European Commission

ERTMS ON-BOARD DEPLOYMENT - ANALYSIS OF COST DRIVERS

Written by EY and INECO
February - 2025

Shape the future with confidence

ineco

EUROPEAN COMMISSION

Directorate-General for Transport and Mobility
Directorate C — Land Transport
Unit C.4 — Rail Safety and Interoperability

Contact: Wawrzyniec Perschke & Christof Schoser

E-mail: Wawrzyniec.PERSCHKE@ec.europa.eu & Christof.Schoser@ec.europa.eu

European Commission
B-1049 Brussels

ERTMS ON-BOARD DEPLOYMENT - ANALYSIS OF COST DRIVERS

Manuscript completed in February 2025

1st edition

Luxembourg: Publications Office of the European Union, 2025

PDF ISBN: 978-92-68-26308-2 doi: 10.2832/0774726 MI-01-25-011-EN-N

Table of contents

List of abbreviations

AERRL	Association of European Rail Rolling Stock Lessors
ATO	Automatic Train Operation
ATP	Automatic Train Protection
B2	Baseline 2
B3	Baseline 3
CCS TSI	Control, Command and Signalling
CEF	Connecting Europe Facility
CER	Community of European Railway and Infrastructure Companies
CTT	Conformity To Type
DeBo	Designated Body
DMI	Driver Machine Interface
DMT	Deployment Management Team
EIM	European Rail Infrastructure Managers
ERA	European Agency for Railways
ERATV	European Register of Authorised Types of Vehicles
ERFA	European Rail Freight Association
ERTMS	European Railway Traffic Management System
ESC	ETCS System Compatibility
ETCS	European Train Control System
EU	European Union
EVC	European Vital Computer
FRMCS	Future Railway Mobile Communication System
HSR	High-Speed Rail
HW	Hardware
IC	Interoperability Constituent
NNTR	Notified National Technical Rule
NoBo	Notified Body
NR	National Rule
OB	On-board
OEM	Original Equipment Manufacturer
RDD	Reference Document Database
RIU	Radio Infill Unit
RSC	Radio System Compatibility
RU	Railway Undertaking
SW	Software
TCMS	Train Control Management System
TSI	Technical Specification for Interoperability
UNIFE/UNISIG	The European Rail Supply Industry Association / Union Industry of Signalling

Executive summary

This report presents the findings of a study initiated based on a data collection on ERTMS deployment costs conducted by the ERTMS Deployment Management Team (DMT)[1]. The data collection found that in recent years, the costs associated with ERTMS on-board deployment have risen significantly. Retrofitting costs have grown from €450.000 to €900.000 per vehicle, and upgrade costs have increased from €200.000 to €400.000 between 2018 and 2022. Moreover, stakeholders are experiencing several challenges when deploying ERTMS on-board. Given the threat such a cost increase imposes on future ERTMS deployment, this study was launched to identify the primary cost drivers behind the cost increases and proposes effective solutions to mitigate them. This study is a first step toward the implementation of the solutions, which will require the involvement of many stakeholders (European Commission, European Railway Agency (ERA), Member States, National Safety Authorities, suppliers, vehicles owners and infrastructure managers) to become effective.

Methodology

The methodological approach for the study applied a stepwise process, where each step built upon the previous one. The approach consisted of four main steps:

1. Targeted interviews: Two rounds of interviews were conducted. The first round focused on collecting data on the deployment cost and performance of ERTMS throughout Europe. This included gathering detailed cost data at project-level to specific costs such as ESC (ETCS System Compatibility[2]) tests. The granularity of the data collected depended on the stakeholders' ability to disclose or possess such information. The second round of interviews aimed at identifying the cost drivers of ERTMS deployment. Seven follow-up interviews were conducted with key stakeholders from the initial round to delve deeper into the reasons behind the identified cost increases.
2. 2024 ERA ERTMS conference: This conference served as a platform for stakeholder consultation, allowing for the exchange of insights and

[1] The ERTMS DMT supports the European Commission DG MOVE in deploying ERTMS. Its objectives are "to ensure an efficient, synchronised and timely implementation of ERTMS along the core network corridors and ensure consistency with other parts of the network." It is governed by "EUROPEAN COMMISSION - DIRECTORATE GENERAL FOR MOBILITY AND TRANSPORT – service contract MOVE/C4/2022-62". Currently, the work of the DMT is carried out by the consultancies EY and INECO who are also the authors of this report.

[2] More info can be found here: https://www.era.europa.eu/content/etcs-and-radio-system-compatibility-escrsc.

feedback on the findings from the interviews and other data collection efforts.

3. Stakeholder workshop: Workshop held with CER, UNIFE/UNISIG, AERRL, ERFA, EIM, ERA and DG MOVE. Facilitated discussions on primarily the solutions identified by the DMT. This step ensured that a wide range of perspectives were considered in the analysis.

4. Stakeholder survey: A survey was conducted to gather additional data and insights from stakeholders. Participants were asked to rank the cost drivers and solutions based on their expected impacts. This helped to validate the findings from the interviews and workshops and provided a more comprehensive understanding of the cost drivers and challenges associated with ERTMS deployment.

The analytical scope of the report focuses on the on-board deployment of the ERTMS across various types of railway vehicles, excluding urban railway systems. The analysis specifically targets retrofitting and upgrade projects, while the fitment of ERTMS in new rolling stock is not considered, as it does not face the same issues. The study encompasses freight and passenger (including High-Speed Rail (HSR)) while yellow fleet vehicles has been excluded. Track-side projects are also excluded from the scope, as data collection on track-side deployment costs is still ongoing.

The cost constituents analysed are divided into three phases: the design phase, the deployment phase and the authorisation phase. This comprehensive scope ensures a detailed understanding of the cost drivers and challenges associated with ERTMS on-board deployment.

Main cost drivers identified

The study has identified a series of cost drivers which are and have been contributing to the cost increase. The cost drivers have been divided into the three main phases of a deployment project, namely the design, deployment and authorisation phases. Some horizontal drivers, affecting the three phases of the project, have also been identified.

The design phase of ERTMS on-board deployment is significantly impacted by several cost drivers. National requirements introduce variability and complexity, as each country has specific rules for train operation, authorisation, and design, leading to increased engineering efforts and costs. The availability of documentation on these national requirements is often limited, adding to the complexity and cost of compliance. Project-specific requirements further hinder the reusability of solutions, necessitating additional engineering activities and increasing costs. Additionally, the transfer of risk associated with different vehicle types adds to the cost, as each type may require bespoke solutions and additional

certification efforts. Incomplete or outdated documentation on vehicle characteristics complicates the adaptation process, leading to higher costs.

The authorisation phase is marked by several significant cost drivers. The lengthy authorisation process, which can take up to three to four years, results in substantial revenue losses due to the prolonged out-of-service status of prototype vehicles. The high demand for documentation, test tracks and laboratories, coupled with limited availability, causes delays and increases costs. Missing scheduled test slots can lead to additional delays and expenses. Third-party assessments, often required due to strict national rules and limited number of recognized assessors, add to the complexity and cost of the authorisation process. Extensive testing requirements, particularly for ESC (ETCS System Compatibility) and RSC (Radio System Compatibility) tests, impose significant financial and resource burdens on the authorisation phase.

Finally, some horizontal cost drivers, affecting all stages of a project, have also been identified. The limited competition on the market, due to the complexity of the system and the way it is integrated today in the vehicles, with no standardized interface, drives up prices. Inflation and the energy crisis of 2022 have also had a profound impact on costs. Rising prices for materials, labour, and transportation have increased overall expenses, affecting every aspect of the deployment process. This economic pressure has led to higher costs across the board, making it more expensive to implement and maintain ERTMS systems. Additionally, the lack of upgradeable products is a significant cost driver. Many current ERTMS products are not designed with future upgrades in mind, meaning that any changes in specifications necessitate significant rework and additional costs. This need for extensive modifications or replacements increases immediate expenses and adds complexity to the deployment process, leading to higher long-term costs.

Solutions

Based on the identified cost drivers a series of solutions were identified by the DMT. These solutions were consequently discussed with the railway sector at a workshop and further to this, stakeholders were surveyed on their perception of the impact and cost of introducing the measures. The solutions have been divided into three categories based on their expected impact: strong, medium and moderate. The figure below provides an overview of the proposed solutions ranked based on their expected impact.

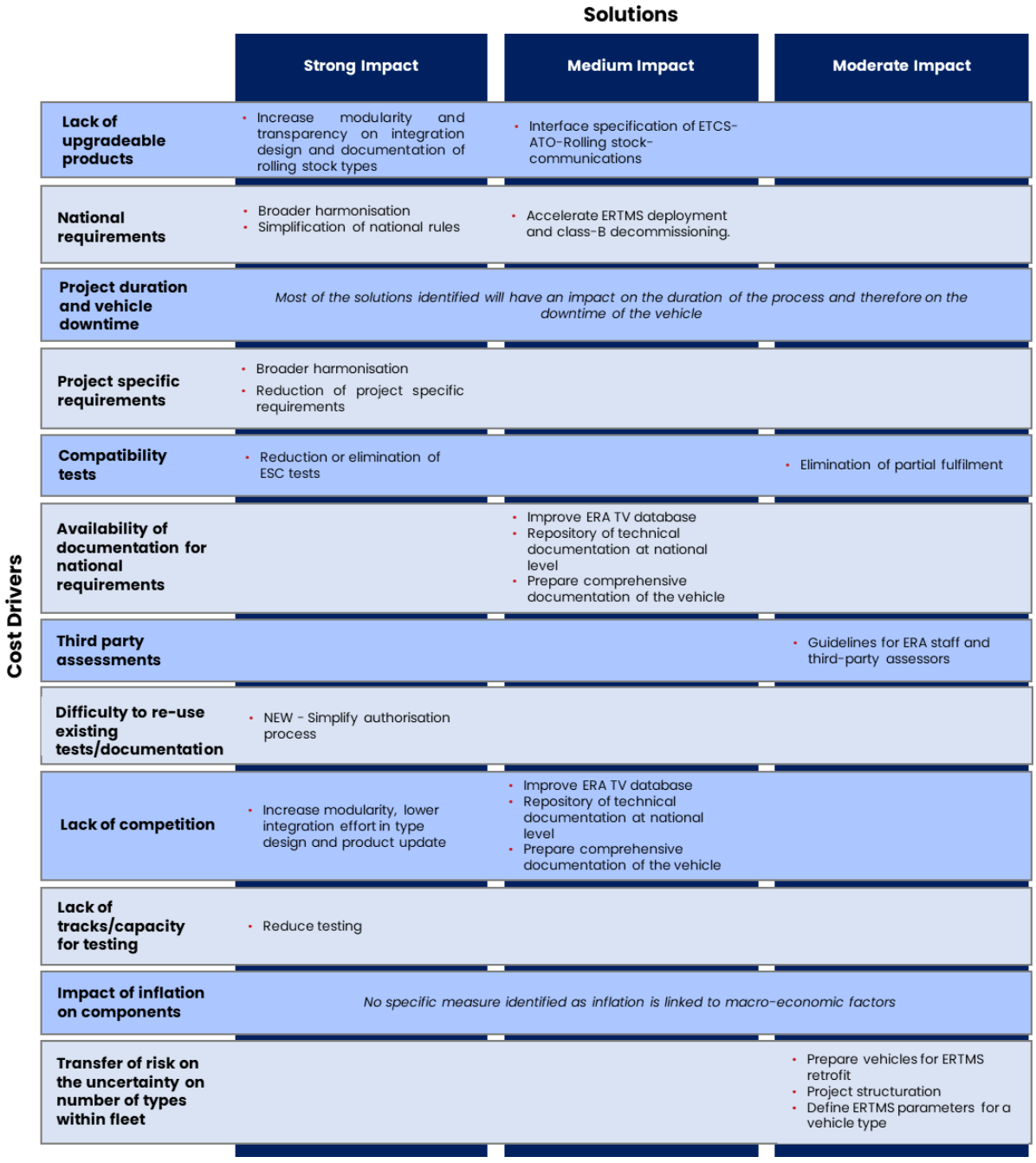

Figure 1: Solutions matrix

Solutions with a Strong Impact

The study identified a handful of solutions to have a strong impact on mitigating the cost drivers especially of the design and authorisation phases.

Firstly, the study recommends focusing on **reducing testing activities**. By simplifying testing through harmonisation and employing numerical and probabilistic analyses of test results, the need for certain tests can potentially be eliminated, thereby reducing vehicle downtime and consequently cutting costs.

Increasing modularity in type design and product updates should be introduced to lower integration efforts and associated costs. Although developing a modular architecture with standardised interfaces may incur short-term expenses, it is expected to significantly reduce the cost of future upgrades hereby mitigating the current cost driver of a lack of upgradeable products. This approach involves defining essential interface specifications, determining the optimal granularity for hardware and software components, and establishing lean software update processes. Standardised gateways on vehicles are recommended to ensure competitive future upgrades and enhance overall cost efficiency.

Broader harmonisation is crucial. The current complexity and flexibility of ERTMS lead to an increase in the demand for ESC/RSC types and tests while the deployment across different network increases the number of national-specific requirements. Harmonising operational processes, signalling concepts, and ERTMS trackside engineering can simplify the system and reduce costs. This broader harmonisation would target two of the main cost drivers identified by the study: National-specific requirements and Project duration and vehicle downtime.

Strengthening the simplification of national rules is proposed to address the broader regulatory landscape governing authorisation and design guidelines. This clean-up exercise would go beyond the one already conducted by ERA. It would target national rules specifically on authorisation, design guidelines and testing procedures. A clean-up exercise for these rules could facilitate a simpler and more transparent approach to accessing and identifying relevant information. This would, in turn, reduce risks associated with unexpected changes during retrofit projects, thereby lowering costs and enhancing transparency. In addition, **project-specific requirements** should be reduced. Project-specific requirements often hinder the reusability of designed solutions. In contrast, more standardised and scalable solutions can be transferred more easily across different fleets or regions, reducing engineering complexity and associated costs.

Finally, **simplifying the authorisation process** is essential to reduce costs linked to prototype work. It is recommended to develop a generic integration assessment template valid for a category of vehicles going beyond the vehicle type. Such a template would allow applicants and assessors to benchmark individual vehicles against the generic integration assessment template. Clear

definitions of changes that do not require new authorisation would further cut costs and streamline the overall process.

Solutions with a Medium Impact

Solutions deemed to have a medium impact included solutions that have already been laid down in legislation but have not yet had a visible impact in the market.

Among the solutions which are included in existing legislation is the **interface specification of ETCS-ATO[3]-rolling stock-communications**. The interface specification suggested to increase the modularity in new vehicles hereby reducing the risk of a lack of competition and mitigating the transfer of risk of different prototypes. This mitigation is still not visible in the market since there are no products with these interfaces in commercial service. Another solution identified in the current legislation is the **error correction process introduced in the Control Command and Signalling Technical Specifications for Interoperability[4] (CCS TSI)**. It will create transparency for the information of detected errors affecting interoperability in the specifications. It is expected that this process will contribute to the mitigation of the risks associated with the compatibility between trackside and on-board CCS systems as well as with the risks associated with the lack of broad ETCS harmonisation. This mitigation is still not visible in the market since the process has not been applied yet.

In the short term, improving project management is crucial. **Improving the accessibility of ERATV** (the European Register of Authorised Types of Vehicles) **and adding more detailed information in the database** could simplify life for both suppliers and vehicle owners. ERATV could be extended to provide detailed information on the system version of ETCS on-board. In addition, the possibility to download a version of the database which includes information on ERTMS should be explored. Furthermore, **creating a repository of technical documentation required for national-level ERTMS projects** can save time and reduce costs by simplifying identification of relevant national rules and guidelines.

