ERTMS Deployment Management Team
Technical support for the deployment of ERTMS along the core network corridors

CCS TSI Revision –revised ERTMS deployment requirements (Impact Assessment)

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Executive summary

ERTMS (European Rail Traffic Management System) is a major industrial project being implemented in Europe, a project that will serve to make rail transport safer and more competitive. Properly delivered, it underpins interoperability to support the delivery of a Single European Rail Area.

ERTMS works via onboard and trackside equipment monitoring the actions of the driver and the train movements. Therefore, ERTMS can only bring the expected benefits if both trackside and onboard are deployed in a coordinated way.

This report examines the current state of play and projected ERTMS deployment and the economic case for changing current ERTMS deployment requirements.

1.1. EU requirements, state of play of ERTMS deployment and forecasts

Member States have legal deadlines for ERTMS deployment:

- On trackside, deadlines are defined in TEN-T Guidelines[1] and European Development Plan (EDP)[2] :
    - The EDP sets target dates until 2023 by which about 33% of the Core Network Corridors (CNC) shall be equipped with ERTMS and the remaining part of the Corridors between 2024 and 2030.
    - The TEN-T guidelines sets that the Core Network (CN)[3] has to be equipped by 2030, and the Comprehensive Network by 2050.

  Furthermore, some Member States have developed national deployment plans for their whole network, which go beyond the EU requirements.
- On onboard equipment, obligations are set in CCS TSI[4], which makes it mandatory for all new vehicles put in operation after the 1st of January 2015 to be equipped with ERTMS, with exemptions.

Recent information coming from Member States, Infrastructure Managers (IM) and Railway Undertakings (RU) show that:

[1] REGULATION (EU) No 1315/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU
[2] COMMISSION IMPLEMENTING REGULATION (EU) 2017/6 of 5 January 2017 on the European Rail Traffic Management System European deployment plan
[3] According to article 2 of the TEN-T guidelines, *"Core network corridors are an instrument to facilitate the coordinated implementation of the core network"*
[4] COMMISSION REGULATION (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability (TSI) relating to the 'control-command and signaling' (CCS) subsystems of the rail system in the European Union, amended by Implementing Regulation (EU) 2019/776 and Implementing Regulation (EU) 2020/387.

- On trackside, the EU deployment goal on the CN may encounter some delays in the short-term:
    - By March 2021, ERTMS was only deployed on 43% of the lines of the Core Network Corridors[5] expected to be equipped by 2023.
    - By 2030, only 65% of the Core Network (instead of 100%) is expected to be equipped with ERTMS.

  However, the medium and long-term outlook for trackside deployment is promising. In fact, some Member States have opted for full network deployment that goes beyond the legal obligations of the Core and Comprehensive Networks and have already set decommissioning deadlines for their class B system (the non-interoperable legacy signalling systems currently installed). Given these national plans, **by 2040, over 80,000km will be deployed on the TEN-T network and less than 20% of the TEN-T Network will still require class B system onboard to run**.

- Onboard deployment is unfortunately going slower than expected: approximately only half of the new vehicles put on the market were equipped with ERTMS between 2015 and 2019[6]due to exemptions under the CCS TSI.
  If this trend continues, a very high proportion of the EU fleet will not be ERTMS equipped by 2040), which means that there is a disconnect between the planned trackside deployment and expected onboard deployment.

As a consequence, there is a clear risk that the full benefits of ERTMS deployment will not be achieved if present trends continue.

1.2. Analysis of the impacts of allowing exemptions

To analyse the impact of the exemptions set out in the CCS TSI 2016/919/EC for onboard deployment, their financial consequences on the overall railway system have been assessed through the comparison of three scenarios:

- Scenario 1 "no changes", which assumes that the exemptions remain and therefore the whole EU fleet is not equipped by 2040, full ERTMS benefits will not be achieved.
- Scenario 2, which assumes that exemptions remain but with an ambitious target for full onboard equipment by 2040, Vehicles are retrofitted between 2031 and 2040 and ERTMS benefits can be achieved by 2040. This scenario assumes that EU legal framework is not changed and it is left to RUs and vehicle owners to decide whether to equip new vehicles or to retrofit at a later stage. ERTMS is deployed and class B decommissioned in line with the known national plans.

[5] CNC EU-27 + NO + CH, UK lines are deducted in these figures (120 km already in operation that are planned beyond 2023 in the EDP).
[6] Based on the number of new vehicles put in operation in Europe (approximately 5,000 vehicles) and on the fact that around 40% of vehicles equipped with ERTMS during the same period (approximately 5,700 vehicles) correspond to new purchase vehicles, it can be assumed that at least 2,700 new vehicles were put on the market without ERTMS during this period.

- Scenario 3, which assumes that exemptions are removed, new vehicles do not have to be retrofitted. ERTMS is deployed and Class B systems decommissioned everywhere on the TEN-T.

In both scenarios 2 and 3, it is considered that the full fleet is equipped by 2040, which means that all unequipped vehicles which are not renewed before 2040 or all vehicles renewed but without ERTMS have to be retrofitted.

The costs considered in the assessment of scenarios are the fitment costs, the retrofitting costs and the extra maintenance costs of the legacy system for Infrastructure Managers.

This is a conservative approach, as only savings on legacy system maintenance costs are considered. Other very significant associated benefits for example, enhanced interoperability for rail freight and passenger transport at European level, improved reliability of rail transportation for passengers, potential obsolescence cost of class B system, ERTMS as an enabler for ATO, ERTMS level 3, etc. are not quantified but are surely benefits of widespread ERTMS deployment.

The economic comparison between scenario 1 and the two other scenarios shows that there is an economic rationale to further foster onboard deployment. Failure to achieve full onboard deployment by 2040 would prevent IMs to reap savings on legacy system maintenance cost, that represents around 940 M€ per year considering that 35% of new vehicles are put in service without ERTMS. Over the period considered, the financial impact would be of about 19,422 M€, the gap between scenario 1 and 3. But, even if the target of full onboard equipment by 2040 remains but EU legislation continues allowing exemptions for new vehicles, retrofitting vehicles before 2040 instead of directly fitting them will result in an additional equipment cost of 1,786 M€, as shows the comparison of scenario 2 and 3.

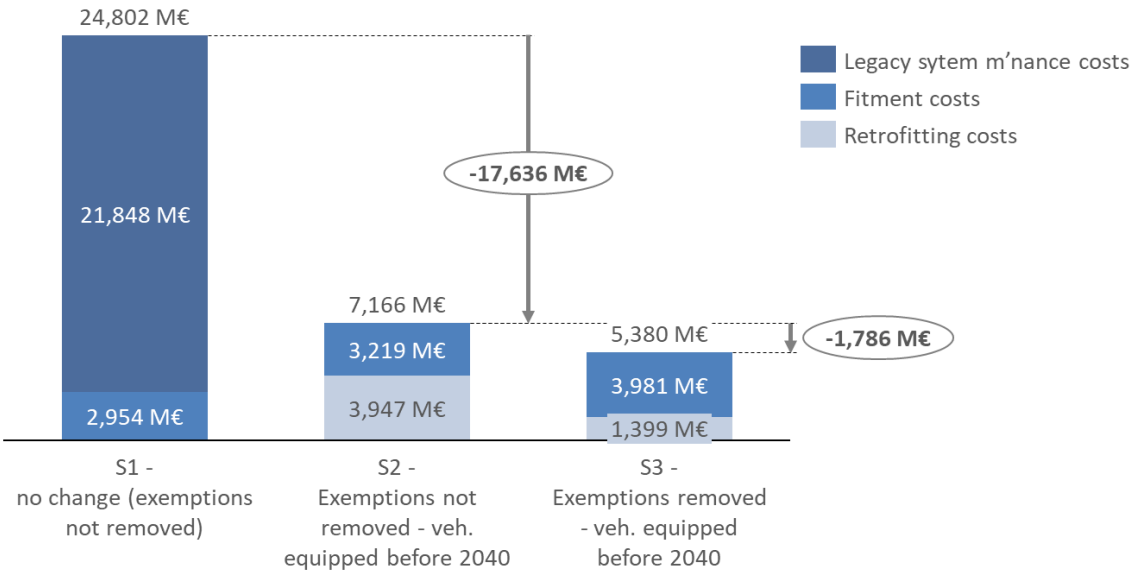


Figure 1 : Comparison of financial costs for the railway system of the different scenarios

1.3. Considering existing national plans, shortening the deadline for deploying the Comprehensive Network to 2040 and setting decommissioning deadlines should be considered

Given national plans and the overall outlook of ERTMS deployment by 2040, shortening the deadline for deploying the Comprehensive Network to 2040 and setting a calendar for decommissioning at EU level the class-B systems as multiple Member States have already done should both be considered.

As first approach, it is reasonable to align the overall comprehensive network deployment with the wider EU deployment and bring forward the expected deadline for ERTMS deployment on the Comprehensive Network to 2040, since the 20% remaining part of the network not equipped will prevent Member States and the industry to reap the full benefit from ERTMS:

- Class B system will become ever more a niche market, and maintenance costs will rise.
- Full benefits of interoperability won't be fully achieved everywhere in Europe, which could limit the capacity to increase the rail market share and to help in achieving the target of the Paris Agreement on climate change.
- Pressure from railway undertakings will rise, as they will have to maintain some class B system onboard on a part of their fleet in order to be able to operate everywhere in Europe.
- Game changer such as ATO and ERTMS level 3 will not be deployed everywhere in Europe, again limiting the capacity of the industry to increase its competitiveness against road (with ATO) or to offer additional capacity on urban nodes for rail transport where it is required.
- The digitalization of the system will not be possible without full ERTMS deployment, as class B system cannot be upgraded.

Furthermore, to go even beyond, EU should set out a deadline for decommissioning class B systems, which will contribute on the one hand to push for ERTMS onboard deployment – RU will be forced to equip their fleet to run in the European network – and on the other hand to cut maintenance costs. For IMs, bringing forward the decommissioning plans to 2040 would result in savings on legacy system maintenance costs of approx. 1.1 bn€ per year, a total of almost 11,5 bn€ between 2041 and 2050[7].

[7] 544 M€/year of savings on legacy system maintenance costs of the Core Network and 529 M€/year of the Comprehensive Network. Only savings on Member States that have no decommissioning plan before 2050 have been considered.

Therefore, in order to set the optimal economic way to achieve the EU and national plans of ERTMS deployment objectives and to reap the expected ERTMS benefits, it should be considered to:

1- **Remove from EU legislation the possibility to claim exemptions to put new vehicles in operation without ERTMS, which correspond to the scenario 3 of the analysis of the impacts of exemptions.**

2- **Shorten the deadline for deploying the Comprehensive Network from 2050 to 2040, to align it with national plans of most of the EU Member States.**

3- **Add decommissioning deadlines, in order to make sure that Member States and all railway stakeholders reap the expected benefits from ERTMS as soon as possible.**

2. Introduction

ERTMS (European Rail Traffic Management system) is a major industrial project being implemented in Europe, a project that will serve to make rail transport safer and more competitive. Properly delivered, it underpins interoperability in order to support the delivery of a Single European Rail Area.

ERTMS refers to two systems:

- **ETCS** (European Train Control System), a system able to supervise train movements and to stop the train if the permitted speed is exceeded or a dangerous situation is encountered.
- **GSM-R** (Global System for Mobile Communications - Railways), the European radio communication standard for railway.

In this document, ERTMS is used to refer to both the overall ERTMS system and to ETCS.

ERTMS works via onboard and trackside equipment monitoring the actions of the driver and the train movements. This is to assure speed limitations are followed and, when exceeded, emergency brakes are activated. Furthermore, it also provides the possibility to calculate and supervise the maximum train speed at all times and optimise traffic management thus improving the efficiency of the network.

Those elements are key to improve cross-border connections, increase capacity and improve the safety levels.

In order to achieve completion of this major industrial project, legal deadlines have been set for ERTMS deployment on trackside and on onboard equipment. Recent information coming from Member States, Infrastructure Managers (IM) and Railway Undertakings (RU) shows that the EU goal for trackside deployment on the Core Network may encounter some delays in the short-term, but the medium and long-term outlook is promising. However, onboard deployment is unfortunately going slower than expected, new vehicles are not systematically equipped relying on exemptions.

Since ERTMS can only bring the expected benefits if both trackside and onboard are deployed in a coordinated way, this report aims to determine a justified approach to reinforce ERTMS deployment requirements in the TEN-T and CCS TSI. To do so, this report:

- Assess the financial consequences of exemptions for onboard ERTMS deployment on the overall railway system, and
- Analyse the opportunity to (i) shorten the deadline for deploying the Comprehensive Network to 2040 and (ii) setting a calendar for decommissioning at EU level the class-B systems, the non-interoperable legacy signalling systems currently installed, given national plans and the overall outlook of ERTMS deployment by 2040.

The report is structured the following way:

- The first part of this report reviews the current legal obligations for ERTMS deployment, both on trackside and onboard, and presents the state of play to-date of the trackside and onboard ERTMS deployment and the foreseen national trackside deployment plans of Member States.
- The second part focuses on the assessment of the financial impacts of allowing onboard fitment exemptions on the overall system.
- The third part points out the benefits of shortened deployment and decommissioning deadlines would bring to the overall system.
- The last part of this report provides recommendations for adjustments on legal obligations in order to find the optimal economic way to achieve the EU and national plans of ERTMS deployment objectives.

3. Context

This section presents:

- The current EU requirements for ERTMS trackside and onboard deployment;
- The state of play of trackside and onboard deployment based on data reported to the Commission and to the EU Agency for Railways (ERA) and collected from Member States;
- The expected trackside and onboard deployment based on National Deployment Plans and on foreseen vehicles renewal;
- The issues to be addressed by comparing requirements and current state of play.

3.1. EU requirements for ERTMS deployment

Requirements and technical specifications related to ERTMS were introduced progressively since beginning of years 2000 and have been amended over the time.

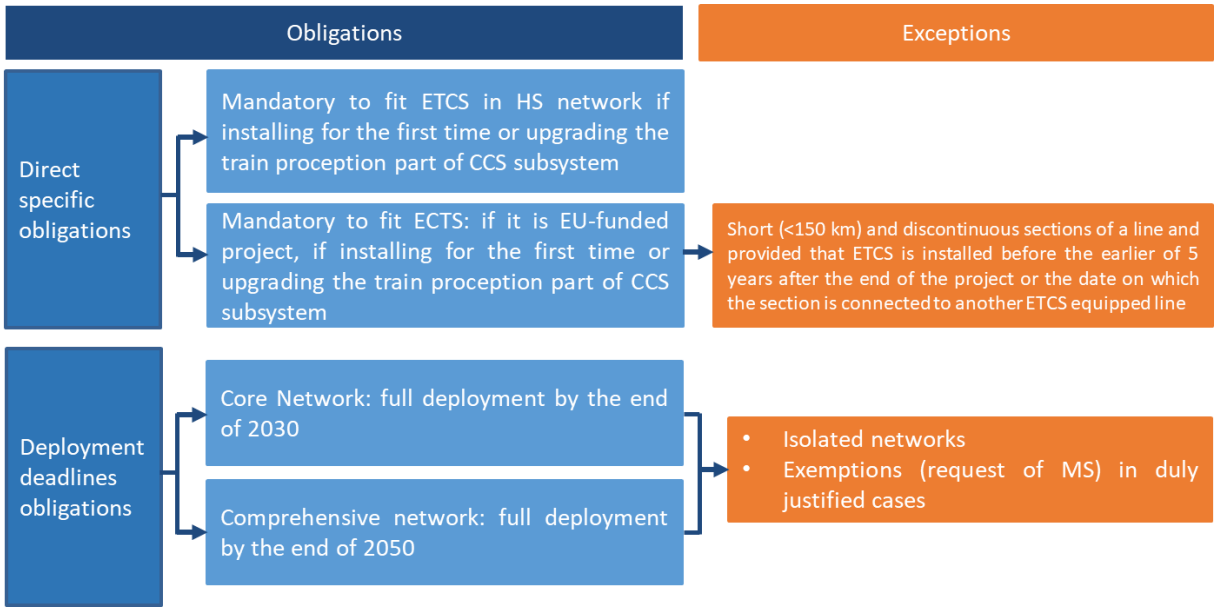
Trackside and onboard requirements should be analysed separately, since they are not comparable. There are deployment obligations for all the high-speed lines and for the sections that are part of the Core and Comprehensive European Network[8], while for onboard deployment there are different types of obligations according to the status of the vehicle (new, upgrade, area of use).

