OCORA

Open CCS On-board Reference Architecture

Economic Modelling Series

Evolution of the modelling

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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	28.10.2022
0.01	▪ Updated with description of the evolution	NPT	09.11.2022
0.02	▪ Final draft for review	NPT	17.11.2022
1.00	Final version ready for Release	MR	06.12.2022
1.10	Review for R4	VI	12.06.2023

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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-BWS02-030 – Technical Slide Desk

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

[7] OCORA-BWS04-010 – Problem Statements

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

[9] 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

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 [8], 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 R3, 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 [6], and the Problem Statements [7]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

2 Evolution of the Product Breakdown Structure (PBS)

2.1 Rationale for a new PBS

The redesign of the economic modeling aims at aligning its structure in line with the resulting architecture as worked out by TWS01 group for the release R2 and described in the Technical Slide Deck [5].

The main resulting expected benefit is to enable the different elements of the resulting Product Breakdown Structure of the model to be considered as building blocks:

- distinct sourceable units;
- Hardware and/or software;
- Standardised functionality/performance/safety/security/interfaces;
- SIL / SRAC.

2.2 The four scenarios for evolution

The modification of the model will also allow the economic assessment of the four scenarios as described in the Technical Slide Deck [5].

- sc1: building blocks without Safe Computing Platform (SCP) – legacy train
- sc2: building blocks with SCP for some applications – legacy train
- sc3: building blocks with SCP for all applications – legacy train
- sc4: building blocks with SCP for all applications – new generation train

Those scenarios are illustrated in the following figures:

