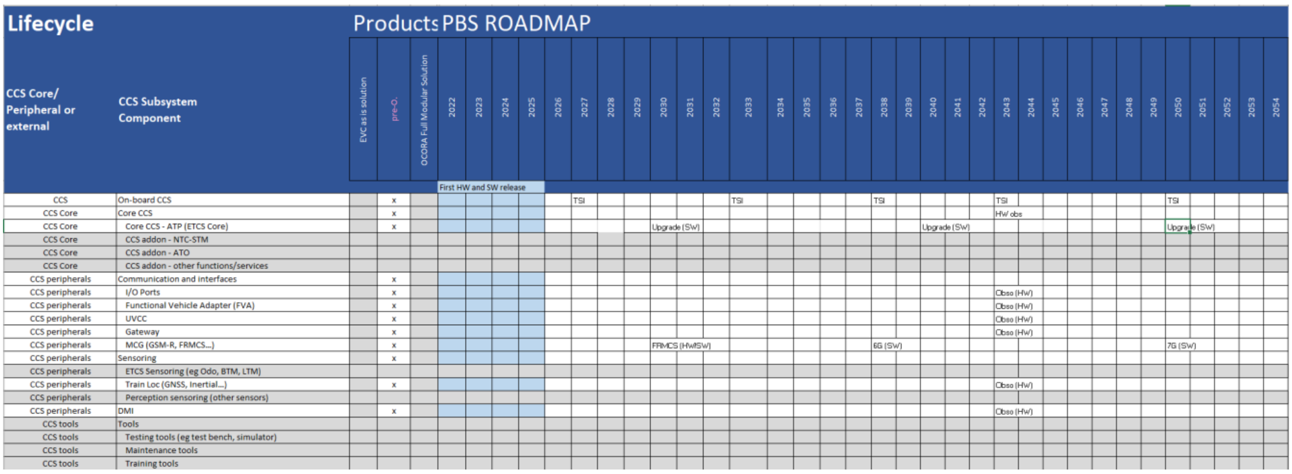

Figure 8 PBS roadmap for the distributed fleet – 10 years frequency for upgrade

4 Results of the sensitivity analysis

4.1 Cost variation: Baseline case

The baseline case (EVC product vs pre-OCORA product) has been applied on the four fleets previously described.

The following table gives the overall impact of the introduction of the pre-OCORA architecture on the global cost for 30 years.

	European fleet	VDB fleet	Distributed fleet	Regional fleet
EVC cost	1 258 940	350 423	90 245	5 524
Pre-OCORA cost	1 192 465	237 517	61 023	4 712
reduction	*-5%*	*-32%*	*-32%*	*-15%*

Table 5 Results for cost variation on three fleets: European fleet, VDB fleet and regional fleet

The resulting reduction clearly depends on the planning of the equipment of the vehicles.

In the case of the European fleet, the reduction with the pre-OCORA product is minored, due to remaining high costs for the obsolescence phase in 2043, balancing the costs for obsolescence of the EVC product in 2033: the number of vehicles in the fleet is higher in 2043 than in 2033, hence the discrepancy.

For a given fleet, the potential foreseen obsolescence for some on-board equipment has to be taken carefully into account for the assessment of the costs linked to the CCS on-board, both for retrofitted and new vehicles.

For VDB and distributed fleets, the reduction appears similar, as all vehicles are equipped by 2030.

For the regional fleet, the effect of having one unique type of vehicle affects the impact of the reduced cost of the pre-OCORA product; less class means here less decrease.

The following sections give the distributions of the costs over years for all considered fleets.

4.1.1 European fleet

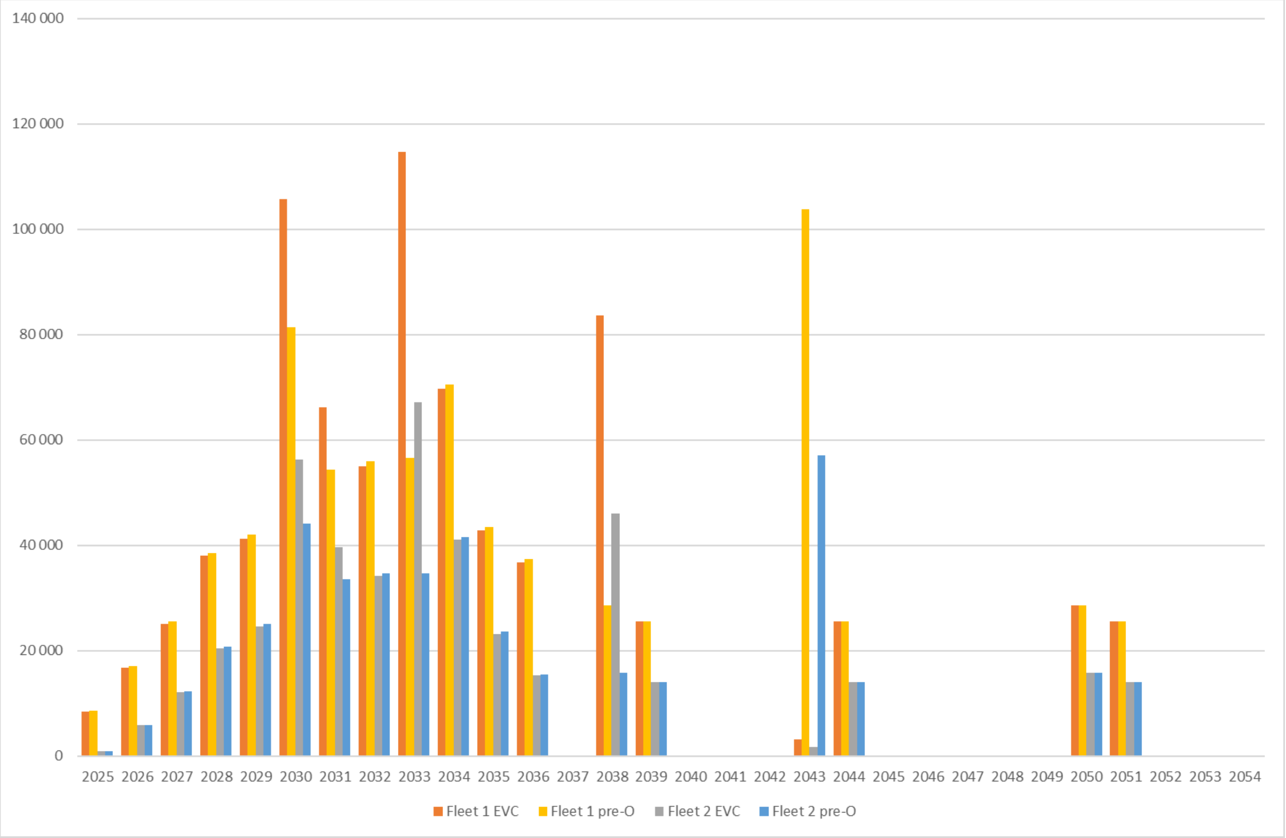

Figure 9 European fleet: Baseline: distribution per fleet (EVC/pre-OCORA)

