Co-financed by the Connecting Europe Facility of the European Union

Final report

Feasibility and technical framework study for a rail bound (light rail or tram) connection from RB Ülemiste passenger terminal to Ten-T core network Tallinn passenger Port

No. RBR 2017/22

LRTEST7001 RG180416C February 2019

IDENTIFICATION

Project	N° doc	indice	nb. pages
LRTEST7001	RG180416	C	243

HISTORY OF MODIFICATIONS

Indice	Date	Issued by	Reviewed by	Approved by	Revision reason
A	30/11/2018	Pool of experts	B.NARCE B.MINNI	JM GIELY	First issue to client
B	11/01/2018	B.NARCE B.MINNI	B.NARCE	JM GIELY	Second version
C	05/01/2018	B.NARCE B.MINNI	B.NARCE	JM GIELY	Third version

The feasibility study for a rail bound (light rail or tram) connection from RB Ülemiste passenger terminal to TEN-T core network Tallinn passenger port is financed from CEF funds substantially. Rail Baltic/Rail Baltica is co-financed by the European Union's Connecting Europe Facility.

PURPOSE

The present document is a deliverable of the feasibility study for a rail bound (light rail or tram) connection from RB Ülemiste passenger terminal to TEN-T core network Tallinn passenger port carried out by Egis Rail, in 2018, on behalf of RB Rail AS.

This document is the final report of the study.

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1. Diagnosis

1.1. Diagnosis on the current public transport system

The public transport network in Tallinn consists of:

- 74 bus lines,
- 5 lines of trolleys,
- 4 tramlines

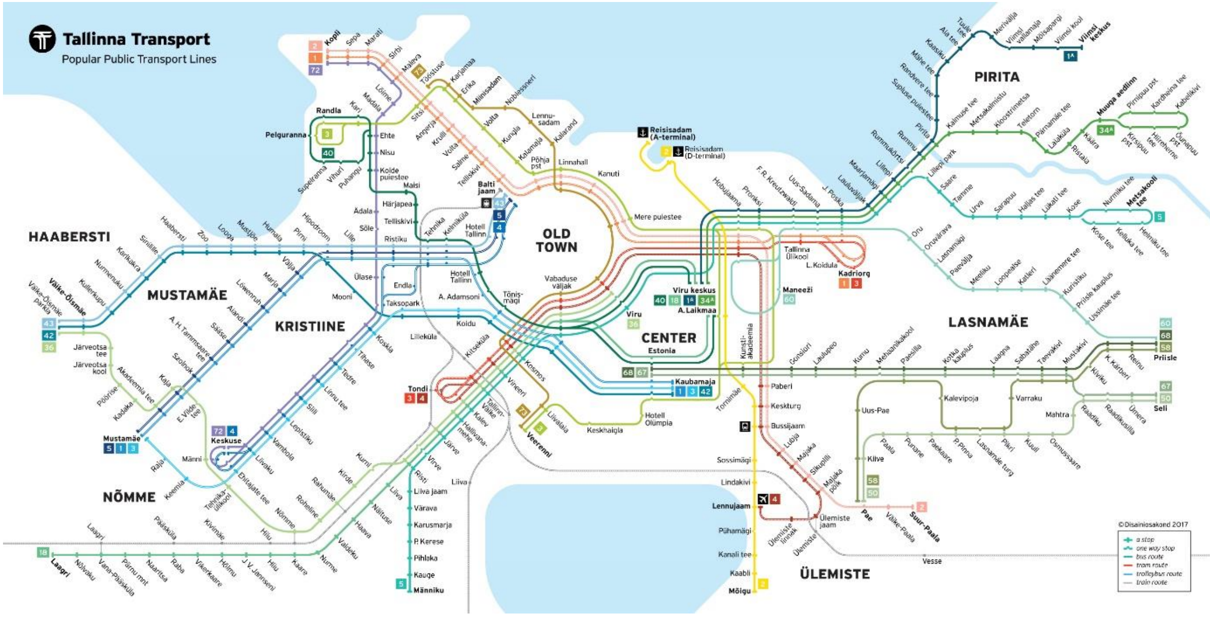


Figure 1 : Map of current public transport network in Tallinn

Tallinn is the only city in Estonia to have ever used trams or trolleybuses. The first tram route was opened in 1888, and in 2008 the tram celebrated its 120th anniversary. Together with the trolleybus network, the tram lines with a total length of 39 km (24 miles) arranged in a roughly cross-shaped layout, provide a backbone for the public transport network in the Estonian capital. All the tram routes meet up at Hobujaama in the city centre. There are three types of trams—Tatra KT4, KTNF6 and CAF Urbos AXL.

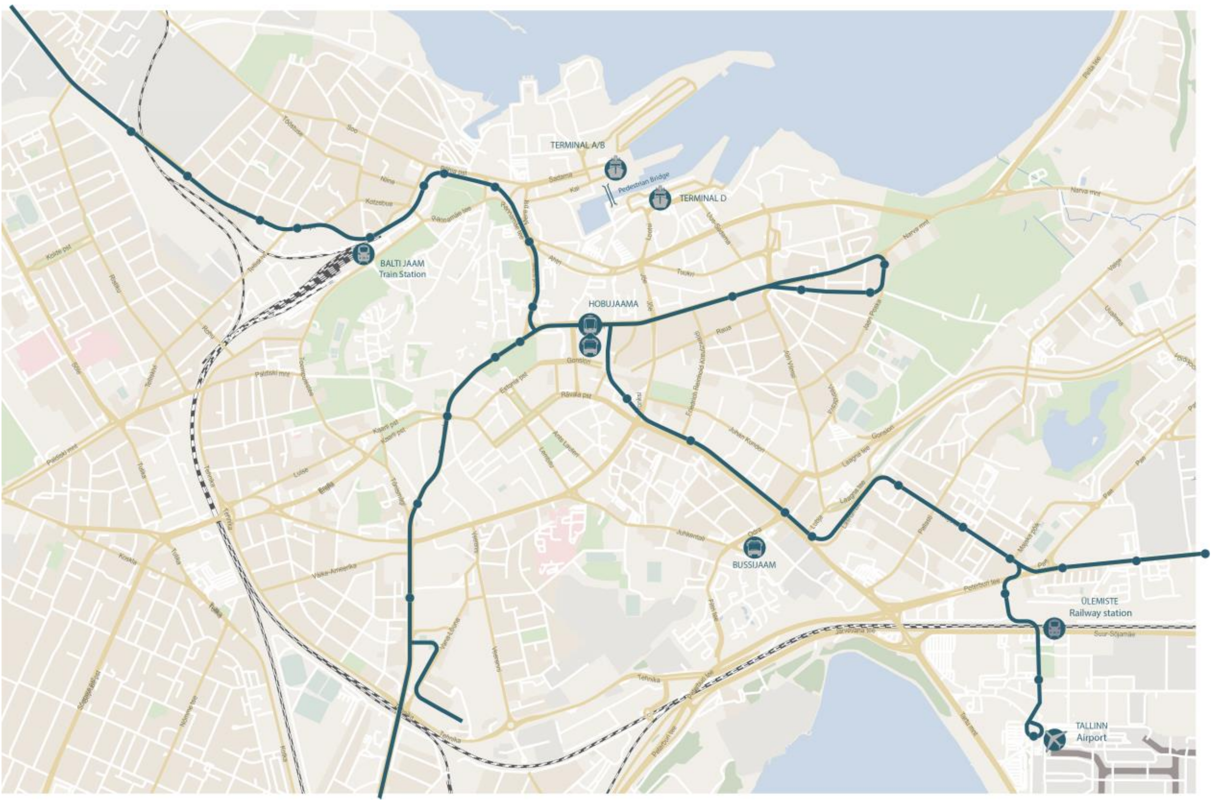


Figure 2 : Map of current tram network in Tallinn

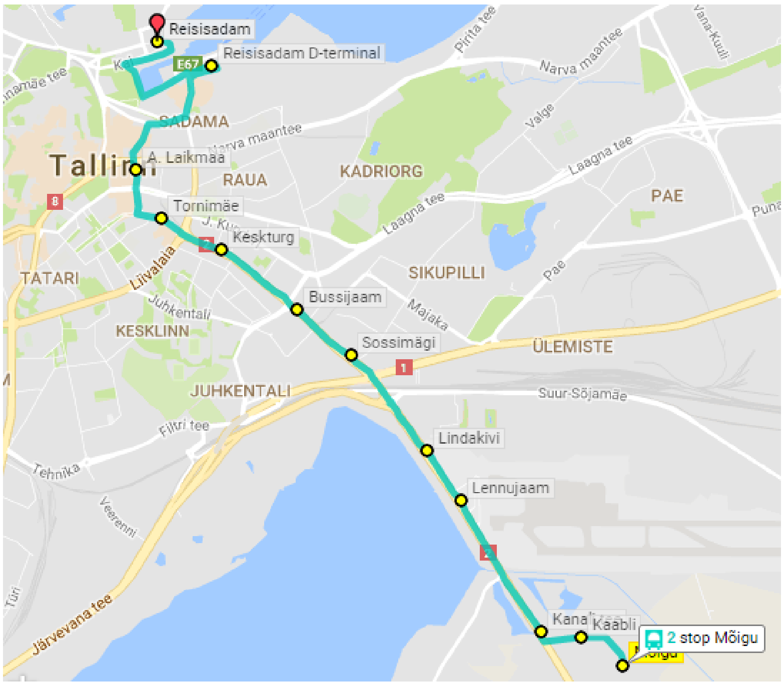


Figure 3 : Map of the current bus line 2 between the port and the airport

Currently, a bus line (line 2) is the only possibility for commuting from Vanasadam to the city center and Airport. Travel time between airport and port (Terminal D) is about 20 mn with an average of only three bus per hour.

Public transport is used for more than 140 million trips per year in Tallinn, with a constant increase since 2010.

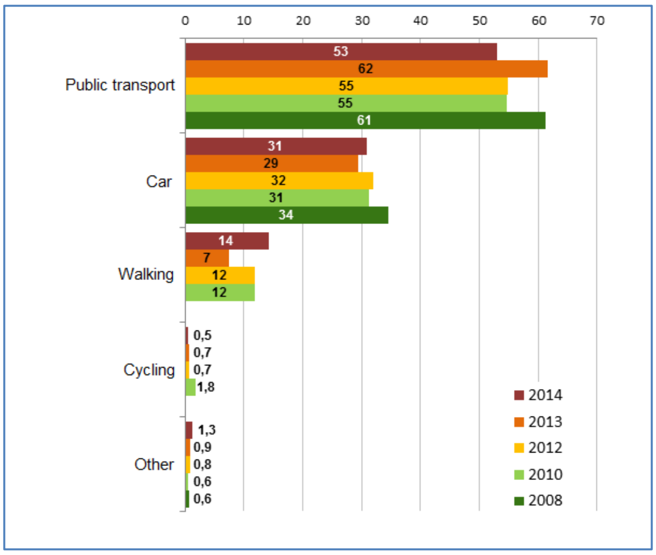


Figure 4 : Main mode of travel to work, school or other main destination on working days, %. (Source: Satisfaction of Residents with the Public Services of Tallinn, 2014) - Source: https://www.tallinn.ee/Indicator-2_Transport_Tallinn

Note: The decrease in the use of public transport in 2014 was caused by the extensive reconstruction of the tram network.

	2015	2016	2017	2018	2019
Number of public transport users (million)	143.7	145.0	148.0	150.0	151.0
Number of on-street public paid parking spaces in Tallinn	7000	7000	7000	7000	7000
Public transport service financing (thousand euros)	60,934	63,194	67,558	72,586	77,959
Acquisition of new vehicles with modern technology (number)	67	34	47	35	30

Figure 5 : Goals of developing the transport system of Tallinn. (Source: indicator_2_transport_tallinn)

Currently, the traffic of the different transport modes increases considerably. With the construction of Rail Baltica, traffic will continue to increase. A connection between the port of Tallinn, its central station, the future Rail Baltica station and the airport becomes necessary.

From this dynamic context on a European scale, new objectives and opportunities appear for the territory of Tallinn.

1.1.1 Existing tram service

The current tram network is really efficient. The network is organized with 4 radial branch which begin at Hobujaama:

- To Kopli
- To Kadriorg
- To Tondi
- And to Lennujaam and Suur Paala.

4 tram lines are operated on the network to avoid a maximum of interchanges each branch is connected to another

- Line 1 : Kadriorg to Kopli - headway : 7,5 minutes
- Line 2 : Suur Paala to Kopli - headway : 7 minutes
- Line 3 : Kadriorg To Tondi - headway : 10 minutes
- Line 4 : Lennujaam and Tondi - headway : 7 minutes

Next figure shows number of trams per hour for each section.

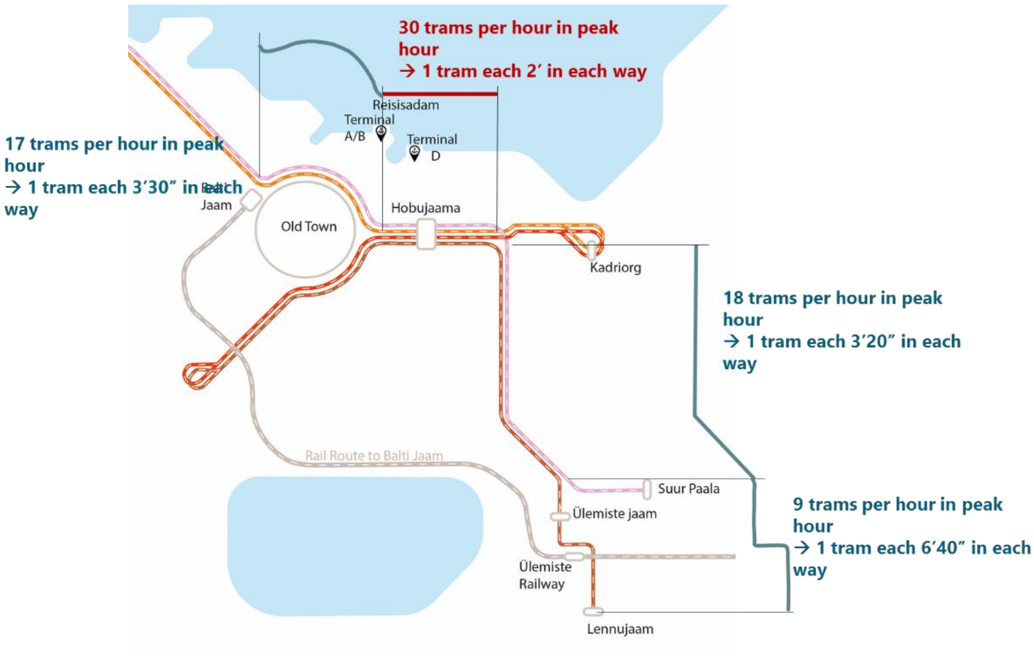


Figure 6: Number of trams per hour and per direction

However, in some section, the commercial speed is very low. This low speed is partly due to close station locations and due to the time lost at roads intersections, indeed tramways have currently no priority. The tram must stop at every junction with the normal probability to have the red light.

Average station spacing and commercial speed are:

- tram line 1 : 440 m | 17,4 km/h
- Tram line 2 : 430 m | 16,4 km/h
- Tram line 3 : 540 m | 16,1 km/h
- Tram line 4 : 470 m | 14,9 km/h

Between Hobujaama and Lennujaam, commercial speed is very low (about 14 km/h)

Figure 7 : Commercial speed on the tram network

Current depots could be stocked at less 8 additional tramways (source AS TLT).

1.1.2 Existing train service

With the modern new trains available throughout the day, more and more Estonians are choosing rail transportation over driving or taking the bus. In fact, passenger figures have gone up by 50 %. According to Elron's figures, in 2014 the fleet made 5.8 million trips – 43 % more than in 2013. By 2015, the fleet was making 6.57 million trips – representing an 11.3 % increase over the year before. This increase in passenger figures also equates to an increase in ticket revenue, which came in at EUR 10.1 million in 2014 – 58% higher than 2013 figures.

It estimates that Ülemiste station served about 610 000 passengers in 2017. 130 000 of them travelled between Balti jaam/Kitseküla and Ülemiste. The rest travelled the other way – Kehra, Aegviidu, Tapa, Narva, Tartu etc.

Concerning, more precisely, the Eastern direction, the number of trains per day per direction on each branch is as follows:

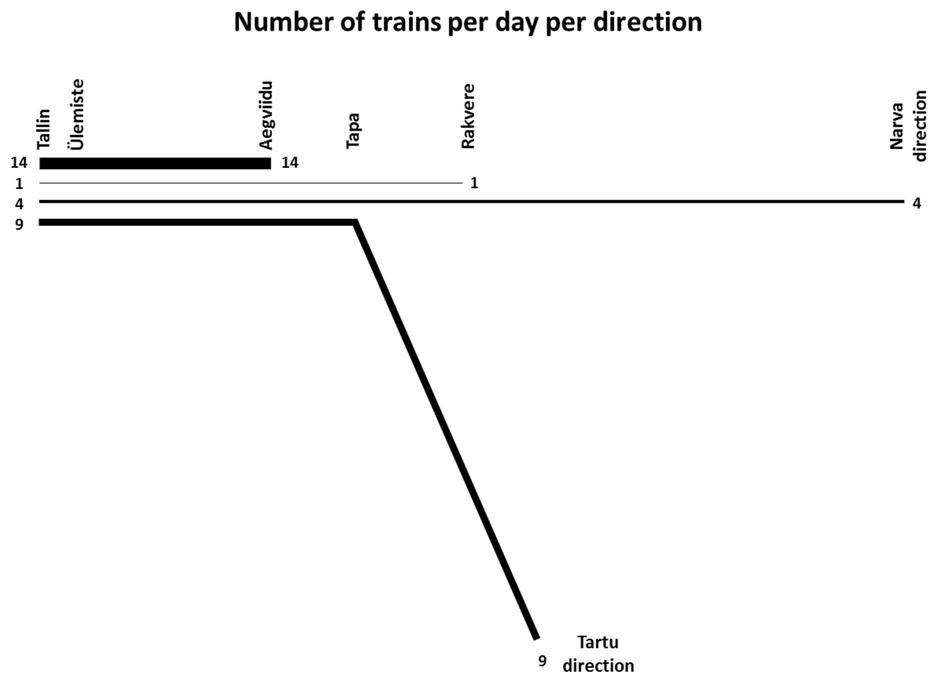


Figure 8 : Number of trains per day and per direction

It is noted that one train out of two begins/ends at Aegviidu station.

The average travel times between Tallinn and the different branches are the following:

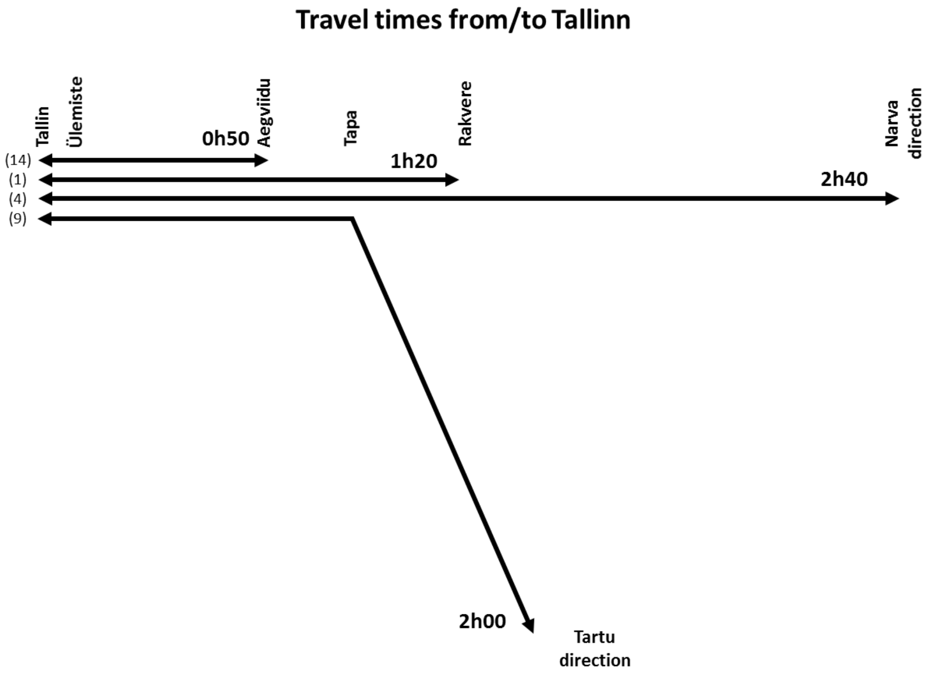
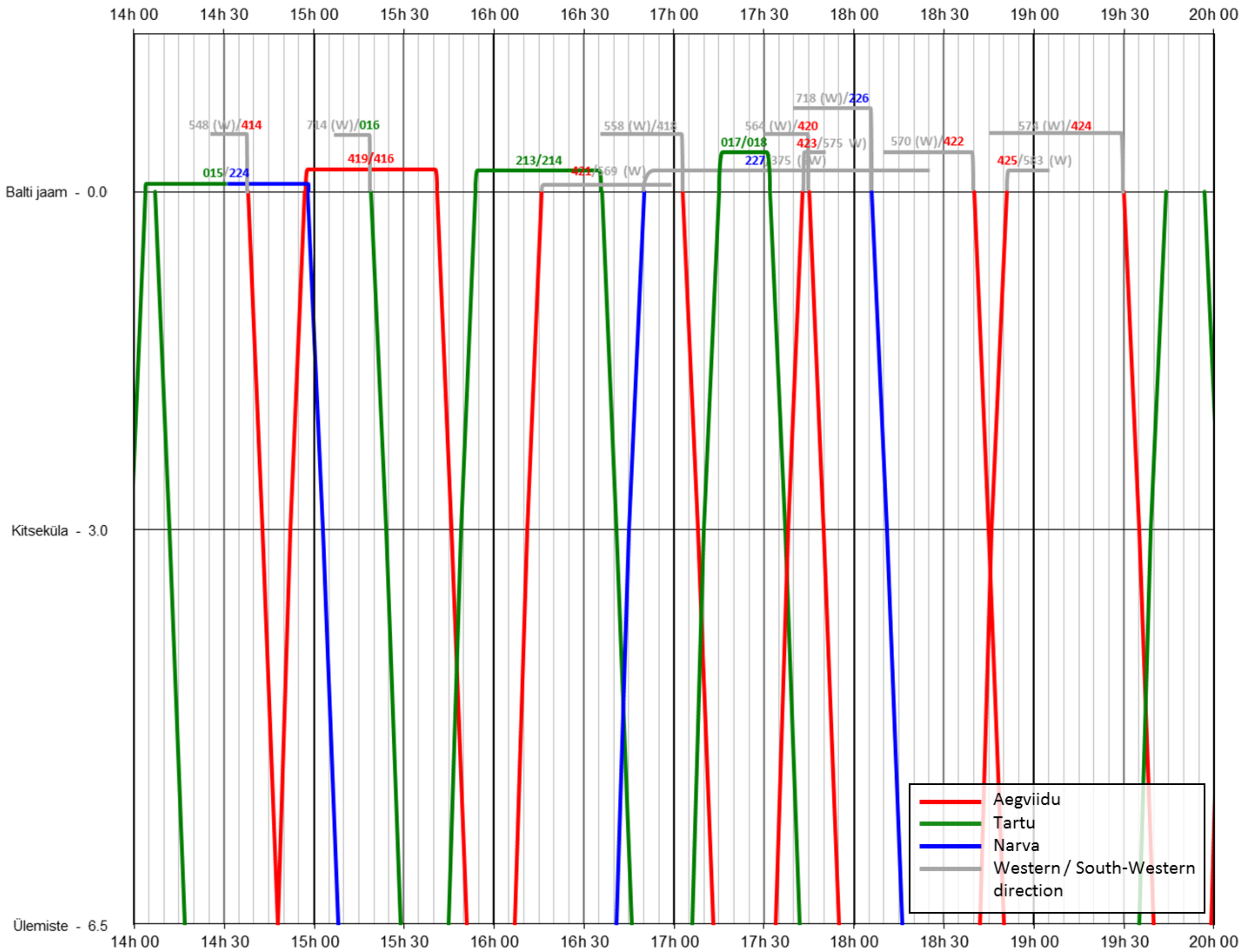


Figure 9 : Current travel times from Balti jaam in train (Eastern direction)

In average, the travel time between Ülemiste and Balti jaam is about 9 / 10 minutes.

It should be noted that each railway service (e.g. Tallinn – Aegviidu, Tallinn – Tartu, etc.) is not operated with a dedicated rolling stock fleet. In the current operation plan, a train arriving at Tallinn from a certain branch can then run on another branch. The following figure, which is the current space-time diagram between Balti jaam and Ülemiste in the afternoon, shows the changes of route operated at Balti jaam terminus for most trains. It should be observed that some trains run on the Eastern network as well as the Western or South-Western network in the same day.



1.1.3 Development of the railway infrastructure

Railway infrastructure must be improved between Ülemiste and Balti jaam. Currently, two single track section limit the number of train on the line. The following scheme shows the project to increase capacity on this section. In this future configuration, there won't be any interface between the eastern direction (To Ülemiste, Narva, Tartu…) and the western direction (Paldisky). The main interface for the eastern direction (To Ülemiste, Narva, Tartu…) will still be with the southern direction (Viljandi/Parnu/Rapla).

With this new infrastructure, it seems plans to reorganize the selection of platform in Balti jaam: each direction could have a dedicated platform.

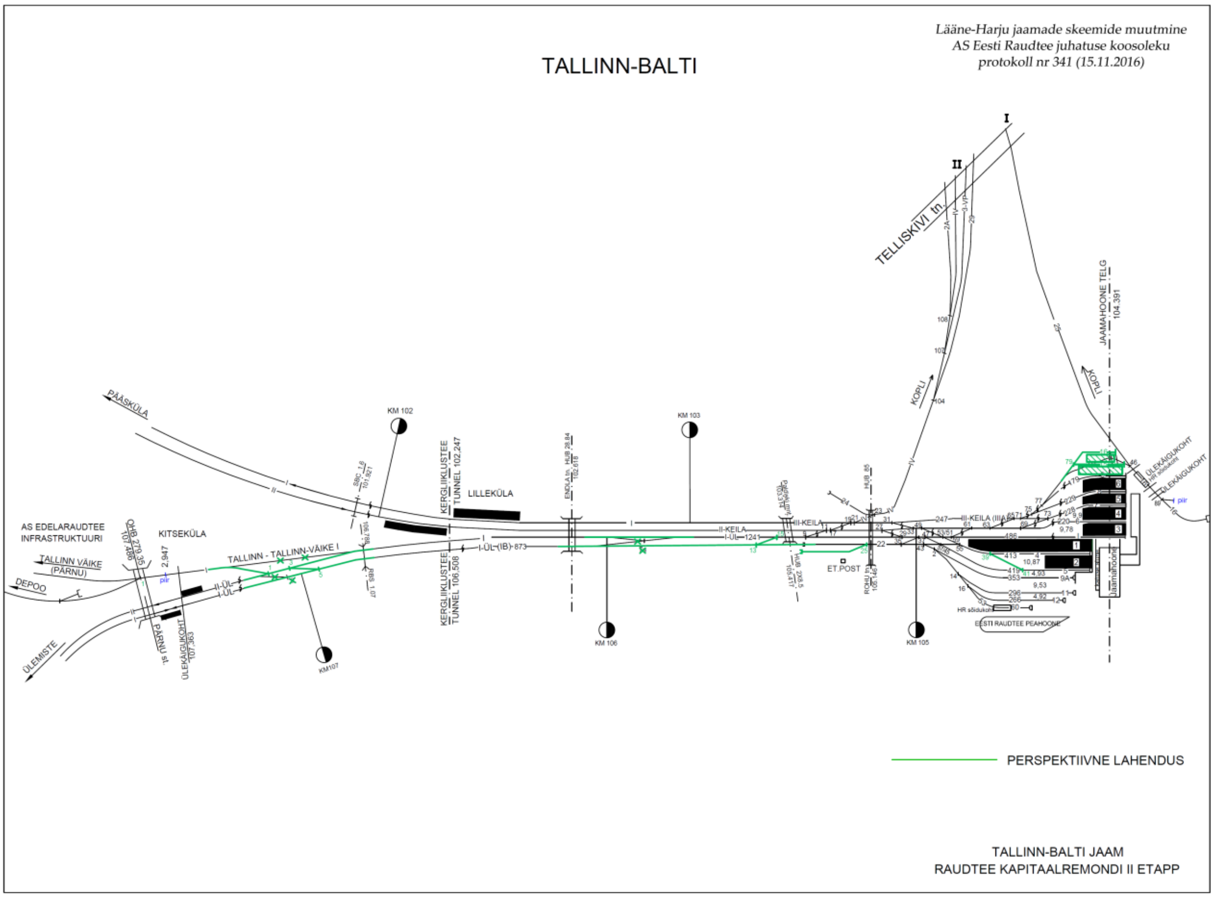


Figure 10 : project of new infrastructure between Ülemiste and Balti jaam

The new developments (new turnout, new tracks…) allow a reduction of crossing over for trains from Paldiski and trains from Parnu or Ülemiste. There will be two dedicated railway line, one for train from Paldiski and the other for trains from Parnu or Ülemiste.

The new development permit also a reduction of the crossing over between trains from Parnu and Ülemiste (only for the direction from Parnu to Balti Jaam).

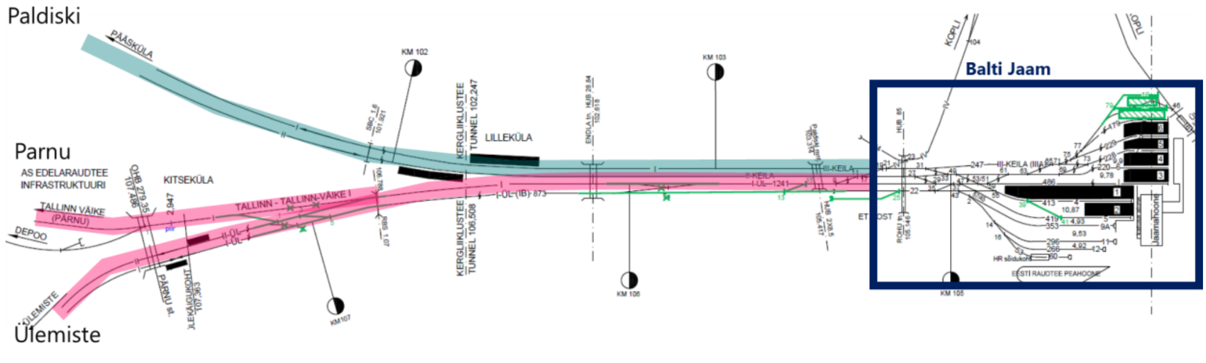


Figure 11 : new developments allow a reducing of crossing over

1.2. Port of Tallinn

Tallinn Port is confronted with a growing demand, the port served more than 10 million passengers in 2017.

Majority of these passengers come from Helsinki 83% and Stockholm. It represents 30 000 commuters per week

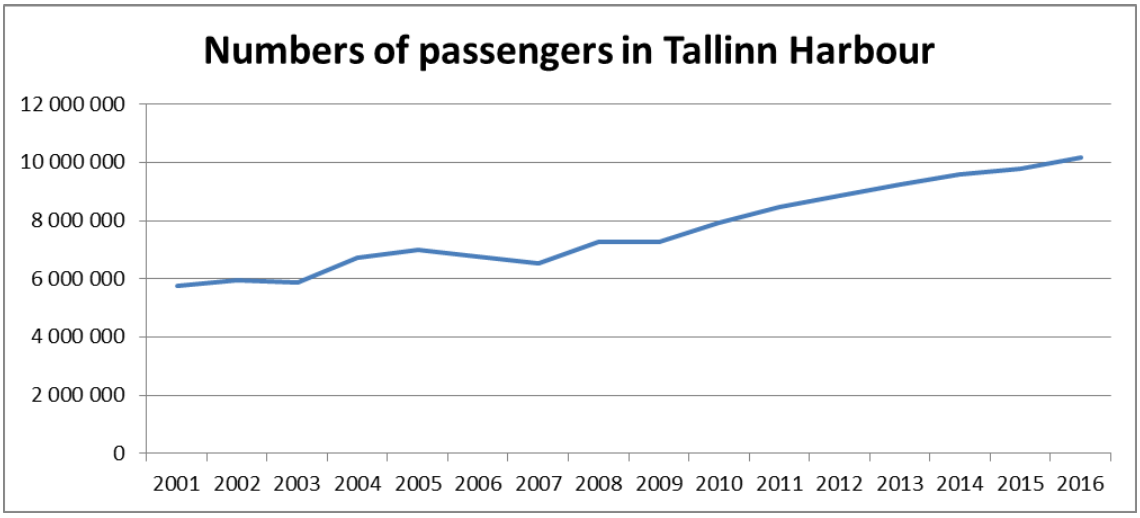


Figure 12 : Numbers of passengers in Tallinn Harbour (source www.tallinn-harbour.ee)

The number of trains per direction on each branch is between 13 and 14 departures and arrivals of ferries per day. The following table shows the arrival and departure per terminal.

Tableau 1 : Departures or arrivals table

		06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Arrival	Terminal								D	D		B			B/D	B				
	Hour								09:30	10:00		11:15			12:30	13:00				
Departure	Terminal	A		A	D						D			A	D		D			
	Hour	06:00		07:00	07:30						10:30			12:00	12:30		13:30			

		15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30
Arrival	Terminal	D				B		D						D	D		B	B		D
	Hour	15:30				17:30		18:30						21:30	22:00		23:00	23:50		00:30
Departure	Terminal			D	A		D	A/B		D						D		D		
	Hour			16:30	17:00		18:00	18:30		19:30						22:30				

1.3. Archaeological constraints

Tallinn's Old Town belongs to the UNESCO World Heritage Site.

All the identified routes to serve the port are located in the protected area of Tallinn's Old Town conservation area (in color blue on the following map). Some alternatives are also passing close to cultural monuments (in black points on the following map) such former factories built on the last century.

The design of these alternatives and their implementation plan will have to deal with these specific constraints especially with the requirement of landscaping integration, the preservation of the structure of the properties and the possible needs of archaeological excavations.

Moreover, all the routes linking Balti jaam railway station to the port are necessarily going through the Old Town Heritage Conservation Area (in color red on the following map) whose boundary is located on Pohja and Mere puiestee. That means that for these alternatives, several regulations will have to be observed (Heritage Conservation Act, Planning and Building Act, Tallinn Temporary Building Regulations).

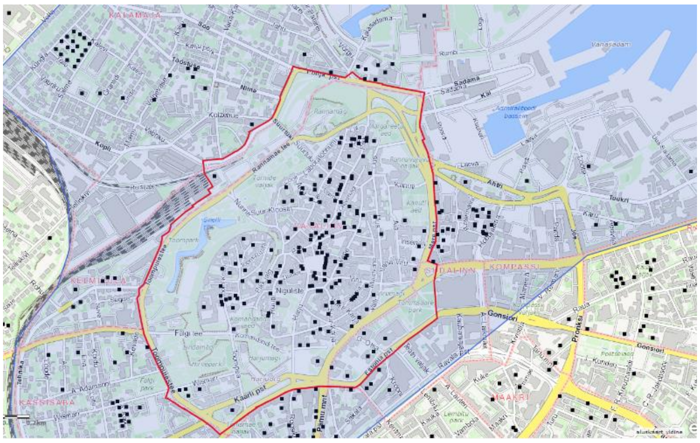


Figure 13: Perimeter of conservation area

1.4. Rail Baltica project

Rail Baltica is include to European strategic infrastructure core network defined in the new TEN-T Guidelines (Regulation EU N° 1315/2013 and could be funded by Connecting Europe Facility instrument.

It is a the major common project of Estonia, Latvia and Lithuania, which aims to build a new railway line with 1435 mm gauge, which will allow continuity of EU Core Railway Network through the Baltic states. The line shall runs from Tallinn to Parnu, Riga, Panevezys, and Kaunas to the Lithuania/Poland state border.

On the longer term, the line will be extended to Warsaw and then to West and South Europe.

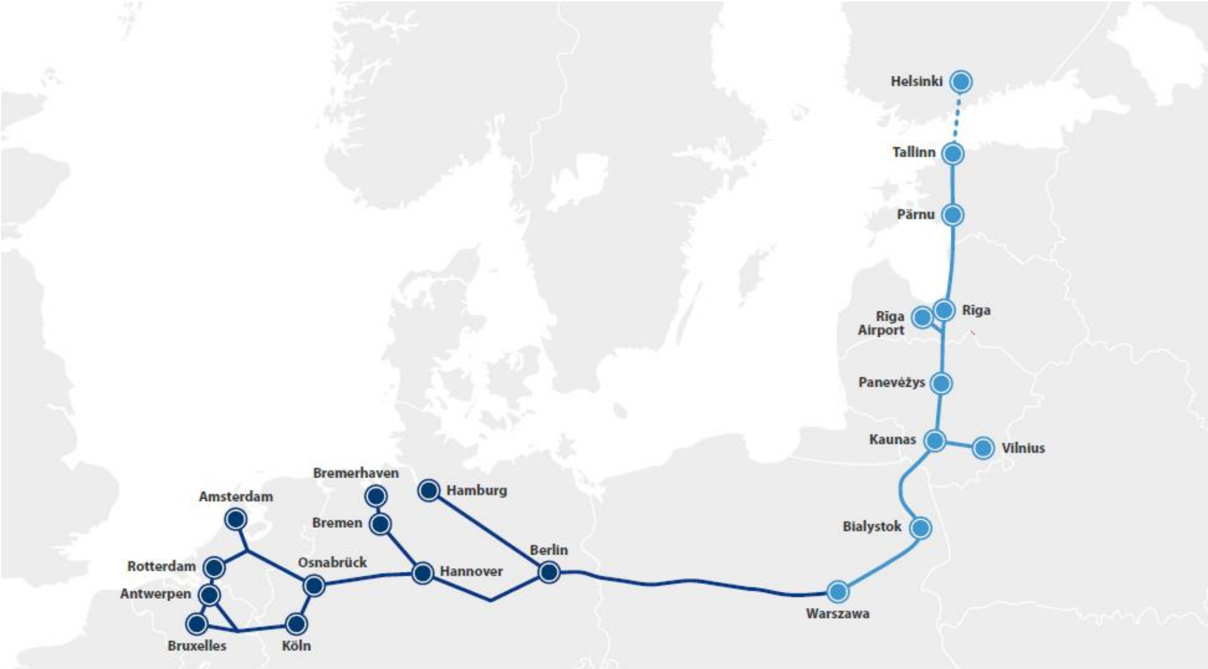


Figure 14 : Future connection with South of Europe (source Rail Baltica)

The aim is to establish a modern, multimodal, North-South connection favorable to European integration. It will take less than two hours to travel from Tallinn to Riga or from Riga to Kaunas against 4 h 30 by road today.

Approximately 5 million passengers a year are expected by 2030 and 12.5 million tons of freight.

Technically, the railway line shall be equipped with double track, electrified in 2x25 kV, with a design speed of 240 km/h, allowing passenger trains to run at 240 km/h, and freight trains at 120 km/h. Signaling system shall be ERTMS Level 2. To summarize, Rail Baltica shall be fully interoperable European line, compatible with the Technical specifications for Interoperability of European Union.

Its length through the Baltic States will be around 700 km.

Description of Rail Baltica in Estonia

In Estonia, the new infrastructure will be 200 km long and will serve the stations of Parnu, Ülemiste (Tallinn airport) and Tallinn main station.

3 new platforms and 6 tracks will be implemented in the future Rail Baltica **Ülemiste station:**

- 1 central platform with a width of 10 m for the 2 Rail Baltica tracks (track gauge 1,435m)
- 1 central platform with a width of 10 m for the 2 tracks of regional and national train (track gauge 1,520m)
- 1 lateral platform with a width of 6 m for the Russian train for 1 track (track gauge 1,520m)

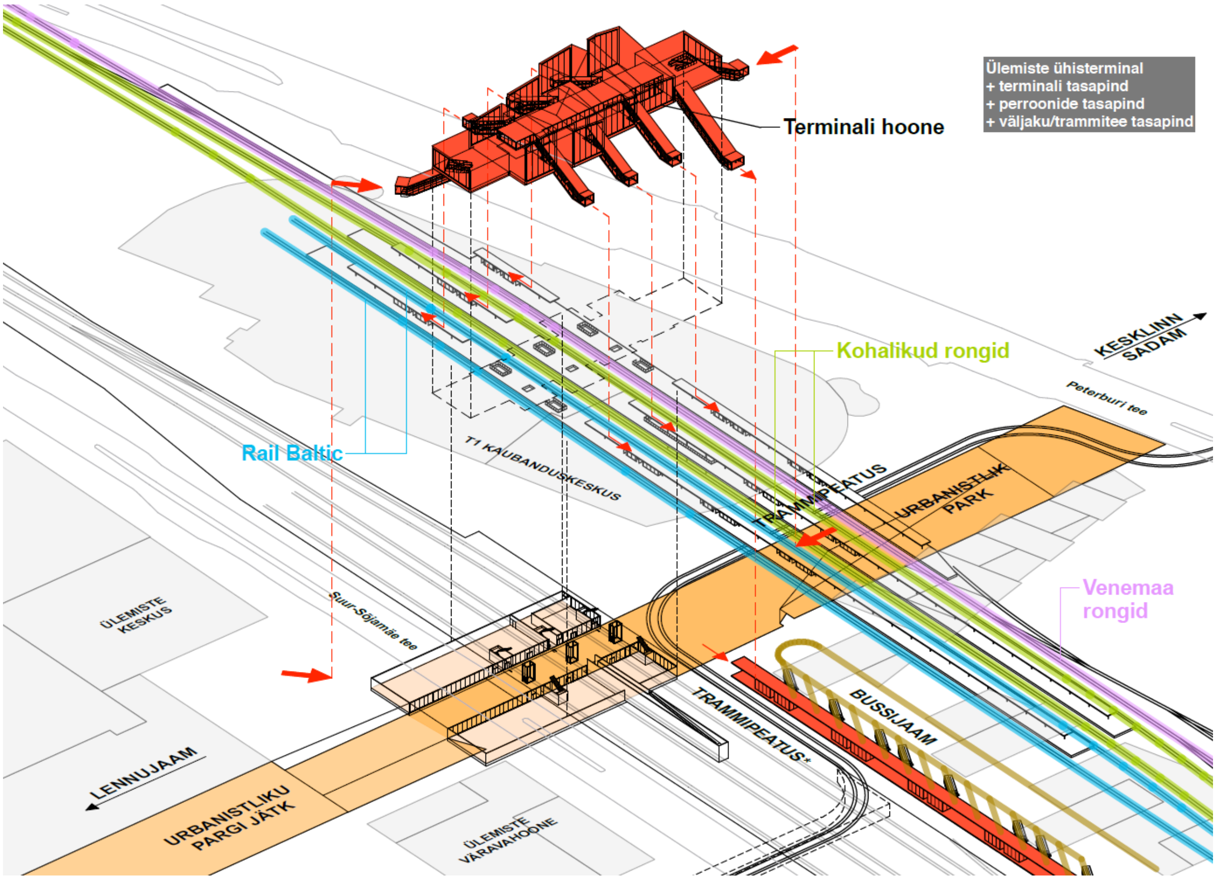


Figure 15 : schematic plan of the different floor organization

Global planning of the RB II project for the three Baltic countries (EE, LV, LT)

The schedule is as follows:

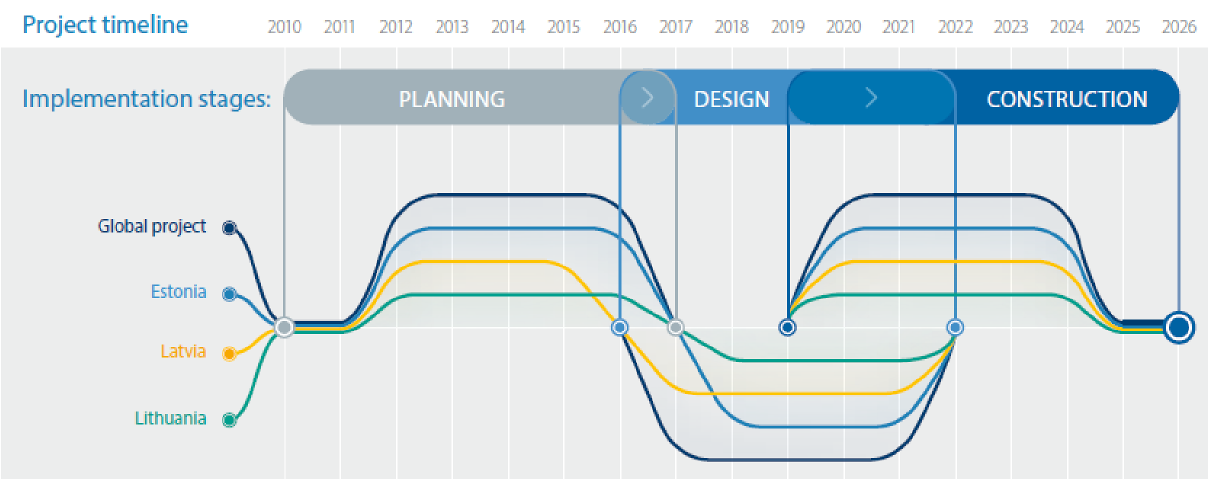


Figure 16 : The provisional schedule (source Rail Baltica)

- National Studies (Detailed Technical Studies, Plan and Schema, EIA, CBA, …….) 2016-2017.