3.1.1. According to EU legal obligation, 55% of the TEN-T Network shall be equipped with ERTMS by 2030

ERTMS trackside deployment is based on CCS TSI 2016/919/EC, which establishes two main types of obligations as presented in the following figure. On the one hand, CCS TSI states that all high-speed lines and EU-funded lines that install for the first time or that upgrade the train protection to be put into service have to be equipped with ERTMS. On the other hand, CCS TSI also sets out a deadline for deploying ERTMS on the Core Network by 2030 and on the Comprehensive Network by 2050 in compliance with the EDP and in general with the TEN-T guidelines.

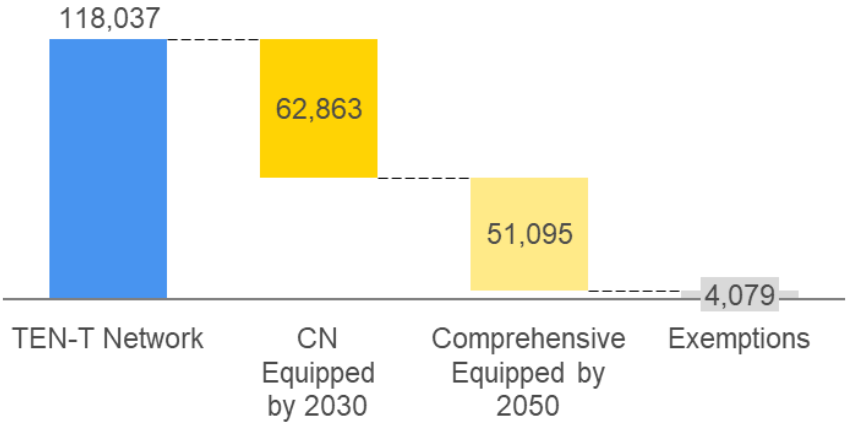
[8] with the only exceptions of isolated networks

Figure 2 : Trackside ERTMS – EU obligations and exceptions



As shown in Figure 1, taking into account both the article 38 of the REGULATION (EU) No 1315/2013 that states "Member States shall take the appropriate measures for the core network to be developed in order to comply with the provisions of this Chapter by 31 December 2030" and the article 39 that establishes sections exempted[9], **the CN should be fully equipped by 2030, which represents 55% of the TEN-T Network without sections exempted from obligation to equip[10].** The Comprehensive Network, 51 095 km without considering exemptions, should be fully equipped with ERTMS by 2050.

Figure 3: According to EU legal obligations, expected ERTMS trackside deployment in line-km[11]



[9] CN exempt sections: Ireland (440 km), Latvia (788 km) and Lithuania (478 km)
[10] EU 27 + NO + CH
[11] Countries considered: EU 27, UK, NO and CH. Countries with exempt sections: Ireland (the whole network), Latvia (1,541 km) and Lithuania (1,583 km)

3.1.2. According to CCS TSI, most of the new vehicles should have been equipped since 2015, and even before for high speed vehicles

The first obligations to fit new vehicles date from 2006. The Commission Decision 2006/860/EC of 7 November 2006 for **high-speed rail** system sets out in the article 7.2.2 the ERTMS implementation rules making it mandatory to fit ERTMS onboard when:

- Any new train protection part of a CCS onboard assembly is installed, or
- Any existing train protection part of a CCS onboard assembly is upgraded, where this would change the functions, performances and/or interoperability – relevant interfaces of the existing legacy system.

Regarding the **conventional rail** system, the first obligations date from 2009. The Commission Decision 2009/561/EC of 22 July 2009 sets out in article 7.2 ERTMS on-board implementation that new locomotives, new railcars and other new railway vehicles able to run without traction equipped with a driving cab, ordered after 1 January 2012 or put into service after 1 January 2015, shall be equipped with ERTMS.

Afterwards, the Commission Decision 2012/88/EU of 25 January 2012 unified the technical specification for high-speed and conventional rail systems in its article 7.3.3 ERTMS.

The latest version of COMMISSION REGULATION (EU) CCS TSI 2016/919/EC establishes three types of obligations for ERTMS fitment:

- For new vehicles: it states that all new vehicles should be equipped with ERTMS.
- For upgrades: it states that it is only mandatory for high speed vehicles.
- For extension of the area of use: it states that it is mandatory for all vehicles that are not already equipped. This case is linked with the exemption described below: if a new vehicle benefitted from an exemption thanks to its area of use, and is then used on an area which would have made it ineligible for an exemption, then the vehicle should be equipped with ERTMS.

However, the CCS TSI also includes several exceptions for onboard ERTMS deployment. In the point 2 of §7.4.3 specifies that Member States may decide to exclude from the obligation set out in the first paragraph of point 7.4.2.1 all new vehicles intended exclusively for national service except when the area of use of those vehicles includes more than 150 km of a section currently equipped or to be equipped with ERTMS within 5 years after the authorisation for placing in service of those vehicles. Member States shall publish their decision for implementing this provision, notify such decision to the Commission and include it in the National Implementation Plan referred to in point 7.4.4.

In addition to that, the point 2 of §7.4.2.1 sets out that the requirement for new vehicles to be equipped with ERTMS does not apply to:

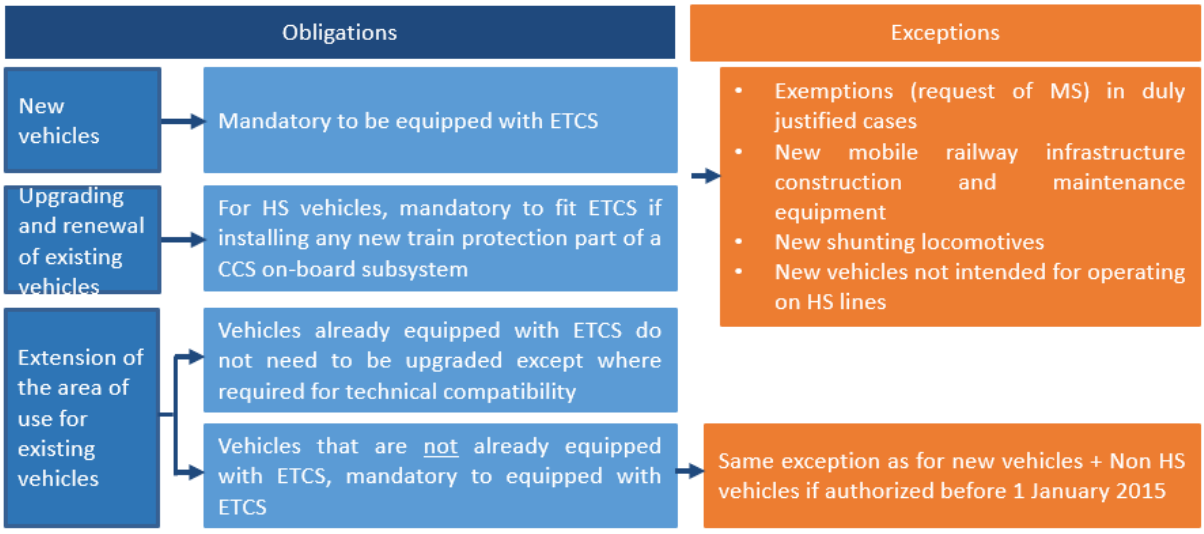
- New mobile railway infrastructure construction and maintenance equipment;
- New shunting locomotives;

- Other new vehicles not intended for operating on high-speed lines:
  - If they are intended exclusively for national service operated outside the corridors defined in point 7.3.4 of Annex III of Decision 2012/88/EU and outside the lines ensuring the connections to the main European ports, marshalling yards, freight terminals and freight transport areas defined in point 7.3.5 of the Annex of Decision 2012/88/EU; or
  - If they are intended for off-TEN cross-border service, i.e. service until the first station in the neighbouring country or to the first station where there are connections further in the neighbouring country.

Similar exclusions apply to extensions of the Area of Use for existing vehicles.

Onboard obligations and exceptions are summarised in the following figure.

Figure 4: Onboard ERTMS – EU obligations and exceptions



Even though current EU legal framework seeks to reinforce onboard deployment, it also includes several exemptions that slow the progress to achieve full equipment of the EU fleet.

3.2. State of play of ERTMS deployment

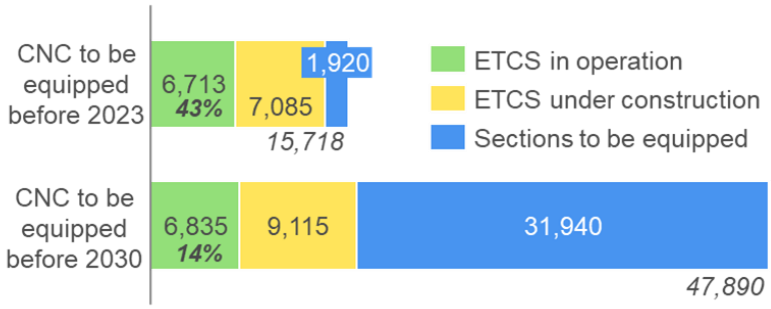
The purpose of this section is to summarise:

- The current state of play of trackside and onboard deployment;
- The forecasted trackside deployment and vehicles renewal in the coming years.

3.2.1. By March 2021, 43% of the Core Network Corridors expected to be equipped with ERTMS by 2023 was already in operation

By March 2021, 43% of the Core Network Corridors (CNC)[12] expected to be equipped with ERTMS by 2023 according to the EDP plans was already in operation. Most projects which are not operational are under construction but with 2-3 years delays.

Figure 5: CNC deployment status in 2021 and target by 2023 and 2030[13]

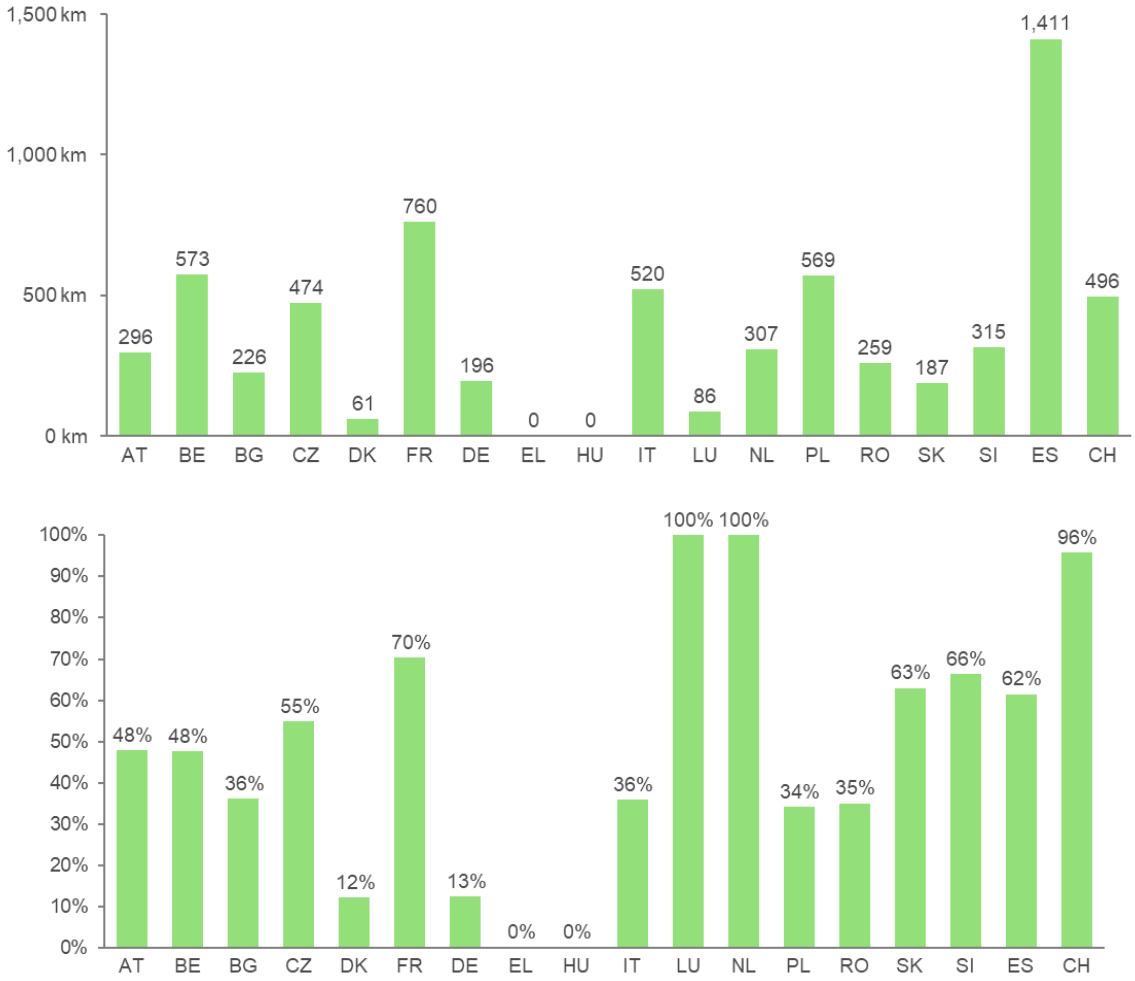


To reach the EU target of full deployment on the CNC and CN by 2030, 31,940 km of the CNC should be equipped between 2023 and 2030 and also the remaining sections of the CN outside the CNC, 14,973 km[14] . However, based on data collected from Member States and press review, it is currently estimated that about 65% of the CN will be equipped with ERTMS by 2030.

The detail per Member State is presented below.

[12] CNC EU-27 + NO + CH, UK lines are deducted in these figures (120 km already in operation that are planned beyond 2023 in the EDP).
[13] Source: ERTMS KPI Report done by DMT T4. DMT performs the monitoring of the ERTMS deployment in the CNC based on the information shared by MS and the EC.
[14] CN length including CNC (exempted sections excluded): 62,863 km. CNC length (exempted sections excluded): 47,890 km.

