

Metro capacity and reliability improvement

Project mandate, Implementation of an Automatic Train Control System

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In cooperation:

Metropolitan City Area Transport Ltd

HKL

HSL – Helsinki Regional Transport Authority

City of Espoo

Länsimetro Oy



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Foreword

HKL, HSL, Länsimetro Oy and City of Espoo have agreed on cooperation for increasing the capacity and reliability of the metro. HKL places orders for the services necessary for the operation, maintenance, asset management and further development of the metro to Metropolitan Area Transport Ltd, to which HKL's personnel and operations have transferred on 1st February 2022.

This project plan presents a plan for the replacement of the automatic train control system of the metro.

There are several systems in use in the metro that are approaching or already at the end of their lifecycle. It is critically important for reliable operations to ensure the functioning of these systems for as long as necessary. A train protection system is a central part of ensuring the safety of metro operations. The current train protection system is at the end of its lifecycle and its reliable useful life is approaching its end. Therefore, it is proposed to invest in a replacement system that enables significantly more efficient operations than the current one.

According to the ridership forecasts made by HSL in the spring of 2018 and updated in the summer of 2020, the passenger numbers of the metro will exceed its capacity during the next decade as land use in the metropolitan area develops. The COVID-19 pandemic has, however, decreased the ridership temporarily and it is assumed that the impacts of this will continue to have a negative impact on the ridership compared to the forecasts made before.

The replacement of the system is proposed to be implemented so that the Automatic Train Supervision system of the metro enables shorter headways when this becomes relevant and additional trains are procured.

The project plan defines the qualitative objectives for the train protection system replacement, sets a cost cap for the implementation and describes the project outcome.

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Abstract

The metro is the backbone of the metropolitan area public transport system on the east-west axis upon which the convenience and attractiveness of the system is built. Therefore, the metro must offer a high-quality, reliable service, and sufficient capacity is essential for the good functioning of the metropolitan area public transport system.

The existing trip stop train protection system of the metro is at the end of its lifecycle. Due to problems relating to maintenance and availability of spare parts, significant investments are necessary and the system's safety integrity level does not fulfil modern requirements set to signalling systems of heavy rail transport. The ageing system sets challenges for the reliability of the entire metro system. Maintenance of the ageing system is also becoming difficult as the number of experts qualified in the ageing technology is decreasing and it is easier to find know-how for newer technologies.

The metro must be developed proactively because the cost-effective replacement of a live operational train protection system requires careful planning, and the work will last several years.

The project is to replace the current train protection system of the metro with a modern system that is cost-effective and provides a higher automation level while also fulfilling the capacity needs of the future. This ensures the metro system's capability to respond to the potentially fast-growing demand. The replacement to be made now enables shortening the headways of the metro and increasing its capacity by 25 %. Shortening the headways will also require additional rolling stock and the replacement of the old train fleets.

Upgrading the traffic control system is a very cost-effective and environmentally friendly way to increase the capacity of the public transport system. Improving the capacity of the existing metro line corresponds to a capacity increase that would require significant infrastructure projects in other modes of transport.

The proposed 25% capacity increase is equivalent to three new light rail lines, ten bus lines with needs for additional street capacity or one motorway lane. This will be achieved without construction of new infrastructure and thus the project can be described as a "digital road widening". In terms of costs, the project naturally compares very favourably to the above-mentioned alternatives.

The ridership of the metro has increased rapidly in the last years until the COVID-19 pandemic, whose impact on the metro remains clearly visible to this day. From 2010 to 2019 the ridership of the metro has increased by circa 62 % and the peak load of the metro has increased by circa 14 % from 2012. A major part of the increase can be attributed to the opening of the Western Metro Extension to Matinkylä.

According to the metro ridership forecast made in the study conducted jointly by HSL and the metro stakeholder municipalities of the metro in 2020, the ridership of the metro would have exceeded its capacity by 2030. On the eastern branches, the load factor varied in different scenarios between 82–97% on the Myllypuro–Itäkeskus section and between 100–111% on the Urheilupuisto–Tapiola section. On the Matinkylä line, passengers have



already described the trains as congested at a load factor of approx. 81%. The current capacity of the metro will, however, lead to congestion on the metro even though the peak hour ridership would decrease by the currently estimated 15% compared to the forecasts.

The above-mentioned forecasts were made using a pre-pandemic ridership model. The pandemic caused the ridership of public transport to collapse. HSL has studied the changes in mobility after the pandemic in 2021 and the assumption is that peak hour demand in particular will permanently remain on a lower level as remote working remains more common. The changes in mobility are still ongoing, and there are currently other considerable uncertainties as well, such as oil prices, which increased in 2021, environmental objectives, the situation of the war in Ukraine and the impact of the sanctions against Russia.

The impacts of a possible deterioration of the metro's service level, i.e., of reliability and punctuality, on metro ridership and consequently on fare revenues and socio-economic costs, have been assessed in the preparation of the project plan.

The project is scheduled to start in 2022 with the launch of the relevant procurements. The target is to sign the delivery contract for the automatic train control system in 2024 and to complete the system by 2029.

The total costs of the project are estimated at 110 million euros.

Glossary

Traffic control system	Overall system of the metro traffic control that consists of Automatic Train Supervision (ATS), interlocking, a data transmission system and various controlled or monitored lineside equipment, for example signals.
Automatic Train Supervision, ATS	System that controls the movement of metro trains through the interlocking. The system monitors the location of the trains and routes their movement automatically while providing the possibility to manually intervene with the traffic.
Interlocking	Controls and monitors the wayside equipment and monitors train safety.
Audio frequency track circuit	Detects the presence of a train in the device's respective metro track section.
Trip stop system	System that gives a stop command to the onboard equipment connected to the brake system by means of a magnetic field when the wayside magnet's field is not disabled. The magnetic field is only disabled when the signal near the way-side magnet shows a proceed aspect.
Automatic train protection or train protection system	System that continuously controls the maximum permitted speed of the train and its distance to the end of the track section it is authorised to run on. If the driver does not obey the speed limit and brake curve to the stopping place, the onboard equipment of the system reduces the speed of the train automatically.



Automatic Train Control System, ATC	Automatic Train Control. Train control system that combines an automatic train protection system with automatic train operation system providing automatic driving.
Greenfield project	A project that is carried out on a new transport system under construction. E.g. the second phase of the Western Metro Extension.
Brownfield project	A project that is carried out on an existing transport system in which existing equipment is upgraded. E.g. the core metro interlocking upgrade.
GoA	Grade of Automation. Degree of automation of the rail transport system. The number is assigned to indicate the degree of automation.
GoA0	Level 0 means driving according to the driver's visual observations.
GoA1	On level 1, the driver drives according to the colour light signals and typically the traffic control system has an ATP system in place.
GoA2	On level 2, semi-automatic driving is used, i.e. the driver's task is to close and, as a rule, open the doors and to give permission for departure of the train. Automation drives the train to the next stopping position.
GoA3	On the 3rd level, automatic driving is used, i.e. driver is not required. Automation drives the train to the next stopping position. However, the train is staffed by an operator for exceptional circumstances.
GoA4	On the 4th level, automatic driving is used, i.e. driver is not required. Automation drives the train to the next stopping position. The train does not normally have operator staff.
M100	Metro train series introduced in 1980–1984,
M200	Metro train series introduced in 2000–2001.
M300	Metro train series introduced in 2017–2018, five option trains will come in 2022.
M400	Metro train series of the future, procurement has not been started yet.
SIL	Safety Integrity Level. Level 4 is the highest level specified to safety-critical systems; level 0 is the lowest that has requirements relating to the quality only.

Background and objectives

The metro as part of the metropolitan area public transport system

The metro is the backbone of the metropolitan area public transport system on the east-west axis upon which the convenience and attractiveness of the system is built. Therefore, the metro must offer a high-quality, reliable service, and sufficient capacity is essential for the good functioning of the metropolitan area public transport system.



The advantage of the metro is its high average speed compared to other alternatives. Only the commuter trains provide comparable average travel speeds.

The production costs of a passenger kilometre also differ positively from other alternatives except for the commuter trains. In 2019 the cost of a passenger kilometre on the metro is less than half of the cost of a bus or tram. In 2020, the significant increase of the cost of a passenger kilometre on the metro and tram relative to bus transport compared to the prior cost can be attributed to the impacts of the pandemic as well as the investments made in the Western Metro Extension.

The metro also is an environmentally friendly mode of transport in many respects. Trains running with electric power without local emissions transport a very high number of passengers with a relatively small footprint and mostly located underground. Hence, the metro has the ability to decrease above-ground traffic significantly in the densely built downtown area.

The existing trip stop train protection system of the metro is at the end of its lifecycle. Due to problems relating to maintenance and availability of spare parts, significant investments are necessary and the system's safety level does not fulfil modern requirements set to signalling systems of heavy rail transport. The ageing system sets challenges to the reliability of the entire metro system.