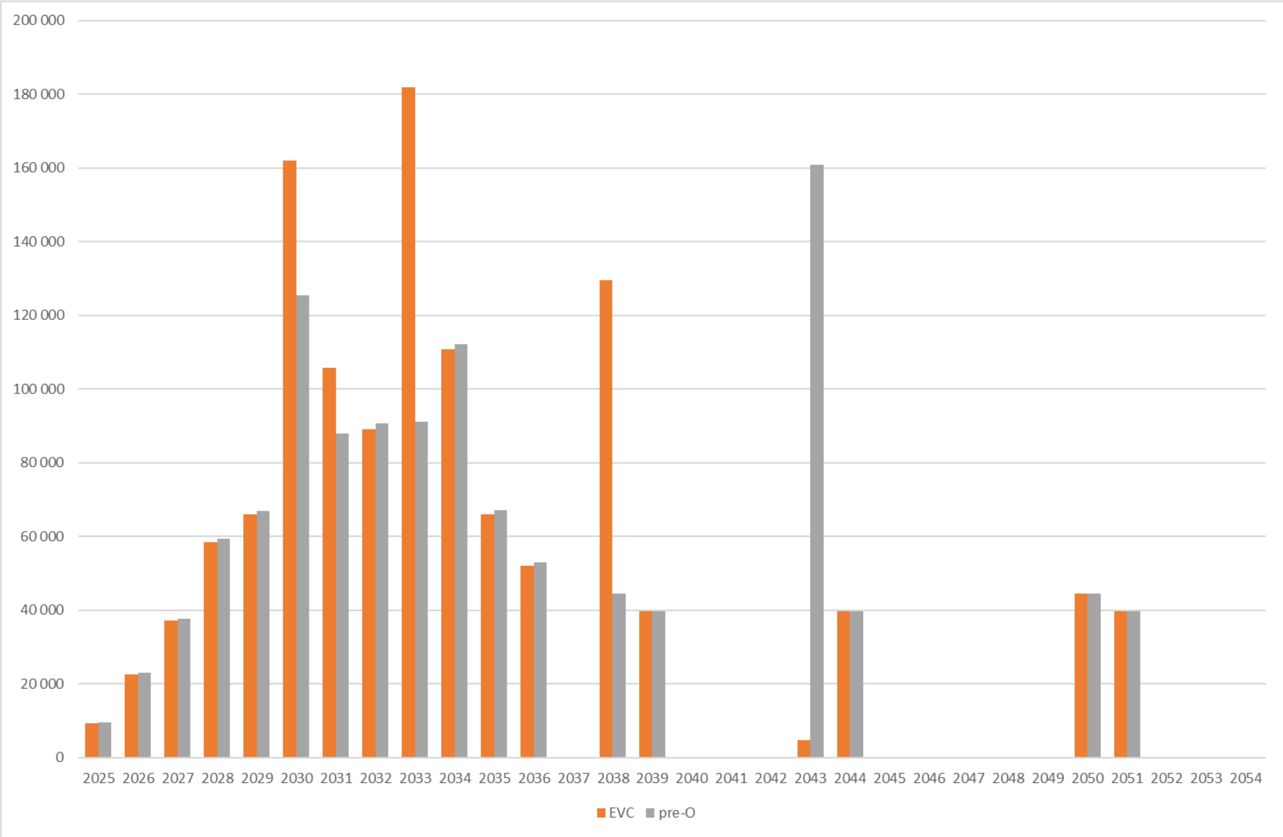

Figure 10 European fleet: Baseline: distribution per product (all fleets)