Preparing comprehensive documentation of vehicles is essential for effective system integration in retrofit projects. Up-to-date technical characteristics of rolling stock and modifications should be documented and made available, preferably in English, to facilitate integration and authorisation processes. This documentation is vital for managing the scope of authorisation and avoiding unexpected cost increases.

[3] Automatic train operation (ATO)

[4] More information on the CCS TSI can be found here: Control Command and Signalling TSI | European Union Agency for Railways

Preparing vehicles for ERTMS retrofit by separating the vehicle preparation and the ERTMS installation can mitigate risks and reduce costs related to the number of prototypes required for a given fleet. Today, this risk on the number of prototypes is transferred to suppliers, who include provisions in their offer to cover this risk. By securing the number of prototypes required for a project, vehicle owners can reduce the risk transferred to suppliers and expect more competitive bids.

To increase efficiency in the last phase of projects, it is proposed to **share lessons learned from authorisation activities with ERA staff and third-party assessors**. In the medium to long term, **accelerating ERTMS deployment and decommissioning Class B systems** can eliminate the complexity of interfacing with multiple national systems. The national requirements linked to the national Class B systems are a significant hurdle for cross-border interoperability of rail services. This acceleration, requested by many participants at the 2024 ERA ERTMS conference, will occur once ERTMS is fully utilised on commercially interesting parts of the network, simplifying integration and reducing costs.

Solutions with a Moderate Impact

The study found two solutions to have an expected moderate impact on mitigating cost drivers. **The elimination of partial fulfilment** was introduced in the latest CCS TSI with the objective of reducing the complexity partial fulfilment creates, mainly in the integration between trackside and on-board ETCS. It is expected to reduce the number of ESC tests by increasing the confidence in the behaviour of the system. It is still not visible in the market since it will take time to materialize as there are no products compliant with the latest version of the CCS TSI in commercial service. In the short term it is suggested to **improve the project structuration** by incentivising the development of larger retrofitting or upgrade projects. This would improve the economies of scale of the projects, however, it is limited by the willingness of vehicle owners to cooperate on projects and applicable EU competition rules.

Synthèse

Ce rapport présente les conclusions d'une étude sur les coûts de déploiement de l'ERTMS réalisée par l'équipe de gestion du déploiement de l'ERTMS (DMT). Les informations récoltées ont révélé qu'au cours des dernières années, les coûts associés au déploiement l'ERTMS à bord des trains ont augmenté de manière significative. Les coûts pour équiper des véhicules déjà en service sont passés de 450.000 € à 900.000 € par véhicule, et les coûts de mise à niveau ont augmenté de 200.000 € à 400.000 € entre 2018 et 2022. De plus, les acteurs interrogés rencontrent un certain nombre de difficultés lors du déploiement de l'ERTMS à bord. Étant donné la menace que cette augmentation des coûts fait peser sur le futur déploiement de l'ERTMS, cette étude a été lancée afin d'identifier les principaux facteurs de coût à l'origine de ces augmentations et de proposer des solutions efficaces pour les atténuer. Cette étude constitue une première étape vers la mise en œuvre de ces solutions, qui nécessiteront l'implication de nombreux acteurs (Commission européenne, Agence ferroviaire européenne, États membres, autorités nationales de sécurité, fournisseurs, propriétaires de véhicules et gestionnaires d'infrastructures) pour devenir effectives.

Méthodologie

La démarche retenue s’est appuyée sur quatre principales étapes consécutives :

1. Entretiens ciblés : Deux séries d'entretiens ont été menées. La première visait à recueillir des données sur le coût et la performance du déploiement de l'ERTMS en Europe, y compris des données de coûts détaillées au niveau des projets, ainsi que sur des éléments spécifiques tels que les tests de compatibilité du système ETCS (ESC). Le niveau de granularité des données collectées dépendait des informations à disposition des acteurs interrogés, et de leur éventuel caractère confidentiel. La seconde série d'entretiens avait pour objectif d'identifier les facteurs ayant un impact sur le coût de déploiement de l'ERTMS à bord. Sept entretiens d’approfondissement ont été menés avec des acteurs du premier tour pour mieux comprendre les raisons de l’augmentation des coûts.
2. Conférence de l’ERA sur l’ERTMS en 2024 : Cette conférence a servi de plateforme de consultation du secteur, permettant d'échanger les points de vue et de recueillir des premiers retours sur les conclusions préliminaires de l’analyse.
3. Atelier avec les associations représentatives du secteur : Un atelier a été organisé avec CER, UNIFE/UNISIG, AERRL, ERFA, EIM, ERA et DG MOVE. Il a permis de discuter principalement des solutions

identifiées par l'équipe de gestion du déploiement de l'ERTMS (DMT). Cette étape a permis d'enrichir et d'améliorer substantiellement les conclusions de l'étude.

4. Enquête auprès des acteurs du secteur : Une enquête a été réalisée pour recueillir des données supplémentaires et l'avis des différentes parties prenantes. Les participants ont été invités à classer les facteurs de coût et les solutions en fonction de leur impact présumé. Cela a permis de valider les conclusions des entretiens et de l'atelier et d'obtenir une compréhension plus complète des facteurs de coût et des difficultés liées au déploiement de l'ERTMS.

Le périmètre de l'analyse présenté dans ce rapport porte sur le déploiement de l'ERTMS à bord des trains sur divers types de véhicules ferroviaires, à l'exception des systèmes ferroviaires urbains. L'analyse cible spécifiquement les projets d'équipement de véhicules existants (« rétrofit ») et de mise à niveau (« upgrade »). L'installation de l'ERTMS dans des matériels neufs n'est pas étudiée ici, car elle ne rencontre pas les mêmes problèmes. L'étude couvre les secteurs du fret et du transport de passagers (y compris les trains à grande vitesse). Les véhicules utilisés pour les travaux ferroviaires ont été exclus. Les projets relatifs à l'infrastructure ne sont pas inclus dans le champ de l'étude, car la collecte de données sur les coûts afférents est encore en cours.

L'analyse présentée dans ce rapport s'intéresse aux trois phases des projets d'ERTMS à bord : la phase de conception, la phase de déploiement et la phase d'autorisation. Cette vision globale assure une compréhension détaillée des facteurs de coût et des défis associés au déploiement de l'ERTMS à bord des trains.

Principaux facteurs de coûts identifiés

L'étude a permis d'identifier une série de facteurs qui contribuent et ont contribué à l'augmentation des coûts. Ces facteurs de coût ont été répartis entre les trois principales phases d'un projet, à savoir la phase de conception, la phase de déploiement et la phase d'autorisation. Certains facteurs transversaux, affectant les trois phases du projet, ont également été identifiés.

La phase de conception du déploiement de l'ERTMS à bord est fortement impactée par plusieurs facteurs. Les exigences nationales introduisent une variabilité et une complexité, car chaque pays met en œuvre des règles spécifiques pour l'exploitation ferroviaire, ce qui entraîne des efforts d'ingénierie accrus et une augmentation des coûts. La disponibilité limitée de la documentation sur ces exigences nationales ajoute à la complexité et au coût de développement de la solution. De plus, les exigences spécifiques à chaque projet empêchent la réutilisation de solutions antérieures, entraînant des développements complémentaires et donc des coûts supplémentaires. Le

transfert du risque associé aux différents types de véhicules entraîne également une hausse des coûts, car chaque type peut nécessiter le développement d'un prototype qu'il faudra certifier. Enfin, une documentation incomplète ou obsolète sur les caractéristiques des véhicules à équiper complique le travail des fournisseurs, entraînant aussi une augmentation des coûts.

La phase d'autorisation est marquée par plusieurs facteurs de coût significatifs. La longueur du processus d'autorisation, pouvant aller jusqu'à trois ou quatre ans, entraîne d'importantes pertes de revenus en raison de l'immobilisation prolongée des prototypes. La forte demande en documentation, en pistes d'essai et en laboratoires, associée à une disponibilité limitée, provoque des retards et une augmentation des coûts. Le manque de sillons disponibles pour les essais peut entraîner des délais supplémentaires et des charges supplémentaires. Les évaluations réalisées par des tiers, souvent requises en raison de règles nationales strictes et du nombre limité d'évaluateurs reconnus, ajoutent à la complexité et aux coûts du processus d'autorisation. Enfin, les exigences de tests approfondis, en particulier pour les tests ESC (compatibilité du système ETCS) et RSC (compatibilité du système radio), imposent une charge importante lors de la phase d'autorisation.

Enfin, certains facteurs de coût transversaux, affectant toutes les étapes d'un projet, ont également été identifiés. La concurrence limitée sur le marché, due à la complexité du système et à son imbrication actuelle dans les véhicules sans interface standardisée, entraîne une augmentation des prix. L'inflation et la crise énergétique de 2022 ont également eu un impact sur les coûts. La hausse des prix des matériaux, de la main-d'œuvre et du transport a entraîné une augmentation globale des dépenses, affectant chaque étape du processus de déploiement d'un projet. Cette pression économique a conduit à une hausse des coûts généralisée, rendant plus onéreuse la mise en œuvre et la maintenance des systèmes ERTMS. De plus, l'absence de produits évolutifs constitue un facteur de coût majeur. De nombreux produits ERTMS actuels ne sont pas conçus pour être facilement mis à jour, ce qui signifie que toute modification des spécifications nécessite un travail de refonte important et des coûts supplémentaires. Ce manque d'évolutivité du système entraîne des coûts plus élevés à long terme.

Solutions

Sur la base des facteurs de coût identifiés, une série de solutions a été proposée par le DMT. Ces solutions ont ensuite été discutées avec le secteur ferroviaire lors d'un atelier, puis les parties prenantes ont été interrogées sur leur perception de l'impact et du coût de la mise en œuvre de ces mesures. Les solutions ont été classées en trois catégories en fonction de leur impact attendu : fort, moyen et modéré. L'illustration ci-dessous présente un aperçu des solutions proposées, classées selon leur impact estimé.

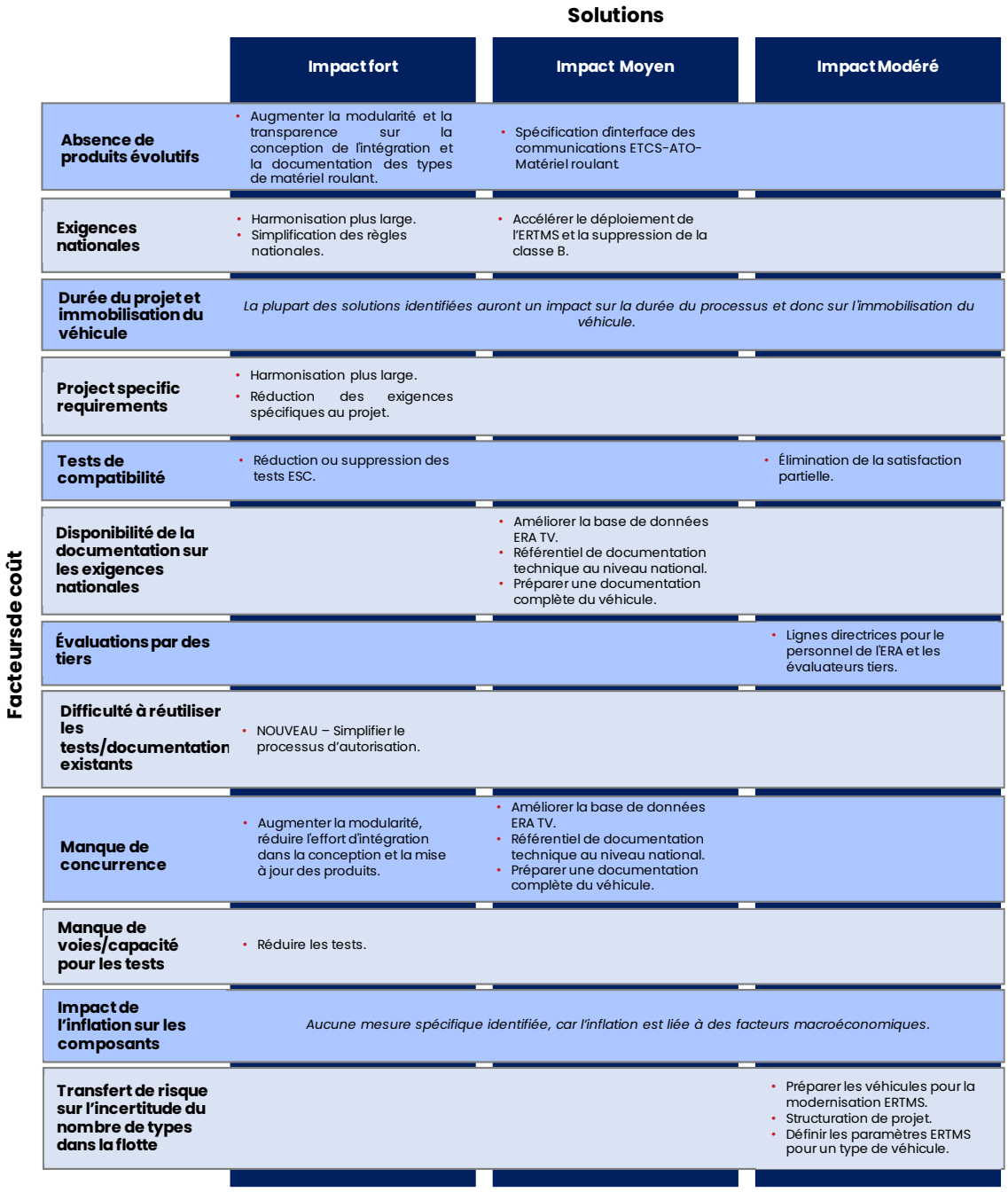

Figure 2: Matrice des solutions

Solutions ayant un impact fort

L'étude a identifié plusieurs solutions susceptibles d'avoir un impact important sur les coûts de l'ERTMS à bord des trains, en particulier sur les phases de conception et d'autorisation.

Tout d'abord, l'étude recommande de travailler à la réduction des activités de test. Des outils numériques pourraient se substituer à certains tests, réduisant ainsi l'immobilisation des véhicules et, partant, les coûts.

Il conviendrait également d'augmenter la modularité du système afin de réduire les efforts d'intégration de l'ERTMS à bord des trains et les coûts associés. Bien que le développement d'une architecture modulaire avec des interfaces standardisées génère des coûts à court terme, cela devrait considérablement réduire le coût des mises à jour futures. Cette approche implique la mise au point de spécifications pour les interfaces, la détermination du niveau optimal de granularité pour les composants matériels et logiciels, et l'établissement de processus de mise à jour de la partie logicielle.

Une harmonisation plus importante des règles opérationnelles est également indispensable. Le développement de solutions spécifiques basées sur l'ERTMS entraîne un manque de confiance dans le système, qui se traduit par le développement de tests ESC/RSC. Par ailleurs, le déploiement de l'ERTMS dans un nombre toujours croissant de pays entraîne une augmentation des exigences spécifiques à chaque pays. L'harmonisation des processus opérationnels et des principes de conception de la signalisation ferroviaire peut simplifier le système et réduire les coûts. Cette harmonisation ciblerait deux des principaux facteurs de coût identifiés par l'étude : les exigences spécifiques aux pays ainsi la durée des projet et l'immobilisation des véhicules.

La simplification des règles nationales est proposée afin de rationaliser le cadre réglementaire régissant l'autorisation et les règles de conception. Cet exercice de simplification irait au-delà de celui déjà mené par l'ERA et ciblerait spécifiquement les règles nationales sur l'autorisation, les règles de conception et les procédures de test. Une clarification de ces règles pourrait faciliter un accès plus simple et transparent aux informations pertinentes, réduisant ainsi les risques liés aux changements imprévus dans les projets de modernisation, réduisant les coûts et améliorant la transparence. De plus, les exigences spécifiques aux projets devraient être réduites. Elles empêchent souvent la réutilisation des solutions conçues, alors que des solutions plus standardisées et évolutives pourraient être facilement transférées entre différentes flottes ou régions, réduisant ainsi la complexité de l'ingénierie et les coûts associés.

