Implementation of the European Rail Traffic Management System (ERTMS/ETCS) in Finland

National implementation plan 2017 according to Commission Regulation (EU) 2016/919

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1 Introduction

Directive 2008/57/EC applies to the interoperability of the rail system within the Community. Commission Regulation (EU) 2016/919 issued thereunder obliges Member States to develop a national plan for the implementation of technical specifications of interoperability and to submit the plan to the Commission by 5 July 2017. The Regulation contains provisions on the contents of the national implementation plans, which shall run over a period of at least 15 years and be updated regularly, at least every five years.

Finland submitted the previous national implementation plan of the ERTMS to the European Commission in 2007. The Finnish Transport Agency published a report in 2014 in support of the scheduling of the trackside and on-board subsystems' installation and funding decisions.

The preparation of this plan was launched in spring 2016 in collaboration between the transport authorities and railway sector operators. As the infrastructure manager, the Finnish Transport Agency was mainly responsible for the preparation. The Finnish Transport Agency requested statements on the draft plan in spring 2017. The detailed report will be published in the Finnish Transport Agency's publication series.

There are no binding decisions on the schedules or funding proposed in this national implementation plan for Finland. Postponement of investments in trackside subsystems will also postpone the implementation of investments in on-board systems. The dates will be specified in future updates of the plan.

2 Initial status of the current train protection system

2.1 Train protection system

The current Finnish train protection system (known by the Finnish acronym JKV) is based on trackside and on-board subsystems which, in combination, constitute the overall system. The system was set up throughout the main state-owned track network between 1992–2009 but its additional construction and completion will continue into the 2020s. System use has been developed throughout the twenty-year construction period and the principles of utilisation are well described and documented. (The Finnish Transport Agency, 2014)

The JKV system is internationally known by the name ATP-VR/RHK, under which it is subjected to the technical specification for interoperability Control-Command and Signalling Subsystems as a so-called Class B system, the use of which may continue throughout the system's life-cycle, but whose technical upgrading and renewal are restricted. System components are provided by two suppliers, currently known as Ansaldo STS Sweden AB (trackside subsystems) and Bombardier Transportation Finland Oy (on-board and trackside subsystems). Hence there is one supplier of on-board subsystems and two suppliers of trackside subsystems for the JKV system.

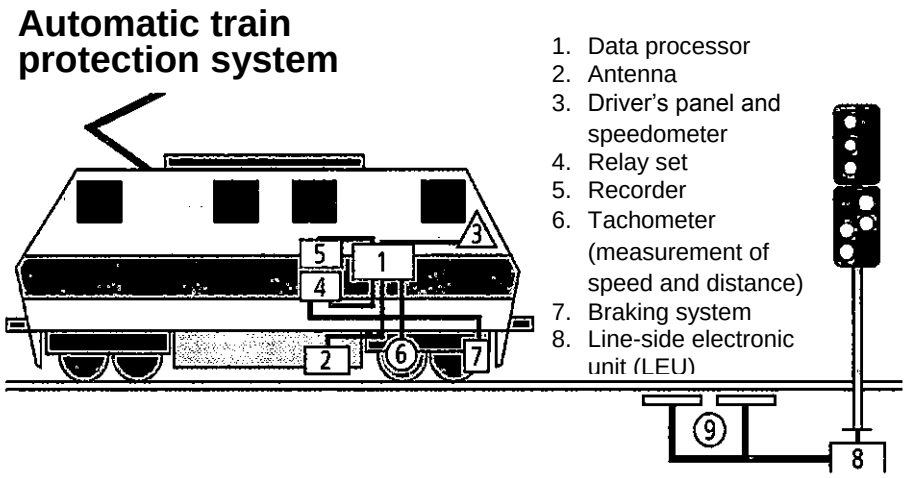

Illustration 1 On-board components of the automatic train protection system (1.–7. in the illustration) and trackside subsystem components (8.–9. in the illustration).

JKV system's on-board and trackside subsystems are shown in Illustration 1. Line-side electronic units (LEUs) in the trackside subsystems are connected to the lamp electrical circuits of the railway safety equipment, from where they transfer the concept data to balises. The balises are operated by energy from the on-board subsystem antenna, returning their message to the on-board subsystem, which steers the locomotive to follow signals.

In Finland, on-board subsystems have been installed in approximately 700 vehicles, and approximately 25,000 balises are installed in the trackside subsystems. JKV system component availability has declined since the early 00s. Not all LEUs used by the various suppliers are available at this time, but substitute products are available on the market. JKV on-board subsystem availability has also declined since the late 00s.

2.2 Plans for JKV system life-cycle management in the 2020–2030s

Illustration 2 describes the gradual construction of the current JKV system. The railway automation industry does not provide support for old product families indefinitely. As the JKV system approaches the end of its life-cycle, transition to the ERTMS/ETCS system becomes inevitable even though it will not necessarily be a step forward or an improvement in comparison with the current system. The new system will be adopted because it is the only one that meets the criteria for long-term life-cycle management in terms of supply continuity in the on-board and trackside subsystems market well into the 2020s and 2030s and because there are multiple suppliers. Both the infrastructure manager and railway companies manage the system's life-cycle systematically.

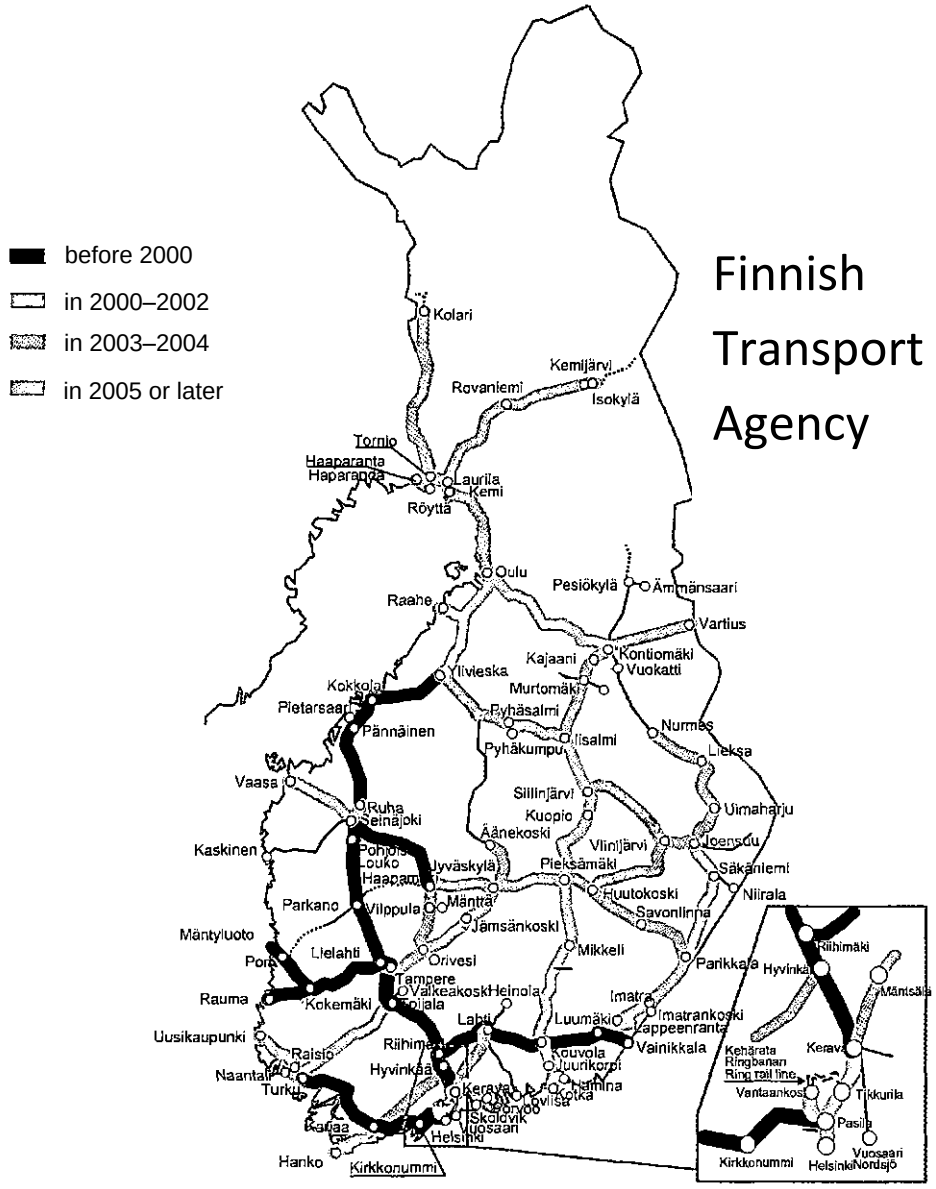

Illustration 2 Deployment times of the current train protection system.