- Studies and Technical Design are to be completed between 2018/2022.
- Land acquisitions will take place from 2019-2020
- The first phase of the construction of the line will be completed in 2022.
- The construction of the Rail Baltica line in the 3 Baltic countries is expected to end in 2026.
- The total cost of the project is estimated at 5,8 billion euro including 1,346 billion euro in Estonia (according to the Cost-Benefit Analysis prepared by EY).

According to this schedule, it is proposed to take 2026 for the beginning of the commercial operation of the project between Ülemiste and Vanasadam.

2. Development of alternatives routes for tramways or light rail

2.1. Objectives

The tramway project or LRT project in Tallinn is in line with the objective to ensure an efficient passenger link between Vanasadam and Rail Baltica Station Ülemiste:

- By providing a sustainable, high quality, high capacity and fast connection
- In order to integrate urban, suburban and international passenger flows

Several alternatives were identified according to these mains issues:

- the definition of the route suitable for this new tram link
- the evaluation of travel time
- the compatibility between traffic forecasts and infrastructure capacity
- the fleet estimation and depot capacity

The purposes of this study are to identify all the most relevant routes to efficiently serve strategic places such as Tallinn main station, the airport and Vanasadam Passenger port.

The different solutions have to consider the following important nodes:

- Tallinn Airport – Lennujaam
- Ülemiste railway Station and the future Rail Baltica station
- Tallinn main railway station – Balti jaam
- International Bus station – Bussijaam
- Urban bus station – Hobujaama
- And the port terminal A/B and D - Vanasadam

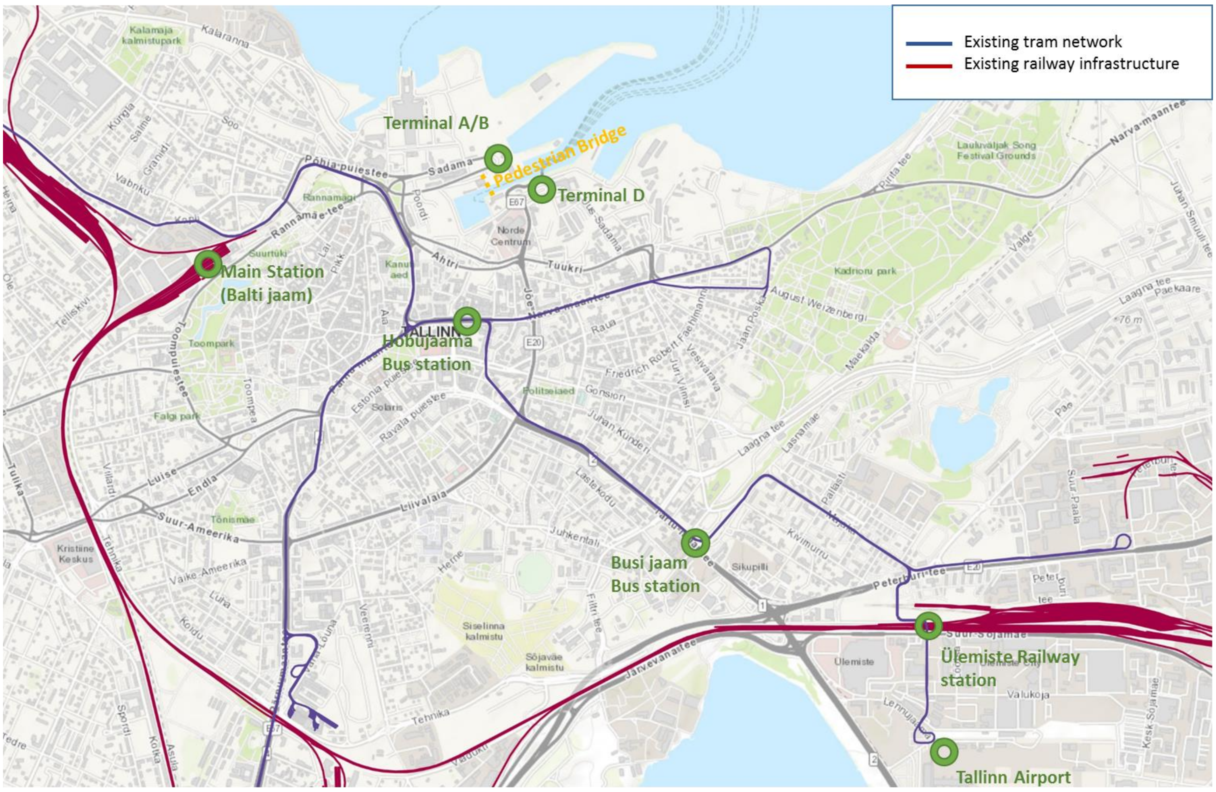


Figure 17 : main public transport network and important nodes of transport

2.2. Presentation of alternatives

In the first stage of the study and after exchanges with stakeholders, several possible routes alternatives have been identified for a rail bound link between the port and RB Ülemiste Station.

These alternatives are based on the existing public transport network both the railway network and the tram network. Some alternatives propose to integrate a new transport system.

In this first stage, different solutions have been found to respond to the objective of the project without consideration of investment cost or technical feasibility. That's why, direct tunnel solution are proposed at the same level as solutions that completely reuse the existing network.

The following figures show schematically what could be the itineraries of these extensions and the system family.

2.2.1 Railway alternatives: solutions using the existing railway infrastructure

Rw 1 : Minimalist solution Train + Tram

Solution with one interchange in Balti jaam between train and tram

Main technical characteristics :

- TRAIN (3000V / track gauge :1 ,520m)
- TRAM (600 V / track gauge 1,067m)

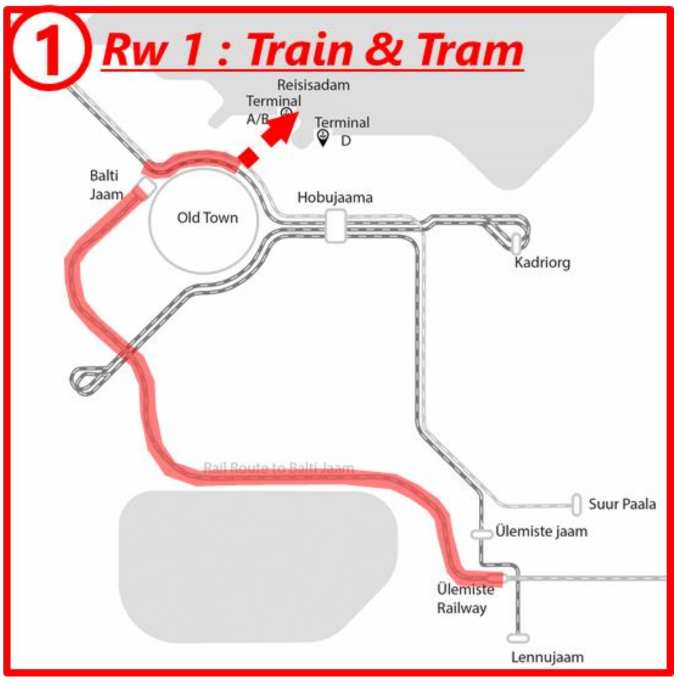
Reusing the existing infrastructure :

- Existing Railways: 6800 m, 2 stations
- Existing tramway line: 900 m, 2 stations

New infrastructure :

- New tramway branch: 650 m, 2 stations
- With a new service (it could be necessary to reorganize the tram network)

1 interchange train/tramway: 10 minutes
Travel time: 25 minutes
Investment cost : [30 – 60 M€]



Rw 2 - direct train on tunnel

This option proposed to extend all train from Ülemiste to the port with the implementation of a tunnel between Balti jaam and the terminal A/B.

Main technical characteristics :

- TRAIN (3000V / track gauge :1 ,520m)

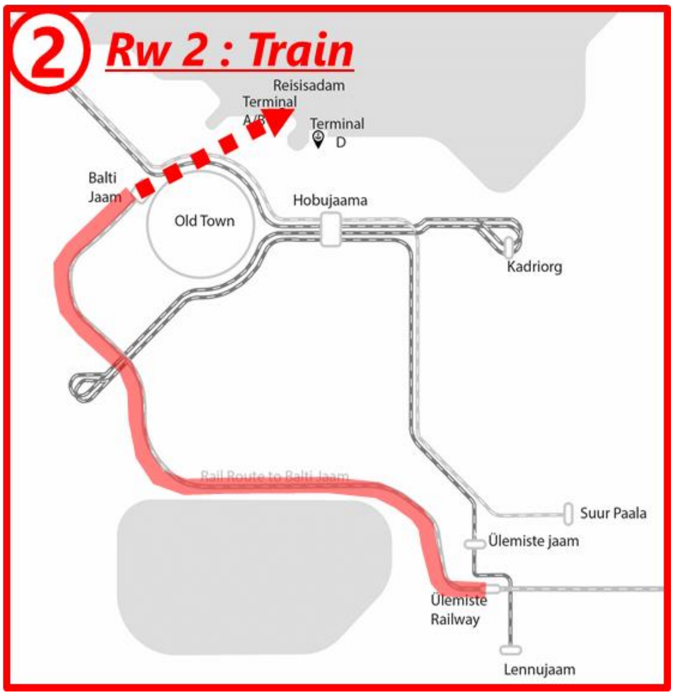
Reusing the existing infrastructure :

- Existing Railways: 6800 m, 2 stations

New infrastructure :

- New train in tunnel: 1500 m and 1 new station
- Existing service at less with if possible an increase of number of train between Ülemiste and Terminal A/B (new service between Ülemiste and Terminal A/B)

Travel time: ~13 minutes
Investment cost : [150– 250] M€



Tram-Train 1 : LRT by Balti jaam

This option proposed to extend all train from Ülemiste to the port with the implementation of a tunnel between Balti jaam and the terminal A/B.

Main technical characteristics :

- LRT (tram – train) → 3000v/600v track gauge: 1,520m

Reusing the existing infrastructure :

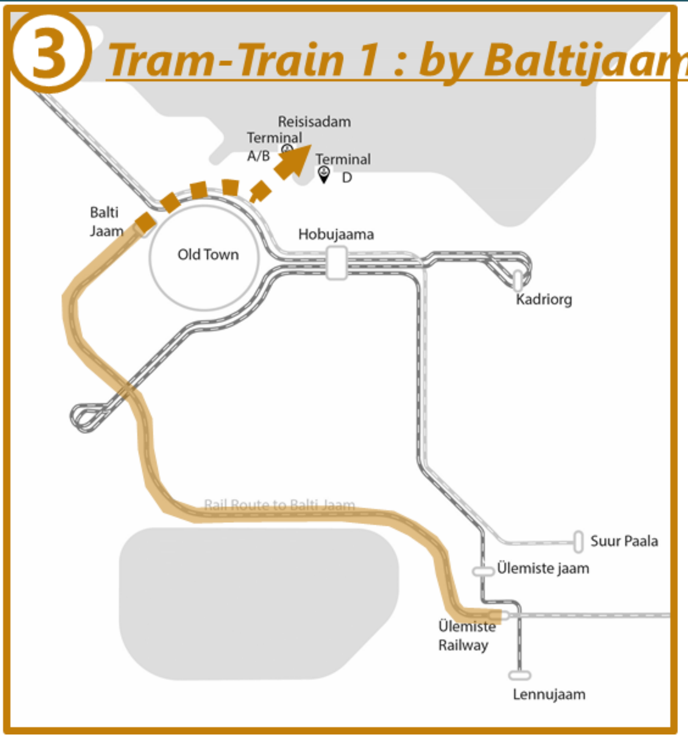
- Existing Railways: 6800 m, 2 stations

New infrastructure :

- New LRT at grade 1550 m (partially in parallel of the existing tramway) 2 new LRT stations

Travel time: ~15 minutes

Investment cost : [40 – 80] M€



2.2.1 Tramway alternatives: options using the existing tramway infrastructure

TRAM 1 - Tram using the existing Infrastructure

This option proposed to reuse at maximum the existing tramway network. 3 sub options are proposed: by Sadama street or Kai street ; by Paadi street or by Jöe street

Main technical characteristics :

- TRAM (600 V / track gauge : 1,067m)

Reusing the existing infrastructure :

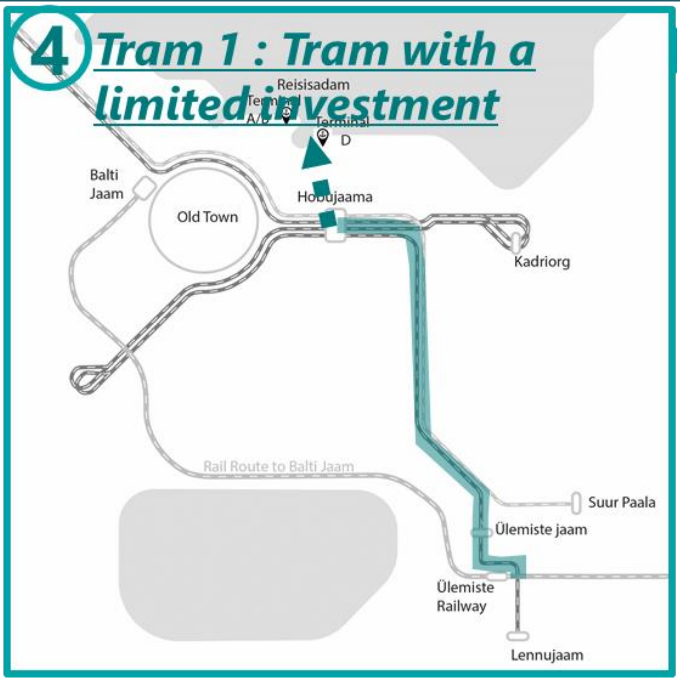
- Existing tramway line: between 2500 and 4200 m (depending on options), between 7 and 11 stations

New infrastructure :

- New tramway branch: between 600 m, 1 or 2 stations
- New service

Travel time: between 18 and 24 minutes

Investment cost : [30 – 60] M€



TRAM 2 – tram direct

Based on the previous option, this option proposed to reduce the length of tramway between Ülemiste and Bussijaam. The proposed route runs along Ülemiste Tee and Tartu Mnt.

Main technical characteristics :

- TRAM (600 V / track gauge : 1,067m)

Reusing the existing infrastructure :

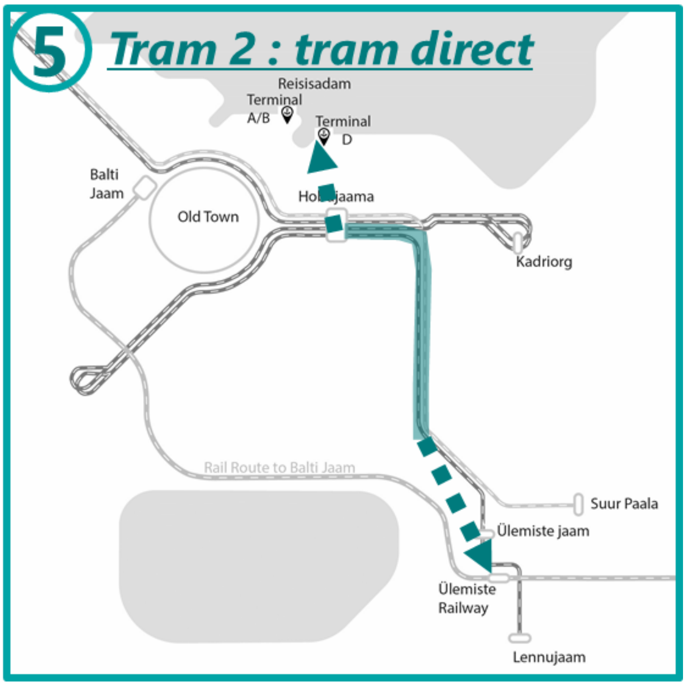
- Existing tramway line: between 1450 m 4 stations

New infrastructure :

- New tramway branch: between 2200 m, 3 stations
- New service

Travel time: 16 minutes

Investment cost : [60 – 100] M€



Tram 3 : maximalist option

Based also on the option 2, this option proposed to extends the new line until Balti jaam railway stations

Main technical characteristics :

- TRAM (600 V / track gauge : 1,067m)

Reusing the existing infrastructure :

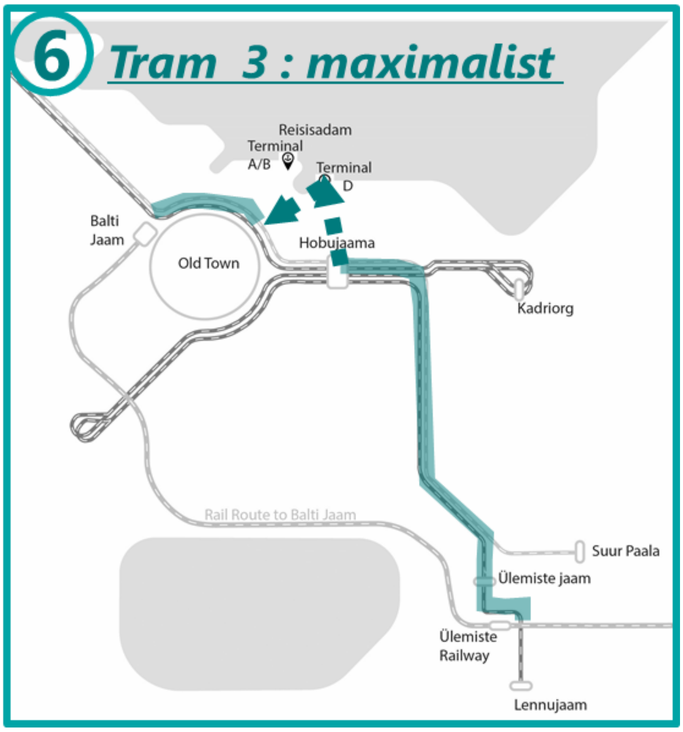
- Existing tramway line: between 3850 m 10 stations

New infrastructure :

- New tramway branch: 1650 m, 4stations
- New service

Travel time: 19 minutes by tram and 27 minutes by tram and train with one interchange at Balti jaam (including travel time in tramway between Port and Balti jaam, waiting time in Balti jaam and travel time between Balti jaam and Ülemiste)

Investment cost : [40 – 80] M€



2.2.2 Other alternatives families: Direct shuttle on tunnel or at grade

Tunnel 1 : tram-train in tunnel

This option proposed to reuse partially the railway infrastructure, then continued in tunnel until Liivalaia and finished at grade in tramway mode.

Main technical characteristics :

- LRT (tram – train) → 3000v/600v track gauge: 1,520m

Reusing the existing infrastructure :

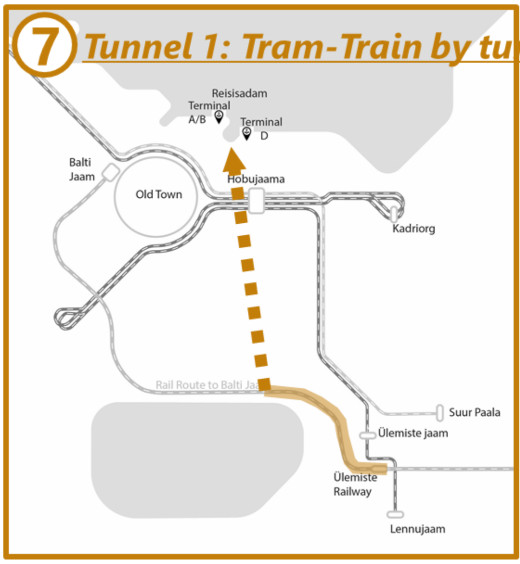
- Existing Railways: 750 m, 1 station

New infrastructure :

- In tunnel: 1650 m,
- At grade : 1200 m

Travel time: 10 minutes

Investment cost : [200 – 250] M€



An alternative of this option is to propose the same option in tramway (track gauge: 1,067m). The tunnel could start since Ülemiste Tee (front of the future RB station). This options permit an interconnection with the existing tramway network

Tunnel 2 : Direct shuttle

This options proposed to implement a new line based on the metro system

Main technical characteristics :

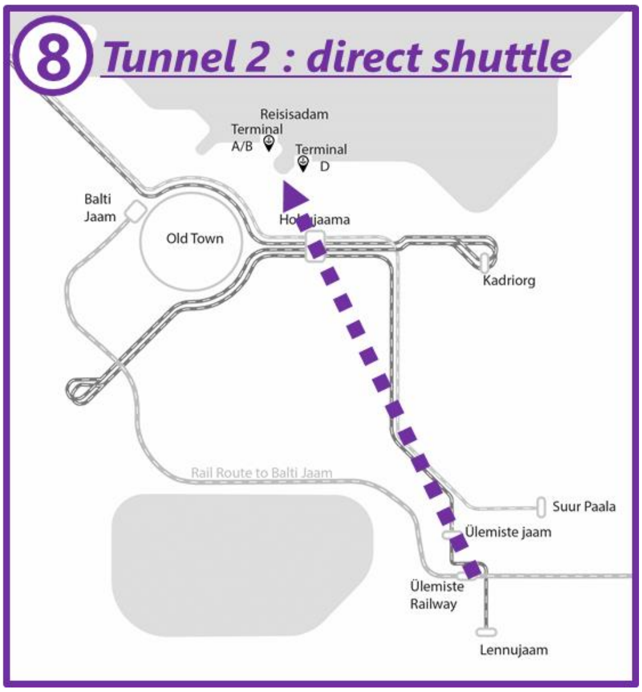
- New system : track gauge to be define (1,520 / 1,45) ;
- light metro : 100 km/h

New infrastructure :

- New line in tunnel branch: 3000 m, 2 stations
- New service

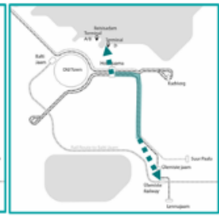
Travel time: 5 minutes

Investment cost : [300 – 350] M€



2.2.3 **Multicriteria analysis**

The following table shows a first analysis of the different options. The different alternatives have been analyzed through several criteria to ease the comparison and in particular the travel time between Ülemiste and the port or the investment cost.

	Family 1 : Railway Network			Family 2 : Tram Network			Family 3 : Tunnel	
	1	2	3	4	5	6	7	8
	TRAIN & TRAM	TRAIN	TRAM - TRAIN	TRAMWAY	TRAMWAY	TRAMWAY	TRAM - TRAIN	direct Shuttle
								
Specifications	1 interchange	By tunnel	2 variants : - By Sadama - By Kai	3 variants : **- By Gonsiori / Laikmaa** **- By Joe**		Alternatives 1 + 4		
New city center conection with the port	–	–	–	+	+	+	–	–
BaltiJaam connection with the port	+	+	+	–	–	+	–	–
Travel time Between Ülemiste station	**25 mn with 1 interchange**	**13 mn**	**15 mn**	**19 - 24 mn**	**16 mn 17 mn with a new Station**	**19 - 24 mn**	**10 mn**	**5 mn**
Investment cost	+ [30 - 60 M€]	+++ [150 - 250 M€]	++ [40 - 80 M€]	+ [30 - 60 M€]	++ [60 - 100 M€]	++ [40 - 80 M€]	++++ [200 - 250 M€]	+++++ [300 - 350 M€]
Technical feasibility		extrension of the railway by a tunnel	**Capacity on the railway network specific rolling stock Impact on heritage area**	Add new service on the tram network	Impact on the car trafic on Tartu Mnt	3 mains Car intersections Narva, Athri and Pohja		

2.3. Alternatives chosen

The following alternatives was selected by RB Rail team and the different stakeholders at the end of the stage 1:

- **Alternative 6**: the tram option connects Ülemiste station to Vanasadam Port and Balti jaam. This option has 3 sub alternatives:
  - **The Alternative 6A**. The proposed route start at Ülemiste station, uses the tram network until Paberi Stop. At Paberi stop, a new infrastructure is created along Gonsiori and Laikma to avoid the bottleneck of Hobujaama. Then the route runs along Hobujaama Street, Paddi or Joey (after Ahtri) to arrive at the port. And return by Leava and Pohja street to come back to the existing infrastructure at the Kenuti station. Then the route continues to Balti jaam.
  - **The Alternative 6B** is an alternative for the alignment. The route proposed to runs along Rävala pst (after Tartu mnt) to Laikmaa and Hobujaama street;
  - **The Alternative 6C** concerns the study of the different possibilities to increase average speed of trams on the exiting network between Ülemiste tramway stop and Paberi stop.

In following chapters, this option will be call "Tram option". The technical feasibility and the alignment options are detailed in the chapter 3 Tram option - Technical feasibility "

- **Alternative 2:** the train option connects also Ülemiste station to Vanasadam Port and Balti jaam by reusing the existing railway network.

In following chapters, this option will be call "Train option". The technical feasibility and the alignment options are detailed in the chapter 4 "Train option – Technical feasibility".

- **Alternative 7:** It is propose to create a new line of public transport with a mass transit system (LRT or tram) and so to continue to develop the public transport network. This alternative will be investigate also in existing tram rolling stock and so the route doesn´t use existing railway at Ülemiste junction

In following chapters, this option will be call "5. Tram in tunnel option". The technical feasibility and the alignment options are detailed in the chapter 5 "Tram in tunnel ".

3. Tram option - Technical feasibility

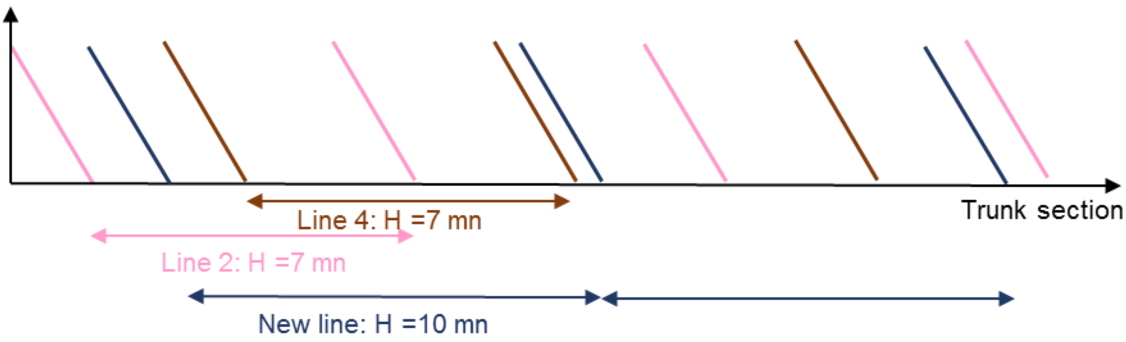
3.1. Description of tram option

3.1.1 Proposed reorganization of the tramway network

The option presented in the first stage proposed to implement a new line of tramway between Ülemiste, Vanasadam and Balti jaam. Initially, a dedicated service was proposed.

A new dedicated service present several difficulties:

- The main difficulty is how to insert new services on the trunk section of line 2 and 4 for the existing network. On this section the headway between tramways is already very short of 3'20'', it is difficult to reduce the headway without impacting the regularity of all tram lines. With headway of 10 minutes for the new line, the trunk section will have a tram each 2 minutes on average but with an irregularity of passage due to the different headway between the lines. The next figure shows the irregularity of passage on the trunk section.



- Another issue is the implementation of a reverse loop and a new tram stop near Balti jaam, it is possible but presents many difficulty (alignment is presented in chapter 3.4.1 Balti Jaam – variant of the terminus of the line).
- A new service requires many new rolling stock.

According these difficulties, the chosen option consists to reorganize the tramway network. It proposed to substitute the route of the current line 2 and line 4 :

- The new route of line 4 could runs from Suur Paala to Tondi.
- The new route of line 2 could runs from Lennujaam to Kopli, by passing through Vanasadam Terminal D.

Current time table is maintained.

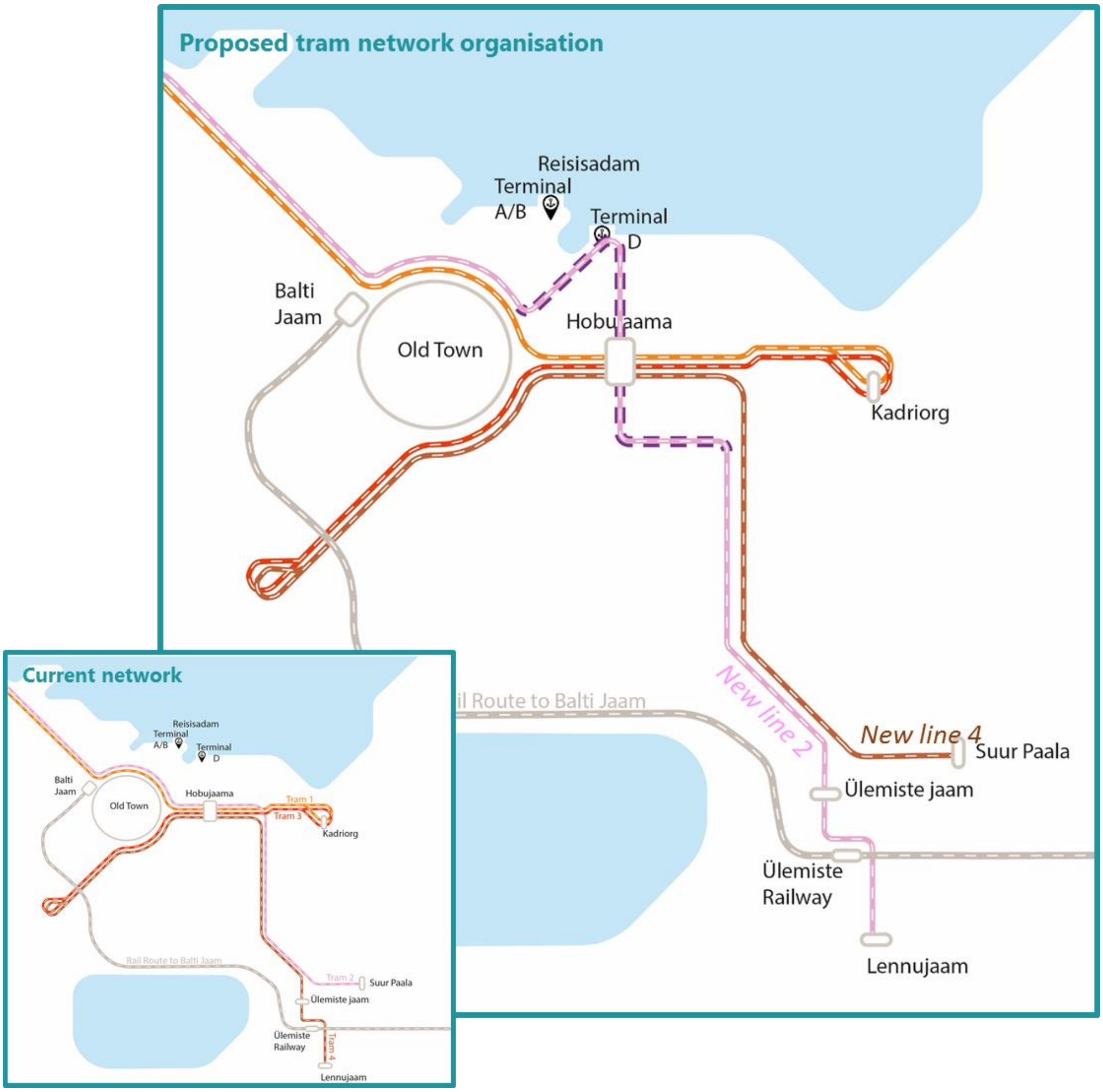


Figure 18 : Tram – option - schematic tramway network

This option has the following advantages:

- A better headway from Ülemiste to Vanasadam: headway of 7 minutes (against headway at 10 minutes maximum with a dedicated line).
- Reduce the number of tramway on the bottleneck of Hobujaama: one tram each 3 minutes against one tram each 2 minutes in the existing situation.
- And keep the same level of service of each branch of the tram network

The main difference could be for trips between the branch of Kopli and Suur-Paala which will require a transfer.

Another difference could be the travel time between the branch of Kopli and the branch to the south-Est (Bussijaam, Ülemiste…). The new route of tram line 2 through the port is longer than the existing route by Mere PST but avoid the bottleneck of Hobujaama. It also the case for trips between Balti Jaam and Hobujaama, however the current line 1 will stay on the current route through Mere and so will keep the current travel time.

The following figure show the route of the new line 2 and the sections in project.

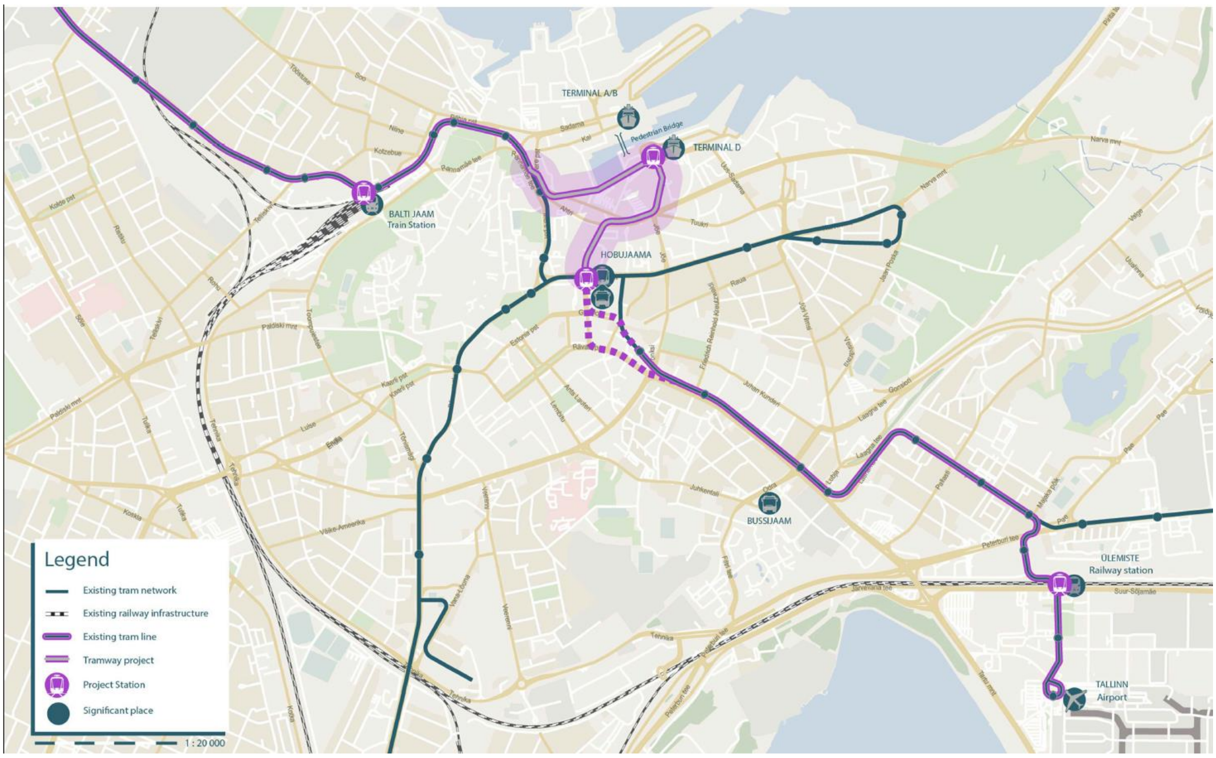


Figure 19 : Route of the new line 2

3.1.2 Alternatives reorganization

As indicated above, the new tramway network has a consequences for the relation Between Tondi and The Airport, this relation require a connection with the new line 4 (Line 2 from Airport to Bussijaam and line 4 between Bussijaam and Tondi.

Another solution could be to reorganize the tramway line 4 with :

- 1 on 2 tramway of tramline 4 to airport
- 1 on 2 tramway to Suur Paala

However this other organization of the tramway line 4 has impact on the airport tramway loop.

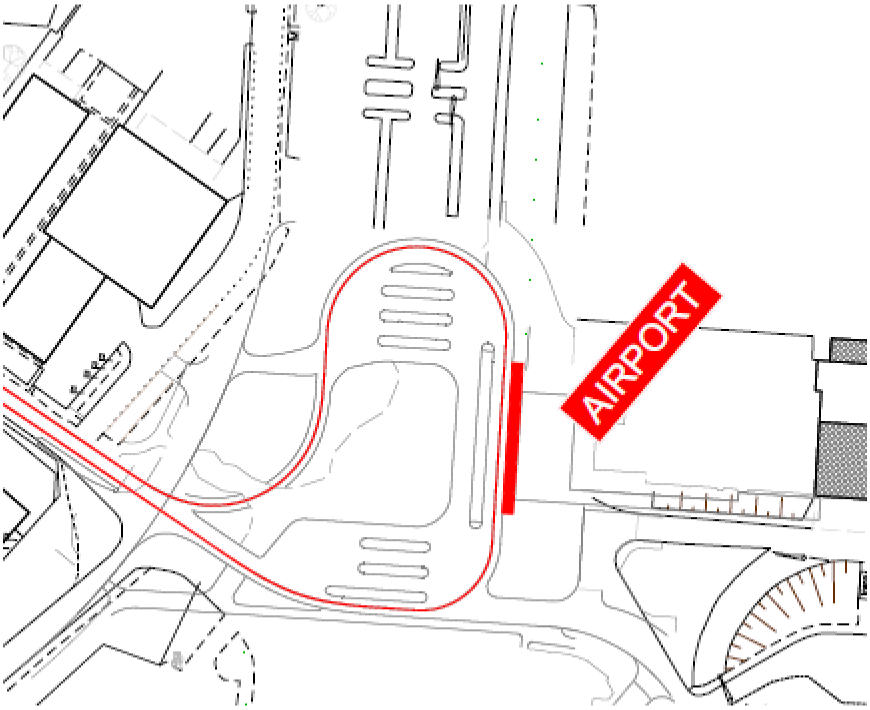


Figure 20 : current organization of terminus loop at Airport

Current terminus front of the airport has a limited capacity due to only one platform. First tramway has to leave the platform before the next tramway arrives (as presented on the following scheme). This loop doesn't allow an important headway doesn't allow to have a good regulation time.

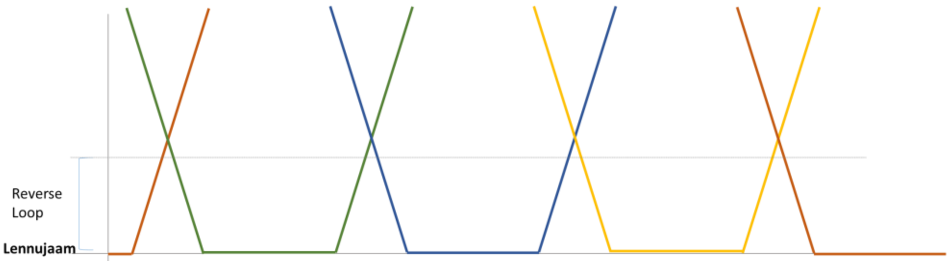


Figure 21 : current organization with 1 tramway line

Adding a part of the new tramway line 4 presents 2 main difficulties:

- More importantly issue of regulation (Decrease of regulation time)
- Tram changes route at the airport (tram 4 becomes 2)

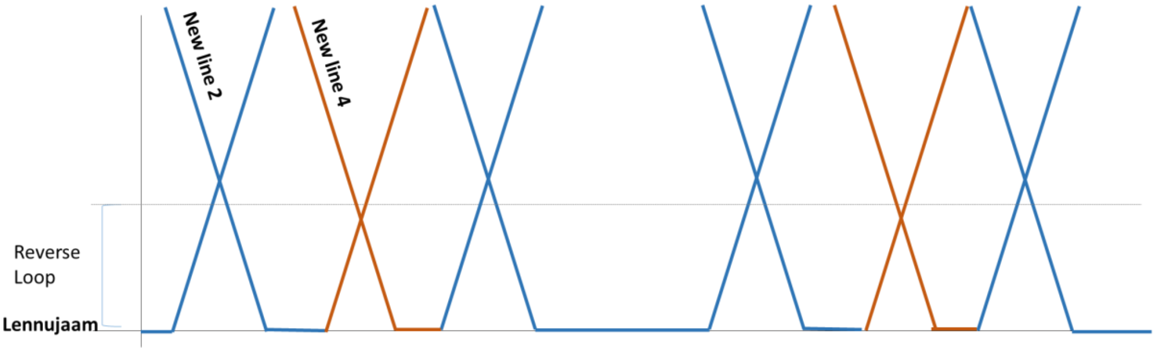


Figure 22 : with new tramway line 4

However, in case it is needed to add a second platform at the terminus Airport station, chapter 3.4.15 Airport station shows the feasibility to implement.

