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Finland's national implementation plan for the European Commission in 2017

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Finnish Transport Agency
P.O.Box 33
FI-00521 HELSINKI, Finland
Tel. +358 (0)29 534 3000

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Summary

The European Rail Traffic Management System (ERTMS) and the European Train Control System (ETCS) are technical solutions that the EU uses to promote its transport policy and the efficient use of transport and infrastructure with the help of information systems and market-based incentives. Another aim is to promote the deployment of intelligent transport systems developed with the help of funding from the EU. ERTMS/ETCS railway signalling solutions are due to be deployed across Europe, and European manufacturers also sell their solutions worldwide.

Railway safety, punctuality, economy and productivity are important aims for infrastructure managers. In addition to signalling control that ensures the safe routing of trains, the railway network needs a train control system that regulates the maximum speeds of trains. Each European country has had its own train control system, which has made it difficult for new operators to enter the market within the single European railway area. The ERTMS/ETCS system will also ultimately replace Finland's current ATC system and therefore remove barriers to entry.

This report contains Finland's national implementation plan for ERTMS deployment. It has been drawn up in accordance with the provisions concerning national implementation plans laid down in Commission Regulation (EU) 2016/919 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union and consists of a general and context description, including facts and figures on existing train protection systems, definitions of the technical migration strategy and the financial migration strategy both at infrastructure and rolling-stock side, and a description of the measures taken to ensure open market conditions for legacy Class B train protection systems. The plan also lays down the dates of ETCS deployment on the different lines of the network and the indicative dates of decommissioning of Class B systems on the different lines of the network. The accumulation of Finnish competence is an important step towards the deployment of the new system.

The Finnish ERTMS/ETCS implementation plan identifies funding as the biggest bottleneck in the deployment process, as both railway undertakings and infrastructure managers struggle to find funds for this purpose. In addition to the funds needed for ERTMS/ETCS trackside implementations, as much as EUR 1.1 billion will need to be invested in new signalling control devices during the same period. It is not financially viable for railway undertakings to invest more than EUR 200 million and for infrastructure managers to invest more than EUR 300 million in train control, which is why operators try to put these unprofitable investments back as far as possible. Securing national funding both for infrastructure managers' ERTMS/ETCS infrastructure and for railway undertakings' rolling stock investments is a key question that must be answered nationally before the system can actually be deployed in Finland.

Foreword

The need to compile this report arose in the spring of 2016, when it became known that a new European Commission Regulation would require Member States to submit national implementation plans for ERTMS/ETCS deployment in 2017.

The Finnish Ministry of Transport and Communications, the Finnish Transport Safety Agency and the Finnish Transport Agency decided that the Finnish Transport Agency would draw up the plan. The Finnish Transport Agency commissioned its track maintenance, technical systems and consultancy partners Proxion Plan Oy, Rejlers Oy and VR Track Oy to help compile the data, produce calculations and write up the plan. The text was finalised with the help of editing workshops and stakeholder consultations.

The following individuals contributed to the writing process or provided comments:

Juha Artukka	VR Group Ltd
Aki Härkönen	Finnish Transport Agency
Juha Inkilä	VR Group Ltd
Toni Jukuri	VR Track Oy
Ari Julku	VR Group Ltd
Hannu Lehikoinen	Fenniarail Oy
Jouni Lehmusto	VR Track Oy
Jussi Nieminen	Proxion Plan Oy
Lassi Matikainen	VR Track Oy
Pekka Myyrä	VR Group Ltd
Keijo Ristolainen	Proxion Plan Oy
Heidi Sunnari	Proxion Plan Oy
Markus Tuomi	Rejlers Oy

Other individuals from various organisations also helped with the planning and background work. The editor was Aki Härkonen. Senior Adviser Jari Gröhn from the Ministry of Transport and Communications put the finishing touches to the text.

Helsinki, September 2017

Finnish Transport Agency
Railway Network Maintenance

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1 Introduction

Directive 2008/57/EC of the European Parliament and of the Council concerns the interoperability of the rail system within the Community. Commission Regulation (EU) 2016/919 issued on the basis of the Directive obligates the Member States to draw up a national implementation plan, describing their actions to comply with the technical specification for interoperability (TSI), and send their plan to the Commission no later than 5 July 2017. The Regulation contains provisions on the contents of the national implementation plans and stipulates that they must run over a period of at least 15 years and be updated regularly, at least every five years.

Finland submitted its last national ERTMS deployment plan to the European Commission in 2007. The Finnish Transport Agency published a report to facilitate the scheduling of trackside and on-board installations and the making of funding decisions in 2014.

Transport authorities and railway operators began work on this plan in the spring of 2016. The Finnish Transport Agency, which is responsible for managing the Finnish rail network, presided over the work. The Finnish Transport Agency invited comments on the draft version of the plan in the spring of 2017.

No final decisions have been made regarding the schedules and funding discussed in this implementation plan. Delays in securing funding for trackside investments will also push back on-board investments. The final dates will be confirmed in subsequent revisions of the plan.

2 Current train control system

2.1 ATP system

The current Finnish automatic train protection (ATP) system consists of interoperable trackside and on-board devices. The system was installed across all the most important national rail lines between 1992 and 2009, but it will also be further extended in the 2020s. The system has been improved continuously during the twenty-odd years it has been in use, and its principles are well documented. (Finnish Transport Agency, 2014)

The system is known internationally as ATP-VR/RHK, which is the name used for it in technical specifications for interoperability relating to 'control-command and signalling' subsystems. The Finnish ATP system is a co-called Class B system, and it can remain in use until the end of its operational life, albeit only limited technical upgrades can be introduced to the system. Two different manufacturers, currently known as Ansaldo STS Sweden AB (trackside equipment) and Bombardier Transportation Finland Oy (on-board and trackside equipment), supply components for the system. In other words, all on-board equipment for the ATP system originates from one supplier, while there are two trackside suppliers.

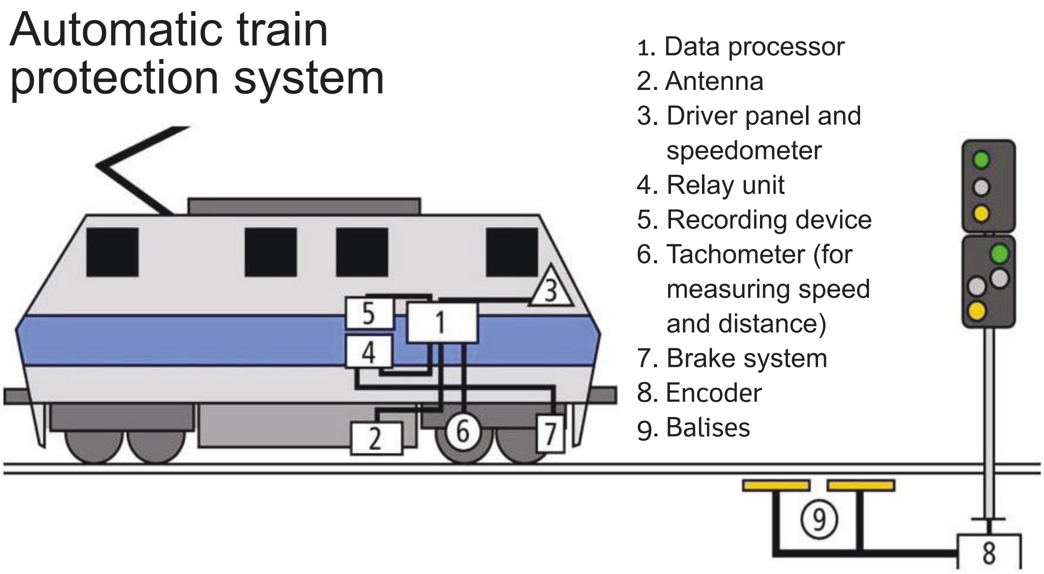


Figure 1 *On-board ATP components (Nos 1–7) and trackside components (Nos 8–9).*

The on-board and trackside components of the ATP system are shown in Figure 1. The trackside encoders are connected to signalling lamp circuits, from where they transmit the signalling aspect data to balises. The balises are powered by an on-board antenna, and they transmit messages to the on-board device, which makes the locomotive abide by signals.

On-board devices have been installed on approximately 700 items of rolling stock in Finland, and there are approximately 25,000 trackside balises. It has been more difficult to get ATP components since the end of the 2000s. Some of the trackside encoders of different suppliers are no longer available, although there are alternatives on the market. The availability of on-board ATP equipment has also decreased since the end of the 2000s.

2.2 ATP life cycle management plans for the 2020s and 2030s

The staggered deployment of the current ATP system is shown in Figure 2. The railway automation industry will not continue to support their old product families indefinitely. As the life cycle of the ATP system is coming to an end, there is no choice but to migrate to the ERTMS/ETCS, even if the new system is not necessarily an improvement compared to the current one. The new system needs to be deployed, as it is the only one that meets the requirements of long-term life cycle management with regard to several suppliers' reliable on-board and trackside equipment far into the 2020s and 2030s. Both infrastructure managers and railway undertakings need to adopt systematic life cycle management practices in respect of the system.

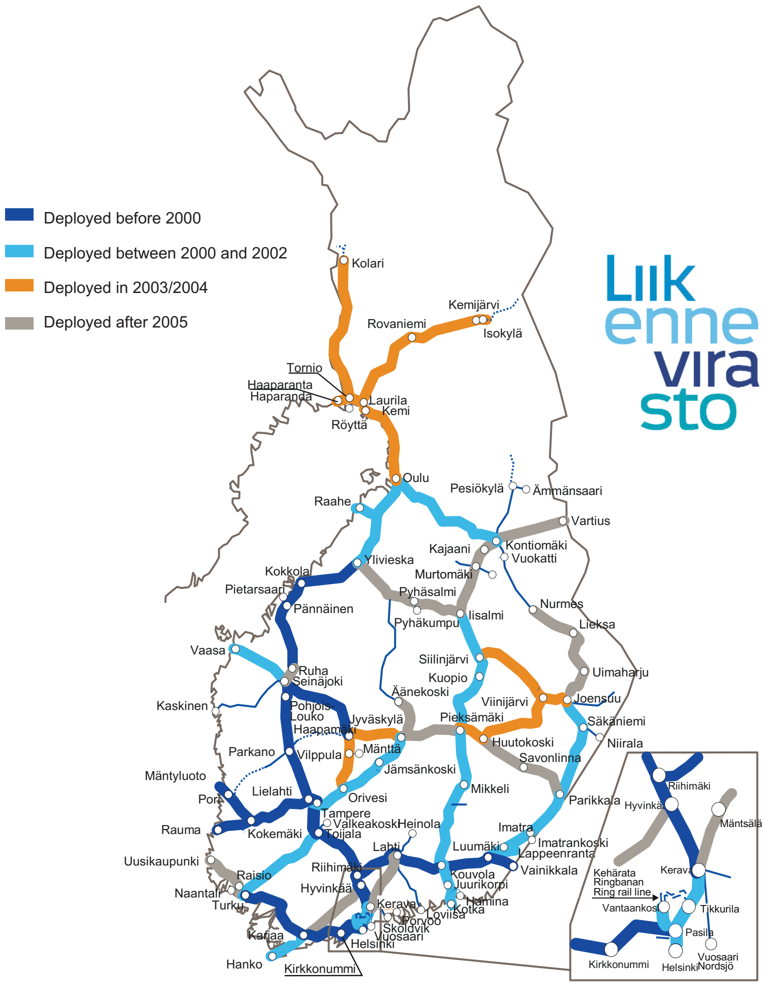


Figure 2 Staggered deployment of the current ATP system.