Figure 6: State of play at March 2021 of trackside ERTMS deployment in the CNC line-km per country in comparison with the EDP targets by 2023



3.2.2. By the end of 2019, around 5 700 vehicles were equipped with ERTMS, representing only 12,5% of the European commercial fleet

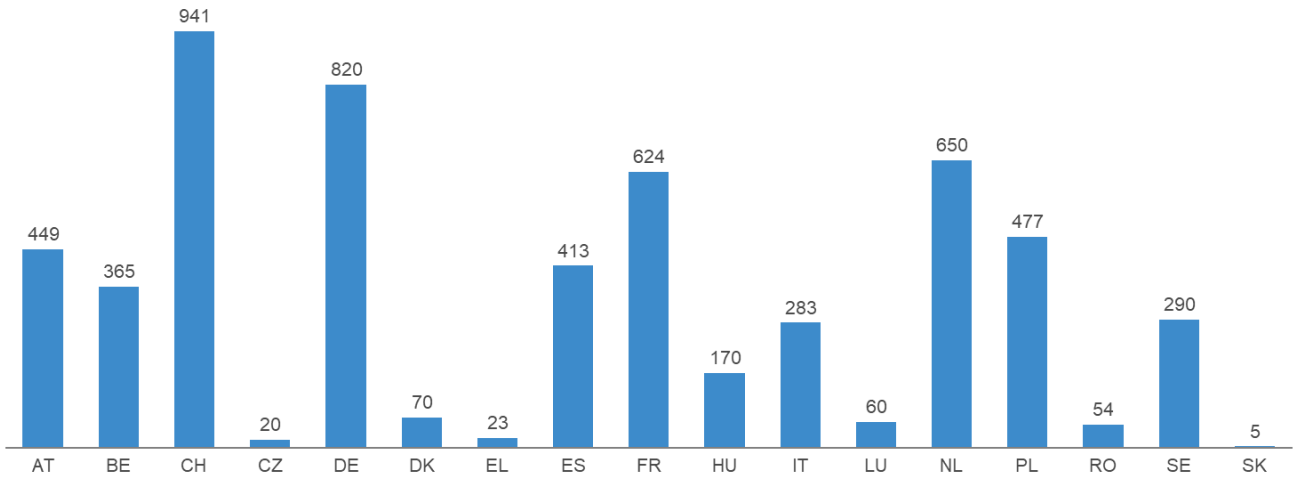
Data for onboard equipment have been collected from multiple sources in order to assess the current status of on-board deployment:

- Data from interviews carried out by Deployment Management Team with railway undertakings,
- Data collected by UNIFE,
- Data collected by ERA,
- Additional desk research.

However, data collection is not a straightforward process, as the analysis of information collected from different sources sometimes show some inconsistencies (due to difference in scope or date for instance). Nevertheless, we believe that the values presented below provide a good overall picture of the state of play of on-board deployment at European level.

The results are presented in the figure below.

Figure 7: Vehicles equipped with ERTMS by 2019 per country



Based on the data collected and cross-checked, we estimate that between 2015 and 2019 there were around 5,700 vehicles equipped with ERTMS.

Among the vehicles equipped during this period, around 40% correspond to new purchase vehicles and 60% correspond to retrofitted vehicles[15], so it can be assumed that approximately 2,300 new vehicles with ERTMS have been put in operation in Europe so far.

[15] Source: UNIFE

Between 2015 and 2019, there was approximately 5 000 new vehicles which were put in operation in Europe. **Therefore, at least 2,700 new vehicles were put on the market without ERTMS during this period.**

Based on this evidence, it is clear that a non-negligible share of new vehicles put in operation are not fitted with ERTMS.

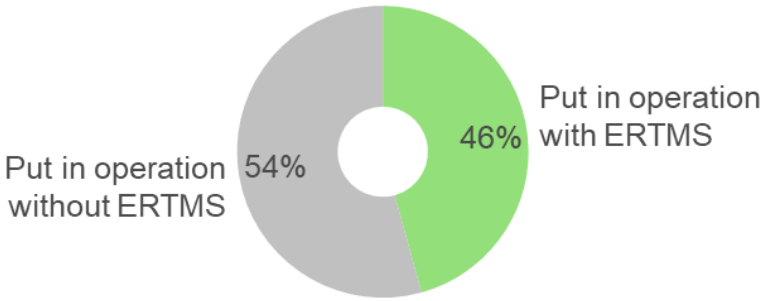


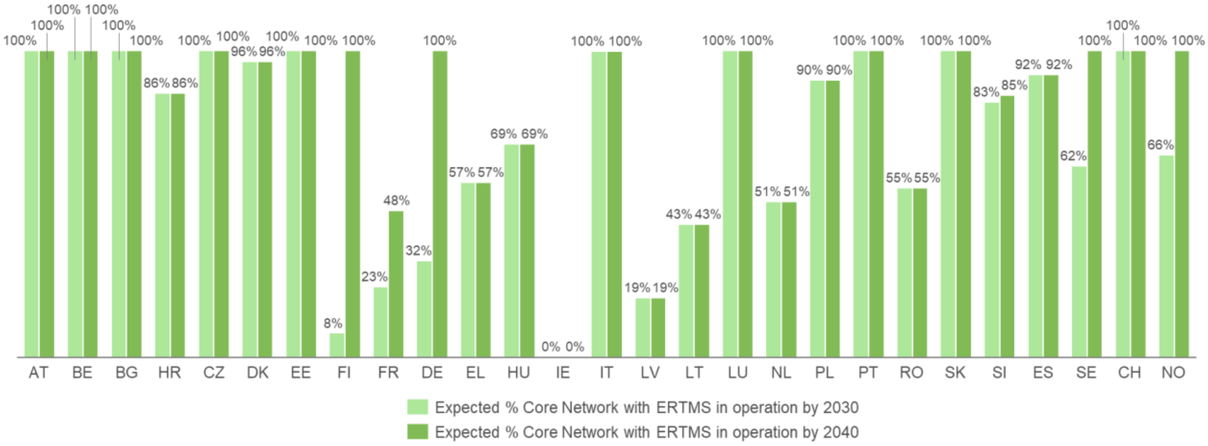
Figure 8: Renewal fleet between 2015 – 2019

3.3. Outlook of ERTMS deployment by 2030 and 2040

3.3.1. According to national deployment plans, class B system on-board will be required on less than 20% of the TEN-T Network after 2040

Based on the national plans and information provided by the MS or collected by the EC, it is estimated that about 46% of the Comprehensive Network and 65% of the Core Network will be equipped with ERTMS by 2030 and 68% and 83% respectively by 2040[16]. The detail per Member State is presented below[17].

Figure 9: Based on national plans and current progress, expected trackside ERTMS deployment per Member State



Not all Member States limit themselves to the Core and Comprehensive Network and the corresponding deadlines (2030 and 2050). Indeed, some Member States have chosen a more ambitious strategy and decided to go for a national deployment (see below). For these MS, their whole network will soon be equipped with ERTMS.

Overall, based on known Member State plans, 68% of the whole TEN-T will be equipped with ERTMS by 2040[18]. The remaining part includes:

- section to be equipped,
- sections that are exempted of deployment (on isolated networks),
- and new lines to be built, as they are supposed to be equipped with ERTMS.

Therefore, it is a reasonable expectation, based on reviewed plans, that a higher percentage of the network would be equipped by 2040.

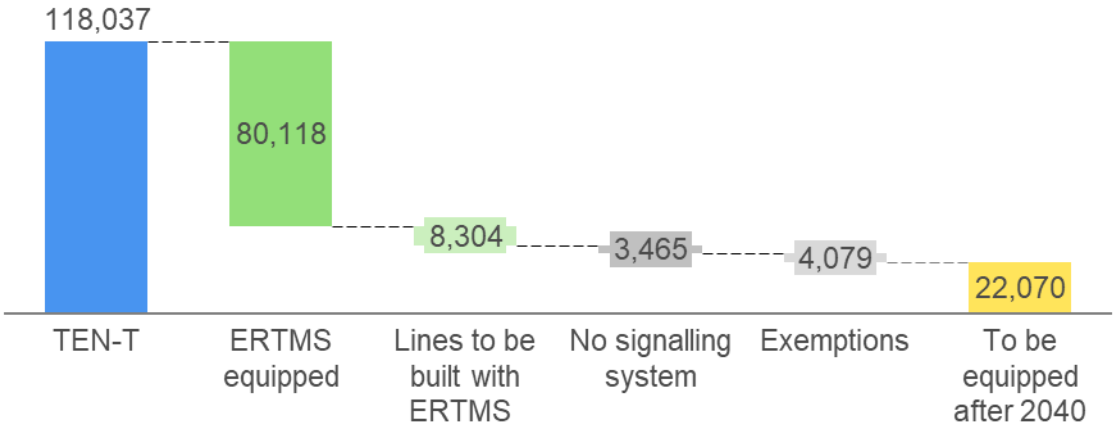
[16] This value is a low bound, as some Member States might be willing to deploy ERTMS but have no official plans today

[1717] The figure does not include Ireland, since its CN is exempted.

[18] It represents 70% of the Comprehensive network to be equipped (exempted sections are not included)

Nevertheless, it is worth noting that on current plans, by 2040 on-board class B system will only be required on less than 20% of the TEN-T Network.

Figure 10: Based on National Plans, expected ERTMS trackside status by 2040



The Member States that have planned to have their entire network equipped with ERTMS by 2040 are **Belgium**, **Czechia**, **Estonia**, **Finland**, **Germany**, **Italy**, **Luxembourg**, **Norway**, **Sweden** and **Switzerland**.

Bulgaria, **Denmark**, **Greece** and **Slovenia** do not plan to have their entire network equipped with ERTMS by 2040, but no Class-B system will be required onboard as the only lines which will be un-equipped do not have any automatic train protection system (3 465 km with "No signalling system" of the figure above).

Among these Member States, some go even further and have already defined their decommissioning deadlines:

- **Belgium**, the whole network is expected to be equipped with ERTMS by 2025. The Class B decommissioning plans is foreseen when lines are equipped with ERTMS, so it is expected to be completed in 2025.
- **Czechia**, the whole network is expected to be equipped with ERTMS by 2040. Class B system will be gradually phased-out starting from 2025.
- **Denmark**, lines currently equipped with automatic train protection systems will be equipped with ERTMS by 2030. The Class B system is decommissioned when ETCS is installed on trackside, so it is expected to be completed in 2030.
- **Finland**, the whole network is expected to be equipped with ERTMS by 2040. Class B decommissioning is planned one year after ERTMS deployment of a given line.
- **Germany,** the whole network is expected to be equipped with ERTMS by 2035. Class B system will be decommissioned by 2035.
- **Italy,** the whole network is expected to be equipped with ERTMS by 2036. No double equipment is expected on Italian network after 2036.
- **Luxembourg,** ERTMS is in service since 2019. Class B system was planned to be decommissioned by end 2020 according to the Network Statement, but this information has not been confirmed yet.
- **Slovenia**, the CN is expected to be equipped with ERTMS by 2025 and the Comprehensive Network by 2031. Class B system on the CN will be decommissioned by 2025 and on the Comprehensive Network and regional lines by 2031.

- **Sweden,** the whole network is expected to be equipped with ERTMS by 2035. The ERTMS will replace the old system on the whole Swedish railway network.

In sum, the deployment plans of ERTMS on the TEN-T Core and Comprehensive Network by 2040 would be (countries that plan to achieve a full ERTMS deployment by 2040 are highlighted in green):

Figure 11: Reviewed ERTMS deployment plans by 2040 in EU27 + NO + CH

3.3.2. More than 20 000 vehicles, representing almost 60% of the commercial European fleet on the CN, are expected to be renewed in the next ten years

Based on the age of the European fleet and the average life time of a vehicle (30 years)[19], around 22,000 vehicles (representing 60% of the commercial European fleet operating on the CN[20]) will reach the end of their life and therefore are expected to be renewed in the next ten years. Between 2031 and 2040, an additional 11,000 vehicles are expected to be renewed. Therefore, almost 90% of the commercial European fleet operating on the CN might be renewed in the upcoming 20 years.

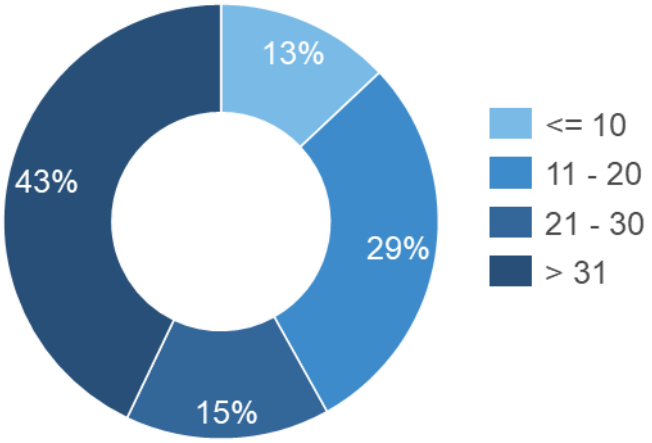


Figure 12: EU fleet per age group

In theory, according to legal obligations, most of this fleet should be equipped with ERTMS. However, as explained above, the share of new vehicles actually equipped with ERTMS is much lower than expected.

[19] Based on information collected in the business case analysis by the Deployment Management Team
[20] The total fleet here is the commercial fleet operating on the Core Network, which means all vehicles but the yellow fleet (fleet dedicated to track repair and construction equipment) and the shunting locomotives. The whole commercial fleet has been considered in all countries but in Spain, France and Poland, which are countries where a non neglectable part of the network won't be equipped with ERTMS as there is no national deployment plan. For those three countries, only 40% of the fleet has been considered.

3.4. Issues and opportunities identified and to be analyzed

Even if the ERTMS trackside deployment is suffering from delays in the short-term, it is still progressing rapidly, and the long-term forecast landscape is positive: by 2040, at least 68% of the whole EU-27+NO+CH TEN-T network is expected to be equipped and less than 20% of the TEN-T Network will still require class B system onboard to run (remaining 12% consisting of exempted lines or lines with no signalling system).

Findings on ERTMS onboard deployment are more problematic. They show that despite the current TSI requirements, between 2015 to 2019 only about 40-45% of new vehicles were equipped with ERTMS. Despite EU requirements, the pace of the onboard deployment is thus slower than what was initially expected by EU and Member States.

Operators do not fit all their new purchased fleet since they do not see the need to invest in ERTMS because most of the lines in their area of operation are not yet equipped with ERTMS and/or they can still use class B systems. At the same time, some Infrastructure Managers delay deployment as no rolling stock equipped is available, which leads the industry into a vicious circle. This situation might jeopardize trackside deployment or force Infrastructure Managers to keep two systems on trackside for a longer time than initially expected. Some impacts on deployment programs have already been noted, for instance in Sweden.