Enfin, la simplification du processus d'autorisation est essentielle pour réduire les coûts liés aux prototypes. Il est recommandé de développer un modèle générique d'évaluation de l'intégration, applicable à une catégorie de véhicules au-delà du type de véhicule spécifique. Ce modèle permettrait aux demandeurs et aux évaluateurs de comparer les véhicules individuels à un cadre de référence commun. Une définition claire des modifications ne nécessitant pas de nouvelle autorisation contribuerait également à réduire les coûts et à rationaliser l'ensemble du processus.

Solutions ayant un impact moyen

Les solutions ayant un impact moyen incluent notamment celles qui sont déjà prévues par le cadre législatif actuel mais dont les effets sur le marché ne sont pas encore visibles.

Parmi ces solutions figurent la définition de l''interface entre l'ETCS, l'ATO, le matériel roulant et le système de communication. L'objectif de cette interface est d'augmenter la modularité des nouveaux véhicules, réduisant ainsi le risque d'un manque de concurrence et améliorant l'évolutivité du système. Cependant, les effets ne sont pas encore visibles, car aucun produit doté de ces interfaces n'est actuellement proposé sur le marché.

Un autre levier législatif identifié est le processus de correction d'erreurs introduit dans la CCS TSI. Ce processus vise à garantir la transparence du mécanisme de correction des erreurs détectées affectant l'interopérabilité. Il devrait contribuer à réduire les risques liés à la compatibilité entre les systèmes ERTMS embarqués et au sol.

À court terme, l'amélioration de la gestion des projets est essentielle. Une meilleure accessibilité à l'ERATV (Registre Européen des Types de Véhicules Autorisés) et l'ajout d'informations plus détaillées dans la base de données pourraient simplifier le travail des fournisseurs et des propriétaires de véhicules. L'ERATV pourrait être étendu pour inclure des informations sur la version du système ETCS embarqué et permettre le téléchargement d'une version enrichie de la base de données contenant des informations sur l'ERTMS. De plus, la création d'un référentiel de documentation technique pour les projets nationaux ERTMS pourrait permettre de gagner du temps et de réduire les coûts en facilitant l'identification des règles et directives nationales pertinentes. La documentation complète des véhicules est également essentielle pour l'intégration efficace des systèmes dans les projets de modernisation. Les caractéristiques techniques à jour du matériel roulant et les modifications apportées devraient ainsi être documentées et rendues accessibles, de préférence en anglais, afin de faciliter les processus d'intégration et d'autorisation.

Préparer les véhicules pour la modernisation de l'ERTMS en dissociant le contrat de modernisation et l'installation de l'ERTMS peut atténuer les risques et réduire les coûts liés à la préparation du matériel roulant pour l'intégration de l'ERTMS. Cette séparation permettrait aux propriétaires de véhicules de mieux gérer les activités d'intégration, favorisant ainsi la concurrence et réduisant les coûts globaux de modernisation.

Pour améliorer l'efficacité de la dernière phase des projets, il est proposé de partager les enseignements tirés des activités d'autorisation avec le personnel de l'ERA et les évaluateurs tiers.

Enfin, à moyen et long terme, l'accélération du déploiement de l'ERTMS et la mise hors service des systèmes de classe B pourraient éliminer la complexité liée à l'interface avec plusieurs systèmes nationaux. Les exigences nationales associées aux systèmes de classe B constituent un facteur de complexité et donc de surcoût pour les projets ERTMS. Cette accélération, demandée par de nombreux participants à la conférence de l'ERA sur l'ERTMS, se produira une fois que l'ERTMS sera pleinement utilisé sur les parties du réseau ayant un intérêt commercial, simplifiant ainsi l'intégration et réduisant les coûts.

Solutions ayant un impact modéré

L'étude a identifié deux solutions ayant un impact modéré sur les facteurs de coût.

L'élimination du concept de "partial fulfilment" (conformité partielle) a été introduite dans la dernière version de la CCS TSI afin de réduire la complexité que cette approche entraîne dans l'intégration entre l'ETCS embarqué et au sol. Cette mesure devrait réduire le nombre de tests ESC en renforçant la confiance dans le fonctionnement du système. Toutefois, son effet ne se fait pas encore ressentir sur le marché du fait qu'aucun produit conforme à la dernière version de la CCS TSI ne soit en service commercial.

À court terme, il est suggéré d'améliorer la structuration des projets en incitant au développement de projets de modernisation ou de mise à niveau de plus grande envergure. Cela permettrait de bénéficier d'économies d'échelle plus importantes et, partant, de réduire les coûts. La portée de cette approche est toutefois limitée pour deux principales raisons : elle est à la fois dépendante de la volonté et contrainte par les règles de concurrence en vigueur au sein de l'UE.

Kurzfassung

Dieser Bericht fasst die Ergebnisse einer Kostenstudie zur ERTMS-Implementierung zusammen, durchgeführt vom ERTMS Deployment Management Team (DMT). Die realisierte Datenerhebung ergab, dass die Kosten für an Bord ERTMS-Implementierung in den letzten Jahren erheblich gestiegen sind. Die Nachrüstungskosten sind von 450.000 € auf 900.000 € pro Fahrzeug gestiegen, während sich die Aufrüstungskosten zwischen 2018 und 2022 von 200.000 € auf 400.000 € verdoppelt haben. Darüber hinaus sehen sich die Akteure mit einer Reihe von Herausforderungen bei der an Bord ERTMS - Implementierung konfrontiert. Diese Studie untersucht die Hauptgründe für die Kostensteigerungen bei ERTMS-Implementierungen und schlägt Lösungen zur Kostensenkung vor. Diese Studie stellt einen ersten Schritt zur Umsetzung der Lösungen dar, die die Beteiligung zahlreicher Akteure (Europäische Kommission, Europäische Eisenbahnagentur (ERA), Mitgliedstaaten, Nationale Sicherheitsbehörden, Lieferanten, Fahrzeughalter und Infrastrukturbetreibern) erfordert, um wirksam zu werden.

Methodik

Der methodische Ansatz der Studie folgte einem schrittweisen Prozess, wobei jeder Schritt auf dem vorherigen aufbaute. Der Ansatz bestand aus vier Hauptschritten:

1. Gezielte Interviews: Es wurden zwei Interviewrunden durchgeführt. Die erste Runde konzentrierte sich auf die Erhebung von Daten zu den Implementierungskosten und der Umsetzung von ERTMS in ganz Europa. Dabei wurden detaillierte Kostendaten auf Projektebene erfasst, darunter spezifische Kosten wie ESC-Tests (ETCS System Compatibility). Der Detaillierungsgrad der erhobenen Daten hing von der Fähigkeit der Stakeholder ab, diese Informationen bereitzustellen oder zu besitzen. Die zweite Interviewrunde hatte das Ziel, die Kostentreiber der ERTMS-Implementierung zu identifizieren. Sieben vertiefende Folgeinterviews mit Schlüsselakteuren aus der ersten Runde wurden durchgeführt, um die Ursachen der identifizierten Kostensteigerungen detaillierter zu untersuchen.
2. 2024 ERA ERTMS-Konferenz: Diese Konferenz diente als Plattform für die Konsultation der Stakeholder und ermöglichte den Austausch von Erkenntnissen und Feedback zu den Ergebnissen der Interviews sowie weiterer Datenerhebungen.
3. Stakeholder-Workshop: Ein Workshop wurde zusammen mit CER, UNIFE/UNISIG, AERRL, ERFA, EIM, ERA und der GD MOVE abgehalten. In diesem Rahmen wurden insbesondere die vom DMT

identifizierten Lösungen diskutiert. Dieser Schritt stellte sicher, dass eine breite Palette von Perspektiven in die Analyse einfloss.

4. Stakeholder-Umfrage: Eine Umfrage wurde durchgeführt, um zusätzliche Daten und Erkenntnisse von Stakeholdern zu sammeln. Die Teilnehmer wurden gebeten, die Kostentreiber und Lösungen nach ihrer erwarteten Wirkung zu bewerten. Dies half, die Erkenntnisse aus den Interviews und Workshops zu validieren und ein umfassenderes Verständnis der Kostentreiber und Herausforderungen im Zusammenhang mit der ERTMS-Implementierung zu gewinnen.

Der analytische Fokus des Berichts liegt auf der an Bord ERTMS-Implementierung bei verschiedenen Typen von Schienenfahrzeugen, wobei städtische Bahnsysteme ausgeschlossen wurden. Die Analyse konzentriert sich speziell auf Nach- und Aufrüstungs-Projekte. Die Ausstattung neuer Schienenfahrzeuge mit ERTMS wird nicht berücksichtigt, da sie nicht mit denselben Herausforderungen konfrontiert ist. Die Studie umfasst sowohl den Güter- als auch den Personenverkehr (einschließlich Hochgeschwindigkeitszüge), während Fahrzeuge der sogenannten “Yellow Fleet“ ausgeschlossen wurden. Projekte im Gleisbereich sind ebenfalls nicht Teil des Untersuchungsbereichs, da die Datenerhebung zu den Implementierungskosten der Strecken noch andauert.

Die analysierten Kostenbestandteile sind in drei Phasen unterteilt: die Entwurfsphase, die Implementierungsphase und die Zulassungsphase. Dieser umfassende Ansatz gewährleistet ein detailliertes Verständnis der Kostentreiber und Herausforderungen im Zusammenhang mit der an Bord ERTMS-Implementierung.

Hauptkostentreiber identifiziert

Die Studie hat mehrere Kostentreiber identifiziert, die zu den gestiegenen Kosten beigetragen haben und weiterhin beitragen. Diese Kostentreiber wurden in die drei Hauptphasen eines Implementierungsprojekts unterteilt: die Entwurfs-, die Implementierungs- und die Zulassungsphase. Zudem wurden einige horizontale Kostentreiber identifiziert, die sich auf alle drei Phasen des Projekts auswirken.

Die Entwurfsphase der an Bord ERTMS-Implementierung wird erheblich von mehreren Kostentreibern beeinflusst. Nationale Anforderungen führen zu Variabilität und Komplexität, da jedes Land spezifische Vorschriften für den Bahnbetrieb, die Zulassung und das Design hat, was zu erhöhtem ingenieurtechnischem Aufwand und steigenden Kosten führt. Die Verfügbarkeit von Dokumentationen zu diesen nationalen Anforderungen ist oft begrenzt, was die Einhaltung zusätzlich erschwert und verteuert. Projektspezifische Anforderungen behindern zudem die Wiederverwendbarkeit von Lösungen,

wodurch zusätzliche Entwicklungsarbeiten erforderlich werden und die Kosten steigen. Darüber hinaus trägt die Übertragung von Risiken im Zusammenhang mit unterschiedlichen Fahrzeugtypen zu den Kosten bei, da für jeden Typ maßgeschneiderte Lösungen und zusätzliche Zertifizierungsmaßnahmen erforderlich sein können. Unvollständige oder veraltete Dokumentationen zu Fahrzeugmerkmalen erschweren zudem den Anpassungsprozess, was zu höheren Kosten führt. Die Zulassungsphase ist durch mehrere wesentliche Kostentreiber gekennzeichnet. Der langwierige Zulassungsprozess, der bis zu drei bis vier Jahre dauern kann, führt zu erheblichen Umsatzeinbußen, da Prototypfahrzeuge über einen langen Zeitraum außer Betrieb bleiben. Die hohe Nachfrage nach Dokumentationen, Teststrecken und Laboren, gepaart mit begrenzten Kapazitäten, verursacht Verzögerungen und steigende Kosten. Das Verpassen geplanter Testfenster kann zu zusätzlichen Verzögerungen und Mehrausgaben führen. Drittanbieter-Bewertungen, die aufgrund strenger nationaler Vorschriften und einer begrenzten Anzahl an anerkannten Gutachtern häufig erforderlich sind, erhöhen die Komplexität und die Kosten des Zulassungsprozesses weiter. Umfangreiche Testanforderungen, insbesondere für ESC- (ETCS System Compatibility) und RSC- (Radio System Compatibility) Tests, stellen erhebliche finanzielle und personelle Belastungen für die Zulassungsphase dar.

Schließlich wurden einige horizontale Kostentreiber identifiziert, die sich auf alle Phasen eines Projekts auswirken. Der begrenzte Wettbewerb auf dem Markt, bedingt durch die Komplexität des Systems und die heutige Art der Fahrzeugintegration ohne standardisierte Schnittstellen, treibt die Preise in die Höhe. Die Inflation und die Energiekrise des Jahres 2022 haben ebenfalls erhebliche Auswirkungen auf die Kosten. Steigende Preise für Materialien, Arbeitskräfte und Transport haben die Gesamtausgaben erhöht und alle Aspekte des Implementierungsprozesses beeinflusst. Dieser wirtschaftliche Druck hat zu allgemein höheren Kosten geführt, wodurch die Implementierung und Wartung von ERTMS-Systemen teurer wird. Zudem stellt das Fehlen aufrüstbarer Produkte einen bedeutenden Kostentreiber dar. Viele derzeitige ERTMS-Produkte sind nicht für zukünftige Modernisierungen ausgelegt, sodass jede Änderung der Spezifikationen umfangreiche Nacharbeiten und zusätzliche Kosten erfordert. Dieser Bedarf an umfassenden Modifikationen oder Ersatzlösungen erhöht die kurzfristigen Kosten erheblich und führt zu einer zusätzlichen Komplexität im Implementierungsprozess, was langfristig zu höheren Gesamtkosten führt.

Lösungen

Basierend auf den identifizierten Kostentreibern wurde von der DMT verschiedene Lösungen erarbeitet. Diese Lösungen wurden anschließend in einem Workshop mit dem Eisenbahnsektor diskutiert, und darüber hinaus wurden die Stakeholder zu ihrer Einschätzung der Auswirkungen und Kosten der

Einführung dieser Maßnahmen befragt. Die Lösungen wurden in drei Kategorien unterteilt, basierend auf ihrer erwarteten Wirkung: stark, mittel und moderat. Die nachfolgende Abbildung bietet einen Überblick über die vorgeschlagenen Lösungen, geordnet nach ihrer erwarteten Wirkung.