Infrastructure managers and railway undertakings need to take steps to ensure that replacing trackside ATP by trackside ETCS does not need to be carried out at too short a notice. The current system could become impractical due to the reduced availability of trackside equipment, the lack of trackside programming tools, the loss of knowhow and expertise relating to the system or other similar reasons. Being forced to migrate to the new system suddenly would result in considerable extra costs both with respect to track maintenance and the budgets of tractive stock owners and operators. It could also lead to considerable traffic and rolling stock turnaround limitations

It does not make sense to hurry ERTMS/ETCS deployment in Finland, as the national gauge means that the only cross-border services departing from Finland are to third countries. It is worth investing in the maintenance of the tried and tested ATP and waiting until the properties of the ERTMS/ETCS have become better suited to Finnish conditions. There is no point rushing the deployment of the new system, which is more expensive, less reliable and less well suited to Finland than the current one.

2.3 Cost-benefit analysis

Cutting costs is not the aim of ERTMS/ETCS deployment in Finland. Instead, the aim is to ensure that the safety and operability of the State-owned rail network can be kept at the present level. The ATP system will in any case need to be replaced in the future, and the ERTMS/ETCS is the only option available by law.

The ERTMS/ETCS is, in practice, the only system that is widely used in Europe and across the world that is capable of replacing the ATP system. Maintaining a system developed nationally in Finland beyond its natural life cycle is obviously not financially viable, when there is an option such as the ERTMS/ETCS, which is supplied by a number of manufacturers and has multiple users, and the components of which will be reliably available far into the future. As these products are only available from European railway signalling suppliers, and as all users must have these products, competition is not expected to lower the prices of the products to the level of products sold on freely competitive markets. The total costs of ERTMS/ETCS solutions are therefore likely to be considerably higher than those associated with old systems. What the market prices will be in the 2020s is difficult to predict.

Trains can also be driven without automatic train protection, and it is therefore possible to not migrate to a new train control system. The number of accidents resulting from speeding or passing signals at danger across the rail network would rise to the level that existed before ATP deployment. The rail accidents of Jokela in 1996 and Jyväskylä in 1998, for example, were largely due to non-existent train control. Of course, serious rail accidents are extremely rare, and there has only been one serious accident per decade in Finland on average, but ATP is largely to thank for the fact that there have been no serious passenger rail accidents in the 21st century. A high level of safety is a key starting point in terms of the appeal of rail transport and passenger rail transport in particular. Rail accidents often result in considerable material damage and personal injuries.

In today's safety culture, a train control system is an essential investment. The only practical alternative to train control in Finland is discontinuing transport operations along unprofitable sections of the track, as making a conscious decision to increase the risk of accidents by decommissioning the current system of railway signalling system would only be possible in exceptional circumstances. As a train control system can be seen as a mandatory standard requirement for modern railways, the purchase price of the ERTMS/ETCS must be examined as part of the total costs of rail transport.

The Finnish railway system will in any case require major investments over the next few years, if the current volume of transport is to be maintained. Interlocking systems have a limited lifespan and will eventually need to be replaced. Long-term funding and investment plans are needed in order to make the necessary investments in a successful and cost-effective manner. The Finnish transport authorities are not currently in a position to make binding decisions on funding for periods exceeding 10 years.

It can be estimated that the annual cost of maintaining the ERTMS/ETCS at level 1 would be at least as much as with the current ATP system. The costs would probably be higher, as the new system is more complex and as there are multiple trackside suppliers, which makes maintenance more complicated. On top of maintenance costs, there would also be additional costs from upgrades and software updates due to the ERTMS/ETCS being more complex than the current system. The rough investment cost estimates discussed below do not factor in maintenance costs.

3 Technical and financial migration strategies

3.1 Technical migration strategy / overlay on-board

3.1.1 On-board ERTMS/ETCS installations

On-board installations will be based on ERTMS/ETCS level 1 with an interface to the Specific Transmission Module (STM), with a possibility of level 2 on-board ERTMS/ETCS at a later date. The aim is to postpone the installations and the resulting costs as far into the future as possible. Rolling stock that is nearing the end of its operational life will not be fitted with the new system.

The State-owned railway company VR Group Ltd's Sr2 and Sr3 locomotives and Edo steering cars will be fitted with on-board ERTMS/ETCS+STM. Testing will be carried out for a period of two or three years on at least three classes of rolling stock before installations proper can begin. The aim of the tests will be to study trackside and on-board interoperability and to modify ERTMS functionalities where necessary and possible. After the tests have been completed, an invitation to tender can be drawn up and the procurement process begun.

VR Group Ltd will equip two Sr2 locomotives and two Edo steering cars for an ERTMS/ETCS pilot experiment in 2022. All new Sr3 (Vectron) locomotives will come with on-board ETCS+STM as standard, and there will therefore be no need to plan a separate installation schedule for them. It is estimated that approximately 50 Sr3 locomotives will have been commissioned by 2023. It should be noted that the on-board ETCS+STM software will need to be updated between 2023 and 2025, while the pilot line is being built. The aim of the software update is to ensure the interoperability of the final version of trackside ERTMS/ETCS (currently Baseline 3) with the on-board ERTMS/ETCS+STM installed on Sr3 locomotives.

The remaining Sr2 locomotives and Edo steering cars will be fitted with on-board ERTMS/ETCS+SMT from 2025 onwards. All Sr2 locomotives and Edo steering cars will have been fitted with the system by 2029.

The operating area of Sm3 trains and Dm12 locomotives as well as the potential modernisation and decommissioning schedule will need to be established by 2023. Sm3 trains will be fitted with the new system between 2026 and 2030, unless it is possible to impose restrictions on the use of the rolling stock instead. All Dm12 trains will have been fitted with the new system by 2030.

Sm4 and Sm5 trains will be fitted with on-board ETCS+STM between 2031 and 2037.

Sm6 trains, which are used on services to Russia, will only be fitted with on-board ETCS+STM once trackside ERTMS/ETCS installations begin on the Helsinki–Lahti–Kouvola–Luumäki–Vainikkala line.

The oldest classes of tractive stock, which are approaching the end of their operational life (Sr1, Sm2, Dv12, Dr14 and Dr16), will not be fitted with on-board ERTMS/ETCS+STM at all. The use of the ageing tractive stock will become more and more restricted as trackside ERTMS/ETCS installations progress.

3.1.2 Special characteristics of rail transport in Finland

ERTMS/ETCS technology factors in all aspects of European rail transport, but its current technical specifications lack some of the functionalities that are essential to rail transport in Finland. VR Group Ltd has identified a number of functional deficiencies in the ETCS, which complicate the use of the ERTMS/ETCS in Finnish rail transport and services to the east at the moment. If these deficiencies cannot be rectified, migrating to the ERTMS/ETCS would be a step down from the current level of transport efficiency and safety.

The following changes are needed to rectify the deficiencies:
- Dropping the minimum braked weight percentage to 10%
- Monitoring increases in brake line pressure during service braking
- Two-staged service braking
- Grip correction coefficients according to operating conditions
- New train classes for international trains

These have been compiled into official Change Requests (CRs) in 2017, which will be incorporated into the European ERTMS/ETCS change management process.

3.1.3 On-board assembly requirements

All new rolling stock placed in service on the Finnish rail network must be equipped with on-board ERTMS/ETCS+STM. On-board ATP can also be fitted on new classes of tractive stock, provided that it has type approval in Finland.

Once the construction of trackside ERTMS/ETCS begins, railway undertakings need to equip their tractive stock with on-board ERTMS/ETCS, if they want to operate on the modernised sections of the rail network.

The investment and authorisation costs of on-board ERTMS/ETCS are extremely high for classes of rolling stock that only consist of a single model. Equipping rolling stock used for track work and on heritage railways with the ERTMS/ETCS therefore does not make financial sense. Railway safety with respect to these vehicles, which will not have on-board ERTMS/ETCS, can be ensured by other means.

3.2 Technical migration strategy / overlay trackside

The schedule for trackside works has been designed on the basis of infrastructure construction. The schedule for ERTMS/ETCS construction takes into account the following factors:
- Critical traffic flows and key stations
- Interlocking compatibility
- Life cycles of interlocking systems
- Traffic control areas and interfaces
- Maintenance areas and geographical cohesiveness
- Potential use of ATP and ETCS side by side

The plan is to carry out the trackside ETCS installation process in a geographically cohesive manner from north to south. The construction schedule is divided into three-year periods. The staged and geographically cohesive approach makes it possible to take other engineering works and investment needs into account. The plan is to begin trackside installations in 2024 at the earliest and for the process to be completed by 2038. The availability of ATP parts may force the schedule to be accelerated.

The years 2020–2023 have been reserved for piloting ERTMS/ETCS construction. The pilot lines will be equipped with ATP and ETCS side by side in order to make transport operation easier and to ensure the performance of the track sections concerned. The track sections chosen for the pilot experiment can be deployed at the same time or gradually during the four-year piloting period. Deployment schedules will be determined on the basis of other track maintenance projects in the area, interlocking system installations as well as the stages and objectives of the pilot experiment.

ERTMS/ETCS deployment at individual stations and the possibility of running ATP and ETCS side by side will need to be decided separately for each station. Station-specific ERTMS/ETCS deployment plans will need to be drawn up in connection with more detailed deployment planning in each area. At least critical traffic flows, tractive stock sorting needs and the traffic control capacity of surrounding areas will need to be taken into account in station-specific solutions. The need to use ATP and ERTMS/ETCS side by side will be determined separately for each area of the rail network on the basis of customer demand, and recorded in more detailed deployment plans for each stage of the process. The exact dates when the ATP system will be decommissioned will be decided on the basis of the plans.

Stations will only be fully equipped with the ERTMS/ETCS once all the track sections connecting to each station have been fitted with the ERTMS/ETCS. The stations given in brackets in the pictures are stations that will not be fitted with trackside ERTMS/ETCS initially.

The schedule for ERTMS/ETCS construction can be decided in more detail on the basis of lessons learnt from construction works and test runs on the pilot lines. Some of the tracks where piloting will be carried out have interlocking systems that cannot be equipped with ERTMS/ETCS interfaces due to technological or financial reasons. On these track sections, ERTMS/ETCS piloting and deployment will also require changes to interlocking systems or new interlocking solutions.

Trackside ERTMS/ETCS construction will begin with intermittent ERTMS/ETCS level 1 train control technology. The possibility of using a continuous ERTMS/ETCS level 2 system on the rail network will be explored at stages 5 and 6. Most of the rail lines in southern Finland are double-track and heavily trafficked, which is why ERTMS/ETCS level 2 technology could bring slight improvements in track capacity in these areas. As ERTMS/ETCS level 2 requires new interlocking systems with Radio Block Centres as well as an interoperable data radio network, considerable extra investments will be needed to achieve benefits, the business viability of which will be explored at a later date.

3.2.1 First stage, piloting in 2020–2023

The first stage of trackside construction is called piloting, as its objective is to gain the first experiences of all stages of the construction process and its impact on transport operation. The necessary testing procedures, such as the ERTMS/ETCS test run vehicles, potential ERTMS/ETCS laboratories, etc., will need to be established before piloting can begin.

The aim of piloting is to assess the functioning of the system in general and at different speed limits, to encode trackside equipment in practice and to study the compatibility of the ERTMS/ETCS with existing interlocking systems of different makes and ages.

The pilot lines will be constructed in cooperation with two different ETCS suppliers. The technical implementation, technical standard and costs of the pilot lines can then be evaluated and the findings used to choose the supplier for the next stage.

The track sections shown in Figure 3 have been chosen for the pilot experiment on the basis of the following characteristics:

- Experiences of ETCS deployment in connection with the modernisation of interlocking systems (Tornio– Kolari, Rovaniemi–Kemijärvi)
- Geographical cohesiveness, as the whole area is governed by the same maintenance scheme and the same traffic control centre
- The interface in Oulu enables the necessary tractive stock procedures when moving from one train control system to another.