4.1.2 VDB fleet

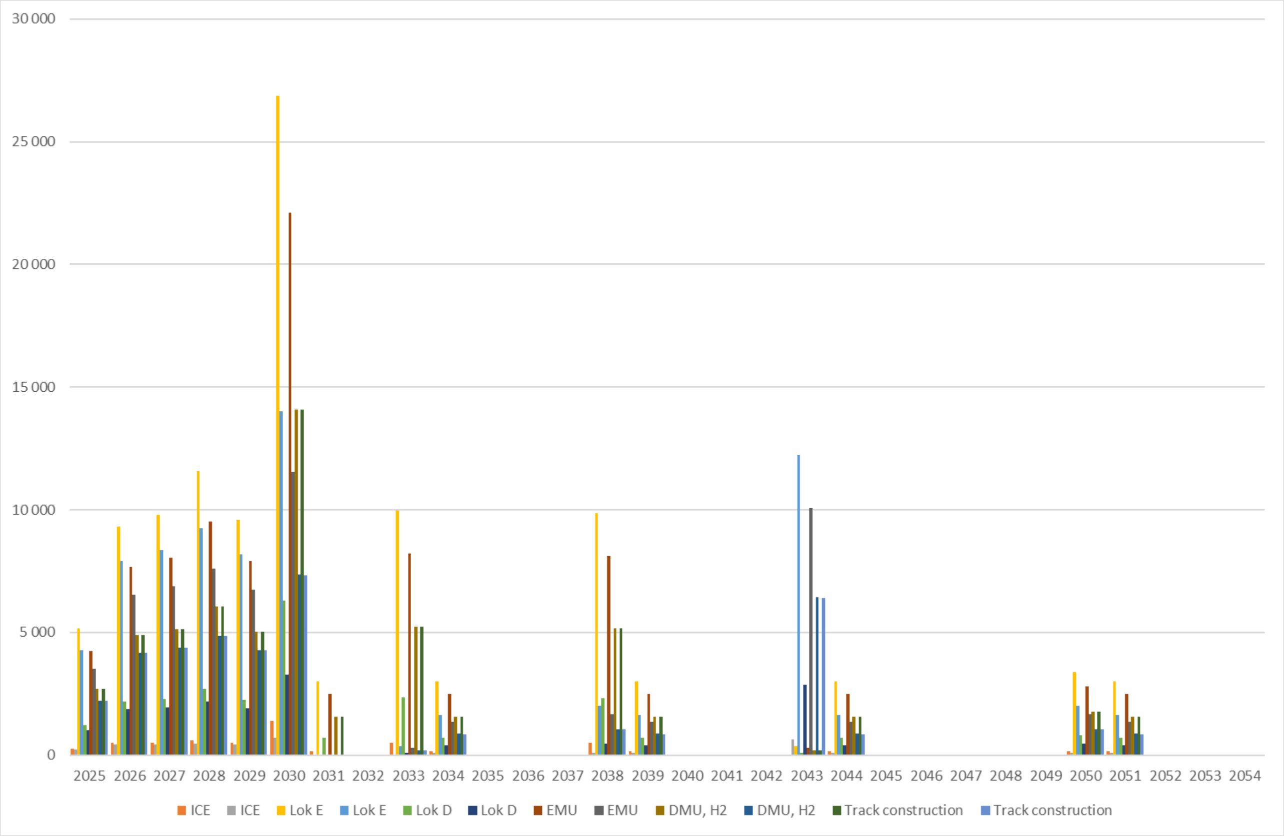

Figure 11 VDB fleet: Baseline: distribution per fleet (EVC/pre-OCORA)

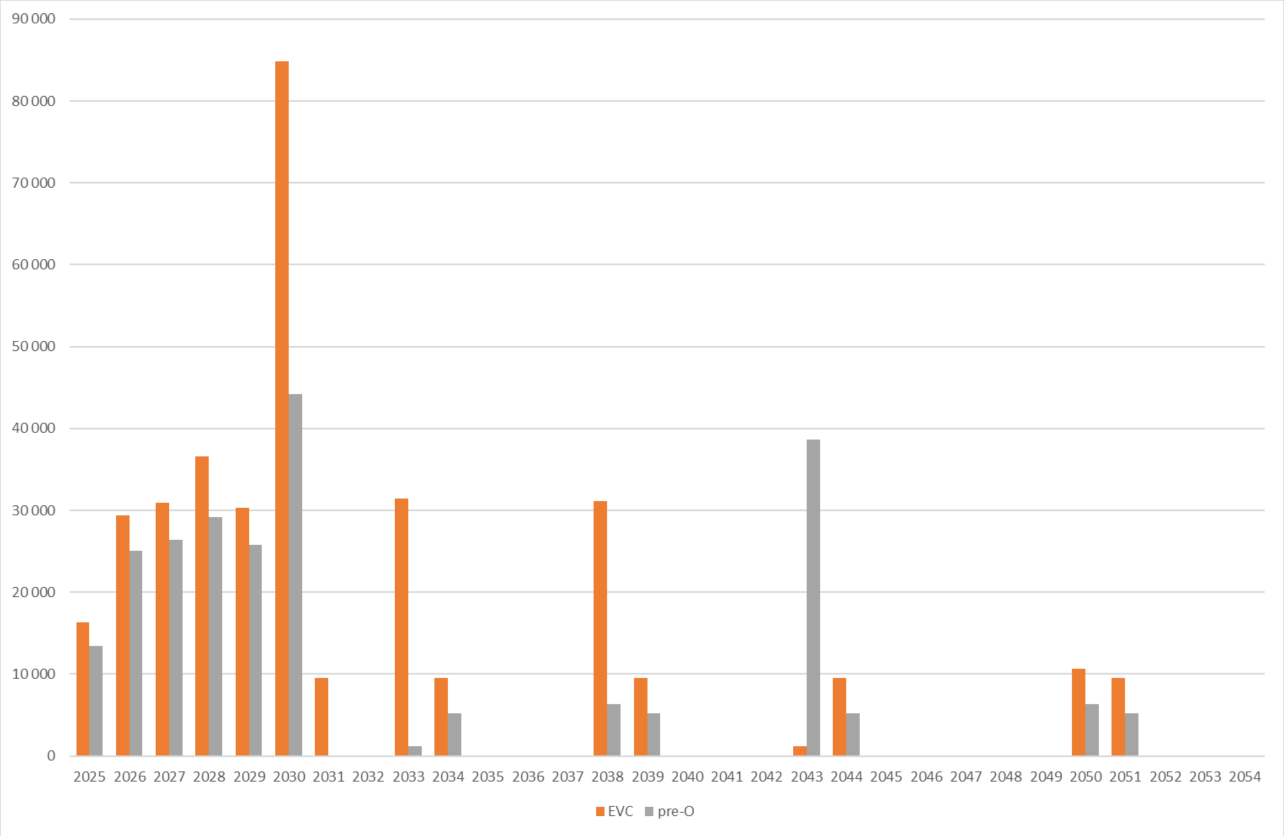

Figure 12 VDB fleet: Baseline: distribution per product (all fleets)