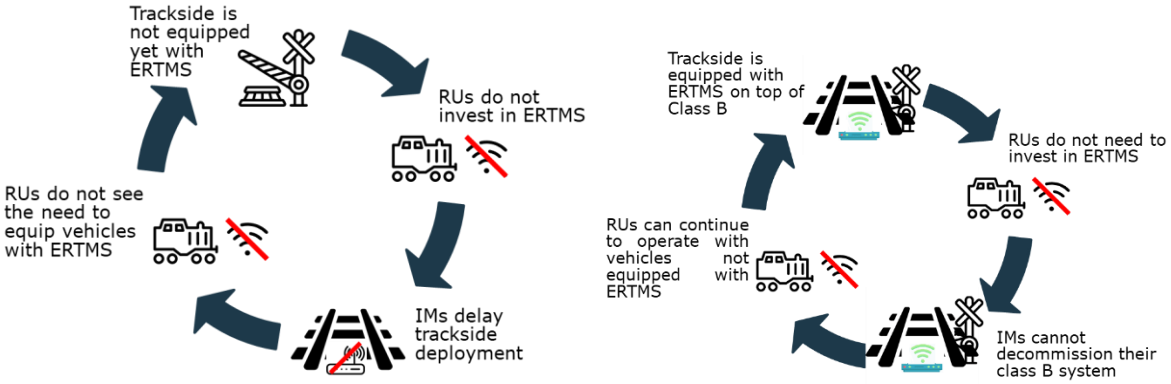


Figure 13: Vicious circle of ERTMS deployment

A continuation of this approach will mean it will not be possible to reap the expected benefits from ERTMS: interoperability for rail transportation in Europe, increase of capacity, increase of safety. As ERTMS business case[21] showed, ERTMS can only bring the expected benefits if both trackside and onboard are deployed in a coordinated way. Dual onboard strategy which consists in equipping the whole fleet with ERTMS on top of the legacy system for the target year of trackside deployed in CN is the best migration strategy. The

[21] DG Move EC. 2019. ERTMS business case on the 9 core network corridors – Second Release

decommissioning of the old national systems (Class B) is only possible if almost the whole fleet is equipped with ERTMS[22].

Therefore, a continuation of a significant proportion of the new rolling stock not being fitted with ERTMS is expected to have a material impact on ERTMS business case and ERTMS deployment overall, as it leads to additional costs in the short and medium term (retrofitting costs) and prevents Infrastructure Managers from getting rid of their class B systems and thus achieving the expected benefits on maintenance.

In the following analysis, we look to estimate:

- The extra costs of keeping or removing onboard exemptions for ERTMS on the railway system;
- Considering national plans and the overall outlook of ERTMS trackside deployment by 2040, the opportunity to accelerate trackside deployment and shorten the deadline for deploying the Comprehensive Network to 2040 and removing class B systems.

In the analysis a very conservative approach has been taken, as only savings on legacy system maintenance costs have been considered.

Other very significant associated benefits for example, enhanced interoperability for rail freight and passenger transport at European level, improved reliability of rail transportation for passengers, potential obsolescence cost of class B system, ERTMS as an enabler for ATO, ERTMS level 3, etc. are not quantified but are surely benefits of widespread ERTMS deployment.

Furthermore, it is assumed that legacy system maintenance costs only grow according to forecasted inflation[23]. However, this is also a very conservative assumption. It is certain that costs will rise when only a few class B systems will still be in operation, due to obsolescence issues and the lack of willingness of suppliers to maintain such systems[24].

[22] Threshold was set at 90% of the fleet equipped in the ERTMS business case analysis.
[23] 1,62% per year
[24] For instance, LZB in Germany is expected to be obsolete by 2030

4. Analysis of the impacts of allowing exemptions

4.1. Scenarios for ERTMS onboard deployment to be compared

The objective is to assess the impacts of the new vehicles put in operation without ERTMS on the costs of the overall railway system under different scenarios.

The EU legal target date for trackside deployment in the Core Network is 2030 and in the Comprehensive Network is 2050. However, according to national deployment plans by 2040, a large part of the Comprehensive Network – and even beyond – is expected to be equipped with ERTMS, and class B system decommissioned. If the whole EU fleet is not equipped by then, full ERTMS benefits will not be achieved.

To illustrate this, a scenario "no change" (scenario 1) is compared with a scenario which also supposes that exemptions remain but with an ambitious target for full onboard equipment by 2040 (scenario 2), aligned with known national deployment and decommissioning plans. In this scenario 2, vehicles are retrofitted between 2031 and 2040 and ERTMS benefits can be achieved by 2040. This scenario assumes that EU legal framework is not changed and it is left to RUs and vehicle owners to decide whether to equip new vehicles or to retrofit at a later stage.

However, if exemptions are removed, new vehicles do not have to be fitted later. In order to show the economic impact of fitting new vehicles versus fitting later on (retrofitting), the scenario 2 is compared to a third scenario (scenario 3) which supposes that new vehicles cannot benefit anymore from exemptions. In both scenarios 2 and 3, the dual onboard strategy[25] is considered to accelerate the deployment and reach full fleet equipped by 2040. It means that all unequipped vehicles which are not renewed before 2040 or all vehicles renewed but without ERTMS have to be retrofitted.

The approach to assess each scenario is mainly based on an economic comparison between scenario 1 and the two other scenarios (see Annexe 3).

For the assessment, three ratios of utilisation of the exemptions have been considered for the new fleet: 25%, 35% and 45% (to be compared with the 54% estimated). The approach taken is thus quite conservative.

[25] In this strategy, the focus is put on equipping the fleet as quickly as possible with ETCS on top of the legacy system on a given time span (retrofitting). See Annex 2.

The three scenarios are detailed in the table below:

		Scenario 1 – no change	Scenario 2 – exemptions not removed but vehicles are equipped before 2040	Scenario 3 – exemptions removed and vehicles are equipped before 2040
Exemptions[26]		Yes	Yes	Removed after 1st January 2023
# of new vehicles not equipped with ERTMS		Between 25 to 45%	Between 25 to 45%	0% after 2023
Equipment of the full fleet	Renewal and fitment	Vehicles are renewed and equipped between 2015 and 2045.	Vehicles are renewed and equipped between 2015 and 2040[27].	
	Retrofitting	The vehicles renewed that are not equipped with ERTMS are retrofitted after 2060.	The vehicles renewed that are not equipped with ERTMS are retrofitted between 2031 and 2040.	The vehicles renewed between 2015 and 2022 that are not equipped are retrofitted between 2031 and 2040.
			Vehicles expected to be renewed between 2040 and 2045 are retrofitted before 2040.	
Track-side deployment plans		All CN sections are equipped with ERTMS by the end of 2030, and national plans are applied.		
Savings on infrastructure maintenance		No	Yes after 2040	

[26] point 2 of §7.4.2.1 of COMMISSION REGULATION (EU) 2016/919 of 27 May 2016
[27] If a given Member State has a national deployment plan, all new vehicles are supposed to be equipped starting 5 years before the deadline for ERTMS deployment (for instance if deadline for ERTMS deployment is 2035, then all new vehicles put in operation after 2031 are supposed to be equipped with ERTMS). The underlying assumption is that RU will fit new vehicles without exception since potential decommissioning of class B system is very close.

4.2. Not removing exemption leads directly to an increase in financial costs for the railway system in the medium and long term

The assessment of the three scenarios shows the economic impact of exemptions on the expected costs and benefits of ERTMS deployment. It is worth recalling that in the economic assessment only savings on legacy system maintenance costs have been considered, which is a conservative approach, as other ERTMS associated benefits should also be considered (interoperability, reliability, track capacity, etc. which represent 90% of the socio-economic benefits expected from ERTMS).

The results of the three scenarios show that there is strong direct financial and broader economic and systemic rationale to promote widespread new on-board equipment:

Scenario	Exemption ratio	Fitment costs (M€)	Retrofitting costs (M€)	Legacy system maintenance costs (M€)	Total (M€)
S1: No change	25%	3,409 M€	N/A	21,848 M€	**25,257 M€**
	35%	2,954 M€			**24,802 M€**
	45%	2,500 M€			**24,348 M€**
S2: Exemptions not removed but vehicles are equipped before 2040	25%	3,483 M€	3,036 M€	0	**6,519 M€**
	35%	3,219 M€	3,947 M€		**7,166 M€**
	45%	2,954 M€	4,857 M€		**7,812 M€**
S3: Exemptions removed and vehicles are equipped before 2040	25%	4,028 M€	1,216 M€	0	**5,244 M€**
	35%	3,981 M€	1,399 M€		**5,380 M€**
	45%	3,934 M€	1,582 M€		**5,516 M€**

Figure 14: Financial cost for railway system according to scenarios

The costs of the scenario 1 are the highest, since the exemption is not removed and new vehicles not equipped are not expected to be retrofitted (or equipped through renewal) before 2060. In the scenario 1, decommissioning the class B system is not possible, benefits are not achieved (no savings on maintenance costs for infrastructure managers).

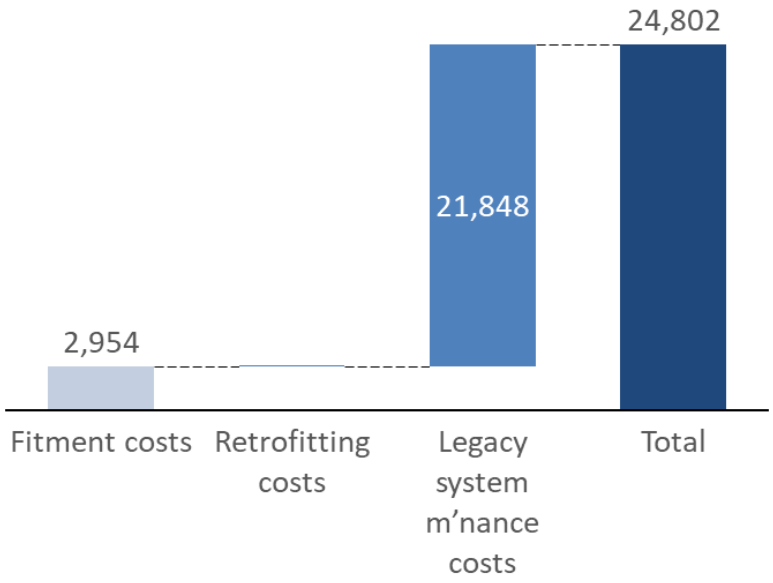


Figure 15: Scenario 1 – no change (exemption rate: 35%)

In scenario 2, even if exemptions remain, the objective of decommissioning class B system is reached, since new vehicles not equipped are retrofitted before 2040. However, the scenario 1 is more realistic, since RUs will not retrofit their fleet if there is no legal obligation.

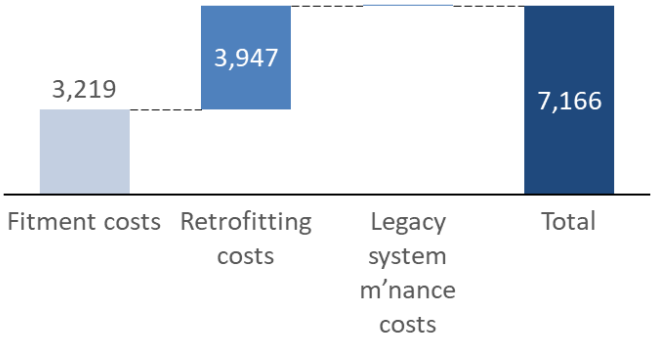


Figure 16: Scenario 2 – Exemptions not removed / vehicles equipped before 2040 (exemption rate: 35%)

The scenario 3 assumes the exemptions are removed in 2022 and newly purchased vehicles are retrofitted between 2031 and 2040. Therefore, fitment costs are higher than in scenario 2, but retrofitting costs much lower.

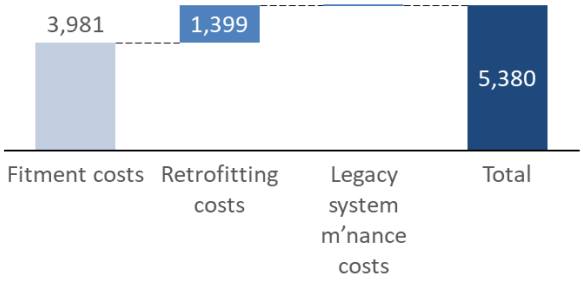


Figure 17: Scenario 3 – Exemptions removed / vehicles equipped before 2040 (exemption rate: 35%)

In scenario 2 and 3, as full onboard deployment is reached by 2040, Class B system decommissioning is possible by then. However, the comparison between scenario 2 and 3 shows that scenario 2 is more expensive, due to additional retrofitting costs given that over the time a number of new vehicles are expected to be purchased according to exemptions without ETCS. The life cycle of these vehicles will not be over by 2040 and an important share of them will need to undergo expensive retrofitting.

Scenario 3 is therefore the most advantageous, as (i) legacy system is removed at the latest in 2040 and (ii) there are less retrofitting costs, since RU are obliged to procure new vehicles equipped with ETCS following the removal of exemptions. Therefore, even if more expensive at purchase, the overall costs of new vehicles over their life cycle will be lower since installing ETCS at production is cheaper than through retrofitting. Design costs, procurement of suitable ETCS on-board units, testing and re-authorisation costs as well as time of vehicles out of operations during retrofitting works can be saved.

5. Considering existing national plans, shortening the deadline for deploying the Comprehensive Network to 2040 and setting decommissioning deadlines should be considered

As already shown in §3.3.1 above, based on current known plans, approximately 70% of the TEN-T Network is expected to be deployed by 2040 and around 10% of the TEN-T Network is not concerned by the deployment plans (lines to be constructed, lines without signalling system or lines exempted). Thus, based on current plans, less than 20% of the TEN-T Network will still require class B systems onboard after 2040.

The remaining part of the network not equipped will prevent Member States and the industry to reap the full benefit from ERTMS:

- **Class B system will become ever more a niche market.**
  Maintenance costs of the few remaining class B systems will surely rise as they will face obsolescence issues and suppliers will have reluctance to maintain them. Only existing suppliers may continue to provide parts and services as new entrants will not be interested to invest in declining and outdated Class- B systems. As preserving the capabilities to maintain the legacy system might become too difficult, renewing the legacy system might not even be feasible.

  A study carried out by ERA[28] suggested two assumptions to estimate the increase of trackside maintenance costs of the legacy systems:
  - 7% yearly increase over 20 years, then stable;
  - 3.44% yearly increase over 40 years, then stable.

  The following figure presents the expected evolution of the legacy system maintenance costs due to obsolescence.

[28] Directive 2001/16 - Interoperability of the trans-European conventional rail system- Addendum "CBA updated", EURA (2004)

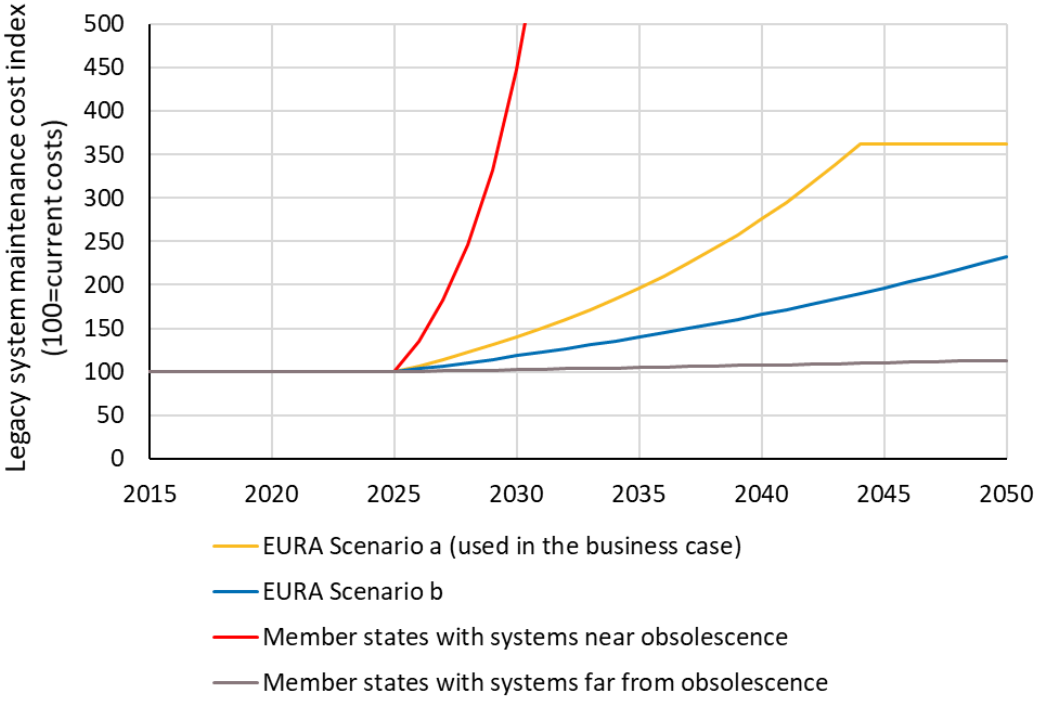


Figure 18: Evolution of the legacy system trackside maintenance costs

- **Full benefits of interoperability won't be achieved everywhere in Europe**.
  The lack of interoperability could limit the capacity of rail to increase the rail market share and help in achieving the target of the European Green Deal.