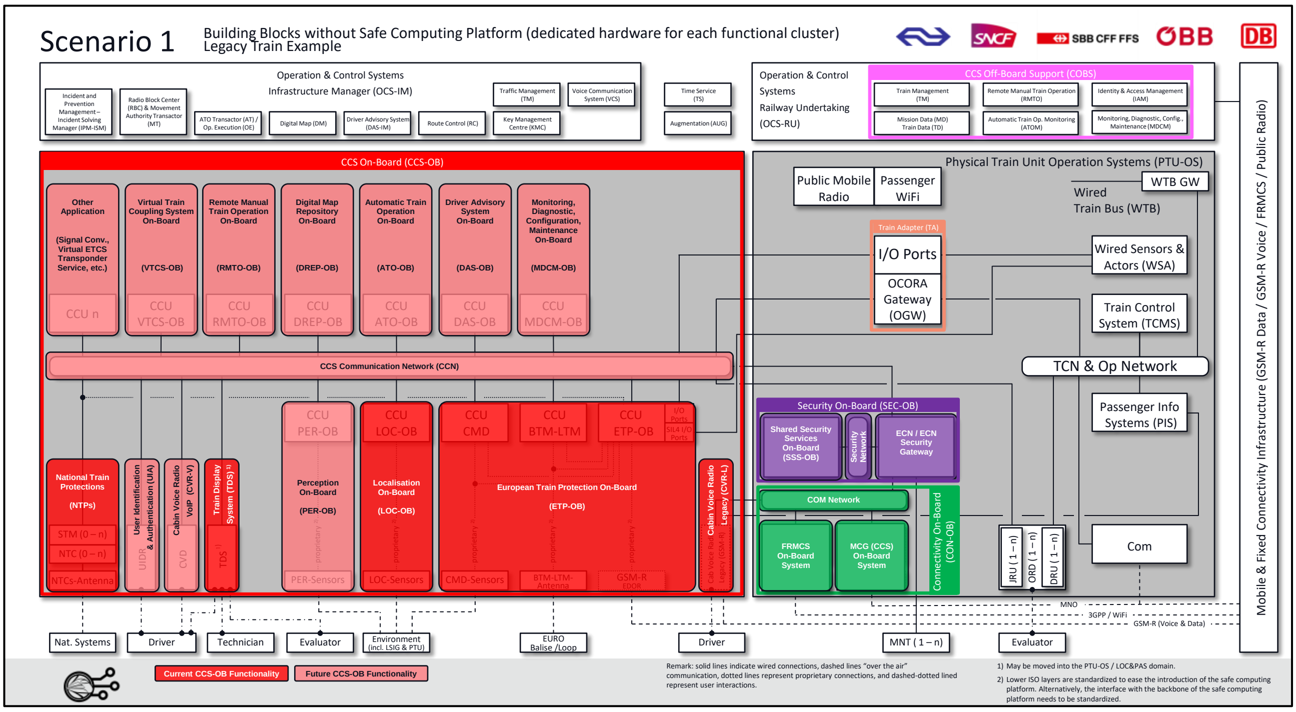

Figure 1 Scenario 1 – building blocks without SCP – legacy train example

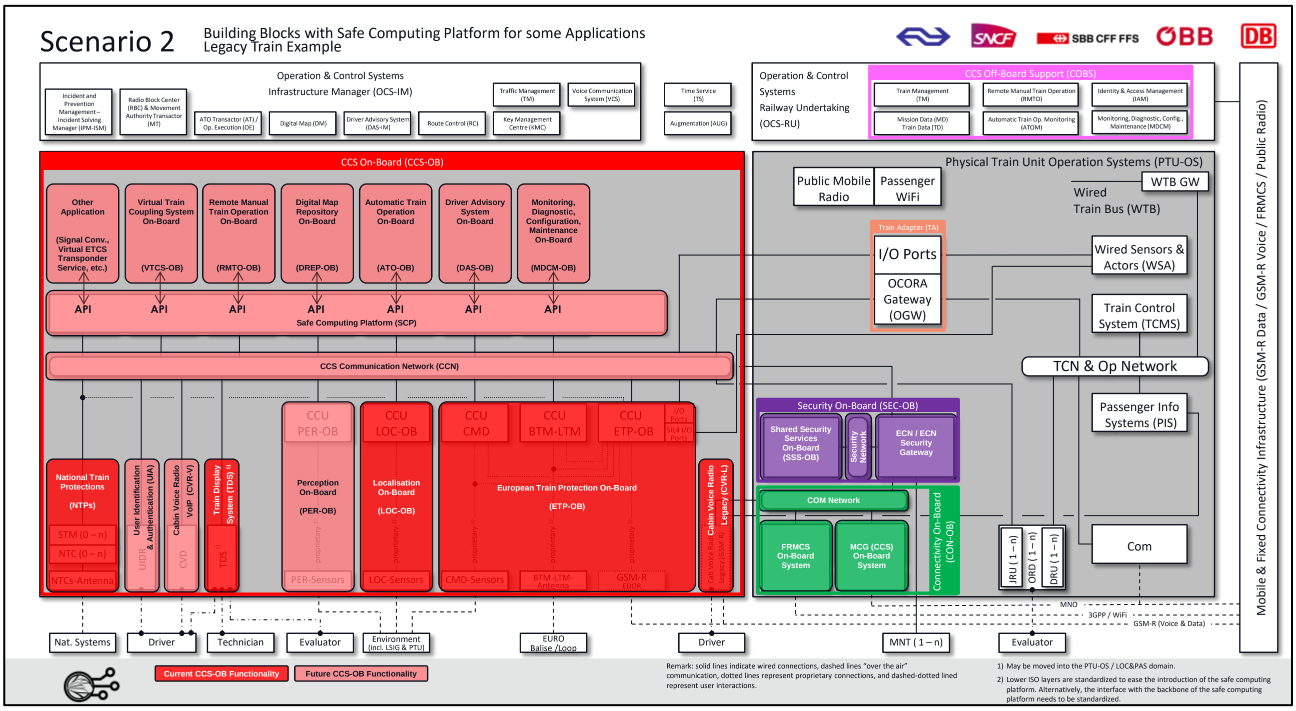

Figure 2 Scenario 2 – building blocks with SCP for some applications – legacy train example