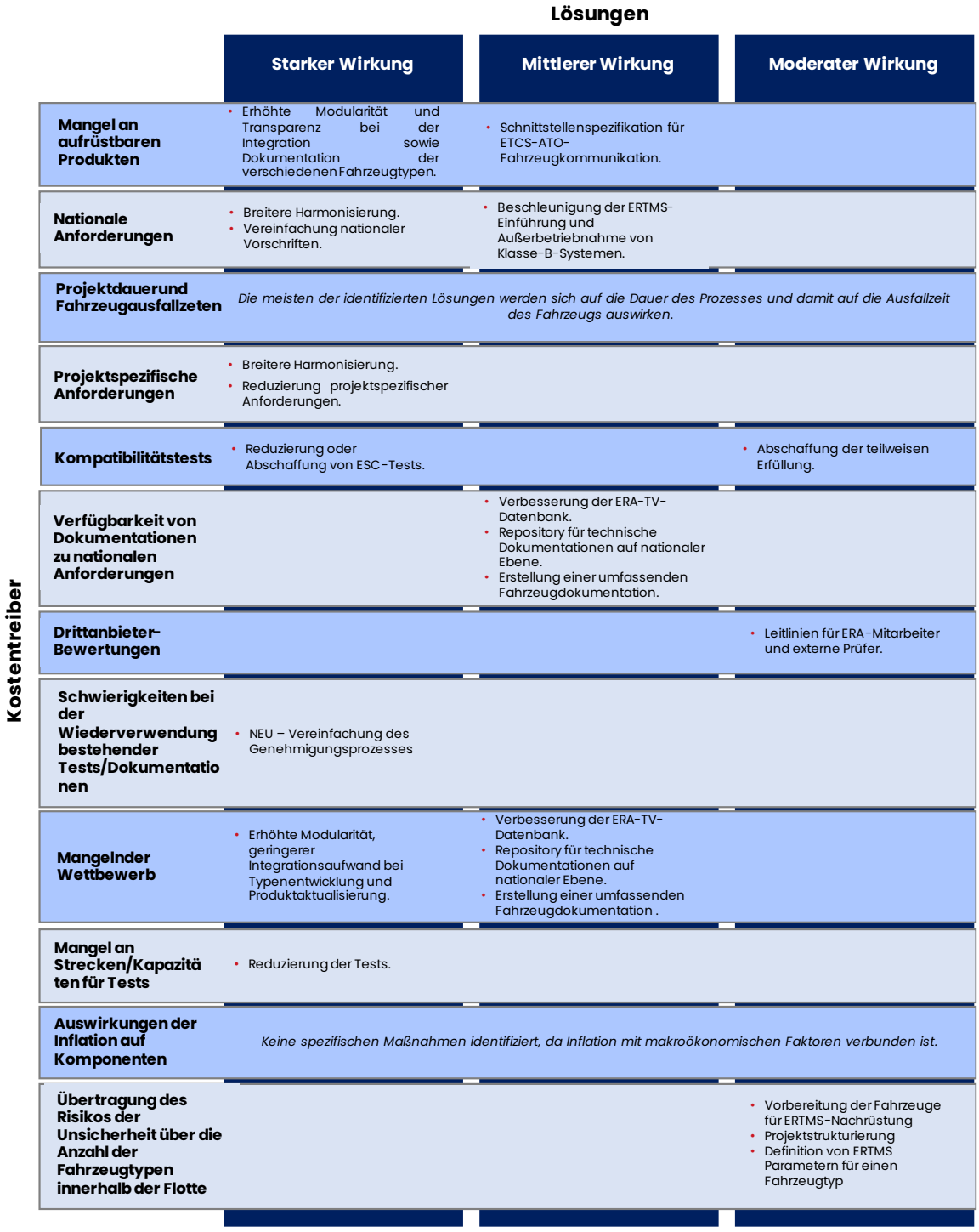

Figure 3: Lösungsmatrix

Lösungen mit starker Wirkung

Die Studie hat eine Reihe von Lösungen identifiziert, die insbesondere in der Entwurfs- und Zulassungsphase eine starke Wirkung zur Minderung der Kostentreiber haben.

Erstens wird empfohlen, den Umfang der Testaktivitäten zu reduzieren. Durch die Vereinfachung von Tests mittels Harmonisierung sowie numerischer und probabilistischer Analysen von Testergebnissen kann die Notwendigkeit bestimmter Tests möglicherweise entfallen. Dadurch ließe sich die Stillstandzeit der Fahrzeuge verringern und somit Kosten senken.

Zudem sollte die **Modularität im Typdesign und bei Produktaktualisierungen** erhöht werden, um den Integrationsaufwand und die damit verbundenen Kosten zu senken. Auch wenn die Entwicklung einer modularen Architektur mit standardisierten Schnittstellen zunächst mit Kosten verbunden ist, wird erwartet, dass dies langfristig die Kosten für zukünftige Upgrades erheblich reduziert. Dies würde die derzeitige Problematik mangelnder aufrüstbarer Produkte entschärfen. Zu diesem Ansatz gehören die Definition wesentlicher Schnittstellenspezifikationen, die Bestimmung der optimalen Granularität von Hardware- und Softwarekomponenten sowie die Einführung schlanker Software-Update-Prozesse. Standardisierte Gateways in Fahrzeugen werden empfohlen, um zukünftige Upgrades wettbewerbsfähig zu gestalten und die Kosteneffizienz insgesamt zu verbessern.

Eine **umfassendere Harmonisierung** ist ebenfalls von entscheidender Bedeutung. Die derzeitige Komplexität und Flexibilität von ERTMS erhöht die Nachfrage nach ESC-/RSC-Typen und -Tests, während der Einsatz in verschiedenen Netzen die Anzahl nationaler spezifischer Anforderungen steigert. Eine Harmonisierung von Betriebsabläufen, Signalgebungskonzepten und ERTMS-Streckenseitentechnik könnte das System vereinfachen und Kosten reduzieren. Diese breitere Harmonisierung würde zwei der Hauptkostentreiber der Studie gezielt adressieren: **nationale spezifische Anforderungen sowie Projektdauer und Fahrzeugstillstandszeiten**.

Die Vereinfachung nationaler Vorschriften wird vorgeschlagen, um das umfassendere regulatorische Umfeld im Bereich Zulassung und Entwurfsrichtlinien zu optimieren. Diese Bereinigungsmaßnahme würde über die bereits von der ERA durchgeführten Arbeiten hinausgehen und sich gezielt auf nationale Vorschriften zu **Zulassungen, Entwurfsrichtlinien und Testverfahren** konzentrieren. Eine solche Bereinigung könnte den Zugang zu relevanten Informationen erleichtern und damit Risiken unerwarteter Änderungen in Nachrüstungsprojekten verringern, was letztlich zu Kostensenkungen und höherer Transparenz führen würde. Zusätzlich sollten projektspezifische Anforderungen reduziert werden. Diese behindern häufig die Wiederverwendbarkeit bereits entwickelter Lösungen, wohingegen stärker standardisierte und skalierbare Lösungen einfacher auf verschiedene

Fahrzeugflotten oder Regionen übertragbar wären, wodurch sich die Komplexität und die Kosten für die technische Entwicklung verringern würden.

Schließlich ist **die Vereinfachung des Zulassungsprozesses** essenziell, um die mit Prototyp-Arbeiten verbundenen Kosten zu senken. Es wird empfohlen, eine **generische Integrationsbewertungsvorlage** zu entwickeln, die über einzelne Fahrzeugtypen hinaus für Fahrzeugkategorien gilt. Eine solche Vorlage würde es Antragstellern und Prüfern ermöglichen, einzelne Fahrzeuge anhand dieser Vorlage zu bewerten. Zudem könnten klare Definitionen für Änderungen, die keine neue Zulassung erfordern, weitere Kosten einsparen und den gesamten Prozess effizienter gestalten.

Lösungen mit mittlerer Wirkung

Lösungen mit mittlerer Wirkung umfassen Maßnahmen, die bereits in der Gesetzgebung verankert sind, jedoch noch keine sichtbaren Auswirkungen auf den Markt hatten.

Eine dieser Lösungen ist die **Spezifikation der Schnittstelle zwischen ETCS, ATO, Fahrzeug und Kommunikationssystemen**. Die Spezifikation dieser Schnittstelle wurde eingeführt, um die Modularität neuer Fahrzeuge zu erhöhen und somit den **Wettbewerbsmangel sowie das Risiko der Übertragung unterschiedlicher Prototyp-Risiken** zu verringern. Diese Maßnahme zeigt jedoch noch keine Wirkung, da bislang keine Produkte mit diesen Schnittstellen im kommerziellen Betrieb sind. Eine weitere bereits gesetzlich verankerte Lösung ist das **Fehlerkorrekturverfahren**, das in die CCS TSI aufgenommen wurde. Es soll Transparenz hinsichtlich der Identifizierung von Fehlern schaffen, die die Interoperabilität der Spezifikationen beeinträchtigen. Erwartet wird, dass dieses Verfahren dazu beiträgt, **die Risiken der Kompatibilität zwischen streckenseitigen und fahrzeugseitigen CCS-Systemen sowie die Risiken mangelnder ETCS-Harmonisierung** zu minimieren. Diese Minderung ist jedoch noch nicht sichtbar, da das Verfahren bislang nicht angewendet wurde.

Kurzfristig ist **die Verbesserung des Projektmanagements** von entscheidender Bedeutung. Eine bessere Zugänglichkeit des **ERATV** (European Register of Authorised Types of Vehicles) und die Bereitstellung detaillierterer Informationen in der Datenbank könnten die Arbeit für Lieferanten und Fahrzeugbesitzer erheblich erleichtern. ERATV könnte dahingehend erweitert werden, dass detaillierte Informationen zur Systemversion von ETCS an Bord abrufbar sind, und es sollte geprüft werden, ob eine Version der Datenbank mit ERTMS-relevanten Informationen zum Download angeboten werden kann.

Zusätzlich könnte die **Einrichtung eines zentralen Repositoriums für technische Dokumentationen** im nationalen Kontext von ERTMS-Projekten Zeit sparen und Kosten senken, indem relevante nationale Vorschriften und Leitlinien leichter identifizierbar werden.

Die **vollständige Dokumentation von Fahrzeugen** ist essenziell für eine effiziente Systemintegration in Nachrüstungsprojekten. Technische Merkmale von Fahrzeugen sowie erfolgte Modifikationen sollten stets aktualisiert und möglichst auf Englisch verfügbar sein, um Integrations- und Zulassungsprozesse zu erleichtern.

Die Vorbereitung von Fahrzeugen für das ERTMS-Nachrüstverfahren, indem die Fahrzeugvorbereitung und die ERTMS-Installation getrennt werden, kann Risiken mindern und Kosten im Zusammenhang mit der Anzahl der für eine bestimmte Flotte erforderlichen Prototypen senken. Heute wird dieses Risiko bezüglich der Anzahl der Prototypen auf die Lieferanten übertragen, die in ihrem Angebot Bestimmungen aufnehmen, um dieses Risiko abzudecken. Durch die Sicherstellung der für ein Projekt erforderlichen Anzahl von Prototypen können Fahrzeugbesitzer das Risiko, das auf die Lieferanten übertragen wird, reduzieren und mit wettbewerbsfähigeren Angeboten rechnen.

Zur Effizienzsteigerung in der letzten Projektphase wird vorgeschlagen, **Erfahrungen aus Zulassungstätigkeiten mit ERA-Mitarbeitern und externen Gutachtern zu teilen**.

Mittel- bis langfristig könnte die **Beschleunigung der ERTMS-Einführung und die Stilllegung der Klasse-B-Systeme** die Komplexität der Schnittstellen mit mehreren nationalen Systemen beseitigen. Nationale Anforderungen im Zusammenhang mit Klasse-B-Systemen stellen eine erhebliche Hürde für die grenzüberschreitende Interoperabilität dar. Viele Teilnehmer der **ERA ERTMS-Konferenz 2024** forderten eine schnellere Umsetzung von ERTMS, insbesondere in wirtschaftlich bedeutenden Netzbereichen, um die Integration zu vereinfachen und Kosten zu senken.

Lösungen mit moderater Wirkung

Die Studie identifizierte zwei Lösungen mit einer erwarteten moderaten Wirkung auf die Reduzierung von Kostentreibern.

Die **Abschaffung der Teil-Erfüllung** wurde in die neueste Version der CCS TSI aufgenommen, um die Komplexität der Integration zwischen streckenseitigem und fahrzeugseitigem ETCS zu reduzieren. Erwartet wird, dass dadurch die Anzahl der ESC-Tests sinkt, da das Vertrauen in das Systemverhalten steigt. Diese Maßnahme ist allerdings noch nicht im Markt sichtbar, da bisher keine Produkte nach der neuesten CCS TSI-Version im kommerziellen Betrieb sind.

Kurzfristig wird vorgeschlagen, die **Projektstrukturierung zu verbessern**, indem größere Nachrüstungs- oder Upgrade-Projekte gefördert werden. Dies würde die Skaleneffekte verbessern, ist jedoch durch die Bereitschaft der Fahrzeugbesitzer zur Zusammenarbeit und geltende EU-Wettbewerbsregeln begrenzt.

1 Context and objective of the report

This report builds on a data collection exercise on the costs of on-board deployment of the European Rail Traffic Management System[5] carried out by the ERTMS Deployment Management Team (DMT)[6]. The objective of this exercise was to collect data and information on the deployment costs and performance of ERTMS. Between 2022 and 2023, a total of 22 interviews were carried out with a broad variety of stakeholders representing suppliers, vehicle owners, railway undertakings (RUs), regulators and other entities involved in ERTMS deployment[7]. Through the interviews the DMT collected a significant amount of data covering the costs of deployment and capturing stakeholders' perspectives and experiences related to the deployment and operation of ERTMS.

The key findings of the exercise were:

- Costs of ERTMS on-board deployment have increased considerably over the past few years and stakeholders face a series of issues when deploying ERTMS.
- Where implemented, ERTMS enhances safety and, depending on the previous Class B system, can also improve system reliability.[8]
- There is a broad consensus that the deployment of ERTMS, both trackside and on-board, is progressing at an insufficient pace.

1.1 A sharp increase of the costs

As indicated above, the DMT's data collection found that the costs of ERTMS on-board deployment projects have increased considerably in the last few years. Notably, the following findings were made in relation to the costs of ERTMS on-board deployment:

[5] ERTMS is the European standard for the Automatic Train Protection (ATP) and command and control systems. It creates an interoperable railway system in Europe that is more efficient and safer. It contributes to making rail operation between the Member States much easier and is an essential element of the Single European Railway Area.

[6] The ERTMS DMT supports the European Commission DG MOVE in deploying ERTMS. Its objectives are "to ensure an efficient, synchronised and timely implementation of ERTMS along the core network corridors and ensure consistency with other parts of the network." It is governed by "EUROPEAN COMMISSION - DIRECTORATE GENERAL FOR MOBILITY AND TRANSPORT – service contract MOVE/C4/2022-62". Currently, the work of the DMT is carried out by the consultancies EY, Blue Arches and INECO who are also the authors of this report.

[7] The list of stakeholders interviewed during this "first round" of interviews is presented in the annex.

[8] While important for ERTMS deployment, these two points have not been investigated further by this study. The pace of deployment can though be seen as a cause of a cost increase and hence can be reduced by addressing the cost drivers.

- The costs of an ERTMS on-board deployment projects have roughly doubled from 2018 to 2022.
    - 2018: €450k per vehicle for retrofit and €200k for upgrade.
    - 2022: €900k per vehicle for retrofit and €400k for upgrade[9].
- These values have been confirmed by EU associations representing railway undertakings and vehicle owners, who quoted even higher values for upgrades (up to €650k).

1.2 A need to change the trend in retrofitting and upgrade costs

In the "ERTMS business case on the 9 core network corridors" published in 2019[10], a suite of target values for retrofit and upgrade costs were set based on multiple discussions with the sector.

For upgrade costs a target value of €300k / vehicle for an upgrade was used. This value represented an average of different types of upgrade projects (pre-B2 to B3, B2 to B3 and upgrades mainly related to software).

While for retrofit projects, multiple scenarios were developed each with their respective costs. The worst-case scenario (*Scenario 0: the patchy deployment scenario*) assumed no coordination between stakeholders resulting in a retrofitting cost of €1 200k / vehicle. Whereas the other scenarios assumed a target retrofit costs of €300k / vehicle. Unfortunately, it seems that currently the sector is closer to the worst-case scenario than to the target envisaged in all other scenarios: Hence, it is crucial to take immediate action to reverse the current trend to reach the initial target retrofit cost of €300k / vehicle.

1.3 Cost drivers analysis

Given the threat increasing costs impose on the future deployment of ERTMS, it was decided to further examine the underlying reasons for the cost increase identified throughout the interviews. Consequently, the present study was commenced with the objective of uncovering the cost drivers and proposing a series of measures to mitigate them and decrease deployment costs. Through a

[9] These values represent a weighted average (taking into account unit price and number of units) for both prototype and serial deployment. A further explanation of these values can be found in section 3. The values relate to projects with different baselines (pre-B2, B2 or B3, as a starting point or as a target) with no clear correlation between the cost and the baseline(s) of the project.