The largest development project of the metro system in the recent years has been the extension of the metro to Espoo. The first phase of the extension from Ruoholahti to Matinkylä comprises eight stations and has increased the ridership significantly. The second phase of the extension to Kivenlahti due to open in 2023 will bring an additional five new stations and again considerably increase the ridership according to studies. The areas newly brought into the metro's catchment area are receiving considerable residential and commercial development, which in turn brings potential for ridership growth. This increased ridership, which was higher than anticipated before the beginning of the pandemic, resulted in the need for increasing the capacity of the metro.

On the other hand, mobility needs have changed substantially due to the pandemic and there is no acute need for additional capacity today. The changes in mobility are, however, ongoing, and currently there are other considerable uncertainties as well, such as oil prices, which increased in 2021, environmental objectives, the situation of the war in Ukraine and the impact of the sanctions against Russia. Because investments are needed in any case and the solutions to be procured have a lifetime of several decades, the investments shall enable the increase of the metro system's capacity as the demand for transport increases.

Evolution of the ridership and loading of the metro

The ridership of the metro has increased rapidly in the last years until the COVID-19 pandemic, whose impact on the metro remains clearly visible to this day. From 2010 to 2019 the ridership of the metro has increased by circa 62 % and the peak load of the



metro has increased by circa 14 % from 2012. A major part of the increase can be attributed to the opening of the Western Metro Extension.

In February 2020, the busiest section of the metro in the morning peak hours was in the east between Sörnäinen and Hakaniemi with ca. 8 400 passengers in one peak hour. Of this number, the loading of the Vuosaari line was approximately 4 500 and the loading of the Mellunmäki line circa 3 900 passengers. In the west, the busiest section was between Lauttasaari and Ruoholahti with approximately 5 800 passengers in one peak hour. Of this, the loading of the Matinkylä line was circa 4 000 and the loading of the Tapiola line was circa 1 800 passengers. The highest observed load on a single train was 515 passengers.

According to passenger counting data, the metro lines are very unevenly loaded in the eastbound direction, particularly in the Espoo section. Westbound the Vuosaari and Mellunmäki metro lines are fairly evenly loaded. In Tapiola, the Matinkylä line reached a more than fivefold load compared to the Tapiola line. The uneven loads of the lines will be exacerbated when the Matinkylä line is extended to Kivenlahti and the other line terminates in Tapiola. There are no turnback tracks between Tapiola and Kivenlahti, so an alternative to balance the uneven loads of the lines is to extend some planned Tapiola services to Kivenlahti. In these plans, challenges relating to the connection to Sammalvuori depot and the capacity of the turnback tracks have been identified, which can be solved at least partly by replacing the automatic train control system.

Factors causing uncertainty in ridership growth estimates

Passenger demand is expected to increase in the future along with the growth in the number of residents and jobs. On the other hand, the pandemic (COVID-19) that started in the beginning of 2020, the 2021 oil price increases, environmental objectives as well as the situation in Ukraine and the impact of the sanctions against Russia set challenges to estimating the future need for capacity.

The changes have brought uncertainty to the rate of the ridership growth, possible changes in demand as remote working has increased at least temporarily, and other possible changes in passenger behaviour, e.g., the recently decreased morning peak demand and the resulting more even demand distribution. It is unclear which ones of these changes are temporary and which ones may become permanent practices in the future. According to the traffic modelling experts, it can take 4 to 5 years before the new travelling practices can be modelled and new modelling can be made based on the updated traffic models.

The COVID pandemic has, however, shown that approximately 30 % of public transport trips will be made even in the worst pandemic situation. When recommendations for remote working were in force in December 2021, the number of boarding passengers has been approximately 35 % lower than in normal times, but the ridership has been up to 50 % lower in the peak hours. The recommendation for the sensitivity analysis at this stage is to use scenarios in which the ridership of the metro during the peak hour decreases by 15



% compared to the current models. A reliable assessment of the magnitude of a possible long-term change can-not be made, but in both cases, this would be a significant change in the transport system and therefore it would be suitable for a sensitivity analysis. Mobility is undergoing changes, and it is being followed closely. Current conditions make reliable travel demand forecasts impossible. The changes in mobility are also significantly affected by public transport fares and their relation to fuel prices.

As a result, the estimates have uncertainties, and this can lead to a situation in which the existing system is congested in an intolerable manner, and it is not possible to react to the situation fast enough. To prevent this risk, the ridership and forecasts will be followed regularly. The conclusion of the analysis made in 2021 is that in peak hours the need for capacity will be 15 % lower than estimated before and 5 % lower at other hours. However, the forecast carries a high uncertainty, and it shall be adjusted constantly when more information about the impacts of the changes is available.

Studies on ridership

Significant factors impacting the ridership of the metro include the development of land use in the areas that the metro is serving, changes in mobility practices, and public transport fares. The passenger demand will continue to increase beyond 2030 as land use develops. To gain insight in the maximum increase in passenger demand for the coming decades, HSL has, in cooperation with the cities and municipalities served by the metro, Helsinki, Espoo, Vantaa, Kirkkonummi and Sipoo, made a new extensive study on the development of land use and the transport system until 2060.

According to the metro ridership forecast made in this study, the ridership will exceed the capacity at the end of the 2020s. Based on these traffic forecasts, the busiest section of the metro is between Kulosaari and Kalasatama where there will be approximately 11 800 passengers per hour. In the forecast the ridership west of Tapiola will be approximately 9 300–10 500 passengers per hour in 2030, clearly exceeding the capacity of the current metro service.

In the study, the ridership of the automated metro operating both lines in headways of 200 seconds exceeds the forecasted ridership of the current metro. A shorter headway would increase the passenger demand of the system and then there will be approximately 12 700 passengers per hour between Kulosaari and Kalasatama.

The study was made before the COVID-19 pandemic and the viewpoints of the municipalities on the development of land use were utilised therein. Due to the pandemic, the ridership of the public transport system has decreased significantly for the time being. HSL has investigated the changes in mobility after the pandemic in 2021 and it is assumed that peak hour demand in particular will permanently remain on a lower level as remote working becomes more common. The changes in mobility are still ongoing and transport and ridership forecasts currently come with other considerable uncertainties as well. The variations in mobility needs between seasons and days of the week may also increase if, for instance, remote working days and office days centre on certain days of



the week. Mobility may also increase in other travel groups, in which case the demand peak for evening traffic in particular becomes more pronounced. HSL is starting a more comprehensive study of the changes in travel groups other than commuters. Changes in fares may also impact the ridership significantly. As for the capacity of the metro, it is necessary to prepare for the possibility of increasing the capacity in accordance with demand when developing the system.

Table 1. Forecasts of the capacity and ridership in accordance with Helmet 3.0 model, Metro 2060 study.

Track section/Station	Passengers per hour	Load factor	
	Capacity	Metro2060	-15%
Urheilupuisto – Tapiola in 2020 (February outturn)	7200	81 %	
Urheilupuisto – Tapiola in 2030 (MAL19)	7200 (150 seconds)	133 %	113 %
Urheilupuisto - Tapiola in 2030 (MAL19)	9000 (120 seconds)	107 %	91 %
Urheilupuisto – Tapiola in 2060 (Metro 2060 perus)	10800 (100 seconds)	110 %	94 %
Kulosaari – Kalasatama (M1 ja M2) in 2020 (February outturn)	7200x2	75 %	
Kulosaari – Kalasatama (M1) in 2030 (MAL19)	7200 (150 seconds)	88 %	74 %
Kulosaari – Kalasatama (M2) in 2030 (MAL19)	7200 (150 seconds)	89 %	76 %
Kulosaari – Kalasatama (M1) in 2030 (MAL19)	9000 (120 seconds)	70 %	60 %
Kulosaari – Kalasatama (M2) in 2030 (MAL19)	9000 (120 seconds)	71 %	60 %
Kulosaari – Kalasatama (M1) in 2060 (Metro 2060 basic)	10800 (100 seconds)	67 %	57 %



	Passengers per hour	Load factor	
Track section/Station	Capacity	Metro2060	-15%
Kulosaari – Kalasatama (M2) in 2060 (Metro 2060 basic)	10800 (100 seconds)	93 %	79 %

Table 1 shows the ridership in the bottlenecks identified in the metro in different forecasts. The Metro 2060 scenario in the table does not correspond to the number of residents and working places identified in the MAL 2019 model, as the number of residents estimated by each municipality within the areas served by the metro. In addition, the ridership has been calculated in the table also so that the ridership of the dimensioning morning peak hours is reduced by 15 % in accordance with HSL's estimation of the permanent impacts of the COVID-19 pandemic on peak hour ridership.