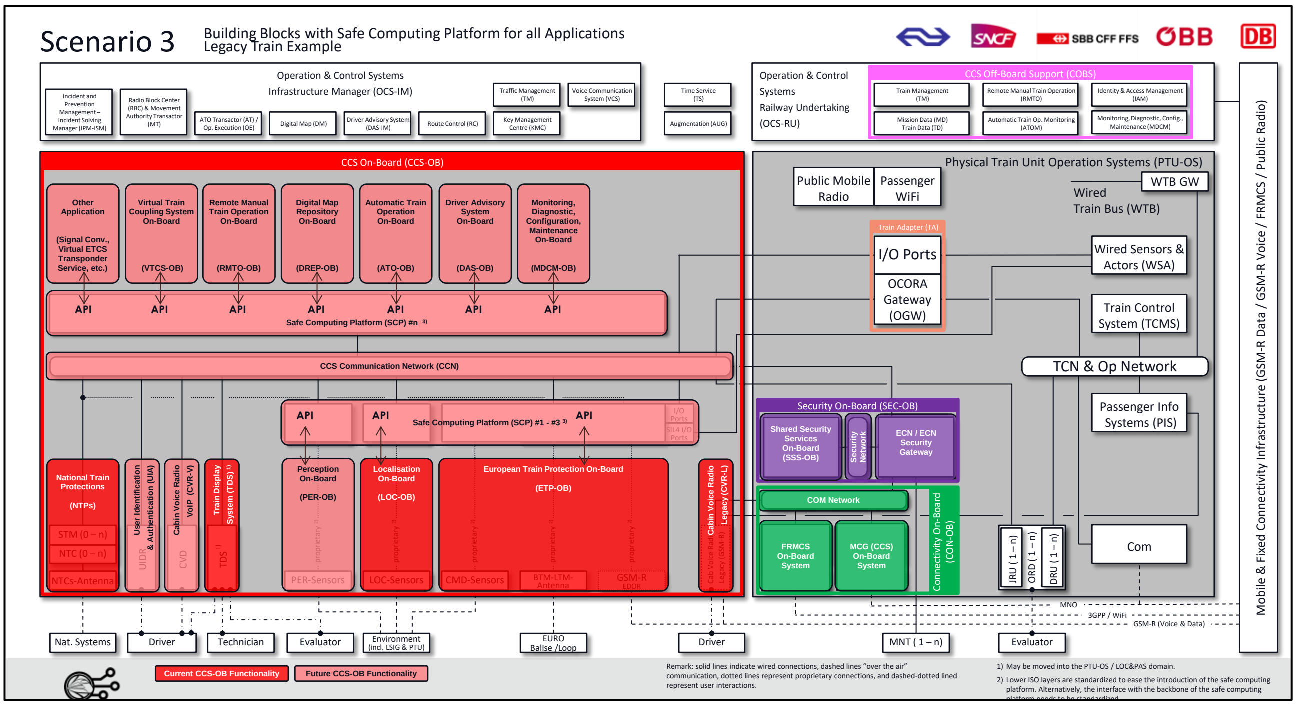

Figure 3 Scenario 3 – building blocks with SCP for all applications – legacy train example

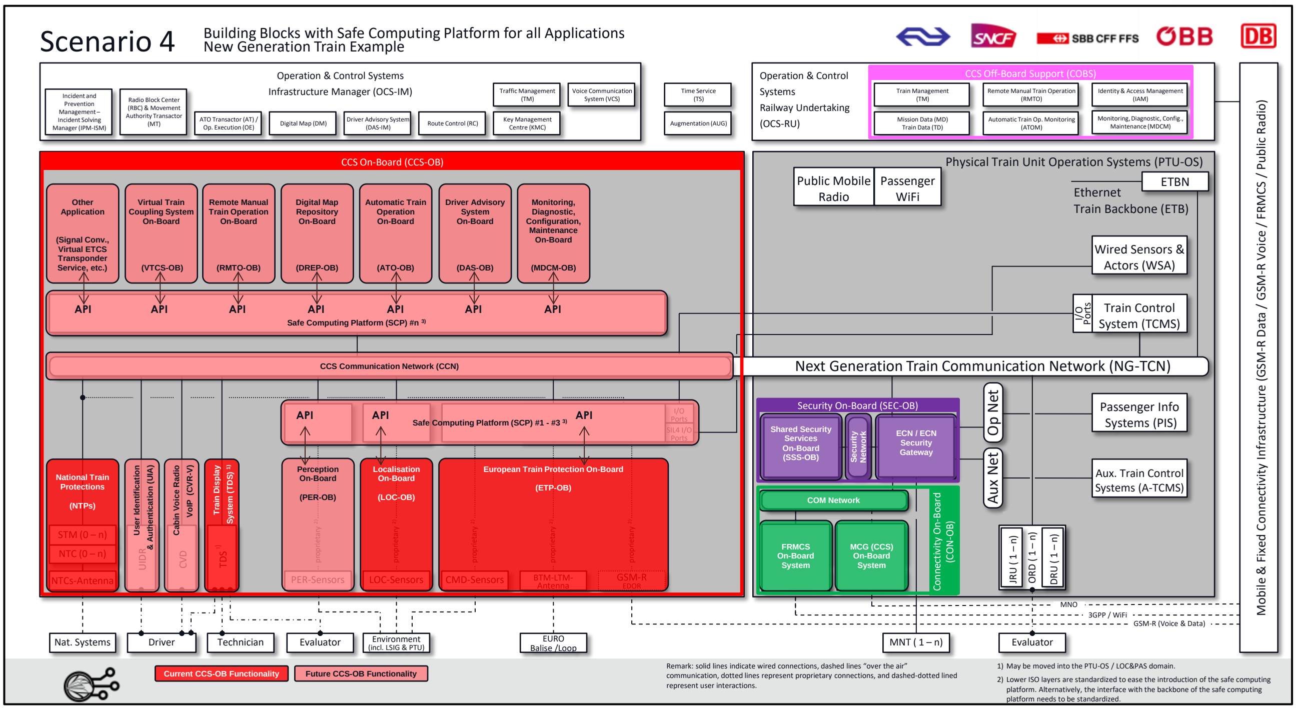

Figure 4 Scenario 4 – building blocks with SCP for all applications – new generation train example

2.3 The resulting updated PBS

Comparing to the modeling of the previous release, the new PBS includes additional features as follows:

- Core CCS:
  - DAS = Driver Advisory System
- Peripherals:
  - VTCS = Virtual Train Coupling System
  - SCV = Signal Converter
  - VETS = Virtual ETCS Transponder Service
  - RMTO = Remote Manual Train Operation
- Sensoring:
  - DREP = Digital Map Repository
- Tools:
  - MDCM = Monitoring, Diagnostic, Configuration, Maintenance

The following figure shows both PBS, the previous one from Release R2 and the new one for Release 3.