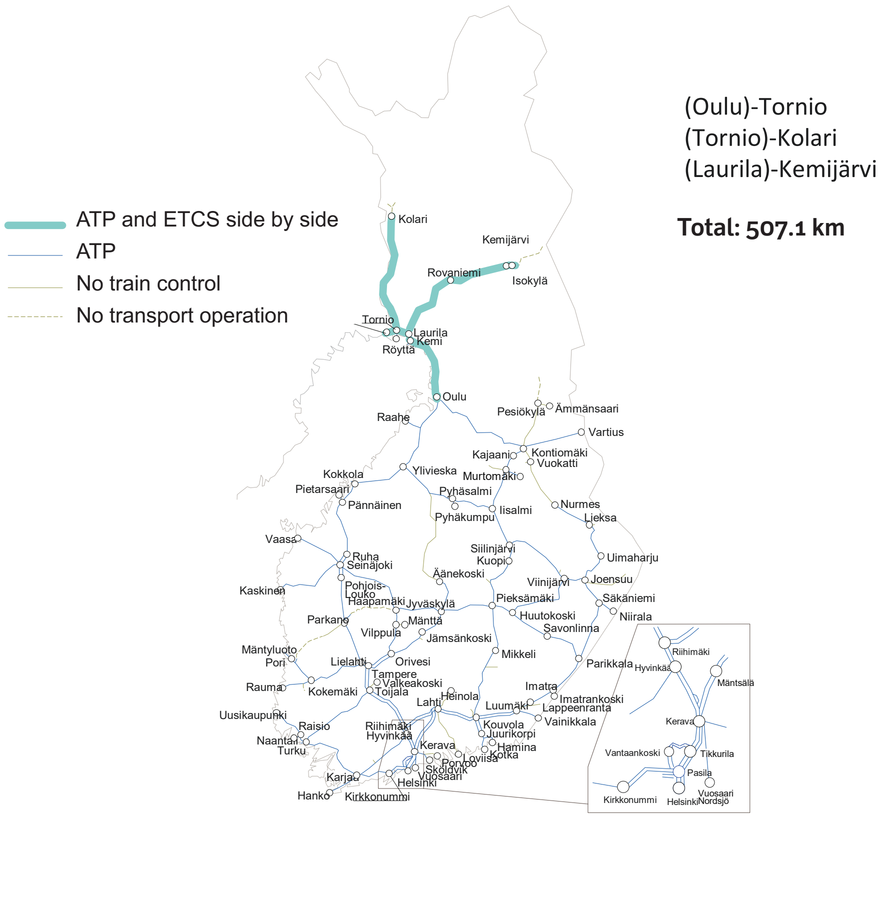


Figure 3 First stage of ERTMS/ETCS deployment, piloting in 2020–2023

3.2.2 Second stage, Vartius–Oulu–(Seinäjoki) in 2024–2026

The track sections to be commissioned during the second stage of trackside construction are well suited to being the first ERTMS/ETCS tracks without ATP due to the following characteristics:

- The Oulu traffic control area will be supplemented with the ERTMS/ETCS
- The Kokkola–Vartius line will be harmonised at the same time on the basis of critical traffic flows
- Interfaces in Seinäjoki and Iisalmi enable the necessary tractive stock procedures when moving from one train control system to another

The most important stations and junctions to be equipped with the ERTMS/ETCS during the second stage will be Oulu, Kontiomäki, Ylivieska and Kokkola. ATP will be decommissioned on the pilot lines during the second stage. At the end of the second stage, all sections of the Oulu traffic control area will run exclusively on the ERTMS/ETCS.

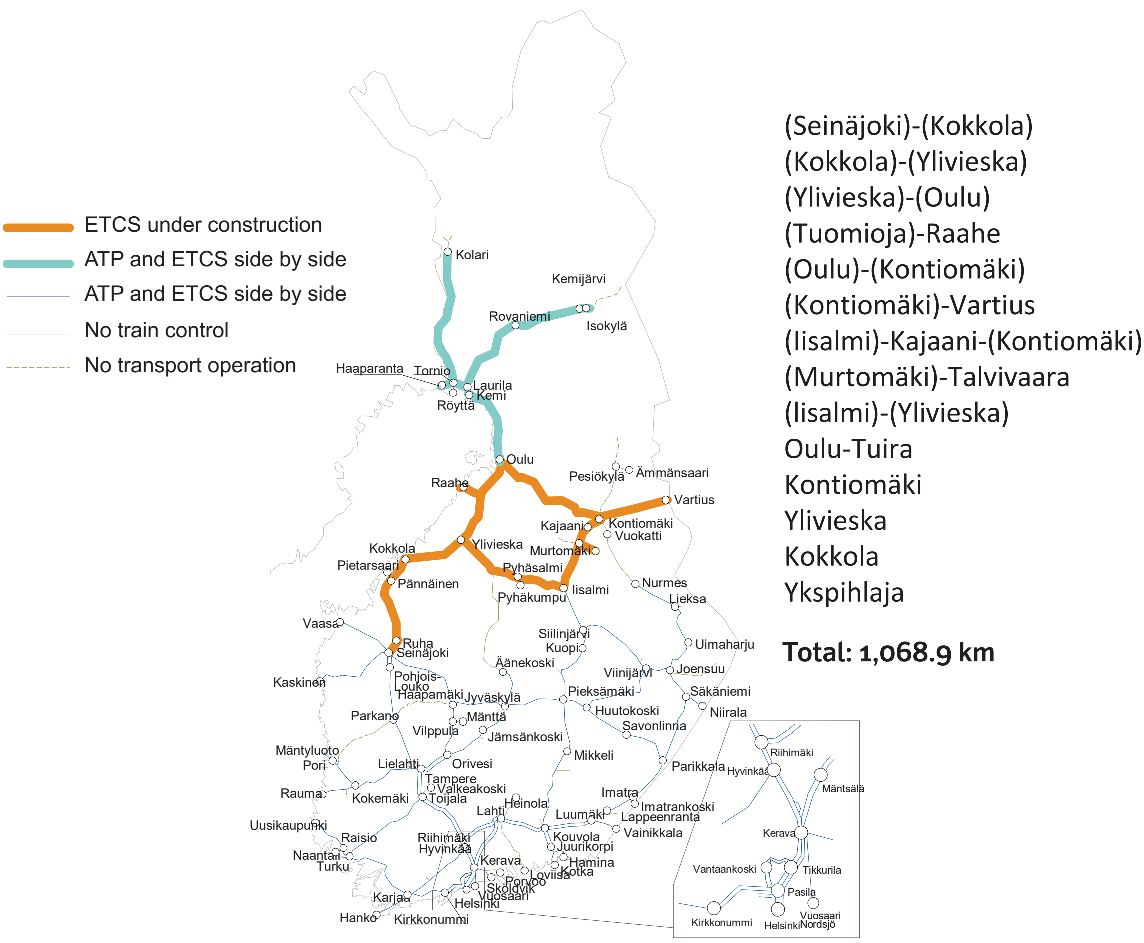
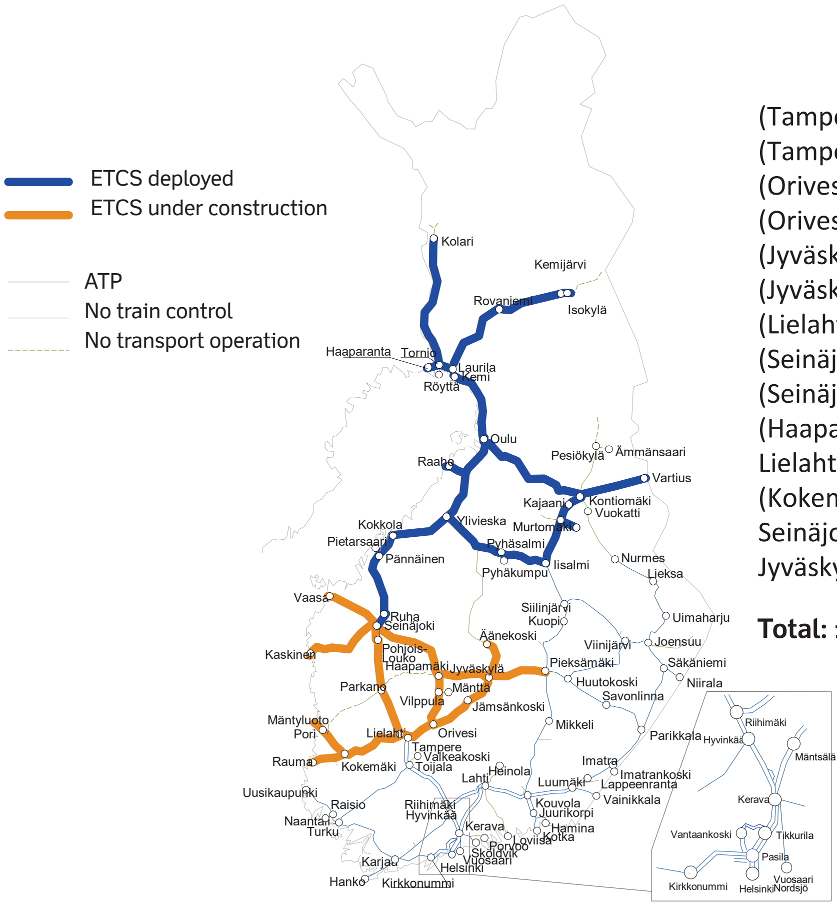


Figure 4 *Second stage of ERTMS/ETCS deployment, Vartius–Oulu–(Seinäjoki) in 2024–2026*

3.2.3 Third stage, western Finland in 2027–2029

The third stage of trackside construction will involve supplementing the heavily trafficked western Finland and harmonising the traffic control area with the ETCS. Interfaces in Tampere and Pieksämäki will enable the necessary tractive stock procedures when moving from one train control system to another. Most of the track sections that will be deployed during this stage are equipped with interlocking systems that are not directly compatible with ERTMS/ETCS interfaces. On these track sections, ERTMS/ETCS deployment will also require changes to interlocking systems or new interlocking solutions.

The most important stations and junctions to be equipped with the ETCS during this stage will be Seinäjoki and Jyväskylä.



(Tampere)-Orivesi
(Tampere)-(Lielahti)
(Orivesi)-(Jyväskylä)
(Orivesi)-Haapamäki-(Jyväskylä)
(Jyväskylä)-Äänekoski
(Jyväskylä)-(Pieksämäki)
(Lielahti)-(Seinäjoki)
(Seinäjoki)-Vaasa
(Seinäjoki)-Kaskinen
(Haapamäki)-(Seinäjoki)
Lielahti-Kokemäki-Rauma
(Kokemäki)-Pori-Mäntyluoto
Seinäjoki
Jyväskylä

Total: 1,161.5 km

Figure 5 Third stage of ERTMS/ETCS deployment, western Finland in 2027–2029

3.2.4 Fourth stage, eastern Finland in 2030–2032

The fourth stage of trackside construction will involve equipping eastern Finland with the ETCS. The southern interface of the area is at Luumäki station. This is to ensure the cohesiveness of the important Vainikkala–Kouvola–Kotka goods transport route. The ETCS modifications on the route in question will be implemented simultaneously during the fifth stage.

Most of the track sections that will be deployed during the fourth stage are equipped with interlocking systems that are not directly compatible with ETCS interfaces. On these track sections, ETCS deployment will also require new interlocking solutions.

The most important stations and junctions to be equipped with the ETCS during this stage will be Pieksämäki, Iisalmi, Parikkala, Joensuu and Imatra.