It can be seen in the table that the existing metro capacity is not sufficient west of Tapiola with the existing system and transport model at the end of this decade in 2030 or in the forecasts for 2060 even if the demand would decrease by 15 %. Preliminary studies implemented by the newer Helmet version have forecasted lower ridership than presented here but it is suspected that ridership forecasts made by said model are too low. Significant uncertainties in the ridership forecasts remain, however the passengers have perceived the metro to be too crowded on the Matinkylä line already before the completion of the Kivenlahti extension when the ridership has been approximately 81 % of the dimensioning capacity.

If the system is developed so that the headway can be shortened to 120 seconds, a reduction of 15 % in peak hour ridership in 2030 compared to the forecasts would be enough to ensure sufficient capacity. On the other hand, the ridership is already so close to the maximum capacity that it is necessary to prepare for a transition to a service pattern in which more than every other train continues beyond Tapiola. This shall be considered in the implementation of the new automatic train control system.

In the baseline scenario of the Metro 2060 study, the Kivenlahti line is near or at maximum capacity between Matinkylä and Kamppi while the Tapiola line only carries very few passengers. The studied solutions for the western end of the metro will enable a service pattern that eliminates the capacity problems caused by uneven loads.

Other investigated alternatives are not sufficient to solve the capacity challenges in the west, but in part of the scenarios the amount of near or at-capacity sections decreases. The "development of bus offering" scenario has the largest impact. The development of tram connections also has an impact, and the Science Tram has a larger impact on loads in the west than the Jokeri 0 light rail line. In the other scenarios the problematic sections in the west do not change compared to the baseline scenario.



Operation and ownership of the metro

The metro system from Ruoholahti eastwards is owned, maintained, and developed by the city of Helsinki (Helsinki City Transport public utility). In addition to the tracks, this comprises all stations and technical systems. From Ruoholahti westwards, Länsimetro Oy owns the tracks, stations and technical systems and holds the responsibilities for maintenance and development. Länsimetro Oy is owned by the cities of Espoo (84,4 %) and Helsinki 15,6 %. The cities have mutually agreed on allocating construction costs in accordance with the city border principle, i.e. each party pays the construction costs incurred in its respective area.

On 1st February 2022, the personnel and operations of the former HKL have transferred to the recently created Metropolitan Area Transport Ltd. However, the metro system remains in the ownership of the Helsinki City Transport public utility, and it remains as the party responsible for the operation of the metro. The Helsinki City Transport public utility, in turn, contracts Metropolitan Area Transport Ltd for the services necessary for the operation, maintenance, asset management and further development of the metro. Länsimetro Oy also contracts Metropolitan Area Transport Ltd for the administration and maintenance of the systems, stations and line based on an agreement with Metropolitan Area Transport Ltd.

In this structure, the core activities relating to the operation, ownership and maintenance are consolidated within one actor. This enables the needs of all activities relating to the operations to be considered in the development of the metro Automatic Train Supervision system so that partial optimisation is avoided, and it is possible to focus on the optimisation of the objectives and lifecycle costs of the whole metro system.

Helsinki Regional Transport (HSL) is the public transport authority that plans and organises the public transport services in its region, the metropolitan area, and procures the metro, tram and ferry operation from HKL, as well as bus, and commuter train services from a number of other public transport operators. HSL approves the fare and ticketing system of the public transport as well as the prices and sales of tickets, and is responsible for revenue protection, marketing and passenger information.

Current system

The total length of the metro network is 35 km, it has 25 stations and one depot. Sixteen stations are underground and 9 above ground. All above-ground stations are located east of Sörnäinen. Stations from Lattasaari to Matinkylä belong to Länsimetro and the remaining stations are part of the core metro of City of Helsinki. The 2nd phase of the Western Metro Extension phase 2 from Matinkylä to Kivenlahti will add 7 km of metro line and 5 stations to the metro system as well as Sammalvuori depot, which has less extensive activities than Roihupelto depot. After the commissioning of the Western Metro Extension phase 2, the total length of the metro network will be 42 km, it will have 30 stations and two depots. 21 stations will be underground and 9 above ground.



The metro of the metropolitan area is currently operated using 45 metro trains of which 36 are required simultaneously to operate the passenger services. There are three different train series: M100, M200 and M300. Five additional M300 train units series have been ordered by exercising the option included in the contract. These train units are being delivered in 2022, and after that there will be 50 metro trains available.

The traffic control system of the Western Metro Extension phase 1 put into operation in 2017 has been procured from Mipro Oy and the main part of its technology is modern. The Mipro systems were also installed on the core metro in January 2019 utilising the existing wayside equipment and since then the entire metro line has had a uniform traffic control system. The same system is also being installed on the Western Metro Extension phase 2 (Matinkylä–Kivenlahti).

Factors affecting the reliability and safety of the system

Today metro services are operated on a 35 km long line. When the second phase of Western Metro Extension opens, the length of the line will increase by 7 km, which may increase the vulnerability of the metro line to disruptions. As traffic gets more intensive and demand increases in comparison to the current situation, the regularity of the service will become even more important.

The wayside equipment of the Helsinki core metro traffic control system mainly dates from the 1980s and the availability of spare parts has deteriorated. Some of the equipment is at the end of its lifecycle and its fault frequency has increased, causing a growing number of service disruption. This together with the increasing length of the lines will increase the risk of disruption and, as a consequence, cause passenger dissatisfaction.

The most critically obsolete system components are the track circuit equipment used for detection of the trains' position, and the trip-stop-based train protection system.

The tripstop system that is responsible for the train protection in the current traffic control system does not meet requirements that would be set to a metro system built today. When a new automatic train control system is procured, the safety level of the metro can be increased at the same time to comply with the state-of-the-art level of requirements. Furthermore, the current equipment is outdated, and the availability of spare parts has become very limited.

The technology of the track circuits that monitor the location of the metro trains is already fully obsolete in the core metro and the manufacturer's support already expired many years ago. There are no spare parts available for the equipment, so the functioning of the system is entirely dependent on repairs carried out by the maintenance department. The track circuits will be replaced on a faster schedule than the automatic train control system and a separate project plan will be prepared for their replacement. The cost of the track circuit project is estimated to be circa 15 million euros and it is scheduled to begin at the end of 2022. The project is included in HKL's and Metropolitan Area Transport Ltd.'s budgets.



Project plan

Project scope

The projects in the capacity and reliability improvement programme of the metro are in the planning phase. The measures presented in the master plan are divided into several projects of which the project presented in this plan has the objective of enabling semi-automatic operation and upgrading the systems so that the reliability of the metro is safeguarded and headways can be shortened in the future.



The project consists of replacing the automatic train control system of the metro trains with a system that satisfies the needs for capacity of the future, is cost effective from a holistic perspective, and provides a higher level of automation. In the project planning phase, definition of system specifications and preparation for the procurement have continued. Additionally, the objectives of the project have been defined in more detail.

Due to the impacts of the COVID-19 pandemic, the need for additional capacity estimated in the capacity study has been delayed. Therefore, the objectives of the project have been revised and the preparations for the capacity needs of the coming decades are made through options. In the project, the reliability of the system is being secured and only the sub-systems necessary for enabling a headway of 120 seconds will be replaced. The trip-stop system of the M300 series will be replaced by an automatic train control system that meets present-day requirements. It was not seen as cost-effective to retrofit the M100 and M200 series as their remaining operational lifetime is limited.

Full operation with the new automatic train control system in GoA2 mode will take place at the turn of the 2030s after the delivery of the M400 series. Significant shortening of headways is not possible before new trains have been delivered, as shortening the headways to 120 seconds requires also 10 additional metro trains as well as replacement of M100 and M200 trains.

The need for a headway of 100 seconds and the implementation of provisions for additional automatic train control system capacity will be assessed at the end of the 2020's, when the long-term effects of the COVID-19 pandemic are known. In the procurement, provisions will be made for shortening the headways from 120 seconds to 100 seconds in the 2030s or 2040s.

The automatic train control project will be implemented in close cooperation with other measures proposed in the master plan, other related projects, and continuously ongoing operational activities. This project does not contain the other measures, which are not direct preconditions for putting the train control system into operation. These measures will be coordinated by the Metro Capacity Programme of Metropolitan Area

Objectives of the project

1. We ensure reliable metro operations

We implement the objectives set for the Automatic Train Supervision.

- We replace the ageing train protection system with a modern automatic train control system.
- We improve the safety level of metro operations.



- We avoid traffic disruptions during the implementation of the system and ensure improved reliability of the metro.
- We safeguard the continuation of the investments made in the metro by the cities.

2. We ensure successful implementation through cooperation and proactive project management

Proactive instead of reactive project management. Changes not identified during planning are expected during the project. This will require changes in operations and maintenance.

- Close cooperation through an integrated system design with all relevant suppliers, the wider organisation, and partners.
- Contradictions and problems shall be re-solved without delay by those parties who have the best competence in the issue.
- Risk Management is a central goal and part of all management processes of the project, promoting open and proactive identification, management, and ownership of risks.
- We create new know-how for the maintenance of the metro.
- Proactive and open project communication.