[10] European Commission: Directorate-General for Mobility and Transport (2019), *ERTMS business case on the 9 core network corridors – Second release.* Retrieved from: https://data.europa.eu/doi/10.2832/813655 .

second round of deep-dive interviews (8 in total) with key stakeholders, stakeholder workshops at both the ERA ERTMS conference and at DG MOVE premises and lastly, a stakeholder survey. This report presents 1) the identified cost drivers and 2) a series of solutions to mitigate the cost drivers.

1.4 Reading guide

The report is structured as follows:

- Section 2 presents the methodological approach.
- Section 3 proposes a tentative split of the costs of ERTMS on-board projects.
- Section 4 lists the main cost drivers and explains their effect on ERTMS deployment projects.
- Section 5 identifies the cost drivers having the biggest impact on the costs.
- Section 6 concludes by proposing the key solutions to the identified cost drivers.

2 Methodology

The following methodological approach and considerations were followed to deliver the current report.

2.1 Analytical scope

The analysis has applied the following scope in relation to the type of ERTMS projects included and the associated costs of ERTMS projects.

2.1.1 Fleet analysed

This report focuses on the on-board deployment on the regular vehicle fleet: the yellow fleet has been excluded from the analysis – even though some information could be collected through interviews on the cost of equipping this fleet with ERTMS. These data showed that this cost is extremely high[11] and is problematic for infrastructure managers. This can be explained by the fact that almost each vehicle is a prototype, and that the capacity for ERTMS works of yellow fleet suppliers (which are usually smaller companies) is limited.

2.1.2 Scope of ERTMS deployment projects

The analysis is focusing on on-board deployment costs, including:

- Retrofit projects.
- Upgrade projects.

Fitment of ERTMS in new trains has not been considered in the analysis, as it is not facing the same technical issues as retrofitting and upgrade projects.

The scope includes all types of railway vehicles, except urban railway and yellow fleet vehicles, covering both freight and passenger vehicles (including HSR). Additionally, vehicles of all ages were considered.

Track-side projects have been excluded from the scope of work due to the ongoing data collection process on track-side deployment costs, which requires a separate analysis.

[11] An interviewed stakeholder mentions values from €2,5-4 million for a single vehicle.

2.1.3 Scope of costs constituents

The following split of the costs for ERTMS projects has been considered in the analysis:

- Design phase: this phase includes all the engineering activities required to deploy ERTMS in a vehicle. It is split in three sub-phases:
  - The requirement phase.
  - The ETCS on-board development / adaptation / interoperability constituent certification (including verification of CCS subsystem).
  - On-board CCS IC integration and OB engineering.
- Deployment: deployment covers the cost of the EVC (European Vital Computer) and the work required to install the EVC in the rolling stock. It is divided into two sub-phases:
  - Vehicle adaptation (including the verification of vehicle modifications).
  - Installation of CCS on-board subsystem.
- Validation activities: this final stage includes the tests, and the preparation of the documentation required for the authorisation. It is divided in two sub-phases:
  - Testing including the different phases from IC until ESC/RSC tests[12] for compatibility with trackside.
  - Documentation necessary for certification and vehicle authorisation.

This split has been used to structure the discussion with stakeholders and present the list of cost drivers in this report.

[12] ETCS- and Radio System Compatibility, more info can be found here: https://www.era.europa.eu/content/etcs-and-radio-system-compatibility-escrsc.

2.2 Methodological approach

The methodological approach of the study adopted a stepwise approach where each step built on top of the previous. It consisted of the four following steps:

1. Targeted interviews.
2. Stakeholder discussions at the ERA ERTMS conference.
3. Stakeholder workshop.
4. Stakeholder survey.

By applying a stepwise approach and a strong focus on consulting all relevant stakeholders, this study has adopted a robust approach ensuring the views of all stakeholders are included.

2.2.1 Stakeholder interviews

Two rounds of interviews were conducted: a first round focusing on collecting data on deployment costs and performance of ERTMS throughout Europe. The second round focused on identifying cost drivers of ERTMS deployment.

2.2.1.1 Stakeholder interviews - first round

The first round interviewed stakeholders on their views on the deployment and performance of ERTMS in Europe. The main focus being the collection of data on the deployment costs related to on-board deployment. A series of costs ranging from project-level costs to the cost of an ESC test were collected. The granularity of the cost data collected was heavily influenced by the ability of the stakeholder to disclose them or be in possession of the costs since some vehicle owners only receive costs at project level. A total of 22 interviews were conducted with stakeholders representing RUs, rolling stock leasing companies, regulators, IMs, suppliers and engineering companies conducting testing and authorisation. The selection of interviewees ensured optimal geographical representation across the EU.

2.2.1.2 Stakeholder interviews – second round

Based on the findings made in the first round[13], a second round of interviews were conducted focusing on understanding the reasons for the identified cost increase.

[13] See introduction.

Seven interviews were conducted with key stakeholders, who were also interviewed for the initial data collection exercise. As such, each interview acted as a follow-up to the initial interview and hence, individual interview guides were made for each interview. Where possible, statements regarding pain points and cost drivers shared during interviews were cross-checked with other interviewees.

The interviews were conducted in the presence of the DMT Economic and Technical experts. Safe for one interview, participants of the second interview were the same as in the first interview. The stakeholders were selected to represent both vehicle owners (rolling stock leasing companies and RUs) and ERTMS suppliers. Since primarily large RUs have the resources to handle ERTMS deployment themselves and receive more detailed cost breakdowns than smaller RUs and vehicle owners[14], the second round of interviews predominantly focused on large RUs. Related to this, it is important to note that finding relevant interview candidates proved to be very challenging, as there are only limited profiles in the EU rail industry with the specific expertise sought for this exercise. The DMT believes to have gathered sufficient knowledge with the 8 interviews conducted.

The interviews identified and highlighted a series of cost drivers, which are elaborated in Section 4. This selection has primarily been based on the number of times the cost driver was mentioned in the interviews, and on the qualitative description of the impact of the driver on ERTMS on-board projects.

The following deep-dive interviews were carried out for the current study:

Stakeholder[15]	Interview focus	Interview date
Supplier	Over-specification and national rules	3/11-2023
RU		17/10-2023
RU	Deployment costs for HSR and testing, authorisation and related downtime	17/10-2023
Rolling stock lessor	Interoperability	27/9-2023
Supplier	Over-specification and national rules	2/10-2023 and a follow-up on 6/11-2023.
Supplier	Over-specification, national rules and SW issues	31/10-2023
Rolling stock lessor	National differences in the required ETCS versions	12/9-2023
Rolling stock lessor	Testing and authorisation, downtime of prototype	15/11-2023

Table 1: Overview of stakeholders interviewed.

[14] The initial series of interviews indicated that some stakeholders only receive a “package deal” from suppliers and therefore are limited in identifying the specific cost components.

[15] The interviewed stakeholders have been anonymised. The European Commission is aware of the interviewed stakeholders.

2.2.2 ERA ERTMS conference

Upon completion of the interviews and subsequent analysis of the identified cost drivers, the 2024 ERA ERTMS conference was used to further discuss cost drivers and potential solutions with stakeholders. Through three sessions of a workshop titled “How to optimise cost for the ERTMS Lifecycle for Trackside and On-board?”, stakeholders identified cost drivers and potential solutions[16]. Cost drivers and solutions mentioned in the workshop are flagged in the report.

2.2.3 Stakeholder workshop

The third step consisted of a stakeholder workshop, held on October 16, 2024, with the main European railway associations involved in ERTMS deployment. The main objective was to discuss solutions to the cost drivers. The participating associations included CER, AERRL, UNISIG/UNIFE, ERFA, and EIM. Additionally, both DG MOVE and ERA attended the workshop. Prior to the workshop a draft report containing the cost drivers and solutions was shared with the participants to provide a basis for the discussion.

2.2.4 Stakeholder survey

As a follow-up to the workshop and to further quantify stakeholder feedback, a stakeholder survey was conducted. Stakeholders were asked to rank each cost driver and solutions from 1 to 5. For cost drivers, participants were asked to rank their impact on increasing deployment costs. For solutions, participants were asked to rank them in terms of a) the potential impact of a solution in reducing the cost of ERTMS deployment, and b) the cost of introducing the solution, together with its impact time. There were hereby 44 questions in total. The survey was administered using EUSurvey[17] and was open from November 27, 2024, to December 20, 2024. CER, AERRL UNISIG/UNIFE participated in the survey with one response each representing their respective members’ views (European railway supply industry, operators and infrastructure managers and rolling stock lessors).

[16] The outcomes of the workshop can be found here: Agenda ERTMS 2024 Conference | European Union Agency for Railways

[17] EUSurvey - Welcome

2.3 Definitions of key terms used

The following table provides an overview of the key terms used throughout the report and their definitions.

Term	Definition
Modularity	The application of a system approach using interoperable sub-systems (modules) that can be changed or upgraded without impacting the overall system, though a new authorisation may be required
Design phase	The stage involving procedures and tasks for designing the prototype (first-in-class)
Deployment phase	The stage involving the actual deployment and fitting of components onto vehicles
Authorisation phase	The stage involving steps and processes required to authorize ERTMS-installed vehicles for operations

Table 2: Definitions of key terms

3 Overall split of the costs

A key information sought from the interviews was the split in costs from ERTMS projects. The cost split is useful to determine which part of a deployment projects drives the costs and potentially any cost increases within these parts. Unfortunately, very limited information could be collected, for two main reasons:

- Vehicle owners have very limited information about the split of the costs, since they receive an overall quote from suppliers with limited details on the cost breakdown.
- Suppliers are not willing to share information about the split of the costs.

Moreover, comparison between different projects is rendered difficult since cost distribution will depend on the characteristics of the project[18], including:

- Size of the fleet considered.
- Number of countries in which the fleet operates.
- Characteristics of the rolling stock: based on the discussions with stakeholders, it seems that recent vehicles and old vehicles are easier to retrofit than vehicles between 15 and 20 years old. While it might sound surprising for old vehicles, this is likely due to the fact that older vehicles have fewer on-board electronics, making them easier to equip with ERTMS.

Nevertheless, selected figures on a split of the costs were tested with some interviewees, who could only confirm the accuracy of the order of magnitude.

Through this exercise, the following cost breakdown was estimated: for a fleet of 20 vehicles operating in a limited number of countries, the indicative distribution would be as follows:

Phase	Share	Costs (in M€ for 20 vehicles)	Note
Design	20-30%	€ 4,5 m	These figures can be significantly higher for a small fleet with several prototypes
Deployment	40-50%	€ 9 m	These figures can be lower if the costs for design and validation are higher
Validation/authorisation	20-30%	€ 4,5 m	These figures can be significantly higher for vehicles operating in 5-6 countries

Table 3: Split of costs per phase

As a result, a project of 20 vehicles will have an average cost of €900 k / vehicle and a total project cost of €18 M.

[18] A specific section on project specific requirements is developed in 0. This includes concrete requirement examples.

4 Cost drivers identified

This section describes the cost drivers identified through the interviews and their impact on the cost of ERTMS and its deployment. Each cost driver is associated with a specific phase and sub-phase of an ETCS on-board project, as presented in the table below:

Phase	Sub-phase	Cost driver
Design	Requirement phase (TSI, national requirements, project specific requirements)	National requirements
		Availability of documentation on national requirements
		Project specific requirements
	ETCS on-board development / adaptation/ interoperability constituents (IC) certification (including verification of CCS subsystem)	Duration of authorisation process (for IC certification and subsystem verification)
		Third party assessments (for IC certification and subsystem verification)
	On-board CCS IC integration and OB engineering	Transfer of risk associated with the vehicle types
		Availability of documentation on vehicles
Deployment	Vehicle adaptation (including verification of modifications of vehicle)	Transfer of risk associated with the vehicle types.
	Installation of CCS on-board subsystem	*No specific cost driver identified*
Authorisation	Testing including the different phases from IC until ESC/RSC tests for compatibility with trackside	Duration of authorisation process
		Lack of capacity for testing
		Third party assessments
		Compatibility tests
	Documentation necessary for certification and vehicle authorisation	Difficulty of re-using old tests and documentation

Table 4: Identified cost drivers per project phase

Moreover, there are three cost drivers which have an impact on all phases of development of an ETCS on-board project:

- Inflation and energy crisis of 2022.
- Limited competition.
- Lack of upgradeable products.

4.1 Design phase

4.1.1 Requirement phase

During the first round of interviews, the cost driver related to more and more complex harmonised functionalities in the ETCS system was identified. During the in-depth discussions with several suppliers in the second round of interviews, particular attention was given to this matter. While it is a general assertion by suppliers, upon further inquiry it became evident in at least one or two supplier interviews that additional functionalities, when standardized and not specific to a particular project, can be incorporated into the general update of the on-board roadmap. Therefore, this does not lead to a significant increase in the cost of retrofit projects. In other words, the functions that can be universally programmed for all the diverse projects do not have a big impact on the costs. As a consequence, this section only focuses on non-harmonized requirements.

4.1.1.1 National requirements

National rules have been mentioned as a cost driver in most of the interviews. Indeed, there are today many different operational rules at EU level which have an impact on train operation. National requirements such as **NR[19], authorisation rules, or design requests** are key cost drivers contributing to the current increase in costs.

This is primarily due to the growing deployment of ERTMS, which has led to an exponential increase in the variability that the ETCS on-board systems must accommodate, as vehicles are now capable of operating with ERTMS across a significantly larger number of countries. This situation contributes to a high risk of overspecification. The overspecification identified during the interviews is not related to the European specifications outlined in the CCS TSI; rather, it stems from the need to harmonize these specifications with an undefined set of numerous national requirements.

The following examples of national rules were shared by stakeholders during the interviews:

- Specific rules for authorisation in Germany, Bekanntgabe 09[20].

[19] National Rules as defined in article 2 (30) of directive (EU) 2016/797

[20] See more here:

- https://www.eba.bund.de/SharedDocs/Downloads/DE/Fahrzeuge/Fahrzeugtechnik/ZZS/31_AK_ZZS_Bekanntgabe_09.html
- Design request IG2012

- Specific national values to be used as parameters for ETCS on-board in Luxembourg [21].
- Some functionalities linked with ERTMS are optional for infrastructure managers, such as the Radio Infill Unit (RIU) and Euroloop[22]. If an infrastructure manager decides to deploy them, the corresponding on-board implementation must be adapted accordingly.
- National operational rules, which are based on the Class-B system, require ERTMS to mirror these rules. This significantly increases the technical complexity of the ETCS on-board systems for international trains. For instance, in Switzerland, operators are required to install a trackside monitoring device on the vehicle. This device monitors the condition of the tracks and alerts the infrastructure manager when maintenance is needed. The issue arises from the requirement that foreign operators must have this device installed, while some CFF trains do not have it. Additionally, there are examples of requests for the ETCS Driver Machine Interface (DMI) to reflect Class-B design, such as certain text messages in Germany.

Furthermore, notified national technical rules (NNTRs[23]), non-notified national rules, clarification notes, and other regulations can be unexpectedly updated during the course of a project, resulting in additional engineering efforts and associated costs to adapt the system to the revised set of requirements.

4.1.1.2 Availability of the documentation for national requirements

Gathering a comprehensive set of documentation for the national requirements applicable on a given project can be challenging:

- The documentation often references other national standards or documents in the national language. While only a few lines of these documents may be relevant to the ERTMS project, they are not clearly highlighted, requiring suppliers to review the entire document or standard to identify the relevant sections[24].
- As discussed in the section above on national requirements, there are sometimes some national rules which are not mandatory in theory, but if a

[21] See more here:

- https://acf.gouvernement.lu/fr/interoperabilite-securite/documents-techniques-acces-au-reseau.html
- https://acf.gouvernement.lu/dam-assets/interoperabilite-et-securite/agrement-materiel/gi-ii-stc-vf-e09.pdf

[22] For further explanation of these functionalities and others related to ERTMS, see here: Subsystems and Constituents of the ERTMS - European Commission

[23] Notified national technical rules

[24] An example of this is the "Bekanntgabe 09 – AK ZZS, Ausgabe 6.0a" in Germany.

project is not compliant with them, it will never get the authorisation to operate in the country where these national rules apply. These national requirements are linked with the Class B system, the associated documentation is not always fully available since it is owned by the initial supplier of the system.