CCS	**On-board CCS**
CCS Core	**Core CCS**
CCS Core	Core CCS - ATP (ETCS Core)
CCS Core	CCS addon - NTC-STM
CCS Core	CCS addon - ATO
CCS Core	CCS addon - other functions/services
CCS peripherals	**Communication and interfaces**
CCS peripherals	I/O Ports
CCS peripherals	Functional Vehicle Adapter (FVA)
CCS peripherals	UVCC
CCS peripherals	Gateway
CCS peripherals	MCG (GSM-R, FRMCS…)
CCS peripherals	**Sensoring**
CCS peripherals	ETCS Sensoring (eg Odo, BTM, LTM)
CCS peripherals	Train Loc (GNSS, Inertial…)
CCS peripherals	Perception sensoring (other sensors)
CCS peripherals	DMI
CCS tools	**Tools**
CCS tools	Testing tools (eg test bench, simulator)
CCS tools	Maintenance tools
CCS tools	Training tools

→

CCS	**On-board CCS**
CCS Core	**Core CCS**
CCS Core	(ETP-OB) European Train Protection On-Board
CCS Core	National Train Protections (NTPs)
CCS Core	Automatic Train Operation On-Board (ATO-OB)
CCS Core	Driver Advisory System On-Board (DAS-OB)
CCS peripherals	Virtual Train Coupling S. On-Board (VTCS-OB)
CCS peripherals	Signal Converter (SCV)
CCS peripherals	Virtual ETCS Transponder Service (VETS)
CCS peripherals	Remote Manual Train Operation On-Board (RMTO-OB)
CCS peripherals	**Communication and interfaces**
CCS peripherals	Functional Vehicule Adapter (FVA)
CCS peripherals	CCS Communication Network (CCN)
CCS peripherals	Connectivity Services
CCS peripherals	**Sensoring**
CCS peripherals	ETCS sensoring (odo, radar, antenna)
CCS peripherals	Localisation On-Board (LOC-OB)
CCS peripherals	Perception On-Board (PER-OB)
CCS tools	Digital Map Repository On-Board (DREP-OB)
CCS tools	Train Display System (TDS)
CCS tools	**Tools**
CCS tools	Moitoring, Diagnostic, Configuration, Maintenance On-Board (MDCM-OB)

Figure 5 Evolution of the PBS: previous PBS from Release R2 (left) to new PBS for Release 3 (right)

3 Costs according to the base 10 approach

3.1 Categories of costs

For this release the modeling aimed at providing an assessment in euros, instead of using a base-10 approach as for the previous Release. The exercise being not fully achieved, the costs considered here remain in the base 10 approach, but for the different scenarios.

The costs throughout the life cycle phases are aggregated on three categories (as shown in **Figure 6** below):

- Generic costs: mainly for concept development, design, engineering, for the whole fleet
- Class costs: for the different types of vehicles to be considered
- Train costs: for the equipment manufacturing, integration and installation

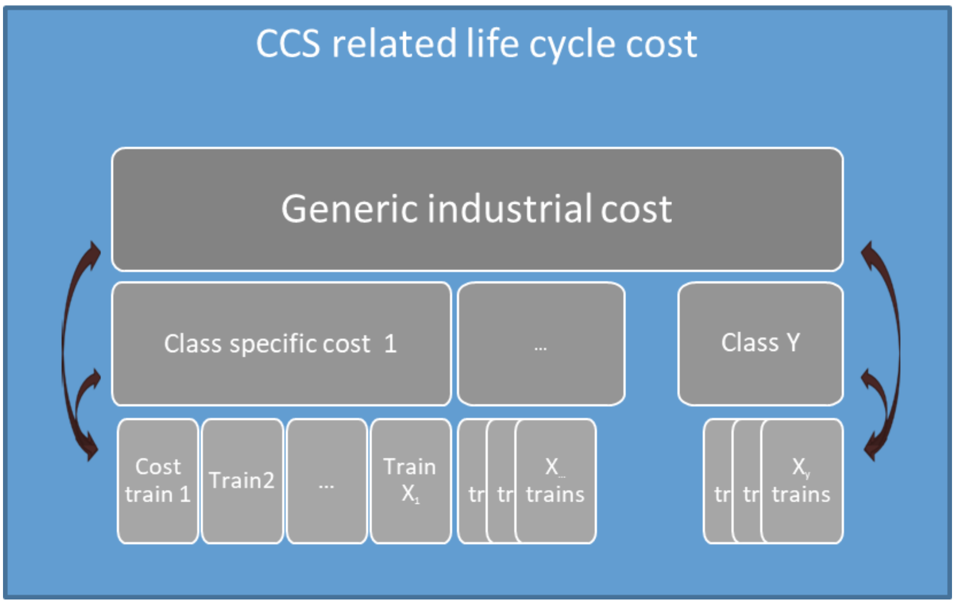

Figure 6 CCS cost aggregation levels

As for the previous release, the costs have to be distributed according to the Work Breakdown Structure (Figure below).