3. We create added value by enabling development of the urban structure

The needs of the cities are taken into account and economical implementation and timely scheduling of the investment is ensured.

- We enable a cost-effective capacity increase and improve the passenger experience.
- We execute the project timely and economically while also considering related projects.
- We focus on the optimisation of the lifecycle costs and environmental impacts of the whole metro in the planning of the project ensuring a solution that works in the future.
- We enable operation with short headways between Kivenlahti and Itäkeskus.

Objectives of the Automatic Train Supervision system

The primary objective of the new automatic train control system is to improve the reliability of the system and enable increasing the capacity of the metro system up to the required level, while the disruption level of operations is as low as possible, and the operating costs do not increase.



The metro of the metropolitan area is a core part of the public transport system. From the passengers' perspective the following objectives for the reliability can be set:

- There are as few operational disruptions as possible that worsen the passenger experience. Disruptions on the metro may cause considerable difficulties to a passenger when alternative connections are missing.
- Disruptions cause as little harm to passengers as possible. Should a disruption occur, it shall be possible to inform passengers about the estimated duration of the disruption, substituting or alternative connections and the reason for the disruption.
- The system shall enable management of the traffic disruptions and fast recovery from disruptions without increasing travel times. The difference between the technically possible and the regular operational headway shall be long enough that reasonable delays e.g. due to passenger behaviour do not cause accumulating traffic disruption.

In order to support these objectives of the metro system, objectives and factors for assessing them have been defined for the replacement of the train protection system so that the decision-making in the project is in line with the objectives of the metro system, HSL and the cities of Helsinki and Espoo.

The costs of the system are estimated using lifecycle costs in which the system's lifecycle target of 30 years is considered. The target in question is a system-level target, which means that the technical lifetime and availability of individual components of the system may have a shorter lifecycle.

Work packages of the Automatic Train Control system replacement project

The onboard and wayside equipment of the existing trip stop system will be replaced by a state-of-the-art automatic train control system. The target is a headway of 120 seconds by 2030. Additionally, it is envisaged to enable semiautomatic operation (GoA2).

Figure 9 shows an overview of the concept of the automatic train control project and the most important related projects. The chart shows the components of this project in the dark blue part.

The automatic train control project is divided into three sub-projects with the overwhelmingly largest investment being allocated to the automatic train control system. The implementation of the automatic train control system additionally requires the implementation of the radio network, which forms the basis for the data transmission between the system's onboard and wayside equipment. The automatic train control system is deeply integrated with the other sub-systems of the automatic train supervision, interlocking and traffic control system, and therefore these will either undergo significant changes or be replaced.

The procurement of the automatic train control system is preceded by a substantial specification of the system and performance requirements that sets the basis for the negotiations in the procurement process. The specifications are made for all changes



required by the above-mentioned systems and necessary interfaces. In the requirements specification phase, a letter of intent will be prepared with the supplier of the existing interlocking and automatic train supervision systems in which equal treatment of the automatic train control system suppliers is guaranteed and the implementation of the changes necessary to enable compatibility between the systems. The letter of intent also aims to guarantee that the further development of the existing system will remain cost-effective as a result of a longer payback time.

The supply agreements will contain to a large extent preparation for possible future extensions, updates and changes of the system during the system's anticipated lifecycle of thirty years. These include among others the procurement of new train series, upgrading the system to moving block as well as geo-graphical extension of the system. The radio network, which is the backbone of data transmissions, will be replaced at least once during the lifecycle of the system; this will be taken into account in the implementation of the system. The interfaces of the sub-systems and the appropriate contract models and contractual mechanisms to ensure their successful implementation will be taken into account in all procurements to be made.

Based on simulations, reaching a headway of 120 seconds requires a few new blocks in addition to the replacement of the automatic train control system and the signals needed for them will be implemented in parallel with the track circuit replacement programme in the core metro and as a separate projects on the Western Metro.

The requirements set by the automatic train control project will be taken into account in substantial replacement projects of the track circuits and signals to be made in the core metro as well as in other projects relating to the development of the existing system.

The system will be implemented so that operations are possible in accordance with the specified grades of automation with a 120 second headway. Shortening headways requires substantial investment in the M400 train series that will replace the existing M100 and M200 train series. An additional 10 trains will also be needed.

Furthermore, the renovation or improvement of certain power substations is necessary to provide the power needed by the higher number of trains. A new simulation of the power supply is being conducted in 2022 to verify the calculations of the required energy in headways of 120 and 100 seconds.

The project also takes the potential further extension of the metro into account. Possible further development of the western end of the metro has been assessed and a separate project plan has been prepared for it. The reason for further development is possible needs to improve train turnback at Kivenlahti station. At the same time, further extension of the metro in the future would be enabled.

In addition to the clear requirements pertaining to, e.g., functionality and reliability, provisions for future increased capacity needs will be made in the project only after they will be better understood once the post-pandemic situation has stabilized. These provisions as part of the project to be executed enable an additional investment if necessary and the stepwise investment reduces the need to write off the depreciation



value of the existing systems in addition to reducing risks. The provisions themselves are not included in this project and they are not described in more detail in this project plan. Table 2 lists some advantages of this stepwise implementation.

Table 2. Advantages of a stepwise implementation of the system.

Capacity	Functional aspects	Economical aspects
System capacity is increases in stages by enabling a 25 % increase initially and a further increase by the same amount later. There is no need for a single investment in unused capacity.	A transition in stages reduces the risk of operational changes. The upgrade from GoA1 to GoA2 enables a level of automation before a decision on GoA4.	High balance sheet value of the recent Traffic Control System investment (20 year write-off-period). A replacement in stages reduces risks while modifying the live system.

System specification and functional requirements

The objectives set in the master plan form the basis for the system requirements specification. The objectives have been revised during the preparation of the project plan and qualitative indicators have been defined for assessing them. In addition to the set objectives, technical standards, the requirements and procedures of the current metro's operational environment and existing systems as well as the products available on the market and their market situation also set boundary conditions.

The specification of requirements covers the automatic train control system, implementation of the radio network as well as the necessary changes to the existing traffic control system. In this type of systems procurement, it is typically advantageous to specify the top-level and performance requirements of the system. The system supplier retains responsibility for further technical requirement specifications and their allocation to sub-systems, so that the operational objectives set by the customer can be fulfilled by systems from several bidders. However, part of the functions can be implemented either in the automatic train control system or in the existing traffic control system, and therefore the customer shall allocate part of the requirements to the systems or determine the allocation during the negotiation procedure.

It is important that requirements can be retraced to their associated project objectives so that all changes to the requirements can be handled in a controlled manner. A systematic change management process is a precondition for rejecting unnecessary changes, and controlled and efficient implementation of the necessary changes. Potential contradictions in the requirements will be handled without delay. This requires open and solution-oriented dialogue between all project stakeholders, system suppliers and members of the customer organisation.



Grade of automation of the system

The system is currently operated in GoA1 in which the driver drives according to lineside signals on routes secured by the interlocking. The objective of the project is to enable GoA2 operation. In this mode of operation, upon departure command given by the driver, the train runs automatically to the next station, where the driver is responsible for safe door operations. The driver also monitors the track for possible people or other foreign items.

The benefits and risks of GoA3 and GoA4 for non-revenue movements, as well as measures for managing them, have been analysed in the project planning phase.

Automation of entry into and exit from revenue service and movements between line and depot was not considered to provide sufficient benefits that it would justify the implementation of the necessary risk management measures.

Turnback of passenger trains at termini has been considered supporting the reliability targets of metro operations to the extent that more detailed planning will go ahead. In addition, the benefits and risks of automated movements in the depot will be assessed in more detail and further action will be planned based on the results.

Table 3. Levels of automation of the rail transport.

GoA1	GoA2	GoA3	GoA4
Driver drives the train according to signal aspects.	Semi-automatic system in which the train runs automatically but the driver closes doors and dispatches the train. Driver is also responsible for emergency braking when necessary and control in an emergency.	Train works unattended but there is a person in the passenger compartment who dispatches the train. In an emergency this person controls the functions of the train.	Fully automatic and unattended train in which the train works without a driver. Hence, functioning of doors and emergencies are also controlled by a machine and crew is not needed on the train for train safety.
Driver drives the train.	There is a driver in the cab.	Train is attended.	Train is unattended.
Normal Train Operation (NTO). Driver drives the train.	Semi-automatic Train Operation (STO). Semi-automatic control.	Driverless Train Operation (DTO). Fully automatic control.	Unattended Train Operation (UTO).

Preliminary phasing of commissioning

The implementation of the project is based on utilising the existing traffic control system, and one of the central objectives of the project is to avoid significant disruption to passengers. Implementation of the project in compliance with the objectives requires



careful phasing of the commissioning that often also defines the solutions to be utilised. A phased plan for obtaining the most important results forms the substantial basis for the dialogue conducted with the suppliers and the planning of the project. In this phase the plan is independent of any technology, equipment supplier or product.