- **Pressure from railway undertakings would rise.**
  Railway Undertakings will have to maintain some class B system onboard on a part of their fleet in order to be able to operate everywhere in Europe.
  For instance, if a cost of 100 k€ / class B system is considered for a new vehicle and considering that 30% of the fleet still has to be equipped with such a system, the extra cost for the industry would be a total of 30 M€ / year[29], 300 M€ between 2040 and 2050.

- **Game changer such as ATO and ERTMS level 3 will not be deployed everywhere in Europe**.
  The full digitalization of the railway system can only be achieved with ERTMS, as it is not possible to upgrade class B systems. Without game changers, the capacity of the industry to increase its competitiveness against road (with ATO) will be limited.

[29] As shown above, there are approximately 1 000 new vehicles put on the market / year, so 1 000 x 30% x 100 k€ = 30 M€ / year

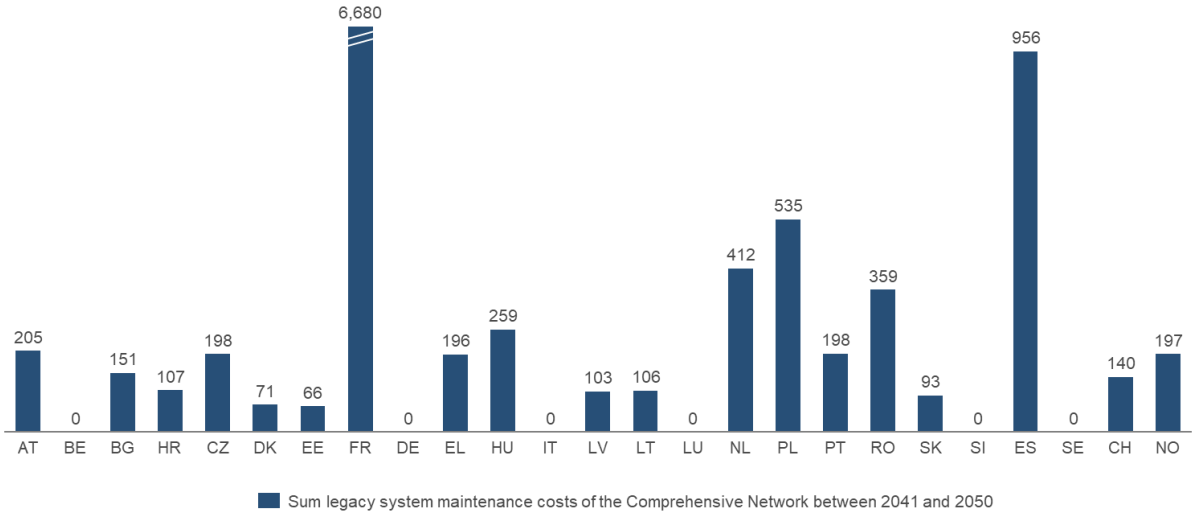
- **Infrastructure Managers will not be able to develop and deploy ERTMS level 3 to increase the capacity of the network at a reasonable cost.**
  ERTMS level 3 allows the use of moving blocks and to get rid of fixed train detection device. This will give the opportunity to increase the capacity of the network and might also be a solution for cheap ERTMS on regional lines with low level of traffic.

Therefore, aligning the target date of Comprehensive Network deployment with the one from most of the Member States (2040) would make sure that all railway stakeholders reap the benefit of the digitalization of the railway system as soon as possible.

To strengthen EU ERTMS deployment plans, setting out a deadline for decommissioning class B systems - as multiple Member States have already done - should be also considered for the following reasons:

- Decommissioning is a huge driver to push for ERTMS onboard deployment. For instance, the decommissioning deadline in Luxembourg has impacts beyond its network, with trains from neighboring countries also needing to be equipped with ERTMS.
- Decommissioning is the only way to cut maintenance costs. Since it is expected a large part of the EU fleet to be equipped with ERTMS by 2040, there will be less and less need to maintain legacy systems, however they will still represent additional cost for the system as a whole.
  For IMs, bringing forward the decommissioning plans to 2040 would result in savings on legacy system maintenance costs of approx. 1.1 bn€ per year, a total of almost 11,5 bn€ between 2041 and 2050[30].

Figure 19: Savings on legacy system maintenance costs



[30] 544 M€/year of savings on legacy system maintenance costs of the Core Network and 529 M€/year of the Comprehensive Network. Only savings on Member States that have no decommissioning plan before 2050 have been considered.

Given the dramatic impact on the pace of onboard equipment with ERTMS of past experiences on decommissioning, it appears that decommissioning plans favour ERTMS trackside and onboard deployment.

As many Member States already foresee a decommissioning of their class B system and in either case the whole EU fleet has to be equipped in order to achieve ERTMS benefits, **setting out obligations for decommissioning deadlines at the EU level is ambitious, but consistent with the overall EU objectives**.

ETCS in operation by 2040 – Core Network
ETCS in operation by 2040 – Comprehensive Network
No ETCS operation – Core Network
No ETCS operation – Comprehensive Network
No ETCS operation, new construction – Core Network
No ETCS operation, new construction – Comprehensive Network
No ETCS operation without train protection system – Core Network
No ETCS operation without train protection system – Comprehensive Network

Figure 20: Reviewed ERTMS deployment plans by 2040 in EU27 + NO + CH

6. Recommendations

ERTMS can only bring the expected benefits if both trackside and onboard are deployed in a coordinated way.

Even though trackside deployment is progressing rapidly, onboard deployment is going slower than expected and new vehicles are not systematically fitted with ERTMS. Continuing this approach will undermine trackside deployment plans and the benefits of systemic ERTMS deployment overall.

The results of the analysis of the impacts of allowing exemptions show there is an economic rationale to further foster onboard deployment. Failure to achieve full onboard deployment by 2040 would prevent IMs to reap savings on legacy system maintenance cost, that represents around 940 M€ per year. Over the period considered, the financial impact would be of about 19,422 M€, the gap between scenario 1 and 3. But, even if the target of full onboard equipment by 2040 remains but EU legislation continues allowing exemptions for new vehicles, retrofitting vehicles before 2040 instead of directly fitting them will result in an additional equipment cost of 1,786 M€, as shows the comparison of scenario 2 and 3.

As demonstrated, not fitting new purchase vehicles has direct financial consequences on the overall rail system. Therefore, it is recommended to remove onboard deployment exemptions set out in the CCS TSI 2016/919/EC.

The outlook of ERTMS deployment also points out that trackside deployment targets of some Member States are more ambitious than EU legal deadlines. It appears that after 2040 less than 20% of the TEN-T Network will still require class B systems onboard.

In line with national strategy, EU should review the trackside deployment legislation to move forward the most beneficial economic scenario at EU level. The remaining part of the network not equipped will prevent Member States and the industry to reap the full benefit from ERTMS. It appears reasonable to align the overall Comprehensive Network deployment with the wider EU deployment and bring forward the expected deadline for ERTMS deployment on the Comprehensive Network to 2040.

To go even beyond, setting a deadline for decommission – as some Member States have already done - should also be considered. Its economic outcome would be legacy system maintenance savings of around 544 M€/year on the Core Network 529 M€/year on the Comprehensive Network, savings have only been considered for the Member States that have not set a deadline for decommission. Beyond savings on maintenance costs, it would also contribute to consolidate ERTMS trackside and onboard deployment.

In order to set the optimal economic way to achieve the EU and national plans of ERTMS deployment objectives and to reap the expected ERTMS benefits, it should be considered to:

1- **Remove from EU legislation the possibility to claim for exemptions to put new vehicles in operation without ERTMS, which correspond to the scenario 3 of the analysis of the impacts of exemptions;**

2- **Shorten the deadline for deploying the Comprehensive Network from 2050 to 2040, to align it with national plans of most of the EU Member States;**

3- **Add decommissioning deadlines, in order to make sure that Member States and all railway stakeholders reap the expected benefits from ERTMS as soon as possible.**

7. Annex

7.1. Annex 1 – Trackside and onboard requirements

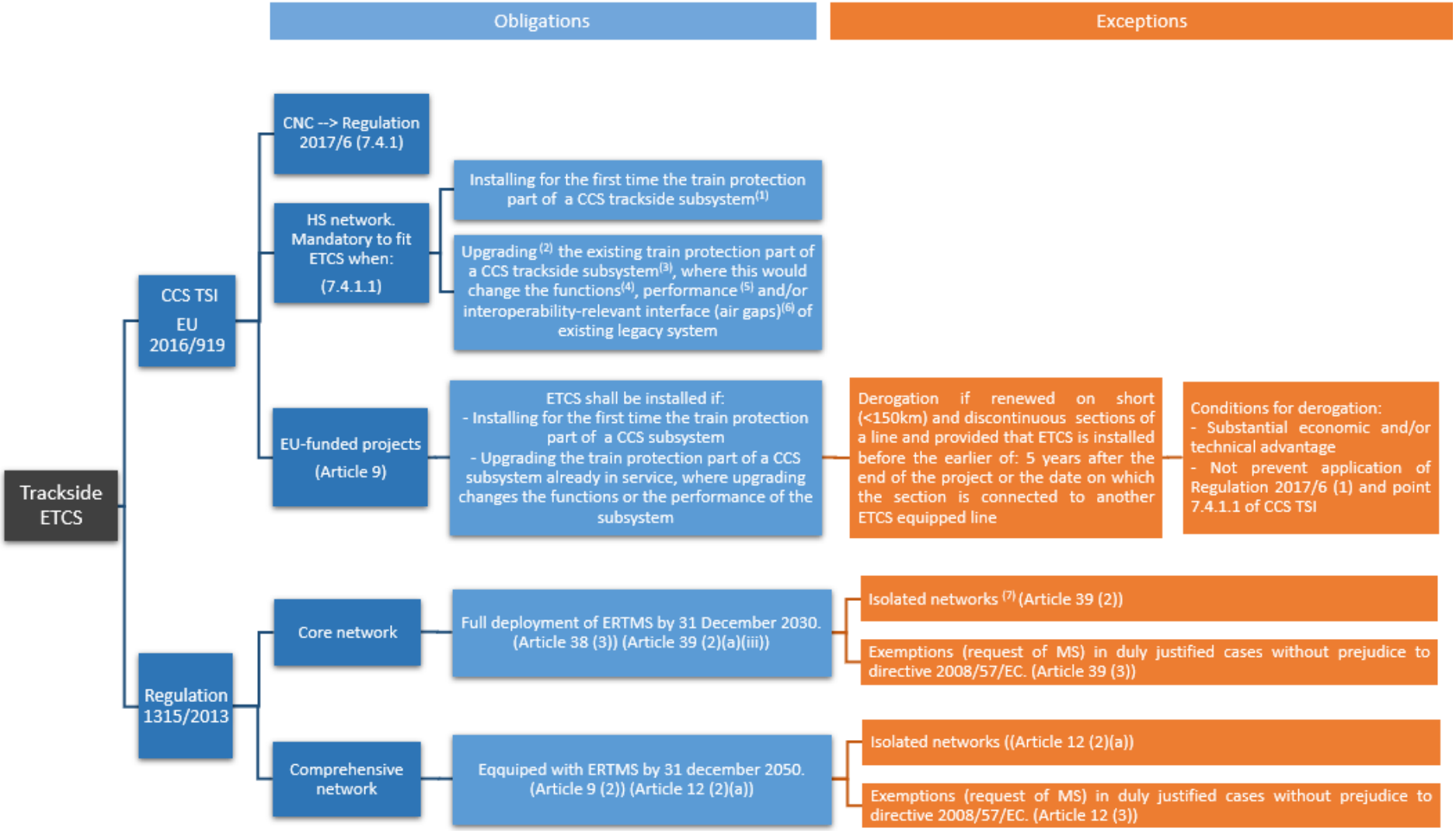


Figure 21 : Trackside ERTMS – EU obligations and exceptions

(1) *Note: Only in case of installing for the first time the train protection part of a CCS trackside subsystem, which excludes installing for the first time the radio communication or the train detection part of the CCS trackside subsystem or other subsystems than the CCS trackside subsystems. Being the definition of trackside CCS according to the Directive 2016/797 as follow: "All the trackside equipment required to ensure safety and to command and control movements of trains authorised to travel on the network."*

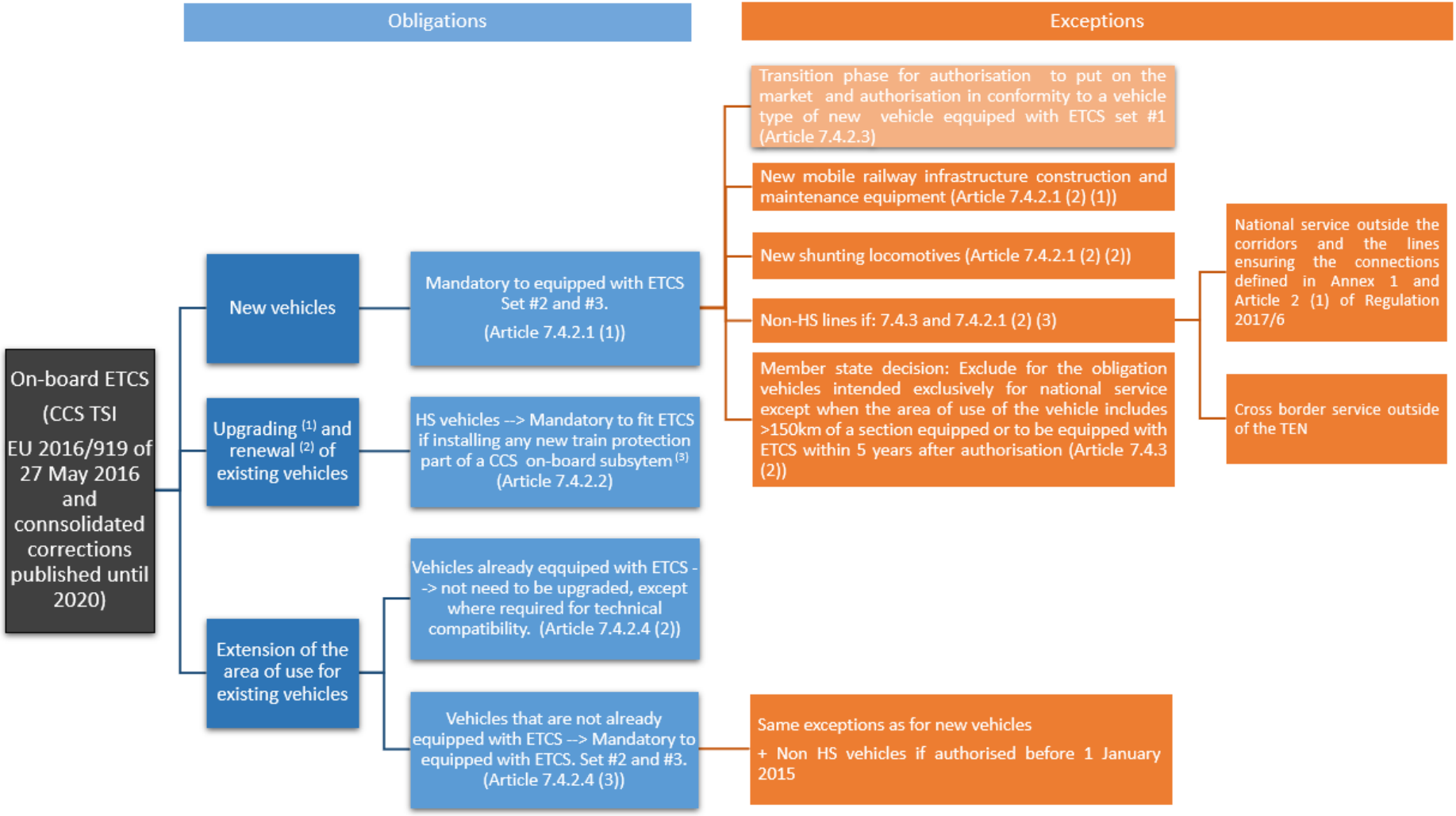
(2) *'Upgrading' means any major modification work on a subsystem or part of it which results in a change in the technical file accompanying the 'EC' declaration of verification, if that technical file exists, and which improves the overall performance of the subsystem. (Article 2 Directive 2016/797*