The infrastructure manager and railway companies engage in long-term operations to ensure that the JKV trackside system will not have to be replaced with the

ETCS trackside system on too short notice. The intended use of the current system could be prevented by declining availability of trackside subsystems, lack of programming tools for the trackside subsystem, weaker system-related know-how and competence and other similar reasons. An unprecedented system replacement would result in considerable additional costs both for railway management and the companies that own or operate traction vehicles. It might also result in the imposition of restrictions which would considerably impede traffic and the circulation of rolling stock.

There is no reason to expedite the introduction of the European ERTMS/ETCS system in Finland because, due to the track gauge, only cross-border railway transport to third countries is possible. Investments in the maintenance of the current well-functioning train protection system are worthwhile in order to allow time for the ERTMS/ETCS system features to develop so as to better suit the conditions in Finland. There is no reason to expedite the transfer to a system that is unreliable, unsuitable and more expensive than the existing system.

2.3 Cost-benefit analysis

In Finland, cost benefit does not constitute grounds for transferring to the ERTMS/ETCS system. Instead, the aim is to maintain the safety and trafficability of the state-owned rail network at the current level. In any event, the JKV system must be replaced in the future and the ERTMS/ETCS is the only legal option for the purpose.

In practice, the ERTMS/ETCS system is the only system widely used in Europe and other parts of the world that could replace the JKV. It is clear that it is not economically reasonable to maintain a system developed at the national level in Finland beyond its natural life-cycle, as the alternative is a system such as the ERTMS/ETCS, with several equipment suppliers and a large number of users, and with good continuity of supply for products well into the future. Because these products are available only from the European railway safety equipment industry and the products are mandatory for users, product price competition is not expected to bring down prices to the level of products subject to free competition. Therefore, the overall costs of ERTMS/ETCS solutions are likely to remain clearly higher than those of the old systems. It is difficult to predict market prices in the 2020s.

Trains can be operated even without a train protection system. This would save the costs of acquiring a new system. In that scenario, the number of accidents in the rail network due to excessive speed or passing a stop signal would rise to equal the numbers before the JKV was acquired. For instance, a major cause for the railway accidents in Jokela in 1996 and Jyväskylä in 1998 was the lack of a train protection system. Serious railway accidents are extremely rare and have occurred in Finland variably, approximately once every ten years, but no such accidents have occurred in passenger transport in the early 2000s, largely thanks to the JKV system. In terms of the attractiveness of railway transport and passenger transport in particular, a high level of safety is a key criterion. Railway accidents often cause considerable material and human damage.

Current safety consciousness makes a train protection system an essential investment. In practice, an alternative to a train protection system in Finland would be to stop traffic on unprofitable rail sections because a conscious decision to increase the risk of accidents by dismantling the current JKV system can only be made in exceptional cases. Because a train protection system can be considered a compulsory standard feature of modern railways, the acquisition price of the ERTMS/ETCS system must be reviewed alongside the total costs of railway traffic.

In any event, major investments must be made in the maintenance of the rail system in Finland if the current traffic volume is to be maintained. Interlocking systems will reach the end of their service life and will have to be replaced in due course. Long-term financing and investment plans are necessary in order for the required investments to be made successfully and cost-effectively. As for now, the Finnish traffic administration does not have the capacity to make binding financial decisions beyond the next 10 years.

The servicing and maintenance of ERTMS/ETCS system Level 1 can be assumed to incur annual costs at least equal to those of the current JKV system. The costs are likely to be higher than at present because the system is more complex and trackside systems may be supplied by several suppliers, making maintenance more complex. In addition, the maintenance costs of the more complex ERTMS/ETCS system are burdened by extra upgrading and software management costs. Management costs are not predicted in the rough investment cost calculations presented later.

3 Technical and financial migration strategy

3.1 Technical migration strategy and overlay on-board

3.1.1 Installation of ERTMS/ETCS on-board subsystems in traction vehicles

Traction vehicles will be equipped with Level 1 ERTMS/ETCS on-board subsystems connected to a Specific Transmission Module (STM), potentially also with Level 2 ERTMS/ETCS on-board subsystems at a later date. The aim is to postpone the installations and the costs incurred from them as far into the future as possible. Systems will not be installed at all in vehicles which are at the end of their service life.

The Sr2 and Sr3 locomotives and Edo steering cars owned by the state-owned railway company VR Group will be equipped with ERTMS/ETCS+STM on-board subsystems. Prior to serial installations, a two- to three-year testing period with at least three vehicle series will be implemented. The interoperability of trackside and on-board subsystems will be examined during the tests, and if necessary, the functionality of ERTMS will be modified within the permitted limits of the system. After the tests, it will be possible to prepare a tender dossier in order to launch the procurement process.

VR Group will equip two Sr2 locomotives and two Edo steering cars in 2022 for the ERTMS/ETCS pilot. As the Sr3 locomotives (Vectron) will be equipped with ETCS+STM on-board subsystems upon delivery, there is no need to plan a separate installation schedule for them. An estimated 50 Sr3 locomotives will be deployed by 2023. It must be taken into account that the ETCS+STM on-board software will have to be upgraded at the same time, in 2023–2025 when the pilot track is built. The purpose of the software upgrade is to ensure the interoperability of the final ERTMS/ETCS trackside system version, to be deployed, (Baseline 3 in use now) with the ERTMS/ETCS+STM on-board software installed in Sr3 locomotives.

The serial installations of ERTMS/ETCS+STM on-board subsystems in Sr2 locomotives and Edo steering cars will begin in 2025. Serial installations in Sr2 locomotives and Edo steering cars will take place in 2025–2029.

The area in which Sm3 trains and Dm12 locomotives operate, and the possible renovation and decommissioning schedule, must be clear by 2023. Sm3 trains will be equipped in 2026–2030 unless the installation can be avoided by placing restrictions on the use of the rolling stock. Dm12 trains will be fully equipped in 2030.

Sm4 and Sm5 trains will be equipped with ETCS+STM on-board subsystems in 2031-2037.

The Sm6 trains operating between Finland and Russia will not be equipped with ETCS+STM on-board subsystems before the rail section Helsinki–Lahti–Kouvola–Luumäki–Vainikkala is equipped with ERTMS/ETCS trackside subsystems.

The oldest traction vehicles (Sr1, Sm2, Dv12, Dr14 and Dr16), which are approaching final scrapping, will not be equipped with ERTMS/ETCS+STM on-board subsystems because they are at the end of their life-cycle. Operational restrictions caused by the progress of the ERTMS/ETCS trackside system construction will be accepted with regard to the old traction vehicles.

3.1.2 Specific aspects of rail traffic in Finland

The ERTMS/ETCS technology takes rail traffic throughout Europe into account on a broad scale, but certain functionalities characteristic of Finnish rail traffic are not included in its current specifications. The functional deficiencies identified by the railway company VR in the ETCS system currently impede the use of the ERTMS/ETCS system in Finnish rail traffic and the service to Russia. Unless the deficiencies are remedied,

migration to the ERTMS/ETCS system would impair the fluency and safety of traffic compared with the current situation.