WBS	Generic costs (Product Dev R&I)	Class specific (Adapt to train class)	Train specific
Specification & Design			
Development	1		
Specification (functional, interfaces, performances...)	1	0.5	
Design (SW/ HW & architecture)	1	0.5	
Industrialization			
Production process, configuration mngt, associated tools	1	0.5	
Integration, Verification & Validation			
Product integration & validation	1		
HW qualification	1		
Class specific integration & validation		1	
Certification	1	1	
Reliability, Availability, Maintainability, Security, Safety - RAMSS & Cyber			
Product (eg GASC)	1		
Class specific (eg SASC)		1	
Configuration studies and production		1	
Installation & Commissionning			
Commissionning (customer)		0.5	0.5
Supply (HW)			1
Install Integrate CCS (HW&SW) with RST (manpower)			1
Removal of CCS (HW&SW) from RST			1
Study train modification		1	
TCMS evolution/adaptation		1	
Adapt Rolling Stock (except. TCMS)		0.5	0.5
Immobilize train for modification			0.5
Maintain CCS (HW & SW)			1

Figure 7 Work Breakdown Structure

The resulting distributions for all scenarios 0 to 4 are given in the following figures.

CCS Core/ Peripheral or external	CCS Subsystem Component	scen.0	scen.1	scen.2	scen.3	scen.4	Development	Specification (functional, interface	Design (SW/ HW & architecture)	Production process, configuration	Product integration & validation	HW qualification	Class specific integration & validat	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissionning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) w	Removal of CCS (HW&SW) from R
CCS	**On-board CCS**	x																		
CCS Core	**Core CCS**	x																		
CCS Core	(ETP-OB) European Train Protection On-Board + Safe Co	x					1000		1	0.2	1	1	1	1	1	1	1.2	0.2	0.2	0.2
CCS Core	National Train Protections (NTPs)	x															3	2	5	1
CCS Core	Automatic Train Operation On-Board (ATO-OB)	x					100	0	1	0.2	1	1	1	1	1	1.5	0.2	0.2	0.1	0.2
CCS Core	Driver Advisory System On-Board (DAS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Virtual Train Coupling S. On-Board (VTCS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Signal Converter (SCV)	x					40	0	1	0.2	1	1	1	1	1	1.5	0.2	0.2	0.1	0.1
CCS Core	Virtual ETCS Transponder Service (VETS)	x					20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.1	0.04	0.04
CCS Core	Remote Manual Train Operation On-Board (RMTO-OB)	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Communication and interfaces**	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Functional Vehicule Adapter (FVA)	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	CCS Communication Network (CCN)	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Connectivity Services	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Sensoring**	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	ETCS sensoring (odo, radar, antenna)	x					0	0	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.2
CCS peripherals	Localisation On-Board (LOC-OB)	x					600	0	1	0.2	0.4	1	0.2	0.4	1	1	2	1	1	0.1
CCS peripherals	Perception On-Board (PER-OB)	x					20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	Digital Map Repository On-Board (DREP-OB)	x					40	0	1	0.2	1	1	1	1	1	1	0.2	0.2	0.1	0.04
CCS peripherals	Train Display System (TDS)	x					20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.1	0.04
CCS tools	**Tools**	x					0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS tools	Monitoring, Diagnostic, Configuration, Maintenance On	x					20	0	0.04	0.04	0.1	0.04	0.1	0.1	0.04	0.1	0.04	0.04	0.04	0.02

Figure 8 Cost distribution for scenario 0 (Base 10 approach)

CCS Core/ Peripheral or external	CCS Subsystem Component	scen.0	scen.1	scen.2	scen.3	scen.4	Development	Specification (functional, interfaces	Design (SW/ HW & architecture)	Production process, configuration m	Product integration & validation	HW qualification	Class specific integration & validatio	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissionning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) with	Removal of CCS (HW&SW) from RST
CCS	**On-board CCS**		x																	
CCS Core	**Core CCS**		x																	
CCS Core	(ETP-OB) European Train Protection On-Board + Safe Compu		x				100		1	0.2	1	1	1	1	1	1	1.2	0.2	0.2	0.2
CCS Core	National Train Protections (NTPs)		x				0	0	0.04	0.04	0.1	0.04	0.1	0.1	0.04	0.1	0.06	0.04	0.1	0.02
CCS Core	Automatic Train Operation On-Board (ATO-OB)		x				100	0	1	0.2	1	1	1	1	1	1.5	0.2	0.2	0.1	0.2
CCS Core	Driver Advisory System On-Board (DAS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Virtual Train Coupling S. On-Board (VTCS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Signal Converter (SCV)		x				40	0	1	0.2	1	1	1	1	1	1.5	0.2	0.2	0.1	0.1
CCS Core	Virtual ETCS Transponder Service (VETS)		x				20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.1	0.04	0.04
CCS Core	Remote Manual Train Operation On-Board (RMTO-OB)		x				0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Communication and interfaces**		x				0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Functional Vehicule Adapter (FVA)		x				100	0	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	CCS Communication Network (CCN)		x				40	0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.06	0.02	0.02	0.04
CCS peripherals	Connectivity Services		x				40	0	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.2	0.02	0.02	0.04
CCS peripherals	**Sensoring**		x				0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	ETCS sensoring (odo, radar, antenna)		x				0	0	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.2
CCS peripherals	Localisation On-Board (LOC-OB)		x				40	0	1	0.2	0.4	1	0.2	0.4	1	1	2	1	1	0.1
CCS peripherals	Perception On-Board (PER-OB)		x				20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	Digital Map Repository On-Board (DREP-OB)		x				40	0	1	0.2	1	1	1	1	1	1	0.2	0.2	0.1	0.04
CCS peripherals	Train Display System (TDS)		x				20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.1	0.04
CCS tools	**Tools**		x				0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS tools	Moitoring, Diagnostic, Configuration, Maintenance On-Boa		x				20	0	0.04	0.04	0.1	0.04	0.1	0.1	0.04	0.1	0.04	0.04	0.04	0.02