3.2. System conception

3.2.1 Rolling stock

The proposed option is to operate with the current rolling stocks:

- The new rolling stock CAF urbos AXL with a length of 31 m and width of 2,3 m;
- The old rolling stock KT6 with a length of 27 m
- and KT 4

The track gauge is 1067 mm.

And the rolling stocks are mono directional and require a reverse loop at each terminus.

Figure 23 : CAF Urbos AXL

Figure 24 : KT6

3.2.2 Tracks

The design of the track's horizontal and vertical alignments shall follow specific design criteria that take into consideration the characteristics of the rolling stock, the requirements for passenger comfort, and the other interfaces with the system in the context of Tallinn.

These criteria shall cover the various technical aspects enabling the proper accomplishment of the following main functions:

- Guide the Tramway (Transition curves, super elevation, horizontal and vertical curves, gradients, rolling stock gauges and widths, pedestrian clearances, etc…);
- Support the Tramway (track form, material, components, fixing system, damp noise and vibrations, etc…);
- Fit with a variety of surfacing material (filling material, joint, nature of surfacing, etc…);
- Ensure proper drainage.

It should be noted that since the Tramway technology already exists, most of the criteria will be based on existing design practice.

The proposed alignment for the new section between Paberi and Kenuti Stop (by Vanasadam) being fully at-grade, the type of track fixing system shall be chosen between the different type of existing fixing systems, whose choice depends on the required level of vibration attenuation, which itself depends on the distance between the track system and the neighboring buildings:

- Concrete track system (for non-sensitive areas);
- Reducing vibration fixing system (for sensitive urban areas);
- Floating slab (for high level of attenuation when neighboring buildings are within a distance of 7 m);

It is here suggested to retain the following hypothesis in the frame of the cost estimations provided in the present feasibility study: concrete track system for the majority of the axis at the exception of Hobujaama Street for which a proportion of reducing vibration and floating slabs system will be integrated. In this street, the tramway track are very close of the historical building.

3.2.3 Traction Power Supply

Traction power distribution

The traction power rectifier substation (RS) converts the applied three-phase AC electrical power of the public network into the required nominal voltage of the contact line network, and supplies it to the Overhead Contact Line Installation.

The voltage for tramways traction in Tallinn is 600 V. The number and positioning of substations, shall be precisely determined at a later stage following a complete electrical simulation (preliminary design). Substations will be supplied in energy derived from the Medium voltage (MV) or high voltage electrical network. Substations will also produce and supply Low Voltage power for the equipments of the stations and the substations itself.

Feeder cable

If the voltage drop is excessive, a feeder wire may be installed to "boost" the power supply between substations. Depending on the aesthetic constraints, the feeder wire can be in ground cable trays, or installed directly on masts.

Overhead contact line

Overhead contact line system: such a system connects the contact wire(s) between supports and/or building fixings. Using only contact wire(s), this system has a low visual impact and is therefore generally preferred over a catenary system for use in urban areas where aesthetic values are relevant.

The overhead power supply lines need to be suspended above the line track. As such, support masts, building fixings, and transversal wires are needed along the entire route to hold the contact wire(s).

Note: alternatives to the overhead wire exist. These new systems allow smoother integration of the tramway line into its urban and architectural setting, and eliminates the technical drawbacks of overhead lines in constrained urban spaces.

There are three types of off-wire technologies: continuous power system (APS, an Alstom proprietary system or Tramwave, an Ansaldo proprietary system), onboard energy storage with a fast charging system and onboard energy storage with slow charging system.

However these new systems requires a replacement of all the rolling stock. It is therefore not advice to select this technologies

The traction voltage considered here will be 600 V.

At this stage of the study we can say that the traction substations could be approximately 85 m² building. They have to be constructed along the line, either in existing buildings or as separate constructions (either underground or above ground).

At this stage, we evaluate the number of substations for the 2 km of new infrastructure between 1 and 2 substations (depending of the residual supply on the existing network). The number and positioning of substations, shall be precisely determined at a later stage (preliminary design).

3.2.4 Central control / command system

The line will be controlled from the existing Operating Control Centre (OCC).

Fare collection system

A Fare Collection System (FCS) is already in place for the tram network.

No investment cost are considered for the cost estimate of the first line.

Passenger information system

The passenger (and staff) information system available in the OCC central server automatically displays, for both passengers and staff, the data received from the Traffic Management Function. The information is displayed:

- on the Passengers Information Displays (PID) installed in stations (1 PID per platform); the data between the OCC and the PIDs is transmitted via the wire transmission network, and it includes date and current time, waiting time for the two next trains but also specific information in case of perturbation or special event;

Figure 25 : existing passengers Information Displays in Lennujaam tram stop

- On the on-board displays installed inside each tram; the data between the OCC and the displays are transmitted via the radio transmission network and the on-board computer, and it includes the terminus of the train, the next station, etc…

Passenger information will be implemented at each new station and on-board new tram.

Public address

The Public Address (PA) is available:

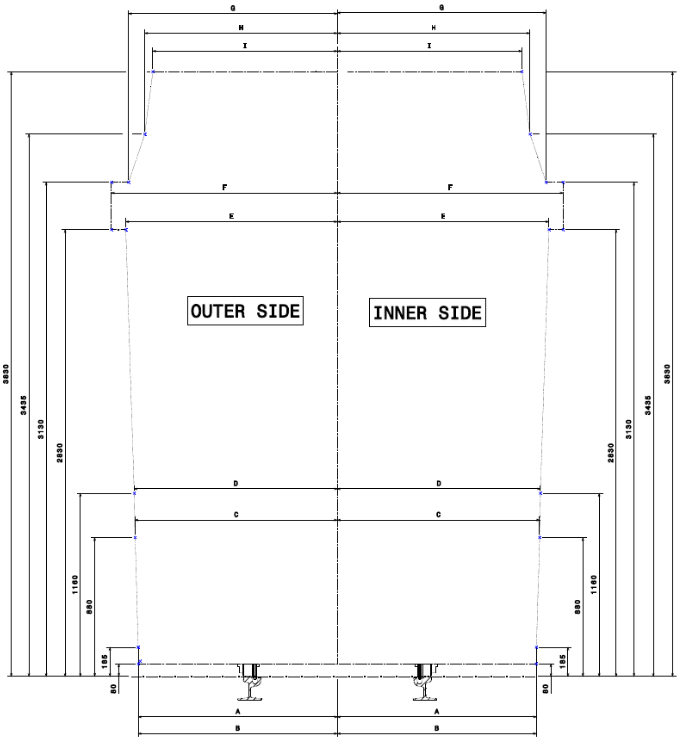
- in stations (loudspeakers installed at each platform): the OCC operators can give vocal information (pre-recorded or not) on service status: trains delayed, service disruption, etc…; the sound between the OCC and the loudspeakers is transmitted via the wire transmission network;
- On-board (loudspeakers installed in each train): the OCC operators can give vocal information (pre-recorded or not) on service status; the sound between the OCC and the loudspeakers is transmitted via the radio transmission network. The driver can also talk to his passengers, and has the highest priority (in case an OCC operator talks simultaneously).

Public address will be implemented at each station and on-board trains.

3.2.5 Design criteria

- Rolling stock

The conception is based on the last rolling stock bought for the Tallinn network the Urbos AXL model of CAF. This model is unidirectional, designed to run on a 1067 mm track gauge. This vehicle features railway wheelsets on its bogies to facilitate curve negotiation and increase the maximum service speed.



LATERAL CLEARANCE TO BE KEPT																		
OUTER SIDE																		
Radius (m)	19	20	25	30	40	50	60	80	100	150	200	300	500	600	800	1000	2000	STRAIGHT
A	1780	1755	1658	1593	1510	1461	1427	1386	1361	1327	1311	1294	1281	1277	1272	1270	1265	1259
B	1782	1757	1660	1595	1512	1463	1429	1388	1363	1329	1313	1296	1283	1279	1274	1272	1267	1260
C	1820	1795	1698	1632	1550	1500	1467	1425	1400	1367	1350	1334	1320	1317	1312	1309	1304	1280
D	1828	1803	1706	1640	1558	1508	1475	1434	1409	1375	1358	1342	1328	1325	1320	1317	1312	1285
E	1924	1899	1802	1737	1654	1604	1571	1530	1505	1471	1455	1438	1424	1421	1416	1413	1408	1339
F	2022	1997	1900	1834	1752	1702	1669	1627	1602	1569	1552	1536	1522	1519	1514	1511	1506	1429
G	1914	1889	1792	1726	1644	1594	1561	1519	1494	1461	1444	1428	1414	1411	1406	1403	1398	1321
H	1820	1795	1698	1632	1550	1500	1467	1425	1400	1367	1350	1334	1320	1317	1312	1309	1304	1219
I	1778	1753	1656	1591	1508	1458	1425	1384	1359	1325	1309	1292	1278	1275	1270	1267	1262	1168
MAX	2022	1997	1900	1834	1752	1702	1669	1627	1602	1569	1552	1536	1522	1519	1514	1511	1506	1429
INNER SIDE																		
Radius (m)	19	20	25	30	40	50	60	80	100	150	200	300	500	600	800	1000	2000	STRAIGHT
A	1581	1562	1489	1442	1382	1346	1323	1293	1275	1259	1259	1259	1259	1259	1259	1259	1259	1259
B	1612	1593	1521	1473	1413	1378	1354	1324	1307	1283	1271	1260	1260	1260	1260	1260	1260	1260
C	1638	1619	1547	1499	1439	1404	1380	1350	1333	1309	1297	1285	1280	1280	1280	1280	1280	1280
D	1645	1625	1553	1505	1446	1410	1386	1357	1339	1315	1304	1292	1285	1285	1285	1285	1285	1285
E	1720	1701	1629	1581	1521	1486	1462	1433	1415	1391	1379	1368	1358	1356	1352	1350	1346	1339
F	1706	1687	1615	1567	1507	1472	1448	1429	1429	1429	1429	1429	1429	1429	1429	1429	1429	1429
G	1706	1687	1615	1567	1507	1472	1448	1418	1401	1377	1365	1353	1344	1341	1338	1336	1332	1321
H	1608	1589	1517	1469	1409	1374	1350	1320	1303	1279	1267	1255	1246	1244	1240	1238	1234	1219
I	1561	1542	1470	1422	1363	1327	1303	1274	1256	1232	1220	1209	1199	1197	1193	1191	1187	1168
MAX	1720	1701	1629	1581	1521	1486	1462	1433	1415	1391	1379	1368	1358	1356	1352	1350	1346	1429
TRACK DISTANCE																		
Radius (m)	19	20	25	30	40	50	60	80	100	150	200	300	500	600	800	1000	2000	STRAIGHT
TD	3665	3621	3451	3338	3196	3111	3054	2983	2940	2883	2854	2826	2803	2797	2788	2784	2775	2672

Figure 26 : vehicle dynamic gauge for tramway in Tallinn

Here below the technical characteristics of the Urbos AXL model (CAF)

	3-carriages
Number of seats	219 (6p/m²)
Length	30,9 m
Width	2,39 m
Maximum speed	70 km/h

- Alignment

Minimum radius curve: 30m in a feasibility study. A radius of 25m could be taken as an outstanding value.

Distance between tracks in straight alignment: 5,1m

Unidirectional tramway, the turn back is realized with a loop.

- Ramp

A maximal ramp of 6% has been taken when necessary.

- Station

Platform length: 31m

Lateral Platform / minimum width: 3,5m

Central platform / minimum width: 5m recommended

Maximal ramp of 4% for disabled persons.

Distance between 2 opposite platforms (2 tracks): around 5,7m.

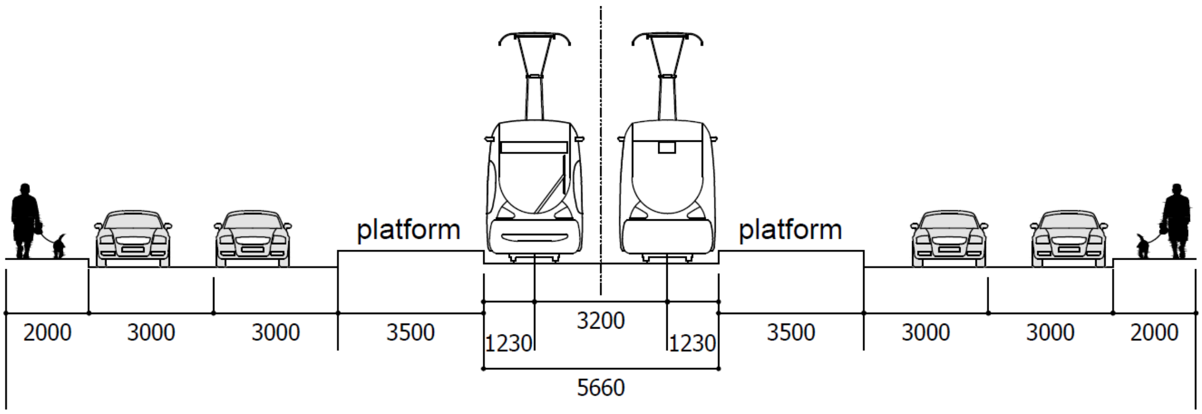


Figure 27 : typical section on a station - Egis

3.3. Tramway system integration principles

Firstly, it is important to remember that the urban integration of the tramway is a crucial factor for the efficiency of the tramway operation and the acceptability of the tram line in urban area to local people, as well as allowing for urban regeneration along the line.

3.3.1 Position of tramway path

Three different positions of the tramway path are possible: axial, lateral (on one side of the road), or bilateral (on both sides). Each position has positive and negative aspects. The choice depends on the characteristic of the existing street and of the project:

- Existing constraints: road width, existing structure, gradient, landscape, etc…
- Functioning of the existing street: private car accesses, one or two directions of car traffic, main generators, etc…
- Proposed functions of the new street after the insertion of the tramway
- Track alignment: curves, turns in the alignment, etc…

Axial position

This solution consists in locating the tramway path in the centre of the road. This system will work with one or two traffic lanes on each side of the tramway path. Each traffic lane is running in the same direction as the tramway.

The axial (central running) integration of the track form is the preferred tram lane insertion for wider highways.

For wider streets it is better to add reservations on each side of the tramway path. They will have several functions:

- Provide platforms for the tramway stops;
- Landscape design to improve the aesthetic of the tramway;
- Traffic islands to allow good pedestrian crossings;
- Integration of technical elements of the tramway system (signals, electrical cabinets, etc.);
- Provide an additional traffic lane to facilitate a right turn for cars at specific crossroads.

Positive aspects of this solution:

- A good commercial speed for the tramway, as it runs separately from the spaces dedicated to pedestrians;
- An easy organization of the access to the neighboring properties and buildings along the street;
- An easy circulation for the different users of the public realm.

Negative aspects of this solution:

- No car parking can be provided when the width of the street is less than 20m ;
- The pavements are directly positioned alongside the traffic circulation
- It may be difficult to insert stops with a street width of less than 22m

The minimum width of the street that allows axial tram lane integration is 17m and 23m at station locations.

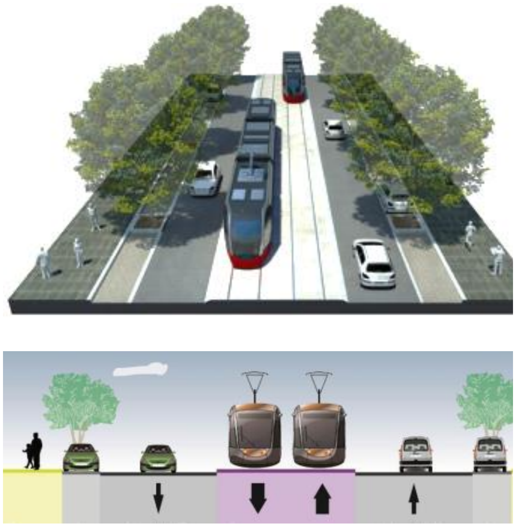


Figure 3.28: example of axial track position

> This arrangement is recommended as a principle for the tramway insertion where the street is wide enough and where two traffic lanes are required.

Lateral position

This solution consists in locating the tramway path on one side of the road. Two cases have to be considered according to the direction of traffic:

1. With two directions of traffic. In this case, there is one side of the platform where the tram and the cars are running on opposite directions. On that side of the platform, it is important to mark a good distance between the tramway and the cars to avoid collisions. A kerb of minimum 1.0 meter wide is necessary.
2. With one direction of traffic. In this case, the position of the tramway path has to be chosen so as to have the traffic flow in the same direction as the adjacent tramway.

Positive aspects of this solution:

- The tramway protects the pedestrians from the car flows, the sidewalk is safe on one side of the road;
- The tramway path can act as an extension of the pedestrian pavement;

- It might be possible to keep existing parking, trees and cycle lanes;
- The width of the station platform on one side might be quite narrow as it is integrated to the sidewalk.

Negative aspects of this solution:

- The car access to the buildings adjacent to the tramway path is complicated;
- The commercial speed is less competitive.

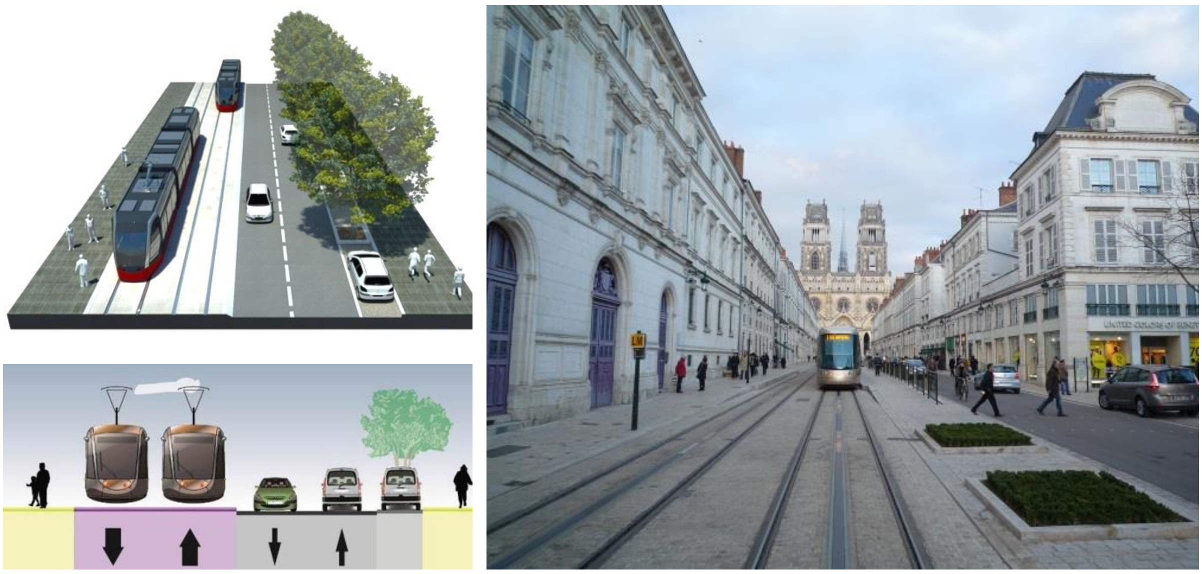


Figure 3.29: example of lateral track position

> This solution might be implemented when there is only one way of car traffic and not too many private accesses on the tram line side of the road.

Bilateral position

This solution consists in positioning one tramway path on each side of the street.

The main interest of this option is the flexibility to integrate the tram stop in the street. The platform can be completely integrated within the pavement for each tram lane direction.

This solution also allows enlarging the pedestrian space by integrating the tramway path within the pavement beside and between the tram lanes. Due to the tracks protection, the feeling of security for the pedestrians is better with a tramway edge than a road.

Nevertheless, this solution generates several disadvantages:

- The car access to the buildings on both sides is very limited;
- It requires the removal of on street parking along the footpath to avoid collision with the tramway;
- It can lead to poor visibility of the tramway path;
- There is an additional investment cost due to the doubling of construction areas and support masts for the overhead contact lines;
- It is impossible to position crossovers and therefore to move tramways from one track line to the other;
- Station platforms are usually narrow because they are also partly used as pavements.

Figure 3.30: example of bilateral track position

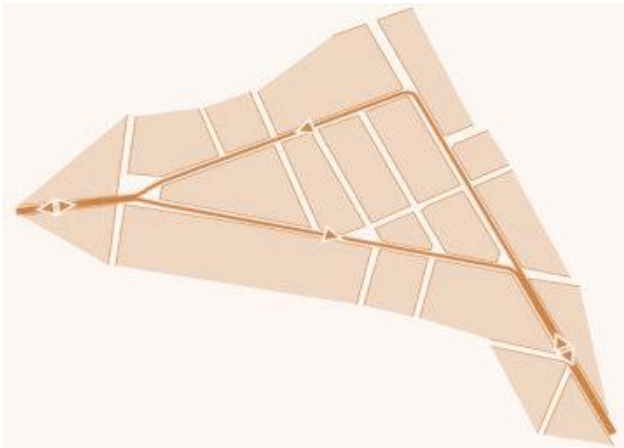
Bilateral tram line insertion is not recommended.

Dissociated tramway paths

It is possible to choose two different streets for each direction of the tramway with one direction in a street and the other in a second street.

This solution is interesting if the two tramway paths are integrated in two parallel roads quite close to each other. The positive aspect consists in conserving certain urban functions (carriageway, footpath, etc.) of narrow streets while implementing a tramway.

Figure 3.31: example of dissociated tramway path



Nevertheless, this solution generates several disadvantages:

- Poor understanding of the network by the users that could create misunderstandings of the perception of the line;
- There is an additional investment cost due to the doubling of construction areas and support masts for the overhead contact lines;
- It is impossible to position crossovers and therefore to move tramways from one track line to the other;
- The two stations platforms in this part of the line are physically and visually disconnected creating difficulties for passengers to orientate themselves.

This option needs a minimal width for each street of 13,50m for tram lanes and 14,50m at tram stops.

> As this integration solution creates negative aspects of the perception of the tram line and on the construction costs, it is not recommended.

Integrated on-street tramway, with priority to the tramway

This arrangement consists in implementing the tramway system on a mixed use road. Cars and tramways are riding together on the same space; however the tramway has the priority at crossroads in order to maintain a good commercial speed.

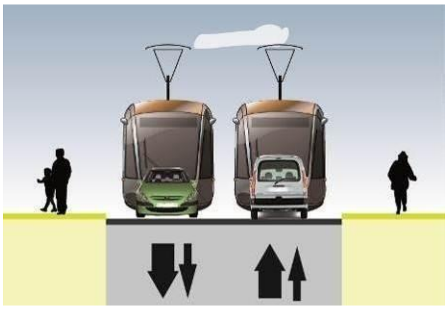
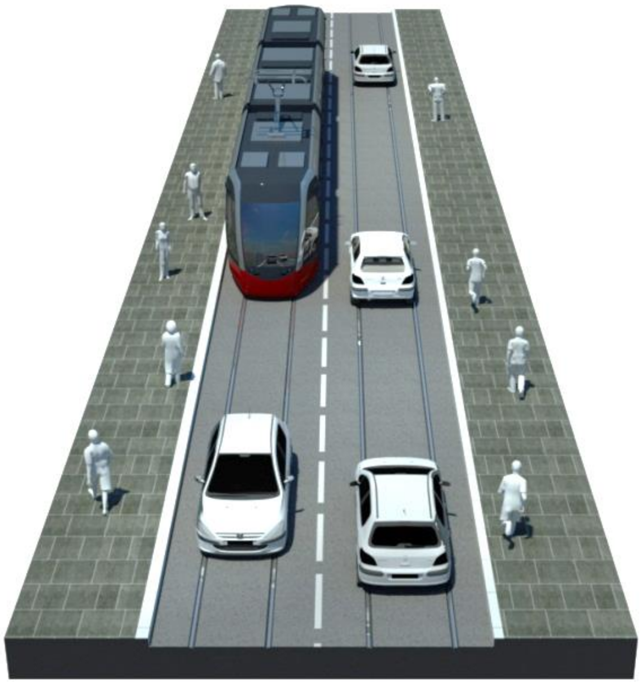


Figure 3.32: Example of tramways integrated on-street



This option can be chosen for narrow streets. A physical separation, for example a kerb, is inserted in the middle of the street to avoid overtaking of cars and potential collision.

Cars have to wait behind the tramway when it stops at stations, but it has to be noticed that cars also take the advantage of the tramway priority. In overall, cars do not lose much time.

Specific arrangements in crossroads have to be planned in order to ensure the first place for the tramway. A passing lane has to be added for cars to temporally separate the two modes.

This solution needs a minimum width of 11m in current sequence**, and 13m with a station.**

> This integration solution of the tram line creates a negative impact on the operation of the tram line in busy areas where traffic congestion is common or where there might be an increase of traffic due to future development. It is not recommended.

Single track system

This solution consists in implementing a narrow tramway path with only one track used for both directions of the tramway. It is a contraflow system. This configuration is mainly used when it is impossible to widen the street, and when a minimum of car traffic is necessary.

The main negative point is the complex operation of the track. This kind of configuration must be limited to short distances.

It also has an important impact on operation, as it limits the minimal headway that can be reached. This solution is impossible to implement when the headway is less than 4 minutes per direction.

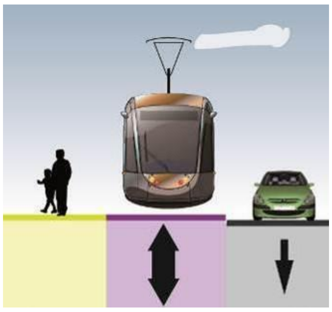


Figure 3.33: Examples of a single track system

This solution needs a minimum width of 15m in tram lane sequence, and 16m with a tram stop.

> This integration solution for the tram line creates important constraints in terms of the operation of the tram line. It is not therefore recommended.

3.4. Identification and analyses of alignment solution

3.4.1 Balti Jaam – variant of the terminus of the line

As explained in the chapter 3.1, the terminus of the line will not be in Balti Jaam, but anyway this configuration has been studied with the scheme below.

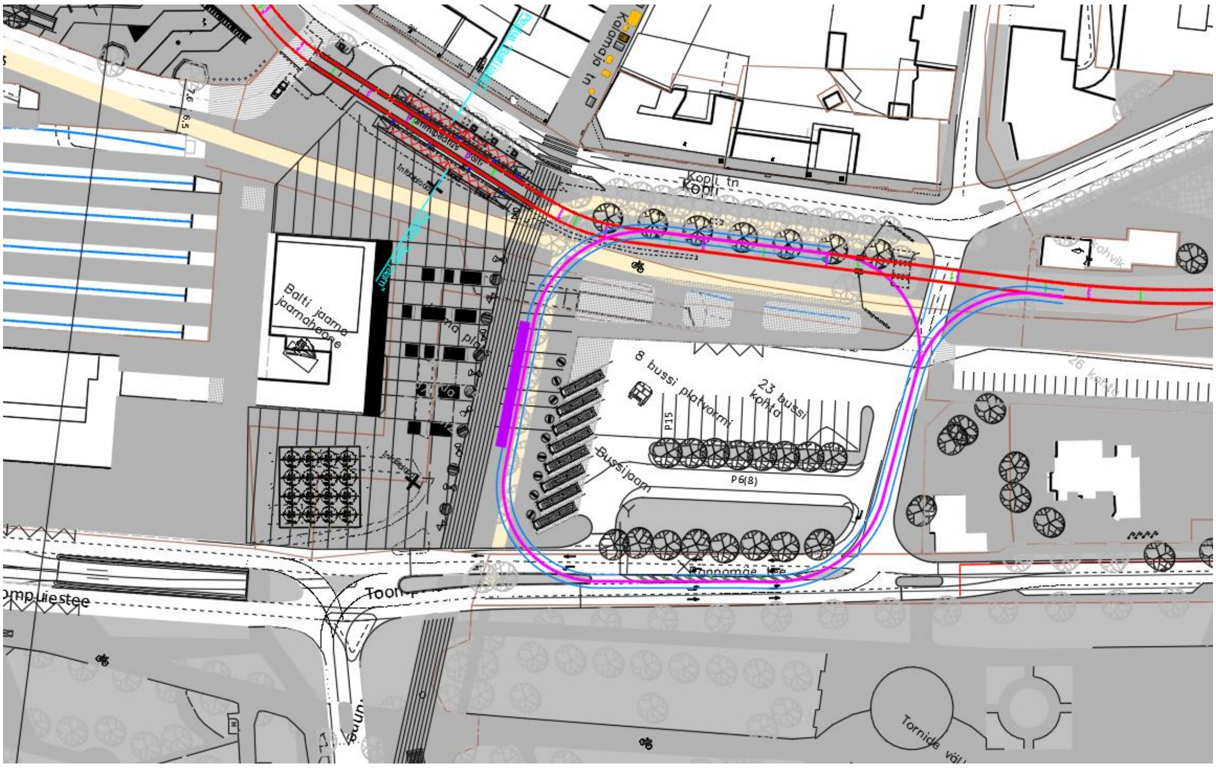


Figure 34 : Tram solution - scheme of a possible terminus loop in Balti Jaam - Egis

The loop could be operate like this. However the alignment presents a small radius curve after the station, with R=25m. If the road cannot be changed in Rannamäe tee and in Kesk-Kalamaja Street due the survey perimeter, a shared space with cars must be proposed. This kind of configuration is not a good solution for operation optimization.

3.4.2 Kanuti station

From Balti Jaam to Kanuti station, the line remains on the existing tramway tracks. The area master plan has been considered in the design of the important intersection Mere Puiestee – Ahtri Street.

Figure 35 : aerial picture of the existing intersection Mere Puiestee – Ahtri Street.

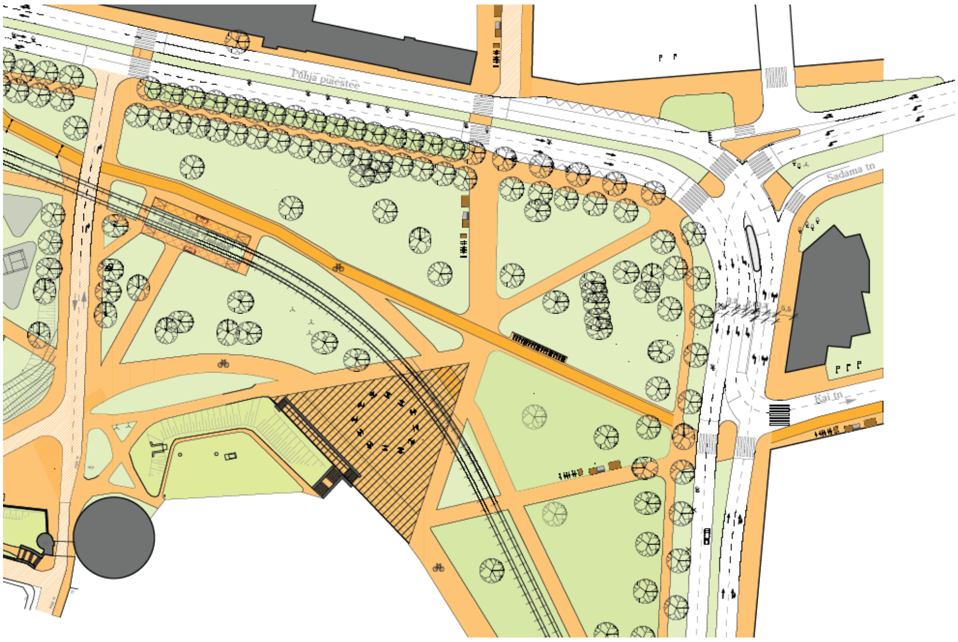


Figure 36 : extract of one of the master plan of the futur of Mere Puiestee area

The master plan indicates a reduction of the number of car lanes. 2X 2 lanes arrive on the crossroad and the removal of Rannamaë Tee. This reduction simplifies the road design of the crossing of the tramway (violet line). It is also less dangerous for the pedestrians.

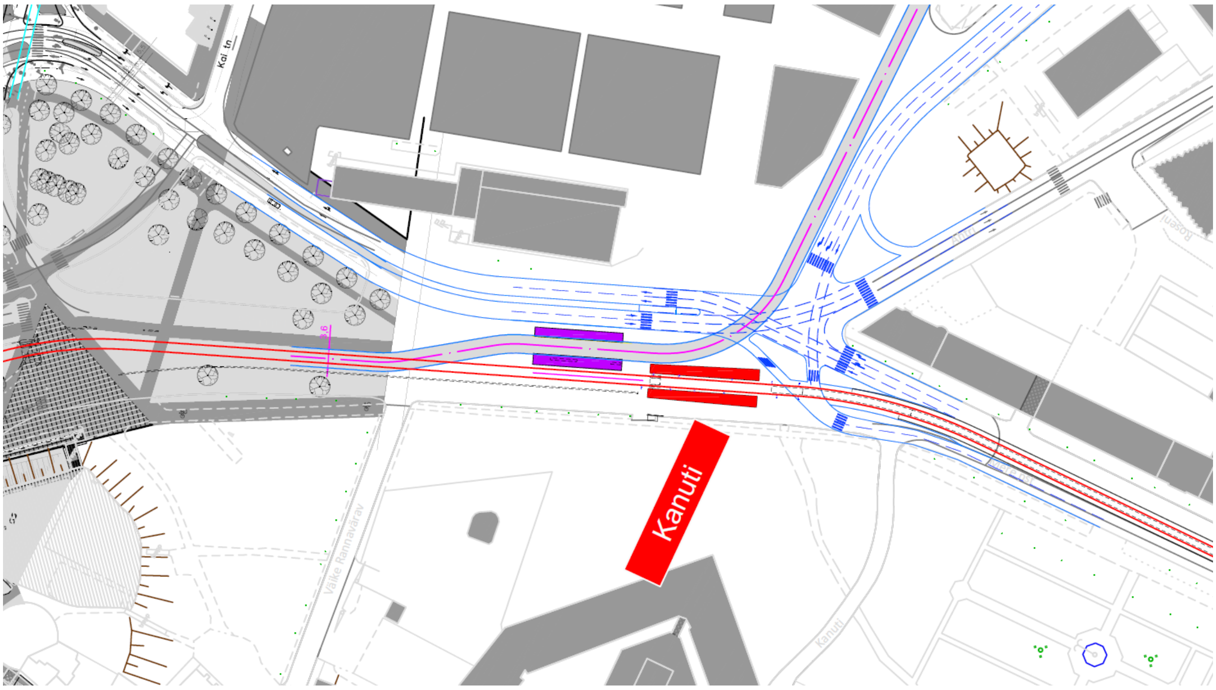


Figure 37 : Tram solution - Kanuti station – 1st solution – Egis

- Configuration of the station

A double station was first proposed to provide more possibilities to operate the connection of the tracks. The existing station would be preserved, and the new station would be parallel but disconnected. The passengers would have to pass from one platform to the other eventually crossing the tracks. Both stations remain close to the pedestrian cross through the huge intersection.

Yet a more compact configuration was imagined as shown below. A dislocation of the existing station further north would save urban space and contribute to the integration of both lines, virtually cancelling the walking distance between stations. This dislocation would also make it possible for a tramway to stop by the platform while another waits without disturbing traffic at the intersection.

A new connection between Väike Rannavärav and Mere Puiestee is proposed on the Northwest side of this station. The platform would be placed at a safe distance from the intersection. This solution requires complex operation procedures during peak hours.

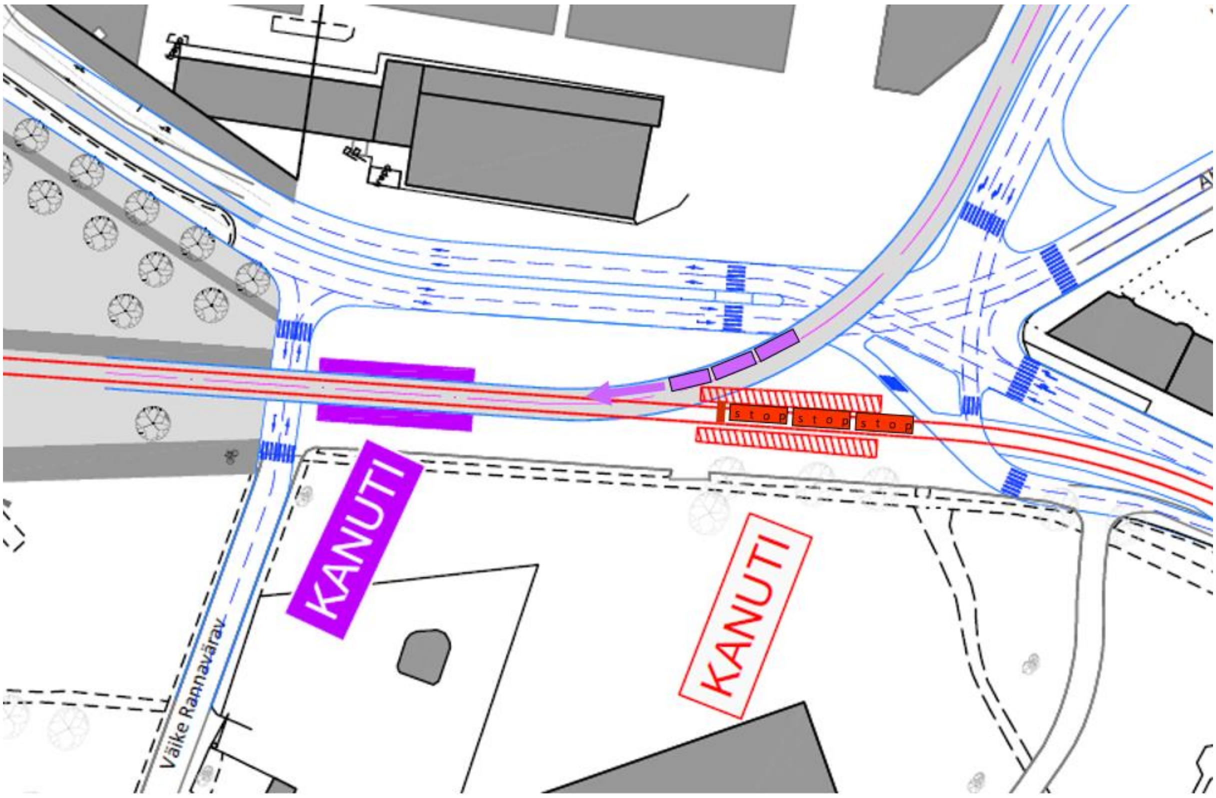


Figure 38 : Tram solution - Kanuti station - 2nd solution - Egis

Since this is a very important intersection to traffic flow a dynamic simulation is required to verify its performance.

Figure 39 : Tram solution - 3D view of Kanuti station - Egis

Finally, the new location of Kanuti station is dedicated to the urban district in front the marina and to the old city. Moreover the Rotermanni district is also in the perimeter of the station, but it also served by 3 other stations: Mere Puistee, Hobujaama and Vanasadam.

The urban network of the future Marina district is creating a connection axis with the old city. The Kanuti station is located right on this new pedestrian axis.

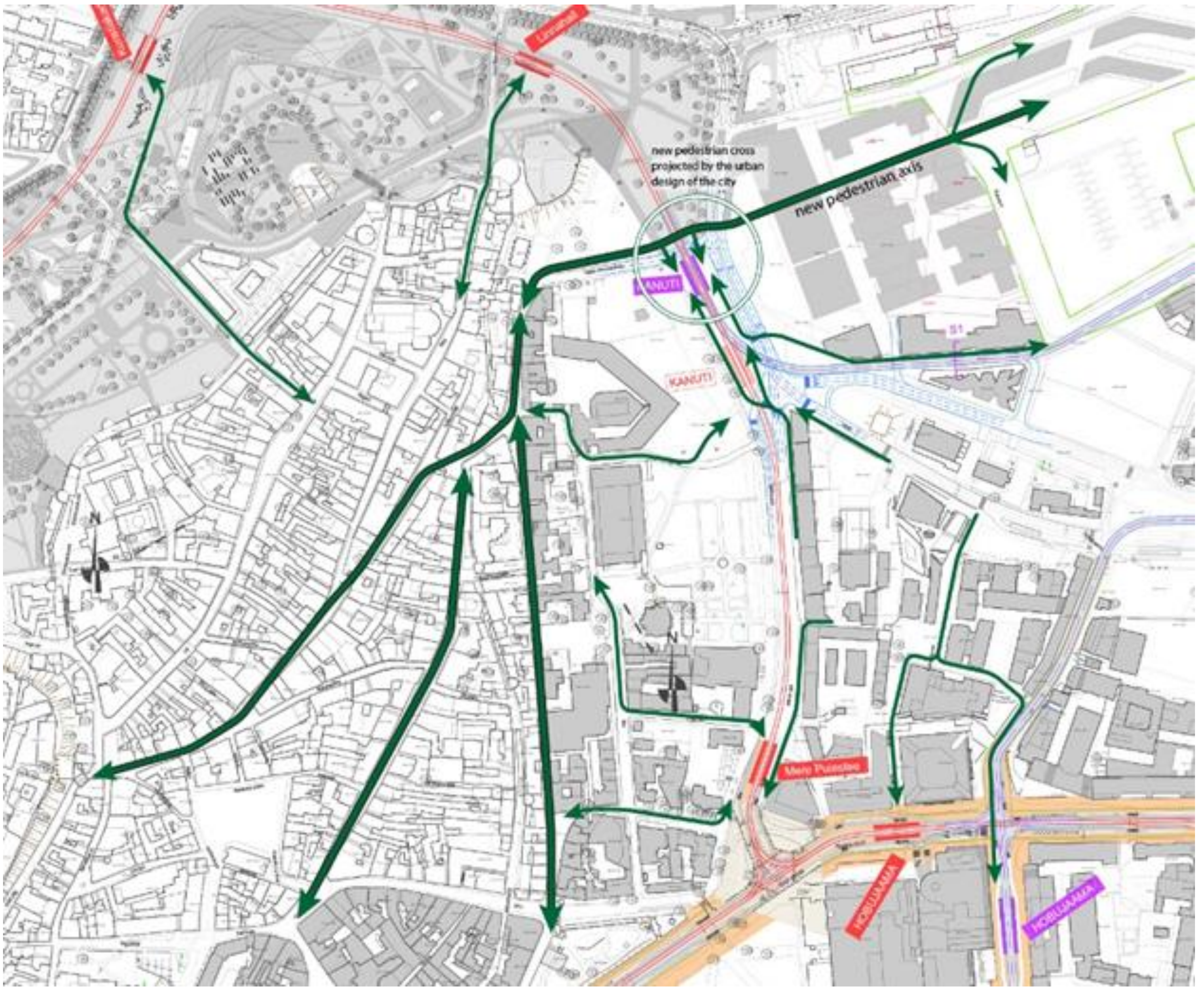


Figure 40 : pedestrian routes around Kanuti station with the new pedestrian axis of Porto Franco - Egis

The conception of the urban integration of the tramway has been done with the future design of Ahtri Street. At the end of the study, the city planning department showed us a new plan of the future design of Ahtri Street. The urban integration of the tramway will be feasible with adaptation of this design in order to integrate bicycle lanes, bus stop, pavements, etc. The configuration of the intersection will also have to be study in traffic flow simulations.