4.1.3 Distributed fleet

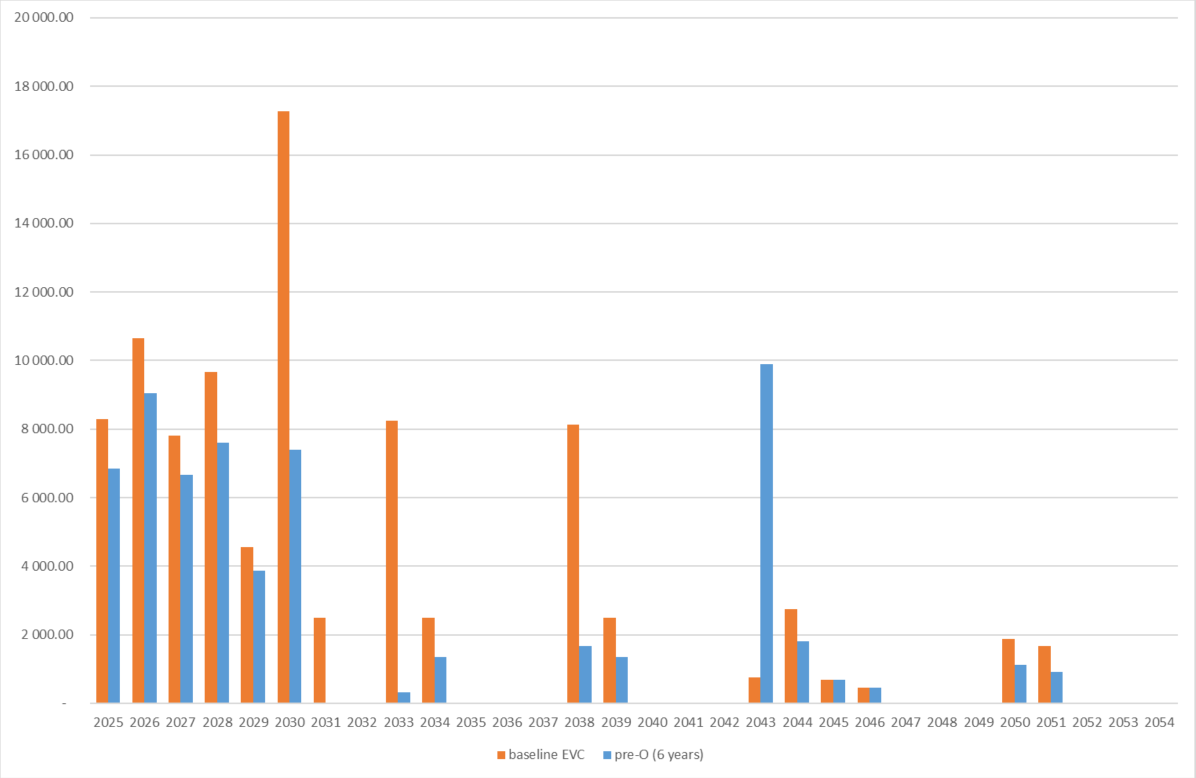

Figure 13 Distributed fleet: Baseline case: distribution per product (all fleets)

4.1.4 Regional fleet

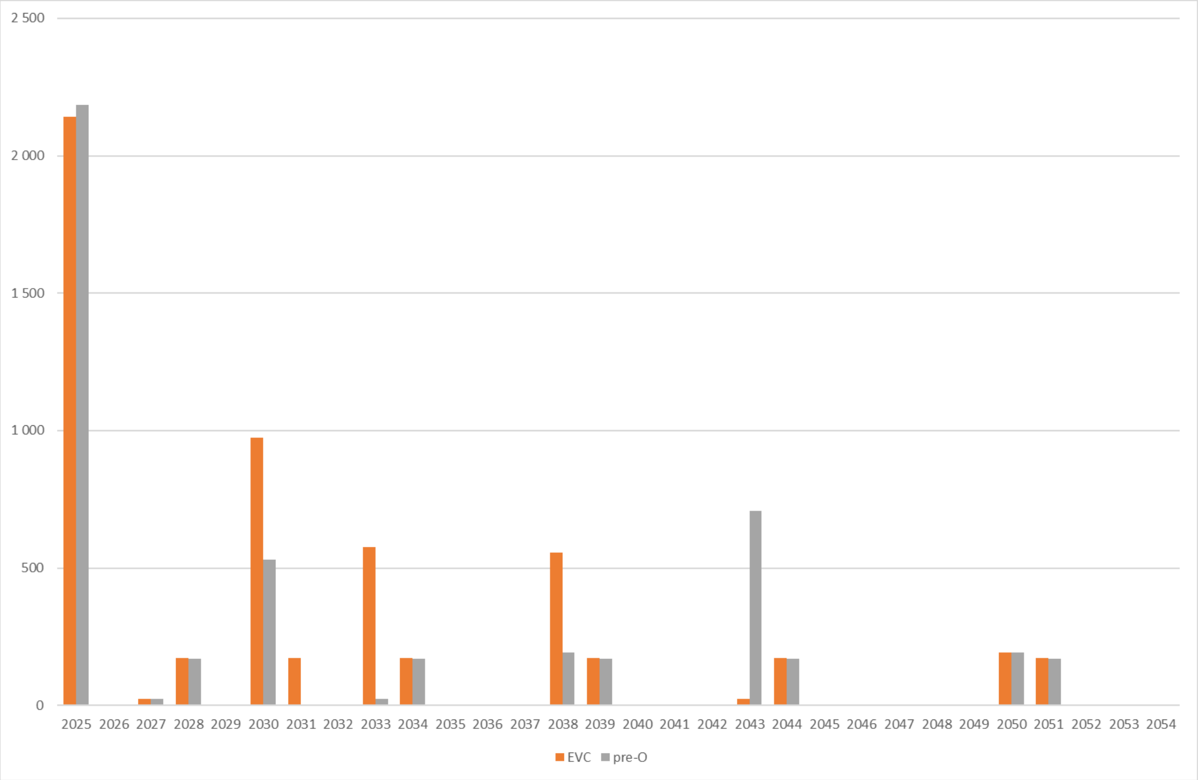

Figure 14 Regional fleet: Baseline: distribution per product

4.2 Cost variation: WBS case (class parameter variation)

The cost variation, from 0.25 to 0.75, for the class parameter has been applied on the two first fleets previously described, namely the European Fleet and the VDB fleet. When developing a new generic product, there is still some adaptation work for each considered class. Therefore, additional costs are to be taken into account at WBS level. The impact of reducing those costs has to be assessed, hence this cost variation.

A third value for the class parameter (a value of 5) is also considered, in order to maximise the potential impact on the overall costs. This case has been computed only for the VDB fleet.

The following table gives the overall impact of the introduction of the pre-OCORA architecture on the global cost for 30 years for the two fleets.