The following changes would be necessary in order to eliminate the deficiencies:
– Lowering of the minimum braking weight percentage value to 10 per cent.
– Control of increased pressure in brake hoses during service braking.
– Two stage service braking.
– Grip correction factors in accordance with the operating conditions.
– New train categories for international trains.

The official CRs (Change Requests) prepared on the basis of these issues were entered in the European ERTMS/ETCS change management process in 2017.

3.1.3 Railway rolling stock installation requirements

ERTMS/ETCS+STM on-board subsystems must be installed in completely new rolling stock acquired for the Finnish rail network. JKV on-board subsystems may be installed even in new vehicle series of the previously type-authorised traction vehicle types in Finland.

When the construction of ERTMS/ETCS trackside subsystems begins, railway companies must equip their traction vehicles with ERTMS/ETCS on-board subsystems if they intend to operate on the modernised sections of the rail network.

The equipment and approval costs of ERTMS/ETCS on-board subsystems are extremely high for vehicle series comprising individual units. Therefore, it is not financially reasonable to equip railway work and museum traffic vehicles with the ERTMS/ETCS system. The railway safety of these units not equipped with the ERTMS/ETCS systems can be managed through other arrangements without ERTMS/ETCS on-board subsystems.

3.1 Technical migration strategy and overlay of railway infrastructure trackside installations

The schedule for the trackside installations is based on infrastructure construction. The following aspects are taken into consideration in the ERTMS/ETCS system construction schedule:
– Critical traffic streams and central traffic points,
– Interlocking system compatibility,
– Interlocking system lifecycles,
– Traffic control areas and interfaces,
– Maintenance areas and geographical entities,
– Possible need for double equipment.

The intention is to install ETCS trackside equipment from north to south in clear geographical entities. The construction schedule is divided into three-year periods. The gradual implementation by region allows other work and investment requirements related to railway management to be taken into account during construction. Trackside system construction will begin in 2024 at the earliest and is due for completion in 2038 at the latest. The schedule may have to be expedited due to the availability of JKV spare parts.

The years 2020–2023 are reserved for piloting of the ERTMS/ETCS system construction. For the pilot, both JKV and ETCS systems will be installed in order to facilitate easier operation in traffic and to ensure the reliability of rail sections. The rail sections selected for the pilot can be taken into use simultaneously or gradually during the four-year pilot period. Factors that influence deployment include other railway maintenance projects, interlocking system modernisations alongside phasing and objectives of the pilot project.

The deployment of the ERTMS/ETCS system at individual traffic points and the possible need for double equipment must be specified separately for each traffic point. The deployment of the ERTMS/ETCS system must be examined for each traffic point in connection with the detailed regional deployment plans. Traffic point-specific solutions must take into account at least the critical traffic streams, the need to arrange traction vehicles and the train protection equipment standards of surrounding areas. The customer-oriented need for rail network sections to be equipped with both the JKV and ERTMS/ETCS systems will be taken into consideration in more specific deployment plans at various stages. The dates for abandoning JKV will be specified on the basis of the plans.

Traffic points will be fully equipped with the ERTMS/ETCS system as soon as all rail sections connected to the traffic point are equipped with ERTMS/ETCS. The traffic points given in parentheses in the illustrations refer to traffic points which will not be equipped with ERTMS/ETCS trackside subsystems in the first stage.

The construction schedule for ERTMS/ETCS can be specified in due course based on experience from construction of the pilot rail sections, test runs and trials. Some of the rail sections involved at the pilot stage are equipped with interlocking systems in which it is not technically or economically reasonable to implement ERTMS/ETCS interfaces. Modification or replacement of interlocking systems will be necessary in order to pilot and deploy the ERTMS/ETCS system on these rail sections.

The construction of ERTMS/ETCS trackside subsystems will begin by utilising discrete wayside control technology of Level 1 ERTMS/ETCS. At stages 5 and 6, the utilisation of a continuous-action Level 2 ERTMS/ETCS system will have to be assessed in the rail network. Since most rail sections in southern Finland are double-track lines with heavy traffic, Level 2 ERTMS/ETCS technology might slightly increase rail capacity. Because Level 2 ERTMS/ETCS requires new interlocking with Radio Block Centres and an interoperable data radio network, considerable additional investments will be required in order to realise the benefits. The commercial profitability of such investments will be estimated in due course.

3.2.1 Stage 1, pilot in 2020–23

Stage 1 of the trackside subsystem construction is called the pilot stage because the purpose is to provide first-hand experience of all phases of construction and their impact on traffic operations. The necessary test procedures, including ERTMS/ETCS test drive vehicles, possible ERTMS/ETCS laboratories, etc., must be decided on before the pilot stage.

The pilot stage will involve assessing system functionality in general and in various speed limit areas, coding of trackside subsystems in practice and testing the compatibility of the ERTMS/ETCS system with the interlocking systems of various makes and ages.

The intention is to use the services of two ETCS system suppliers for the rail sections involved in the pilot. This will facilitate the assessment of the technical implementation, technical quality and costs of the pilot sites and utilisation of results in selecting the partner for implementation of the following stage.

The following characteristics favour the rail sections shown in Illustration 3 to be taken into use at the pilot stage:

– experiences of ETCS system deployment in connection with interlocking system renewal (Tornio–Kolari, Rovaniemi–Kemijärvi),
– a clear geographical entity, the area belongs to the same maintenance area and is managed by the same traffic control centre,
– the interface in Oulu facilitates potential traction vehicle arrangements necessary for transfer from one train protection system to another.

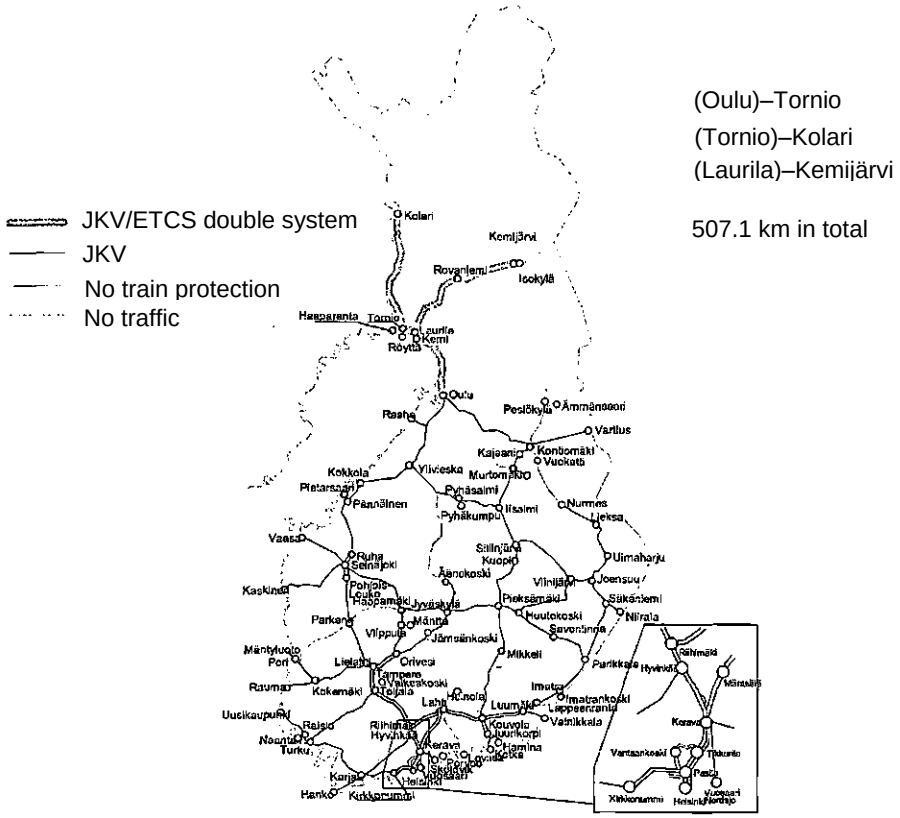

Illustration 3 Stage 1 of ERTMS/ETCS system deployment, pilot in 2020–23.