(3) *Note: Only in case of upgrading the train protection part of a CCS trackside subsystem, which excludes installing for the first time the radio communication or the train detection part of the CCS trackside subsystem or other subsystems than the CCS trackside subsystems.*

(4) *Airgap "means the set of interfaces between track and train. (Subset -023 v3.3.0)*

(5) *'isolated network' means the rail network of a Member State, or a part thereof, with a track gauge different from that of the European standard nominal track gauge (1 435 mm), for which certain major infrastructure investments cannot be justified in economic cost-benefit terms by virtue of the specificities of that network arising from its geographic detachment or peripheral location.*

Figure 22: Onboard ERTMS – EU obligations and exceptions

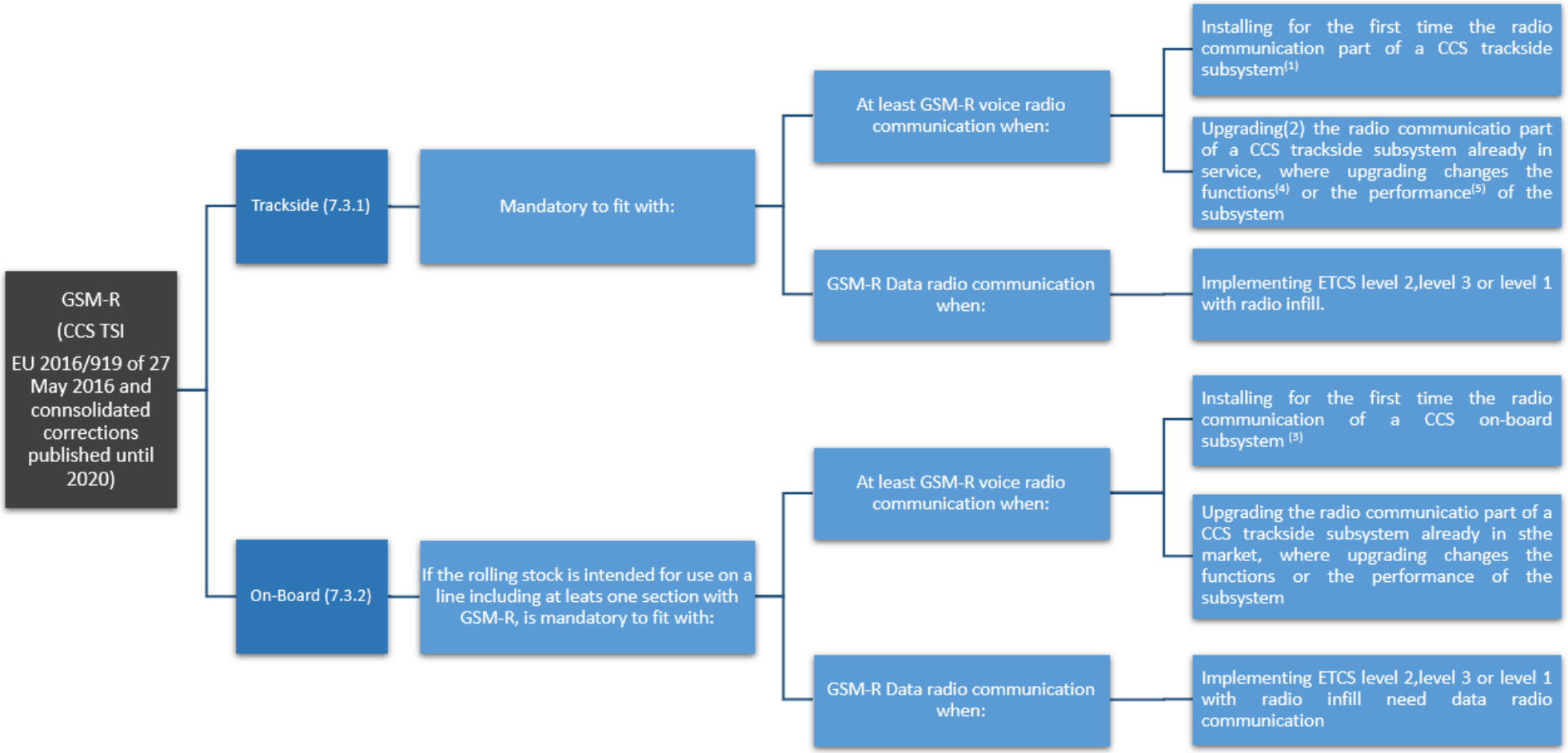


(1) 'Upgrading' means any major modification work on a subsystem or part of it which results in a change in the technical file accompanying the 'EC' declaration of verification, if that technical file exists, and which improves the overall performance of the subsystem. (Article 2 Directive 2016/797)

(2) *'Renewal' means any major substitution work on a subsystem or part of it which does not change the overall performance of the subsystem; (Article 2 Directive 2016/797)*

(3) *Note: Only in case of installing a new train protection part of a CCS on-board subsystem, which excludes upgrading and renewal in the radio communication part of the CCS on-board subsystem or other subsystems than the CCS on-board subsystem. Being the definition of On-board CCS according to the Directive 2016/797 as follow: "All the on-board equipment required to ensure safety and to command and control movements of trains authorised to travel on the network."*

Figure 23: Trackside and onboard GSM-R – EU obligations



(1) *Note: Only in case of installing for the first time the radio communication part of a CCS trackside subsystem, which excludes installing for the first time the train protection or the train detection part of the CCS trackside subsystem or other subsystems than the CCS trackside subsystems. Being the definition of trackside CCS according to the Directive 2016/797 as follow: "All the trackside equipment required to ensure safety and to command and control movements of trains authorised to travel on the network."*

(2) *"All the on-board equipment required to ensure safety and to command and control movements of trains authorised to travel on the network"*

(3) *'Upgrading' means any major modification work on a subsystem or part of it which results in a change in the technical file accompanying the 'EC' declaration of verification, if that technical file exists, and which improves the overall performance of the subsystem. (Article 2 Directive 2016/797*

(4) *Note: Only in case of installing for the first time the radio communication part of a CCS on-board subsystem, which excludes installing for the first time the train protection of the CCS on-board subsystem or other subsystems than the CCS on-board subsystems*

7.2. Annex 2 - Overview of the business case

It is important to remind the main assumptions of the business case[31], which is the tool for comparison between different deployment strategies and approaches.

7.2.1. Deployment strategy

As presented on the Business Case Report, two main strategies can be clearly identified:

- The **dual trackside migration strategy.** In this strategy the lines are equipped with both legacy system and ERTMS, keeping the legacy system functioning until every locomotive is equipped with ERTMS. In this strategy, no special efforts are made for the on-board deployment, which is done just by the "natural replacement" of the fleet, due to obsolescence of non-equipped rolling stock and the obligation to equip all newly purchased locomotives as of 2015 without exemptions. In the worst-case scenario, all the rolling stocks purchased before 2015 are not equipped. In this case, the full on-board deployment of ERTMS will not be possible before the renewal of the most-recent non-equipped locomotive, purchased in 2014. Based on the standard lifetime for railway equipment, this transition will make the year 2045 the first year in which all the fleet will be equipped with ERTMS. While benefits can be achieved even before a full deployment of the fleet (the threshold is assumed to be 90 %), these benefits cannot be fully achieved before 2045.
  However, the assumption that all new vehicles from 2015 were to be equipped has not been met. As explained in §3.3.1, all new vehicles put in service after 2015 are not equipped with ERTMS relying on exemptions.

- The **dual onboard migration strategy**. In this strategy, the focus is put on equipping the fleet with ERTMS on top of the legacy system on a given time span (12 years starting from and including 2019, which is the first year of expected availability for baseline 3). All vehicles that are not renewed during this time span have to be retrofitted. As soon as the whole fleet is equipped (by the end of 2030), IMs can deploy ERTMS instead of their legacy system rather than on top of it. Thus, while the dual onboard migration strategy includes more costs (on-board deployment) than the dual trackside, it also brings two advantages compared to the other strategy:
  - Operational benefits thanks to a full ERTMS system are achieved earlier.
  - Savings on the renewal of legacy system when fleet is deployed before infrastructure. Due to the deployment duration, this benefit is equal to zero in the business case, as both fleet and infrastructure are only expected to be deployed in 2030. But it can be an incentive for a faster paced for on-board deployment.

[31] DG Move EC. 2019. ERTMS business case on the 9 core network corridors – Second Release

7.2.2. Perimeter

The assessment is carried out on 25 countries (23 countries of the EU and 2 countries of EFTA):

Austria	**Denmark**	**Hungary**	**Netherlands**	**Slovenia**
Belgium	**Estonia**	**Italy**	**Poland**	**Spain**
Bulgaria	**France**	**Latvia**	**Portugal**	**Sweden**
Croatia	**Germany**	**Lithuania**	**Romania**	**Switzerland**
Czechia	**Greece**	**Luxembourg**	**Slovakia**	**Norway**

Some EU countries have been excluded from the business case because of the specificities of their railway network, which is isolated or not existing (Finland, Malta, Cyprus and Ireland).

In order to assess the onboard deployment strategy costs and benefits, four input data are used for each country:

- The fleet of the country;
- The number of rolling stock unit operating on TEN-T corridors;
- The number of rolling stock currently (as of 2015) equipped with ERTMS;
- The number of rolling stock units per country which will be aged less than 30 years before 2030. This information is calculated from the full age distribution of the rolling stock.

As it has been impossible to collect reliable data on the rolling stock operating on TEN-T corridors, assumptions have been applied.

For France, Spain and Poland, it has been considered that a part of the fleet can be operated without going through the Core European Network. For these countries, it is assumed that 60% of the fleet does not operate on the Core Network and, thus, be exempted from ERTMS deployment needs.

7.3. Annex 3 - Costs and benefits between 2030 and 2060

The breakdown of costs and savings considered in each are scenario are:

		Scenario 1 – no change	Scenario 2 – exemptions not removed but vehicles are equipped before 2040	Scenario 3 – exemptions removed and vehicles are equipped before 2040
Exemptions		Not removed	Not removed	Removed in 2023 (effective)
Costs	**Fitment**	Between 2015 – 2045	Between 2015 - 2040	Between 2015 – 2040
	Retrofitting	No retrofitting	Between 2031 and 2040 (vehicles renewed and not equipped -– exempt - and vehicles to be renewed between 2040 and 2045)	Between 2031 and 2040 (vehicles renewed and not equipped -– exempt - and vehicles to be renewed between 2040 and 2045)
	Legacy system maintenance	Maintenance costs for IMs: - On Core Network between 2041 and 2060 - For Member States with class B decommission plans, maintenance cost of the whole national network between the decommission year and 2060	No legacy system maintenance costs for IMs	
Savings		No savings for IMs	Savings of maintenance costs for IMs: - On Core Network between 2041 and 2060 - For Member States with class B decommission plans, maintenance cost of the whole national network between the decommission year and 2060	

Fitting costs

The fitment cost for L2 which has been used is **100 k€$_{2015}$ / unit**.

Retrofitting costs

The costs of retrofitting include ERTMS equipment and installation costs, testing and authorization and unavailability of the vehicle. The retrofitting costs are supposed to decrease in the next years, since technical standards focus on further facilitating the integration of ERTMS into a vehicle.

The following figure presents the assumption of the evolution of retrofitting costs during the considered period. It is supposed that over the years the cost will decrease in constants euros from 445,5 k€$_{2015}$/unit in 2018 to 297 k€$_{2015}$/unit in 2026 and then will remain constant.

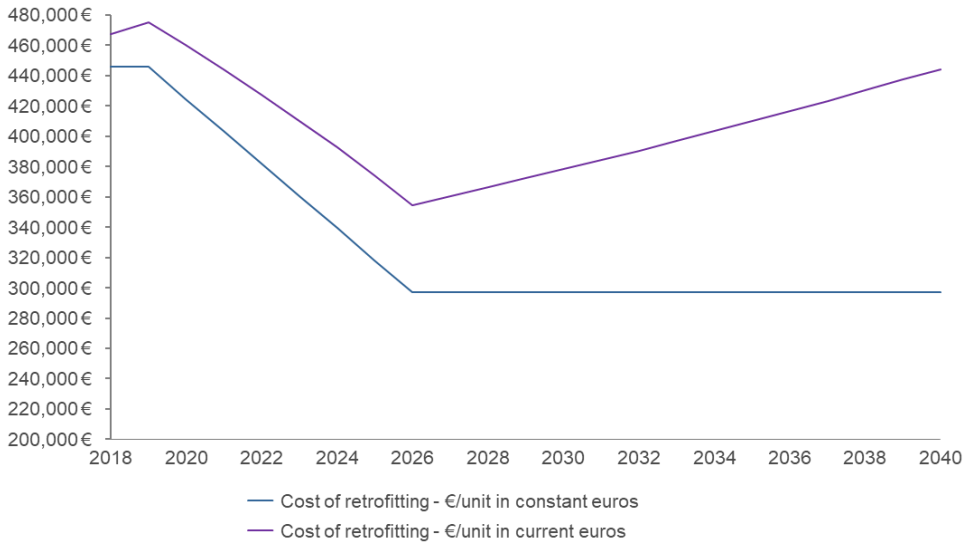


Figure 24: Evolution of cost of retrofitting (€/unit)

ERTMS equipment over-costs due to obsolescence

Some of the components of ERTMS on-board units will certainly face some obsolescence issues before 2040. However, it is difficult to identify which component would be obsolete, by when, and what could be the cost of the new component. Therefore, it is not possible to assess properly the impact of obsolescence on ERTMS on-board.

Moreover, if over-costs of ERTMS due to obsolescence was considered in the assessment, the same should be done for class B systems. The deployment of ERTMS will accelerate the obsolescence of class B systems as suppliers might not be willing to produce them anymore. Keeping the capabilities to maintain a given class B system might become more and more expensive.