3.4.3 Laeva Street

The tramway integration proposed is axial. It is strongly constraint by private property and the Marina, which make Laeva Street quite narrow. The removal of private car traffic, leaving it to public transportation, namely tramway, will accentuate the pedestrian character of the port area. A width provision will allow emergency, port service and delivery vehicles access.

The accesses to the underground parking are kept and directly linked to Ahtri Street. The cross of the tramway tracks will be regulated with traffic lights for cars, with the priority for tramways.

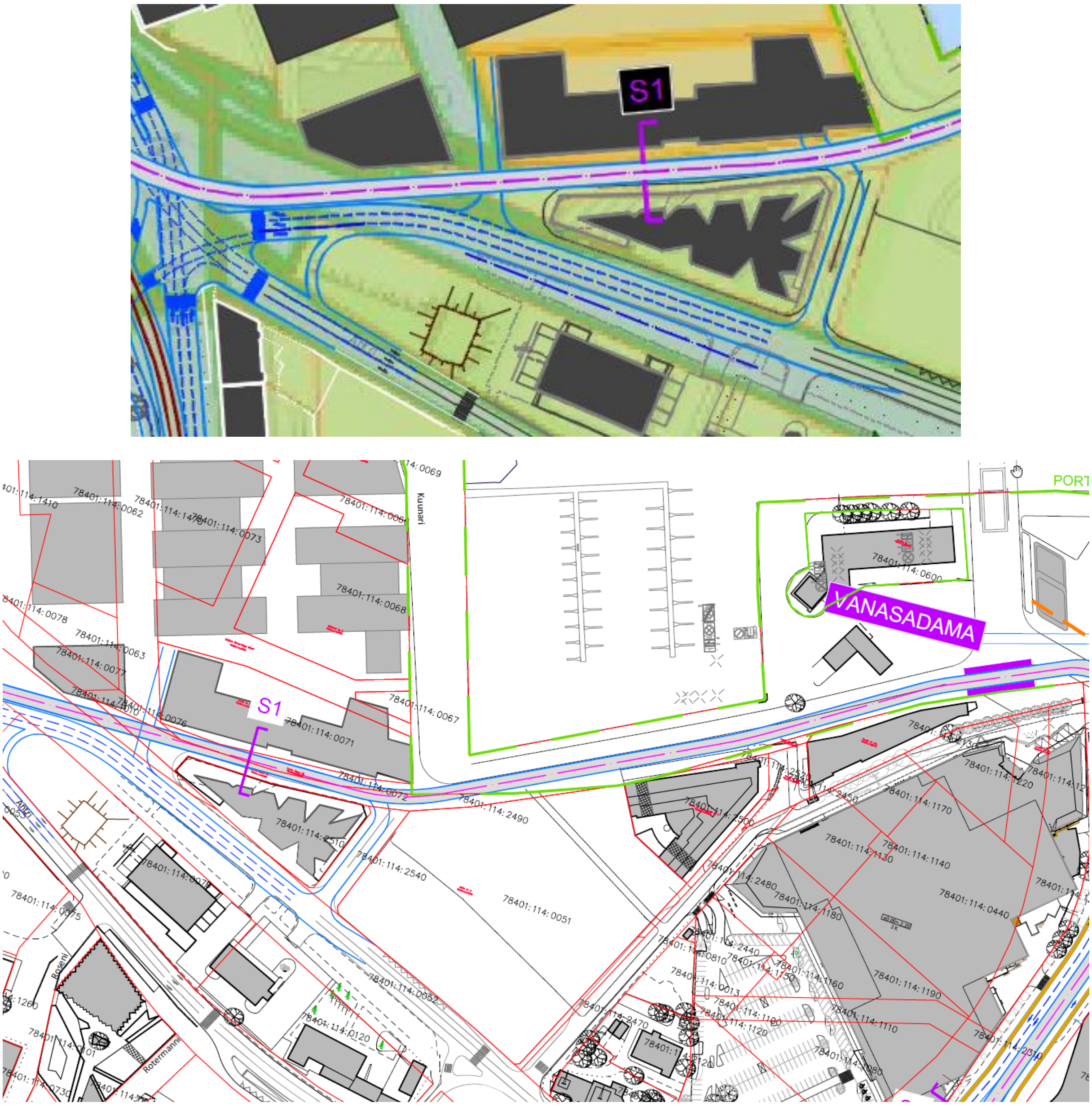


Figure 41 – Track alignment and private property on Laeva Street.

On the East side of Laeva Street the alignment runs along through private property, along the pedestrian pavement, until it reaches lands belonging to the port. The proposed alignment needs to expropriate private lots between two buildings. These lands are free of constructions and identified with the following numbers :

- Laeva tänav T1 78401:114:2490
- Laeva tänav T1 78401:114:0072

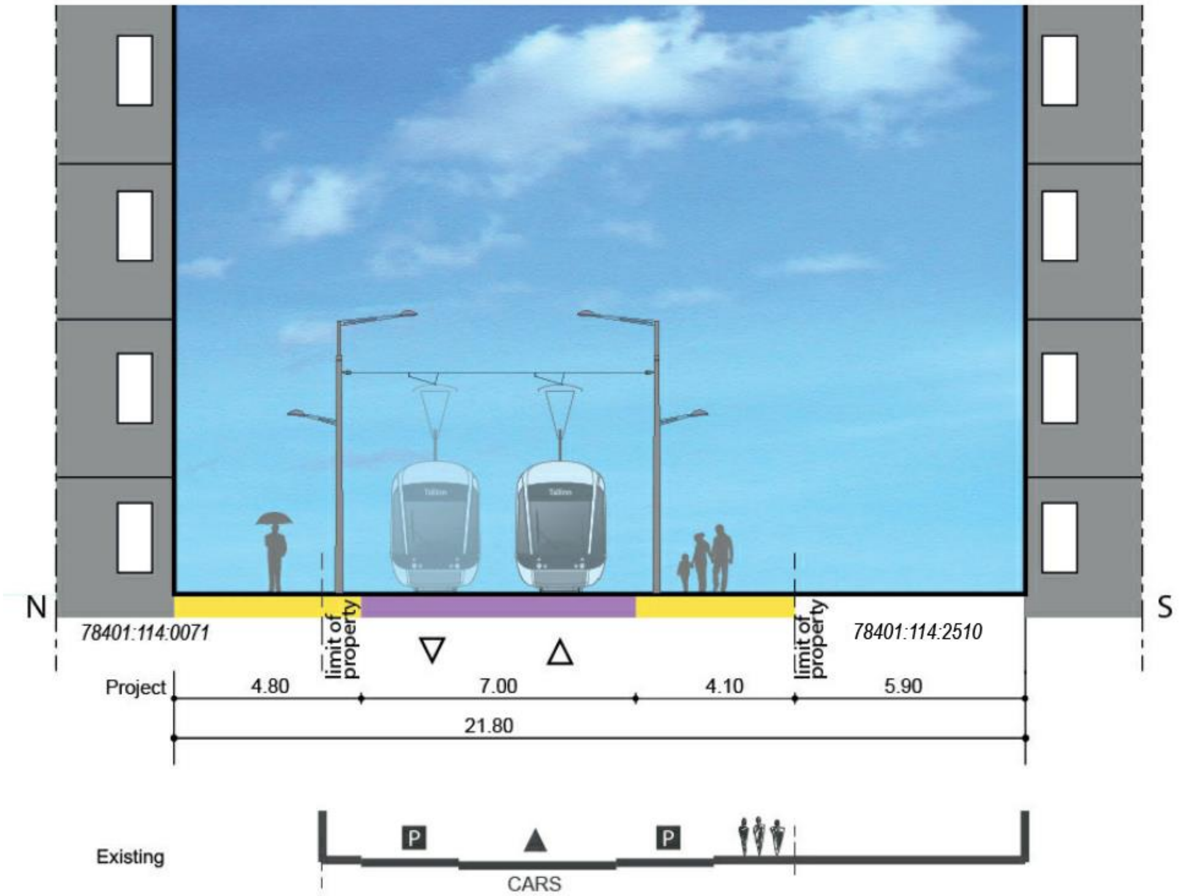


Figure 42 : Tram solution – cross section n°1 on the East side of Laeva Street – Egis

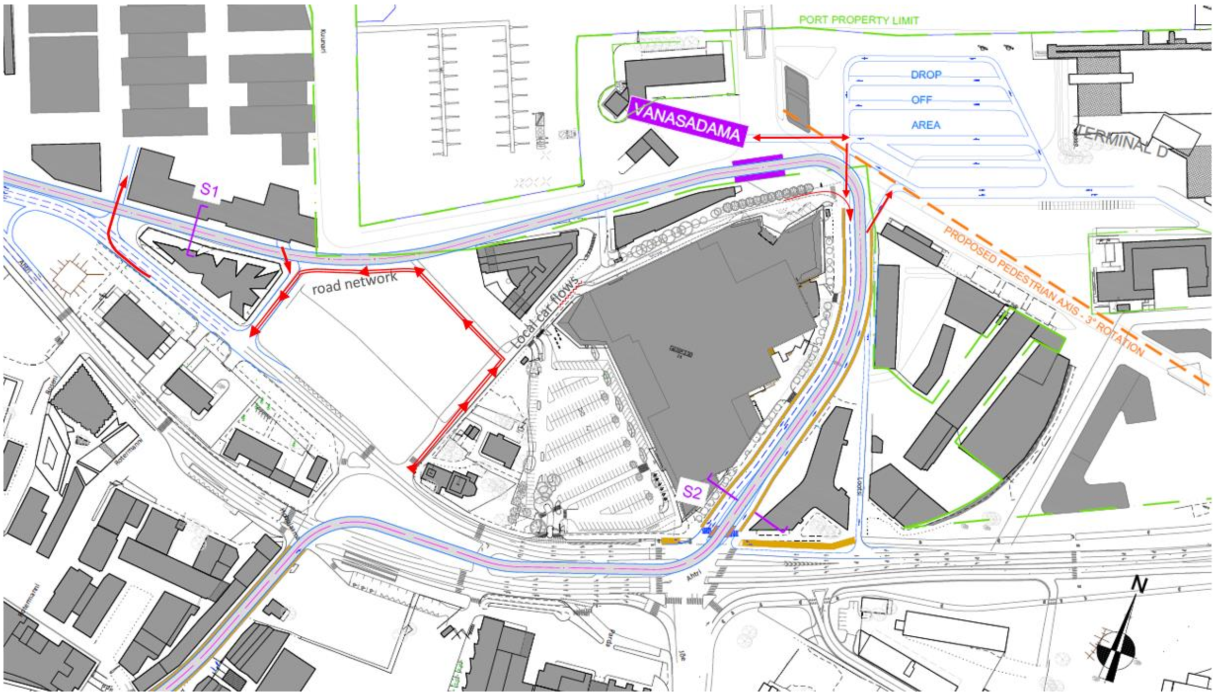


Figure 43 : Tram solution – plan in Laeva Street with proposed road network – Egis

On the East part of Laeva Street, the road network could be organized with a loop passing by Paadi Street. The access to Europa Hotel, the private street of the mall and the residential building must be served by a local network to avoid congested alternative drop off in this area.

Figure 44 : image of Zaha Hadid's project – Laeva street

3.4.4 Kuunari / Kai Street Variant:

A variant passing through Kai and Kuunari Street to reach the Port was studied, yet this option proved unfit for purpose due to the overwhelming presence along two fronts of the marina, the disturbance of the access to the buildings on the west of the alignment and finally the sinuosity of the line would have strong impact on the operation speed and comfort of the passengers. Therefore Kai Street will have high traffic flows

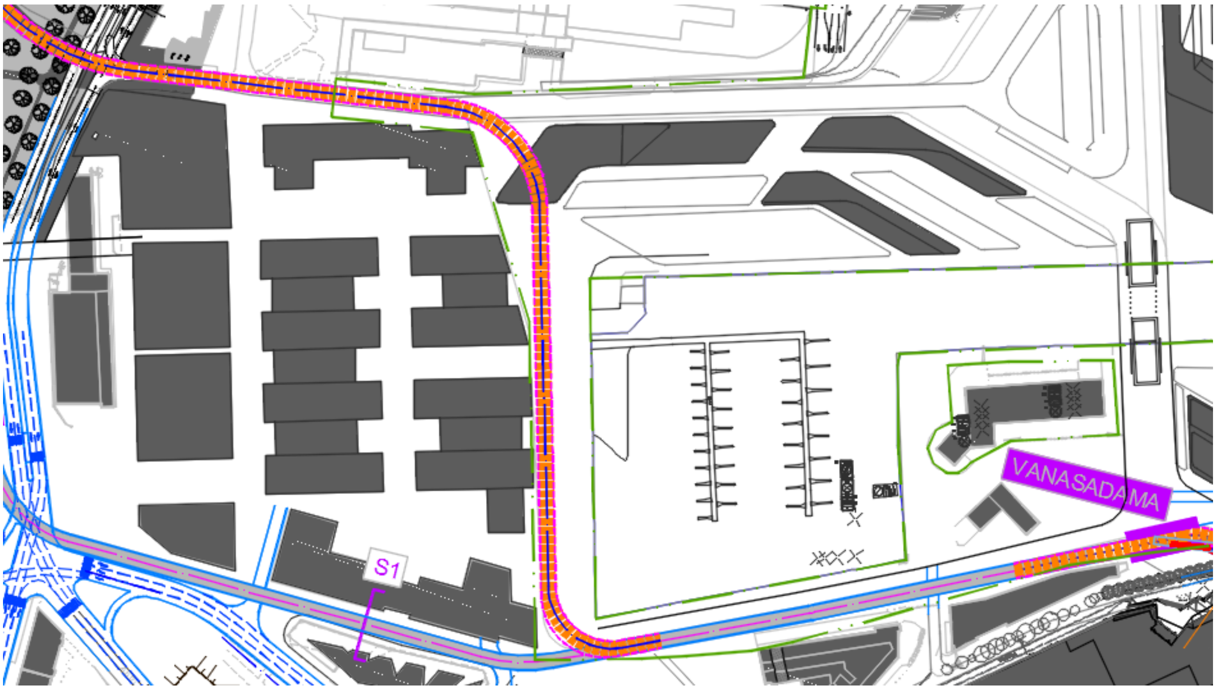


Figure 45 : Kuunari / Kai Street variant that shows the closeness of the tramway to the Porto Franco buildings.

3.4.5 Vanasadam - Terminal D

The plan below proposes a direct route between Joe's Street and Laeva Street. A very small radius (R=30m) is necessary. However the tramway station is located directly after the small curve, in this way the tramway doesn't lose too much time.

The station is also positioned in front of the pedestrian bridge which serves the terminal A and B, and also has a direct visual connection with the Terminal D. The orientation of the passengers is natural and the distances between the station and the terminals are nearly equal: 215m.

The station could be integrated to the urban design of the pedestrian mall. However the curve and the tracks impact the pedestrian mall during a short distance. This could be avoided with a slight modification of the masterplan. Another possibility is to use similar floor material for the tramway and for the pedestrian, but it could be dangerous.

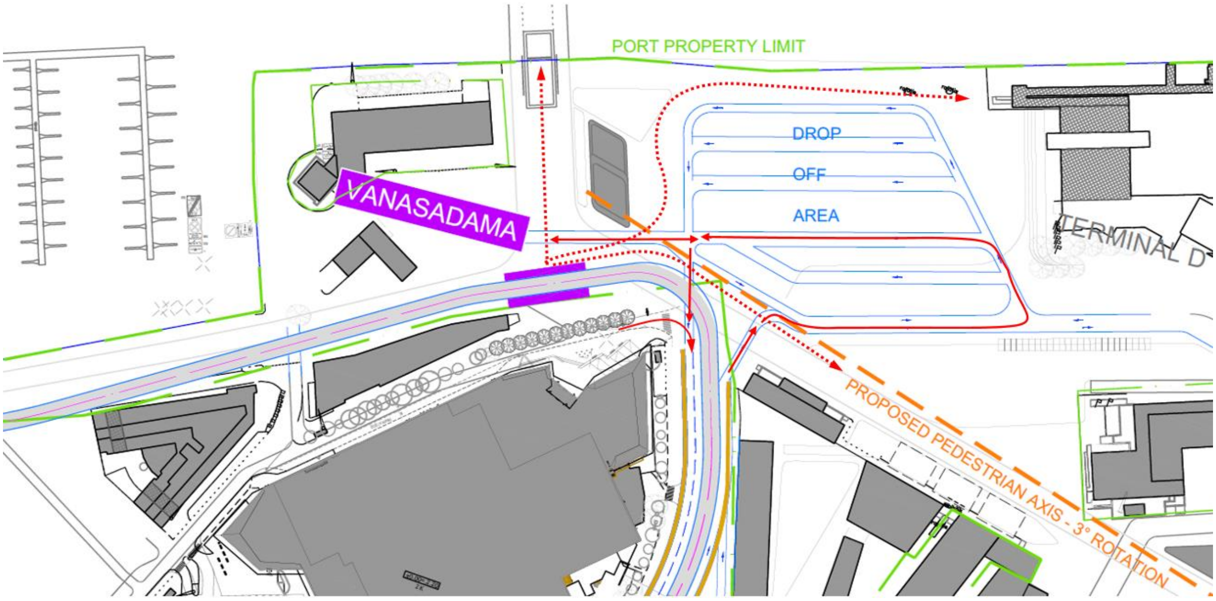


Figure 46 : Tram solution - Vanasadam station and port service traffic scheme- Egis

This location also let free the space for the drop off. The draw of the drop off is only a proposition that must be studied more deeply. The car access to the building located on the left of the pedestrian bridge cross the mall from the drop off network. This cross is located in order to be the shortest.

The short curve of the tramway cross the existing design of the pedestrian mall of the masterplan of the Port. This cross could be avoided by changing the orientation of the pedestrian axis with a 3° rotation. (orange dot line in the drawing below) This change would impact the projected building between the pedestrian bridge and the Terminal D. Those modifications are illustrated on the 3D view here after.

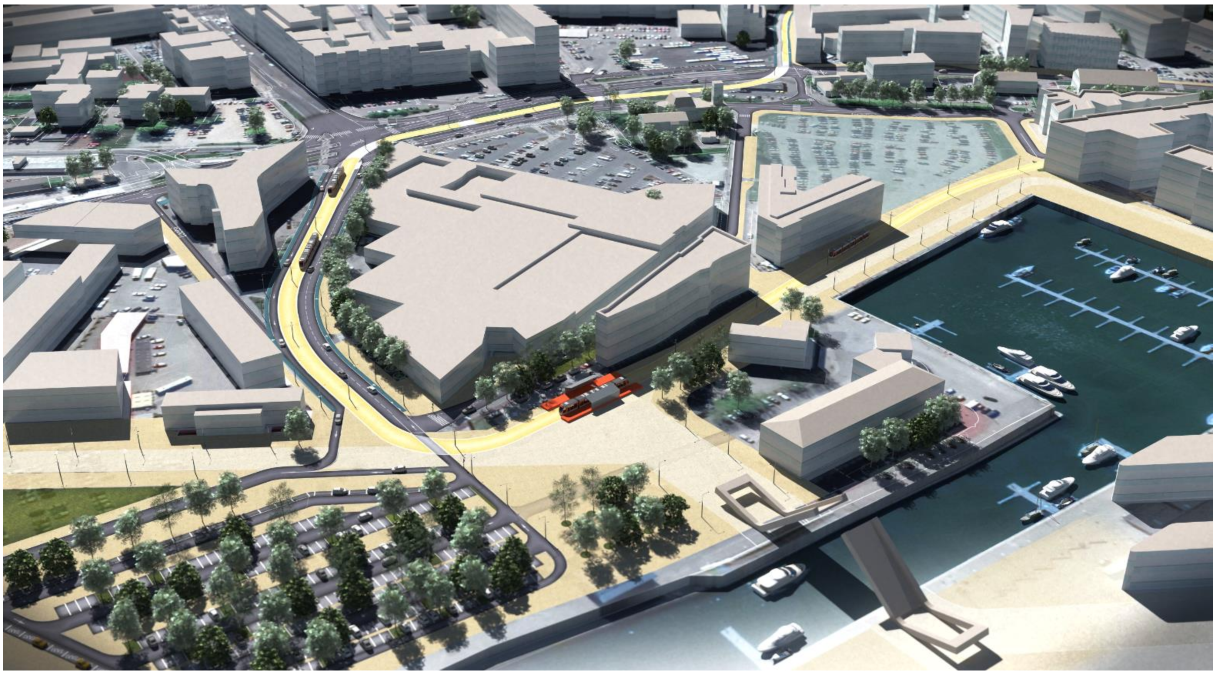


Figure 47 : Tramway solution - 3D view of Vanasadama station

Private car parks at the head of the building are not impacted by the project. The tramway infrastructure is positioned on the port's lands and public lands. . The pedestrian flows of the Norde Centrum mall are not impacted. The car flow which rides along the mall is in a one way direction and exits the private road by going to the south without crossing the tramway.

3.4.6 Joe's street and Ahtri Street

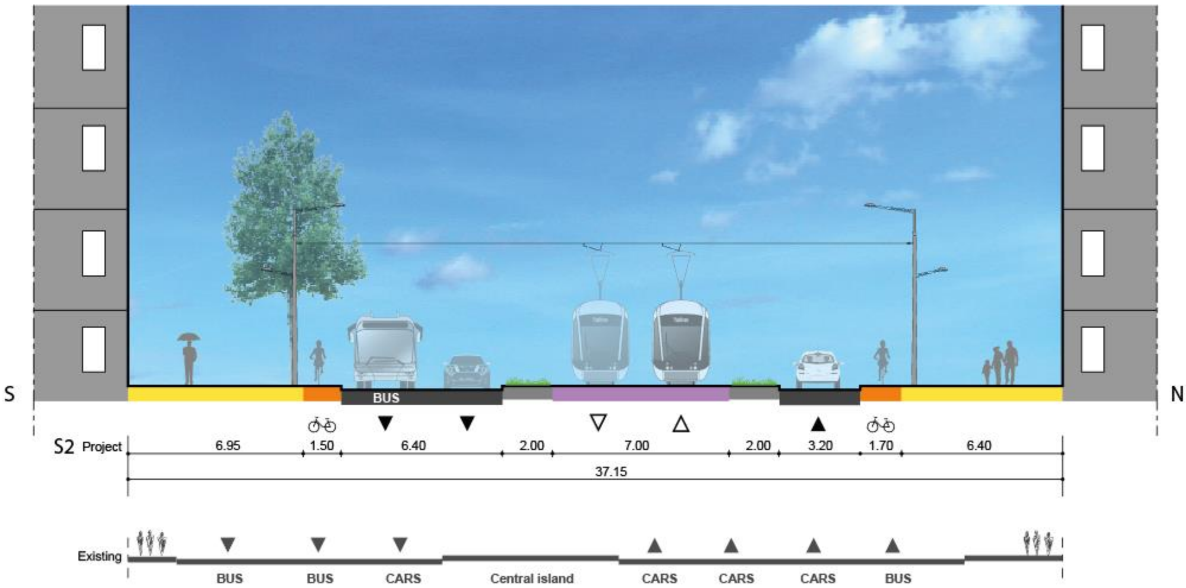


Figure 48 : Tramway solution - section in Joe's Street - Egis

The urban integration of the tramway in Joe's Street is chosen in axial. This position allows less impact on the delivery of the Norde Centrum Mall. The trajectory of the trucks in the curve crosses the two car lanes and avoids the tramway tracks.

This configuration keeps the same number of car lanes as proposed by the project of the new Ahtri Street. Integrating two road lanes on the North South Direction the eastern of the two arrays of trees must be removed, yet, if the traffic department agrees on a single traffic lane in each direction, both tree arrays may be preserved.

Cycle lanes are proposed on each side of the street along the pavement.

The renovation of Ahtri Street keeps the central island which is wide enough to integrate the tramway tracks. This integration works well. However an analysis of the two U-turns must verify the compatibility. Anyway traffic lights must be installed if they are kept in the road design.

3.4.7 Additional stations in Laeva Street and Ahtri Street

The placement of a station was suggested along Ahtri Street and Laeva Street. Given the short distance to the next stations, around, these ones would be redundant and too close to Vanasadam Station and Hobujaama Station. Finally the idea was abandoned.

Laeva station: the interstation with Kanuti station is 250m, and the interstation with Vanasadam station is 360m

Ahtri station: the interstation with Hobujaama station is 450m, and the interstation with Vanasadam station is 370m.

All the interstations are less than 600m, that's why these supplementary stations don't serve more effectively the area. The picture here-after shows with circle of 500m radius the cover of the different stations.

Anyway, the alignment allows the implementation of these stations.

Concerning the plots, Ahtri station is on public perimeter. Laeva station needs to acquire 2 more pieces of plots (78401:114:2510, 78401:114:0071), which includes existing buildings. It could be harder to acquire these areas than the 2 free plots that are needed to build the tramway alignment. **A contact with the owners could confirm the hypothesis on this station.**

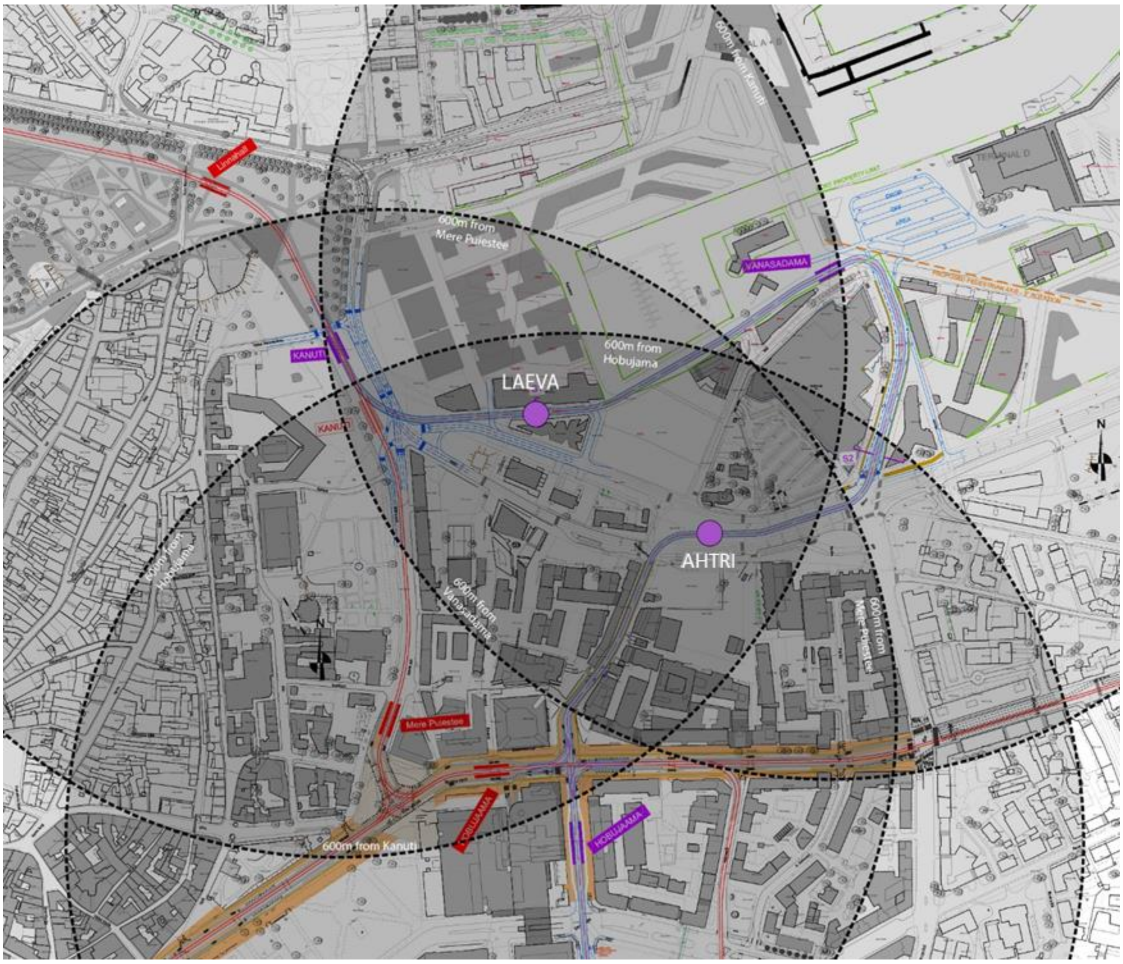


Figure 49 : Short distance to the closest stations makes a station in Ahtri Street and Laeva Street redundant.

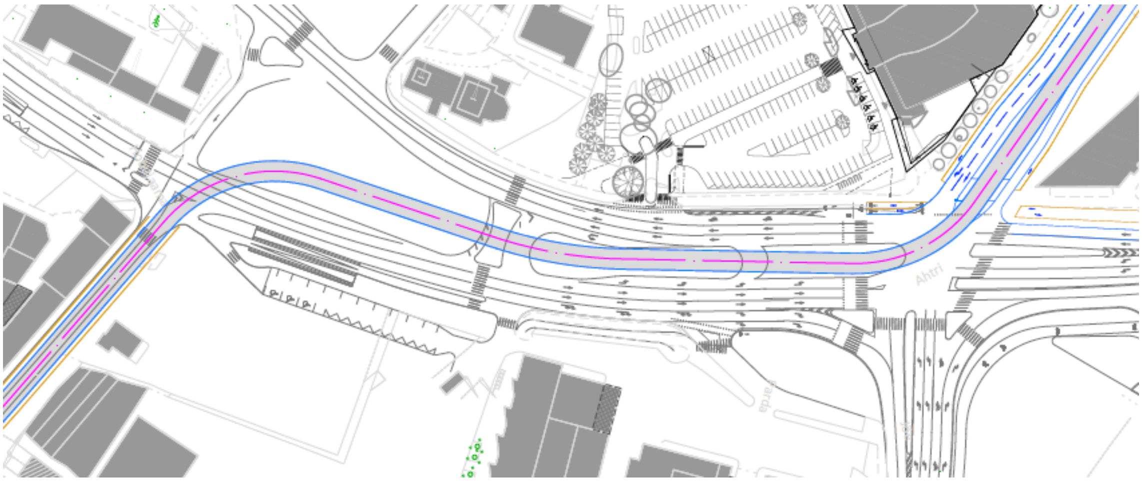


Figure 50 : Ahtri Street - Tramway integration proposed – Egis

3.4.8 Variant Terminal D by Paadi Street

The variant passing by Paadi Street reveals no quality. Several points show that it is not a good solution:

- The curves to pass between the Hotel and the residential building is really not comfortable. The straight alignment between the small radius curves is about 16m long. It is a minimum.
- The two infrastructures are parallel during 110m and remove the pedestrian mall.
- The loop in front of the terminal D gives big constraints to organize the drop off.

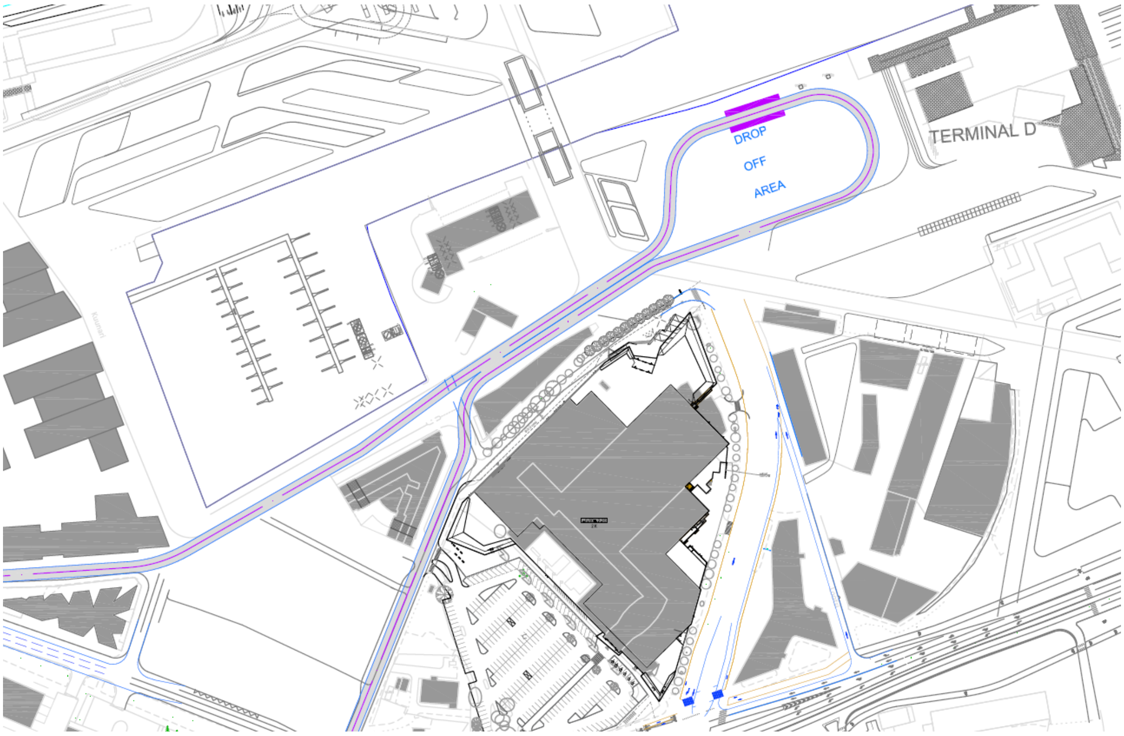


Figure 51 : Tram solution - Vanasadam station – studied alternative 1- Egis

This solution has been abandoned.

Another option (n°1 in the plan below) is to create a common track during 110m, but it creates operation constraints and only solves the problem of the impact on the pedestrian mall.

A second option could be a curve around the hotel to avoid the loop, but it is too short. A radius of 25m impacts the building of the hotel (n°2 in the plan below).

Finally it is possible to turn left before the hotel to avoid all the difficulties, but the station is not visible and too far away from the two terminals. This solution does not answer well to the purpose of the project (n°3 in the plan below).

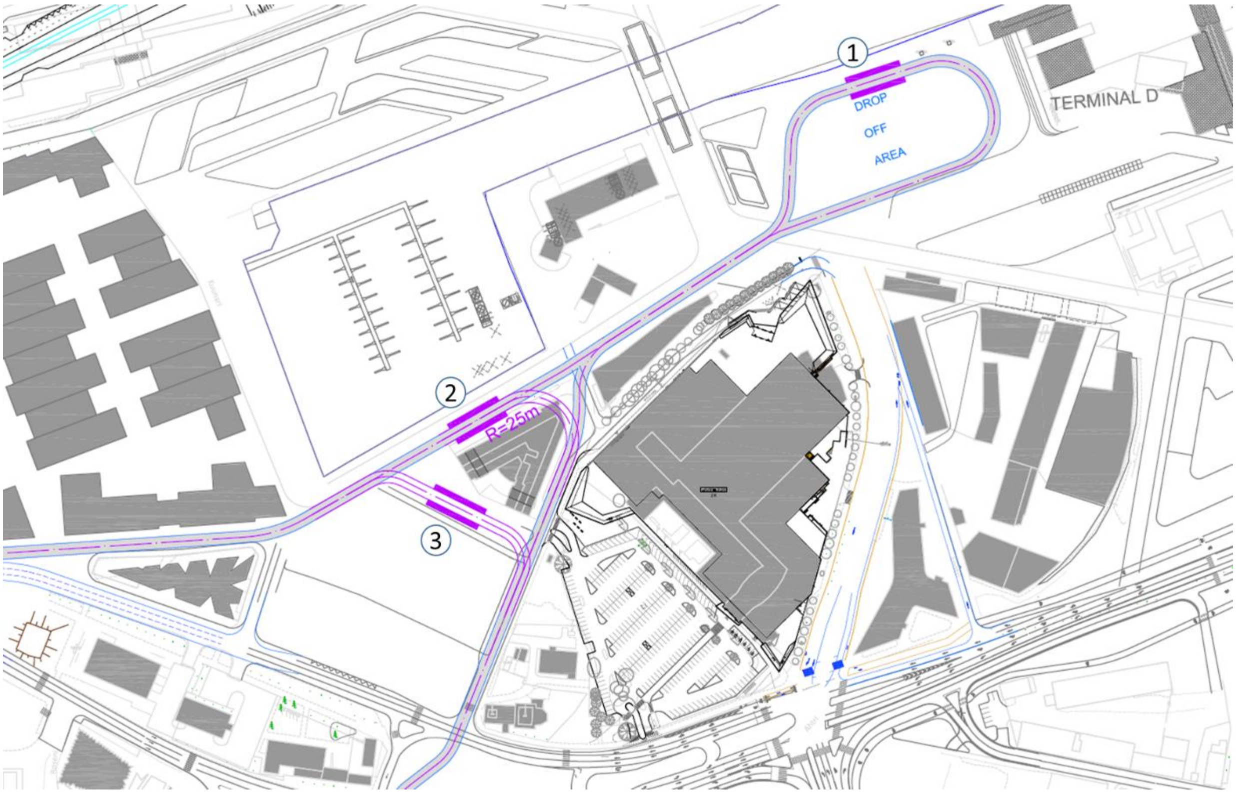


Figure 52: Tram solution - Vanasadam station – abandoned alternatives - Egis

3.4.9 Hobujaama Street

Figure 53 : picture of Hobujaama design - project of the city

As planned by the city, the integration of the tramway in Hobujaama Street proposes a road design with, pedestrian spaces and a mixed cars and tramway carriage way. However the pavement are smaller than in the former design in order to install bicycles lanes. The Hobujaama Street is narrow and has got several car accesses to underground carpark and to Rotermanni Street, that's why cars cannot be removed completely. In order to minimize the impact on operation of the tramway an option could be to limit the cars which ride in this street by organizing a one way road from South to North. Nevertheless a car junction in necessary between Rotermanni and Narva Mnt in the North – South direction. It is shown below on the schema of road network.

The project proposes also that the buses could ride on the tramway tracks.

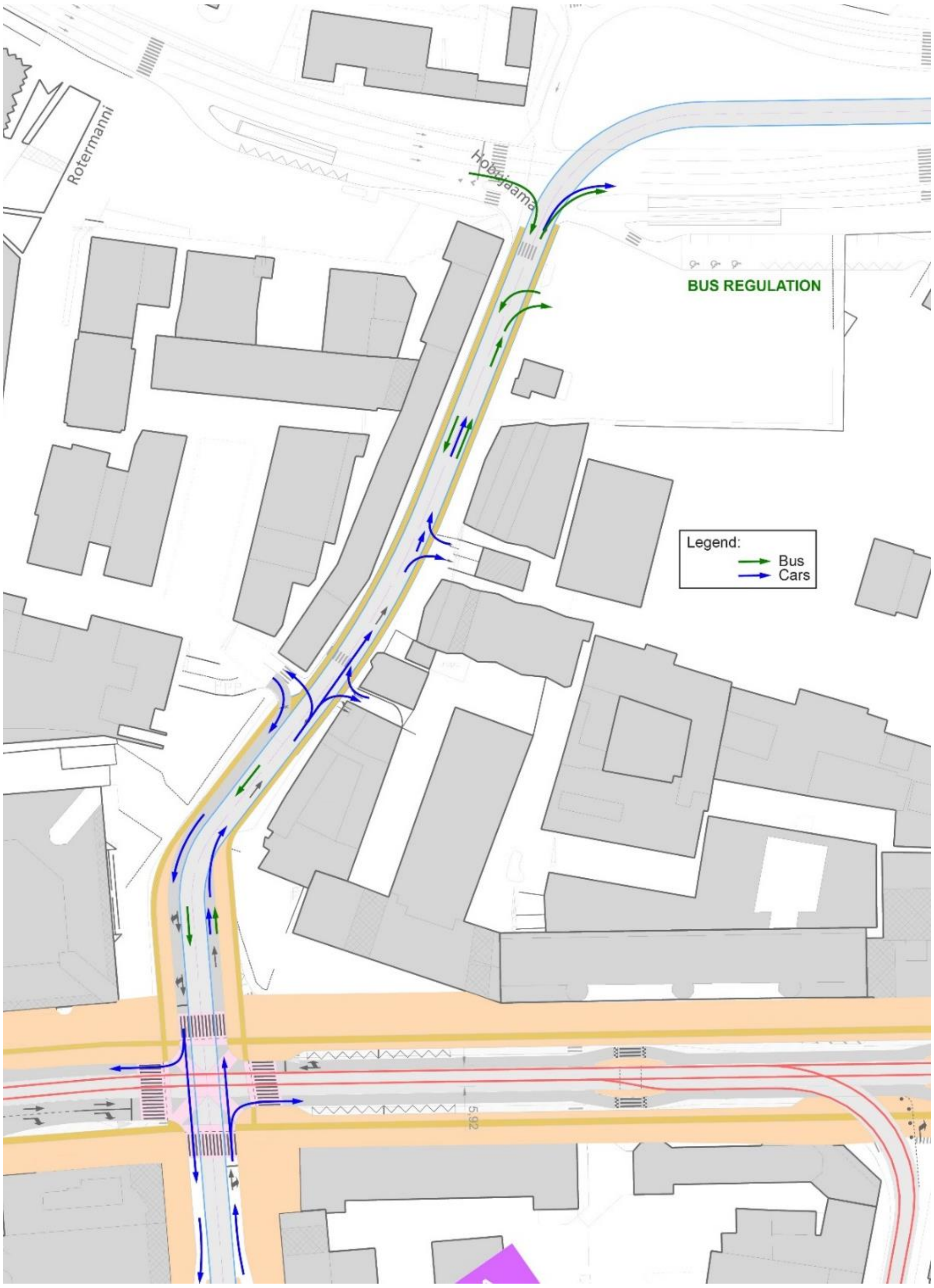


Figure 54 : Tram solution - schema of traffic flows on Hobujaama Street.