3.2.2 Stage 2, Vartius–Oulu–(Seinäjoki) in 2024–26

The rail sections to be deployed at Stage 2 of the trackside subsystem construction are well-suited as the first ones to be equipped with ERTMS/ETCS without JKV, for instance, due to the following:

– the Oulu traffic control area will be completed with the ERTMS/ETCS system
– based on critical traffic streams, the rail section Kokkola–Vartius will be made coherent simultaneously
– interfaces in Seinäjoki and Iisalmi facilitate potential traction vehicle arrangements necessary for transfer from one train protection system to another.

Stage 2 will see the significant traffic points and junctions of Oulu, Kontiomäki, Ylivieska and Kokkola equipped with the ERTMS/ETCS. The JKV system will be dismantled from the pilot track sections during Stage 2. At the end of this stage, all rail sections in the Oulu traffic control area will only be equipped with ERTMS/ETCS.

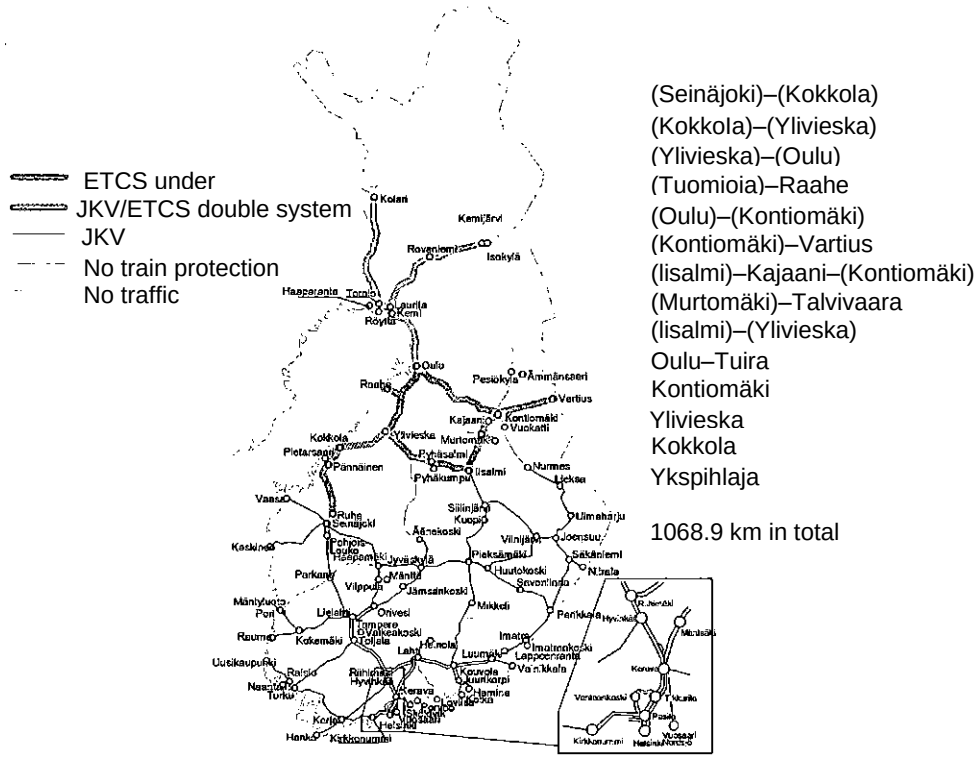

Illustration 4 Stage 2 of ERTMS/ETCS system deployment, Vartius–Oulu–(Seinäjoki) in 2024-26.

3.2.3 Stage 3, Western Finland in 2027–29

Stage 3 of the trackside construction project will involve the completion of Western Finland, an area with heavy traffic, with the ETCS system, and make the traffic control area coherent. Interfaces in Tampere and Pieksämäki facilitate potential traction vehicle arrangements necessary for transfer from one train protection system to another. Most of the rail sections involved at this stage are equipped with interlocking systems in which ERTMS/ETCS interfaces cannot be directly implemented. These rail sections will require a modification or renewal of interlocking due to the introduction of the ERTMS/ETCS.

This stage will see the significant traffic points and junctions of Seinäjoki and Jyväskylä equipped with the ERTMS/ETCS.

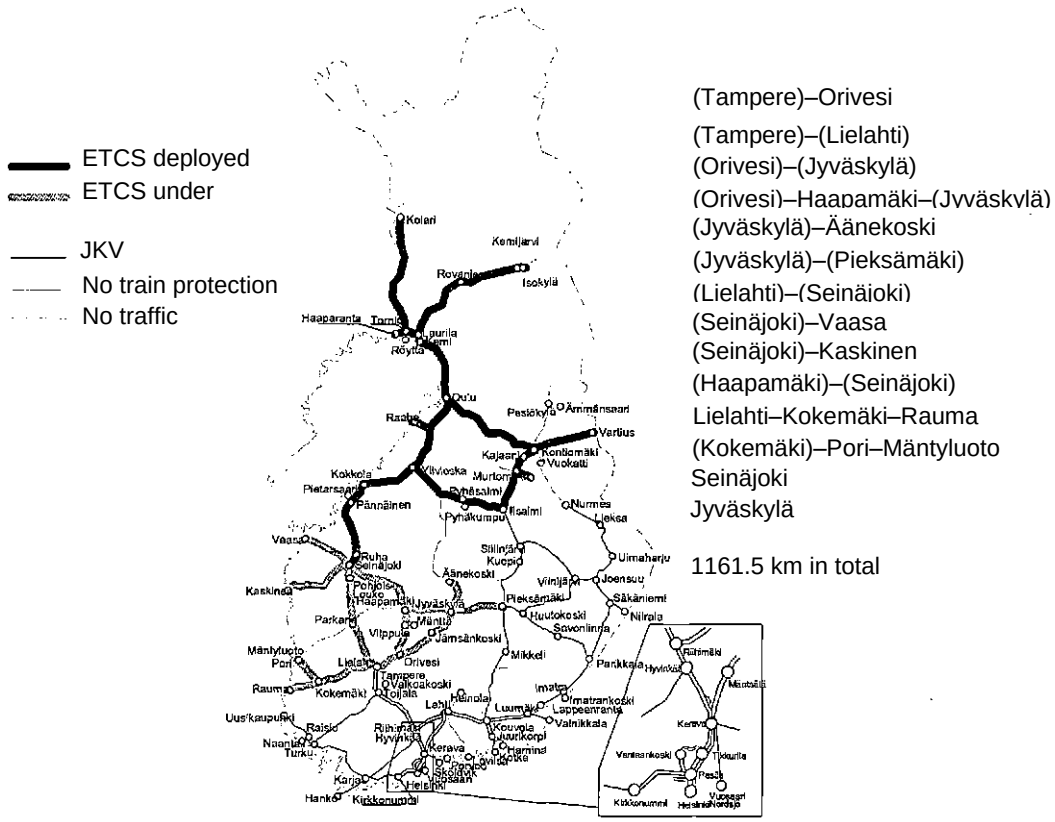

Illustration 5 Stage 3 of ERTMS/ETCS system deployment, Western Finland in 2027–29

3.2.4 Stage 4, Eastern Finland in 2030–32

Stage 4 of the trackside construction project will involve the completion of Eastern Finland with the ETCS system. The southern interface of the area is at the Luumäki traffic point. This will ensure the coherence of the Vainikkala–Kouvola–Kotka section, key in terms of goods transport. ETCS will be installed in that section simultaneously in Stage 5.

Most of the rail sections involved at Stage 4 are equipped with interlocking systems in which ETCS interfaces cannot be directly implemented. These rail sections will require a renewal of interlocking due to the introduction of the ETCS.

This stage will see the significant traffic points and junctions of Pieksämäki, Iisalmi, Parikkala, Joensuu and Imatra equipped with the ETCS.