Considering those facts, it is not possible today to estimate whether ERTMS obsolescence costs will be higher than legacy system obsolescence costs and, therefore, in the comparison of scenarios, these costs are not considered.

Onboard dual system maintenance over-costs

The assessment does not consider the costs of maintaining two signalling systems onboard until the class B system is decommissioned.

Stakeholders interviewed for ERTMS business case[32] listed those costs as marginal, therefore they are expected to have a marginal impact on the results of the assessment.

Onboard ERTMS upgrade costs

In the ERTMS business case, the costs of ERTMS upgrades were considered in the analysis. Two categories of upgrades were considered:

- Upgrades to move ERTMS units put in operation before 2019 from Baseline 2 or pre-Baseline 2 to Baseline 3
- Later upgrades due to future changes in the specifications. The cost of this upgrade is estimated at 50 k€2015/fleet unit. The assumption used was to consider an upgrade every 10 years, starting in 2031. Upgrade costs were not considered anymore when class B systems were becoming obsolete: at this point in time, class B systems would also require an upgrade, therefore there would not be additional costs in the situation with ERTMS compared with the situation without ERTMS.

For the assessment presented in this report, the upgrades from Baseline 2 or pre-Baseline 2 to Baseline 3 are considered in all scenarios.

For the other upgrades, it was decided to neglect those costs as:

- The gap in ERTMS on-board deployment between S1, S2 and S3 is not so significant
- The obsolescence of class B systems at national level should also be considered, which complexifies the calculation for an impact expected to be limited

This assumption has been validated through a sensitivity analysis carried out to estimate the impact of upgrade costs on the different scenarios (see annex 4).

Trackside dual system maintenance over-costs

While all vehicles are not equipped with ERTMS, Infrastructure Managers still have to maintain their legacy systems. When the trackside is equipped with ERTMS, Infrastructure Managers also bear the cost of trackside ERTMS maintenance.

The assumptions for maintenance costs used in the business case are based on the national values when available, and default values when no national values were provided by stakeholders.

[32] DG Move EC. 2019. ERTMS business case on the 9 core network corridors – Second Release

By default, the trackside legacy system maintenance cost per year considered is **4 100 €$_{2015}$/km-line**.

Once all the fleet is equipped with ERTMS, Infrastructure Managers can decommission their legacy system and deploy ERTMS instead of renewing their class B system which brings benefits to IMs (trackside legacy system maintenance savings).

7.4. Annex 4 – Results of the analyses of the impacts of allowing exemptions per scenario

7.4.1. Scenario 1 – no changes

Foreseen yearly number of vehicles renewed between 2015 and 2045

This scenario assumes the exemptions are not removed and vehicles exempt are not equipped with ERTMS before 2060.

The figure below shows the difference between the number of vehicles renewed[33] and equipped with ERTMS in the situation where there is no exemption and the scenario considered. If 35% of the fleet renewed request an exemption, only 20,979 renewed vehicles are equipped with ERTMS before 2040.

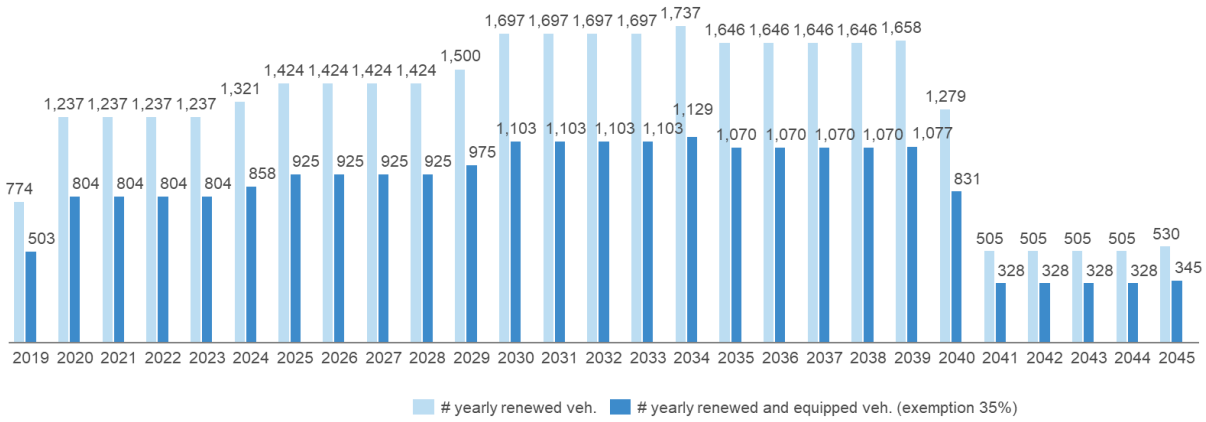


Figure 25: Yearly number of vehicles renewed and vehicles renewed and equipped with ERTMS between 2015 and 2045 (exemption of 35% until 2045)[34]

The number of vehicles equipped with ERTMS vary according to the assumption on the number of vehicles benefitting from an exemption.

Exemption ratios	Renewed and equipped vehicles between to 2015 – 2040	Remaining fleet not equipped
25%	24,207	9,845
35%	20,979	13,073
45%	17,752	16,300

Figure 26: Scenario 1 - # of vehicles renewed and equipped with ERTMS between 2015 and 2040 and remaining fleet not equipped (following three different exemption ratios)

[33] The forecast renewal of vehicles is based on 30 years life cycle per vehicle.
The business case calculator uses a database that provides the fleet per country and per segment (freight, high speed and passenger) and per age group (5 years). The business case calculator considers that the fleet is linearly distributed per age period.
[34] The business case calculator considers a deployment ramp-up period for fitment of new vehicles. Thus, it is assumed that before 2018 vehicles put in service are not equipped with ERTMS.

The figures below present the main results of scenario 1. In this scenario, the vehicles exempt of ERTMS equipment are retrofitted after 2060, thus there are no retrofitting costs considered in the calculation. However, there is no savings on legacy system maintenance costs. IMs have to maintain both Class-B and ERTMS systems until 2060.

- **Impacts on on-board costs (fitment and retrofitting costs)[35]**

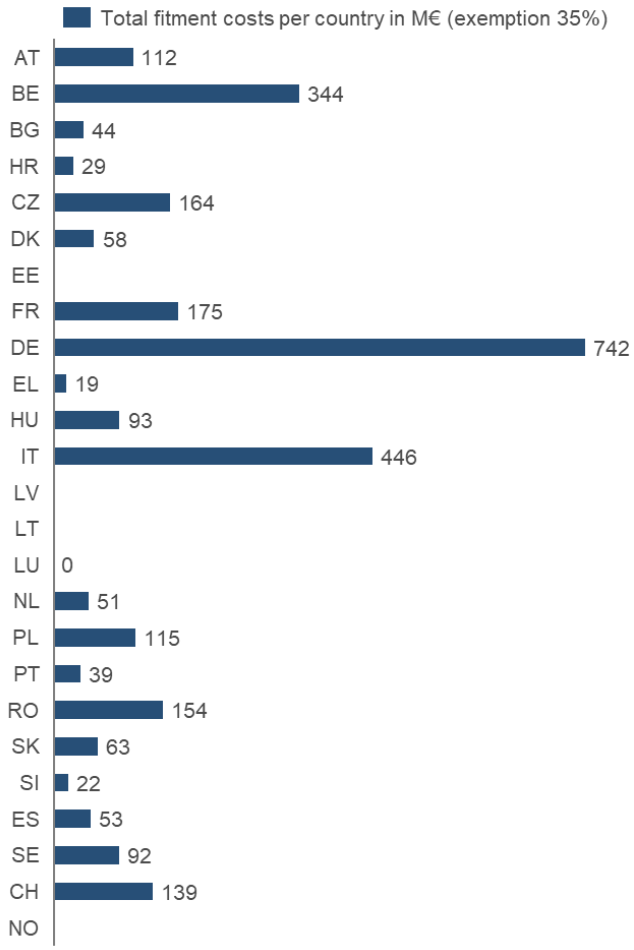


Figure 27: Scenario 1 – Fitment costs per country (M€)[36] – exemption 35%

Country	Scenario 1 – Exemption rates		
	25%	35%	45%
AT	129	112	95
BE	397	344	291
BG	50	44	37
HR	33	29	24
CZ	189	164	138
DK	67	58	49
EE			
FR	202	175	148
DE	857	742	628
EL	22	19	16
HU	108	93	79
IT	515	446	377
LV			
LT			
LU	-	-	-
NL	58	51	43
PL	133	115	98
PT	45	39	33
RO	178	154	130
SK	73	63	53
SI	25	22	18
ES	61	53	45
SE	107	92	78
CH	161	139	118
NO			
TOTAL	3 409	2 954	2 500

Figure 28: Scenario 1 – Fitment costs per country (following three different exemption ratios)

[35] The total fitment costs per country following the exemption rate are estimated by applying the following formula: Fitment costs (€) = Exemption rate * Fitment costs per vehicles (€/vehicle) * Vehicles to be fitted
[36] See Annex 3.

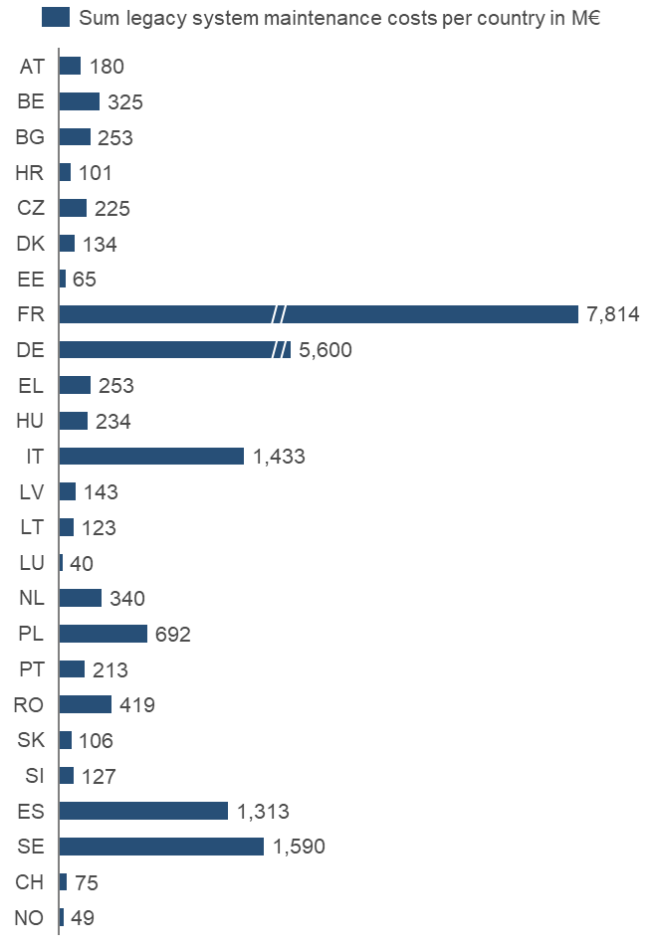
- **Impacts on track-side costs**

In this scenario, vehicles are not equipped with ERTMS before 2060, decommissioning Class B system is therefore not possible by 2040 (when a large part of the Comprehensive Network – and even beyond – is expected to be equipped with ERTMS) and IMs cannot reap the benefits of the decrease of maintenance costs before 2060.

The economic impact is the total cost ("sum") of:

- The legacy system maintenance costs on the Core Network between 2041 – 2060;
- The legacy system maintenance costs on the Comprehensive Network and beyond for the Member States that have planned to equip their full network, the period considered is between the decommission year and 2060.

The Net Present Value of the annual legacy system maintenance costs is also presented here below, the rate considered is 8% (rate applied in European projects)



Country	S1 – Legacy system maintenance costs (2041 – 2060)	
	Sum	NPV (8%)
AT	180	85
BE	325	153
BG	253	120
HR	101	48
CZ	225	106
DK	134	63
EE	65	30
FR	7 814	3 685
DE	5 600	2 641
EL	253	119
HU	234	110
IT	1 433	676
LV	143	67
LT	123	58
LU	40	19
NL	340	160
PL	692	326
PT	213	101
RO	419	198
SK	106	50
SI	127	60
ES	1 313	619
SE	1 590	750
CH	75	36
NO	49	23
TOTAL	**21 848**	**10 304**

Figure 29: Scenario 1 – Legacy system maintenance costs between 2041 - 2060[37]

In total, the onboard costs in the situation where the exemption is not removed and no retrofitting is expected are:

Exemption ratios	Total cost in M€ (fitment and legacy system maintenance costs)
25%	25,257 M€
35%	24,802 M€
45%	24,348 M€

Figure 30: Scenario 1 – Fitment and legacy system maintenance costs (following three different exemption ratios)

[37] Analysis of the DG Move EC. 2019. ERTMS business case on the 9 core network corridors – Second Release Confidential data that cannot be shared in this report.

7.4.2. Scenario 2 – exemption is not removed and vehicles are equipped between 2031 and 2040

Foreseen yearly number of vehicles renewed between 2015 and 2040

The EU legal target date for onboard deployment in the Core Network is 2030 and in the Comprehensive Network is 2050. However, according to national deployment plans by 2040, a large part of the Comprehensive Network – and even beyond – is expected to be equipped with ERTMS, and class B system decommissioned. If the whole EU fleet is not equipped by then, full ERTMS benefits will not be achieved.

Therefore, this scenario considers that exemptions remain but with an ambitious target for full onboard equipment by 2040 (scenario 2), aligned with multiples national deployment and decommissioning plans. The new vehicles not equipped are retrofitted between 2030 and 2040.

The figure below shows the yearly number of new vehicles equipped and of retrofitted vehicles (which benefited from an exemption when they were put in operation). If 35% of the fleet renewed request an exemption, only 24,821 renewed vehicles would be equipped with ERTMS before 2040.

In this scenario, it is considered that 7,454 new vehicles are put in operation without ERTMS and have to be fitted 10 years later and that 1,776 vehicles to be renewed between 2040 and 2045 are retrofitted before 2040.

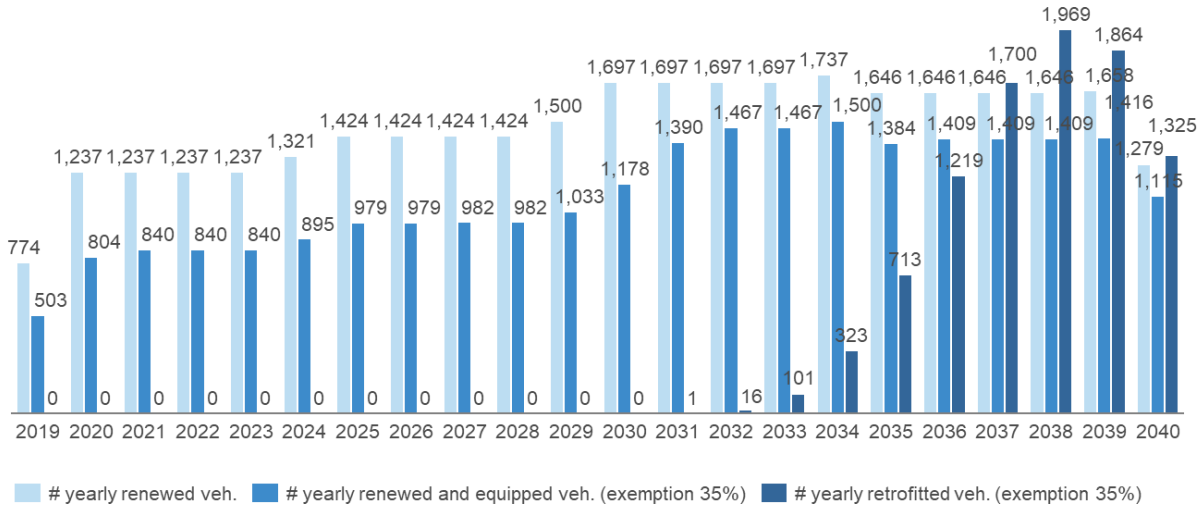


Figure 31: Yearly number of vehicles renewed, vehicles renewed and equipped with ERTMS between 2015 and 2040 and vehicles retrofitted between 2031 and 2040

The number of vehicles equipped with ERTMS vary according to the assumption on the number of vehicles benefitting from an exemption.