	European fleet		**VDB fleet**	
EVC cost	1 258 940		350 423	
Pre-OCORA (WBS 025) cost	1 192 441	*- 5.2800%*	237 453	*- 32.225%*
Pre-OCORA (WBS 050) cost	1 192 465	*- 5.2802%*	237 517	*- 32.220%*
Pre-OCORA (WBS 075) cost	1 192 490	*- 5.2804%*	237 580	*- 32.215%*
Pre-OCORA (WBS 500) cost			238 657	*- 31.908%*

Table 6 Results for cost variation (WBS case) on two fleets: European fleet and VDB fleet

There is clearly a very slight impact of the cost variation as introduced at the WBS level.

As expected, the difference is proportional to the number of classes of trains, hence the stronger discrepancies between the three cases for the VDB fleet, where 6 types are considered.

Even when considering an important cost for the classes (Ten times more, with parameter at 5 instead of 0.5), the overall costs remain almost the same, with a similar reduction. This parameter appears definitely not as the main cost driver.

The following sections give the distributions of the costs over years for the two fleets.

4.2.1 European fleet

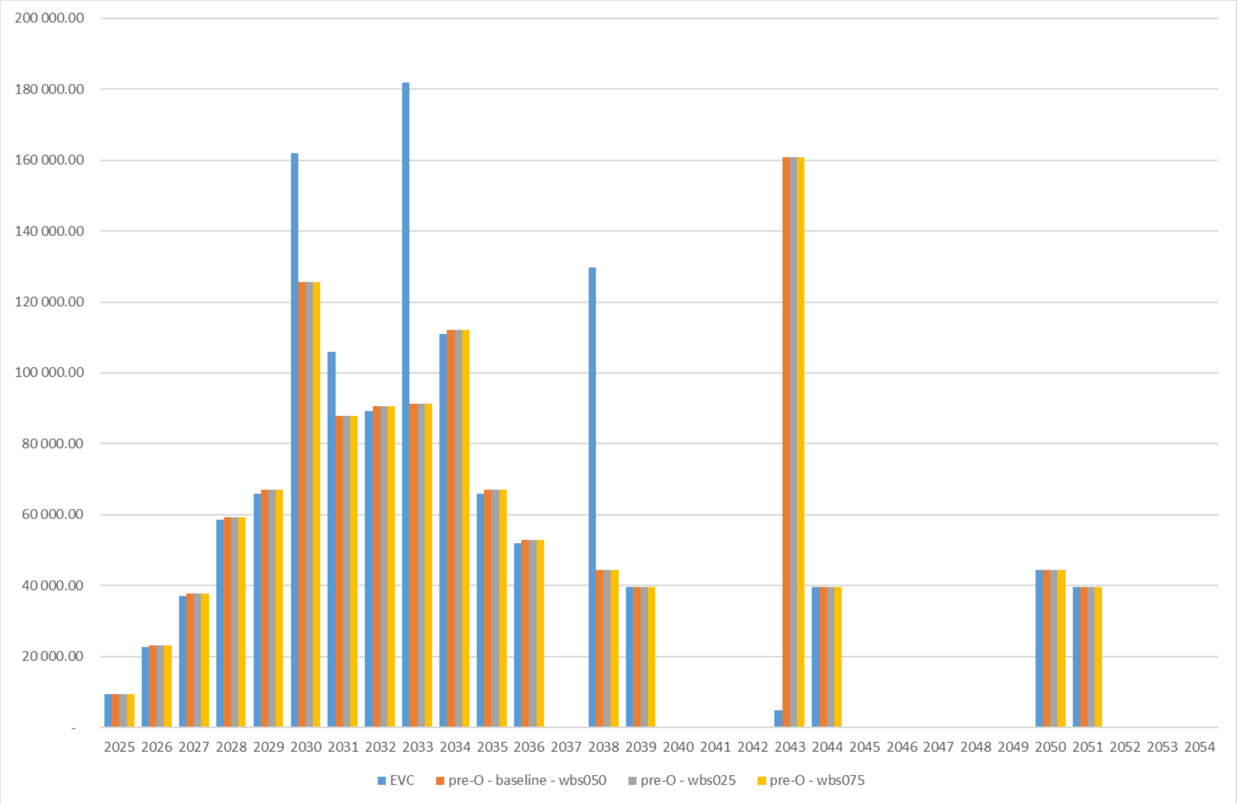

Figure 15 European fleet: influence of the class weight

4.2.2 VDB fleet

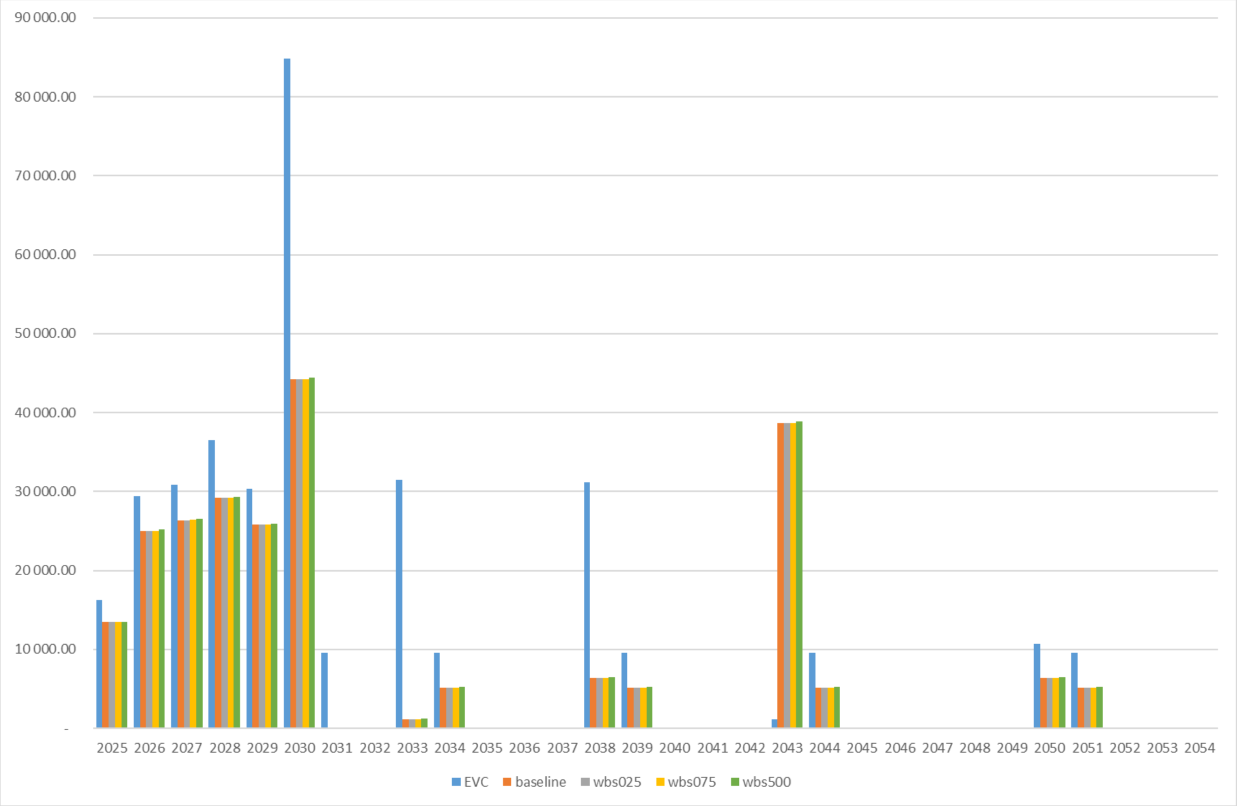

Figure 16 VDB fleet: influence of the class weight

4.3 Cost variation: Commissioning case

The commissioning cost variation has been applied on the three fleets: European fleet, VDB fleet and Regional fleet.

The following table gives the overall impact of the introduction of the pre-OCORA architecture on the global cost for 30 years for those three fleets.

	European fleet		VDB fleet		Regional fleet	
EVC cost	1 258 940		350 423		5 524	
Pre-OCORA baseline cost	1 192 465	*- 5 %*	237 517	*- 32 %*	4 712	*- 15%*
Pre-OCORA "com2" cost	656 059	*- 48 %*	162 096	*- 54 %*	2 380	*- 57 %*

Table 7 Results for cost variation (Commissioning case) on three fleets: European fleet, VDB fleet and Regional fleet.

The decrease of the commissioning costs when introducing the pre-OCORA architecture strongly impact the overall costs.This decrease affects the three fleets the same way, regardless of the number of vehicles and types and the planning of their introduction.

The following sections give the distributions of the costs over years for the three fleets.