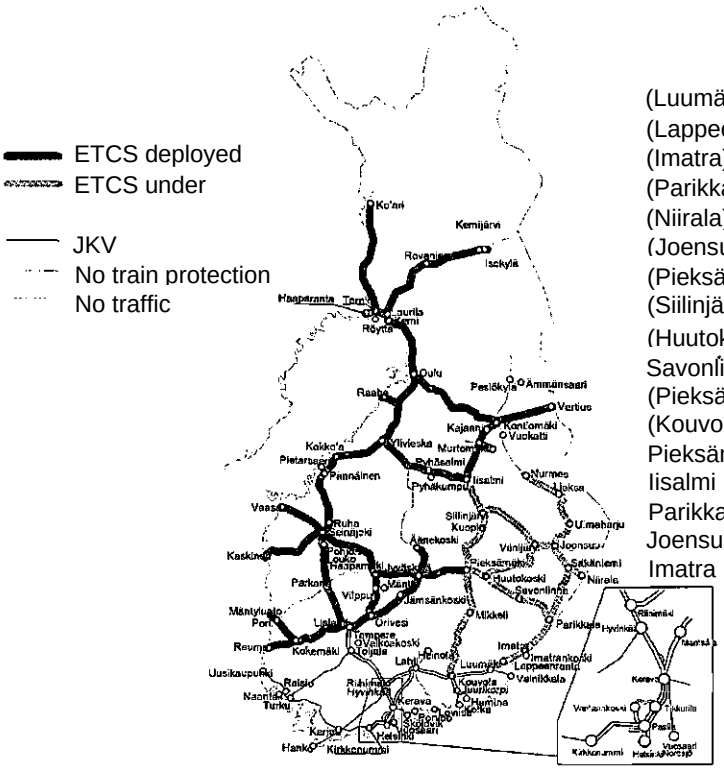

Illustration 6 Stage 4 of the ERTMS/ETCS system deployment, Eastern Finland in 2030–32

3.2.5 Stage 5, Southern Finland in 2033–35

Stage 5 of the trackside construction project will involve the completion of Southern Finland, excluding the commuter traffic zone, with the ERTMS/ETCS. The rail sections Hyvinkää–Riihimäki and Huopalaht–Kirkkonummi will be equipped with both JKV and ERTMS/ETCS trackside systems in order to ensure the functionality of the Helsinki metropolitan area commuter traffic and traction vehicle arrangements at the Riihimäki traffic point when transferring from one train protection system to another.

This stage will see the significant traffic points and junctions of Turku, Tampere, Hämeenlinna, Toijala, Kouvola, Lahti and Vainikkala equipped with the ERTMS/ETCS. Stage 5 interfaces with regard to commuter traffic and the possible need for a double system will have to be specified at a later date. The restrictions presented in this report are based on the 2017 commuter rail traffic model.

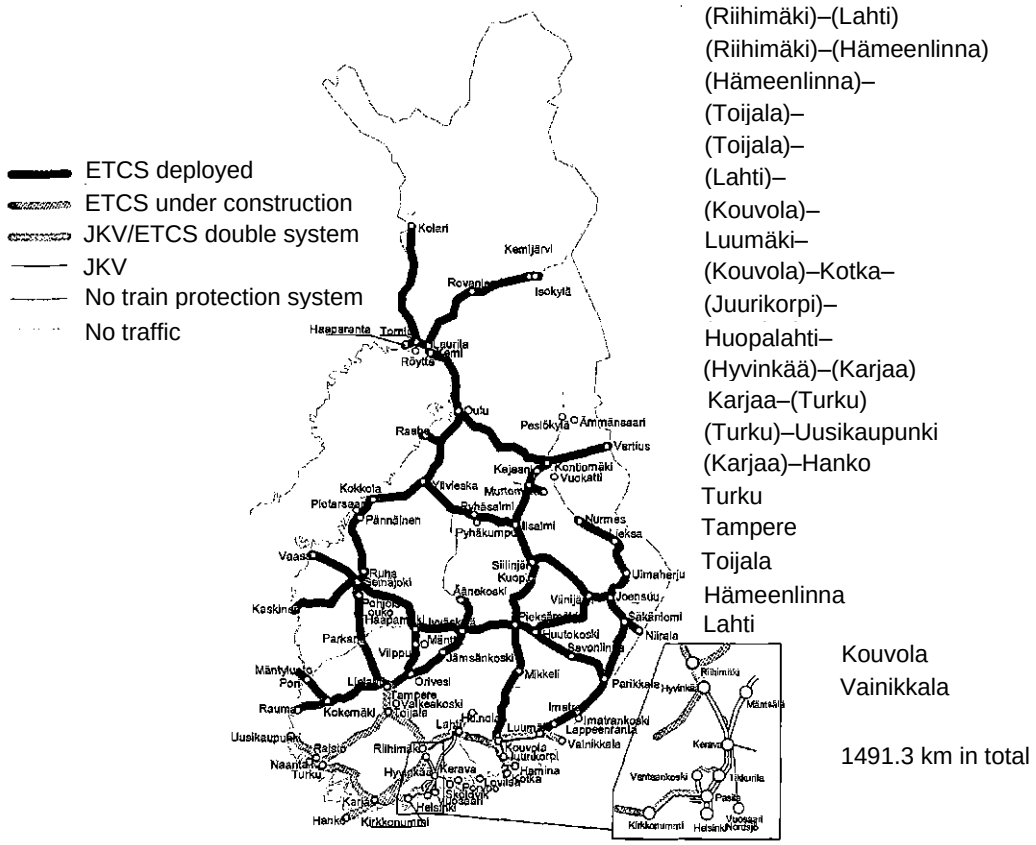

Illustration 7 Stage 5 of the ERTMS/ETCS system deployment, Southern Finland in 2033–35

3.2.6 Stage 6, Helsinki metropolitan area 2035–2038

The Helsinki metropolitan area will be the last in the deployment of the ERTMS/ETCS system because of the specific challenges posed by the railway safety equipment technology and the complex railway infrastructure of the area. This stage will be the most challenging of all due to high traffic volumes, traffic disturbances due to construction and the high number of equipment and rolling stock modification required.

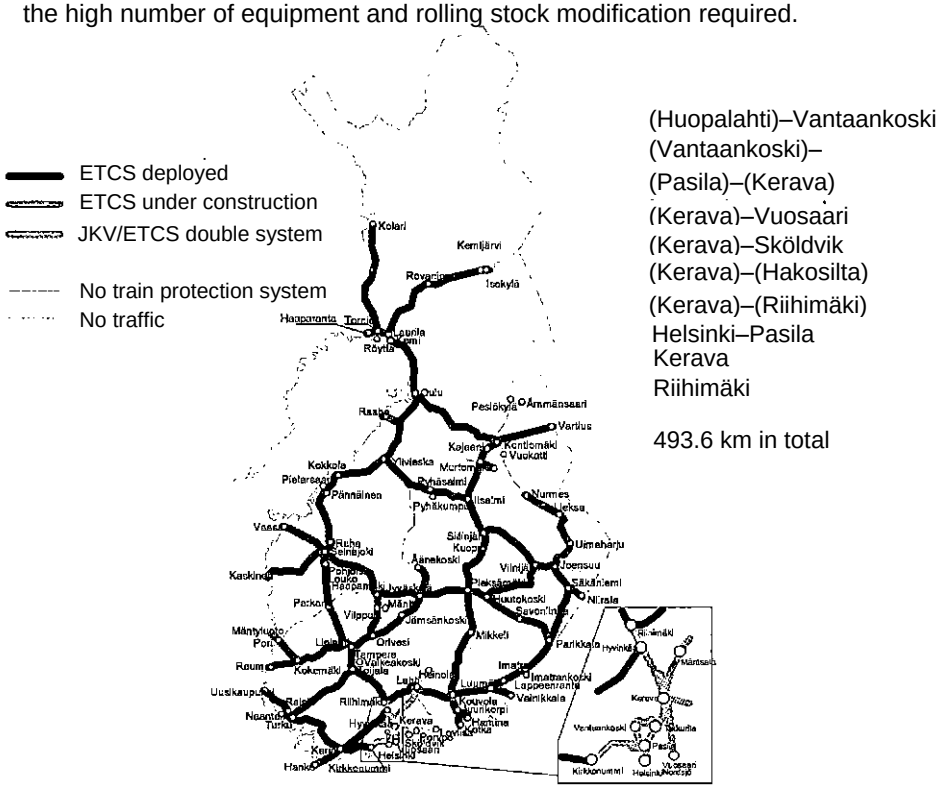

Illustration 8 Stage 6 of the ERTMS/ETCS system deployment, Helsinki metropolitan area in 2035–2038