Exemption ratios	Renewed and equipped vehicles between to 2015 – 2040	Vehicles retrofitted between 2031 and 2040	Total
25%	26,951	7,101	34,052
35%	24,821	9,231	34,052
45%	22,691	11,361	34,052

Figure 32: Scenario 2 – Number of vehicles renewed and equipped with ERTMS between 2015 and 2040 and those retrofitted between 2031 and 2040 (following three different exemption ratios)

The figures below present the main results of scenario 2. Since the vehicles exempted of ERTMS equipment are retrofitted between 2023 and 2030, retrofitting costs are considered in this scenario.

Benefits can only be achieved with full deployment of the fleet therefore IMs have to maintain both systems until 2040. But from 2040 to 2060, IMs save maintenance costs of Class B systems thanks to decommissioning.

- **Impacts on the onboard costs (fitment and retrofitting costs)[38]**

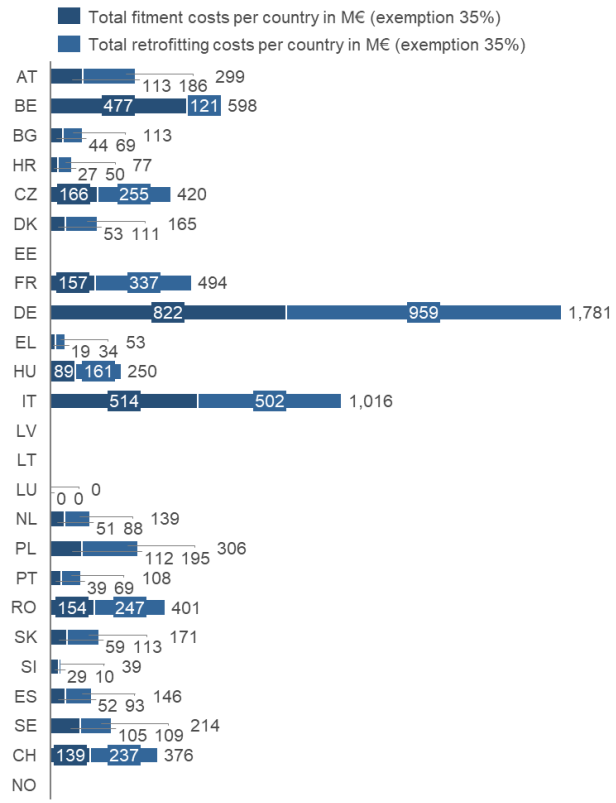


Figure 33: Scenario 2 – Fitment costs per country (M€)[39] – exemption 35%

Country	Scenario 2 – Exemption rates					
	25%		35%		45%	
	Fit.	Retro.	Fit.	Retro.	Fit.	Retro.
AT	130	129	113	186	95	243
BE	479	113	477	121	475	128
BG	50	47	44	69	37	92
HR	31	37	27	50	23	64
CZ	183	195	166	255	149	314
DK	61	84	53	111	45	138
EE						
FR	181	257	157	337	133	418
DE	861	819	822	959	783	1 100
EL	22	24	19	34	16	43
HU	102	116	89	161	75	207
IT	544	395	514	502	484	609
LV						
LT						
LU	-	-	-	-	-	-
NL	58	62	51	88	43	115
PL	129	136	112	195	95	253
PT	44	49	39	69	33	90
RO	177	168	154	247	130	327
SK	68	82	59	113	50	143
SI	30	7	29	10	29	13
ES	61	66	52	93	44	120
SE	111	87	105	109	99	130
CH	160	164	139	237	117	310
NO						
TOTAL	3 483	3 036	3 219	3 947	2 954	4 857

Figure 34: Scenario 2 – Fitment and retrofitting costs per country (following three different exemption ratios)

In total, the onboard costs in the situation where the exemption is not removed but retrofitting is applied are:

Exemption ratios	Total cost in M€ (fitment and retrofitting)
25%	6,519 M€
35%	7,166 M€
45%	7,812 M€

Figure 35: Scenario 2 – Fitment and retrofitting costs (following three different exemption ratios)

[38] The total fitment costs per country following the exemption rate are estimated by applying the following formula: Fitment costs (€) = Exemption rate * Fitment costs per vehicles (€/vehicle) * Vehicles to be fitted
The total retrofitting costs per country following the exemption rate are estimated by applying the following formula: Retrofitting costs (€) = Exemption rate * Retrofitment cost per vehicle (€/vehicle) * Vehicles to be retrofitted
[39] See Annex 3.

7.4.3. Scenario 3 – exemption is removed and vehicles are equipped between 2031 and 2040

Foreseen yearly number of vehicles renewed between 2015 and 2040

This scenario is similar to scenario 2, but this scenario assumes the exemption is removed in 2022 (effective in 2023). The new vehicles not equipped are retrofitted between 2030 and 2040.

The figure below shows the yearly number of new vehicles equipped and of retrofitted vehicles (which already benefited from an exemption when they were put in operation).

Based on the renewal forecast, if 35% of the fleet renewed request an exemption between 2015 and 2022, 1,496 renewed vehicles would not be equipped with ERTMS. In this scenario, it is considered that these new purchase vehicles are retrofitted between 2031 and 2040 and that 1,776 vehicles to be renewed between 2040 and 2045 are be retrofitted before 2040.

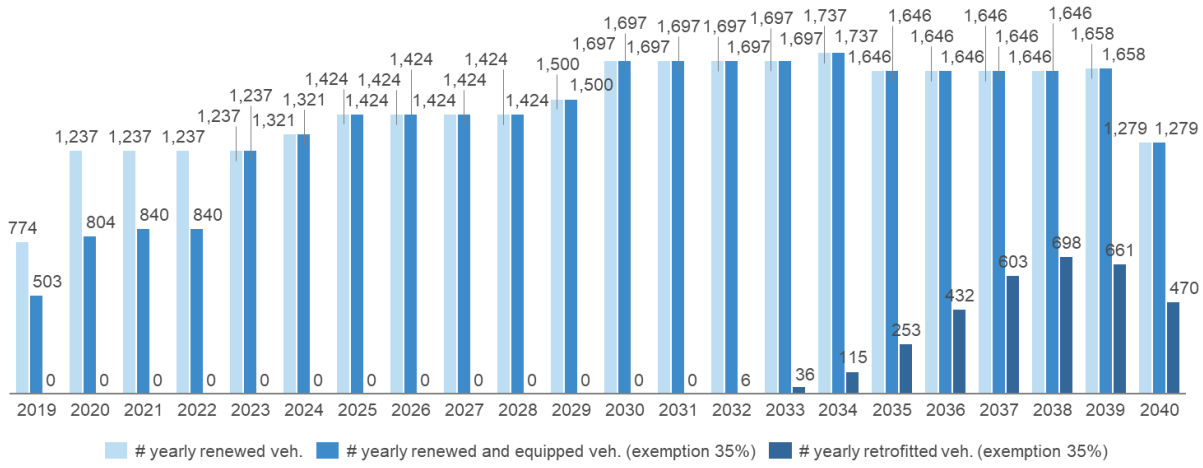


Figure 36: Yearly number of vehicles renewed and vehicles renewed and equipped with ERTMS between 2015 and 2040 and vehicles retrofitted between 2031 and 2030

The number of vehicles equipped with ERTMS vary according to the assumption on the number of vehicles benefitting from an exemption.

Exemption ratios	Renewed and equipped vehicles between to 2015 – 2040	Vehicles retrofitted between 2031 and 2040	Total
25%	31,207	2,845	34,052
35%	30,779	3,273	34,052
45%	30,352	3,700	34,052

Figure 37: Scenario 3 - Number of vehicles renewed and equipped with ERTMS between 2015 and 2040 and retrofitted (following three different exemption ratios)

The figures below present the main results of scenario 3. As in scenario 2, since the vehicles exempted of ERTMS equipment are retrofitted between 2023 and 2030, retrofitting costs are considered.

Benefits can only be achieved with full deployment of the fleet, therefore IMs have to maintain both systems until 2040. But from 2040 to 2060, IMs save maintenance costs of class B systems thanks to decommissioning.

- **Impacts on the onboard costs (fitting and retrofitting costs)[40]**

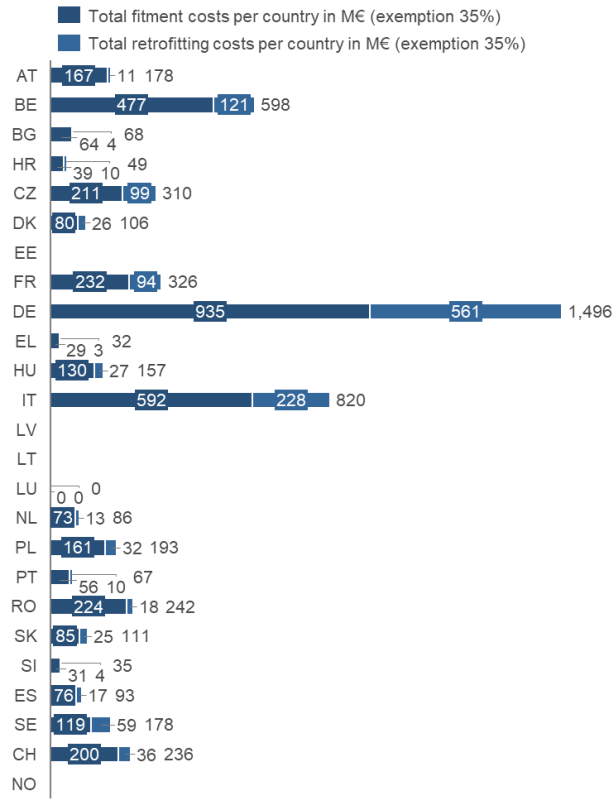


Figure 38: Scenario 3– Fitment costs per country (M€)[41] – exemption 35%

Country	Scenario 3 – Exemption rates					
	25%		35%		45%	
	Fit.	Retro.	Fit.	Retro.	Fit.	Retro.
AT	169	4	167	11	165	19
BE	479	113	477	121	475	128
BG	65	0	64	4	63	8
HR	40	7	39	10	39	12
CZ	215	84	211	99	207	115
DK	80	23	80	26	79	29
EE						
FR	234	84	232	94	229	105
DE	942	534	935	561	928	588
EL	29	2	29	3	28	4
HU	132	20	130	27	128	34
IT	599	199	592	228	585	257
LV						
LT						
LU	-	-	-	-	-	-
NL	75	8	73	13	72	18
PL	164	20	161	32	158	45
PT	57	7	56	10	55	14
RO	228	5	224	18	221	32
SK	87	20	85	25	84	31
SI	31	3	31	4	30	6
ES	77	11	76	17	74	22
SE	121	51	119	59	117	66
CH	204	21	200	36	196	51
NO						
TOTAL	4 028	1 216	3 981	1 399	3 934	1 582

Figure 39: Scenario 3 – Fitment and retrofitting costs per country (following three different exemption ratios)

[40] [40] The total fitment costs per country following the exemption rate are estimated by applying the following formula: Fitment costs (€) = Exemption rate * Fitment costs per vehicles (€/vehicle) * Vehicles to be fitted
The total retrofitting costs per country following the exemption rate are estimated by applying the following formula: Retrofitting costs (€) = Exemption rate * Retrofitment cost per vehicle (€/vehicle) * Vehicles to be retrofitted

[41] See Annex 3.

In total, the onboard costs in the situation where the exemption is removed and retrofitting is applied are:

Exemption ratios	Total cost in M€ (fitment and retrofitting)
25%	5,244 M€
35%	5,380 M€
45%	5,516 M€

7.4.4. Sensitivity analysis

A sensitivity analysis is carried out to assess the extra-cost of onboard ERTMS upgrade costs in scenario 2 and 3 compared to scenario 1.

The results of the sensitivity analysis are presented below:

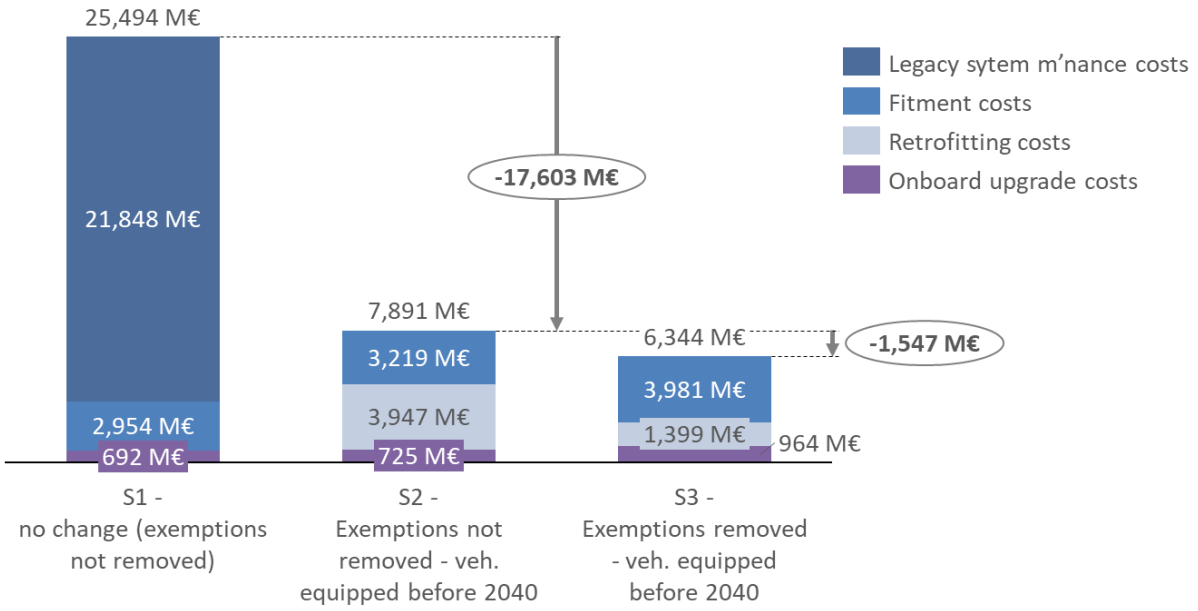


Figure 40 : Comparison of financial costs for the railway system of the different scenarios

As most vehicles are fitted before 2030 and retrofitting starts in 2031, the difference on the number of vehicles to be upgraded in the different scenarios is not significant. Therefore, the impact of upgrade costs are limited: it decreases the difference between scenario 1 and 2 by approximately 33 M€ and between 1 and 3 by approximately 272 M€.