3.4.10 Hobujaama station – Laikmaa Street

The project integrates the future amenities of Narva Mnt. They propose a long platform for collective transport as tramway and buses. It occurs a shared use of the tramway alignment with the buses. Two carriage ways are installed to serve the hotel and the mall, for taxis and cars and deliveries.

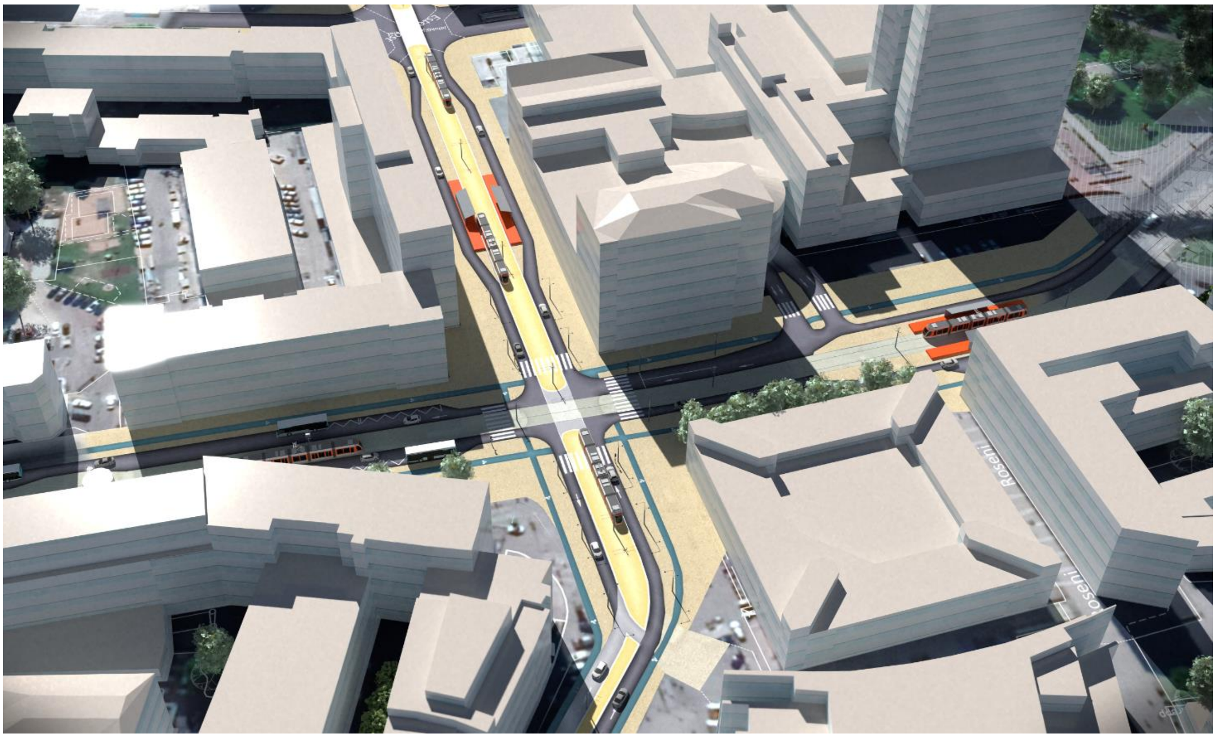


Figure 55 : Tram solution - 3D view of Hobujaama area.

The possibility of detouring to Narva Mantee in case of need may be considered with a slight adjustment of the urban plan to accommodate the curve in the intersection by Hobujaama. This solution will prevent interruption of service shall a blocking of the way to the port occur.

This projected crossing and connection requires a specific railway design analysis to check the following points:

- The **vertical alignment** of existing line railtrack should be lightly reshaped to permit new line to be designed properly, without cant in straight alignment.
- As connection turnouts are very close to this crossing, all these railway equipment should be implemented in a **flat and horizontal area**. Despite this constraint, coating efficient drainage should be proposed, for example with grate-covered gutters.
- The **turnout** study must define detailed geometry for each track, because this has operation and maintenance consequences.
- About operation, **tram speed** may be reduced for turnout movements and even straight movement at rail crossing. The transition curve may be implemented, even for train movements without passengers.

- **Arrangements** must be adapted to turnout studies, because for safety and maintenance reasons, pedestrian and road crossings should not be implemented at moving pieces of turnouts. About maintenance, during design stage, the choice should be made of eventual motorized turnout (depending on future use).
- Signaling and overhead line must be studied as well, because this may have an important impact on arrangements and existing utilities especially underground.

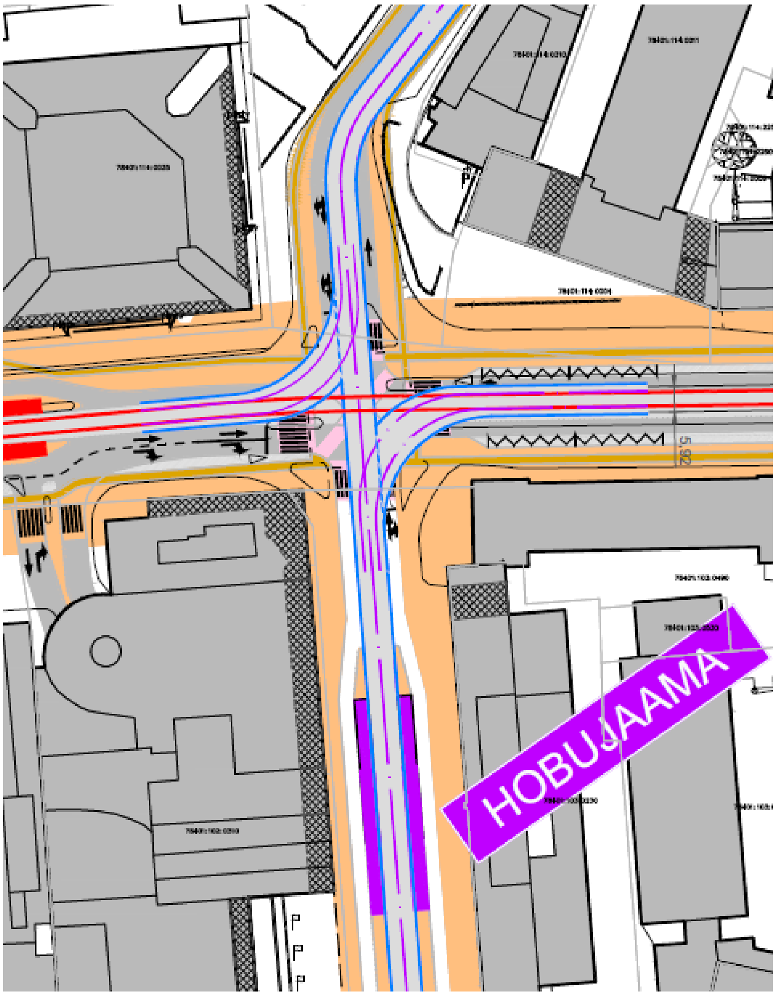


Figure 56 : Tram solution - Hobujaama station with detour to Narva Maantee- Egis

3.4.11 Variant Rävala puiestee

The alignment has been studied through Rävala puiestee. The car traffic is very busy on this avenue and the crossroad with Liivalaia Street is also very busy. Nevertheless the feasibility is recommendable for several reasons:

- a reduction of the number of car lanes on A. Laïkmaa, South-North direction;
- Small modifications of the drop off of the Radisson Hotel to keep a pavement.

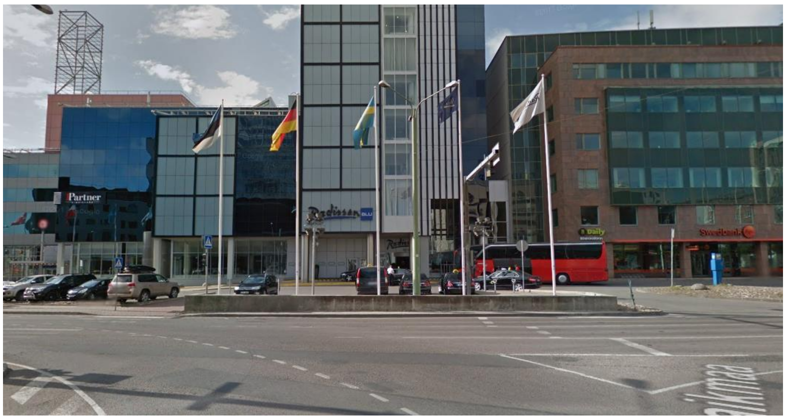


Figure 57 : picture of the Radisson Hotel Drop off - Google

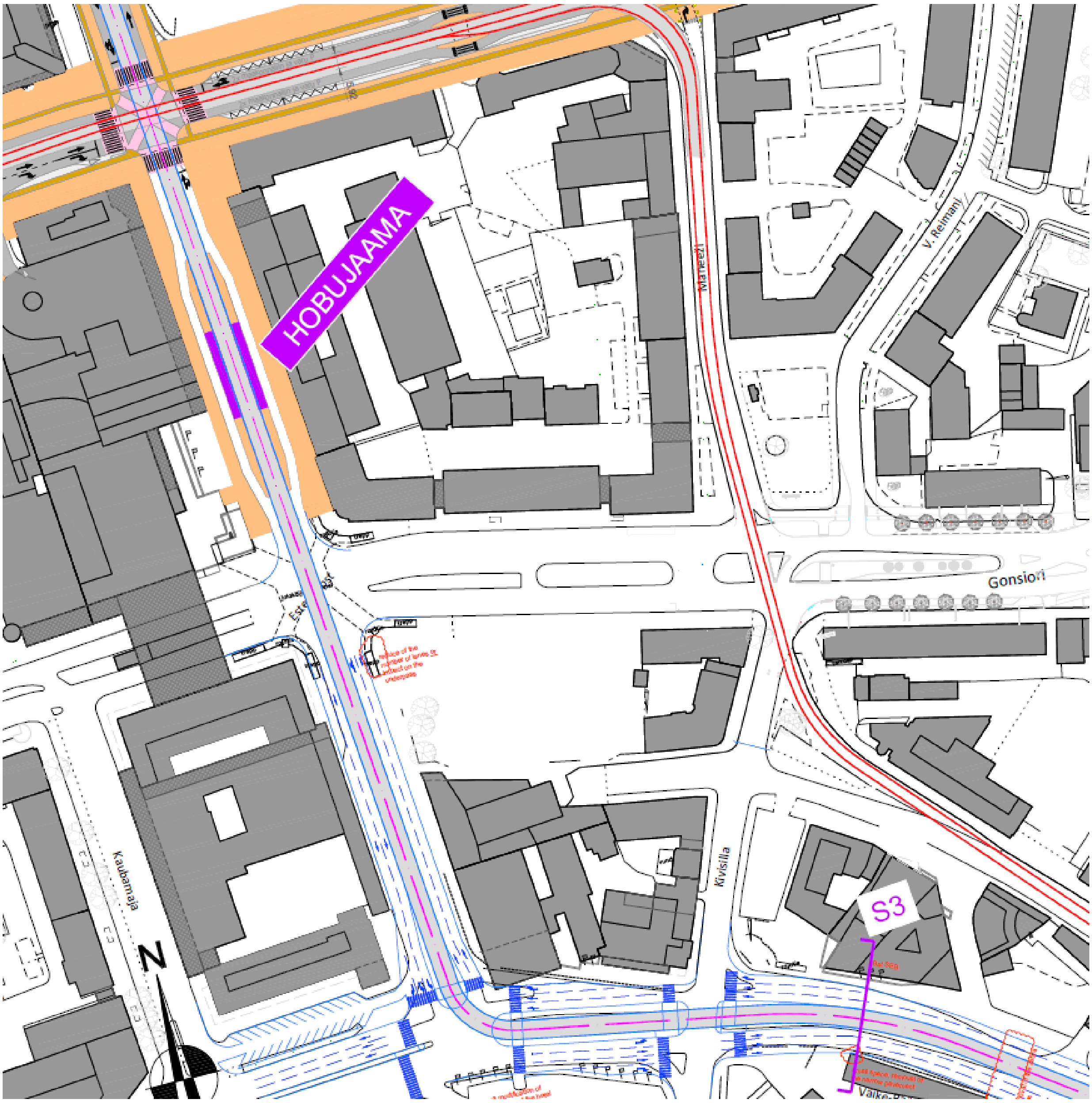


Figure 58 : Tram solution - route through Rävala Street - Egis

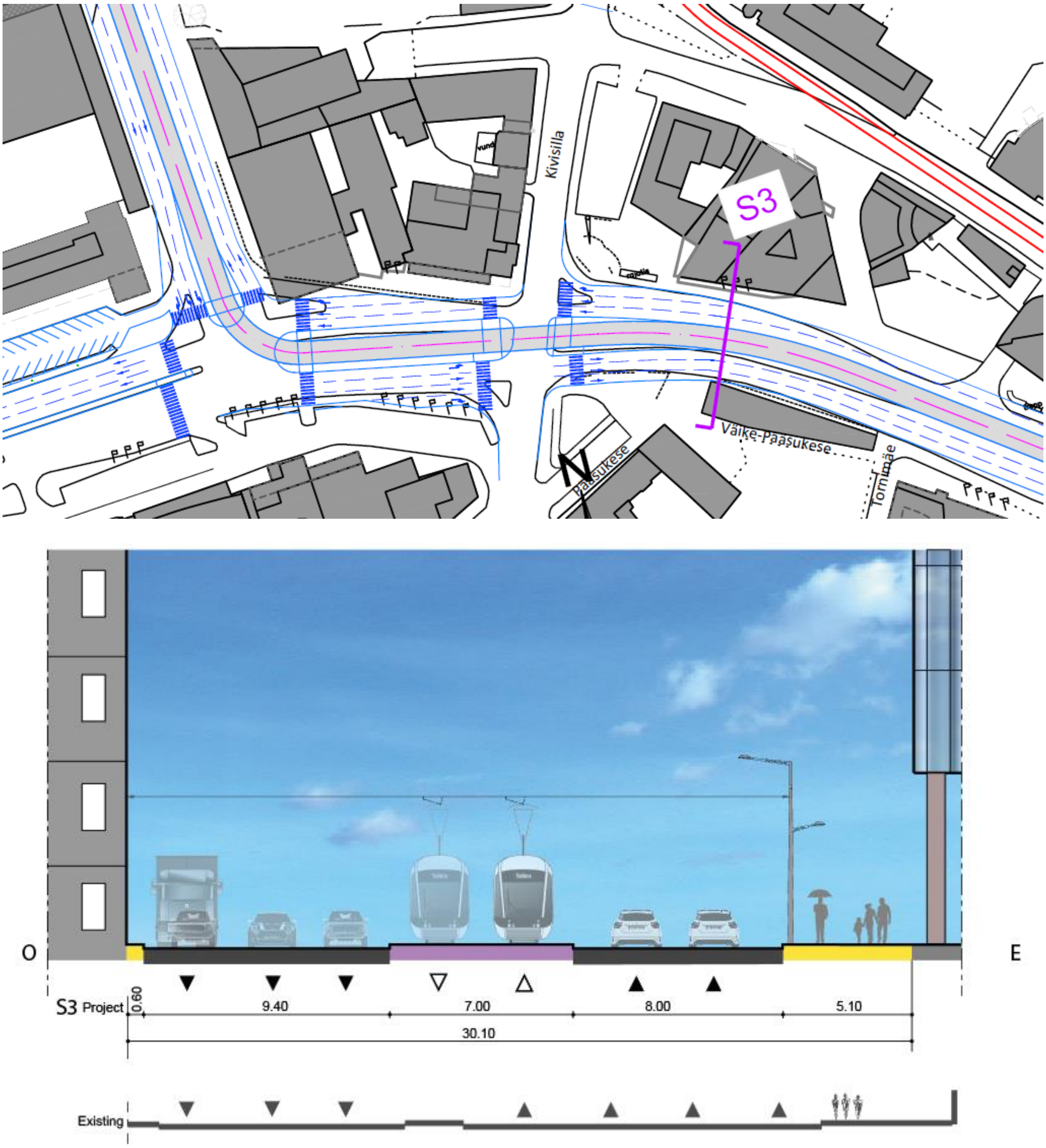


Figure 59 : Tram solution - alternative route on Rävala Street – Egis

- Remove of a pedestrian cross on Rävala Street, because there is not enough place to create pedestrian islands between the carriage ways and tramway tracks.
- The number of car lanes are kept on Rävala Street.
- The organization of the traffic light on Rävala intersection should be very accurate with the introduction of a second line of tramway. The time of each phase will be modified.
- A third line is proposed along Tartu Mint to cope with the two lines with different routes circulating on a common section.

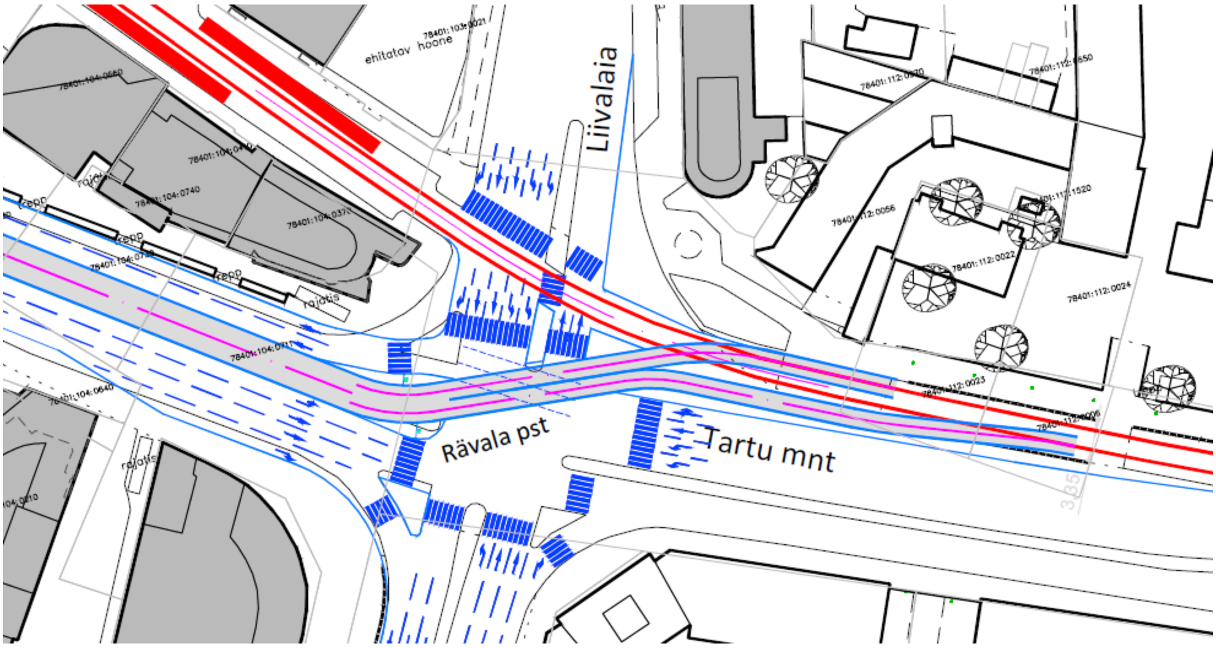


Figure 60 : Tram solution - alternative route on Rävala Street - Egis

Additional stations in Rävala Street

The two additional stations are separate of 225m long. This kind of interstation is more relevant for a bus line than a tramway line. That's why only one station seems to be necessary to serve the area, which is already served by Paberi station. We propose to position it in front of the Radisson Blue Hotel on the Rävala Street which is named Rävala in the picture here after. However the urban integration of this station will need to remove 2 more car lanes. This kind of choice must be confirmed by the traffic department of the city. Therefore the urban integration would have to be studied specifically to compare the axial integration with the lateral north / south integration.

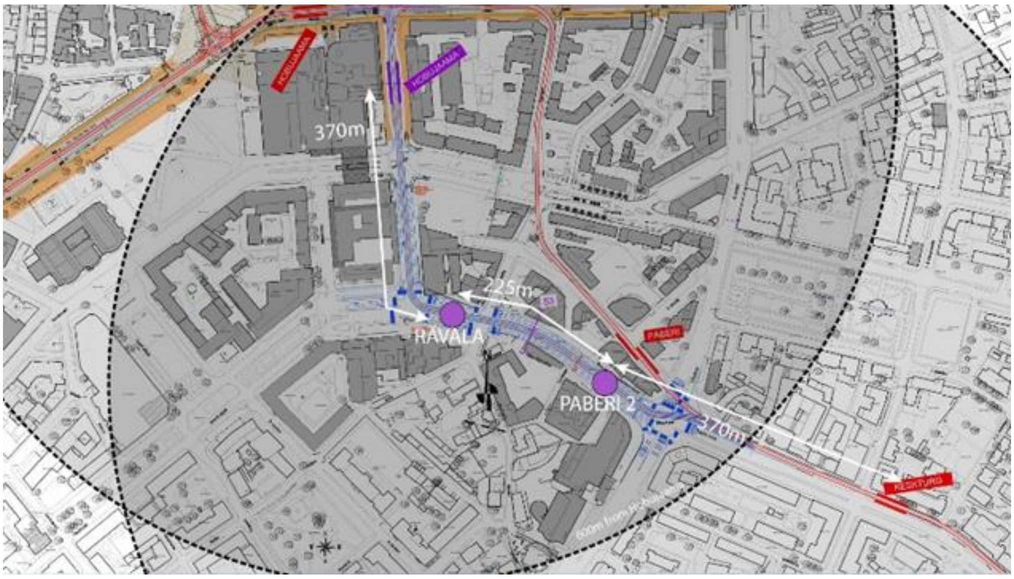


Figure 61 - additional stations on Rävala Street – egis

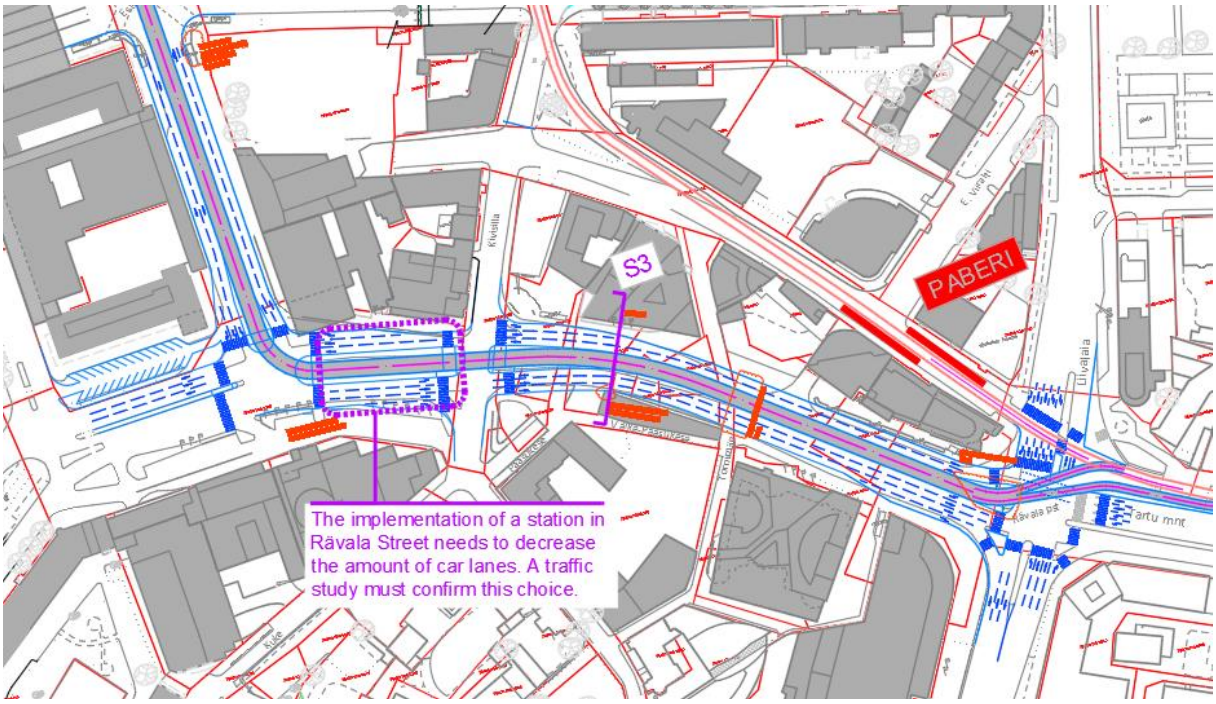


Figure 62 : Proposition of a station on Rävala Street in front of the Radisson Blue Hotel

2nd Alternative route

An alternative route would be study in the future studies. The alternative here-after simplifies the Rävala – Liivalaia junction. However the new Paberi station will imply to reduce the number of car lanes. It has to be confirmed by the traffic department of the city.

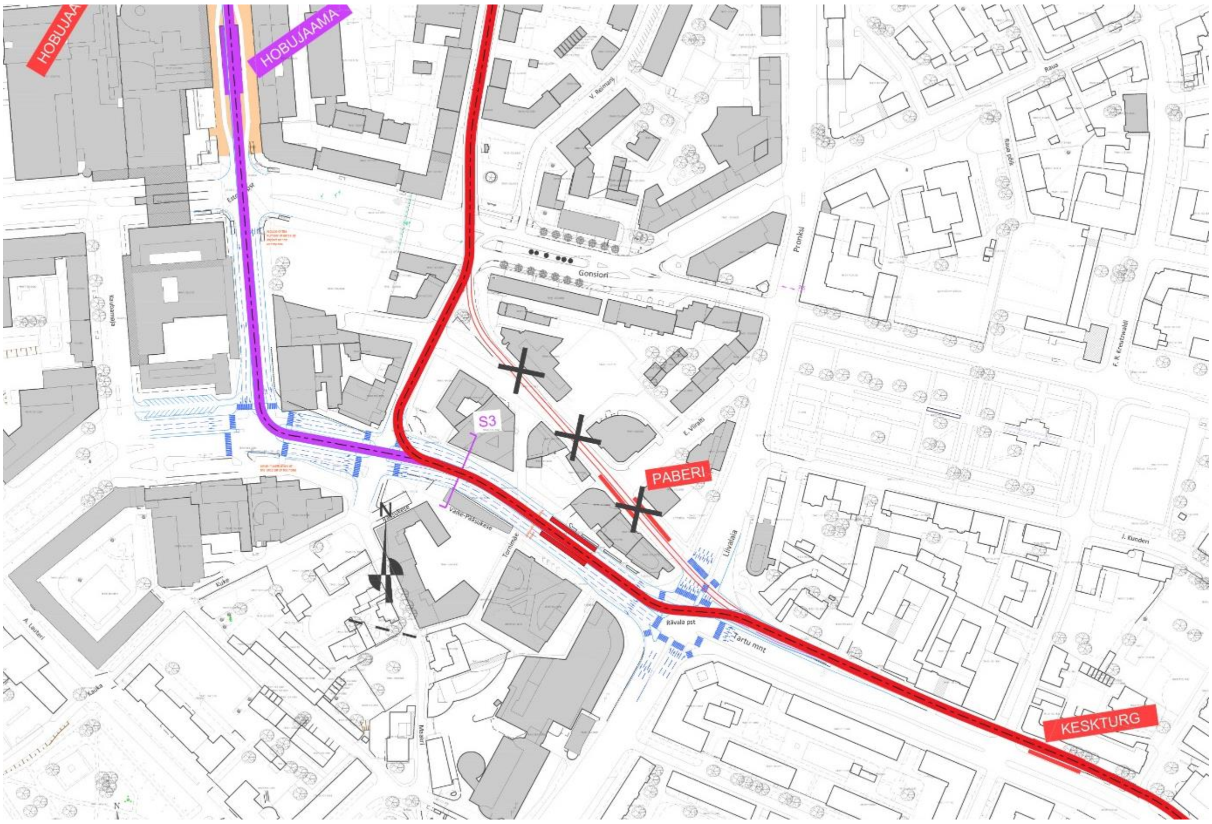


Figure 63 : 2nd alternative route on Rävala Street - Egis

3.4.12 Variant Gonsiori Street

Gonsiori Street is a large avenue with a wide central island with specific bus lanes. The East part was working in May 2018. The future design is integrated to the project. Only the West part is impacted by the tramway amenities.

The alignment needs tight sharp curves to enter and to exit from Gonsiori Street, 30m and 25m. These curves imply to break down the tramway speed that reduces the commercial speed.

Bicycle lanes on each side of the avenue are proposed and bus stops are kept on pavement.

The avenue is wide enough to plant trees on each side.

During the feasibility phase the designers learnt of a major traffic tunnel project that makes the alignment through Gonsiori Street completely impossible, for this reason the study proceeded to study the alignment option through Rävala Puistee.

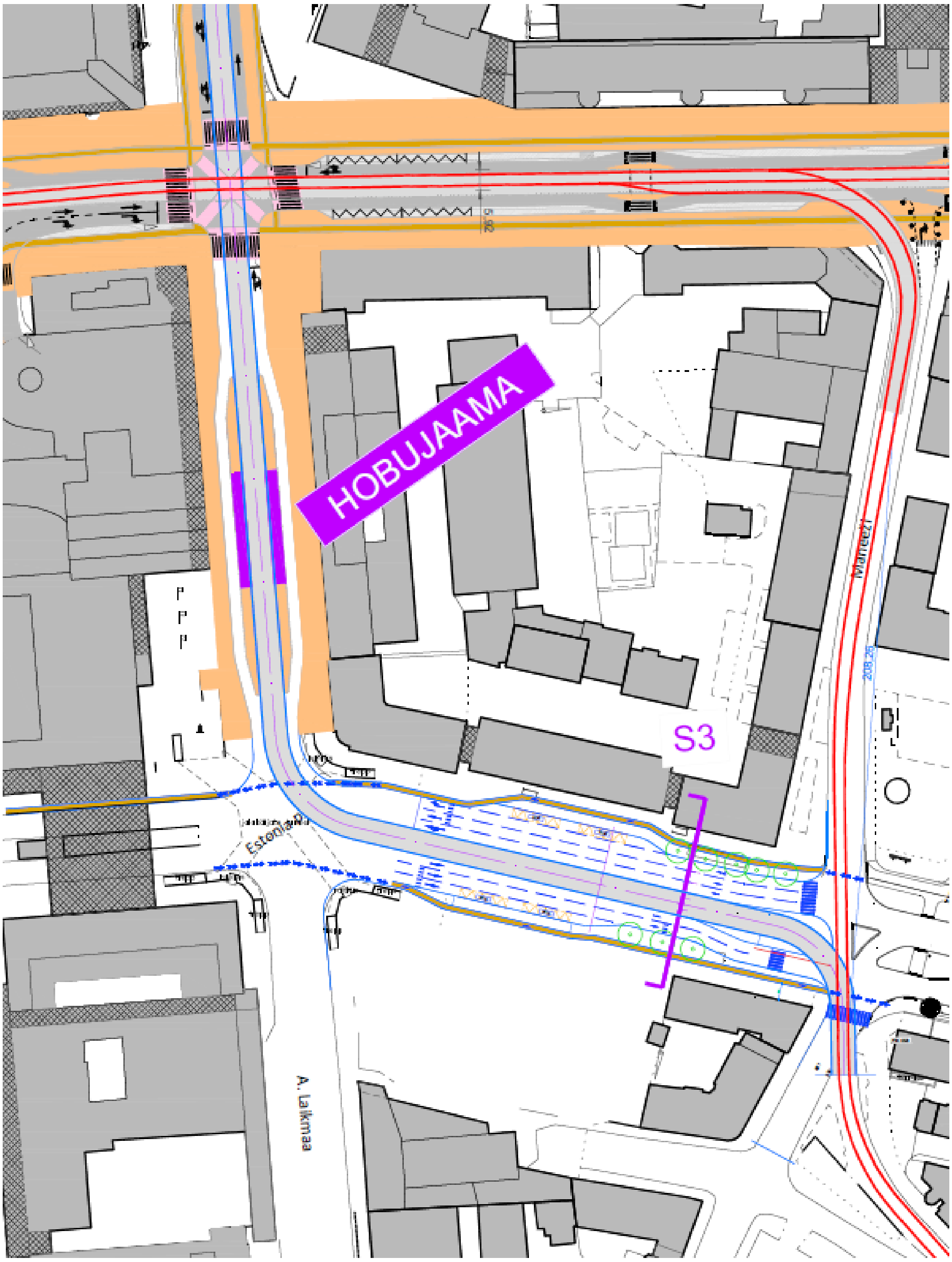


Figure 64 : Gonsiori Street Variant difficult to implement due to future tunnel construction – Egis

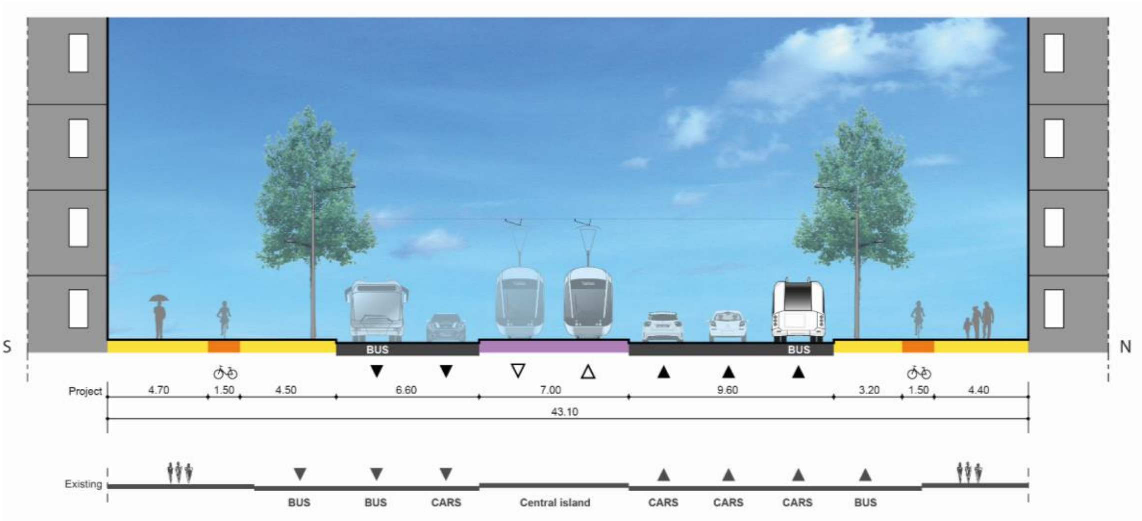
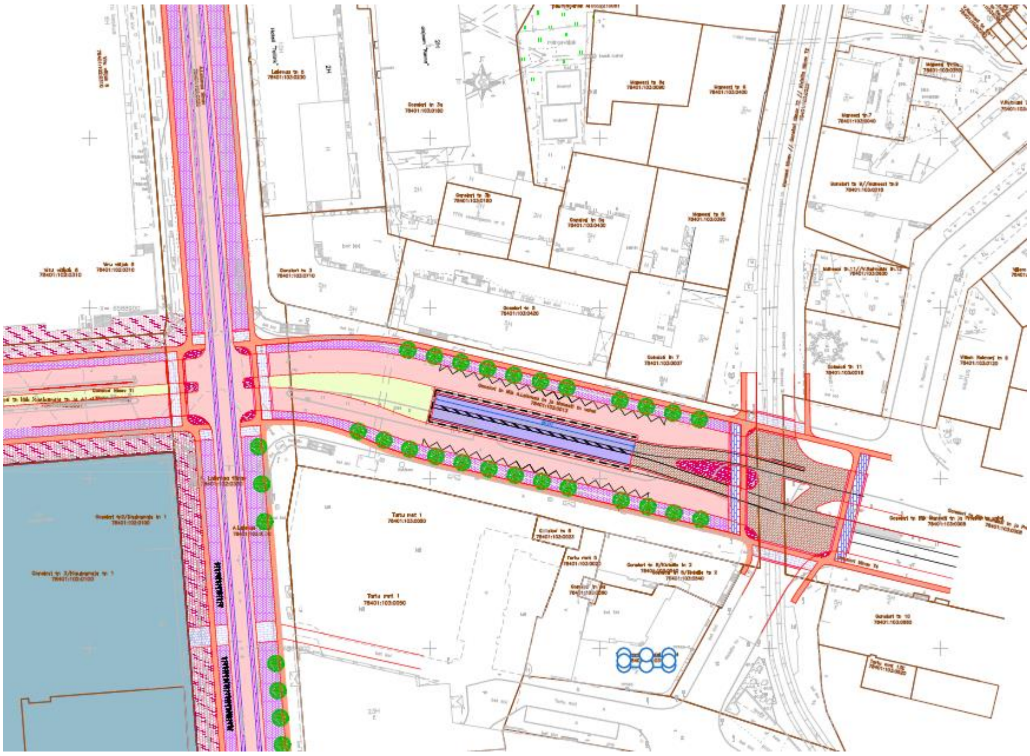


Figure 65 : Tram solution - Section on Gonsiori Street; impossible to implement due to future tunnel construction. – Egis

During the feasibility phase the designers learnt of a major traffic tunnel project. It consists in creating a large underground network under the existing streets of the district. It is a long term vision and not already a planned project. But, the alignment through Gonsiori Street is not compatible with this future project, because a car slope is located on the central island of Gonsiori Street in place of the tramway tracks. An important modification of the project is needed. Either the tramway alignment has to design with a bilateral integration, or a modification of the location of the car ramps has to be imagined.



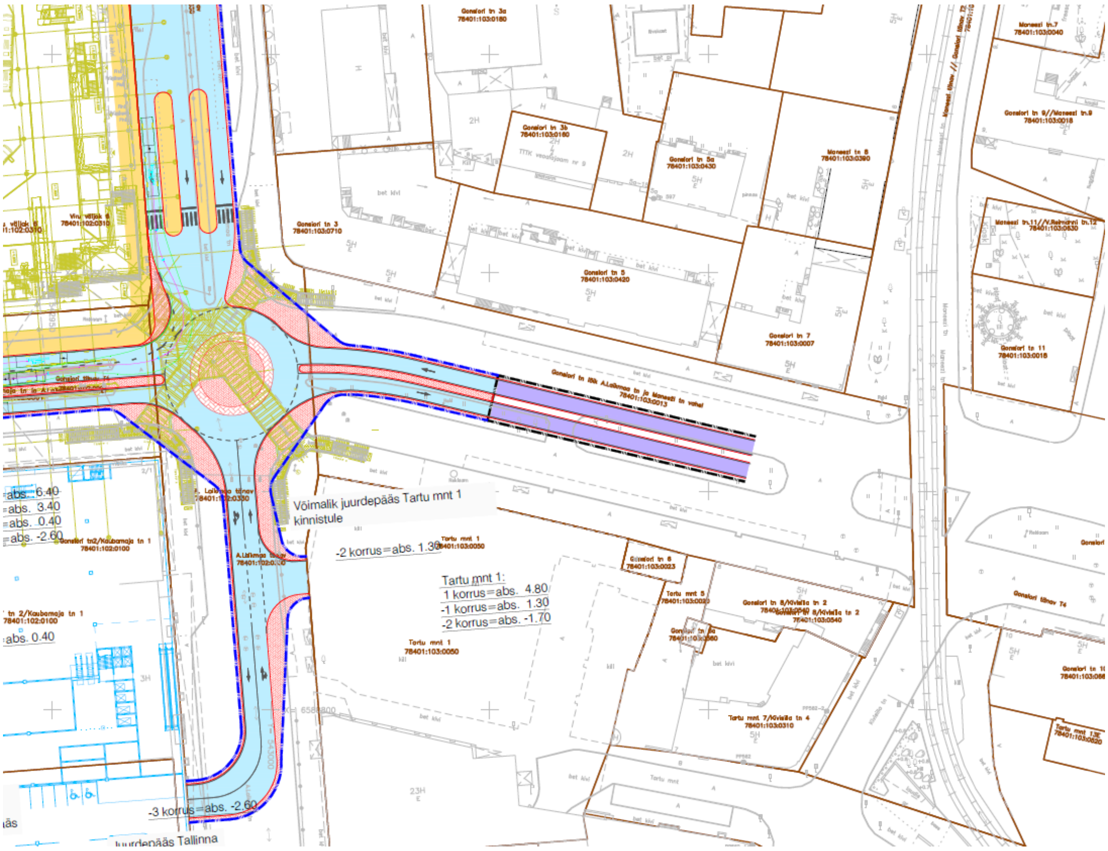


Figure 66 : extracts of the drawing of the project of the tunnel network. Ground Level and underground level.

Here after a possible urban design, that changes a little the position of the ramp access to the North. In this case it is difficult to plant trees along the street.

Another possibility could be to propose an on-street tramway integration. Buses would share the space with the tramway. However it could be less efficient during peak hour with longer travel time.

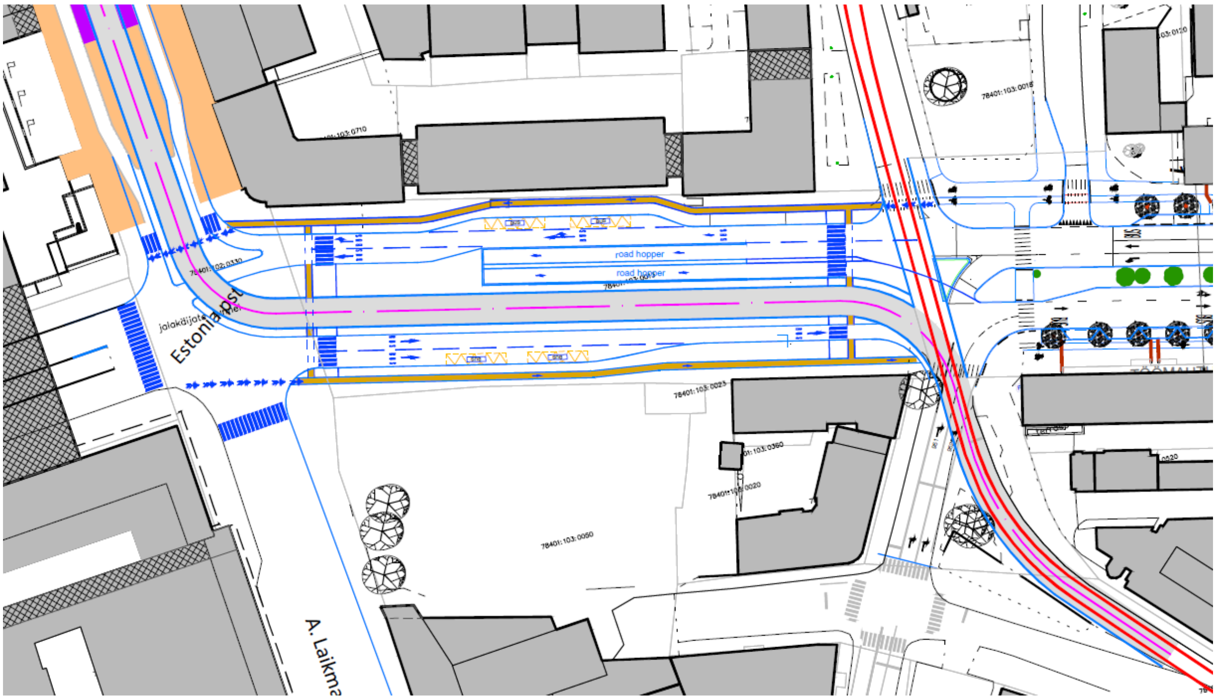


Figure 67 : Tramway option - variant Gonsiori street

In any case, the implementation of the tunnel project of the city will seriously impact the new tramway line during the civil works.