Figure 9 Cost distribution for scenario 1 (Base 10 approach)

CCS Core/ Peripheral or external	CCS Subsystem Component	scen.0	scen.1	scen.2	scen.3	scen.4	Development	Specification (functional, interfaces	Design (SW/ HW & architecture)	Production process, configuration m	Product integration & validation	HW qualification	Class specific integration & validatio	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissionning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) with	Removal of CCS (HW&SW) from RST
CCS	**On-board CCS**			x																
CCS Core	**Core CCS**			x																
CCS Core	(ETP-OB) European Train Protection On-Board + Safe Computing P			x			100		1	0.2	1	1	1	1	1	1	1.2	0.2	0.2	0.2
CCS Core	National Train Protections (NTPs)			x			0	0	0.04	0.04	0.1	0.04	0.1	0.1	0.04	0.1	0.06	0.04	0.1	0.02
CCS Core	Automatic Train Operation On-Board (ATO-OB)			x			40	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Driver Advisory System On-Board (DAS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Virtual Train Coupling S. On-Board (VTCS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Signal Converter (SCV)			x			20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Virtual ETCS Transponder Service (VETS)			x			10	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Remote Manual Train Operation On-Board (RMTO-OB)			x			0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Communication and interfaces**			x			0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Functional Vehicule Adapter (FVA)			x			100	0	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	CCS Communication Network (CCN)			x			40	0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.06	0.02	0.02	0.04
CCS peripherals	Connectivity Services			x			40	0	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.2	0.02	0.02	0.04
CCS peripherals	**Sensoring**			x			0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	ETCS sensoring (odo, radar, antenna)			x			0	0	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.2
CCS peripherals	Localisation On-Board (LOC-OB)			x			40	0	1	0.2	0.4	1	0.2	0.4	1	1	2	1	1	0.1
CCS peripherals	Perception On-Board (PER-OB)			x			20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	Digital Map Repository On-Board (DREP-OB)			x			20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Train Display System (TDS)			x			20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.1	0.04
CCS tools	**Tools**			x			0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS tools	Moitoring, Diagnostic, Configuration, Maintenance On-Board (MD			x			20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02

Figure 10 Cost distribution for scenario 2 (Base 10 approach)

CCS Core/ Peripheral or external	CCS Subsystem Component	scen.0	scen.1	scen.2	scen.3	scen.4	Development	Specification (functional, interfaces	Design (SW/ HW & architecture)	Production process, configuration m	Product integration & validation	HW qualification	Class specific integration & validatio	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissionning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) with	Removal of CCS (HW&SW) from RST
CCS	**On-board CCS**				x															
CCS Core	**Core CCS**				x															
CCS Core	(ETP-OB) European Train Protection On-Board + Safe Computing Platforr				x		100		1	0.2	1	1	1	1	1	1	1.2	0.2	0.2	0.2
CCS Core	National Train Protections (NTPs)				x		0	0	0.04	0.04	0.1	0.04	0.1	0.1	0.04	0.1	0.06	0.04	0.1	0.02
CCS Core	Automatic Train Operation On-Board (ATO-OB)				x		40	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Driver Advisory System On-Board (DAS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Virtual Train Coupling S. On-Board (VTCS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Signal Converter (SCV)				x		20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Virtual ETCS Transponder Service (VETS)				x		10	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Remote Manual Train Operation On-Board (RMTO-OB)				x		0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Communication and interfaces**				x		0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Functional Vehicule Adapter (FVA)				x		100	0	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.2	0.1	0.04	0.04
CCS peripherals	CCS Communication Network (CCN)				x		40	0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.06	0.02	0.02	0.04
CCS peripherals	Connectivity Services				x		40	0	0.2	0.1	0.1	0.1		0.2	0.2	0.4	0.2	0.02	0.02	0.04
CCS peripherals	**Sensoring**				x		0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	ETCS sensoring (odo, radar, antenna)				x		0	0	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.2
CCS peripherals	Localisation On-Board (LOC-OB)				x		40	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Perception On-Board (PER-OB)				x		20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Digital Map Repository On-Board (DREP-OB)				x		20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Train Display System (TDS)				x		20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.1	0.04
CCS tools	**Tools**						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS tools	Moitoring, Diagnostic, Configuration, Maintenance On-Board (MDCM-OE				x		20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02

Figure 11 Cost distribution for scenario 3 (Base 10 approach)