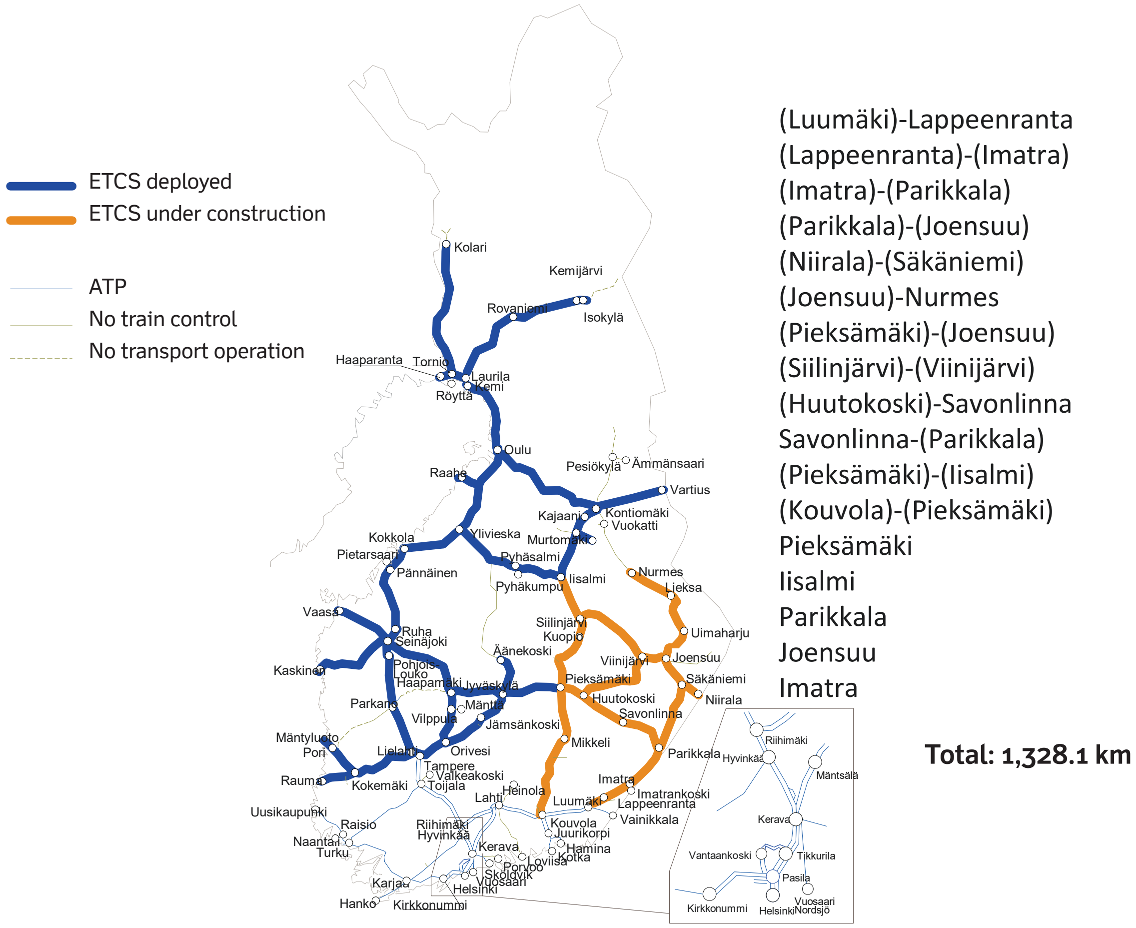
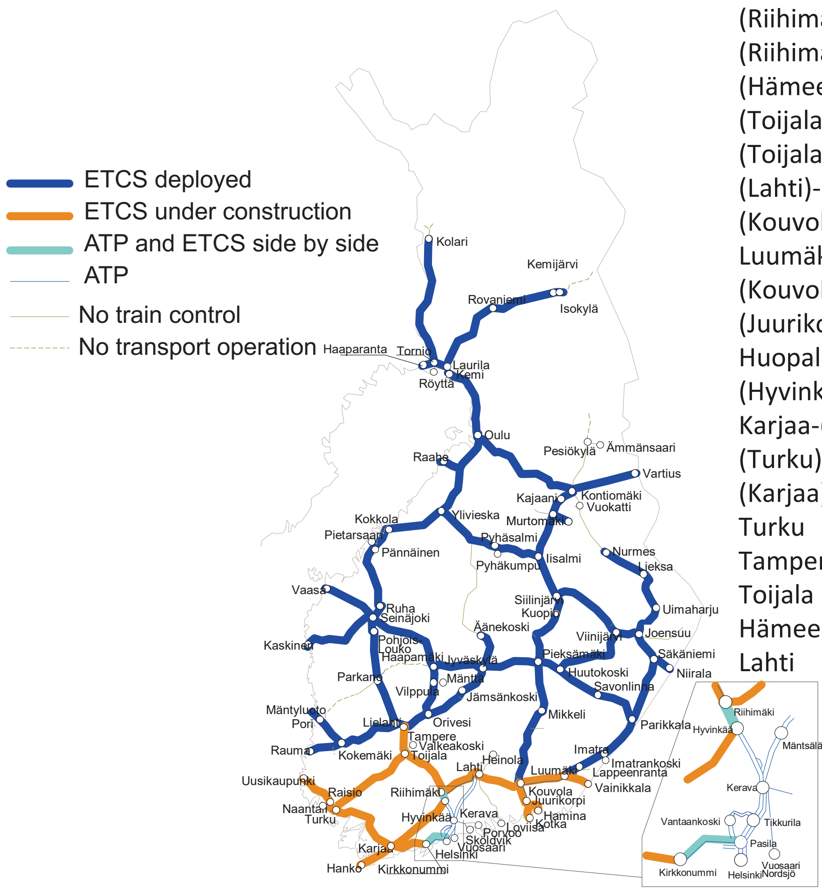


Figure 6 *Fourth stage of ERTMS/ETCS deployment, eastern Finland in 2030–2032*

3.2.5 Fifth stage, southern Finland in 2033–2035

The fifth stage of trackside construction will involve equipping southern Finland, with the exception of Greater Helsinki, with the ERTMS/ETCS. The Hyvinkää–Riihimäki line and the Huopalahti–Kirkkonummi line will be equipped with both ATP and trackside ERTMS/ETCS in order to ensure the smooth running of local transport in the capital region and tractive stock procedures at Riihimäki station when moving from one train control system to another.

The most important stations and junctions to be equipped with the ERTMS/ETCS during this stage will be Turku, Tampere, Hämeenlinna, Toijala, Kouvola, Lahti and Vainikkala. The interfaces needed for the fifth stage will need to be explored in more detail later with regard to commuter transport and the need for running ATP and the ERTMS/ETCS side by side. The geographical boundaries discussed in this report are based on the 2017 commuter rail transport model.



(Riihimäki)-(Lahti)
(Riihimäki)-(Hämeenlinna)
(Hämeenlinna)-(Toijala)
(Toijala)-(Turku)
(Toijala)-(Tampere)
(Lahti)-(Kouvola)
(Kouvola)-(Luumäki)
Luumäki-(Vainikkala)
(Kouvola)-Kotka-
(Juurikorpi)-(Hamina)
Huopalahti-(Karjaa)
(Hyvinkää)-(Karjaa)
Karjaa-(Turku)
(Turku)-Uusikaupunki
(Karjaa)-Hanko
Turku
Tampere
Toijala
Hämeenlinna
Lahti
Kouvola
Vainikkala

Total: 1,491.3 km

Figure 7 Fifth stage of ERTMS/ETCS deployment, southern Finland in 2033–2035

3.2.6 Sixth stage, Greater Helsinki in 2035–2038

Greater Helsinki will be the last area to be equipped with the ERTMS/ETCS due to special challenges posed by railway signalling technology and the complexity of the railway infrastructure. This stage will also be the most challenging due to large traffic volumes, disruptions resulting from construction works and the high number of on-board modifications needed.

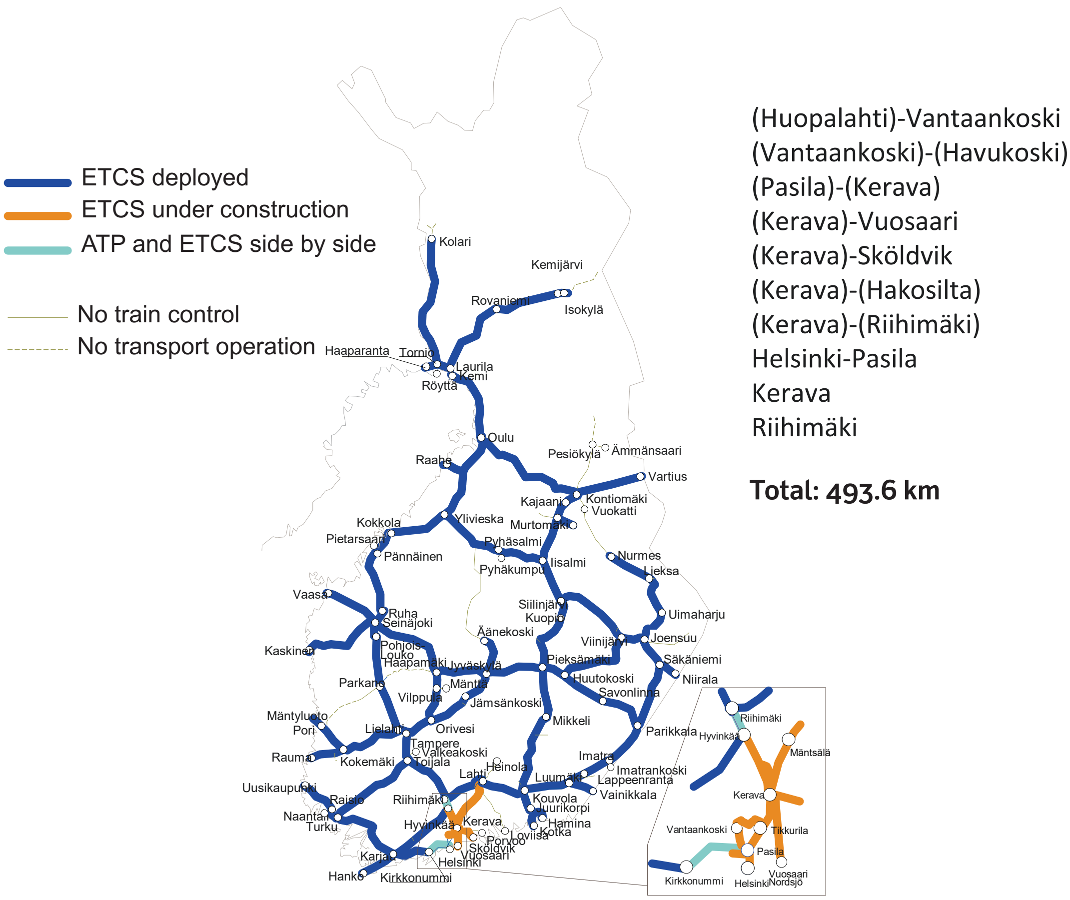


Figure 8 *Sixth stage of ERTMS/ETCS deployment, Greater Helsinki in 2035–2038*

3.3 Financial migration strategy on-board and trackside ERTMS/ETCS financing

3.3.1 On-board ERTMS/ETCS financing

Railway undertakings compete with each other and with other forms of transport on the logistics market. On-board ERTMS/ETCS installations will not bring them any benefits that could be justified from a business point of view. On the contrary, they will incur extra costs from investing in the new system, interruptions resulting from installation works, maintenance and upgrades. It is not currently known whether railway undertakings will benefit from any external financial incentives.

Appendix 1 describes certain potential on-board ERTMS/ETCS financing models. Without financial clarity and incentives, railway undertakings' on-board ERTMS/ETCS installations may need to be postponed further. The European rules for national assistance towards on-board installations are disjointed, which goes some way to delay ERTMS/ETCS deployment both in Finland and elsewhere.

The provisional cost estimate is based on the tractive stock of VR Group Ltd, Pääkaupunkiseudun Junakalusto Oy and Oy Karelian Trains Ltd (joint venture of VR Group Ltd and the Russian national railway company JSC Russian Railways (JSC RŽD) as well as Fenniarail Oy. The cost estimate does not factor in the vehicles of any future operators or the associated costs. The estimated costs are based on 100 on-board ETCS+STM units. (European Commission 2016b)

Equipping locomotives and trains with on-board ETCS+STM will cost approximately EUR 230 million. All new tractive stock will be delivered with on-board ETCS+STM already installed, and the cost of the on-board unit is therefore included in the purchase price.