The preliminary implementation of the project utilises a phased approach:

- Phase 1: Radio network implementation.
- Phase 2: Automatic train control system and interfaces with the existing traffic control system.
- Phase 3: Commissioning of the M400 series (an option of this project, not included).

A prerequisite for the train control system implementation is completion two subprojects, the first of which is the implementation of a radio network, which is the backbone of the train control system's data transmissions. The second prerequisite subproject for the train control system is the implementation of the necessary interfaces and changes to the functioning principles of the interlocking and the ATS system, which shall be implemented in close cooperation with the supplier of the existing ATS and interlocking system.

The new automatic train control system will initially only be installed on the M300 train series, which means that the system will be operated in mixed mode traffic in which the M100 and M200 series trains operate using the trip stop system and the M300 series uses the new train control system. The transition from mixed traffic to full ATP operation will take place when the M400 series trains have been commissioned. The exact point in time for this will be set when the growth rate of the passenger demand is known and the lifecycle of the M100 and M200 series ends. Hence, the safety benefits of equipping the M300 train series will materialise before the procurement of the M400 series and because of the phased approach, the risk profile of both projects will be lower. Equipping the M300 series alone will decrease the risk level of the metro operations and the resilience of the transport system against disruptions will improve significantly.

Project schedule

The preliminary schedule of the implementation of the automatic train control system in the traffic control system has been done. A breakdown of work has been prepared in connection with the project planning in which the project is divided into four main phases.

Phase A: Preparation of the project mandate

Phase A means the project planning phase that has ended with the completion of this project mandate document.

Phase B: Preparation of the invitation to tender documents

This phase comprises preparation of the technical and commercial documents needed for the invitation to tender. In this phase, the dialogue with the suppliers is continued and the



planning of the project enters more detailed specification. After the contract models and technical solutions have been revised, the implementation schedule of the radio network and the changes to the existing system will be planned in more detail. Phase B will begin in early 2022 and it will last until late 2022.

Phase C: Procurement process of the automatic train control system

This phase comprises the publishing of the contract notices and the implementation of the procurement process that will begin after it. The phase covers the negotiations to be conducted with the tenderers, preparation of the final invitation to tender and evaluation of the tenders as well as contract negotiations and preparation of the contract. This phase has begun immediately after phase A in 2022 and will end with the signature of the contracts at the beginning of 2024.

Phase D: Implementation of the automatic train control system

This phase comprises the engineering, manufacturing, delivery, and installation as well as testing and commissioning of the systems and equipment to be procured. Phase D is divided into phases under the lifecycle process that complies with the EN 50126 standard. Phase D will begin after the signature of the contracts and will last until the end of 2028.

Implementation of the radio network

The procurement and implementation of the radio network, the backbone of the automatic train control system's data transmissions, will be scheduled so that the radio network is fully operational before testing of the automatic train control system begins, taking possible delays into account.

Changes to the current traffic control system

Specification of the changes to the existing system will begin after the contract has been signed with the supplier of the automatic train control system. Modifications will be implemented in close cooperation between the two equipment suppliers. The changes to the existing system shall be commissioned in a proactive way so that the automatic train control system project can perform the necessary testing in the schedule agreed jointly while taking possible delays into account.

Related projects

Related projects will be implemented according to separate project plans. The timings in the adjacent schedule are indicative and are based on the current estimates.

Risks and opportunities

The risks in this project can be divided into two categories: project risks and train safety hazards. The project risks may cause additional costs, quality problems or schedule delays to the project if they materialise. The train safety hazards are directly linked to the metro's operational safety level. These risk categories are managed in very different



ways: project risks are managed in accordance with the risk management process defined for the project whereas the train safety hazards are managed by the safety management system defined in accordance with standards in cooperation with the equipment supplier. This chapter deals with the project risks.

In accordance with the risk management process specified for the project, handling of the risks begins by assessing the risk category as one of the following three. Risks of category 1 are risks that can lead to cancellation of the project or other very serious consequences if they materialise and require high-priority action. Risks of category 3 are risks that can be mitigated with a one-time, minor, or simple countermeasure and are not considered to necessitate a more detailed magnitude assessment. Risks of category 2 require a deeper analysis of their severity and likelihood as well as monitoring of their evolution. The opportunities of the project are also handled in parallel with the project risks in a similar manner. During the project planning phase, 165 project risks have been identified, of which 29 are risks of category 1. Risks of category 1 shall be eliminated or managed to a lower level before starting the procurement.

The risk assessment shows that the most critical risks concern problems with specifying the system requirements and resourcing the project. Preparation of the system specification with insufficient market dialogue and experience was identified as the main potential cause for risk materialisation. The main potential causes for materialisation of the risks related to project resourcing are insufficient participation and commitment of the stakeholders, excessive workload on the project personnel and competence and experience of the supplier's resources.

The identification and management of risks and opportunities is actively continued over the entire duration of the project. The risk profile for the period ranging from the beginning of the project to the end of the joint specification made with the supplier is very high. A prerequisite for advancing from the specifying and planning phase to the implementation phase of the project is sufficient reduction of the risk profile.

Table 4. Possible risks and risk mitigation actions.

Risks	Risk mitigation actions
Technical implementation is not successful. The project's ambitions are not in line with what is realistically possible to implement.	Functional objectives are defined jointly with the stakeholder groups. The project communicates the solutions of the system suppliers to the stakeholder groups. The stakeholder groups participate in the contract negotiations.
Technical description of the invitation to tender is too inaccurate. This results in a lack of uniformity between the tenders or unrealistic implementation, the tenderer can't clearly understand what is being requested.	People who have experience of similar projects are used as experts. Active utilisation of the specifications available on the market in the tendering material. Suitability of the specifications will be ensured by a development phase focused on compatibility. Market dialogues, cooperative contract model, the buyer specifies functional matters and uses external experts who have experience of



Risks	Risk mitigation actions
	corresponding projects. Utilisation of existing and commonly used specifications in the invitation to tender.
<p>Technical description in the invitation to tender is too detailed. This results in lack of competition because the changes needed to the products implemented by equipment suppliers with different architecture and functionality prevent the submission of a competitive bid.</p>	<p>Functional and operational requirements serve as selection criteria. The customer does not specify technical solutions. The procurement process is a negotiated procedure.</p>
<p>The tenderer has not made similar systems, there are always differences concerning at least application and country. Cooperation between the suppliers does not work.</p> <p>There are challenges in the implementation that have not been fully assessed when the offer was being prepared. When the equipment supplier starts making a loss, conflicts arise within the project</p>	<p>Good cooperation in the development phase. Defining modification management including penalties in the contract. Ensuring the compliance of the sub-phases with the requirements by a phase-gate process. Big room working.</p> <p>All parties are committed to the values of the project and acting in compliance with them is required. Ability to cooperate is evaluated in the selection criteria. The project anticipates the amount of support needed from the stakeholder groups.</p>
<p>A supplier or the customer has not committed sufficient resources. This results in delays in the work of the supplier, the customer does not have sufficient resources to steer and control the work.</p>	<p>Sufficient competent resources of the supplier are ensured by the contract. The customer is prepared for the project's workload through agreements with experts and by ensuring the support of the stakeholder groups. The quality of the supplier's work is ensured constantly through the phase-gate process.</p>
<p>At the beginning of the project, it is not possible to estimate the real costs of the project and the budget may be exceeded. This also results in reputational damage.</p>	<p>Risk and project provisions will be made based on the implementation of similar projects. Cost control is carried out in real-time, and the project and risk provisions are updated continuously based on simulations.</p>

Post-project activities

The requirements for onboard automatic train control equipment for future rolling stock procurements will be specified in the project so that the equipment can be delivered as part of the procurement of the M400 series and possible new maintenance vehicles. The project will be prepared for the procurement of the M400 series to begin before the commissioning of the automatic train control system. Shortening the headway to 120 seconds is possible after the commissioning the M400 series trains. The shortening will require 10 additional trains compared to the current situation.



The project will ensure that the maturity of the technology used in the automatic train control system enables upgrading to 100-second headway and moving block in the future. At this stage it is not beneficial to prepare the procurement in more detail, however it will be requested as a future option. The point in time at which the capacity needs will require a 100-second headway will be known more precisely only after the impacts of the pandemic have settled. The system shall also enable raising the grade of automation to GoA3/4. This change will also require further substantial measures, and therefore the decision on increasing the grade of automation of the system will be made at the same time as the decision on further shortening the headway and not now.

Impacts on the organisation

The change in grade of automation of the operations will affect all operational activities of the metro and in the worst case it will cause significant technical and operational problems as well as problems related to wellbeing at work. Representatives of the operational functions will be included to a considerable extent in the system requirements specification and change implementation design processes, so that the best operational competence can be utilised when defining the future operational processes.