3.4.13 Optimization of operation

- Third tracks on station

A solution of a third tracks on stations has been studied to propose the possibility for a fast line from Ülemiste Station to the Port to avoid stopping at specified stations. The first element that is needed is a minimum width of the road. The only station we identified is KESKTURG station.

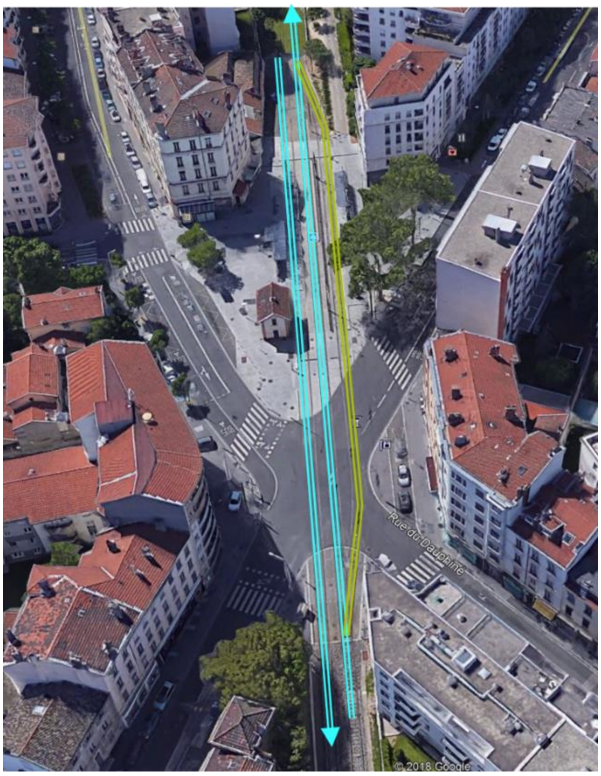


Figure 68 : example of a station in Lyon with a third track - Egis

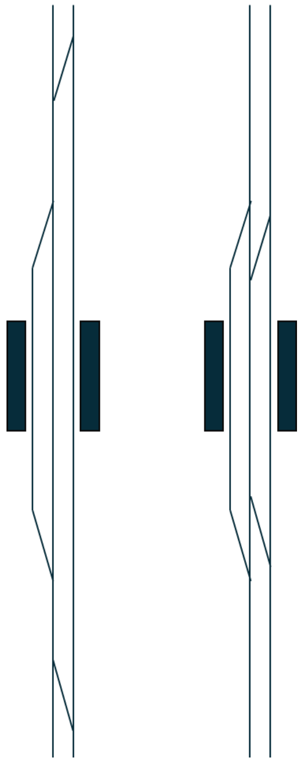


Figure 69 : schema of the tracks configuration in the project (Left) – ideal compact configuration (Right) – Egis

Figure 70 : plan of a third tracks station - Egis

The single crossover should better be installed out of the pedestrian crossroad and out of the road. It is also necessary to position the single crossover out of the curves.

The "ideal" configuration is quite compact but the curve of the road is too close from the station too install this configuration, that's why the second configuration (left one) has been chosen.

The actual frequency of tramways on this line in peak hour is about 3 minutes. The length between the extreme single crossovers is too long to add a train in the opposite direction. It is possible to avoid the station only in the direction from Hobujaama and only for 1 station : Keskturg station.

This solution is not really efficient because the optimization of travelling time is only possible in one direction.

- **Remove of Lubja station**

It is proposed to remove Lubja station because it is very close to Bussijaam station (about 140m). This remove increases the travelling time.

- Reorganization of Majaka area

The average length between the 3 stations in Majaka area is about 340m. This distance could be shorter with a tramway mode because we can consider a radius of 600m of attraction for passengers. Here below 3 options are consider.

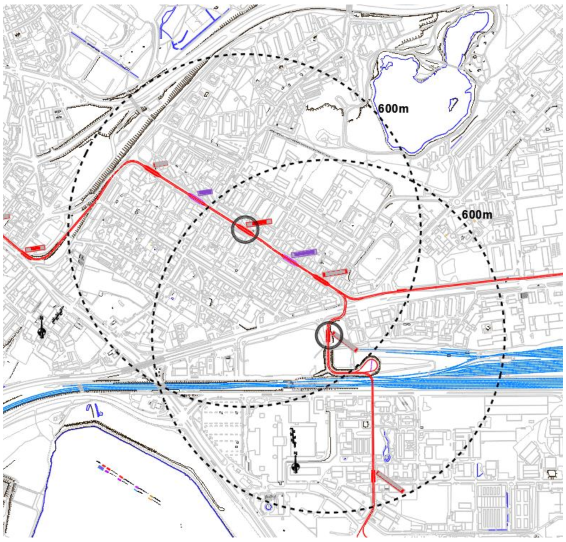


Figure 71 : Tram solution - Majaka area option 1 - egis

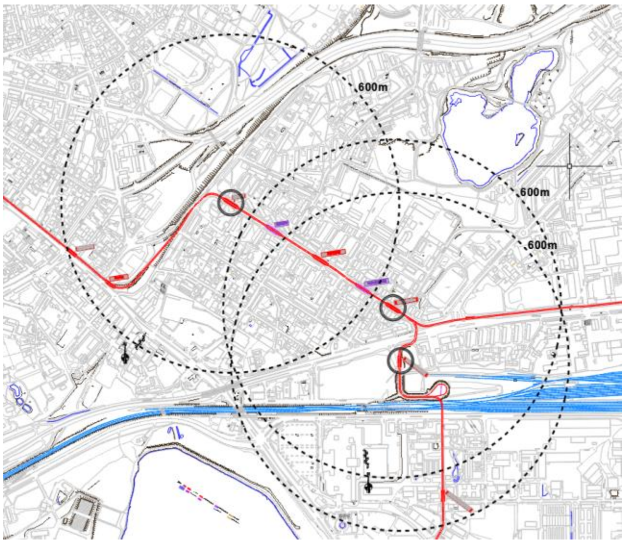


Figure 72 : Tram solution - Majaka area option 2 - egis

Option 1 : remove of 2 existing station – Majaka Poik + Majaka

Option 2 : remove of the central station Sikupilli

Option 3 : remove of the central station and reposition of the 2 extreme stations

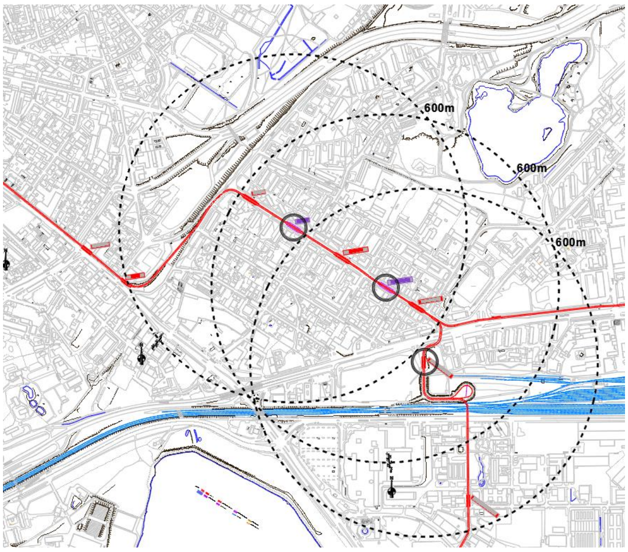


Figure 73 : Tram solution - Majaka area option 3 - egis

Due to the recent implementation of this 3 stations, it is proposed to apply the central station (option 2), even if theoretically the central station (option 1) could be enough to serve the area.

Finally, in a long term vision the option 3 could be consider.

3.4.14 Ülemiste station

The location of the Ülemiste station could be placed nearer to the railway station, moreover the existing location is placed next right to the begin of the pedestrian ramp that gives access to the railway station above the railway tracks.

A new location parallel to the railway tracks will imply a very short distance with the hall in a narrow pavement. Even if it reduces the time of inter-connexion, there could be flows' congestion in peak hour. A minimum distance of 100-150m allows to lengthen the passenger flows.

The next studies of the train station could eventually study an optimization of the distance between the train station and the tramway stop.

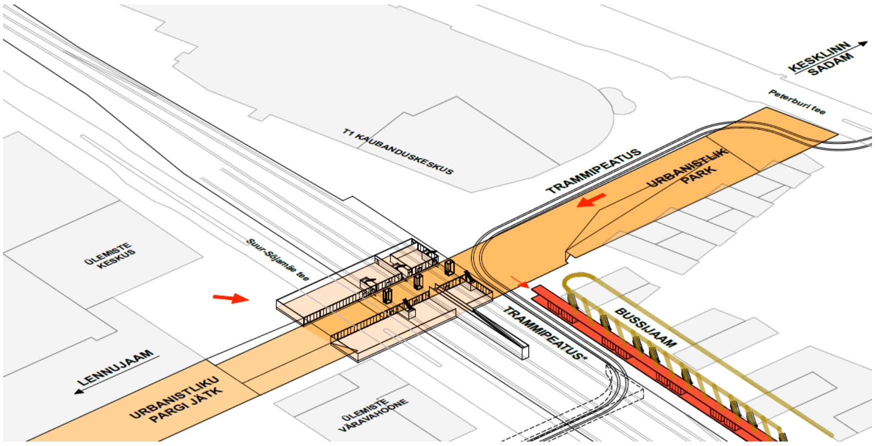


Figure 74 : Existing schema of the tramway stops in Ülemiste station

Figure 75 : existing space between tracks and wall of railway tracks in Ülemiste

3.4.15 **Airport station**

In case it is needed to add a second platform at the terminus Airport station, it is possible to implement it with a new alignment (purple in the image hereafter) which integrate 20m radius. This value implies noise emission, a decrease of the speed of the rolling stock and a premature wear of the rails. Therefore the new alignment impacts the bus station, which needs to be reorganize or shifted.

It gives the possibility to serve the Airport with the lines 4 and 2.

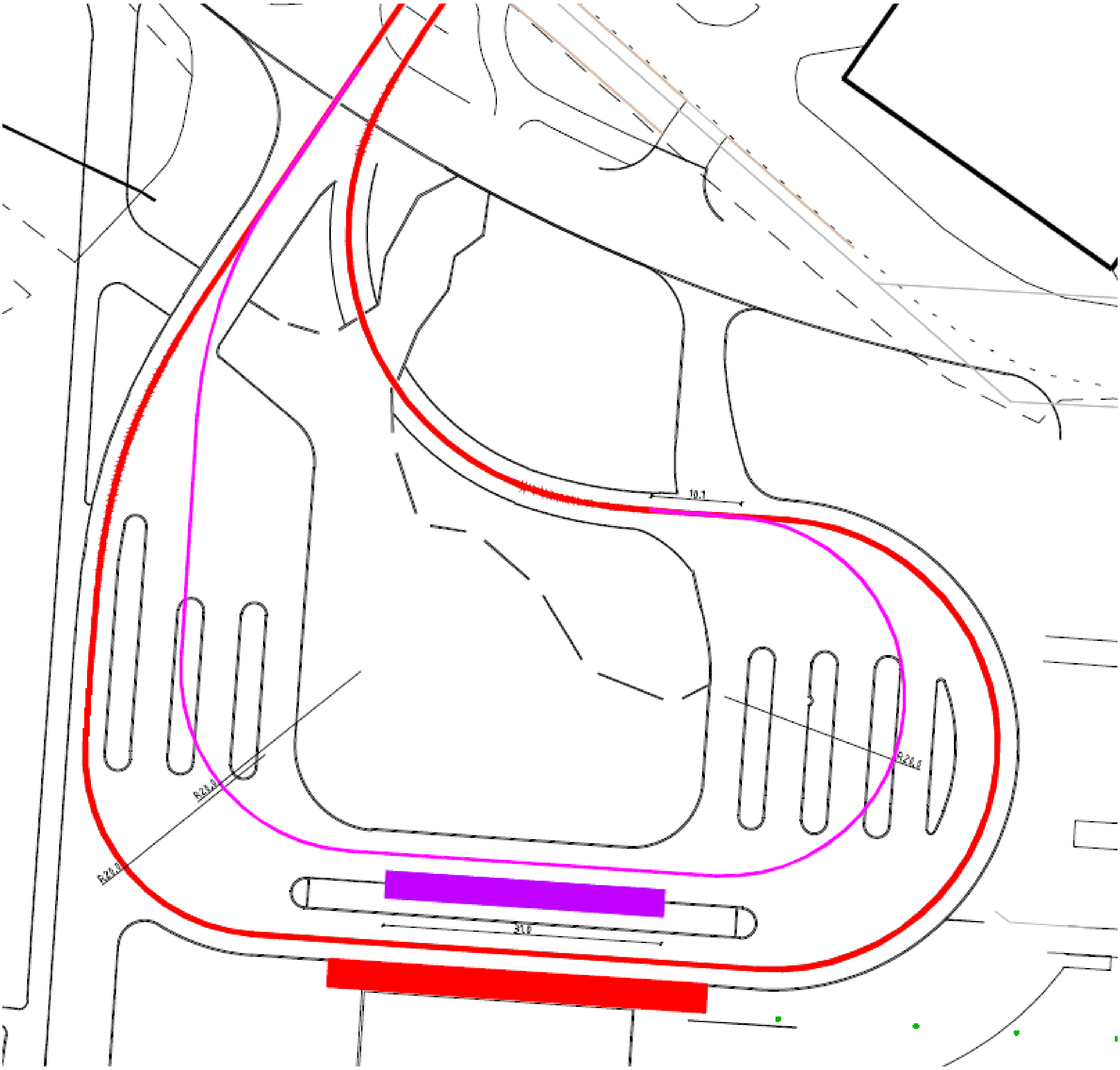


Figure 76 : proposed alignment in purple for a second platform in Airport station. Existing alignment in red.

3.4.16 Conclusion

This solution is feasible and offer a good urban integration of the line.

Vanasadam station could be problematic for the urban planner, but with some iterations, a compromise could certainly be found. The choice between Laikmaa and Gonsiori options would have to be done after considering traffic flows analysis on big intersections and with a deeper work on the future tramway network in Tallinn.

3.5. Operational characteristics

3.5.1 Round trip time calculation of the existing situation

Calculation principles

The round trip duration estimation has been made:

- According the current travel time
- And using specific Egis software that has been designed for feasibility and preliminary studies.

Our software takes into account the main characteristics of the line in order to compute the commercial speed, the number of kilometers travelled each year, the required rolling stock fleet and other operating figures.

Commercial speed of the tram line depends on three elements:

- the general velocity profile allowed by the geometrical characteristics of the route (distance between stations, curves, slopes and ramps) and the rolling stock performances;
- the number and duration of stops in station;
- the time lost at roads intersections according to the priority level tram will have in average at intersections.

The estimation is based on our current knowledge of the line and will be refined in the following steps of the study.

In first time, a recalculation of the existing travel time has been made to calibrate our software and to evaluate the priority level tram at roads intersections and the current fleet on the line 2 and 4.

Operation speed

The general principle of driving is the run-on-sight, considering the driver as being responsible for the speed he will make a decision according to the urban environment and signaling.

Although vehicles can reach the speed of around 50 km/h (source: Technical requirements for tramline construction for reference). According the urban environment (priority of tramway in intersection, design alignment, pedestrian proximity…), and geometrical characteristics of the route, the speed on the line will not exceed 30 km/h. Depend on the areas the tram pass, more restrictive limits may be considered to take into account the safety requirements, the density of pedestrians or the width of the street.

Optimum run time and coasting slack time factors

The calculation is performed in "optimum run time", e.g. on the basis of maximum acceleration and deceleration operating values. Therefore, the calculation also takes into account a “coasting/slack” time of 10% of the travel time to take into account driving irregularities.

Stations dwelling time

Commonly the station dwelling time is between 25 and 40 seconds depending on the attractiveness of the sector and number of passengers boarding and alighting. For the line 2 and 4 of Tallinn, the station dwelling time is an average of 18 seconds.

Lost time at roads intersections estimation

Despite the priority principle of tram at the junction, lost time is inevitable throughout the line. Crossing intersections depends largely on the regulation principle and system to be adopted.

Different levels of tram priority can be considered:

- Absolute priority (100%). This is the most optimum situation for the LRT. No time is lost whatsoever. The tram can approach all of the junctions from any direction at its intended speed and cross them all without having to either slow down or stop.
- Maximum priority (80%-100%). At some junctions, the tram will have to slow down and stop for a moment in front of the traffic lights (waiting for a change of sequence, from red to green), before restarting.
- No priority (50% -60%). The tram must stop at every junction with the normal probability to have the red light.

The simulation of the current situation shows that the tram don't have priority. The priority rate are around 60% at traffic lights for the tramway.

Turnaround time at the terminus

The turnaround time at the terminal includes:

- stopping time required for passengers alighting (about 20 seconds);
- time for the vehicle to perform its operation: the turning movement itself when there is a reverse loop and dwell time, which includes the driver short break (minimum 90 seconds);
- time that corresponds to regulation time in order to absorb the hazards of travel time: these hazards are proportional to the length of the line, assuming 10% of the overall journey time (if the driver arrives on time, he / she can use this time to take a short break longer);
- stopping time required to passengers boarding is considered by including in the regulation time.

The turnaround time is between 5 min and 7 min 45 seconds per terminus depending of the length of line and if there is a reverse loop, this allows for regulation and technical operations.

Calculation results of the current situation

Existing Line 4

The complete commercial travel time for the line 4 is about 31 minutes from Lennujaam to Tondi and 31 min 30 from Tondi to Lennujaam and the commercial speed is about 15 km/h which is a little bit slower than modern tramways operating in a similar urban environment.

Tableau 2 : simulation of total travel time Existing line 4 Lennujaam - Tondi

Existing line 4 Lennujaam - Tondi	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival (h:m:s)	Departure (h:m:s)
Lennujaam	0	0	0	0			00:00:00
Ülemiste linnak	374	20	0	62		00:01:01	00:01:21
Ülemiste jaam	586	20	0	95		00:02:56	00:03:16
Majaka põik	200	20	1	62		00:04:18	00:04:38
Sikupilli	308	20	0	45		00:05:22	00:05:42
Majaka	377	20	1	68		00:06:50	00:07:10
Lubja	615	20	0	118		00:09:08	00:09:28
Bussijaam	172	20	1	44		00:10:12	00:10:32
Keskturg	617	20	2	125		00:12:36	00:12:56
Paberi	398	20	2	81		00:14:16	00:14:36
Hobujaama	540	30	3	181		00:17:36	00:18:06
Viru	549	20	2	114		00:19:59	00:20:19
Vabaduse väljak	338	20	1	70		00:21:29	00:21:49
Kosmos	516	20	1	99		00:23:27	00:23:47
Vineeri	495	20	1	95		00:25:22	00:25:42
Tallinn-Väike	1183	20	1	204		00:29:06	00:29:26
Tondi	442	0	1	87		00:30:52	

Tableau 3 : simulation of total travel time Existing line 4 Tondi - Lennujaam

Existing line 4 Tondi - Lennujaam	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival (h:m:s)	Departure (h:m:s)
Tondi	0	0	0	0			00:00:00
Kalev	249	20	0	53		00:00:53	00:01:13
Tallinn Väike	560	0	1	106		00:02:58	00:02:58
Vineeri	1159	20	1	201		00:06:18	00:06:38
Kosmos	473	20	1	92		00:08:09	00:08:29
Vabaduse vjk	472	20	1	92		00:10:00	00:10:20
Viru	566	20	1	107		00:12:06	00:12:26
Hobujaama	368	20	3	108		00:14:14	00:14:34
Paberi	556	30	3	151		00:17:05	00:17:35
Keskturg	394	20	2	80		00:18:55	00:19:15
Bussijaam	617	20	2	125		00:21:19	00:21:39
Lubja	180	20	0	32		00:22:11	00:22:31
Majaka	613	20	0	118		00:24:28	00:24:48
Sikupilli	381	20	1	69		00:25:56	00:26:16
Majaka põik	281	20	0	42		00:26:57	00:27:17
Ülemiste jaam	189	20	1	61		00:28:17	00:28:37
Ülemiste linnak	573	20	0	94		00:30:10	00:30:30
Lennujaam	373	0	0	59		00:31:29	

The simulation is very close than the real travel time. The following table shows the comparison of the current travel time send by TLT (Tallinna Linnatranspordi Astsiaselts) and our simulation.

Tableau 4 : difference in absolute and relative value between Egis Simulation and the current travel time – Line 4 Lennujaam - Tondi

Existing line 4 Lennujaam - Tondi	Simulation	Current Travel Time (TLT)	Difference: Absolute value	Difference: Relative value
Lennujaam	0,0	0,0		
Ülemiste linnak	1,4	1,5	0,1	10%
Ülemiste jaam	1,9	2,0	0,1	4%
Majaka põik	1,4	1,3	-0,1	-5%
Sikupilli	1,1	1,2	0,1	12%
Majaka	1,5	1,4	-0,1	-5%
Lubja	2,3	2,3	0,0	0%
Bussijaam	1,1	0,6	-0,5	-44%
Keskturg	2,4	2,6	0,2	8%
Paberi	1,7	1,6	-0,1	-5%
Hobujaama	3,5	3,7	0,2	5%
Viru	2,2	2,6	0,4	16%
Vabaduse väljak	1,5	1,2	-0,3	-20%
Kosmos	2,0	2,1	0,1	6%
Vineeri	1,9	2,1	0,2	9%
Tallinn-Väike	3,7	3,5	-0,2	-6%
Tondi	1,4	1,3	-0,1	-10%
Total journey time	31,0	31,0	0,0	0%

Tableau 5: difference in absolute and relative value between Egis Simulation and the current travel time – Line 4 Lennujaam - Tondi

Existing line 4 Tondi - Lennujaam	Simulation	Current Travel Time (TLT)	Difference: Absolute value	Difference: Relative value
Tondi	0,0	0,0		
Kalev	1,2	1,5	0,3	23%
Tallinn Väike	1,8	1,7	-0,1	-3%
Vineeri	3,7	3,4	-0,3	-7%
Kosmos	1,9	2,0	0,1	7%
Vabaduse vjk	1,9	2,0	0,1	7%
Viru	2,1	1,8	-0,3	-15%
Hobujaama	2,1	2,4	0,3	12%
Paberi	3,0	3,0	0,0	-1%
Keskturg	1,7	1,8	0,1	8%
Bussijaam	2,4	2,8	0,4	16%
Lubja	0,9	0,6	-0,3	-31%
Majaka	2,3	2,1	-0,2	-9%
Sikupilli	1,5	1,3	-0,2	-12%
Majaka põik	1,0	1,0	0,0	-2%
Ülemiste jaam	1,3	1,6	0,3	19%
Ülemiste linnak	1,9	2,0	0,1	5%
Lennujaam	1,0	1,0	0,0	2%
Total journey time	30,4	30,5	0,1	0%

Existing Line 2

The complete commercial travel time for the line 2 is about 39 minutes from Suur Paala DP to Kopli and 38 min from Kopli to Suur-Paala DP and the commercial speed is respectively of 16,5 and 17 km/h which is a little bit slower than modern tramways operating in a similar urban environment.

Tableau 6 : simulation of total travel time Existing line 2 Suur-Paala - Kopli

Existing line 2 Suur-Paala - Kopli	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival (h:m:s)	Departure (h:m:s)
Suur-Paala	0	0	0	0			00:00:00
Väike-Paala	353	20	1	56		00:00:56	00:01:16
Pae	367	20	0	47		00:02:03	00:02:23
Majaka põik	234	20	0	47		00:03:10	00:03:30
Sikupilli	308	20	0	45		00:04:14	00:04:34
Majaka	377	20	1	68		00:05:42	00:06:02
Lubja	615	20	0	118		00:08:00	00:08:20
Bussijaam	172	20	1	44		00:09:04	00:09:24
Keskturg	617	20	2	125		00:11:28	00:11:48
Paberi	398	20	2	81		00:13:08	00:13:28
Hobujaama	540	30	3	181		00:16:28	00:16:58
Mere puiestee	375	20	2	127		00:19:05	00:19:25
Kanuti	369	20	0	79		00:20:43	00:21:03
Linnahall	327	20	0	51		00:21:54	00:22:14
Põhja puiestee	412	20	0	71		00:23:24	00:23:44
Balti jaam	444	20	0	75		00:24:59	00:25:19
Telliskivi	342	20	0	53		00:26:12	00:26:32
Salme	216	20	0	41		00:27:13	00:27:33
Volta	444	20	0	60		00:28:32	00:28:52
Krulli	369	20	0	51		00:29:43	00:30:03
Angerja	635	20	0	74		00:31:16	00:31:36
Sitsi	441	20	0	55		00:32:30	00:32:50
Maleva	915	20	0	102		00:34:31	00:34:51
Sirbi	459	20	0	57		00:35:47	00:36:07
Marati	442	20	0	55		00:37:01	00:37:21
Sepa	281	20	0	39		00:37:59	00:38:19
Kopli	225	0	0	38		00:38:57	
Kopli DP	*228*	*0*	*0*		*43*		

Tableau 7 : simulation of total travel time Existing line 2 Kopli – Suur-Paala DP

Existing line 2 Kopli - Suur Paala DP	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival (h:m:s)	Departure (h:m:s)
Kopli	0	0	0	0			00:00:00
Sepa	299	20	0	65		00:01:04	00:01:24
Marati	282	20	0	39		00:02:03	00:02:23
Sirbi	439	20	0	55		00:03:17	00:03:37
Maleva	467	20	0	57		00:04:34	00:04:54
Sitsi	909	20	0	101		00:06:35	00:06:55
Angerja	443	20	0	55		00:07:49	00:08:09
Krulli	633	20	0	74		00:09:22	00:09:42
Volta	370	20	0	52		00:10:33	00:10:53
Salme	443	20	0	60		00:11:52	00:12:12
Telliskivi	219	20	0	42		00:12:53	00:13:13
Balti jaam	341	20	0	53		00:14:06	00:14:26
Põhja pst	451	20	0	76		00:15:42	00:16:02
Linnahall	390	20	0	68		00:17:10	00:17:30
Kanuti	337	20	0	53		00:18:22	00:18:42
Mere pst	368	20	0	78		00:20:00	00:20:20
Hobujaama	348	30	2	120		00:22:20	00:22:50
Paberi	556	20	3	151		00:25:21	00:25:41
Keskturg	394	20	2	80		00:27:01	00:27:21
Bussijaam	617	20	2	125		00:29:25	00:29:45
Lubja	180	20	0	32		00:30:17	00:30:37
Majaka	613	20	0	118		00:32:34	00:32:54
Sikupilli	381	20	1	69		00:34:02	00:34:22
Majaka põik	281	20	0	42		00:35:03	00:35:23
Väike-Paala	618	20	0	98		00:37:01	00:37:21
Suur-Paala	373	20	0	48		00:38:09	
Suur Paala DP	*461*	*0*	*0*		*126*		

As for the line 4, our simulation is very close than the real travel time. The following table shows the comparison of the current travel time send by TLT (Tallinna Linnatranspordi Astsiaselts) and our simulation.

Tableau 8 : difference in absolute and relative value between Egis Simulation and the current travel time – Existing line 2 Suur-Paala - Kopli

Existing line 2 Suur-Paala - Kopli	Simulation	Current Travel Time (TLT)	Absolute value	Relative value
Suur-Paala				
Väike-Paala	1,3	1,3	0,0	3%
Pae	1,1	1,4	0,3	25%
Majaka põik	1,1	1,1	0,0	-2%
Sikupilli	1,1	1,2	0,1	12%
Majaka	1,5	1,4	-0,1	-5%
Lubja	2,3	2,3	0,0	0%
Bussijaam	1,1	0,6	-0,5	-44%
Keskturg	2,4	2,6	0,2	8%
Paberi	1,7	1,6	-0,1	-5%
Hobujaama	3,5	3,7	0,2	5%
Mere puiestee	2,5	2,4	-0,1	-2%
Kanuti	1,6	1,6	0,0	-3%
Linnahall	1,2	1,0	-0,2	-16%
Põhja puiestee	1,5	1,4	-0,1	-8%
Balti jaam	1,6	1,6	0,0	1%
Telliskivi	1,2	1,3	0,1	6%
Salme	1,0	0,8	-0,2	-22%
Volta	1,3	1,7	0,4	28%
Krulli	1,2	1,0	-0,2	-16%
Angerja	1,6	1,8	0,2	15%
Sitsi	1,2	1,2	0,0	-4%
Maleva	2,0	2,3	0,3	13%
Sirbi	1,3	1,2	-0,1	-6%
Marati	1,2	1,2	0,0	-4%
Sepa	1,0	0,7	-0,3	-29%
Kopli	0,6	0,6	0,0	-5%
Total journey time	39,2	39,0	-0,2	0%

Tableau 9: difference in absolute and relative value between Egis Simulation and the current travel time – Existing line 2 Kopli - Suur Paala DP

Existing line 2 Kopli - Suur Paala DP	Simulation	Current Travel Time (TLT)	Difference	
			Absolute value	Relative value
Kopli	0	0		
Sepa	1,4	1,1	-0,3	-22%
Marati	1,0	1	0,0	2%
Sirbi	1,2	1,6	0,4	29%
Maleva	1,3	0,8	-0,5	-38%
Sitsi	2,0	1,7	-0,3	-16%
Angerja	1,2	1,4	0,2	12%
Krulli	1,6	1,9	0,3	22%
Volta	1,2	1,2	0,0	1%
Salme	1,3	1,6	0,3	20%
Telliskivi	1,0	0,8	-0,2	-22%
Balti jaam	1,2	1,3	0,1	6%
Põhja pst	1,6	1,6	0,0	0%
Linnahall	1,5	1,2	-0,3	-18%
Kanuti	1,2	1,4	0,2	15%
Mere pst	1,6	1,5	-0,1	-9%
Hobujaama	2,5	2,7	0,2	8%
Paberi	2,9	3	0,1	5%
Keskturg	1,7	1,8	0,1	8%
Bussijaam	2,4	2,8	0,4	16%
Lubja	0,9	0,6	-0,3	-31%
Majaka	2,3	2,1	-0,2	-9%
Sikupilli	1,5	1,3	-0,2	-12%
Majaka põik	1,0	1	0,0	-2%
Väike-Paala	2,0	2,2	0,2	12%
Suur-Paala	1,1	1,4	0,3	23%
Total journey time	38,7	39,0	0,3	1%

3.5.2 Fleet size calculation of the existing situation

The rolling stock fleet size is composed of:

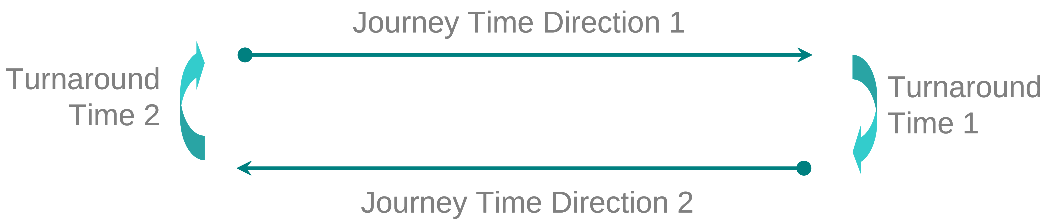
- Vehicles required on line, during the operating hours;
- Vehicles under maintenance;
- Vehicles on operating reserve.

The number of rolling stock vehicles required on-line, during the peak hour, is the round trip time divided by the minimum operating headway.

The round trip time is the sum of:

- Journey times estimated for both directions;
- Turnaround times at each terminus, composed of the following actions:

- Passengers alighting (arrival at the last station),
- Trainsets manoeuvred into turnback position (if turnback behind the station),
- Passengers boarding (departure from the first station),
- Regulation time (added to the turnaround time in order to ensure that the next departing trainset can leave the terminus on time, should it arrive late).



Line	Way	Itinerary (O/D)	Commercial Speed	Travel time commercial	Time at terminus (stop + short break)	Regulation time	Round trip duration	Minimal interval (peak hour)
Existing Line 4	↑	Lennujaam - Tondi	14,99	30:52	01:50	03:05	01:12:15	07:00
	↓	Tondi - Lennujaam	15,25	31:29	01:50	03:09		
Existing Line 2	↑	Suur-Paala - Kopli	16,45	38:57	02:33	03:54	01:31:17	07:00
	↓	Kopli - Suur-Paala	16,91	38:09	03:55	03:49		

With 7 minutes headway and about 1 hour and 12 min round trip time for the line 4, 11 trainsets are needed in operation during peak period and with the same headway and about 1 hour and half for the line 2, 14 trainsets are needed.

Line	Way	Itinerary (O/D)	Rolling stock			
			in line (peak hour)*	in reserve for maintenance *	in reserve for operation*	TOTAL
Existing Line 4	↑	Lennujaam - Tondi	11,00	2	1	14
	↓	Tondi - Lennujaam				
Existing Line 2	↑	Suur-Paala - Kopli	14,00	2	1	17
	↓	Kopli - Suur-Paala				

A reserve fleet for maintenance and operation has to be considered in addition to the fleet for peak period operation:

- a maximum of 15% reserve for maintenance, depending on the maintenance strategy (number of daily and weekly shifts…) and for operation reserve.

Our simulation resulted in a total fleet size of 14 trainsets for the line 4 and 17 trainsets for the line 2.

This simulation of the existing travel time and the fleet size was required to evaluate the additional train number of the new route through the port.

3.5.1 Round trip time calculation of the future network

Future Line 4 – Suur-Paala to Tondi

The complete commercial travel time for the future line 4 is about 30 minutes from Suur-Paala to Tondi and 30 min 15 from Tondi to Lennujaam and the commercial speed is about 15 km/h (respectively 15,1 and 15,5 km/h) which is a little bit slower than modern tramways operating in a similar urban environment.

Tableau 10 : simulation of total travel time future line 4 Suur-Paala - Tondi

New line 4 Suur-Paala - Tondi	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival *(h:m:s)*	Departure *(h:m:s)*
Suur-Paala	0	0	0	0			00:00:00
Väike-Paala	353	20	1	56		00:00:56	00:01:16
Pae	367	20	0	47		00:02:03	00:02:23
Majaka põik	234	20	0	47		00:03:10	00:03:30
Sikupilli	308	20	0	45		00:04:14	00:04:34
Majaka	377	20	1	68		00:05:42	00:06:02
Lubja	615	20	0	118		00:08:00	00:08:20
Bussijaam	172	20	1	44		00:09:04	00:09:24
Keskturg	617	20	2	125		00:11:28	00:11:48
Paberi	398	20	2	81		00:13:08	00:13:28
Hobujaama	540	30	3	181		00:16:28	00:16:58
Viru	549	20	2	114		00:18:51	00:19:11
Vabaduse väljak	338	20	1	70		00:20:21	00:20:41
Kosmos	516	20	1	99		00:22:19	00:22:39
Vineeri	495	20	1	95		00:24:14	00:24:34
Tallinn-Väike	1183	20	1	204		00:27:58	00:28:18
Tondi	442	0	1	87		00:29:44	

Tableau 11 : simulation of total travel time new line 4 Tondi - Suur-Paala

New line 4 Tondi - Suur-Paala	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival *(h:m:s)*	Departure *(h:m:s)*
Tondi	0	0	0	0			00:00:00
Kalev	249	20	0	53		00:00:53	00:01:13
Tallinn Väike	560	0	1	106		00:02:58	00:02:58
Vineeri	1159	20	1	201		00:06:18	00:06:38
Kosmos	473	20	1	92		00:08:09	00:08:29
Vabaduse vjk	472	20	1	92		00:10:00	00:10:20
Viru	566	20	1	107		00:12:06	00:12:26
Hobujaama	348	30	2	120		00:14:26	00:14:56
Paberi	556	20	3	151		00:17:27	00:17:47
Keskturg	394	20	2	80		00:19:07	00:19:27
Bussijaam	617	20	2	125		00:21:31	00:21:51
Lubja	180	20	0	32		00:22:23	00:22:43
Majaka	613	20	0	118		00:24:40	00:25:00
Sikupilli	381	20	1	69		00:26:08	00:26:28
Majaka põik	281	20	0	42		00:27:09	00:27:29
Väike-Paala	618	20	0	98		00:29:07	00:29:27
Suur-Paala	373	20	0	48		00:30:15	
Suur Paala DP	*461*	*0*	*0*		*126*		

Future Line 2 – Lennujaam – Ülemiste – Vanasadam - Kopli

The complete commercial travel time for the line 2 is about 40 minutes 30 in both directions and the commercial speed is about 17,5 from south to north and 17,2 km/h to south which is a little bit slower than modern tramways operating in a similar urban environment.

The travel time between Vanasadam and Ülemiste is about 17 minutes

Tableau 12 : simulation of total travel time new line 2 Lennujaam - Kopli through Vanasadam

New line 2 Lennujaam - Kopli	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival *(h:m:s)*	Departure *(h:m:s)*
Lennujaam	0	0	0	0			00:00:00
Ülemiste linnak	374	20	0	62		00:01:01	00:01:21
Ülemiste jaam	586	20	0	95		00:02:56	00:03:16
Majaka põik	200	20	1	62		00:04:18	00:04:38
Sikupilli	308	20	0	45		00:05:22	00:05:42
Majaka	377	20	1	68		00:06:50	00:07:10
Lubja	615	20	0	118		00:09:08	00:09:28
Bussijaam	172	20	1	44		00:10:12	00:10:32
Keskturg	617	20	2	125		00:12:36	00:12:56
Paberi	398	20	2	81		00:14:16	00:14:36
New Hobujaama	**470**	**20**	**2**	**115**		00:16:31	00:16:51
New Vanasadaam	**955**	**20**	**3**	**197**		00:20:08	00:20:28
New kenuti	**580**	**20**	**1**	**103**		00:22:11	00:22:31
Linnahall	327	20	0	51		00:23:22	00:23:42
Põhja puiestee	412	20	0	71		00:24:52	00:25:12
Balti jaam	444	20	0	75		00:26:27	00:26:47
Telliskivi	342	20	0	53		00:27:40	00:28:00
Salme	216	20	0	41		00:28:41	00:29:01
Volta	444	20	0	60		00:30:00	00:30:20
Krulli	369	20	0	51		00:31:11	00:31:31
Angerja	635	20	0	74		00:32:44	00:33:04
Sitsi	441	20	0	55		00:33:58	00:34:18
Maleva	915	20	0	102		00:35:59	00:36:19
Sirbi	459	20	0	57		00:37:15	00:37:35
Marati	442	20	0	55		00:38:29	00:38:49
Sepa	281	20	0	39		00:39:27	00:39:47
Kopli	225	0	0	38		00:40:25	
Kopli DP	*228*				*43*		

Tableau 13 : simulation of total travel time new line 2 Kopli – Lennujaam through Vanasadam

New line 2 Kopli - Lennujaam	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival *(h:m:s)*	Departure *(h:m:s)*
Kopli	0	0	0	0			00:00:00
Sepa	299	20	0	65		00:01:04	00:01:24
Marati	282	20	0	39		00:02:03	00:02:23
Sirbi	439	20	0	55		00:03:17	00:03:37
Maleva	467	20	0	57		00:04:34	00:04:54
Sitsi	909	20	0	101		00:06:35	00:06:55
Angerja	443	20	0	55		00:07:49	00:08:09
Krulli	633	20	0	74		00:09:22	00:09:42
Volta	370	20	0	52		00:10:33	00:10:53
Salme	443	20	0	60		00:11:52	00:12:12
Telliskivi	219	20	0	42		00:12:53	00:13:13
Balti jaam	341	20	0	53		00:14:06	00:14:26
Põhja pst	451	20	0	76		00:15:42	00:16:02
Linnahall	390	20	0	68		00:17:10	00:17:30
New kenuti	**337**	**20**	**0**	**53**		00:18:22	00:18:42
New Vanasadaam	**580**	**20**	**1**	**103**		00:20:25	00:20:45
new Hobujaama	**955**	**20**	**3**	**197**		00:24:02	00:24:22
Paberi	470	20	2	115		00:26:17	00:26:37
Keskturg	394	20	2	80		00:27:57	00:28:17
Bussijaam	617	20	2	125		00:30:21	00:30:41
Lubja	180	20	0	32		00:31:13	00:31:33
Majaka	613	20	0	118		00:33:30	00:33:50
Sikupilli	381	20	1	69		00:34:58	00:35:18
Majaka põik	281	20	0	42		00:35:59	00:36:19
Ülemiste jaam	189	20	1	61		00:37:19	00:37:39
Ülemiste linnak	573	20	0	94		00:39:12	00:39:32
Lennujaam	373	0	0	59		00:40:31	

3.5.2 Fleet size calculation of the future network

Line	Way	Itinerary (O/D)	Commercial Speed	Travel time commercial	Time at terminus (stop + short break)	Regulation time	Round trip duration	Minimal interval (peak hour)
New line 2	↑	Lennujaam - Kopli	17,57	40:25	02:33	04:03	01:33:25	07:00
	↓	Kopli - Lennujaam	17,22	40:31	01:50	04:03		
New line 4	↑	Suur-Paala - Tondi	15,14	29:44	01:50	02:58	01:11:44	07:00
	↓	Tondi - Suur-Paala	15,55	30:15	03:55	03:02		

With 7 minutes headway and about 1 hour and 12 min round trip time for the new line 4, 11 trainsets are needed in operation during peak period and with the same headway and about 1 hour and half for the new line 2, 14 trainsets are needed.

Line	Rolling stock			
	in line (peak hour)*	in reserve for maintenance *	in reserve for operation*	TOTAL
New line 2	14,00	2	1	17
New line 4	11,00	2	1	14

The fleet in operation during the peak period with the reorganization of the tram network (and the new route through Vanasadam) is finally the same than the current situation.