The cost estimate is based on the following assumptions:

- The purchase price of on-board ETCS+STM is EUR 375,000 per unit.
- The installation works will take 400 hours per on-board ETCS+STM unit.
- Engineering a single class of rolling stock will take 1,500 hours.
- The cost of ETCS software updates per Sr3 locomotive is EUR 50,000.

It is important to note that the cost estimate does not include the following expenses:

- Training for drivers and maintenance contractors
- Project management
- Indirect costs, such as losses incurred from rolling stock being out of operation

Table 1 Cost estimate based on the number of on-board installations

Tractive stock class	Num-ber	Costs	Notes
Sr2	46	EUR 24.7 million	VR Group Ltd. Heavy electric locomotive, Transtech. Decisions on installations have not been made.
Sr3	(80)	EUR 4.9 million	VR Group Ltd. Heavy electric locomotive, Siemens AG. Includes ETCS software updates. Decisions on installations have not been made.
Edo	42	EUR 22.6 million	VR Group Ltd. Steering car, Transtech. Decisions on installations have not been made.
Sm3	17	EUR 18.9 million	VR Group Ltd. Pendolino, Fiat Ferroviaria. Covers two on-board ETCS+STM units per train. Decisions on installations have not been made.
Sm6	4	EUR 4.7 million	Oy Karelian Trains Ltd. Allegro, Alstom. Covers two on-board ETCS+STM units per train. Decisions on installations have not been made.
Dm12	16	EUR 9.3 million	VR Group Ltd. Railcar. ČKD Vagonka. Decisions on installations have not been made.
Sm4	30	EUR 38.9 million	VR Group Ltd. Electrically powered low-floor commuter train. Fiat Ferroviaria. Covers two on-board ETCS+STM units per train. Decisions on installations have not been made.
Sm5	81	EUR 103.6 million	Pääkaupunkiseudun Junakalusto Oy. Electric multiple unit. Stadler Rail. Covers two on-board ETCS+STM units per train. Decisions on installations have not been made.
Dr18	5	EUR 2.5 million	Fenniarail Oy. Modernised heavy diesel locomotive, diesel-electric transmission. ČKD. Decisions on installations have not been made.
Total:	**241 (+80)**	**EUR 230 million**	

Based on Table 1, the biggest investment costs will be incurred from Sm4 and Sm5 trains, which are used on suburban services and in commuter transport in the capital region. The costs associated with both tractive stock classes could be halved, if only one ETCS+STM unit were needed per train (depending on the properties of the ERTMS equipment). This would lower the total cost by approximately EUR 71 million.

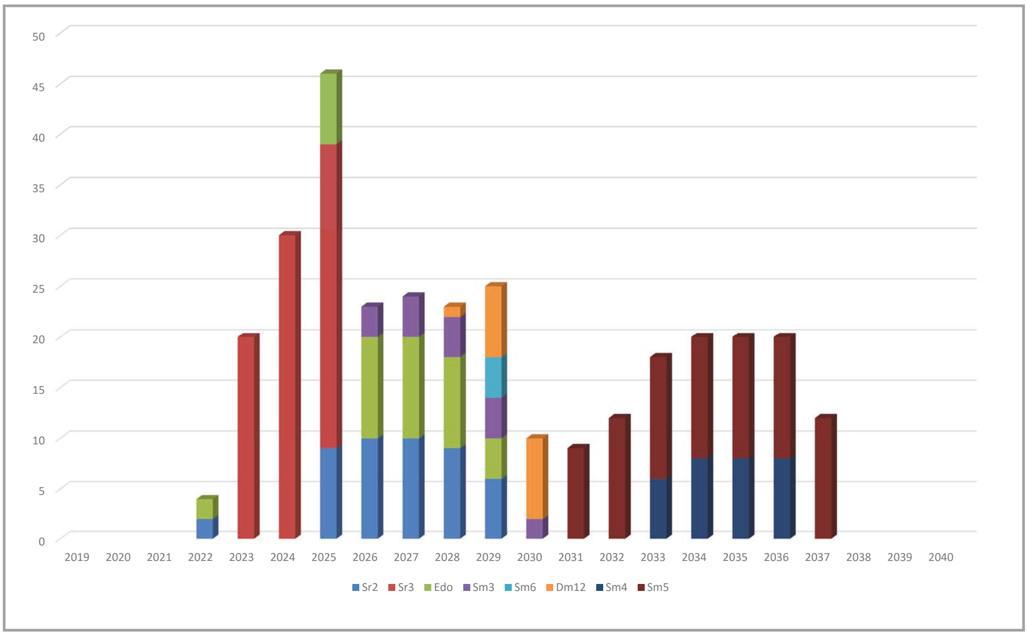


Figure 9 *Annual on-board ETCS+STM installations per tractive stock class*

Figure 9 shows the annual numbers of on-board ETCS+STM installations per tractive stock class. It is worth noting that, in 2023–2025, ETCS+SMT installations on board Sr3 locomotives can be carried out in the form of software updates.

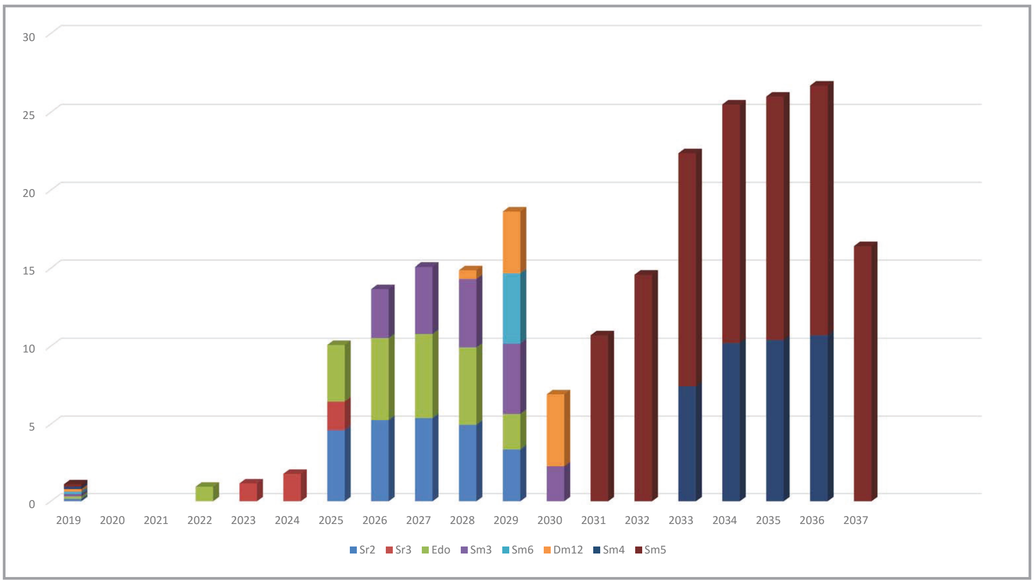


Figure 10 *Cost estimate for on-board ERTMS equipment per year (EUR million)*

Figure 10 shows EUR 160,000 in engineering costs for the first locomotive in each tractive stock class in 2019. The installation cost in 2025–2037 will be EUR 17 million on average. The total cost of ERTMS software updates on Sr3 locomotives has been estimated at approximately EUR 5 million.

3.3.2 Trackside ERTMS/ETCS financing

The Finnish rail network will require substantial investments in the next 25 years in order to maintain the current standard of service. A considerable number of current railway signalling systems will need to be replaced by 2040. The operational life of traditional relay interlocking systems is approximately 50 years, and the operational life of modern computer-based interlocking systems is approximately 30 years. The performance of existing interlocking systems does not fully satisfy current requirements. Some of the interlocking systems will need to be replaced prematurely when the ERTMS/ETCS is deployed.

The current infrastructure manager on the State-owned rail network is the Finnish Transport Agency. It is responsible for infrastructure investments and railway signalling installations. The plan is to take most of the financing required for ERTMS/ETCS investments from the Finnish Transport Agency's budget while also making use of other potential funding instruments. Producing a long-term cost estimate is challenging, especially as there are no guarantees of the continued availability of financing.

ERTMS/ETCS investment costs vary considerably depending on the chosen technology. Technologically and financially speaking, the option that makes the most sense on Finland's single-track network where there is relatively little traffic is intermittent ERTMS/ETCS level 1 train control. With this concept the interlocking systems and trackside ERTMS/ETCS construction would come in at approximately EUR 1.4 billion. Continuous ERTMS/ETCS level 2 train control would cost many times more, and the investment would be several billions of euros. (UIC a, b 2012), (European Commission 2016b)

The cost estimate is based on a scenario where almost the entire rail network would be upgraded by 2040, in which case the cost of interlocking systems would be approximately EUR 1,100 million and the cost of trackside ERTMS/ETCS level 1 installations would be approximately EUR 320 million. The cost estimates include interlocking system deliveries, outdoor and indoor installations as well as project management and contracting authority duties. The calculation factors in the aforementioned ERTMS deployment scenario which progresses from north to south and from west to east.

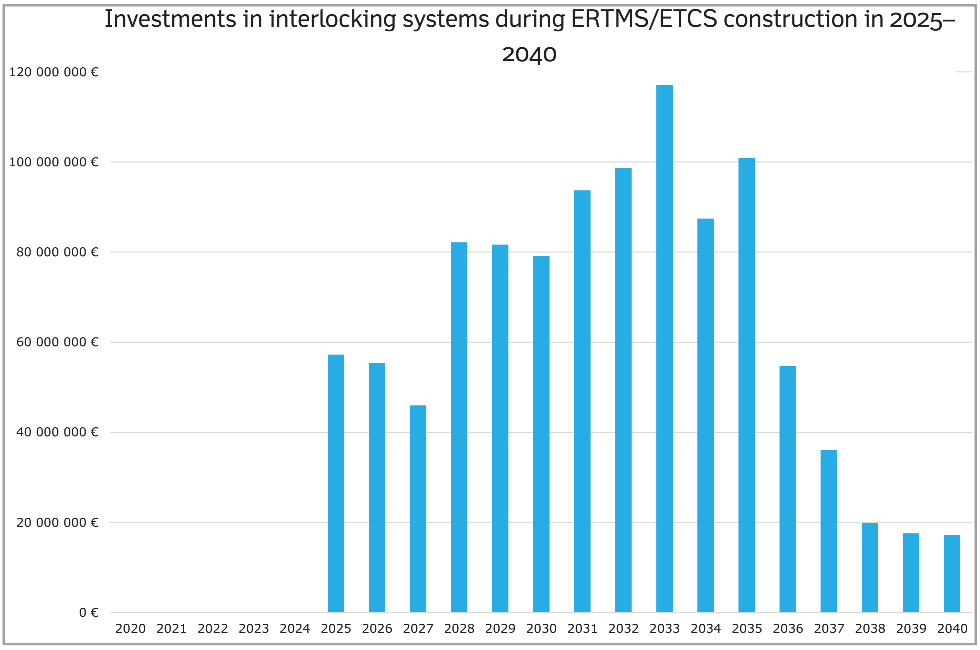


Figure 11 *Investments in interlocking systems during ERTMS/ETCS construction in 2025–2040*

Figure 11 illustrates estimated investments in interlocking systems from the year 2025 onwards, excluding investments in 2017–2024. If approximately EUR 50 million would be invested in interlocking systems annually from the year 2017 onwards, there would be less pressure to invest during the ERTMS/ETCS construction phase in 2025–2040. The picture illustrates the considerable scale of the investments needed in the 2020s and 2030s, when both relay and computer-based interlocking systems will come to the end of their operational lives.