- The documentation is in the national language, yet ERTMS operates in a European market and the working language of the engineers is English, which creates additional translation costs — and the risk of misunderstandings — that are passed on to suppliers.

This cost driver does not have the same impact on all projects: large vehicle owners will have more resources to collect and prepare the right set of documentation, whereas smaller vehicle owners, who often sub-contract the project management of the projects, face considerable barriers when searching for documentation and specific requirements and subsequently translating it.

4.1.1.3 Project specific requirements

Stakeholders frequently highlight that project-specific requirements[25] imposed by clients on on-board ETCS systems significantly increase costs. These bespoke demands often exceed standard specifications, necessitating customized solutions that increase complexity and development time

Below are some illustrative examples of project-specific ETCS on-board requirements that contribute to these challenges:

- **National ATP Specific Functions**: Additional requirements include interfacing with three safe outputs for controlling response times and intervals of the vigilance control operator during fully supervised ETCS modes. These functions are tailored to national regulations, further increasing complexity.
- **Cybersecurity Requirements:** Cybersecurity demands are becoming increasingly prominent, though not yet fully codified in Technical Specifications for Interoperability (TSIs). Many clients require advanced and diverse cybersecurity features, which often deviate from the standardized ETCS requirements.
- **Pantograph Control for De-Energized Areas:** Some specifications require that the ETCS on-board equipment automatically lowers the pantograph 10 seconds before entering a de-energized area. This fallback functionality is not part of standard specifications, necessitating bespoke implementation.
- **Door Opening Variants:** Diverse functionalities related to door opening, especially at station stops, are frequently mandated. These vary

[25] UNIFE reports between 150-1500 requirements per project.

significantly between projects and require dedicated configuration and programming.

4.1.2 ETCS on-board development / adaptation / Interoperability constituent certification

The certification of interoperability constituents and the verification of subsystems are going through an authorisation process facing similar difficulties as the integration of ETCS in the vehicle. Therefore, the cost drivers “Duration of authorisation process” and “Third party assessments” described in the §4.3.1 below can also have an impact on the cost of certification of interoperability constituent and the cost of subsystems verification.

4.1.3 On-board CCS Interoperability constituent integration and on-board engineering

4.1.3.1 Transfer of the risk on the uncertainty on the number of types within the fleet

Currently, there is no clear definition of the technical parameters defining an ERTMS prototype. Therefore, within a given fleet assumed to be of the same type, there might be small differences between vehicles which require a different design. This may also lead to a new authorisation process for a vehicle. Stakeholders quoted several examples of this issue:

- For the same series of a given vehicle, if a first vehicle has been bought in a given year, and a new one 5 years later, small changes might have been made to the vehicle. These changes can lead to different variants, which might result in the need of a new prototype. The vehicles must be analysed in detail to detect the potential impact on ETCS deployment: small changes of the wiring in the cab leading to “ghost failures”, different refresh rates for power supply, etc.
- A supplier produced the first vehicle of a theoretically homogeneous fleet and then began serial deployment. However, after the delivery of the first five vehicles, one vehicle was found to have a cubicle installed in the space designated for some ETCS components. As the client opted not to relocate or remove the cubicle, the supplier had to find alternative ways to deploy ETCS on-board. This new design required additional engineering work, which, due to the existing contract, had to be covered by the supplier.

A specific set of technical characteristics could standardise a vehicle type, allowing vehicles from various fleets or countries to share the cost of integrating ERTMS into the vehicle (as initial engineering and development costs could be shared with multiple vehicle owners). Stakeholders such as DB have already

begun this process, considering it critical for their retrofit program. It has been acknowledged that support for this process at the European level would be highly valuable. The initial step would involve identifying the technical criteria, followed by categorising the different fleets into a series of prototypes. The following issues should be noted in this regard:

- These criteria might be strongly impacted by the characteristics of the products, which are not harmonised today (e.g. size of the components or electrical characteristics). Therefore, support from the suppliers to achieve this goal is indispensable.
- The costs and risks for the suppliers will only be reduced if there is a horizontal approach to prototypes (limit the number of prototypes and only pay once for the prototype of a given type) versus an approach of integration exclusively project by project (large number of prototypes, risk of replicating the work).

Moreover, integration of ERTMS and ATO into the vehicle increases the amount of cost estimation to cover risks. Some of the reasons mentioned by the stakeholders are:

- The need to interact with the train SW (Train Control and Monitoring System (TCMS) for which only supplier or OEM has the information).
- Even when vehicle suppliers are expected to contribute with the information on the train interface, this is not realised with the necessary details.

This risk is not addressed today during the tendering process. Suppliers usually have access to only one vehicle of a given type during the tendering process. This is due to the fact that it is not possible to take the entire fleet out of service. Moreover, the documentation available (when present) is not comprehensive, and some past modifications might not be traced.

Therefore, an important risk, not properly mitigated, is currently transferred to the suppliers, who are taking provisions for this risk. These provisions are reflected in their final price to the customer.

Of course, this cost driver is not applicable to all situations, as there will be some retrofitting projects with high integration costs, not due to the uncertainty on the vehicles to be equipped, but due to the current architecture of the vehicle and its CCS.

This cost driver does not aim to understand a 'one size fits all' approach, but rather to be capable of identifying the aspects that differentiate one prototype from another from a technical perspective.

4.1.3.2 Availability of the documentation on the vehicles

Suppliers mentioned the documentation prepared by vehicle owners for the call for tender as an issue.

This documentation is necessary to realise the integration of ETCS on-board, but it is often incomplete. There can be multiple reasons behind this:

- The documentation has not been stored properly by the vehicle owner.
- The documentation has not been fully delivered by the initial supplier.
- The vehicle has been sold several times, and the documentation has been lost during transfers.

Partial documentation will lead to extra engineering work to gather or estimate missing information, leading to extra costs.

Vehicle owners are also voicing dissatisfaction, as the technical evaluation produced during authorisation of the ERTMS products and the technical information of the ERTMS system is not always delivered by the suppliers. This will increase the likelihood of this cost driver impacting the future, significantly affecting the systems' upgradeability and, in some cases, obstructing the operation of retrofitted ETCS systems.

4.2 Deployment phase

4.2.1 Vehicle adaptation (including verification of modifications of vehicle)

4.2.1.1 Transfer of the risk on the uncertainty on number of vehicle types within the fleet

This cost driver is already described in §4.1.3.1, but it is also affecting the deployment phase.

4.3 Authorisation phase

Overall, the authorisation process is seen as very complex by the sector: it has been identified as an important cost driver during interviews and the 2024 ERA ERTMS conference.

4.3.1 Testing including the different phases from IC until ESC/RSC tests for compatibility with trackside

4.3.1.1 Duration of the process

The duration of the overall authorisation process, which can take up to three to four years on some projects, is seen as an important opportunity cost, as the prototype will be out of service for this duration. This time out of service, also quoted during the 2024 ERA ERTMS conference, represents an important loss of revenues for fleet owners. Moreover, any difficulty encountered in the process might lead to significant delays in the project, due to the lack of tracks for testing (see below). Identifying an issue at a late stage can also have a big impact in the project since there is a need to repeat (at least part of) the verification and validation process (testing and documentation).

It should also be pointed out that the European authorisation for placing on the market is not the only driver of this lengthy process: participants to the 2024 ERA ERTMS conference also quoted the “national rules of the authorisation” still required to operate with a train equipped with ERTMS (due to the fact that the vehicles are still equipped with Class B system).

4.3.1.2 Lack of tracks / capacity for testing

Part of the increase in cost at the authorisation stage is related to the required testing. According to some stakeholders, the cost increase mainly pertains to the high demand for test tracks and laboratories, which often are unavailable. As a result, any delays in the project that cause it to miss its scheduled test slot will lead to further setbacks, as test tracks often have a waiting time of up to six months.

4.3.1.3 Third party assessments

Third party assessments are mentioned as a cost driver by most of the stakeholders. The main reasons are the following:

- The limited number of assessors recognised by some NSAs to conduct assessments in accordance with national legislation, coupled with the strict

interpretation of national rules. Although this legislation is not directly related to ETCS, it complicates and increases the cost of obtaining authorisation. For example, in some countries, different configurations of ERTMS-equipped trains must be assessed separately. Even factors such as the length of a train, which is considered configuration data in ETCS, can require different authorisation processes for the same type of train with varying compositions.

- Re-evaluation by a safety authority of the documentation provided by a certified body (NoBo or DeBo). If there are issues with the quality of the certified body's work, these should be addressed through the monitoring of the body, rather than by systematically challenging the documentation provided by the body for the application.

4.3.1.4 Compatibility tests

The amount of compatibility tests is increasing mainly due to the fact that there are more lines equipped and also there is a lack of harmonisation in the different lines being placed in service. For that reason, there are countries with more than one ESC/RSC type where tests have to be made in different lines of the network. There are other networks where even if it is a unique ESC/RSC type the number of tests is extensive. There is also a high demand for both laboratory testing and testing on the tracks themselves. It has been reported that the demand for track testing, in particular, can drive up project costs. Due to this high demand, tracks are booked well in advance, meaning that any unforeseen project delays can lead to significant postponements in deployment. This leads to higher downtime and consequently opportunity costs. Since tests are very expensive (in a range of €100-500k / test), vehicles owners are incurring considerable extra costs with the increase in testing. It has been reported that, in theory, almost all tests could be conducted in labs.

After having acquired rolling stock, which is fully compliant with the applicable TSIs rolling, stock owners indicate they have to take the initiative in contacting IMs in order to demonstrate the compatibility of the vehicle with the line in question.

4.3.2 Documentation necessary for certification and vehicle authorisation

4.3.2.1 The difficulty to re-use existing tests / documentation

As explained before, very small variations within a vehicle can lead to the need to have a new prototype. In this case, all the tests and all the documentation have to be re-started for the new prototype and only a small part of the work can be re-used. This leads to extra costs, which are provisioned by suppliers due to the transfer of the risk on the vehicle type by vehicle owners.

Moreover, as of today, an ETCS project consists in the integration of several Interoperability Constituents (IC) within the vehicle. The IC have certificates, obtained from NoBos. But in the current authorisation process, the applicant must demonstrate that the IC have been integrated properly in the vehicle. In the documentation associated with integration of ICs in the vehicle, there are a lot of similarities from one project to another. But all the documentation must be produced by NoBos for each project, and then all the documentation has to be reviewed by ERA. This is a time-consuming process and might become a bottleneck in the near future with the retrofitting of more vehicles associated with large upgrades project (like the one anticipated with FRMCS).

4.4 Cost drivers affecting all the phases of the project

4.4.1 Lack of competition

There are a handful of suppliers present in the market for ERTMS on-board solutions in Europe (Hitachi, Alstom, Siemens, CAF, Stadler, the Signaling Company, …). However, competition specifically in this regard is under pressure for several reasons. First, the high complexity of the ERTMS system results in not many companies having the scale to support the development of such system. Suppliers note that this complexity results from a complex regulatory and authorisation environment. This introduces risks not all companies are willing (or have the scale) to take. Second, since the merger of Alstom with Bombardier, the number of ERTMS suppliers has decreased.

Furthermore, although in theory any supplier should be able to equip a fleet with ERTMS, in practice, in most of the cases, only the original rolling stock supplier is capable of installing the system on board. Indeed, the integration of ETCS in the overall control command system requires a deep knowledge of the vehicle itself, and the documentation available is not always sufficient for an alternative supplier to make an offer – and even if it was, the time required to understand the system and how to integrate ETCS into it would be prohibitive. Moreover, in order to install ETCS on-board, a supplier also needs to interact with the train software: the support of the supplier of the TCMS has to be requested during the project.

Therefore, there is a vendor locked-in situation on the market: vehicle owners cannot receive multiple quotes for their projects. This is even more visible in vehicles with complex TCMS. This issue has been raised multiple times by vehicle owners during interviews and during the 2024 ERA ERTMS conference.

Finally, there is also a question on the profitability of such projects for suppliers. ETCS projects are indeed using a lot of engineering capacity for a limited turnover in the end compared to other projects, such as new trains or new metro network (which also requires signalling engineers).

4.4.2 Impact of inflation

Due to Russia's war of aggression against Ukraine, inflation has been strong in Europe in 2022-2023. Since 2016, prices have increased by 27% in the EU, as shown in the figure below:

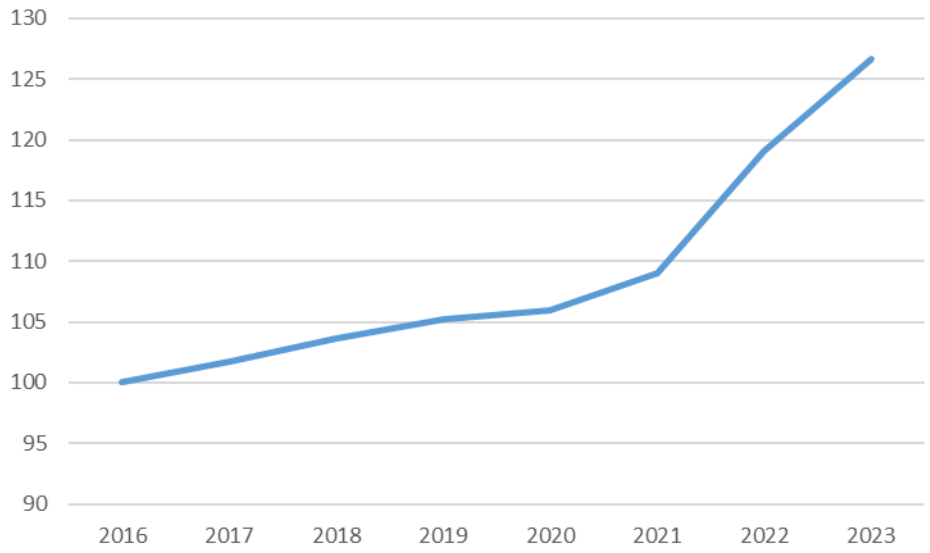

Figure 4: EU inflation (2016-2023)

Inflation has an impact on all phases of an ETCS on-board project:

- Inflation leads to an increase in salary costs[26], in all sectors of the economy. This has an impact on all engineering activities, in the design phase but also in the authorisation phase.
- Inflation also impacts on the components used to deploy ETCS on-board (EVC, cables, …) leading to an increase of the cost of ETCS on-board.

It should however be highlighted that inflation alone cannot explain overall increase of the costs, as the price increase (+15% between 2018 and 2022) is significantly lower than the increase of the retrofit and upgrade costs.

4.4.3 Lack of upgradeable products

In most discussions – including during the workshop in the 2024 ERA ERTMS conference – the instability of the specifications has been put forward as a significant cost driver. There are two types of changes in the ERTMS specifications: error corrections and enhancements.

[26] Eurostat (2024), *Annual increase in labour costs.* Retrieved from: https://ec.europa.eu/eurostat/web/products-euro-indicators/w/3-16092024-bp

On **error correction**, even if the process on this topic in the TSI was a very conflictive point, a significant number of stakeholders, when requested examples, mentioned new functionalities like FRMCS or enhancements rather than maintenance of specifications through error correction as a cost driver.

On SW changes, it cannot be concluded from the interviews that they are responsible for the recent cost increase, as most cases, SW updates were planned and not due to identified errors in the specifications.

On the enhancements of the system, interview feedback suggests that current products are heavily influenced by any requested changes. Indeed, in the current architecture, the EVC is deeply intertwined with other parts of the vehicles. Therefore, upgrading from a system version to another one can have an impact on other components.