3.3 Financial migration strategy, i.e. ERTMS/ETCS funding for both rolling-stock and infrastructure

3.3.1 Funding of ERTMS/ETCS on-board traction units

Railway companies compete in the logistics market both with each other and transport companies using other modes of transport. On-board ERTMS/ETCS installations do not involve any commercial benefits for them. Instead, additional costs will be incurred from investments in the new system, downtime due to installations, maintenance and upgrades. For now, it is not known whether external economic incentives will be introduced for railway companies.

Possible funding models for the ERTMS/ETCS on-board subsystem are presented in Annex 1. Without financial clarity and incentives, railway companies may further delay the implementation of ERTMS/ETCS on-board subsystems in their traction units. European rules for national aid for on-board systems are unclear. This obviously causes delays in the deployment of ERTMS/ETCS both in Finland and in other countries.

A preliminary cost estimate has been prepared on the basis of the number of traction units held by VR Group, Pääkaupunkiseudun Junakalusto Oy and Oy Karelian Trains Ltd (a joint venture owned by VR Group and Russian state-owned railway company OAO Rossijskije zeleznyje dorogl, RZD) and Fenniarail Oy. Vehicles owned by potential future operators or costs targeted at them are not taken into account in the cost estimates. The estimated costs are based on the acquisition of 100 ETCS+STM on-board units. (European Commission 2016b)

The installation of ETCS+STM on-board subsystems in rolling stock (locomotives and trains) will cost approximately EUR 230 million. Since new traction units ordered at a later date will be delivered complete with ETCS+STM on-board subsystems, the price of on-board subsystems is included in the purchase price of the vehicles.

The following costs are used as default in the calculation:
– The procurement price of on-board ETCS+STM is EUR 375 k / unit,
– The installation will require 400 hours / on-board ETCS+STM,
– The planning per vehicle series requires 1,500 hours,
– The price of an ETCS software upgrade per Sr3 locomotive totals EUR 50 k.

Please note that the following costs are not included in the cost estimates:
– Training of drivers or maintenance personnel,
– Project management,
– Indirect costs such as costs incurred from downtime.

Table 1 Cost estimate per equipment to be installed and per number of installations.

Type of traction unit	**Number**	Costs	Note!
Sr2	46	EUR 24.7 M	VR Group Heavy electric locomotive, Transtech. No decisions on installations are made.
Sr3	(80)	EUR 4.9 M	VR Group Heavy electric locomotive, Siemens AG. Covers ETCS software upgrade. No decisions on installations are made.
Edo	42	EUR 22,6 M	VR Group Steering car, Transtech. No decisions on installations are made.

Sm3	17	EUR 18.9 M	VR Group Pendolino, Fiat Ferroviaria. Covers two sets of on-board ETCS+STM per train. No decisions on installations are made.
Sm6	4	EUR 4.7 M	Oy Karelian Trains Ltd. Allegro, Alstom. Covers two sets of on-board ETCS+STM per train. No decisions on installations are made.
Dm12	16	EUR 9.3 M	VR Group Railbus. CKD Vagonka. No decisions on installations are made.
Sm4	30	EUR 38.9 M	VR Group Electric low-floor commuter train. Fiat Ferroviaria. Covers two sets of on-board ETCS+STM per train. No decisions on installations are made.
Sm5	81	EUR 103.6 M	Pääkaupunkiseudun Junakalusto Oy. Electric motor train. Stadler Rail. Covers two sets of on-board ETCS+STM per train. No decisions on installations are made.
Dr18	5	EUR 2.5 M	Fenniarail Oy. Modernised heavy diesel locomotive, diesel-electronic power transmission. ČKD. No decisions on installations are made.
Total:	**241 (+80)**	**EUR 230 M**	

Table 1 indicates that the highest investment costs will involve the Sm4 and Sm5 trains, used in urban traffic and commuter traffic in the Helsinki metropolitan area. In the best-case scenario, the cost may be halved for both traction units if only one ETCS+STM on-board subsystem per train is needed (depending on the features of the ERTMS equipment). This would reduce costs by approximately EUR 71 million.

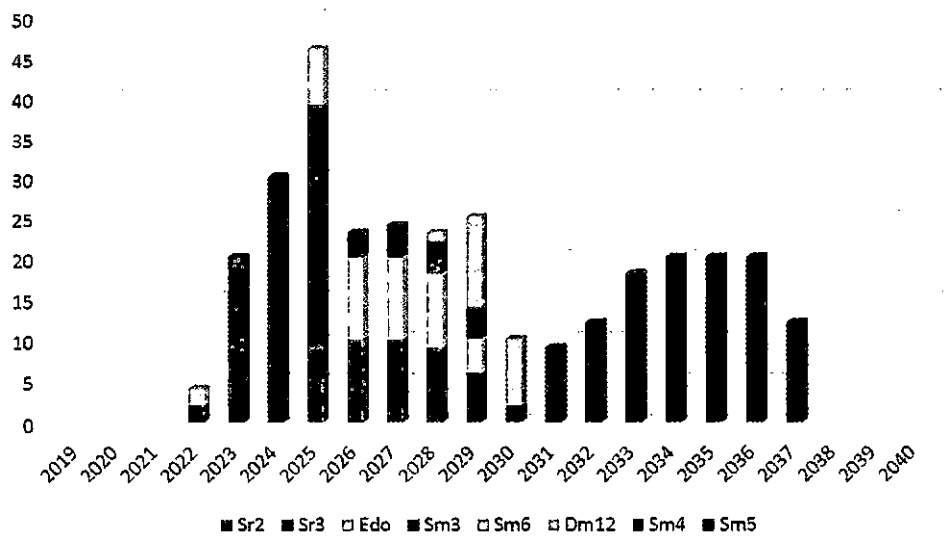

Illustration 9 The annual installations of ETCS+STM on-board subsystems per type of traction unit.

Illustration 9 shows the annual installations of ETCS+STM on-board subsystems per type of traction unit. It is noteworthy that the installation of ETCS+STM on-board subsystems in Sr3 locomotives in 2023–2025 only require a software upgrade.

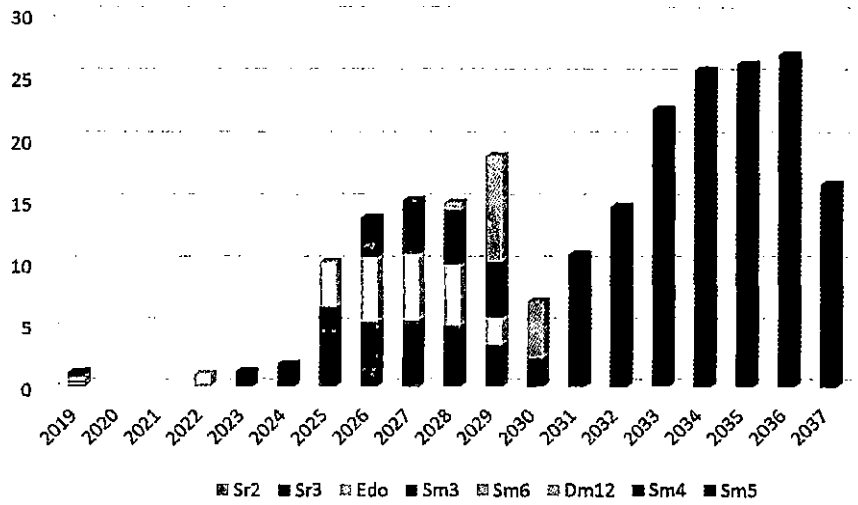

Illustration 10 Cost estimate of ERTMS on-board subsystem installations per year (EUR M).