Job descriptions may also need to be updated because of the change in grade of automation in order to safeguard wellbeing at work and the attractiveness of different roles. When executing this task, the focus will be on the personnel and wellbeing at work.

The drivers will experience the most significant change in their jobs as their tasks will change from active driving to a more supervising role. This has impacts among others on driver vigilance and special attention will be paid to managing it.

The changes to be made to the metro traffic control operations will not have any significant impact. The regularity of operations and fault tolerance of the system may decrease the burden of work, but because of the personnel needed for the management of faults and disruptions, a significant change in the resources in the traffic control centre is not realistic. Increasing automation provides more precise information about fault causes, which would potentially enable remote interpretation of faults and disruption.

Automation and new technology will increase the special competencies required from maintenance personnel. Utilising the know-how of the maintenance unit in the installation, testing and commissioning phase of the system not only smoothens the project's progress, but also increases the competence of the personnel and helps the maintenance personnel deepen their knowledge of the system's functioning. This has significant positive impacts on fault repair times and reliability in the commissioned system.

The system commissioning phase will create a higher workload to drivers, operation control centres and maintenance personnel. The situation will be taken into consideration during project planning, and it shall be strived to manage it mainly through normal staff turnover and proactive recruiting.



Project communications

The Metro Capacity Programme together with the communication unit of Metropolitan Area Transport Ltd. and with the parties of the project (HSL, Länsimetro Oy, City of Espoo) are responsible for the project's media communications and publications. After the approval of the project mandate, a communications plan will be prepared in which the various areas of communication, such as courses of action, stakeholder groups, communication channels and responsibilities, will be defined in more detail.

The progress and impacts of the project will be communicated actively but the impacts of the project on passengers and city environment are minor. Possible disturbances and problems in the project will be communicated to an appropriate extent. The automation of the metropolitan area metro has also aroused interest among the public throughout the history of the metro. The risk of misunderstandings is high, and therefore the communications shall be carried out openly and proactively.

Internal communication is very important for the project's success. The project has a considerable impact on metro operations and the challenges caused by the changes will be handled with the traffic operations unit in an active dialogue. The dialogue will be ensured by allowing representatives of the metro operational and service personnel to participate in the decision-making.

Ensuring the objectives

Project management model

The strategic objectives of the project are tracked and controlled ensuring that the objectives set to the project by the metropolitan area and each municipality can be reached, and that they are steered appropriately in accordance with ongoing developments. The project is part of the project portfolio of the Metro Capacity Programme.

The project will follow a phase-gate process with a purpose to ensure that the risk of rework is minimised and well-defined scope packages are being implemented. The manager of each sub-project is responsible for managing in compliance with the phase-gate process to ensure that the project complies with the requirements. The managers of sub-projects are responsible for the management of changes and risks within their respective defined scope.



Project decision-making bodies

The capacity and operational reliability improvement programme reports to a senior-level cooperation group, the Sponsor Board, consisting of the directors who report on the project's progress to the political decision makers. HKL, the City of Espoo, HSL, Länsimetro Oy and Metropolitan Area Transport Ltd are represented on the Sponsor board.

The activities of the Sponsor Board have a key role as the parties responsible for funding are on it, and different parties may have dissimilar interests. The Sponsor Board is responsible for the preparation of decisions on the project in accordance with the objectives set by the cities. The model for cooperation is defined in the cooperation agreement for planning the programme as agreed between the City of Espoo and HKL, as well as other current and future agreements on implementation of projects and sharing of costs.

The Programme Director is responsible for the entire capacity improvement programme. A key element of increasing the capacity is the replacement of the train control system, and the Programme Director reports on its progress to the Sponsor Board. The project director is also responsible for the progress of the other works relating to the capacity and reliability improvements presented in the master plan and coordinates the cooperation and objectives for the related investments. The costs of these other works and projects are not covered by this project plan.

The project will have an important impact on the operation of the metro regarding all its operational activities and therefore a Coordination committee has been set up for the work. Its task is to ensure that the project fulfils the requirements of all key parties and to agree on resolution of potential conflicts. The Coordination committee has representatives from all units of the operator of the metro as well as from HSL and Länsimetro Oy. The steering committee of the project is responsible for supervising the management of the project whereas the project team is responsible for the controlling, reporting and planning of the project. The viewpoint of drivers, maintenance and traffic control will be raised by the user group that maintains a regular dialogue with the project. Other project teams will be set up according to the needs of the project phases. In addition, separate expert teams which convene regularly have been defined for managing the project risks and functional safety.

Costs and their sharing



Cost estimate

The cost estimate of the project is 110 million euros at January 2022 cost level. The cost estimate is divided into project costs, procurement of the automatic train control system and radio network as well as changes to be implemented to the current system. Additionally, a risk provision of 8,5 million euros has been made separately based on the results of the risk management process as well as a project contingency of 10 % for unforeseen expenses and costs.

The project management costs will mainly incur from the work of the project employees of the customer, work of external experts as well as also substantial amount of work from other units of the customer, such as work of maintenance and operation units. In addition, the costs contain the premises, software and other necessary tools and services.

The cost of the automatic train control system will be split to the control centre, track and rolling stock. In addition of the cost level of the system supplier, the cost of the automatic train control system is affected by the limitations and specified obligations of the agreed work as well as the support of the buyer's organisation and appropriateness of the specified requirements and supplied initial information.

The implementation alternatives define the relation between the investment cost and operation cost of the radio network. This will become more accurate based on negotiations to be conducted with the system suppliers and operators of the radio network.

The cost of the modified functionality and interfaces to be implemented in the current traffic control system will become more accurate only after the negotiations conducted with the supplier of the automatic train control system.

The objective is to achieve the lowest lifecycle costs for the most economical advantageous solution for the entire metro. Therefore, partial optimization and restricting solutions by specifications made too early and binding shall be avoided especially concerning the current traffic control system and automatic train control system. The lifecycle costs will be used in the comparison criteria instead of the up-front investment costs. The liability for risks and implementation shall be allocated to the parties who can manage them at the lowest cost and best competence.

Because the negotiations with the suppliers of equipment are pending, the cost estimate will not be opened regarding the above-mentioned sub-areas. Based on the information gathered during the project planning, the range of the costs has been simulated as per scope package. A project contingency of 10 % and risk provision (approximately 7,5%) based on the risks remaining outside the estimates as per sub-area have been considered in the estimation in addition to the variation included in the simulation of the cost risks.

Cost split between the parties



The cost split used in the project plan is cost sharing principles for the metro as defined in the agreement between Helsinki and Espoo. It has been defined that the costs of Länsimetro will be shared between Espoo and Helsinki in accordance with the territorial matching principle i.e. according to the principles of sharing of costs in accordance with the city borders. HKL bears the costs allocated to the core metro and Länsimetro the costs allocated to its own area. It has additionally been agreed between Helsinki and Espoo that the costs allocated to the control centre systems and rolling stock are on the responsibility of HKL.

The costs incurred from the preparation and planning of the project will be shared between the funders in accordance with the matching principle in proportion with the track kilometres, the proportion of Helsinki of these costs is 58% and the proportion of Espoo 42%. Excluding the MAL funding the proportion of City of Helsinki of the costs of the project is 68,0 million euros related to HKL's systems and 6,5 million euros related to the systems of Länsimetro, i.e in total 74,5 million euros. Considering the MAL funding the investment of Helsinki is 52,2 million euros. The share of Espoo of the project excluding the MAL funding is 35,3 million euros as an investment implemented by Länsimetro, considering the MAL funding the investment is 24,7 million euros. The total investment of Länsimetro is 41,9 million euros.

The cost of the implementation of the project will be shared between HKL and Länsimetro. It has been assumed here that the costs of Länsimetro will be allocated to Helsinki and Espoo in proportion of the share of ownership. Table 5 presents the allocation made in the cost estimation in accordance with the above-mentioned principles for different cost items between Helsinki and Espoo / HKL and Länsimetro Oy that has been used for allocating the cost analysis to different parties. MAL financing will be applied for the project and then the state would assume 30 % of the costs.

A separate agreement on the implementation of the project and sharing of its costs will be agreed by a separate agreement between HKL, Länsimetro Oy and Metropolitan Area Transport Ltd.

The total costs estimated in the master plan for the project were 90–125 million euros.



Table 5. Proportions used in sharing of costs.

Object	HKL	Länsimetro Oy	City of Helsinki	City of Espoo
Project costs	50,2 %	49,8 %	58,0 %	42,0 %
Cost of track equipment	Until border			
Radio network	Until border			
Costs of control centres	100,0 %	0,0 %	100,0 %	0,0 %
Costs of trains	-	-	-	-

Project impact assessment

Key impacts

"The Most Functional City in the World" is the vision of the City of Helsinki, and "Espoo is a Responsible and Humane Pioneering City" the vision of the City of Espoo of what kind of experience each of the cities want to offer to people.