At moment, line 4 is fully operated with the new rolling stock CAF urbos. Line 2 is partially operated with the old rolling stock (estimated around 40%).

It seems possible to operate the new line 2 (Ülemiste – Vanasadam) at 100% with the new CAF.

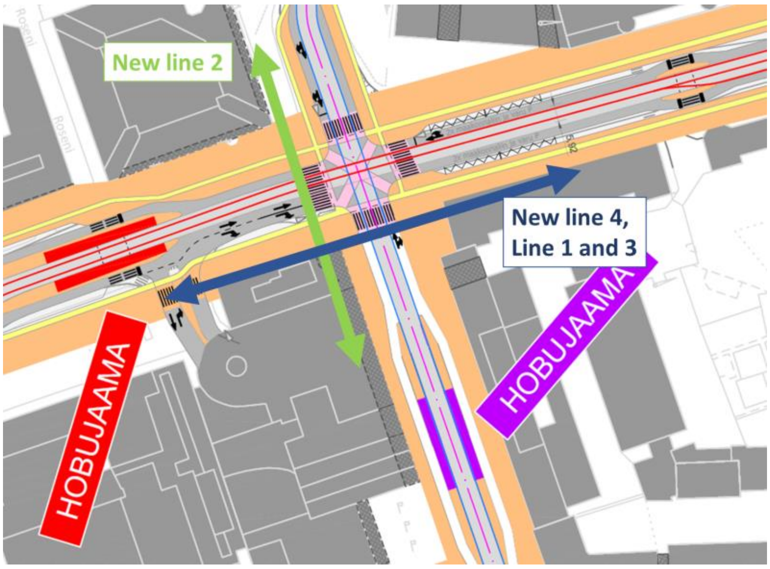
A reserve fleet for maintenance and operation has to be considered in addition to the fleet for peak period operation:

- a maximum of 15% reserve for maintenance, depending on the maintenance strategy (number of daily and weekly shifts…) and for operation reserve.

Our simulation resulted in a total fleet size of 14 trainsets for the new line 4 and 17 trainsets for the new line 2, as for the current situation. There won't be impact on the depot.

3.5.3 Intersection of Hobujaama

The intersection between the two lines requires speed restrictions for the tram lines due to the cross of the rail.



For the priority, 2 possibilities could be apply:

- First in, first served
- Or always to one line

The first solution is the best solution in this case.

3.5.4 Intersection of Liivalaia / Rävala

For the sub option by Rävala, a third line is proposed along Tartu Mint to avoid conflict between line 2 and line 4 to the direction to Tartu mnt.

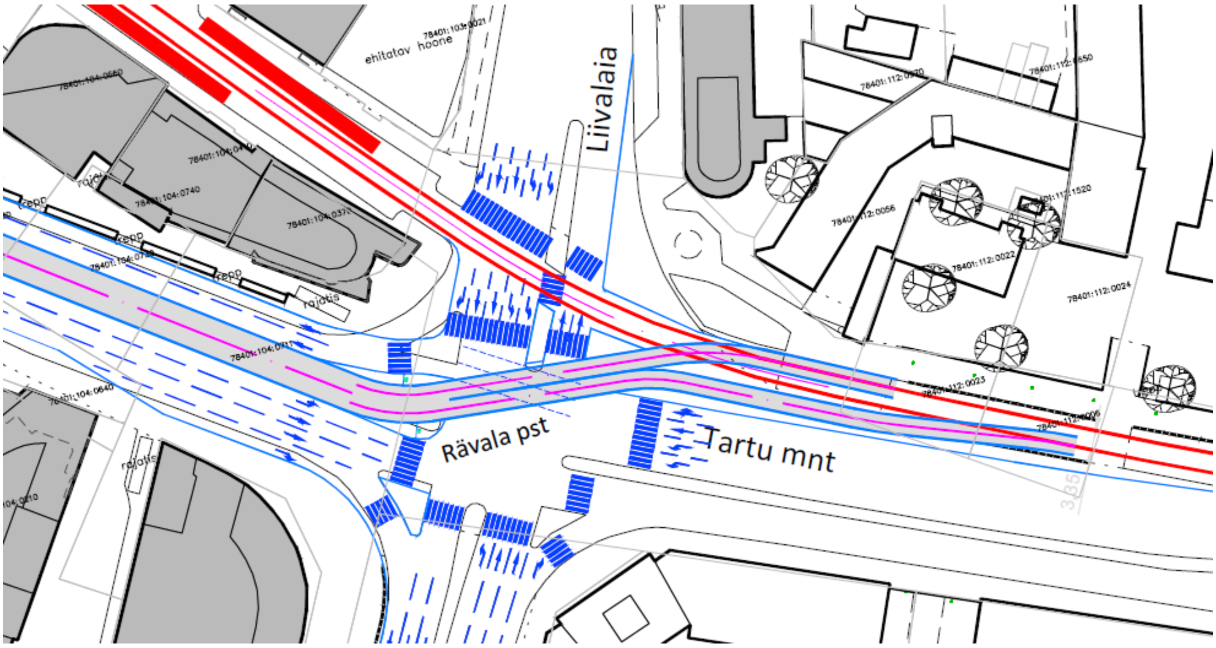


Figure 77 : Tram solution - alternative route on Rävala Street – Egis

Only one conflict between the two lines could have an impact on car traffic when a tramway line 2 from Tartu go through Rävala. A tramway line 4 (green) need to stop to Paberi before go to Tartu mnt.

Tramway movements are shown on next figure. All movement are feasible simultaneously at the exception of one (green tramway).

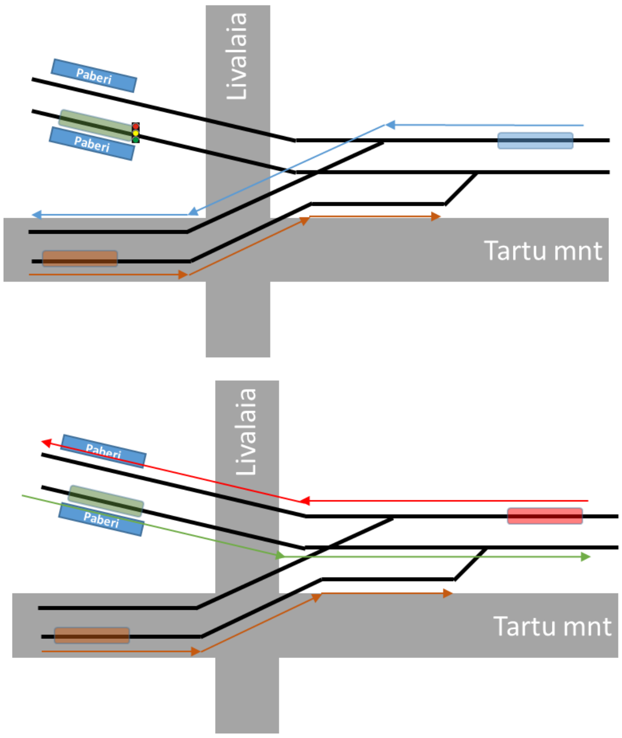


Figure 78 : tramway movements on Rävala / Tartu mnt

3.6. Optimization of travel time on the existing tram line

First solution to reduce the travel time on the existing tramline is to increase the speed limit. First analysis have been made in that way.

The current integration of the tramway mainly on Tartu Mnt don't allowed an improvement of the commercial speed. It is not feasible in terms of investment cost or urban integration to improve the tramway separation from pedestrian or car to increase the speed limit (reconstruction of car roads and accesses, keep away the pedestrian with a barrier for example).

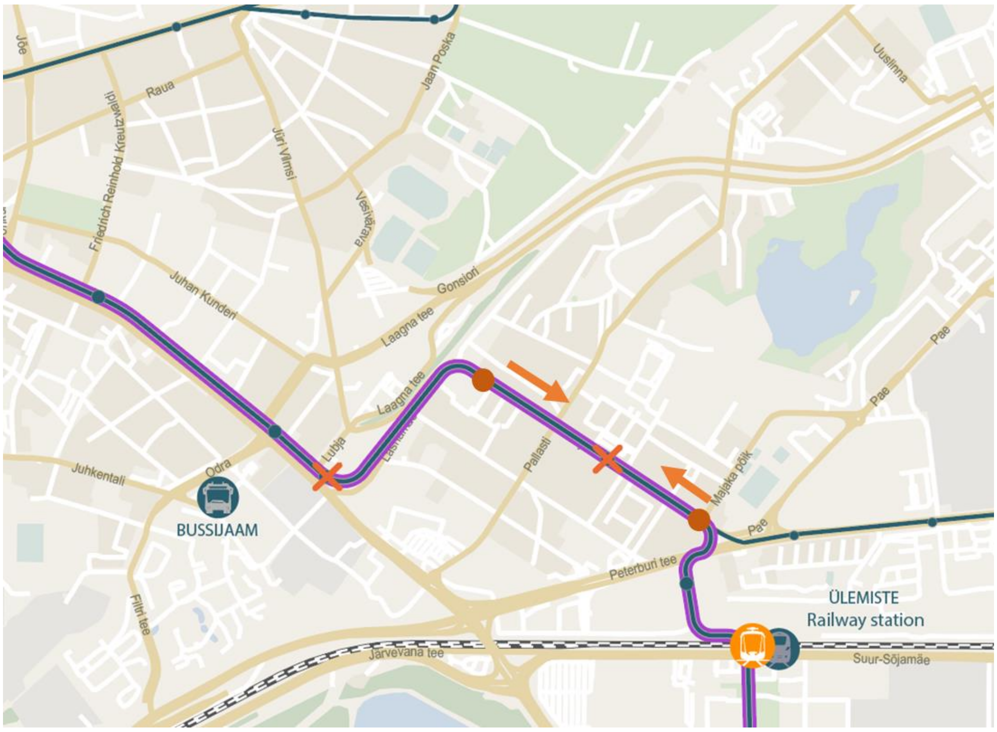
However other solutions are possible and proposed to improve the commercial speed of the tram line between Balti jaam and Ülemiste:

- Reduce the number of stations when the inter-distance is too small (<350-400m)
- By introducing light priorities at intersections
- By creating a 3rd track on existing station in order to stop only on the main stations ;

The urban integration of the third solution is not feasible on the existing line

3.6.1 Reduce number of station:

As explained in the previous paragraph, it is proposed to remove Lubja station and to remove one of the three stations in Majaka area.



The remove of this two stations improves the commercial speed and therefore the travel time between the port and Ülemiste.

In the base solution, the travel time between the port and Ülemiste is about 17 minutes. The remove of the both station reduce the travel time by 1 minute.

This solution is not advice for this project.

3.6.2 Tram priority

At moment, no priority is done to the tramway, it's possible to improve the priority to a level of maximum priority (80%-100%) with a traffic lights regulation. This system allows:

- A better regularity
- An increase of commercial speed
- But a decrease of traffic flow capacity.

Proposed solution

Following chapter specify the main requirements of the Traffic Signaling System. This system will provide the highest LRT priority at the traffic junctions, compatible with the private traffic.

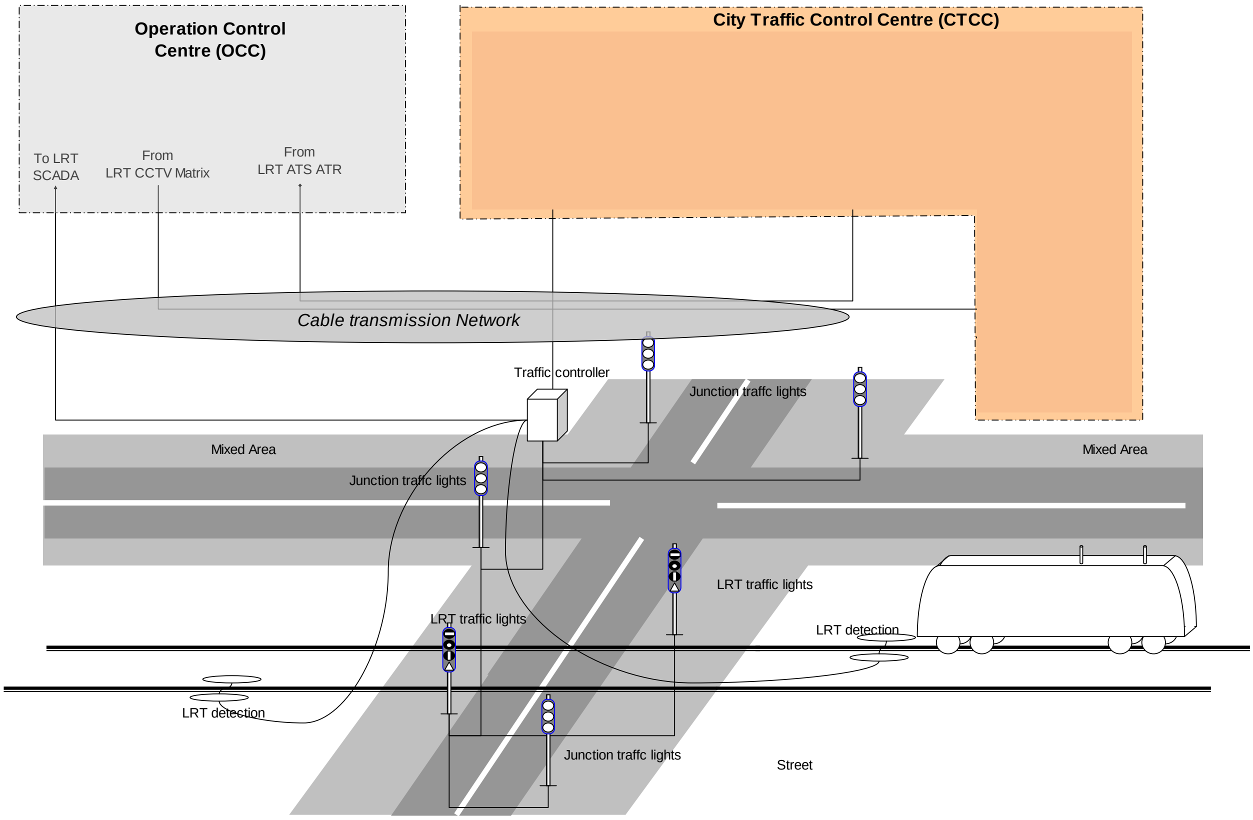
The functions of the traffic signaling are the following;

- Detect the LRT trains approaching a junction,
- Detect the private car traffic reaching the junction,
- Detect the pedestrians crossing requests,

For all normal commercial operations, the traffic signaling system will manage LRT priority at junctions, in addition to routing on the mainline that will be governed by signaled interlocking. The entire mainline shall be double tracked and trains will normally run on the right hand track

Traffic Control shall be provided for traffic junctions situated on mixed traffic areas, as listed in the executive summary and the alignment/profile related drawings.

Technical description



Train detection and location

Train detection and location is ensured using two means:

- For the dedicated right of way, by inductive loops (similar to usual car traffic detection loops),
- For the mixed areas, through the signaling Detection Loops, in order to detect only trams amongst other possible cars or trucks.

Train detectors are generally located upstream the junction considering the train direction:

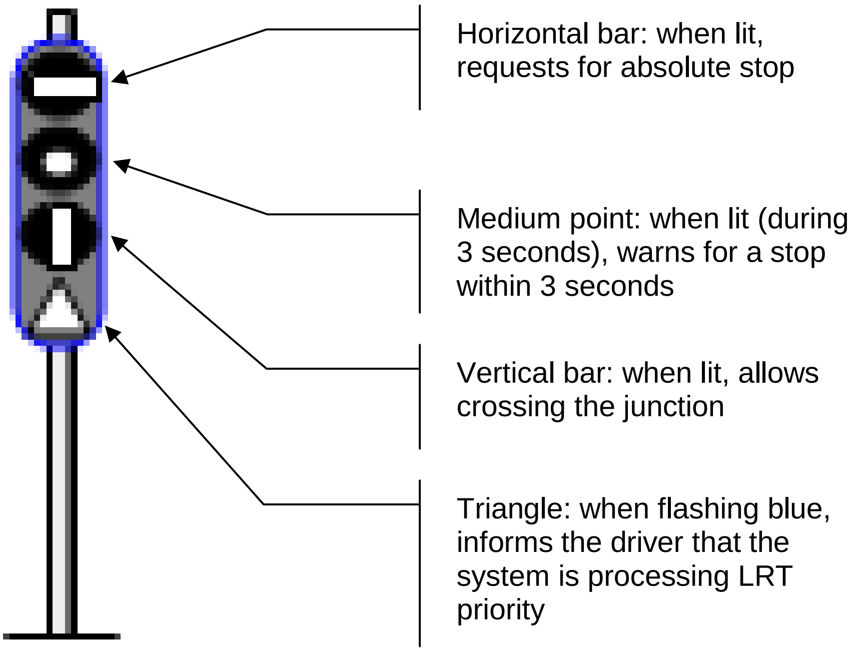
- First approach detector: usually located such as the train has to run about one light cycle before reaching the junction (typically 90 seconds): this detector allows making a first estimate of the "LRT priority window", and therefore to modify the cycle time location itself,
- Middle approach detector: usually located upstream the "driver decision point" (where the driver has to decide or not to start stopping the train to stop before the traffic light with a service deceleration). This information will allow adjusting the start of the LRT Priority window within the cycle, and confirm that priority process is proceeding,
- Close approach detector; usually located a few meters upstream the junction: This detector, when activated will confirm the train crossing, and when de-activated, will trigger the release of the train priority.

These detectors can have different uses with regards to several successive junctions. For instance, a close approach detector for a given junction can play the role of a first detector for the downstream junction.

Tram Traffic Signals

The LRT traffic signals will show different aspect from:

- The City Junction traffic light, to be obeyed by private cars,
- The interlocking signals, related to the safety versus other trains and/or points,
- The following sketch shows the different LRT traffic signal aspect.



Improve of commercial travel time for the line 2 / 4

Traffic lights regulation and LRT signaling on the current section (on Tartu mnt) could improve tram priority to a level of maximum priority of 80 %.

The travel time decrease by 1 minute.

3.6.3 Conclusion

In conclusion, both solutions reduce the travel time by 2 minutes. The travel time between the port and Ülemiste could be about 15 minutes

3.7. Project costing and implementation schedule

3.7.1 Investment costs

Methodology and main hypothesis

The cost estimates are determined on the basis of unit prices applied to quantities:

- The quantities are at feasibility study level of details, they are based on the cross sections and the systems conception presented in the previous sections of the report.
- The costs are Estonian costs for civil works and buildings, and French costs for systems. The Estonian civil works costs are taken as being 75% of the French civil works costs. For the items that mix civil works and systems like "Rail systems" and "Power supply equipment", their price has been taken as 90% of the French costs.

These prices are expressed in euro exclusive of taxes (both internal taxes like VAT, and import taxes) as of their January 2018 value.

Contingencies are added on top of these costs. The contingencies amount is intended to ensure that the project cost does not exceed the overall budget on a constant program basis. At the current level of study, they are included at the level of 15 %.

For the section of infrastructure, the main hypotheses are the following:

Table 1 : Characteristics of the different sections of infrastructure

	Through Gonsiori	Through Rävala
Line length	2 039	2359
Nb of new stations	3	3
Nb of rolling stock units	0	0

Detailed hypothesis

The cost of the project has been broken down into different items which limits are described here below and which description shall always be shown together with the final synthesis table.

Client's direct costs / Consultancy services

This item contains the costs of project management, consultancy services and complementary studies or services (such as detailed project, legal assistance, insurance, communication, consultation, public surveys, archaeological excavations, and topographical, noise and soil surveys, compensation for inconvenience or loss of business during works etc.).

These costs are estimated to be 10% of the total project cost excluding rolling stock.

Land acquisition

Land acquisition are not included in the cost estimates.

Utilities diversion

This involves the costs of diversion of the underground utilities in order to keep independent the operation of the transport system and the maintenance of utilities, whether funded by the organizing authority or otherwise.

For the feasibility study, costs of utilities diversion are difficult to estimate in details. The cost of diversion of utilities diversion are estimated according a ratio per kilometer based on from previous international experience in tramway construction excepted for the main utilities as main pipe of gas or main pipe of heating pipe which are estimated specifically.

Preparatory works

This item includes all the preparatory works for work completion on public property, such as: release of right-of way, cutting down of trees, road diversions, temporary lighting, work site facilities, temporary roads for traffic diversions, etc.

No particular hypothesis has been taken into account.

Civil Engineering works

This item includes all major civil engineering works like tunnels, underpasses, bridges.

For the project, no civil engineering works has been taken into account.

Track way

This item contains the excavation and concrete required to support the rail systems, it also includes the multitubular works.

14 300 m^2 of track way are taken into account.

Rail systems

This item includes the track system adapted to the tramway (sleepers, tracks, water drainage embedded concrete) and track points and crossings located along the line or at the stations backyards.

The track is 2039 m long included the modification of existing track for the intersection of Hobujaama and the link with the existing line at Kanuti and at the intersection between Gonsiori and Tartu mnt. 250 m are considered to be floating slabs systems on Hobujaama Street.

Track way cover

This includes the right-of-way covering: filling between rails, surface covering and separators of right-of-way.

The separator in made of concrete all along the line. The covering is 100% concrete except for intersections.

Roads and public spaces

It includes the roadway and public spaces works required for restoring the public space: earthworks, structural works, pavements and coverings.

The estimate takes into account 15 000 m² of renewed streets and 14 200 m² of renewed sidewalks and bicycle lanes.

Urban Facilities

It includes the urban equipment located along the line: planting, urban furnishings, benches, fences and guard rails.

The following hypotheses are taken into account: 10 trees are planted, 3 000 m² of grass is laid out, 2 000 m of public lightning are renewed.

Road traffic signaling

It includes the road signaling:

All the major junctions are equipped with traffic lights.

Stations

This item includes the civil engineering: structural work and finishing work. It also includes the station equipment: station furnishings including shelters, benches, fences, lighting.

3 new stations are implemented.

Power supply equipment

This item includes all the facilities needed to distribute power to the electric traction vehicles: substations, power instrumentation and control system, connection to the distribution networks, overhead line and its poles and anchors.

The estimate take into account 2 substations for this project (1 substation could be enough depending of the residual supply on the existing network). *The whole line is equipped with an overhead contact line. Standard support masts are implemented* at the exception of *Hobujaama Street and Gonsiori Street where the line will be fixed on building.*

Low voltage and OCC

This item includes all the low voltage equipments of the systems (especially stations equipment). It also includes tramway signaling and the OCC equipment required for the centralized management of the system. The OCC building is part of the next item.

The low voltage equipments are listed in section "System conception" of this report. The estimation don't take into account of new OCC. The turnouts at intersections with the existing infrastructure are equipped with signaling.

Workshop & Depot

This item includes all the elements of the depot and workshop, including buildings and equipments: internal tracks, overhead lines and poles, signaling, washing and maintenance equipments…

For the project, no investment on the depot has been taken into account.

Rolling Stock

In addition to the vehicles themselves, this item includes the cost of testing and commissioning equipment.

No new rolling stock is required.

Results

With these assumptions, the cost of the extension is estimated in the range of 21 to 24 million euros depending on the preferred alternative (2018 cost excluding taxes, without land acquisition and utilities diversion).

For each alternative, the synthesis tables are presented according to the above mentioned cost breakdown:

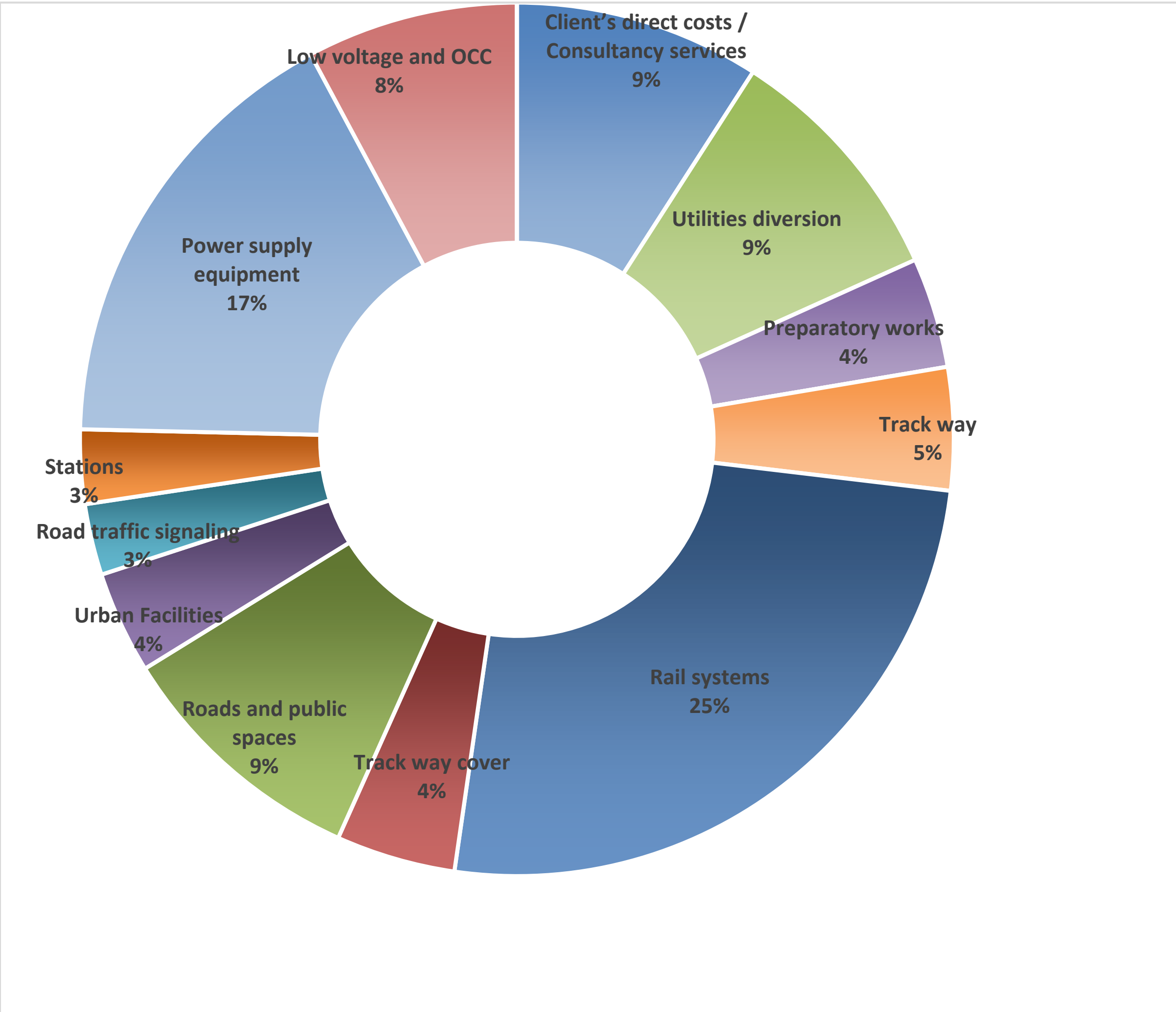

Client's direct costs / Consultancy services 9%
Utilities diversion 9%
Preparatory works 4%
Track way 5%
Rail systems 25%
Track way cover 4%
Roads and public spaces 9%
Urban Facilities 4%
Road traffic signaling 3%
Stations 3%
Power supply equipment 17%
Low voltage and OCC 8%

Table 2 : Investment costs for the solution through Gonsiori

Client's direct costs / Consultancy services	**2 121 k€**
Land acquisition	
Utilities diversion	**2 139 k€**
Preparatory works	**953 k€**
Civil Engineering works	**0 k€**
Track way	**1 060 k€**
Rail systems	**5 928 k€**
Track way cover	**1 031 k€**
Roads and public spaces	**2 216 k€**
Urban Facilities	**883 k€**
Road traffic signaling	**615 k€**
Stations	**640 k€**
Power supply equipment	**3 922 k€**
Low voltage and OCC	**1 826 k€**
Workshop & Depot	**0 k€**
Rolling Stock	**0 k€**
Total	**23 336 k€**

Table 3 : Investment costs for Rävala alternative

Client's direct costs / Consultancy services	**2 396 k€**
Land acquisition	
Utilities diversion	**2 475 k€**
Preparatory works	**1 148 k€**
Civil Engineering works	**0 k€**
Track way	**1 241 k€**
Rail systems	**6 665 k€**
Track way cover	**1 209 k€**
Roads and public spaces	**3 109 k€**
Urban Facilities	**981 k€**
Road traffic signaling	**615 k€**
Stations	**640 k€**
Power supply equipment	**4 033 k€**
Low voltage and OCC	**1 846 k€**
Workshop & Depot	**0 k€**
Rolling Stock	**0 k€**
Total	**26 360 k€**

The cost of the alternative through Rävala is 12% more expensive than the base alternative through by Gonsiori.

3.7.2 Implementation schedule

Overview

After the approval of the current feasibility study, the main elements that have to be taken into account in the implementation schedule are:

- The preliminary and detailed design, followed by the tendering process for the extension of the line works.
- The administrative procedures including the land acquisitions, if any.
- The testing and commissioning of the system.

All these tasks have to be supervised by a strong project implementation unit and/or a general consultant.

The hypothesis taken here is that the project will be implemented through traditional public procurement.

Detailed design

The detailed design will be the basis for the tender documents. This study requires an approved preliminary design and some public consultation to make sure that the project will be granted public approval.

The experience of past tram lines show that this phase is one of the most critical study phase: it is the stage when all decisions have to be taken and finalized. As the detailed design maps will be used by the contractors performing the works in order to draft their shop drawings, they should be as close as possible to the final project.

Administrative procedures

This task includes all the administrative procedures required to get the necessary permits for starting the construction works and performing the land acquisitions.

Main line works phasing

After the tendering process, the works of the main line start on all sections simultaneously and take about 24 months. Civil works start first followed by the system implementation. This allows an opening of the line at the end of 2023.

Testing

After completion of works on the main line, testing can start. Full testing of a tram line takes about 6 months.

Results

With the hypotheses considered here, the extension of tram line until the port could be

The summary planning is shown below and the detailed planning after.

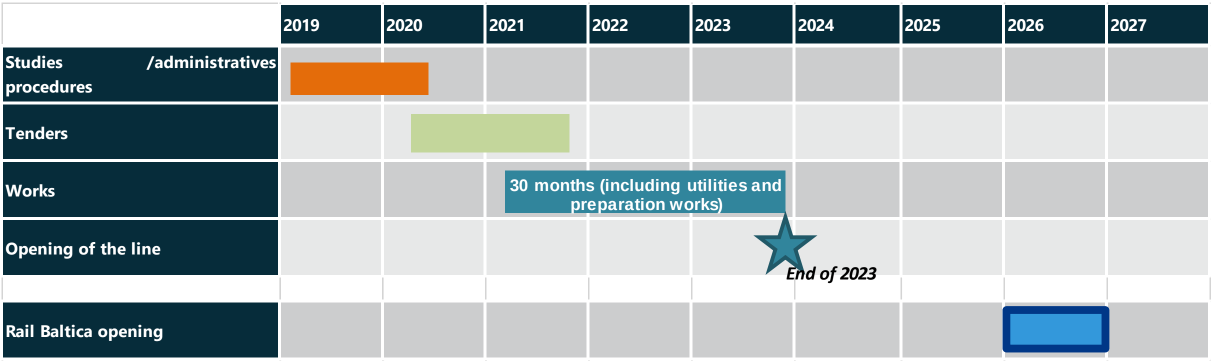


Figure 79 : Tram option - Summary implementation schedule

However, according the **opening of Rail Baltica, it is proposed to take 2026 for the beginning of the commercial operation of the project between Ülemiste and Vanasadam.**

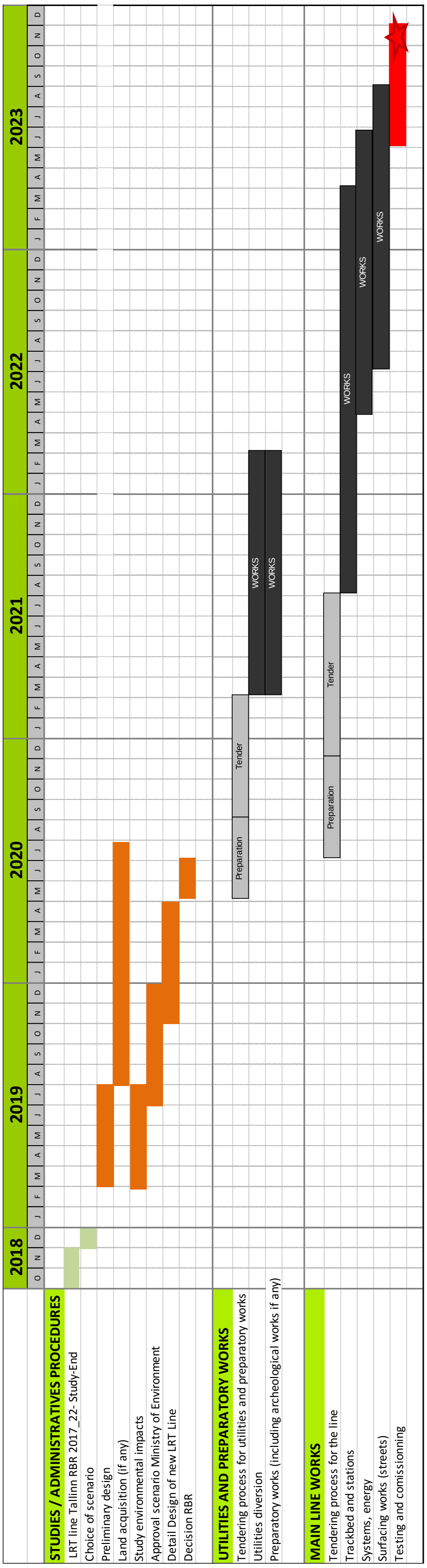
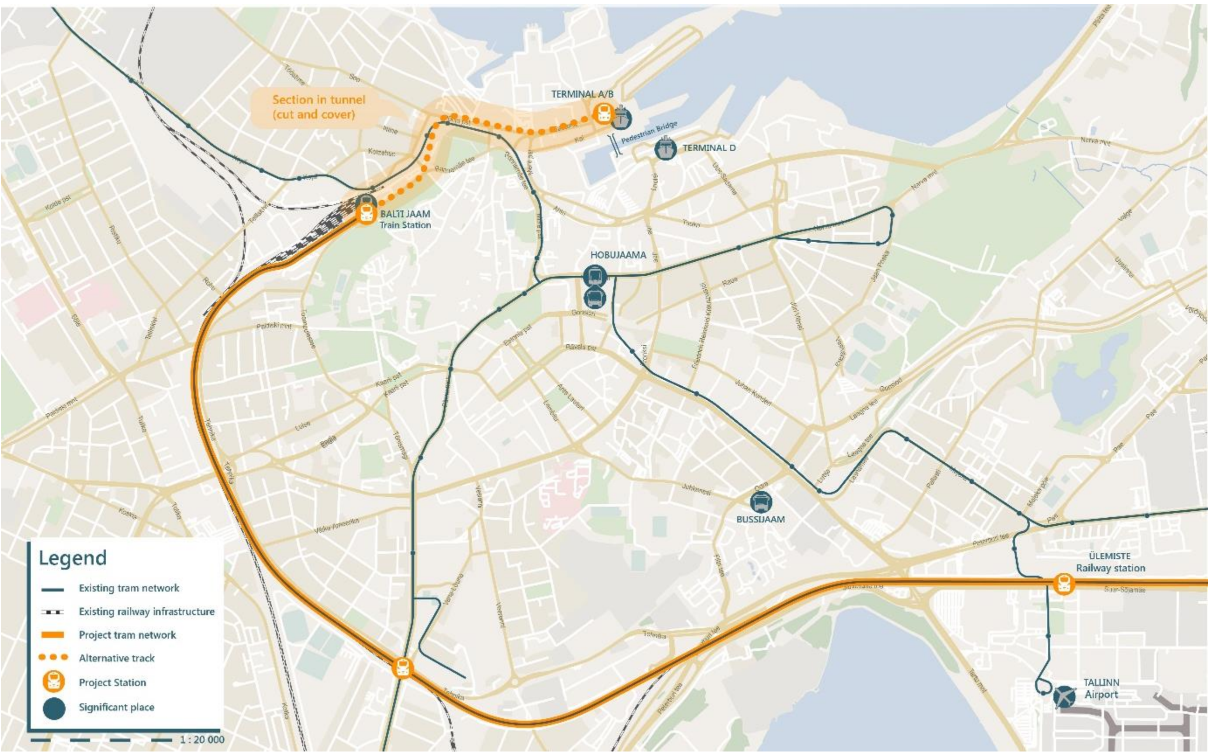


Figure 80 : Tram option - Detailed implementation schedule

4. Train option – Technical feasibility

4.1. Description of the option

This option propose to connect Ülemiste Rail Baltica station to Vanasadam by reusing the existing ring railway infrastructure between Ülemiste and Balti jaam and creating a new underground infrastructure between Balti jaam and Terminal A/B.



Only one new railway stop is added to the terminal.

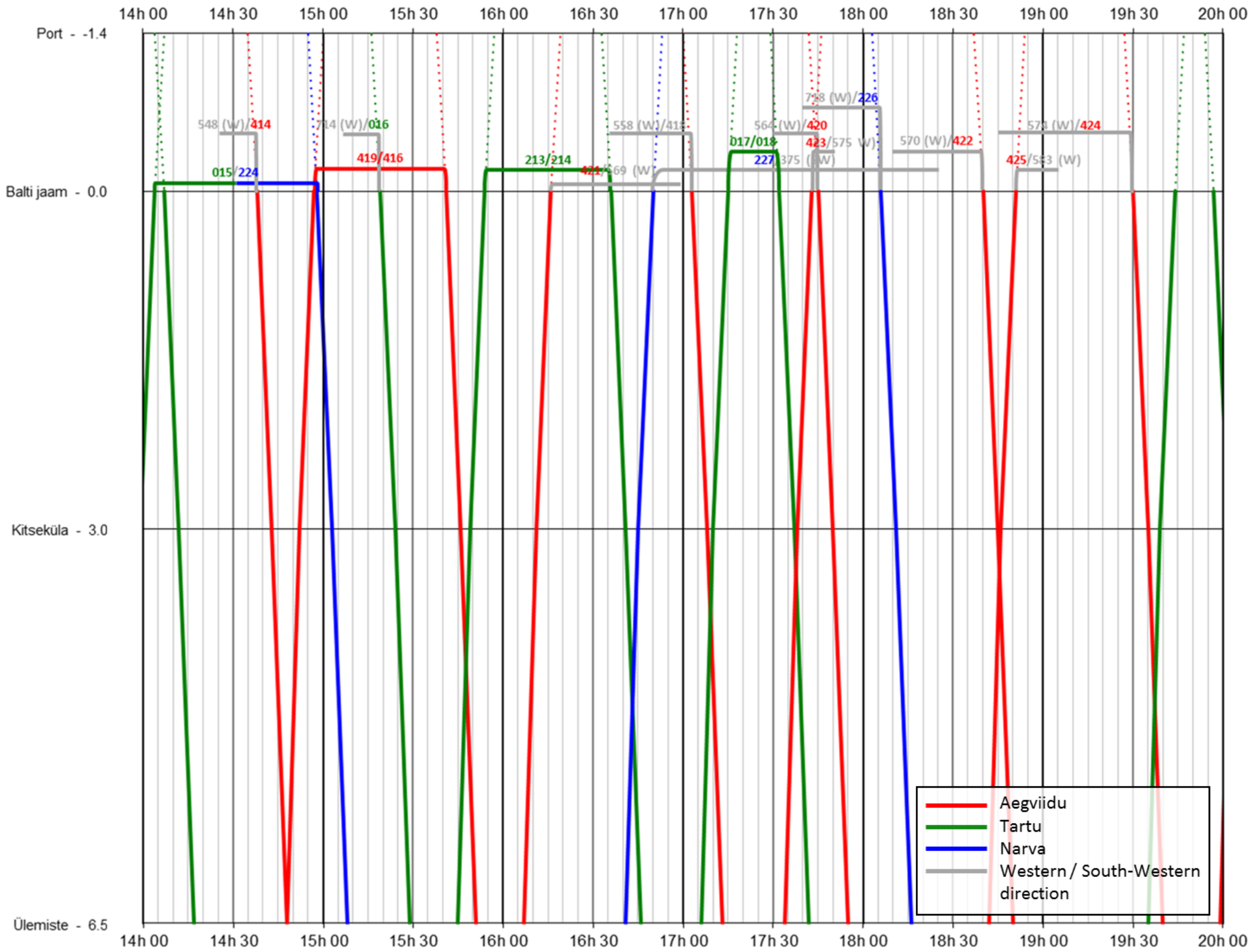
No additional stations are added between Old Harbour and Ülemiste RB terminal, the main purpose of the study is to study the options to connect quickly the both node and so to keep a limited travel time. For this reason no new stations were considered for train option.

However, that does not take into account traffic potential of ridership for new stops or Origin-Destination relations between existing stops (e.g. Kitseküla – Ülemiste) new node type stops for interconnections.

Service definition

As presented in chapter *1.1.2 Existing train service,* the current operation plan is quite complex. This chapter aims at outlining the proposed train option, without reconsidering the whole operating concept of the railway network.

First of all, it should be noted that an extension of every Eastern services from Balti jaam to the Port (as represented by dotted lines in the figure below) would require at least the same number of tracks as the tracks used today at Balti jaam terminus station for these eastern services. However, the creation of an extensive track layout at the Port terminal station is not conceivable in this scenario.