4.3.1 European fleet

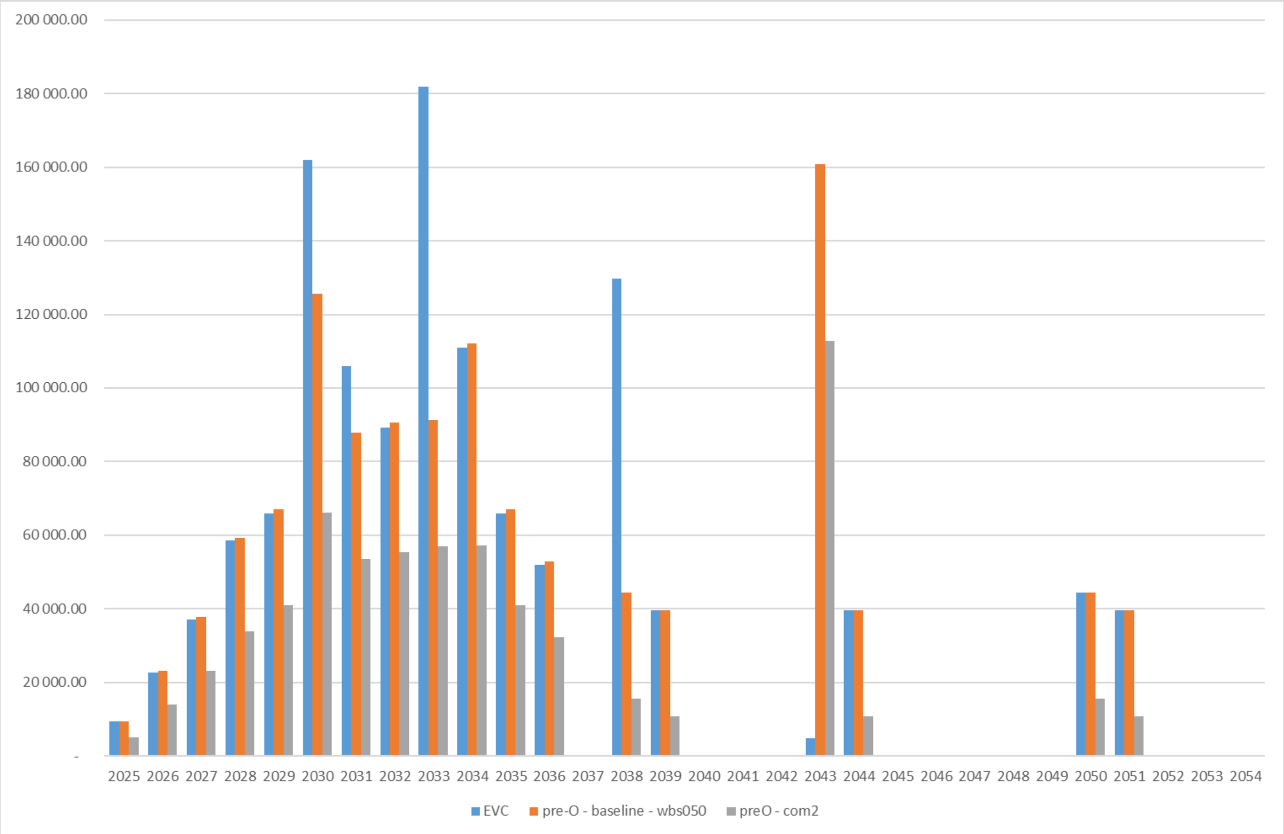

Figure 17 European fleet: influence of the commissioning cost

4.3.2 VDB fleet

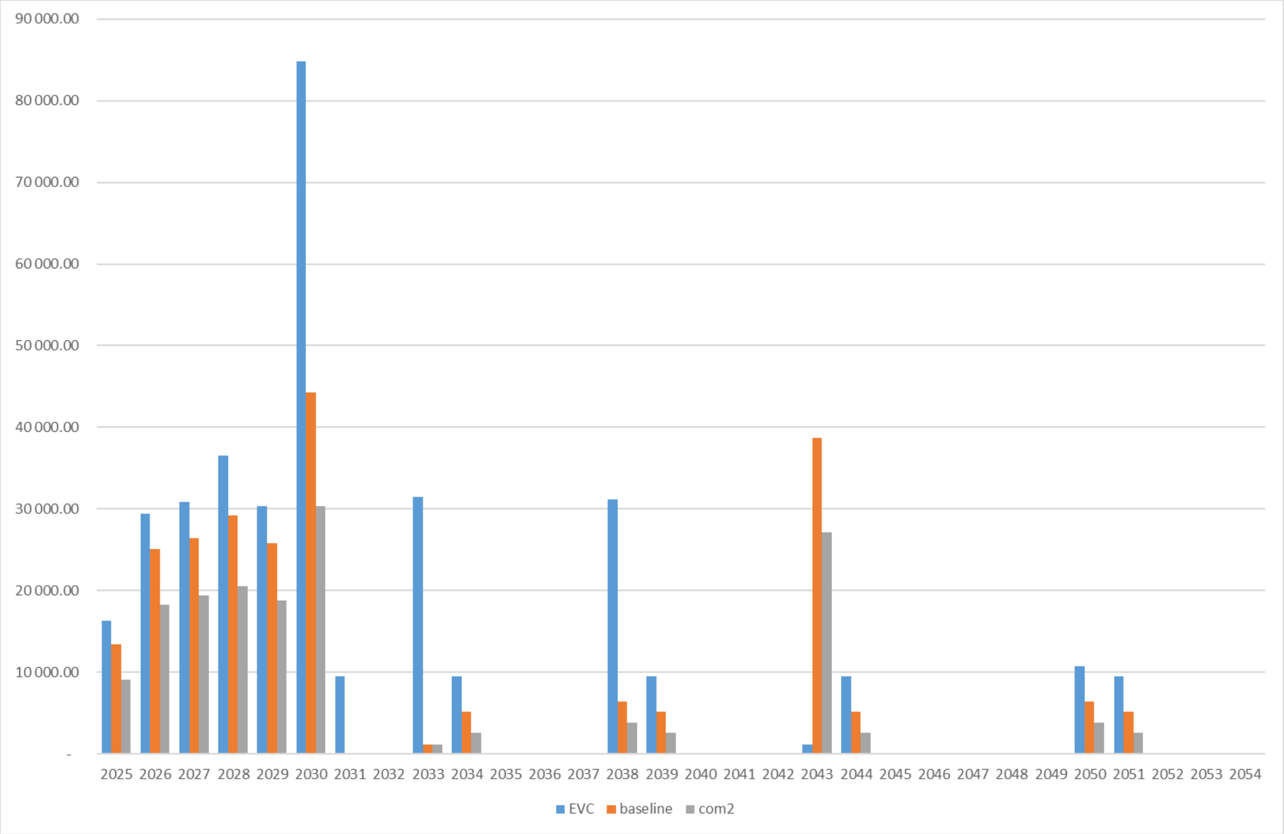

Figure 18 VDB fleet: influence of the commissioning cost

4.3.3 Regional fleet

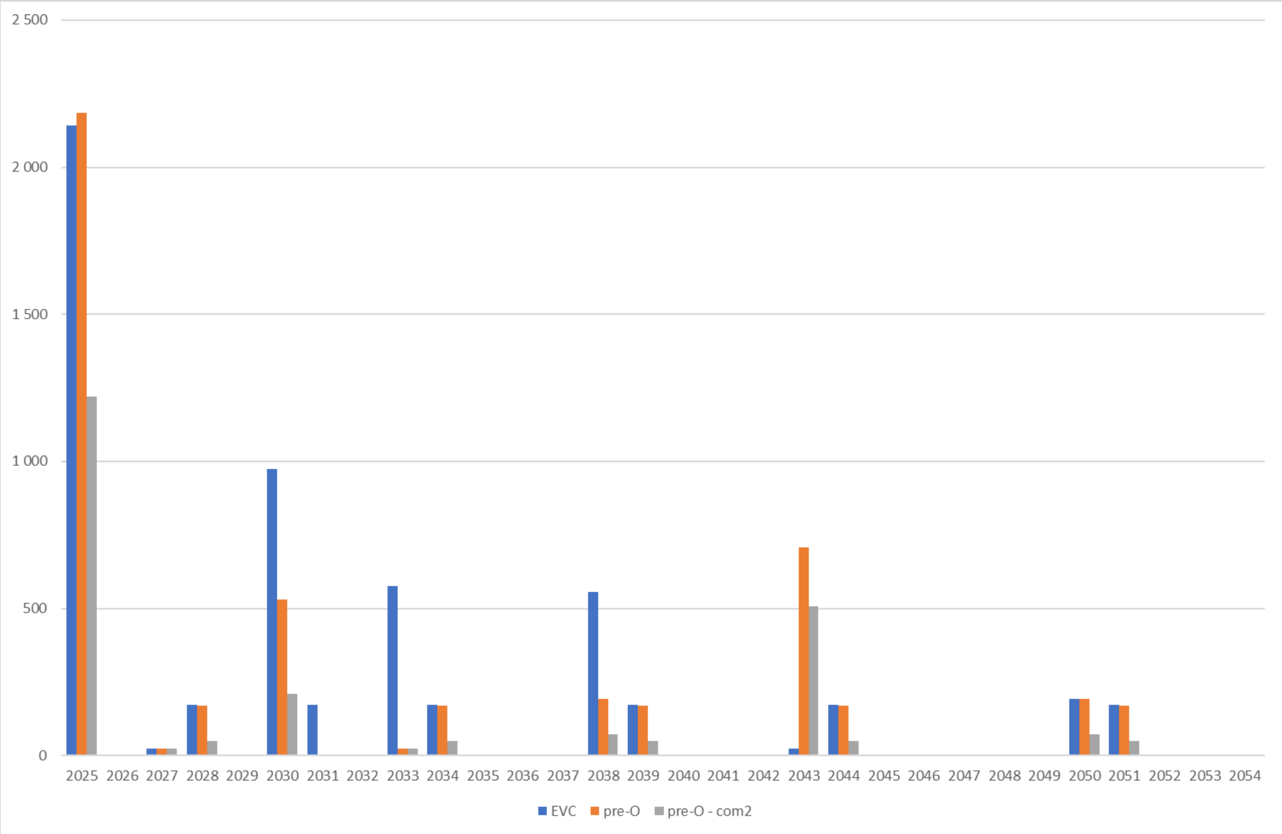

Figure 19 Regional fleet: influence of the commissioning cost

4.4 Upgrade frequency variation (on distributed fleet)

The results obtained for the variation of the frequency of the upgrade of the CCS sub-system are shown in the following table. The goal is to identify the impact of changing the upgrade frequency within the pre-OCORA solution. The baseline has been set at the baseline upgrade frequency (approximately 6 years). The changes have been made according the table below.