A functional public transport is a key element of a functional and modern cityscape. It is a network composed of several different modes of public transport and the metro works as its backbone offering a fast, high-capacity connection between east and west. The popularity of the metro is reflected in growing ridership and thus maintaining the service level requires increasing its capacity. Increasing the capacity of the metro and improving the reliability of the system will have a positive impact on the image of both cities. Higher capacity will allow continuous construction in the area affected by the metro when there is enough capacity for also new passengers. Hence, increasing the capacity of the metro will shape the cityscape.

According to the forecasts of the metro, the most significant impacts of the Metro Capacity Programme are on the congested parts, especially west of Tapiola and in the sections Herttoniemi–Kalasatama and Myllypuro–Itäkeskus. West of Tapiola, a new timetable model shall be introduced in all studied cases during this decade as the ridership will increase and exceed capacity. The Crown Bridges project will decrease the loading of the eastern metro by approximately 11 % starting from 2027, which will postpone the point in time when shorter headways are needed eastbound. Without the Crown Bridges project,



the ridership would be at capacity by 2030, if the changes caused by the pandemic to mobility needs are not permanent.

The most important change is the implementation of the automatic train control system. It will enable shortening the headways from the current 2,5 minutes on the core sections first to 2 minutes and through additional investment further to 1 min 40 seconds. Hence, in the two-line system it is possible to operate both lines with a 4-minute headway each instead of the current 5 minutes, and if the further additional capacity becomes necessary, with a headway of 3 min 20 s, which will shorten the average waiting time of passengers and increase the attractiveness of the transport mode further. More frequent trains will also decrease the maximum number of passengers per train during peak hours thus further improving the passenger experience. The new train control system also enables automation of functions that will provide many kinds of advantages and benefits to the operation.

The safety level of the metro can be increased by the new automatic train control system. The Helsinki metro has been in operation for forty years without a serious train accident. There have been a few cases that can be classified as "near miss" situations. The very low accident level has been reached thanks to good work of the personnel. The reliability of the technology has been on a sufficient level before, but it has been assessed that the reliability will start to significantly worsen in the coming years, although it is challenging to forecast this evolution exactly.

In the future it will be necessary to improve the safety level because an accident of a high-capacity passenger vehicle often has big consequences. Replacing the automatic train control system and introducing new technology enables significant improvement in the safety level.

Basis of the assessment: The objectives set to the Metro Capacity Programme in the master plan have been used as the basis for the assessment of the impacts of the automatic train control system project.

Several studies have been made in connection with the master planning of the Metro Capacity Programme and the observations and findings made in them have been taken into account in this project plan. Changes to the estimations of the ridership caused by the worldwide pandemic significantly affected the master plan. They have also impacted the solutions presented in this project plan.

1. Impacts on the accessibility and service level

The planned train control system will increase the track capacity by 20–33 % through utilisation of shorter headways in the whole track network:

- Decreases the minimum headway and increases the available track capacity.
- Minimum headways can be shortened from the current 150 seconds to 120 seconds.

Improved punctuality on the whole track network. (This is also a prerequisite for increasing the number of trains.)



- Eases the recovery from disruptions as it is possible to depart quicker after the train running ahead, decreases harmful effects of disruptions to passengers.
- Enables systematic traffic optimisation based on the loads identified by the system.

Improves the accessibility and lowers the threshold of travelling as the train service improves (quantity and quality):

- Possibility to minimise disruptions during the construction period.
- Better service by more reliable and real-time traffic information.

2. *Impacts on the economic sustainability*

It is essential to compare the lifecycle costs of different scenarios with each other, as the investment is needed in any case. The maintenance costs of the current system will continue to increase significantly as the system ages and availability of spare parts decreases.

- Other investments shall also be considered which are needed in any case, for example the radio network that replaces MetroLAN.

The automatic train control system enables also socio-economic benefits in addition to cost reduction:

- Saving of time through disruption management, improved punctuality, and increased transport.
- Improves e.g. the profitability of the metro line projects already implemented as by the same investment in the infrastructure more transport can be produced and this way more benefits can be obtained, such as Western Metro Extension phase 2.
- Optimization of the maintenance costs is possible.
- Future needs for development can be responded flexibly for example by utilizing automation.

3. *Impacts on the social sustainability*

Increasing the transport offer improves also social sustainability because improved offer increases opportunities of mobility of the residents on a mode of transport that is accessible and open for all mobility groups.

- Metro system is accessible and easy to use and improving the offer pro-motes equal opportunities of mobility.

Improved opportunities of mobility also promote the development of regional development supported on sustainable modes of transport.

- Development of the metro transport supports the travel chains of sustainable modes of transport as e.g. transporting bikes on the metro is possible.



4. *Impacts on the safety of the transport system*

The reliability of the current system will decrease as the components which have already been in use for 40 years are approaching the end of their useful life. From the perspective of safety and reliability, the replacement of the train protection system is thus necessary.

- The technology that is in use has reached the end of its lifecycle.

The automatic train control system will improve safety:

- Reliability of the system improves, and risk of accidents can be minimised.
- It is easier to utilise real-time information.
- Anticipation of the traffic situation improves as the information is more reliable and runs in both directions.
- Safety in track work improves.
- Traffic restrictions can be better monitored and automated.
- Tendency to disruptions lowers, impacts of disruptions decrease and recovery from disruptions becomes faster.
- Up to date communication and additional services improve the safety perceived by passengers.

It shall also respond to new kinds of safety and security threats such as cyber-security.

A modern digital train control system enables taking other technologies into use or integration into the system (e.g. introduction of various different sensors).

- Enables further development of the system, development of the current old technology is not viable.

5. *Impacts on the ecological sustainability*

Finland has committed to halving the transport emissions by 2035. Helsinki and Espoo have set their goal to be carbon neutral by 2030. The objectives will not be reached unless the proportion of the rail transport increases significantly.

From the perspective of the climate change, the most effective are projects which enhance the utilization of the existing infrastructure, such as development of the automatic train control system and small improvement actions which do not have significant impact regarding materials.

Modern automatic train control system provides tools for decreasing emissions.

- More effective use and better accessibility of the track capacity by shortening the headways.
- Better transport offer and punctuality support the transition of the mode of transport to sustainable modes.



- More capacity at peak hours increases the proportion of transport modes that have less emissions.
- Supports reaching the emission reduction targets in the Helsinki region by increasing capacity and punctuality.
- Additional capacity enables more dense land use in the periphery of the track.
- Enables a driving pattern that is optimal from the perspective of energy saving which decreases the energy consumption of the metro transport.
- Possibility to utilize automation in full.
- Reduction of the quantity of wayside equipment decreases the material impact

6. Savings to the operator from the development of the traffic control

Energy is saved.

- Energy is saved as the need for electric energy of the metro decreases because unattended operation decreases the consumption of the traction energy by 20–25 % compared to the situation in which an energy saving system is not in use. On the other hand, part of these savings will be reached already today using a driver assistant system so that it is estimated that the net benefit is 8–13 %.

Maintenance costs of metro trains will decrease.

- If semi-automatic operation is introduced, metro trains are driven more smoothly and wear of both brakes and wheels will decrease, and their maintenance costs will decrease approximately by 20 %.

Impacts on the revenues and social benefits of the metro system

Travel times get shorter in the public transport and car traffic

Waiting times and change times in stations are short. Using the metro is effortless and fast also in the branches of the network. It is not necessary to follow timetables. Using 10 euros/hour as the value of time, the benefit would be approximately 2,5 million euros per year in 2030 when the headway is 120 seconds.

When the metro is extended, the benefits of the travel time will increase in relation to the number of passengers.

The investments would also provide benefit to car drivers as travel time savings and decreased cost of accidents.

Savings in the investments in roads and streets as well as environmental costs and accident costs



When the attractiveness of the public transport increases, the growth of the car traffic will stabilize. Hence, the need for investing in increasing the capacity of the road and street network will decrease.

The increase of the social incomes and savings are presented in Table 7; calculated annual monetary benefits of the increased capacity in 2030. The biggest individual benefit is the time benefits of passengers on the public transport in the comparison situation.

Use of public transport will increase

As the travel times get shorter, the use of the metro and the whole public transport will increase. Part of new passengers come from the users of light traffic and car traffic. Part of the trips are new trips which are resulted in due to shorter distances, and part are new metro users who transfer to faster routes from other modes of public transport.

Boarding the metro per day will increase by 2,3 % based on the model analysis in the scenario of 2030 when the headway shortens to 120 seconds (compared to scenario 2030 150 KIL) and by 3,7% when the headways shorten to 100 seconds (compared to scenario 2030 150 KIL).

When the length of the metro network increases, the number of new passengers can be more than double from what has been stated above.