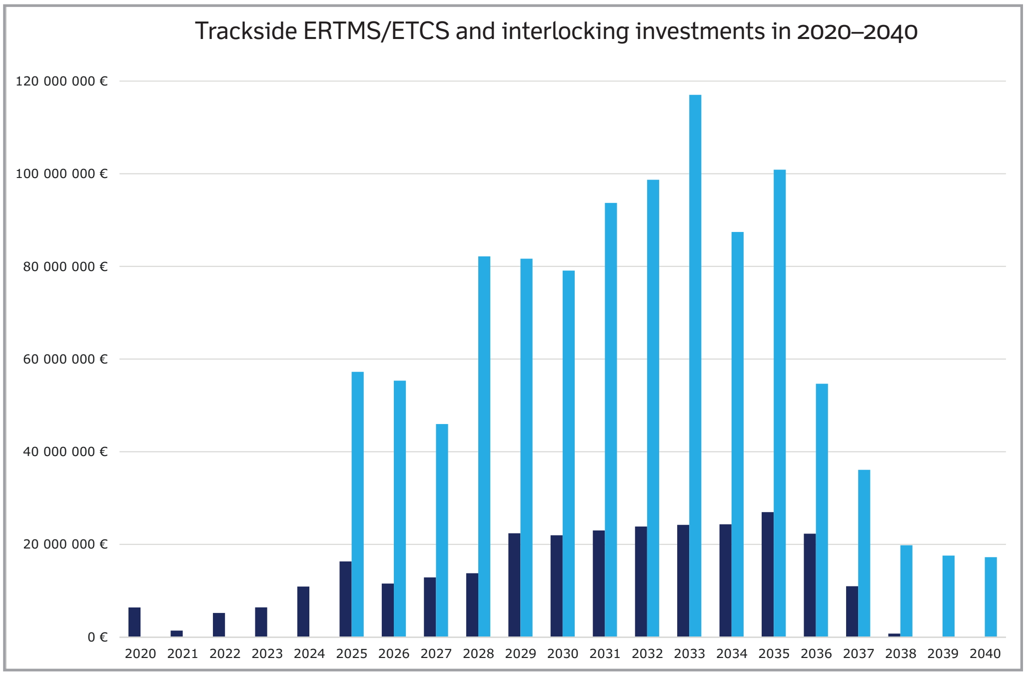


Figure 12 Trackside ERTMS/ETCS and interlocking investments in 2020–2040

Figure 12 illustrates the relative share of the approximately EUR 320 million in trackside ERTMS/ETCS level 1 investments compared to total railway safety device investments. The train control system is only one of the costs incurred from maintaining the railway infrastructure.

3.4 Developing ERTMS/ETCS knowhow

ERTMS/ETCS projects bring up new technological and commercial questions. Systematic knowhow development is needed in the various rail-sector organisations in order to be able to test, build, authorise and use the systems. Infrastructure managers, railway undertakings as well as authorisation service providers and safety authorities all need to ensure that they acquire the necessary ERTMS/ETCS knowhow well in advance of major projects.

The national infrastructure manager plays a key role, as it is responsible for producing railway infrastructure guidelines. It must support the knowhow development of different organisations by engaging in open cooperation with them and putting a wide range of tangible ERTMS/ETCS projects out to tender.

4 Open market conditions for legacy Class B train protection systems

Railway undertakings wishing to operate on the ATP-equipped sections of Finland's State-owned rail network need to equip their tractive stock with the Finnish Class B train protection system, known as ATP. Railway undertakings have two commercial alternatives available for this on the railway safety device market: On-board ATP or on-board ERTMS/ETCS+STM. Both on-board ATP and on-board ERTMS/ETCS+STM create a considerable barrier to entry into the railway market, as the units are expensive and acquiring authorisation for placing them in service is labour-intensive. The authorisation of on-board ERTMS/ETCS+STM, in particular, takes a long time and costs a considerable amount of money due to European authorisation processes, which delays railway undertakings' entry into the market.

4.1 On-board ATP

The limited availability of on-board ATP units has made it difficult for new railway undertakings to enter the market in earlier years, but there are currently no such problems. According to the supplier, Bombardier Transportation Finland Oy, on-board ATP units will be available until around the year 2025. However, ensuring access to on-board units requires commercial contract negotiations between railway undertakings and the supplier, including discussions on price, delivery schedules and other terms and conditions. It would be technologically possible to make use of decommissioned on-board units, but the supplier's contract terms prevent the resale of second-hand units. On-board ATP antennae are subject to wear, which is why the availability of antennae and other similar components also affects the maintainability of the system.

Fenniarail Oy is a private Finnish goods rail transport operator founded in 2009, which began to operate transport in the summer of 2016. Its locomotives are equipped with on-board ATP.

4.2 Specific Transmission Module (STM)

Finland has created open market conditions for the legacy Class B train protection system, ATP-VR/RHK, by bringing out a compatible Specific Transmission Module (STM). The ATP-STM was developed specifically for Finland by a Swedish company called Ansaldo STS Sweden AB, which is part of the Japanese Hitachi Group. It is sold to everyone on transparent commercial terms agreed between the contracting parties, which depend on factors such as order volumes, the complexity of system integration and schedules.

The STM is installed on board a locomotive, which is why its integration with on-board ERTMS/ETCS is the responsibility of the tractive stock owner or operator. Deployment requires integrating software products of two railway signalling suppliers and authorisation for the placing in service of the on-board ERTMS/ETCS+STM unit. European authorisation processes are extremely expensive and long-winded, which is why purchasing on-board ERTMS/ETCS+STM is labour-intensive and expensive for railway undertakings.

The Finnish rail transport market is open from the perspective of the availability of on-board units, but the length and cost of the projects delay new railway undertakings' entry into the market in practice. Purchasing on-board ERTMS/ETCS+STM is a huge investment for small railway undertakings and one of the biggest bottlenecks.

5 Decommissioning the Class B train protection system

The picture shows the schedule for decommissioning Finland's Class B train protection system, ATP. The schedule is based on the aforementioned regional ERTMS/ETCS deployment schedules.

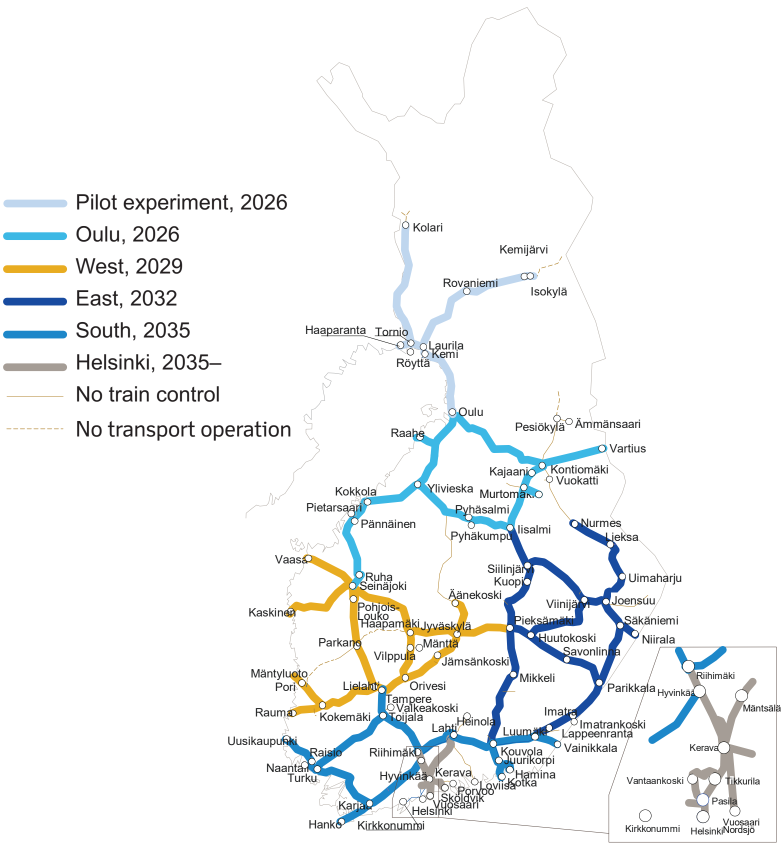


Figure 13 Regional ATP decommissioning schedule

The ATP system will be decommissioned in connection with ERTMS/ETCS deployment. The specific time of decommissioning will be the last year of each deployment project, where possible in terms of track maintenance and transport operation. During the third stage, for example, ERTMS/ETCS installations will take place in western Finland in 2027–2029, and the ATP system will be decommissioned there in 2029. On the pilot lines where ATP and the ETCS have been used side by side, ATP decommissioning will take place according to the second-stage decommissioning schedule in 2026.

These schedules may need to be pushed back if ERTMS/ETCS projects do not progress as planned. The exact dates for each track section will be determined in connection with planning each actual implementation project, so that the works can be coordinated with other track maintenance projects, interlocking system upgrades and traffic needs.

Bibliography

European Commission (2016a). *COMMISSION REGULATION (EU) No 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union*. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0919&from=EN European Commission. Visited on 21 February 2017.

European Commission (2016b). *Business Case on the 9 core network corridors – Business Case Provisional Report July 2016*. 7/2016, version 0.9.8. http://www.erfarail.eu/UPLOADS/pageimages/ru%20dialogue/T7_DEL_7%201%203_Report%20ERTMS%20Business%20Case%20CNC.pdf European Commission. Visited on 24 January 2017.

Härkönen, A & Järvinen, L (2014). *Konkretiaa eurooppalaisen junien kulunvalvonnan käyttöönottoon rataverkolla ja vetävässä kalustossa [Concrete points on the implementation of the train control system within the rail network and on powered rolling stock]*. Research reports of the Finnish Transport Agency 44/2014. ISBN 978-952-317-010-0. Published in November 2014.

Härkönen, A & Matikainen, L (2016). Rautatietekniikkalehti [Railway Technology Journal] 4/2016. ISSN: 1237–1513. Published in December 2016.

Finnish Transport Agency (2014). *Junien kulunvalvonta JKV, Ratatekniset ohjeet (RATO) osa 10 [Automatic Train Protection (ATP), Railway Engineering Guidelines (RATO), Part 10], Instructions issued by the Finnish Transport Agency 8/2014.* ISBN 978-952-255-424-6. Published in November 2014.

Finnish Rail Administration (2006). Eurooppalaisen rautatieliikenteen hallintajärjestelmän (ERTMS) Suomen kansallinen toteuttamissuunnitelma [National ERTMS Deployment Plan of Finland]. 28 December 2006. https://ec.europa.eu/transport/sites/transport/files/modes/rail/ertms/doc/edp/national_deployment_plans/finland_ndp.pdf Visited on 21 February 2017.

Tuomi, M (2016). *Rautatieturvalaitteiden kustannuslaskentamalli – Yksikköturvalaite-kustannusten laskenta [A model for cost estimation of railway signalling systems – Signalling Equivalent Unit calculation]*. Research reports of the Finnish Transport Agency 25/2016. Helsinki: Finnish Transport Agency.

UIC (2012a). International Union of Railways. *ERTMS Implementations Benchmark Final Report – February 2012*. 25 March 2012, version 01. ISBN 978-2-7461-2079-2.

UIC (2012b). International Union of Railways. *ERTMS Implementations Benchmark CASE STUDIES: Project Context & Company Profile*. March 2012. 20 March 2012, version 1. ISBN 978-2-7461-2080-8.

Vainiomäki, V (2014). *JKV-järjestelmän merkitys rautateiden turvallisuudelle ja kilpailun syntymiselle [Role of the ATP system in railway safety and generating competition].* Helsinki: Finnish Transport Safety Agency.

On-board ERTMS/ETCS financing models

As the use of the ERTMS/ETCS does not bring business benefits to railway undertakings, ERTMS/ETCS deployment is an investment in railway safety, which the industry strives to postpone as far into the future as possible. As the financing needed for investments in on-board units and the lack thereof are the biggest obstacle to ERTMS/ETCS deployment in Finland, Finland's national implementation plan includes a review of certain foreign financing models and national alternatives.

FOREIGN FINANCING MODELS

Foreign on-board ERTMS financing models were studied by sending a questionnaire to 13 different European countries: Italy, France, Sweden, Spain, Belgium, United Kingdom, Germany, Luxembourg, Norway, Slovenia, Switzerland, the Netherlands and Austria. The questionnaire was targeted at partners who were known to have contributed to ERTMS/ETCS deployment in their respective countries. Replies were received from a total of nine countries.