In any case, the difficulties and therefore costs increase due to the need to upgrade and evolve the products are one of the main cost drivers of the increase in the ERTMS cost.

In some projects, the complexity of updates is referring to the dependency of the ETCS on-board IC SW to the specific product integration in the vehicle. The issue of the complexity of the system has also been raised during the 2024 ERA ERTMS conference, where participants quoted the interface between ETCS and the Class B system as a strong cost driver. This means that vehicles owners have two options:

- Asking for an update of a single error correction in the SW, and they will have to pay the full price for it.
- Taking the new SW version developed by the supplier for their product according to their roadmap. In this case, there will be a higher risk of a need for a complete retesting and authorisation of the system due to the impact of changes in the Interoperability constituent core SW as regards to the integration in the specific vehicle - including the need for a revision of the constraints due to limitations of the vehicle.

Difficulty in upgradeability is not only visible in the development and integration stages. It also has a great impact in the costs associated to authorisation stages. When a stakeholder is not the owner of the type, any update in the vehicle implies higher costs for the documentation for authorisation due to the need to get the support for the change of the type owner.

4.5 Other issues raised

Most of the messages from the different stakeholders are aligned when it comes to the identification of key cost drivers for the ETCS on-board projects. But some of the issues either could not be confirmed through several interviews or are not cost drivers per se. For instance, the lack of stability of the specification has been quoted several times as an important problem for vehicle owners, as it generates extra costs to update the system according to the latest version available. This issue has already been identified in the "ERTMS business case on the 9 core network corridors"[27], and one of the main pillars of the "Breakthrough Program" of the Work Plan of the European Coordinator Karel Vinck published in 2014 was to get a stable product.

Yet, unfortunately, it seems that some stakeholders are still asking for some additional functionalities for ERTMS, whereas others would like to have a more stable system. These contradictory views show the importance to develop a common roadmap of specification evolution at EU level, which is currently carried out by the Europe's Rail Joint Undertaking System Pillar (see §6.1.2.2 below). The lack of stability of the specifications mainly reflects the problem of the lack of upgradeability of the product: as already explained in §4.4.3 any change in the specifications leads to an important change in the system on-board due to its current architecture.

Moreover, some interviewees also quoted the verification of the conformity to type (CTT) as a problem, but as it was not systematic, it is not possible to assert that there is a problem with the process.

The Association of European Rail Leasing Companies (AERLL) has also highlighted other critical issues contributing to the high costs associated with on-board deployment:

- The complexity stemming from varying baselines and infrastructure-side variants complicates compatibility and increases adaptation expenses.
- The absence of a standardised vehicle gateway (i.e. ETCS-vehicle interface) and the necessity of involving legacy OEMs add further technical and procedural challenges.
- The lack of comprehensive cost-benefit analyses underpinning the adoption of TSIs results in mandatory upgrades without sufficient economic justification.

It should be noted that the latest interviews were conducted during the period from September to November 2023. Recent changes to the specifications and CCS TSI are expected to have a positive impact by reducing the impact of cost

[27] European Commission: Directorate-General for Mobility and Transport, (2019). *ERTMS business case on the 9 core network corridors – Second release*, retrieved from https://data.europa.eu/doi/10.2832/813655

drivers. However, this effect is not yet observed due to the lack of experience with the specifications or the new regulatory processes.

5 The main cost drivers

As indicated earlier in the report, a survey with the sector (AERRL, CER, UNISIG) has been carried out in order to rank cost drivers. The results are presented in the table below:

Main cost driver	Section reference	Average Score[28]
Lack of upgradeable products	Section 4.4.3	4,67
National requirements	Section 4.1.1.1	4,33
Duration of the process	Section 4.3.1.1	4,33
Project specific requirements	Section 4.1.1.3	4,33
Compatibility tests	Section 4.3.1.4	4,00
Availability of the documentation for national requirements	Section 4.1.1.2	3,67
Third party assessments	Section 4.3.1.3	3,67
The difficulty to re-use existing tests / documentation	Section 4.3.2.1	3,67
Lack of competition	Section 4.4.1	3,67
Lack of tracks / capacity for testing	Section 4.3.1.2	3,00
Impact of inflation	Section 4.4.2	2,33
Transfer of the risk on the uncertainty on the number of types within the fleet	Section 4.1.3.1	2,00

Table 5: Main cost drivers identified

[28] This column represents the average response score from survey respondents (UNIFE, CER, and AERRL) regarding the impact of various cost drivers on the overall costs of ERTMS deployment. The scores range from 1 (lowest impact) to 5 (highest impact). The full survey data is provided in

Annex 2 – Stakeholder Survey Results

6 Proposed solutions to mitigate the cost increase

This section focuses on proposing solutions to address the cost drivers delineated above[29].

The solutions have been proposed by the Deployment Management Team, based on:

- Its own expertise on ERTMS.
- Propositions received during interviews.
- Follow-up discussions with the European Commission and ERA.

These solutions were repeatedly refined and validated with industry stakeholders. This process included a presentation at the ERA ERTMS conference, further discussion at a dedicated stakeholder workshop, and final validation through a stakeholder survey, as detailed in Section 2.

The main body of this section is structured around the following three sub-sections:

- Solutions with a strong impact;
- Solutions with medium impact;
- Solutions with moderate impact.

This structure is based on the stakeholder survey (in the annex). As for the selection of the main cost drivers, the solutions were ranked in terms of their potential impact on reducing the costs of ERTMS deployment as perceived by the sector stakeholders, with one exception: the solution for defining ERTMS parameters for a vehicle type that is considered to have a significant impact on the number of prototypes in Europe and their identification by the DMT.

Further to this initial division, sections are further structured according to the timing of their effects. In the last updates of the legislation, several changes have been introduced which can mitigate some of the cost drivers identified. Some of these have already been implemented, while others would need to be set up. As regards to solutions already implemented, part of the impact of these mitigations are still not visible since the products following the updated specifications are not in operation yet or the procedures introduced have only been implemented for a short period of time.

It has to be noted that not all of the cost drivers have solutions proposed to counter their effect. This is specially the case with section 4.5 above regarding other issues which could not be confirmed through several interviews. Moreover,

[29] These solutions align with the ones of the ETCS Retrofit Projects - UNIFE Action Plan.

some solutions quoted during the 2024 ERA ERTMS conference have not been kept, as they were too generic to be detailed properly (managing digital improvements on the system).

The matrix below[30] provides an overview of the solutions proposed in this report and the main cost drivers they target. The solutions and how they target cost drivers are explained in further detail in the sub-sections below.

[30] It has to be noted that not all cost drivers identified are mentioned in this matrix. The Ukraine war and inflation crisis is mentioned as a cost driver, however, it's beyond this report to suggest solutions to this and hence not included.

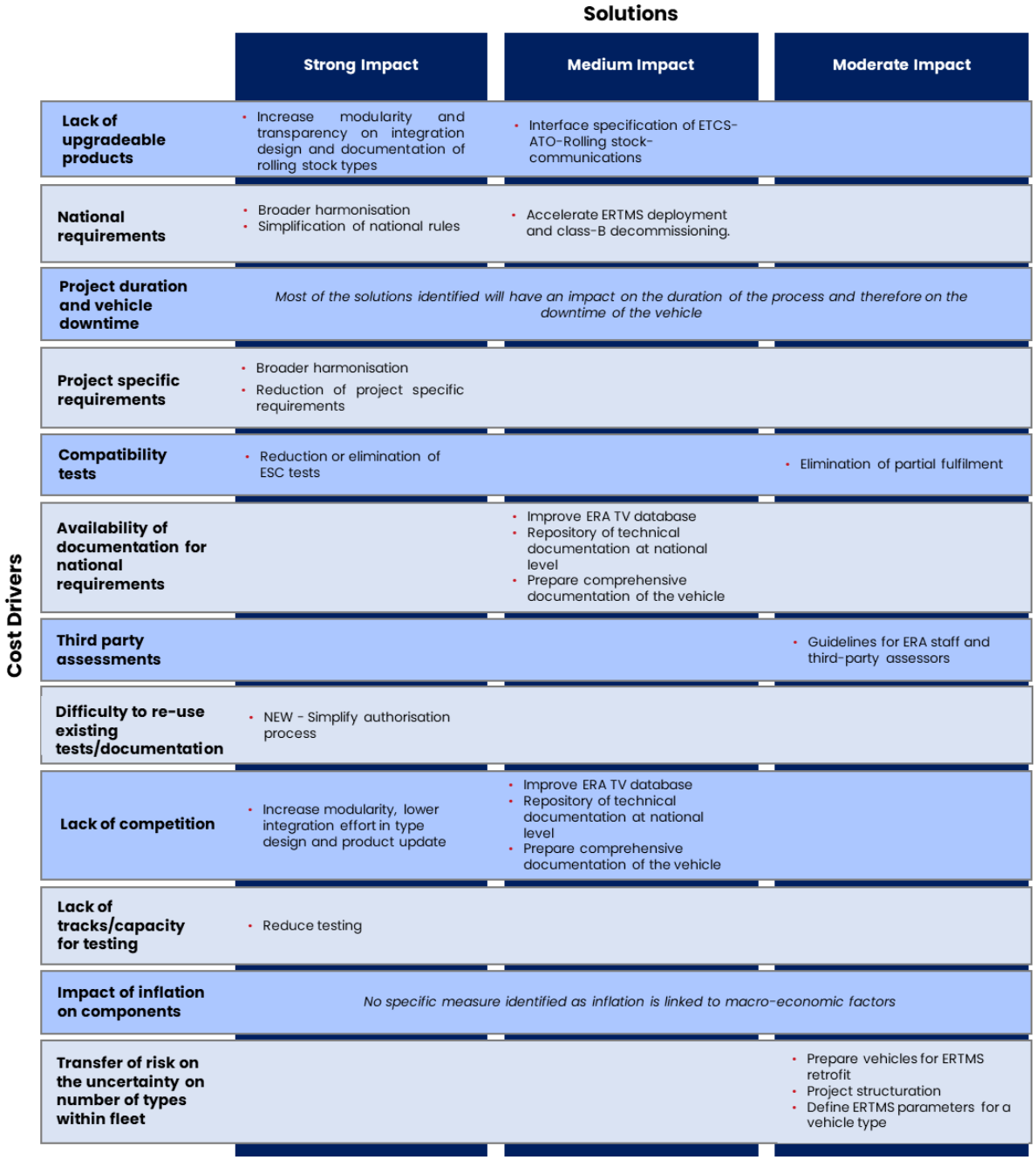

Figure 5: Solutions matrix[31]

[31] A new solution called “simplification of authorization process” has been introduced, based on the comments received on the report and during the workshop, and further consultations with ERA. This solution is expected to have a high impact.

6.1 Solutions with strong impact

6.1.1 Short term solutions

6.1.1.1 Reduction or elimination of ESC tests

Reducing testing activities is a clear request from the sector expressed during the 2024 ERA ERTMS conference.

Besides simplifying testing through harmonisation, it is valuable to explore additional potential for reducing testing, especially during later stages of the project where detected failures have the most significant impact. One proposed mitigation measure is to analyse not just test design or types but also testing results. Numerical and probabilistic analyses of test outcomes could enhance confidence in certain tests, potentially obviating the need to conduct them altogether.

There is an ERA topical workgroup in order to analyse specific actions to reduce testing as a result from the ERA report on ESC/ RSC phasing out ("TSI CCS (EU) 2023/1695 Article 12, ERTMS compatibility and future revision"[32]).

Responsible: ERA, sector

6.1.2 Medium term solutions

6.1.2.1 Increase modularity to lower integration effort in type design and product update

The CCS TSI 2023 already includes a step forward towards achieving a modular on-board architecture. **Many participants to the 2024 ERA ERTMS conference were also asking for more modularity in the system.**

However, moving towards a more modular architecture and at the optimal level of granularity must be analysed from a technical and economical point of view. Developing a modular architecture with normalised interfaces will indeed generate extra costs in the short term but is expected to lead to a price decrease of future upgrades.

[32] ERA (2023) *TSI CCS (EU) 2023/1695 Article 12, ERTMS compatibility and future revision* Retrieved from: https://www.era.europa.eu/sites/default/files/2024-12/2024-rep-art.12_ccs_tsi_v2.0_0.pdf?t=1736334423

Introducing modularity does not immediately allow for interchangeability of modules, but it provides a sufficient definition of the interfaces to allow different suppliers to build the systems with reasonable effort of integration.

There are still some elements of this broader modularity that need to be defined:

1. To address the issue of limited competition in ETCS retrofit projects, it is crucial to pinpoint the essential interface specifications and determine how they affect the potential need for product modifications during integration with other systems. This aspect closely ties to the necessity of defining ERTMS parameters for specific vehicle types.
2. To address the issue of limited upgradeability, it is essential to determine the optimal level of granularity for both hardware (HW) platforms and software (SW) components. Developing a more modular software architecture would streamline upgrades by reducing the scope of software that needs updating, although it may increase integration complexity. Additionally, defining which functions of the CCS on-board systems can be managed through data or parameterisation would facilitate easier implementation of changes. Identifying elements that hinder obtaining a generic certificate for products, enabling modular integration at the subsystem level rather than project-specific integration, is crucial. Despite provisions in the current CCS TSI to avoid impacting certification or authorisation procedures for SW updates due to error corrections, this hasn't been effectively implemented in projects. It is necessary to explore reasons for this discrepancy across various retrofit projects.
3. The means to achieve a lean SW update of digital systems installed in the rolling stock need to be defined. The identification of which changes can be done without HW updates will be beneficial.

Allocating public money to the development of standardised interfaces on new and existing vehicles to secure future upgrades with more competition between ETCS providers should therefore be considered as a priority for the sector.

Responsible: Europe's Rail Joint Undertaking

6.1.2.2 Broader harmonisation

ERTMS is characterised by both flexibility and complexity. Given its current deployment and the increasing number of retrofit projects spanning different networks, national-specific requirements contribute to an exponential overspecification. Furthermore, the system's flexibility and complexity pose difficulties in conducting comprehensive testing, leading to a heightened demand for various ESC/RSC types and a greater number of test cases per compatibility campaign.

Achieving broader harmonisation, particularly in operational processes, signalling concepts, and ERTMS trackside engineering, could simplify the system. However, it is essential to establish a realistic target for the level of detail required for such harmonization. What level of detail in harmonised processes is necessary to reduce national overspecification? Similarly, what level of detail in engineering rules is needed to facilitate minimal compatibility testing between trackside and on-board systems?

ERA has launched an action to identify if further harmonisation of ERTMS deployments can be added to the TSI application guide and there is an ongoing technical working group to achieve this. In addition, Europe's Rail Joint Undertaking System Pillar supports a coherent and coordinated approach to the evolution of the rail system with a specific focus, among other, on the control-command and signalling subsystem. The System Pillar system view is expressed in the Standardisation and TSI (Technical Specifications for Interoperability) Input Plan. It is then followed up by the development of input to selected standards and technical specifications for interoperability for the command, control and signalling subsystem.

Responsible: ERA, Europe's Rail Joint Undertaking

6.1.2.2.1 Define ERTMS parameters for a vehicle type

The latest TSI has introduced new subsets to delineate the interface between rolling stock and the CCS on-board subsystem. However, the influence of these specifications on retrofit projects remains unclear. Additionally, certain technical parameters that could affect vehicle types appear unrelated to the technical interface. Examples include the space required for equipment installation and the vehicle's electrical configuration.

Reducing uncertainty in tenders regarding the number of required vehicle types for a given fleet could be achieved by establishing a list of technical parameters for consideration in this decision-making process. Such a technical list would also mitigate the risk of identifying technical disparities within the fleet after retrofitting has commenced and design work is complete. Instances of late identification of minor differences that necessitate new type designs have significant cost implications for projects.