Ticket revenues will increase

The increased ridership will bring more ticket revenues. In the current extent of the metro network and current level of ticket prices the additional revenue would be 1-1,6 million euros in 2030.

In 2050 the additional revenue would be approximately 2,4 million euros per year.

Basis of the evaluation

As increased revenues are counted:

- *Increased ticket revenues that have been defined using the ridership fore casted by the Helmet 3.1 transport model.*
- *Increase of the lease and advertisement incomes which can be considered comparable with the increase of the number of boardings onto the metro.*

As social impacts are counted:

- *Benefits to the passengers of the public transport in time and service level*

regarding both passengers of the comparison situation and transferring new passengers. The performances regarding travel time and travel resistance have been calculated by the Helmet 3.1 model, and values of time (ca. 10 €/h) according to the instructions for the assessment of track projects of the Finnish Transport Infrastructure Agency. (Finnish Transport Infrastructure Agency, 2013)

- *Savings in time of the road traffic due to decreasing car traffic have been calculated by the Helmet 3.1 model, and values of time (ca. 10 €/h for car trips and*



ca. 33 €/h for lorry trips) according to the instructions for the assessment of track project of the Finnish Transport Infrastructure Agency. (Finnish Transport Infrastructure Agency, 2013)

- Costs of accidents of road traffic which have been defined according to the kilometre performances and accident levels as per route type produced by the Helmet 3.1 model. As cost of an accident regarding personal injuries 598 899 €/accident has been used according to the instructions for the assessment of track project of the Finnish Transport

Infrastructure Agency. (Finnish Transport Infrastructure Agency, 2013)

Costs of CO₂ emissions of the road traffic which have been defined based on the kilometre performances of the road traffic produced by the Helmet 3.1 model and unit emission coefficients calculated based on the VTT's ALIISA and LIISA models. VTT's estimates for the CO₂ unit emission coefficients for 2030 are 93 g/km (car) and 560 g/km (lorry). The emission coefficient of 2050 are 46 g/km (passenger car) and 408 g/km (lorry). (VTT, 2020).

Evaluation of the cost-effectiveness

The increase of the incomes and social impacts identified at this stage have been considered in the evaluation of the cost-effectiveness. The social benefit/cost is 1,05 during an operation period of twenty years.

Investment costs have been considered in accordance with the highest value of the forecast. In the evaluation the investment cost has been considered as depreciations in a write-off period of 20 years as straight-line depreciations. Evaluation of the cost-effectiveness can be seen in the adjacent table.

Updating the system so that 120 seconds headway can be reached will result in an effect of 3,5–4,0 million euros to the annual operation and social economy. This change is presented in the system upgrade, but it also requires procurement of 10 additional trains. Considering the procurement of additional trains, the capacity increase of the metro will pay back, and the cost-efficiency of the project is based on ensuring the continuation of the lifecycle of the metro.

Table 6. Evaluation of the impacts of the project on HSL'S compensation for infrastructure and operation.

Compensation for infrastructure	Investment	HSL's depreciation and interest in total	HSL's depreciation and interest 1st year
HKL Infra, Helsinki	29,60	31,12	2,15
Länsimetro Infra, Helsinki	5,16	4,32	0,29
Länsimetro Infra, Espoo	24,16	20,29	1,32





Operation

HKL operation	18,00	21,03	1,17
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Write-off period is 20 years, interest of infrastructure during construction period 5%, interest of operation during construction 3 %. HSL's compensations for infrastructure and operation will start in 2029.

Calculation does not contain investment in additional trains.



Table 7. Evaluation of the profitability. Source: Analysis of the impacts of the changes of the headways of the metro, Ramboll, J.Rinta-Piirto, 12/2020.

	2030
Million euros/year	150 seconds versus 120 seconds
Social impacts	
Travel time benefits of the public transport	3,55
Service level benefits of the public transport	1,70
Time cost savings of the road traffic	0,69
Accident costs of the road traffic	1,08
CO2 emission costs of the road traffic	0,02
Savings in investments in routes	Benefits are not evaluated
More dense city structure	Benefits are not evaluated
Increased ticket revenues	-0,98
Social impacts in total	6,06
Increased incomes	
Increased ticket revenues	0,98
Increased incomes from rents	Benefits are not evaluated
Increased income from advertisement	Benefits are not evaluated
Increased incomes in total	0,98
Saving of costs	
Saving of traction energy	0,50
Saving relating to drivers	0,10
Savings in overground traffic	
Maintenance of the current train protection system	0,30
Saving of costs in total	0,90
Benefits in operational economy in total (million €/year)	1,88
Increased costs	
Maintenance of the new system	-0,30
Change of depreciations (traffic control, write-off period 20 years)	-3,85
Change of depreciations (10 additional trains, write-off period 30 years)	-2,67
Increased costs in total	-6,82
Impact on the operational economy	-4,94
Impacts on the operational economy and social economy in total	1,12



Impacts of not implementing the automatic train control system

As the current equipment and their technology ages, challenges will be encountered which can affect the reliability of the metro transport. Impacts of possible worsening of the service level i.e. reliability and punctuality of the metro on the ridership of the metro and this way ticket revenues and socio-economic costs.

The technical ageing of the train equipment of the metro has impacts on the operation of the metro. Impacts can come from two different technical viewpoints:

- Faults of trains. If the onboard equipment of old trains break down in a manner that there are no spare parts available, the concerned trains shall be taken out of traffic for a long period because equipment of a newer generation shall be installed to them. Removal of trains from operation means lengthening of headways of the metro at peak hours.
- Lower speed limit shall be set to certain track sections. If repair actions shall be made in the metro, it may require speed limits to certain track sections for the duration of the repair. This result in longer travel times and possibly longer headways at peak hours if the circulation times of the metro will increase so much that the headway shall be lengthened.
- In addition to the impacts that can be measured purely in the travel time, decreased reliability affects the selection of the route and mode of mobility of passengers, if people start avoiding travelling on the metro perceived as more unreliable than before.

A situation has been analysed by the traffic forecast model that has been assessed to be the most difficult imaginable. In the most difficult situation, the following factors would be in force simultaneously:

- Faults in metro trains lead to longer headways at peak hours. If approximately 10 % of trains would be out of operation, this would mean approximately 15 seconds longer headway at peak hours.
- Lower speed limits on the metro track will lead to longer travel times and possibly longer headways at peak hours. Due to lower speed limits, the average speed will drop by approximately 10 km/h because the fault requires stopping the train at a signal, radio communication and after that a maximum speed of 35 km/h. If the fault is in the trunk section during peak hours, exceptional arrangements should be taken into use, departures would be cancelled and operated in 30 seconds longer headways.
- Decrease of the perceived reliability of the metro. According to customer satisfaction studies made by HSL, commuter train is perceived as the least punctual vehicle of the public rail transport that is described in the modelling of the current situation so that the perceived travel time of passengers using a commuter train is 2 minutes longer than the real travel time. On metro trips there is no such perceived additional travel time currently. If travelling on the metro would be perceived like travelling on a commuter train regarding its reliability, this would mean an extension of the perceived travel time by 2 minutes.



The most difficult imaginable situation has been compared with the metro that complies with the current situation complemented by the Länsimetro extension in which the headway between Tapiola and Itäkeskus is 150 seconds. The study has been made using a transport demand that is based on the number of residents and working places estimated for 2030.

The table 8 shows the impacts of the most difficult imaginable situation on the socio-economic costs in a situation in which the problems last longer. The impacts are not so big if the problems can be remedied quickly.

The impacts of the most difficult imaginable situation on the time losses of the public transport are big that is caused by the allocation of longer headways and longer travel times to all passengers of the metro transport. Approximately one third of the impacts is caused by the decrease of the perceived reliability of the metro that has thus been described the lengthening of the perceived travel time by 2 minutes. Trips are moved away from the public transport which reduces ticket revenues and increases road traffic and its drawbacks such as congestion, accidents, and emissions.

The most difficult imaginable long-lasting situation has been used in the study. The impact of disruptions on travelling does not occur linearly but it can be assumed that random disruptions are not of big importance, but if disruptions take place, or it is perceived that they occur often, it affects the perceived service level of the metro transport. A long-lasting situation decreases the reliability of the system and then passengers move to other vehicles of the public transport or other ways of travelling. This can also generate indirect additional costs if there will be requirements e.g. for arranging bus transport parallel to the metro.

Table 8. Impacts of degradation of service level of the metro on the socio-economic costs, the difficult imaginable situation. Analysis of degradation of service level of the metro, Ramboll, J.Rinta-Piirto, 11/2021.

Damages per year 2030, millions of euros	150 second headway
Time lost in public transport	-28,7
Time lost in car traffic	-1,0
Decreased ticket revenues	-4,4
Increased costs of accidents and emissions	-1,3
Socio-economic damages in total	-35,5