	Distributed fleet	
Pre-OCORA 6 years cost (baseline)	61 023	
Pre-OCORA 2 years cost	70 557	*+16% %*
Pre-OCORA 4 years cost	63 294	*+4 %*
Pre-OCORA 8 years cost	59 662	*- 2 %*
Pre-OCORA 10 years cost	58 743	*- 4 %*
Pre-OCORA no upgrade	55 122	*-10%*
EVC cost	90245	

Table 8 Results for upgrade frequency variation on the distributed fleet

As expected, the increase of the upgrade frequency leads to an increase of the overall costs on the 30 years. Also the relation between the increase of frequency is corresponding to the increase of cost. As such the model provides the expected results. Given the current cost assumptions the difference between no upgrades and the baseline is a difference of 10%

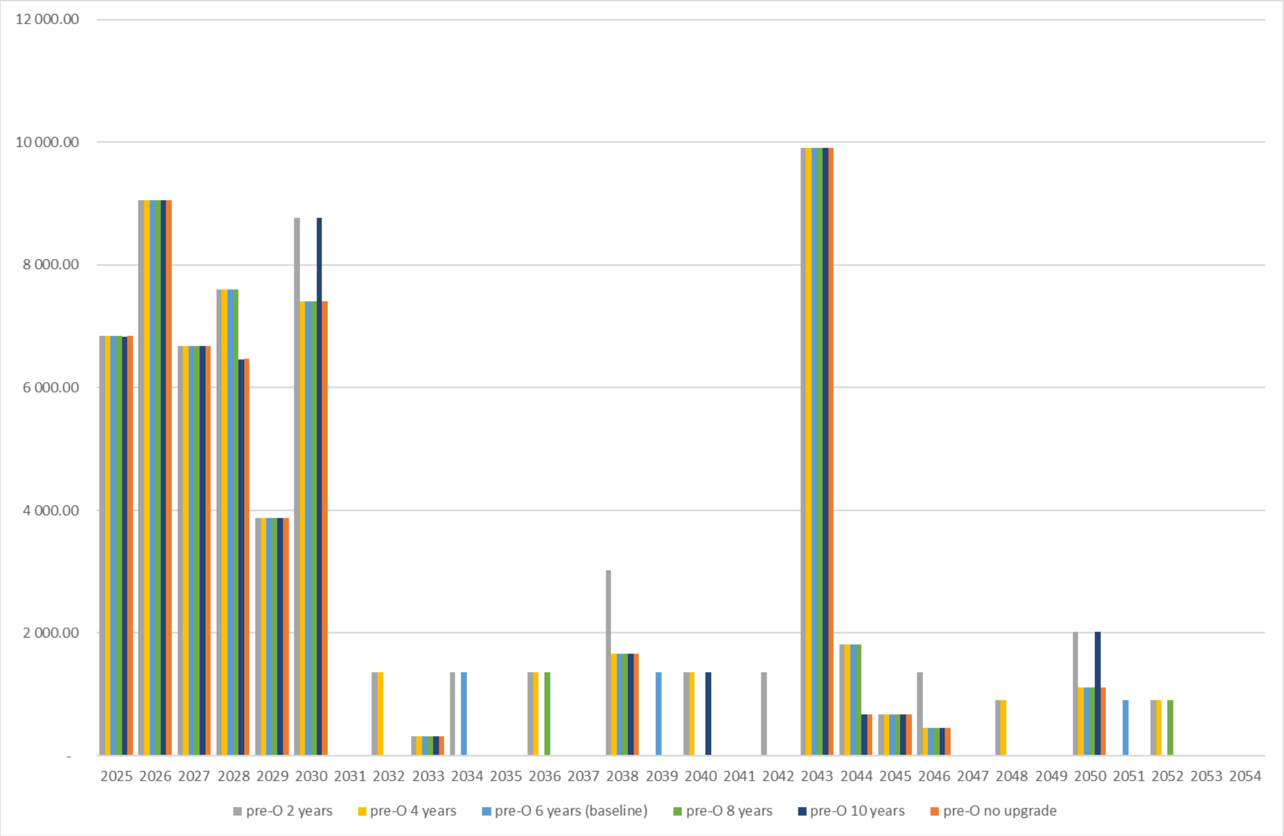

Figure 20 Distributed fleet: influence of the upgrade frequency variation

5 Conclusion

Different scenarios (fleets, roadmaps…) have been run with the economic model and presented in this report. The effects of variations on both WBS class parameter and commissioning costs have been quantified:

- There is a very slight impact of the cost variation as introduced at the WBS level,
- The decrease of the commissioning costs when introducing the pre-OCORA architecture strongly impact the overall costs,
- The increase of the upgrade frequency leads to a decrease of the overall costs on the 30 years.

The next development steps for the economic model consist in:

- finalizing the model and its associated tool, including the assessment of the costs (in euros),
  - Refinement of modelling assumption down to technology choices aligned with OCORA architecture principles.
  - Enhance the model with parameter costs: all the costs, including the maintenance costs (preventive, curative, repair).
- identifying several scenarios (fleets, roadmaps…):

  The deployment scenarios to help understand cash flows for different stakeholders involved.
  There should be a consistency check of the roadmap, preferably automated within the model itself, to prevent any unnecessary activities especially regarding the HW and SW upgrades.

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.

In addition, following issues may have to be considered for the next Release:

- 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 and R1 releases) 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.

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The model is enabling enhanced analysis potential to quantitatively identify and validate common business objectives for stakeholders. Europe’s rail would be the natural place 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.