The replies were analysed as thoroughly as possible, taking into account what was known about the status of ERTMS/ETCS deployment and the history of railway operators and infrastructure managers in each country. The replies clearly indicate that the shortage of national or EU funding is a major obstacle to large-scale on-board ERTMS/ETCS deployment. In conclusion, the replies suggest that even where infrastructure managers have received EU funding for ERTMS/ETCS deployment, the ERTMS/ETCS investment costs of rail transport operators have been ignored and have been left almost exclusively on the operators' shoulders.

When evaluating the suitability of foreign financing models to Finnish conditions, it is important to note that the replies do not represent the official views of the countries in question but were collected via informal channels and through personal contacts. Some of the replies were difficult to interpret.

The most popular among foreign ERTMS/ETCS financing models is the so-called CLASSIC model, where 50% of the costs of on-board ERTMS investments are covered by the government budget. The replies also indicate that the EU rarely grants assistance towards on-board ERTMS/ETCS investments.

Swedish model

In Sweden, on-board ERTMS investments are financed by tractive stock owners, who can apply for assistance from the EU. The Swedish State does not subsidise on-board ERTMS investments. The infrastructure manager provides advice and coordinates the EU funding application process. The same financial model is used for new and retrofit installations.

So far, EU assistance for on-board ERTMS investments has covered purchasing the units, engineering as well as the authorisation and harmonisation process. Losses incurred from tractive stock being out of operation are not reimbursed, however.

The previous EU funding round has now ended. However, it may be possible to apply for more EU funding for on-board ERTMS investments via the Innovation and Networks Executive Agency (INEA) in the future. The EU funding model for on-board ERTMS investments may change further down the line.

The infrastructure manager has financed the entire STM development project without assistance from the EU.

German model

Owners of tractive stock are responsible for securing their own ERTMS funding. Germany has applied for 50% CEF funding for interoperability constituents via Trans-European Transport Networks (TEN-T). No decision has been made on the application so far. The same financial model is used for new and retrofit installations.

EU funding for on-board ERTMS could cover purchasing the units, engineering, authorisation and harmonisation as well as indirect costs such as losses incurred from tractive stock being out of operation.

The previous EU funding round has now ended. Germany has not received EU assistance for on-board ERTMS investments. Germany is extremely dissatisfied with the EU's funding decisions so far.

Germany has tried to agree on a joint funding model of tractive stock owners and the infrastructure manager for sharing the costs of the first installations in each rolling stock class. EU assistance was applied for in this context as well, but unsuccessfully.

The German State does not subsidise on-board ERTMS investments. The infrastructure manager has not contributed to ERTMS financing but is responsible for all aspects of the interoperability of on-board and trackside ERTMS and compliance with standards. The infrastructure manager is also responsible for the implementation of Germany's national ERTMS programme. To this end, the infrastructure manager also cooperates with neighbouring countries, such as Switzerland and the Netherlands.

Germany is currently planning a project involving the standardisation of the interface between on-board ERTMS and the locomotive. This would also involve incorporating Germany's Class B system(s). There has been no STM financing or development in Germany.

French model

In France, on-board ERTMS investments are financed by the owners of tractive stock. France has applied for EU assistance to cover some of the on-board ERTMS units for tractive stock used on European goods transport routes. However, no EU assistance has been forthcoming. There have been no on-board ERTMS retrofit installations so far; only new locomotives and trains have been equipped with on-board ERTMS. The State does not subsidise on-board ERTMS investments, and no clear answer was given concerning the role of the infrastructure manager with regard to on-board unit purchases.

One State-owned operator has financed STM development and harmonisation as far as France's national systems are concerned.

UK model

In the UK, the State pays for on-board ERTMS for the first locomotive in each tractive stock class. The infrastructure manager coordinates the funds and pays them to a consortium of rolling stock leasing companies. The leasing companies own the rolling stock and lease it to operators.

The leasing companies finance on-board ERTMS installations for classes of passenger transport locomotives on the basis of the terms of their operating licences.

On-board ERTMS units for goods transport locomotives are financed via the infrastructure manager in accordance with the "polluter pays" principle. A considerable portion of the costs are reimbursed. So far, the State's subsidies for ERTMS retrofit installations have covered purchasing the units, engineering as well as authorisation and harmonisation, losses incurred from rolling stock being out of operation, training for drivers and maintenance workers as well as costs incurred from business restructuring.

The system will remain in place for at least the next five years. The infrastructure manager must demonstrate that the State's ERTMS funding has been put to efficient use. The system only covers existing tractive stock. Operators are responsible for ordering new locomotives and equipping them with on-board ERTMS. The UK is also contemplating on-board ERTMS installations for track work machinery and financing these through the State according to the same principle that has been applied for rolling stock used in goods transport.

No applications have been made for EU assistance.
STMs are not in use in the UK.

Norwegian model

The Norwegian Ministry of Transport and Communications began to explore different kinds of ERTMS financing models in 2013. The work was completed in 2014, after which a funding model was developed and submitted to the ESA (EFTA Surveillance Authority) for approval in 2016.

State aid is available for on-board ERTMS investments in Norway. The State's budgetary funding amounts to EUR 146 million in total. The State's ERTMS funding covers 50% of the costs, however not exceeding EUR 550,000 for the first installation in each rolling stock class or EUR 220,000 for subsequent locomotive installations.

The infrastructure manager oversees the use of the State's ERTMS funding and manages the on-board ERTMS project. The infrastructure manager coordinates on-board ERTMS purchases and pays for the harmonisation of on-board ERTMS for different types of rolling stock. Rolling stock owners can sign a partnership agreement with the infrastructure manager and the chosen system supplier, who will integrate on-board ERTMS into each vehicle.

The State's ERTMS funding is available for all tractive stock in use in Norway in 2016. There is one exemption, however: If a tractive stock owner replaces their eligible tractive stock by new tractive stock, the new vehicles also qualify for the State's funding.

The State's funding for on-board ERTMS covers purchasing the units, engineering, decommissioning old units and modifications, testing and authorisation, project management in general and costs incurred from having to use replacement vehicles. Indirect costs are not covered.

A new TEN-T EU funding round began in October 2016. EU funding can be applied for through the CEF until February 2017.

STMs are covered by the State's ERTMS funding as part of the on-board ERTMS units.

Austrian model

In Austria, on-board ERTMS units have been purchased both with government budget funds and with the help of EU assistance. Two new high-speed tracks were inaugurated in 2012, at which time 382 locomotives (of three different types) and 51 steering cars were equipped with on-board ERTMS. EU assistance was secured for 122 locomotives to the maximum amount of EUR 75,000 per locomotive. All other rolling stock received funding from the government budget to the maximum amount of EUR 150,000 per retrofit and EUR 100,000 per new installation. The State aid granted towards this amounted to EUR 45 million in total. Funding from the government budget was granted subject to a minimum volume of ERTMS transport operation on the Austrian rail network for at least five years, which would be verified and reported by ÖBB-infra AG.

The Austrian State has not subsidised on-board ERTMS purchases since 2012. Funding granted from the government budget towards on-board ERTMS has so far covered purchasing the units, software, engineering as well as authorisation and harmonisation. Budgetary funds have also been available for modifications to existing train control equipment, integration and indirect costs (up to 7%), such as project management and driver training. Funding from the government budget could not be used to cover losses incurred from rolling stock being out of operation due to testing, installations or authorisation.

The previous EU funding round has now ended. It may nevertheless be possible to apply for EU funding for on-board ERTMS via the CEF in the coming years.

STMs are not in use in Austria. Austria's ERTMS tracks are equipped with the national Class B train protection system and the ERTMS side by side. Integration between national on-board train protection units and the ERTMS has been covered by budgetary funds for retrofit installations.

Potential on-board ERTMS/ETCS financing models to be applied in Finland

At the moment, it appears that financing on-board ERTMS/ETCS will fall largely on Finland's shoulders, as international experiences show that EU assistance for on-board installations has not been very forthcoming. The EU has mostly financed ERTMS deployment by subsidising the building of ERTMS rail routes. Large, influential EU countries, such as France and Germany, have applied for EU assistance for their on-board ERTMS investments, but have been unsuccessful. Several ERTMS rail routes pass through France and Germany that can be seen as crucial for the integration of the EU through the deregulation of goods and passenger transport. If these countries cannot get EU assistance, it is unlikely that Finnish operators or undertakings that operate in Finland would either. The EU has primarily provided financial assistance to ERTMS rail routes that are considered to have strategic importance in terms of goods and passenger transport. There is one TEN-T rail route that passes through Finland: Turku–Helsinki–Vainikkala, which is part of the Scandinavian–Mediterranean TEN-T corridor, which in turn represents a crucial north-south axis for the European economy. Finland is also home to one EU Core Network: Helsinki–Tampere–Oulu–Tornio. However, ERTMS deployment is not crucial for the operation of these routes, as the track gauge in Finland differs from that of other European TEN-T corridors.

The technological starting point for the proposals is ERTMS/ETCS level 1, as experiences from projects implemented so far indicate that trackside ERTMS/ETCS level 2 technology is approximately five times as expensive per one kilometre of track as ERTMS/ETCS level 1. (UIC a, b 2012), (European Commission 2016). If, in the future, ERTMS/ETCS level 2 or 3 solutions end up being more cost-effective in terms of RBC or network interoperability technologies relative to infrastructure capacity benefits, it could make financial sense to use them instead.

This is why there are justifications for spending the State's investments on a more affordable replacement for the current train protection technology, i.e. ERTMS level 1 solutions, and adding infrastructure capacity, if necessary, by building double-track railways, for example. The proposals factor in the maintenance costs of on-board ETCS+SMT as part of the life cycle costs of the units' estimated 40-year operational life.

The following are 11 factors of financing and procurement models that together form various procurement concepts:

- Funding granted from the government budget to operators directly
- Interest-free State loans to operators
- Joint funding by the State and an investment company
- ERTMS compensation for track access charges (discounts and surcharges)
- Consortium of operators and the infrastructure manager (joint purchasing and cost sharing)
- Self-financing by rolling stock owners and operators
- Joint purchasing of on-board ERTMS units by operators
- EU funding instruments
- Completely new financing models, such as crowdfunding
- On-board ERTMS leasing company

CLASSIC – potential on-board ERTMS financing model

Financial assistance granted by the State has traditionally played an important role in major investments. In the traditional CLASSIC model, the State subsidises operators' on-board ERTMS purchases by paying 50% of the costs from its annual budget.

50 % State aid from budgetary funds; positives:
+ No impact on operators' track access charges
+ Promotes operators' on-board ERTMS investments
+ Facilitates new operators' entry into the market
+ Available to all on equal terms

Negatives:
- Calls for a long-term political commitment to purchasing ERTMS technology
- 50% self-financing is costly for small operators (purchasing few units)

In this model, State funding would be available in 2020–2025, when some of the existing tractive stock will be equipped with on-board ERTMS. The model corresponds to foreign financing models. State funding would cover 50% of eligible total costs. Total costs would consist of the cost of new on-board ERTMS units and the associated installation and integration works, decommissioning the old train protection equipment, project management, driver training and authorisation. Losses incurred from rolling stock being out of operation or other indirect costs would not be covered. Purchases would be the responsibility of operators, who would need to apply to the State for funding towards 50% of their eligible costs. The maximum amount of reimbursement for the first locomotive in each rolling stock class would be EUR 200,000, and the maximum amount for subsequent installations would be EUR 100,000. State funding would cover both on-board ERTMS and the STM.