Illustration 10 proposes EUR 160 k in planning costs for the first locomotive of each traction unit series for the year 2019. In 2025–2037, the costs incurred from system installation will average approximately EUR 17 million. The total price of the ERTMS software upgrade for the Sr3 locomotive series is estimated at approximately EUR 5 million.

3.3.2 Funding of railway infrastructure ERTMS/ETCS trackside subsystems

In the next 25 years, significant investments in Finland's railway network are required in order to maintain the network's current service level. A considerable number of the currently used railway safety equipment will have to be replaced by 2040. The service life of traditional relay interlocking devices is around 50 years and that of modern computerised interlocking systems, around 30 years. The functionality of the interlocking devices in use is not fully compatible with current requirements. Some of the interlocking systems will have to be replaced prematurely due to the introduction of the ERTMS/ETCS system.

Today, the Finnish Transport Agency is the infrastructure manager, responsible for investments in the rail network and installations of railway safety equipment. The intention is to allocate funding required for the ERTMS/ETCS investments primarily from the Agency's budget, while utilising other possible financial instruments. It is challenging to estimate long-term costs, particularly as continuous financing is not guaranteed.

The ERTMS/ETCS investment costs vary greatly depending on the technology chosen. In Finland's single track railway network where the traffic volume is relatively low, the technically and economically most reasonable option is discrete wayside control utilising Level 1 ERTMS/ETCS technology. This concept will enable the construction of interlocking and ERTMS/ETCS trackside subsystems with a cost of approximately EUR 1.4 billion. Implemented using continuous-action Level 2 ERTMS/ETCS system technology, the investments required would multiply to several billions of euros. (UIC a, b 2012), (European Commission 2016b)

The starting point for the calculation is upgrading of almost the entire railway network by 2040, which would incur approximately EUR 1,100 million in costs from interlocking systems and around EUR 320 million from Level 1 ERTMS/ETCS trackside subsystem construction. Cost estimates include interlocking system deliveries, installation of systems outdoors and indoors, and project and commissioner tasks. The ERTMS deployment scenario, presented above, progressing from north to south and west to east, is taken into consideration in the calculations.

Interlocking system investment costs during the construction of ERTMS/ETCS in 2025–2040

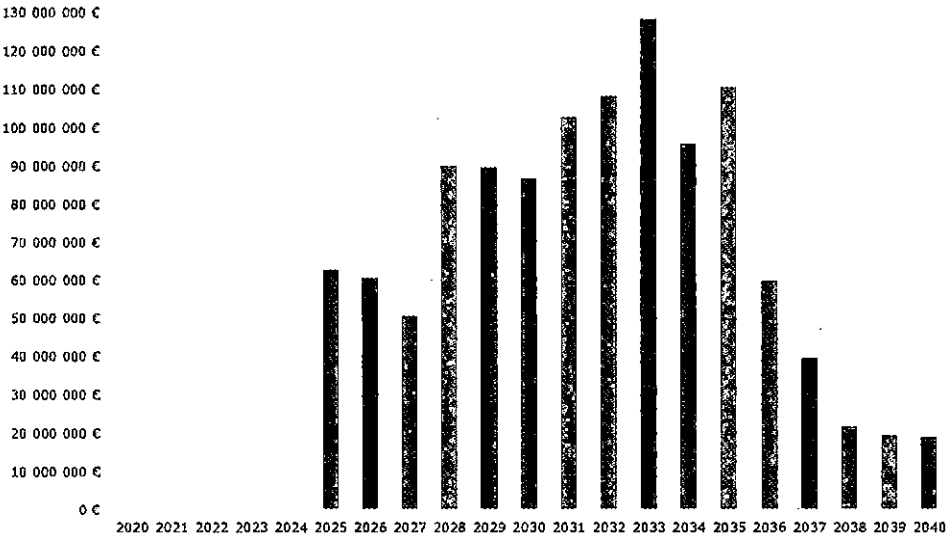

Illustration 11 Interlocking system investment costs during the construction of ERTMS/ETCS in 2025–2040.

The estimated interlocking system investment costs from 2025 alone, excluding the investments implemented in 2017–24, are illustrated in Illustration11. If investments in interlocking systems began from 2017 at around EUR 50 million per year, there would be less annual investment pressure during the construction of ERTMS/ETCS trackside subsystems in 2025–2040. The figure illustrates the considerable investments required in the future as the lifecycle replacements of both relay and computerised interlocking systems, which become outdated, accumulate in the 2020s to 2030s.

Costs incurred from the construction of ERTMS/ETCS trackside subsystems and investments in interlocking systems in 2020-2040

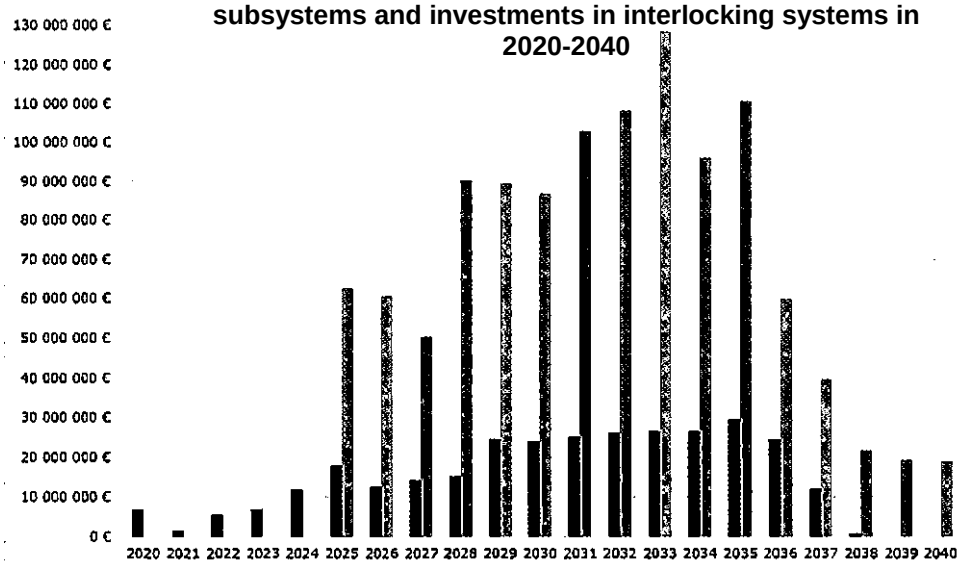

Illustration 12 ***Costs incurred from the construction of ERTMS/ETCS trackside subsystems and investments in interlocking systems in 2020–2040***

The relative share of EUR 320 million in investments in Level 1 ERTMS/ETCS trackside subsystems of the total investments in railway safety systems is illustrated in Figure 12. The train protection system is only a fraction of the costs of railway infrastructure maintenance.

3.4 Development of competence related to the ERTMS/ETCS system

ERTMS/ETCS projects involve new technical and commercial issues. Systematic enhancement of expertise is required in various organisations in the railway sector in order to facilitate the testing, construction, approval and use of the systems. All parties concerned, the infrastructure manager, railway companies and service providers in the approval process, as well as safety authorities, must ensure the development of competence relating to the ERTMS/ETCS projects well in advance of the launch of large projects.

The infrastructure manager plays a key role as the agency responsible for railway infrastructure instructions. It must support competence development in various organisations through open cooperation and extensive competitive tendering of concrete ERTMS/ETCS projects.