CCS Core/ Peripheral or external	CCS Subsystem Component	scen.0	scen.1	scen.2	scen.3	scen.4	Development	Specification (functional, interfaces	Design (SW/ HW & architecture)	Production process, configuration m	Product integration & validation	HW qualification	Class specific integration & validatio	Certification	Product (eg GASC)	Class specific (eg SASC)	Commissionning (customer)	Supply (HW)	Install Integrate CCS (HW&SW) with	Removal of CCS (HW&SW) from RST
CCS	**On-board CCS**					x														
CCS Core	**Core CCS**					x														
CCS Core	(ETP-OB) European Train Protection On-Board + Safe Computing Platform					x	100		1	0.2	1	1	1	1	1	1	1.2	0.2	0.2	0.2
CCS Core	National Train Protections (NTPs)					x	100	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Automatic Train Operation On-Board (ATO-OB)					x	40	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Driver Advisory System On-Board (DAS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Virtual Train Coupling S. On-Board (VTCS-OB)						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS Core	Signal Converter (SCV)					x	20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Virtual ETCS Transponder Service (VETS)					x	10	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS Core	Remote Manual Train Operation On-Board (RMTO-OB)					x	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	**Communication and interfaces**					x	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	Functional Vehicule Adapter (FVA)					x	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	CCS Communication Network (CCN)					x	40	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
CCS peripherals	Connectivity Services					x	40	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02
CCS peripherals	**Sensoring**					x	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS peripherals	ETCS sensoring (odo, radar, antenna)					x	0	0	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.2	0.2
CCS peripherals	Localisation On-Board (LOC-OB)					x	40	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Perception On-Board (PER-OB)					x	20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Digital Map Repository On-Board (DREP-OB)					x	20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02
CCS peripherals	Train Display System (TDS)					x	20	0	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.4	0.2	0.2	0.1	0.04
CCS tools	**Tools**						0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCS tools	Moitoring, Diagnostic, Configuration, Maintenance On-Board (MDCM-OB)					x	20	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02

Figure 12 Cost distribution for scenario 4 (Base 10 approach)

4 Application to several deployments

4.1 The fleets investigated

4.1.1 Introduction

Two fleets are considered to perform the sensitivity analysis. They are chosen for they give a realistic view of national fleet.

4.1.2 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 [9] 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 1 Number of relevant vehicles per year to the ratio of the vehicle types from the VDB report.

4.1.3 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.

Table 2 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 2 Number of relevant vehicles per year for the distributed fleet.

4.2 Results of the sensitivity analysis

4.2.1 Total results

The different scenarios from Sc0 to Sc4 have been computed for the two fleets. The application of the scenario 4, and possibly the 3, can of course not be perceived as a realistic way of applying a deployment strategy of the on-board architecture, as all applications cannot yet, and even in the few next years to come, be connected to the safe computing platform.

The following table gives the obtained results for the whole fleets.

	VDB Fleet		**Distributed fleet**	
Scenario 0	119996		30844	
Scenario 1	65926	*-45%*	16992	*-45%*
Scenario 2	50269	*-58%*	12967	*-58%*
Scenario 3	23892	*-80%*	6457	*-79%*
Scenario 4	19267	*-84%*	5279	*-83%*

Table 3 Results for the two fleets and the different scenarios

The impact of the scenario, hence of the level of the modularity of the architecture, seems identical for both fleets.

The scenario 1, with the introduction of the building blocks (and the CCN communication network), already allows a large reduction of costs, with a gain of 45%.

The Scenario 4 gives the maximal gain which could be obtained, even if, as said previously, this is not yet a realistic deployment scenario.

4.2.2 Evolution of the costs

For illustration, the following graphs show the evolution of the costs for all scenarios over the 30 years considered in the simulation.