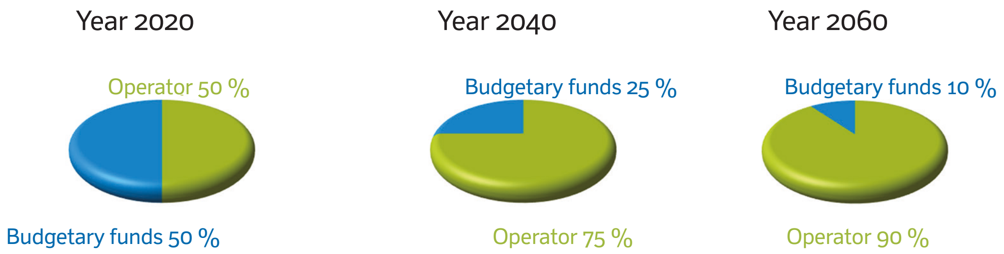


Figure. Estimate of the division of life cycle costs in the CLASSIC model

With the CLASSIC model, the State's share of the investment's life cycle costs (LCC) would initially be 50% and the operators' 50%. State funding would no longer be available after 2025, and the State's share of LCC would drop to 25% by the mid-point of the investment's life cycle. The State's share of LCC would shrink by a further approximately 15 percentage points towards the end of the life cycle, as the operator would be responsible for maintaining the equipment. At the end of the life cycle, the State's share of the on-board ERTMS investment would amount to approximately 10% in total.

CONDUCT – potential on-board ERTMS financing model

CONDUCT is a two-part model, in which the State's and operators' investment costs are divided into short-term and long-term financing. A total of 25% of operators' costs would be covered by discounted track access charges, which would mean that operators' initial investment would amount to 75%. On the other hand, life cycle costs financed by the State would only materialise in the distant future, which means that the discounted track access charges would compensate for the costs incurred early on.

- 25% State aid from budgetary funds
- 25% as track access charge discounts (over a period of 10–15 years)

Positives:
+ Encouragement for new operators (calls for substantial start-up capital)
+ Long-term State support in the form of track access charge discounts
+ No large one-off investment from the State required

Negatives:
- Calls for substantial start-up capital, i.e. 75%, from new operators
- Modest degree of subsidisation

In this model, State funding would be available in 2020–2035, when most of the existing tractive stock will be equipped with on-board ERTMS. State funding would be granted as a lump sum to cover 25% of the eligible total costs, in addition to which the State would give discounts on track access charges to rolling stock equipped with on-board ERTMS, which would amount to 25% of the investment's life cycle costs over the following 10–15 years. Total costs would consist of the cost of new on-board ERTMS units and the associated installation and integration works, decommissioning the old train protection equipment, project management, driver training and authorisation. Losses incurred from rolling stock being out of operation or other indirect costs would not be covered. Purchases would be the responsibility of operators, who would need to apply to the State for funding towards 25% of their eligible costs. The maximum amount of reimbursement for the first locomotive in each rolling stock class would be EUR 100,000, and the maximum amount for subsequent installations would be EUR 50,000. State funding would cover both on-board ERTMS and the STM.

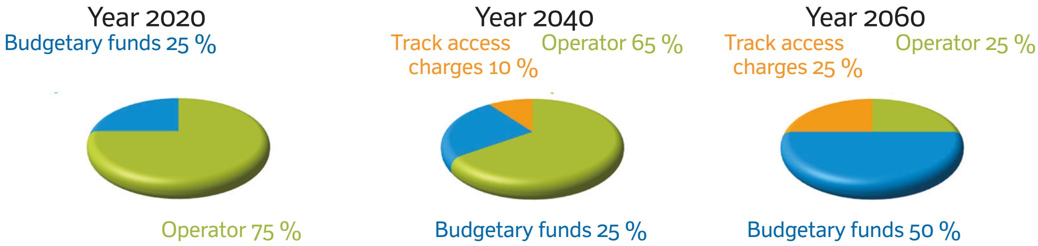


Figure. Estimate of the division of life cycle costs in the CONDUCT model

With the CONDUCT model, the State's estimated share of the investment's life cycle costs (LCC) would initially be 25% and the operators' 75%. State funding would no longer be available for on-board ERTMS installations after 2035, but the State's share of LCC would increase to 35% by the mid-point of the investment's life cycle thanks to discounted track access charges. The State's share of LCC would increase by a further 15 percentage points towards the end of the life cycle, thanks to the track access charge discounts. At the end of the life cycle, the State's share of the on-board ERTMS investment would amount to 50% in total.

SPURT – potential on-board ERTMS financing model

The SPURT model is aimed at incentivisation and flexibility by means of combining different financing and procurement models. The State's direct contribution from budgetary funds would be low initially, but the State would commit itself to supporting operators' ERTMS purchases in the long term through interest-free loans and track access charge discounts. Operators would need little self-financing, and the discounts on track access charges would promote on-board ERTMS investments. On the other hand, operators would need to take out interest-free loans to cover the initial investment. The model could be adjusted periodically to optimise the effect of incentives according to the circumstances.

- Up to 20% State aid from budgetary funds
- Up to 70% interest-free loan from the State (20 years)
- Up to 50% ERTMS compensation for track access charges (over a period of 10–20 years)
- 10–30% self-financing from operators

Positives:
+ Risk-free self-financing investment for operators thanks to interest-free loans from the State
+ Encouragement for on-board ERTMS purchases thanks to ERTMS compensation for track access charges
+ No large one-off investment from the State required
+ Flexibility to account for different situations and operators in different financial circumstances

Negatives:
- Major commitment from the State in terms of the interest-free loans and track access charge discounts
- Modest degree of direct State contribution from budgetary funds relative to total funding
- Annual readjustments according to the State's financial situation required
- Labour-intensive implementation

In this model, State funding would be available in 2020–2039, when all the existing tractive stock will be equipped with on-board ERTMS. The model would allow a range of State aid models to be employed side by side. The State's contribution from budgetary funds would cover up to 20% of eligible total costs. In addition, the State would grant interest-free loans for up to 70% of the costs as well as discounts on track access charges to rolling stock equipped with on-board ERTMS, which would amount to up to 50% of the investment's life cycle costs over the following 10–20 years. Total costs would consist of the cost of new on-board ERTMS units and the associated installation and integration works, decommissioning the old train protection equipment and authorisation. Losses incurred from rolling stock being out of operation, project management costs, driver training or other indirect costs would not be covered.

All in all, State funding would cover up to 70–90% of the investment's life cycle costs in the long term. Purchases would be the responsibility of operators, who would need to apply to the State for assistance each year. The maximum amount of reimbursement for the first locomotive in each rolling stock class would be EUR 200,000, and the maximum amount for subsequent installations would be EUR 100,000. State funding would cover both on-board ERTMS and the STM as well as software and updates.

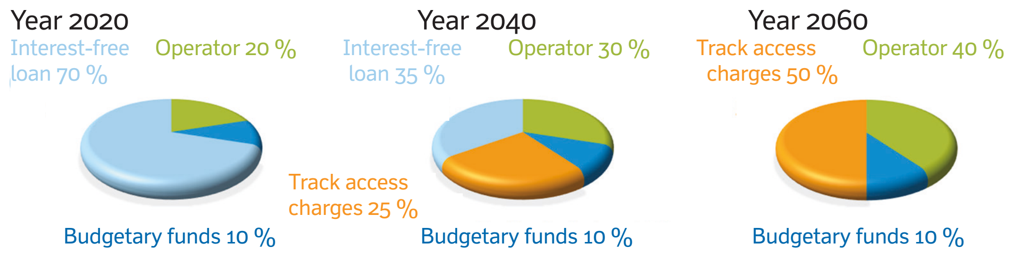


Figure. Estimate of the division of life cycle costs in the SPURT model on average

With the SPURT model, the State's estimated share of the investment's life cycle costs (LCC) would initially be up to 20% and the operators' 10–30%, in addition to which the State would cover the rest of the operators' initial investment by interest-free loans. The State's share of LCC would increase to at least 35% by the mid-point of the investment's life cycle thanks to discounted track access charges. The State's share of

LCC could increase by a further 25 percentage points at the most towards the end of the life cycle, thanks to the track access charge discounts. At the end of the life cycle, the State's share of the on-board ERTMS investment would amount to approximately 60–70% in total, depending on State aid decisions made during the investment's life cycle. The extent of the State's contribution would be highly dependent on the scale of track access charge discounts, and operators' total share of the investment would depend on the size of their interest-free loan.

HOP – potential on-board ERTMS financing model

The HOP model is based on financing on-board ERTMS purchases by means of crowdfunding. Crowdfunding can be reward-based (such as free or discounted passenger or goods transport services) or equity-based (in return for shares). The benefit of the model lies in the general public's desire to invest in and use operators' services. The HOP model is completely independent from ERTMS funding from the State.

- 100% crowdfunding

Positives:
+ Completely independent from State or EU funding
+ Large existing pool of users (reward-based crowdfunding)
+ Suitable for operators who are just starting out

Negatives:
- Uncertainty
- Requires convincing and transparent business model marketing
- Likely to take a long time from business model formulation to the beginning of ERTMS transport operation

With this model, rail transport operators would draw up a business plan and market it to the public. After accumulating 100% of the initial investment through reward-based or equity crowdfunding, they could begin to purchase on-board ERTMS units and then start operating transport. There would be no State funding, and instead operators would cover their entire initial investment by means of crowdfunding.

With the HOP model, operators would be responsible for 100% of the investment's life cycle costs (LCC). The division of costs during the investment's life cycle would depend on the chosen form of crowdfunding, the services given as rewards or the return paid on investment. The division of costs between operators and crowdfunding investors could vary considerably. Operators might have to pay interest on their funding.

STEPS – potential on-board ERTMS financing model

The STEPS model divides the investment costs of the State and operators 50/50 in the long term. Five per cent of operators' life cycle costs would be covered annually over a period of 10 years, which would make the total contribution 50%. Operators' initial investment would be 95%, and they would get 50% of the investment's life cycle costs back over a period of 10 years. The State would contribute to the initial investment by granting a 95% interest-free loan and paying 5% outright.

- 5% State aid from budgetary funds annually (for a period of 10 years)
- 95% interest-free loan (10 years)

Positives:
+ Small initial investment from operators
+ Facilitates new operators' entry into the market
+ Risk-free self-financing investment for operators thanks to interest-free loans from the State
+ Operators' life cycle costs are taken into account as a whole

Negatives:
- Major commitment from the State in terms of the interest-free loans
- Modest degree of subsidisation

In this model, State funding would cover 5% of eligible annual life cycle costs over a period of 10 years. The scheme would be in effect until 2029, and the interest-free loans would therefore need to be paid back by 2039. The investment's life cycle costs would include all the costs incurred by operators from their ERTMS investment. However, losses incurred from rolling stock being out of operation or other indirect costs would not be covered. Purchases would be the responsibility of operators, who would need to apply to the State for funding towards 5% of their life cycle costs annually and make repayments on an interest-free loan for a period of 10 years.

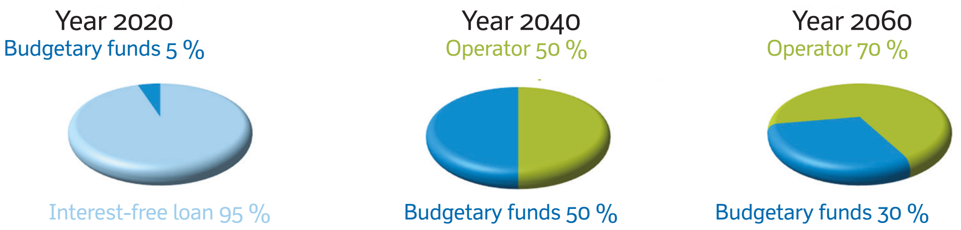


Figure. Estimate of the division of life cycle costs in the STEPS model

With the STEPS model, the State's share of the investment's life cycle costs (LCC) would initially be 5%, and operators' interest-free loans would cover 95%. State funding would no longer be available after 2039. The State's share of LCC would increase by 45 percentage points by the mid-point of the investment's life cycle (2040) thanks to budgetary funds, assuming that operators apply for State funding for at least half of their tractive stock. The State's contribution would no longer increase towards the end of the investment's life cycle. At the end of the life cycle, the State's share of the on-board ERTMS investment would amount to up to 50% in total. The State's total costs would be likely to amount to less than 30% due to the short lifespan of the model, as operators would no longer get assistance from the State after 2029.

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