4 Open market conditions for legacy Class B train protection systems

Any railway company operating in the state-owned railway network in Finland will have to install a Class B train protection system, JKV, in its trains if it intends to operate trains in the railway network equipped with the JKV trackside system. For this purpose, two options are commercially available for railway companies in the railway safety system market: a JKV on-board system or a ERTMS/ETCS+STM on-board subsystem. Both the JKV and the ERTMS/ETCS+STM on-board subsystem constitute a major threshold for entering the railway market, because the systems are expensive and their approval for use is highly labour-intensive. The approval of ERTMS/ETCS+STM on-board subsystems in the European approval process is very expensive and takes a long time. That slows down railway companies' access to the railway network.

4.1 JKV on-board system

In past years, delivery problems have impeded the availability of JKV on-board systems in the market, but there are no such problems at present. Based on information received from the equipment supplier, Bombardier Transportation Finland Oy, on-board systems will be available until approximately 2025. However, ensuring the availability of on-board systems is a matter of commercial agreement between the railway companies and the equipment supplier, including prices, delivery times and other terms and conditions. Technically, it would be possible to utilise decommissioned on-board systems, but due to contractual reasons of the equipment supplier, the resale of used equipment has not been possible. JKV system locomotive antennae are subjected to wear and tear during use. Therefore, the supply continuity and availability of the antennae and other similar sub-components affect the maintenance of the system.

Fenniarail Oy, established in 2009, is a privately owned Finnish goods transport rail operator which began operating in the rail network in summer 2016. The locomotives Fenniarail acquired are equipped with the JKV on-board system.

4.2 The Specific Transmission Module (STM)

Finland has created open-market conditions for the legacy Class B train protection system JKV, i.e. ATP-VR/RHK, by bringing a compatible, specific transmission module STM into the market. The JKV-STM developed for Finland is a product of the Swedish equipment supplier Ansaldo STS Sweden AB, which belongs to the Japanese Hitachi Group. It is sold openly to all purchasers on commercial terms agreed between the contracting parties. The terms depend on the volume of the purchase, the complexity of the required equipment integration, and schedules.

The STM device is installed on board the locomotive. Therefore, the owner of the traction vehicle is responsible for linking and integrating it with the ERTMS/ETCS on-board subsystem. Such a project requires the coordination of software products by two railway safety equipment suppliers and approval of the ERTMS/ETCS+STM on-board subsystem. European approval processes are extremely costly and take a long time, which makes the acquisition of ERTMS/ETCS+STM on-board subsystems laborious and expensive for railway companies.

The Finnish railway traffic market is open in terms of the availability of on-board systems, but in practice, the long time span and high cost of projects impede railway companies' entry into the market. The acquisition of ERTMS/ETCS+STM on-board subsystems is a major investment for small railway companies and one of the major bottlenecks.

5 Dismantling of the Class B train protection system

The figure shows the dismantling timeline of the current JKV system, i.e. the class B train protection system. The schedule is based on the previously presented schedules for deployment of the ERTMS/ETCS system on each rail section.

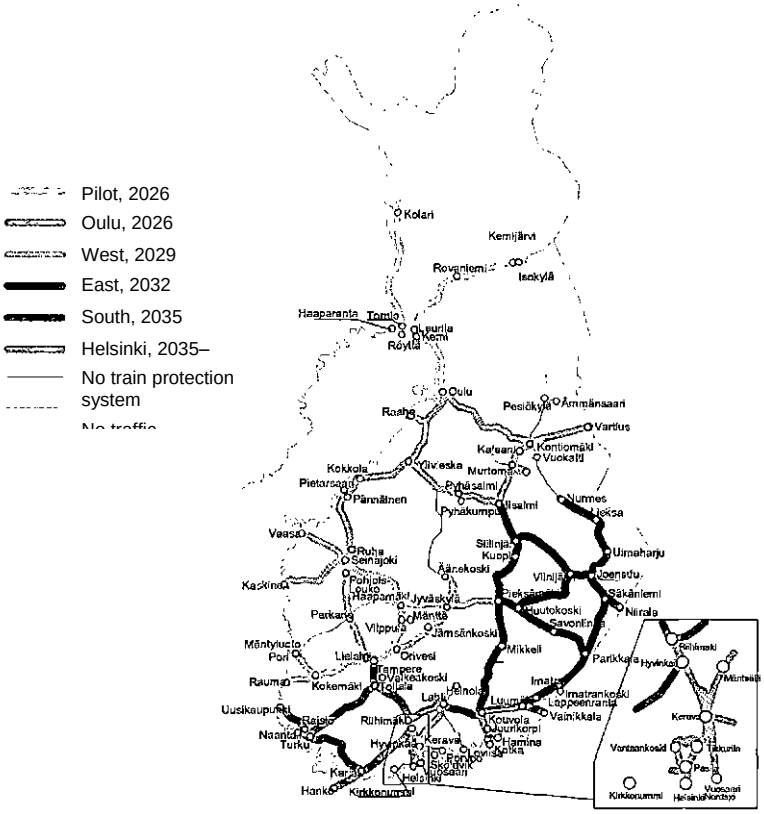

Illustration 13 Timeline for dismantling the JKV system by region.

The JKV system will be dismantled in connection with the deployment of the ERTMS/ETCS system. The actual time for deployment is the final year of each project, provided that it is appropriate in terms of railway maintenance and traffic operations. For instance, at stage 3, in Western Finland, ERTMS/ETCS will be installed in 2027–2029 and JKV decommissioned in 2029. The double system in place on pilot rail sections will be dismantled in line with the stage 2 decommissioning schedule, in 2026.

The proposed schedule may have to be postponed if the ERTMS/ETCS projects are not implemented as planned. The precise dates for each rail section will be specified during the planning of the actual implementation project, involving coordination of the work with other railway maintenance projects, interlocking upgrades and traffic requirements.

Sources

European Commission. (2016a). *COMMISSION REGULATION (EU) 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/FI/TXT/PDF/?uri=CELEX:32016R0919&from=FI European Commission. Referred to 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/UPLQADS/pageimages/RU%20dialogue/T7 DEL 7%2 01 %203 Report%20ERTMS%20Business%20Case%20CNC.pdf Euroopan komissio.
Referred to on 24 January 2017.

Härkönen, A. & Järvinen, L. (2014) *Konkretiaa eurooppalaisen junien kulunvalvonnan käyttöönottoon rataverkolla ja vetävässä kalustossa.* Liikenneviraston tutkimuksia ja selvityksiä 44/2014. ISBN 978-952-317-010-0. Published 11/2014.

Härkönen, A. & Matikainen, L. (2016) Rautatietekniikka-lehti 4/2016. ISSN: 12371513. Published 12/2016.

Finnish Transport Agency (2014). *Junien kulunvalvonta JKV, Ratatekniset ohjeet (RATO) osa 10, Liikenneviraston ohjeita 8/2014.* ISBN 978-952-255-424-6. Published 11/2014.

Finnish Rail Administration. (2006). Eurooppalaisen rautatieliikenteen hallintajärjestelmän (ERTMS) Suomen kansallinen toteuttamissuunnitelma. 28.12.2006. https://ec.europa.eu/transport/sites/transport/files/modes/rail/ertms/doc/edp/national deployment plans/finland ndp.pdf
Referred to on 21 February 2017

Tuomi, M. (2016). *Rautatieturvalaitteiden kustannuslaskentamalli - Yksikköturvalaite-kustannusten laskenta.* Liikenneviraston tutkimuksia ja selvityksiä 25/2016. Helsinki: Finnish Transport Agency

UIC. (2012a) International Union of Railways. *ERTMS Implementations Benchmark Final Report - February 2012.* 25.3.2012, 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. 20.3.2012, version 1. ISBN 978-2-7461-2080-8.

Vainiomäki, V. (2014). *JKV-järjestelmän merkitys rautateiden turvallisuudelle ja kilpailun syntymiselle.* Helsinki: Finnish Transport Safety Agency Trafi.