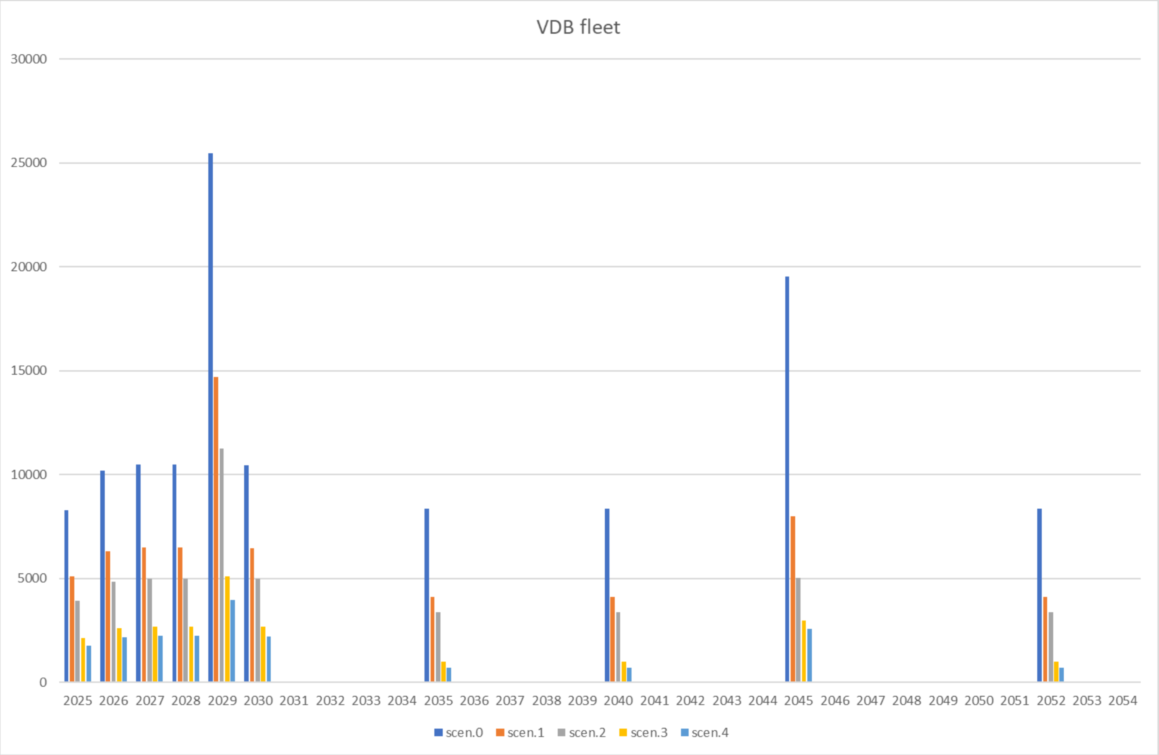

Figure 13 Cost distribution for VDB fleet

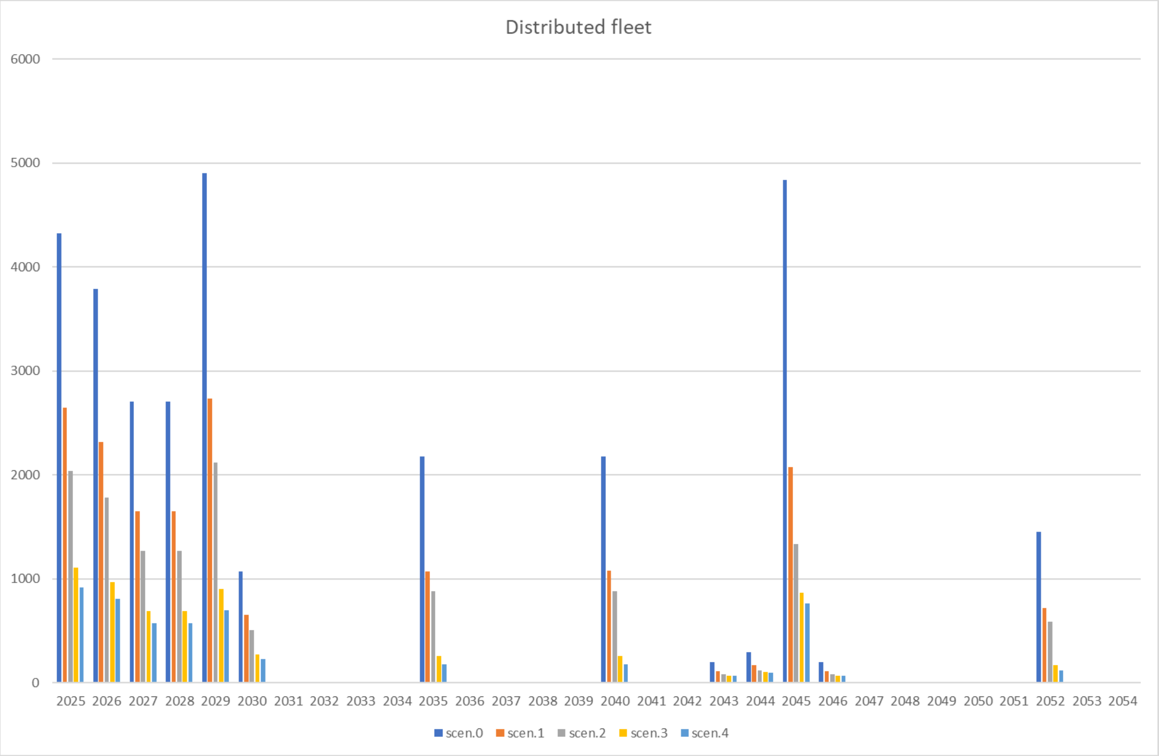

Figure 14 Cost distribution for the distributed fleet

5 Conclusion

For this release, the major development steps for the economic model consists in the refinement of the modelling assumption down to technology choices aligned with OCORA architecture principles.

So, different scenarios of architecture have been run with the Economic Model and presented in this report.

The effects of variations of those scenarios have been quantified, even if the most modular approach still cannot be considered as an available solution before the next few years.

The next development step for the Economic Model will be to perform the assessment of the costs in Euros, together with a validation of some dedicated cases.

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 amortisation 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 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 follow:

- 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.