Responsible: ERA with sector

6.1.2.2.2 Strengthening of simplification of national rules

The process of streamlining the National Rules[33] (NR) undertaken by ERA has reduced the number of NRs required for vehicles entering various networks. This effort has also enabled suppliers and Railway Undertakings (RUs) to access NR

[33] National Rules as defined in article 2 (30) of directive (EU) 2016/797

information in a unified manner, eliminating the significant cost burden associated with identifying current NRs for retrofit projects.

However, as explained above, it is important to note that NRs are not the sole regulations governing ERTMS on-board equipment in each country. There are also national rules pertaining to authorisation and, in some cases, design guidelines that effectively serve as requirements for retrofit projects.

A similar clean-up exercise, akin to the one conducted for NRs, could be carried out for these additional rules governing authorisation, design guidelines and testing procedures. It was requested during the 2024 ERA ERTMS conference and would facilitate a simpler and more transparent approach to accessing and identifying relevant information, with the added benefit of unifying these rules in the English language.

Such mitigation measures would reduce risks associated with unexpected changes in national rules during later stages of retrofit project development, which could otherwise incur significant costs.

Responsible: ERA, NSA

6.1.2.2.3 Reduction of project specific requirements

Reducing the project-specific requirements in on-board ETCS projects can lead to significant cost savings and efficiency improvements. A study conducted by UNIFE[34] highlighted that many projects include specific requirements set by operators, which are often unrelated to ETCS itself. These operator-specific requirements frequently hinder the reusability of designed solutions, even when applied to the same type of vehicle operated by a different operator. As a result, additional engineering activities are often required to tailor the system to each operator's unique specifications. This lack of standardisation increases complexity and costs, which could otherwise be avoided.

By minimising the use of such project-specific requirements, operators can enhance the interoperability and scalability of their systems, allowing solutions to be easily transferred and adapted across different fleets or regions. This approach aligns well with an emphasis on standardising operational procedures at the operator level, rather than relying on custom technical adaptations. Standardizing operational procedures can streamline project execution, reduce variability, and further support the cost-effective deployment of ETCS solutions across a broader range of vehicles and operators.

Responsible: MS, NSA, project sponsors

[34] UNIFE (2020). *ETCS Retrofit Projects - UNIFE Action Plan*

6.1.2.3 Simplify authorisation process

In order to enhance the effectiveness of prototype work, the authorisation process must be re-evaluated to facilitate easier retrofitting of projects with reduced variation according to the prototype, while also delineating the associated responsibilities. The main challenge expressed by the sector is the following:

> *The retrofit of trains, requiring authorisation from the RS supplier for ERTMS installation, introduces an additional stakeholder and costs, as the current process holds the requester responsible for the entire design authority of the train, prompting the need for regulatory changes to limit responsibility to the modified parts in case of vehicle modification.*

ERA is currently undertaking an initiative to assess ERTMS as an interoperability component and to streamline the verification process of the subsystem.

Moreover, the opportunity to develop a generic integration assessment template, valid for a category of vehicles (to be defined by the sector) going beyond the vehicle type, should also be explored. Applicants would only have to identify gaps against this generic integration assessment template, and assessors would only have to review gaps against the “default assessment template”, saving a lot of time for applicants, Notified Bodies and ERA.

Finally, a clear definition of the changes that do not require a new authorisation could be envisaged. Once an agreement would be reached between EC, ERA and the sector, a modification of the legal framework (article 15 b of Regulation (EU) 2018/545) would be required.

Responsible: ERA, DMT with sector

6.2 Solutions with medium impact

6.2.1 Solutions implemented in the current legislation

6.2.1.1 Interface specification of ETCS-ATO-Rolling stock-communications

In the 2023 CCS TSI, several technical specifications were introduced related to increasing the modularity, hence interface specifications in the vehicles. These technical specifications can be part of the mitigation measures for the lack of competition and the transfer of the risk on the number of prototypes.

Achieving modularity would partially mitigate the risk of lack of competition since it would be easier for suppliers to participate in tenders for specific modules. In

addition, it contributes to mitigate the transfer of risk of different prototypes due to the specification of interface towards the rolling stock. Even if the specification of this interface does not cover the full risk of different prototypes, it will cover part of this integration challenge.

This mitigation is still not visible in the market since there are no products with these interfaces in commercial service. Also, additional harmonisation to subset 119/139 is being already part of technical work the sector is currently carrying out, e.g. completion with subset 147.

Because the modularity requirements are only mandatory for newly built vehicles, the DMT expects this measure to only decrease costs for retrofit projects where the train interface is made compliant to the CCS TSI standard.

Consequently, this solution will help only with future upgradability of projects or vehicles not yet built.

6.2.1.2 Error correction process

The error correction process introduced in the latest CCS TSI creates transparency for the information of detected errors affecting interoperability in the specifications. It is expected that this process will contribute to the mitigation of the risks associated to the compatibility between trackside and on-board CCS systems as well as with the risks associated with the lack of broad ETCS harmonisation.

The requirements included in the technical specifications for interoperability are defined to allow for ERTMS trackside and on-board systems to interface. Errors detected in these specifications can therefore hinder this interoperability.

The latest CCS TSI introduces obligations for all stakeholders to analyse the trackside and on-board systems to identify whether such errors in the specifications create scenarios which would not allow for commercial service of their integration. These checks can be done with documentation check instead of the need of compatibility testing.

Also, the process allows for such changes to be realised in the products without the need of authorisation of the SW update which is expected to decrease the cost of this upgrade. This mitigation is still not visible in the market since the process has not been applied yet.

6.2.2 Short term solutions

6.2.2.1 Improve project management

6.2.2.1.1 Improve ERA TV database

The ERA is already maintaining the ERATV, a database established according to Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community and Commission Implementing Decision 2011/665/EU of 4 October 2011 on the European register of authorised types of railway vehicles. This database is collecting all types of railway vehicle authorised by ERA or the Member States.

But unfortunately, ERATV is not comprehensive as ERA is only responsible of the authorisation delivered for ERTMS retrofitting and upgrade projects since the 4th Railway Package, and because it is not mandatory to go through ERA to ask for a vehicle authorisation. Therefore, there is not a complete list of all vehicle types available in Europe.

Moreover, exploring the ERATV database is not always easy, as the extract which can be downloaded does not contain all the information related to ETCS on-board. Finally, the ERATV database is not complete: for instance, the system version of ETCS deployed on a vehicle is not specified, as the authorisation only refers to a set of specification (set_1, set_2, set_3) which can cover several system versions of ETCS.

As the European Union has already been financing the retrofitting and upgrade of more than 2 348 vehicles[35], the EU is in a unique position to collect, translate and share all the information publicly available on ERTMS prototypes throughout Europe. Completing and improving the accessibility of ERATV would make it possible:

- For a vehicle owner to check if a prototype of the same series has already been authorized at EU level.
- For a supplier to have access to some technical information.

The impact of this action is expected to increase dramatically once the ERTMS parameters for a vehicle type will be defined (see §6.1.2.2.1).

Responsible: ERA

[35] ERTMS Work Plan – Second Edition - 2022

6.2.2.1.2 Develop, share and maintain a repository of the technical documentation required to develop and authorize an ERTMS project at national level

As explained before, the National 'technical' rules as currently available in the reference document database (RDD) are not the sole regulations governing ERTMS on-board equipment in each country. There are also additional National Rules[36] pertaining to authorisation and, in some cases, design guidelines that effectively serve as requirements for retrofit projects. Identifying these rules without extensive experience in each country has been identified as a major cost driver.

Developing a repository with all this information would dramatically help the project team and save time. This repository would have to compile the whole documentation and:

- Be translated into English.
- Extract the relevant part of the national norms for ERTMS projects.

This action would also be a first step towards a larger effort to simplify national rules (see §6.1.2.2.2), and will facilitate the work of applicant during the "requirements capture" phase of the project. A change in article 13 of regulation 2018/545 on "requirements capture" might also be required.

Responsible: EU & ERA for requirements capture, Member States / NSA

6.2.2.1.3 Prepare comprehensive documentation of the vehicle

Retrofit activity is in its core a system integration activity. In order to integrate systems, there is a need to have access to a minimum set of technical characteristics of each of them that allow the integration. This statement is not a reality in many of the retrofit projects.

For assets with long life-cycle times, effort needs to be deployed to keep an up-to-date comprehensive documentation of the rolling stock and the modifications that have been realised within the different vehicles of each type. This documentation should be made available preferably in English to facilitate its use by integrators. The documentation that is relevant in a vehicle is not only the one related to the rolling stock. The ERTMS systems that would be installed need to be completely documented (incl. information on the interface and complete technical file for the authorisation) and these files transferred to the owner of the vehicle.

[36] National Rules as defined in article 2 (30) of directive (EU) 2016/797

Having a complete documentation of the vehicle is not only relevant for the technical integration of the systems, but it is also necessary in case of the need for a new authorisation. This is due to the fact that all changes made to the vehicle, even if unrelated to ERTMS, will be evaluated and not only the latest integration of the ERTMS which initially triggers the authorisation. As a result, the scope of the authorisation could increase unexpectedly resulting in higher costs.

Despite the fact that this mitigation can be achieved within the current regulatory framework and in any ongoing projects, there are some caveats related to this solution:

- The technical parameters of the rolling stock that could impact the integration with ERTMS systems have not been formally identified. Therefore, this action will only be fully effective once the ERTMS parameters for a vehicle type will be defined (see proposition in §6.1.2.2.1).
- The transfer of documentation becomes more complex due to the change in rolling stocks' ownership among various stakeholders at different times. Implementing configuration management systems equipped with modern digital tools would be beneficial in managing these activities.

Responsible: vehicle owner and suppliers

6.2.2.1.4 Prepare vehicles for ERTMS retrofit

The transfer of the risk from the vehicle owners as regards the ERTMS interfaces and necessary integration activities is one of the main drivers identified in the analysis of cost increase in the last years. Lack of competition in many of the retrofit projects is due to the risks ERTMS suppliers estimate for the preparation of the rolling stock and the interface for integrating the ERTMS system.

To mitigate this risk, RUs and vehicle owners could separate the retrofitting contract of the rolling stock and the ERTMS installation. Depending on the size of the fleet and the nature of the contract between the RU or vehicle owner and the rolling stock manufacturer, this separation could eliminate the risk associated with the ERTMS agreement, thereby reducing the overall cost of retrofitting the fleet.

Responsible: vehicle owner

All the solutions mentioned above (improvement of project management) will reach their maximum potential if they are deployed all together and once the ERTMS parameters for a vehicle type will be defined.

6.2.2.2 Guidelines FAQ for ERA staff and third-party assessors

Lessons learnt from the validation or authorisation activities of deployment projects should be shared with the relevant ERA staff and third-party assessors. This would lead to a more uniform treatment of the applications, which would facilitate the work of applicants. This is expected to increase efficiency in the last phase of the projects and minimise the downtime of locomotives, hereby decreasing project costs.

Responsible: ERA

6.2.3 Medium / long term solutions

6.2.3.1 Accelerate ERTMS deployment and Class B decommissioning

The complexity related to integrating ERTMS increases exponentially when there is a need to interface not only to the rolling stock but to each of the Class B systems of the different networks in the area of use of the vehicle, including the national rules related to those.

Deployment acceleration on the trackside and decommissioning of Class B would eliminate this complexity and was clearly requested by many participants to the 2024 ERA ERTMS conference. This will occur once ERTMS is fully utilised on commercially interesting parts of the network and Class B is decommissioned.

Responsible: MS, infrastructure managers

6.3 Solutions with moderate impact

6.3.1 Solutions implemented in the current legislation

6.3.1.1 Elimination of partial fulfilment

Variability in the products allowed by the partial fulfilment creates complexity in the ERTMS, mainly in the integration between trackside and on-board ETCS. Therefore, the reduction of the possibility for the ERTMS products for deviating from the specifications will facilitate their integration.

One of the main cost drivers of ERTMS retrofit projects is the ESC tests. It is therefore foreseen that this change introduced in the latest CCS TSI will allow to increase the confidence in the behaviour of the system and therefore reduce the number of tests necessary.

This mitigation is still not visible in the market since and will take time to materialize as there are no products compliant with the latest version of the CCS TSI in commercial service and the length of the network equipped with ERTMS in Europe is still limited. But the more kilometres of ERTMS will be deployed in multiple European countries, the more impact this measure will have.

6.3.2 Short term solutions

6.3.2.1 Improve project structuration

Incentives could be put in place in order to promote the development of larger retrofitting or upgrade projects. This could be done through a differentiated level of support for large projects, for instance for projects of more than 100 vehicles. This differentiation could be done at EU level (through Connecting Europe Facility (CEF) or cohesion funds) or at national level. Moreover, an online “network of vehicle owners” could be put in place with the support of the sector in order to identify the owners of the same series willing to equip their fleet with ERTMS and to facilitate their gathering under a single project.

Of course, this solution will be based on the willingness of vehicle owners to cooperate on a project and will have to comply with EU rules regarding competition.

Responsible: EU, vehicle owners

Annex

Annex 1 – List of stakeholders interviewed – first round

#[37]	Stakeholder group	Stakeholder[38]
1	Infrastructure manager	*Anonymised*
2		*Anonymised*
3		*Anonymised*
4		*Anonymised*
5 & 6		*Anonymised*
7 & 8	Railway operators	*Anonymised*
9 & 10		*Anonymised*
11		*Anonymised*
12		*Anonymised*
13 & 14		*Anonymised*
15	Suppliers	*Anonymised*
16		*Anonymised*
17 & 18		*Anonymised*
19	Rolling stock leasing companies	*Anonymised*
20		*Anonymised*
21		*Anonymised*
22		*Anonymised*
23		*Anonymised*
24		*Anonymised*
25		*Anonymised*
26	Rail regulators	*Anonymised*
27	Others	*Anonymised*

[37] A brief follow-up interview was held with some interviewees. Hence, why some points have two entries. These entries do not refer to the second round of interviews.

[38] The European Commission is aware of the interviewed stakeholders.

Annex 2 – Stakeholder Survey Results

From the stakeholder survey results, the DMT was able to rank the solutions according to their perceived and/or projected impact. This is presented in the table below:

Solution	Section reference	Average Score[39]
Broader harmonisation	Section 6.1.2.2	4,67
Strengthening of simplification of national rules	Section 6.1.2.2.2	4,67
Reduction or elimination of ESC tests	Section 6.1.1.1	3,67
Increase modularity to lower integration effort in type design and product update	Section 6.1.2.1	3,67
Develop, share and maintain a repository of the technical documentation required to develop and authorize an ERTMS project at national level	Section 6.2.2.1.2	3,33
Prepare comprehensive documentation of the vehicle	Section 6.2.2.1.3	3,33
Accelerate ERTMS deployment and Class B decommissioning	Section 6.2.3.1	3,33
Interface specification of ETCS-ATO-Rolling stock-communications	Section 6.2.1.1	3,00
Error correction process	Section 6.2.1.2	3,00
Guidelines FAQ for ERA staff and third-party assessors	Section 6.2.2.2	3,00
Prepare vehicles for ERTMS retrofit	Section 6.2.2.1.4	2,67
Guidelines FAQ for ERA staff and third-party assessors	Section 6.2.2.2	2,67
Improve project structuration	Section 6.3.2.1	2,00
Define ERTMS parameters for a vehicle type	Section 6.1.2.2.1	1,67
Elimination of partial fulfilment	Section 6.3.1.1	1,00

[39] This column represents the average response score from survey respondents (UNIFE, CER, and AERRL) regarding the impact of various cost drivers on the overall costs of ERTMS deployment. The scores range from 1 (lowest impact) to 5 (highest impact).

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696,
- via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

MI-01-25-011-EN-N

Publications Office
of the European Union