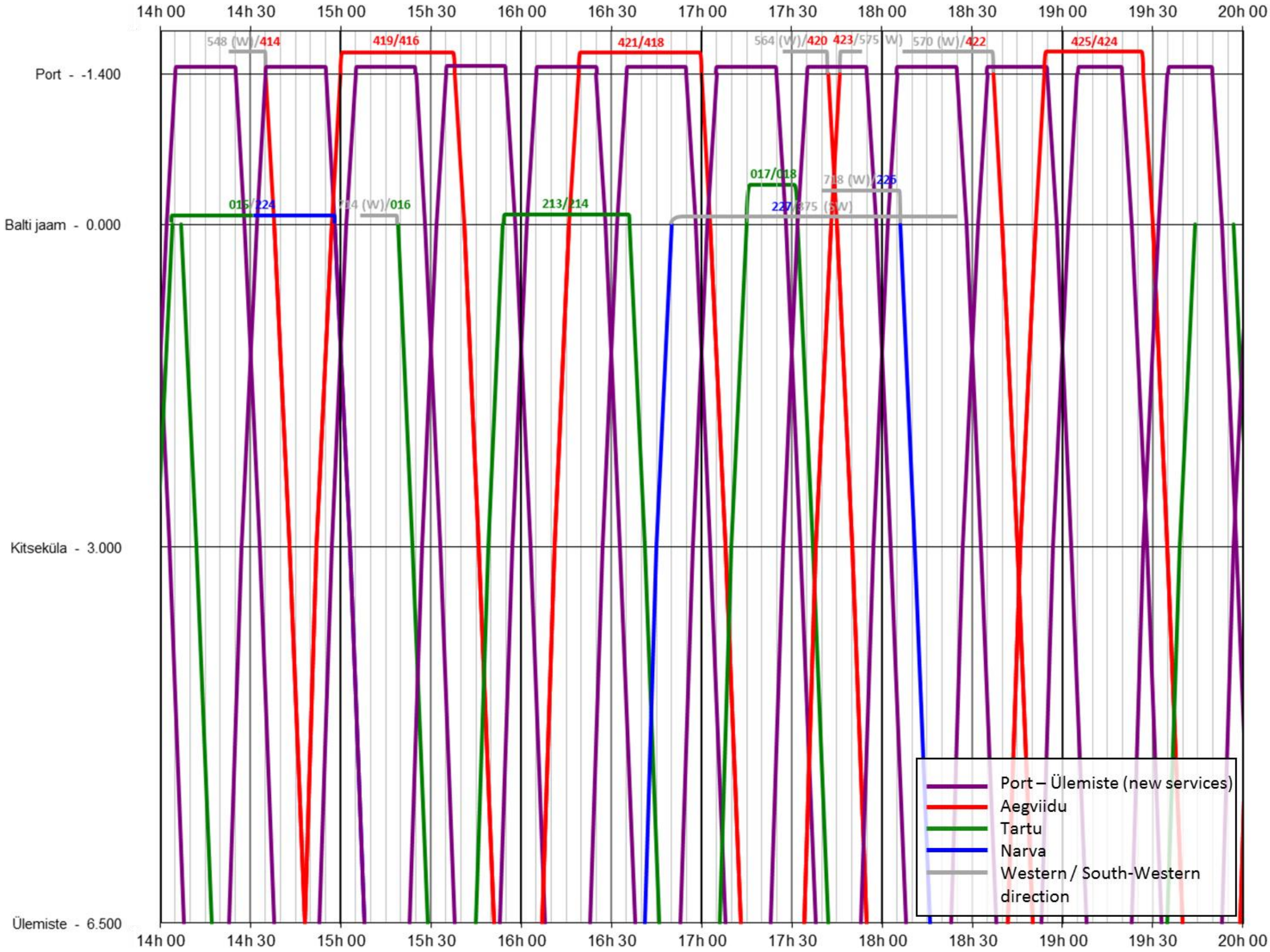


This is why the proposed concept consists in extending, among the existing services, only the services from/to Aegviidu, in order to keep enough capacity to create new services between Ülemiste and the Port.

In this option, new services Port – Ülemiste are created with a headway of 30 minutes (two trains per hour per direction). These new services, represented in purple in the following space-time diagram, are assumed to have:

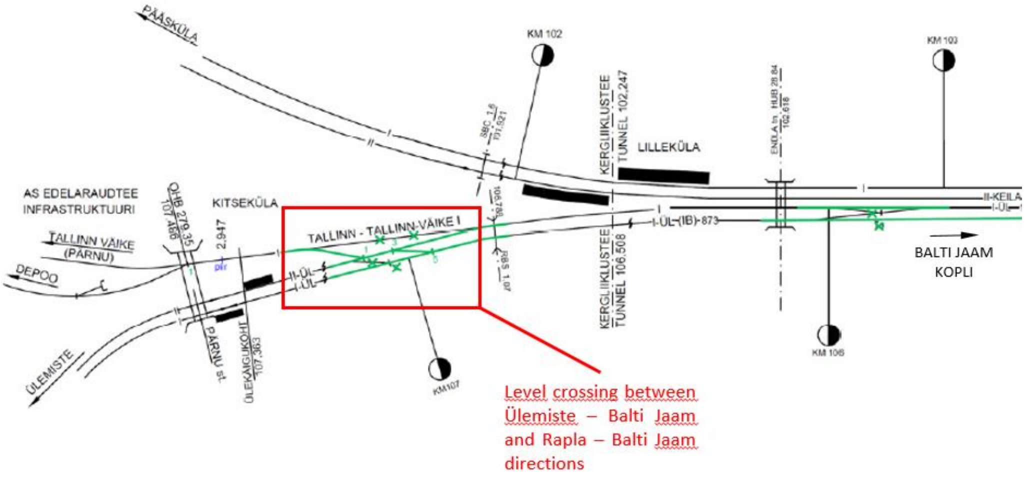
- A journey time of 13 minutes from the Port to Ülemiste and from Ülemiste to the Port this travel time includes the current travel time between Ülemiste and Balti Jaam (about 9 min), the dwell time in Balti Jaam (about 2 min) and the travel time between the Port and Balti jaam (about 2 min)

- A turnback time of 15 to 20 minutes at Port and Ülemiste terminal stations.



With minor adaptations of the existing services which are extended to the Port (shorter times in the terminus…), it is estimated that **two tracks** are necessary at the Port terminus station.

The impacts on the other branches have to be analyzed as part of a specific operation study of Balti Jaam rail hub. This study should include a detailed analysis of the potential conflicts between Port-Ülemiste new services and directions Tapa-Balti Jaam and Rapla-Balti Jaam.



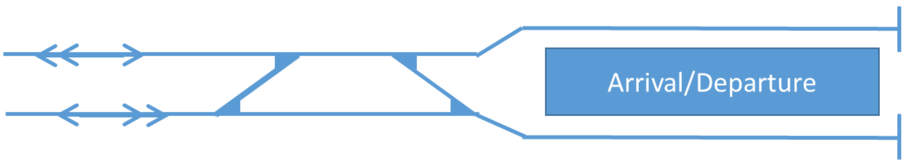
4.2. System conception

4.2.1 Track layout design

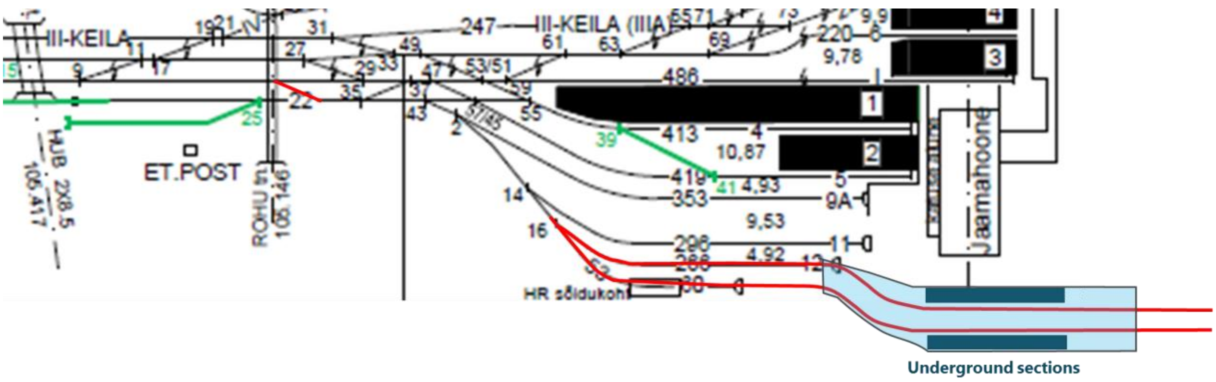
The track plan illustrates the overall functional layout of the line.

- In Vanasadam, turnback in front of the station to can located the plateforms in front of Terminal A/B

Vanasadam



- In Balti jaam, the extension require modification of the track layout, and signaling and platforms



  – A new turnback is required

- The extension ties-in with current tracks n°12 and 60. Track n°11 is also impacted as it is accessible via the single track section where the extended services will run.
- Estonian Railways indicate that these 3 tracks are necessary for supporting roads for international passenger trains and tourist trains, reserve trains for domestic passenger trains and infrastructure for managing rolling stock, considering also the prospect of eliminating Kopli's cargo station.
- It is noted that operational adaptations are required to recreate these functions, representing an important constraint for this scenario.

- Design of Turnback behind Ülemiste station has not been studied. Indeed Ülemiste Rail Baltica project is under development. According to the uncertainties of implementation of Rail Baltica station, it proposed to stay at a functional analysis of the requirement (in the project costing, it is considered the turnback: crossovers and tracks behind the station and signaling modification).
- It is noted that 3 to 4 trains run at the same time on the extension. In case of traffic disruption on the line, trains can be stabled in the stations. A short service may also be implemented between Balti jaam and Vanasadam (to be confirmed with more detailed information in further studies).

4.2.2 Rolling stock

The round trip time for the new services Port – Ülemiste is 60 minutes. With a headway of 30 minutes, the rolling stock fleet on-line comes to 2 trains. In the project costing, it is considered an additional train (reserve for operation and maintenance), leading to a total rolling stock fleet of **3 trains**.

4.2.3 Traction Power Supply

Traction power supply is 3Kv on the current network. Eesti Raudtee confirmed that no new traction substation will be required for new services.

4.2.4 Signaling system

Signaling system will be adapted at the current signaling system. Train control system is ALSN.

4.2.5 Traffic management system

According to Estonian Railways, the traffic management system of the additional line must be linked to the EVR traffic management system. Port - Ülemiste line will likely be part of Estonian Railways traffic scheduling/timetable system.

4.2.6 **Cut and cover construction**

Underground sections can be constructed with cut-and-cover technology when the alignment goes along wide enough arterials or along green area, meaning from Balti jaam and the port. The impact of the construction stage is maximal, but the technology is simpler and cheaper than with tunnel sections, and it allows shallower alignment and stations.

The track level would there be at 14 m below ground, leaving a space above in station Balti jaam for a distribution mezzanine. This also keeps the possibility of crossing major transversal utilities and minimizes the impact of train vibrations on the adjacent buildings in comparison with a shallower alignment.

Between stations, the track line will be shallower with a minimum of 8 m.

4.2.7 **Design criteria**

First of all, the extension between Balti Jaam and the Port is only dedicated to passengers. There is no fret in this part.

- Rolling stock

The conception is based on the rolling stock: Flirt of Stadler

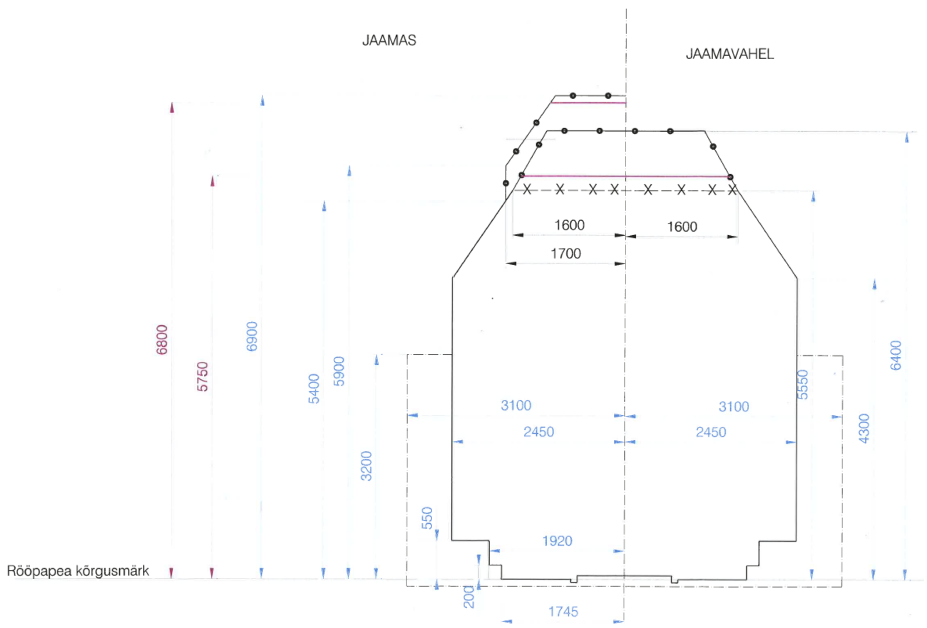


Figure 81 : vehicle obstruction gauge limit for train in Estonia

Here below the technical characteristics of the Flirt (Stadler)

– Electric trains

	3-carriage	*4-carriage*
Number of seats	196	274
Standing room	160	222
Gross weight	130 t	159 t
Length	57,7 m	75 m
Width	3500 mm	3500 mm
Maximum speed	160 km/h	160 km/h
Acceleration	1.2 m/s²	1.2 m/s²

– Diesel trains

	2-carriage	*3-carriage*	*4-carriage*
Number of seats	105	161	214
Standing room	99	154	211
Gross weight	124 t	148 t	176 t
Length	45,5 m	59,9 m	74,3 m
Width	3500 mm	3500 mm	3500 mm
Maximum Speed	160 km/h	160 km/h	160 km/h
Acceleration	1.05 m/s²	0.85 m/s²	0.85 m/s²

- Alignment

Minimum radius curve: 250m / 150m outstanding value without significate ramp (<2%)

Distance between tracks in straight alignment: 5,1m

- Ramp

At this stage of feasibility we propose first values that fit to passengers transport.

Length (m)	Ramp %
∞	<20 ‰
≤2000m	<25 ‰
≤1000m	<30 ‰
≤400m	<35 ‰

- Station

Platform length: 150m (double trains)

Lateral Platform / minimum width: 3,5m

Central platform / minimum width: 4 m

Distance between 2 opposite platforms (2 tracks): 8,6m.

4.3. Identification and analyses of alignment option

4.3.1 From Ülemiste station to Balti Jaam

The trains are passing through the existing railway tracks from Ülemiste until the beginning of Balti Jaam tracks. The trains have a Russian gauge, and for this reason they are naturally on the tracks on the side of the center of the city all along the route.

The concept consists in localizing the underground station just next to the existing train station on the South side, under Toompuiestee. With the maximal ramp of 3,5%, the trains must start the slope quite far away before the existing train station. The difficulty of the alignment is to manage to zigzag between the EESTI RAUDTEE building and the SHNELLI HOTEL building, both with 7 stories. No underground parking has been identified. It is possible to slalom by keeping around 3m minimum of distance between the wall of the cut and cover and the buildings. This sequence is technically feasible with a width of 12.8m for the cut and cover tunnel.

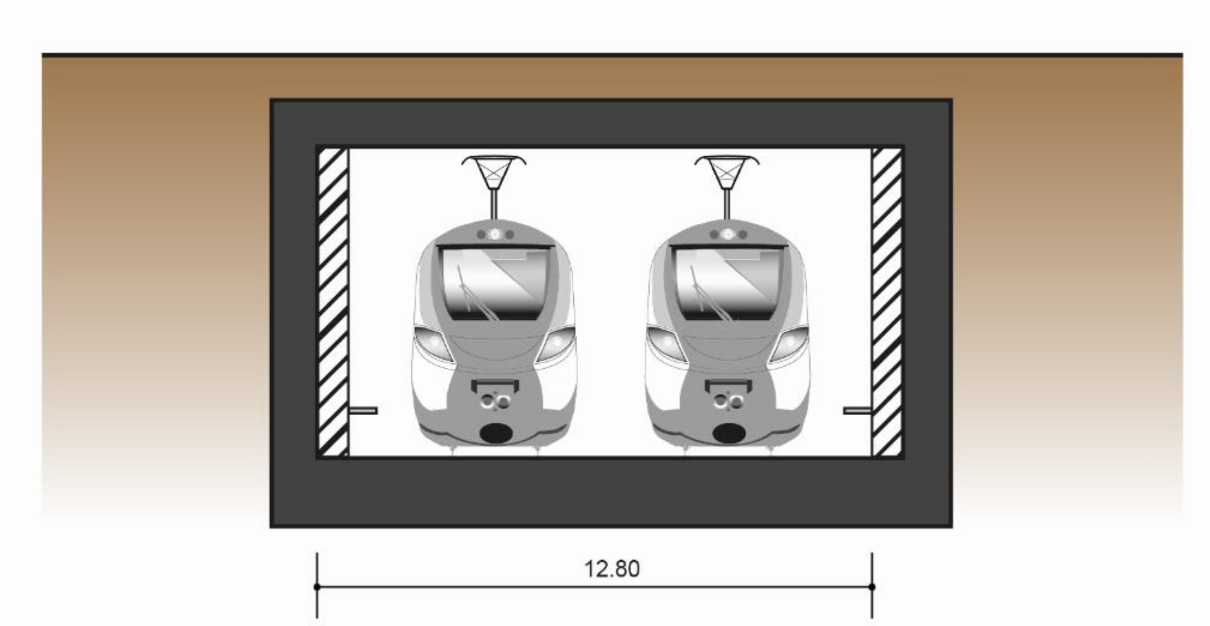


Figure 82 : Train option - section on cut and cover tunnel - Egis

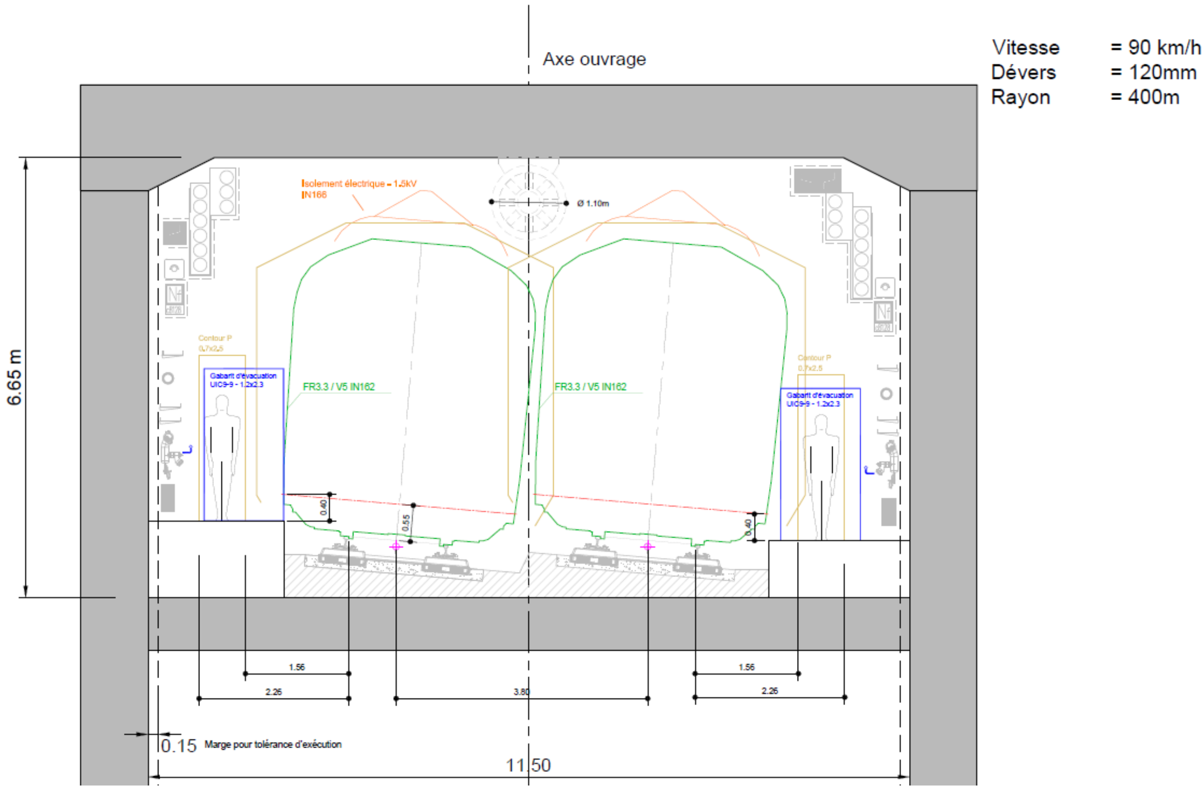


Figure 83 : typical section of cut and cover tunnel for train – NFL - Egis

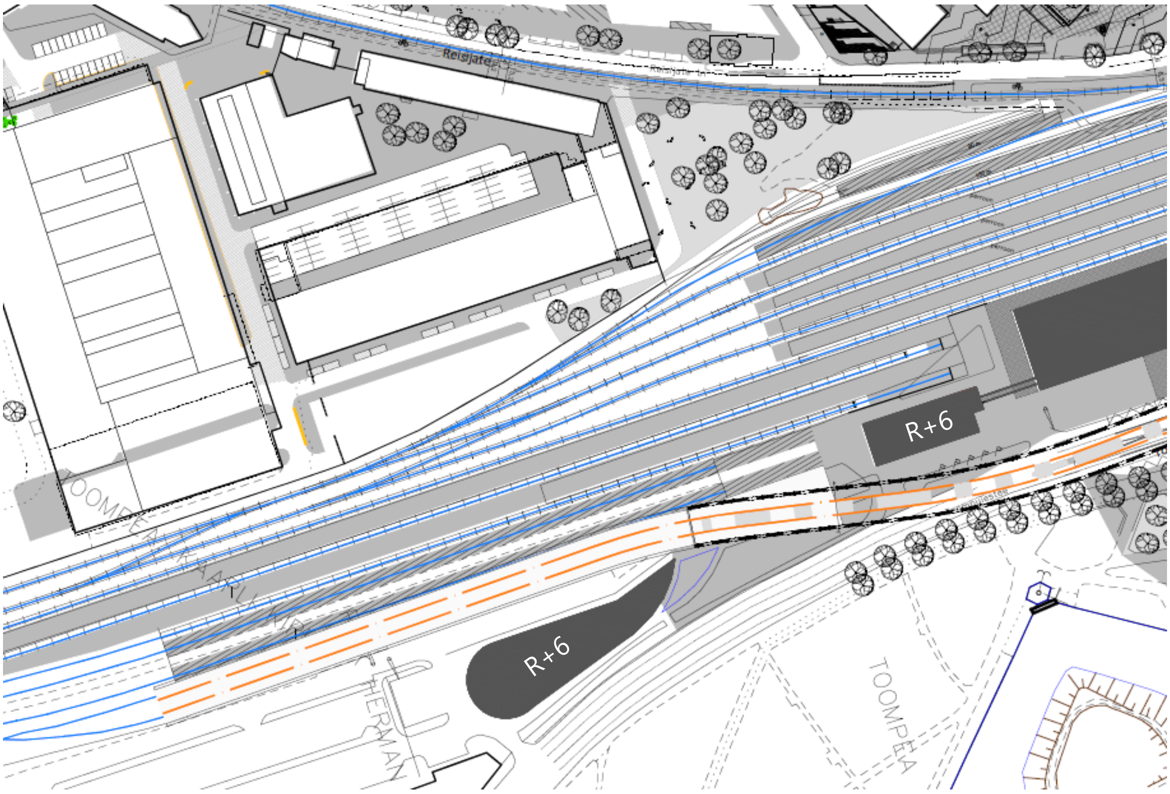


Figure 84 : Train option - plan of the alignment of the ramp in zig zag in Balti Jaam - Egis

Figure 85 : Train option - longitudinal section of the ramp – Egis

Anyway the ramp must be completely close to people. Fences must be install all around the perimeter, that's why the ramp must begin as soon as possible.

4.3.2 Balti Jaam – underground station

The access to the underground station is close to the train station's building, to be clearly identified by the passengers. If needed the access could be integrated to the existing building. The projected platforms are in a lateral configuration. It is more compact than with a central platform.

A concourse level is proposed in order to keep the underground passage for pedestrians. In the same time the concourse level allows passengers to choose easily the good platform with a unique access. For more convenience and in order to provide an underground passage to cross the road. There are 2 accesses on the West side and 1 access on the East part.

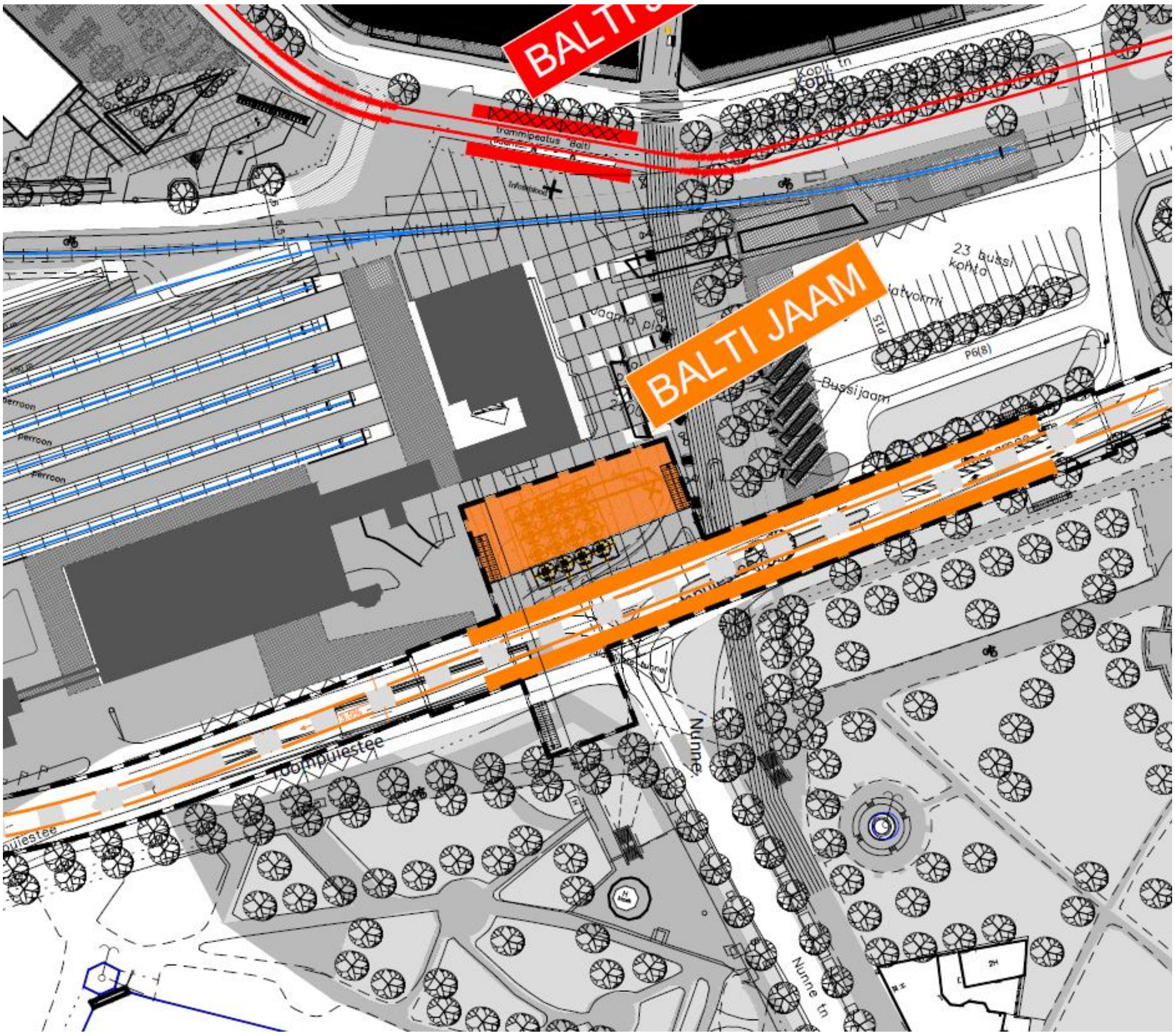


Figure 86 : Train option - Balti Jaam station - Egis

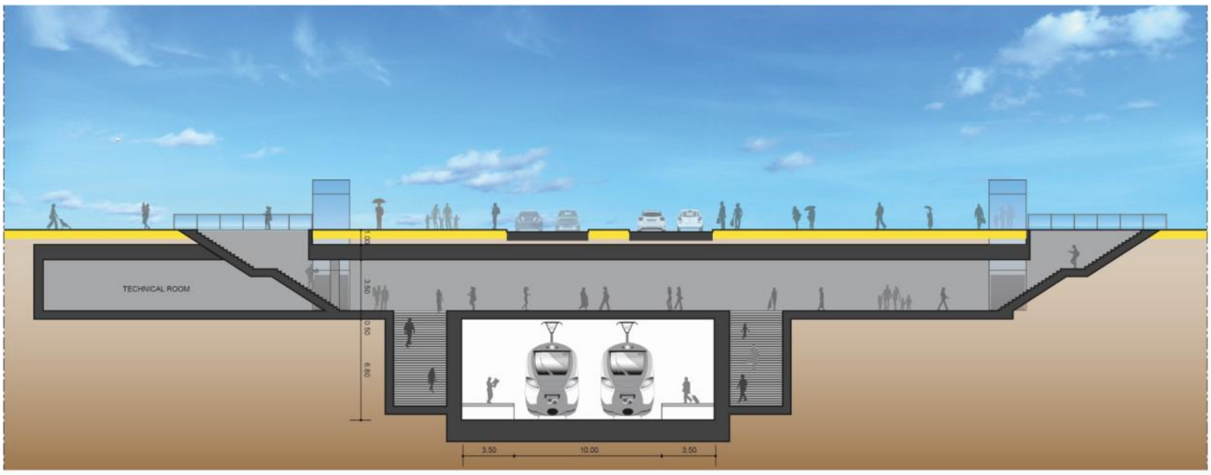


Figure 87 : schematic transversal section of the station - Egis

Two extra emergency stairs are positioned at the North extremity of the station in order to avoid long dead-end on the platform. Emergency calculation should be necessary in the later stage of study.

4.3.3 From Balti Jaam station to Vanasadam station

The alignment of the train line is always in a shallow underground integration under the green field of the park. To avoid the existing buildings, and the wall of the bastion that is classified as heritage to preserve, it will run under the existing tramway line. The radius of the curves span from the minimal 150m to 300m. Whenever the minimum 150m radius is used a decrease of speed required and a technical specification must be issued to the section.

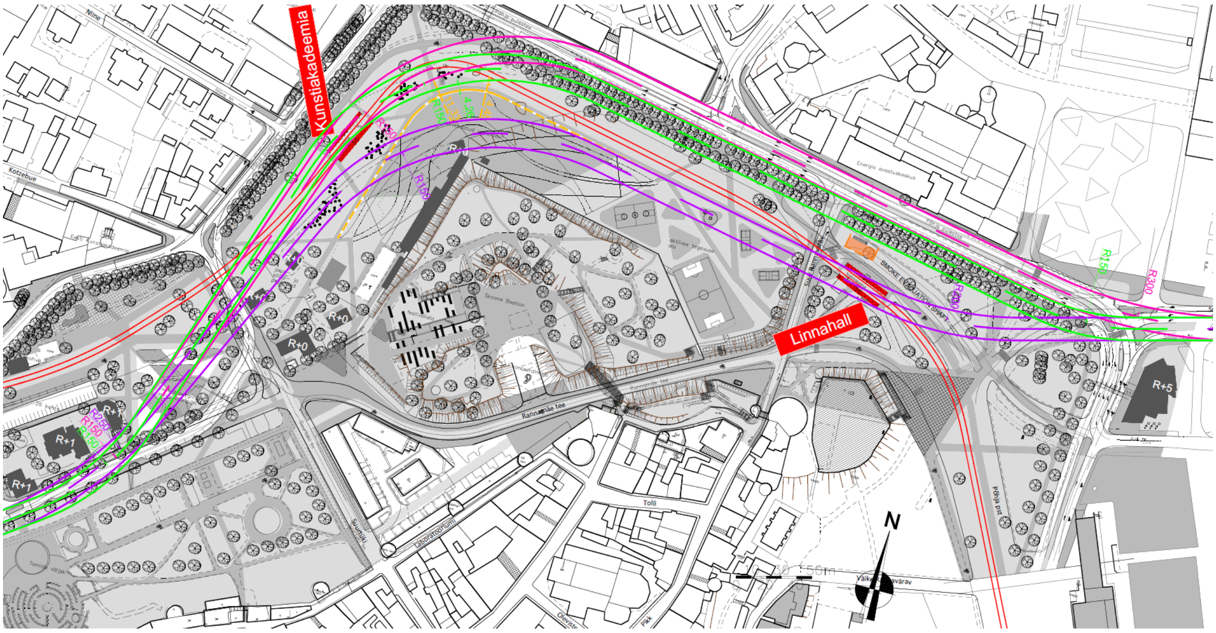


Figure 88 : Train option - alignment around the bastion - Egis

The figure above show three possible options to the track alignment.

Violet – before the acquaintance of the existence of a wall to be preserved by the bastion (yellow in the scheme), the proposal would pass completely inside the park around the bastion, and turn to Sadama road still within the perimeter of the park. This option would not interfere with the operation of the existing tramway nor with the traffic on Põhja Puistee. **Not feasible for heritage preservation reasons**.

Green – To prevent the intersection of the heritage wall a first section will pass under the existing tramway line, with major impact on its operation during construction, and a second section would run alongside Põhja Puistee, forcing the removal of the existing tree array. **Not considered for tree preservation purposes.**

Pink – another option that prevents the classified wall, passes under the tramway line on a first section and under Põhja Puistee on a second section before joining Sadama street axis. This option obliges to the interruption of the tramway circulation and a deviation of Põhja Puistee traffic during construction, and, **given the proximity of the northern urban front, the removal of the northern tree array might be necessary to implement it.**

The Heritage department of Tallinn is more favorable with the pink solution. After the green fields, the alignment passes under the central island of Sadama Street until the terminal A-B.

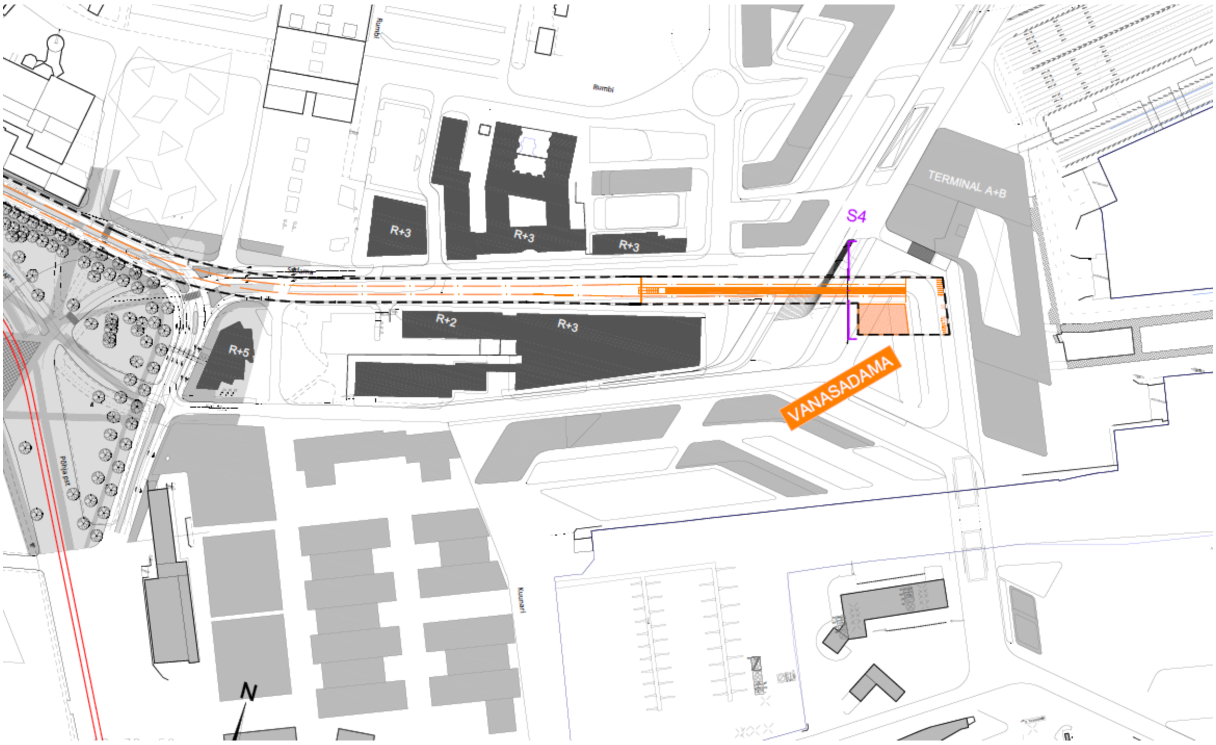


Figure 89 : Train option - Vanasadam sequence - Egis

This section under the Sadama Street and the station are proposed here in shallow underground in order to keep high qualitative urban design. The new quarter of the port already combines a lot of different flows (pedestrians, bicycles, cars and coaches) and needn't a hard urban rupture that would occur a train station and a train ramp forbidden to people. It could represent a length of 350m which could not be crossed by pedestrians nor cars.

4.3.4 Vanasadam station

The train station is still underground with a central platform. This configuration avoids a long turn-back of the train, which is impossible without being very deep. Here the platform is very shallow. At the same time it implies less stairs and elevators on the surface. Due to the future drop off it could be interesting to limit the impact on it by limiting the number of stairs. The main access is localized just in front of the building of the terminal A-B and with a straight route to the pedestrian bridge and to the terminal D.

A second access is proposed on the central island of Sadama Street. It provides also an emergency exit of the platform, which is 150m long.

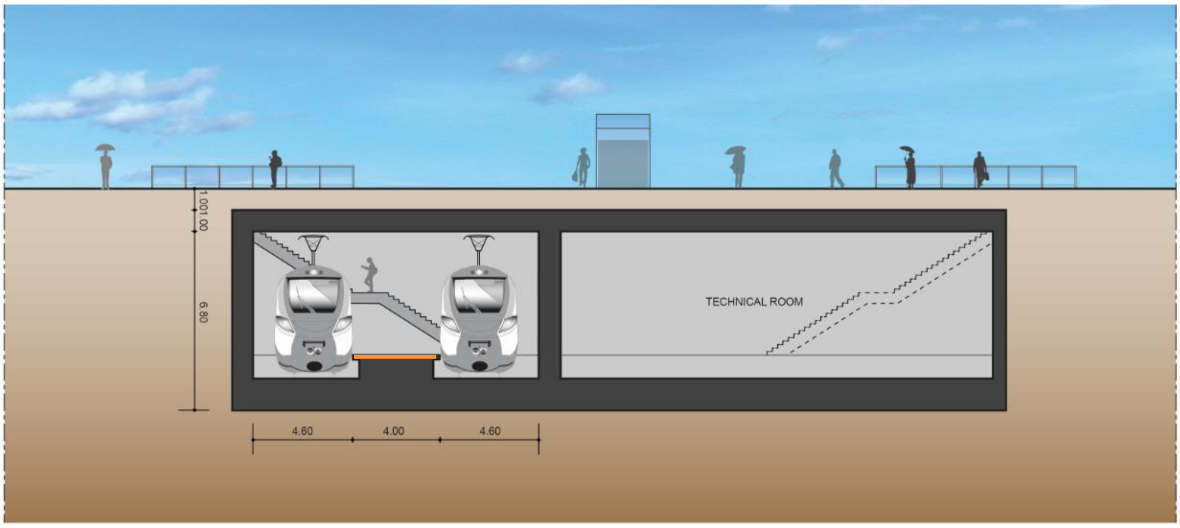


Figure 90 : schematic transversal section of the Vanasadama station – Egis

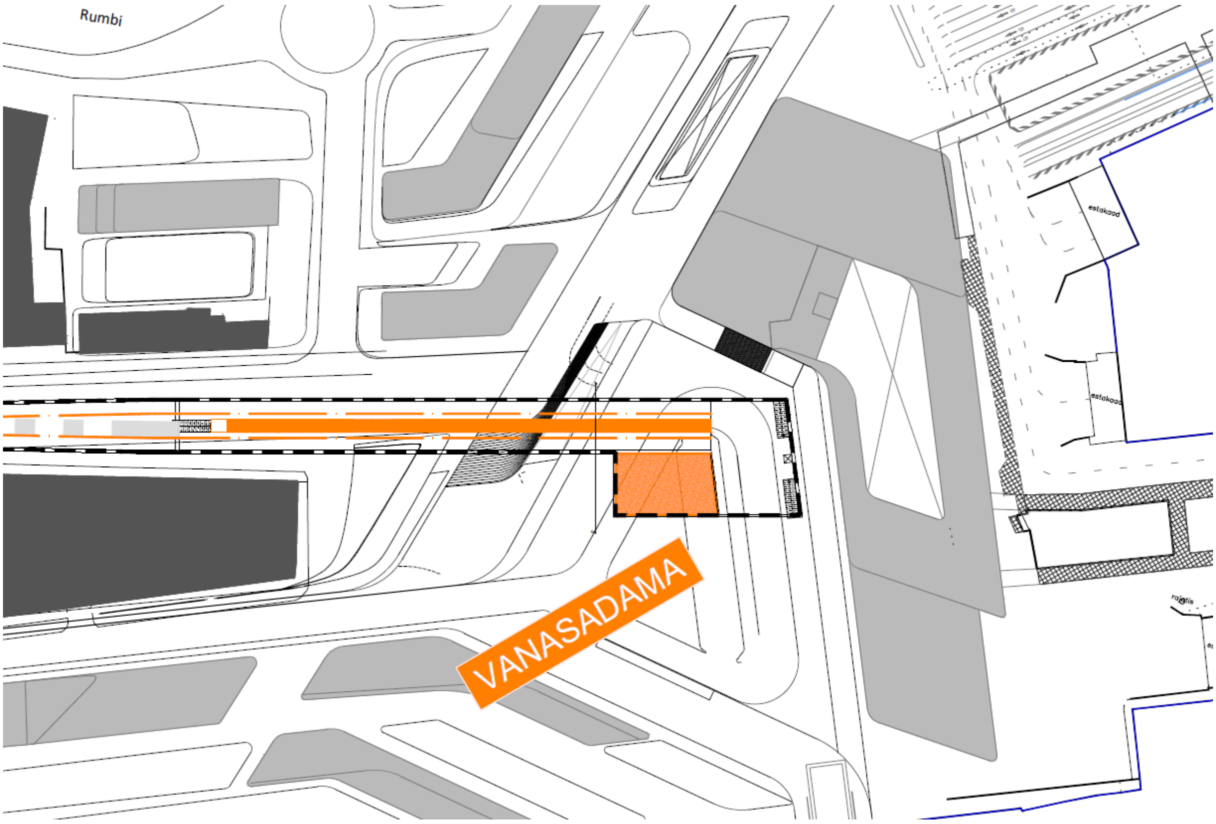


Figure 91 : Train option - Vanasadam station - Egis

4.3.5 Safety equipment of the tunnel

The stations integrate smoke evacuation shaft and allow the evacuation of passengers. An additional smoke evacuation shaft and an emergency exit is also positioned close to Suur Rannavärav Street in the middle of the two stations in order to respect the maximal distance of 800m.

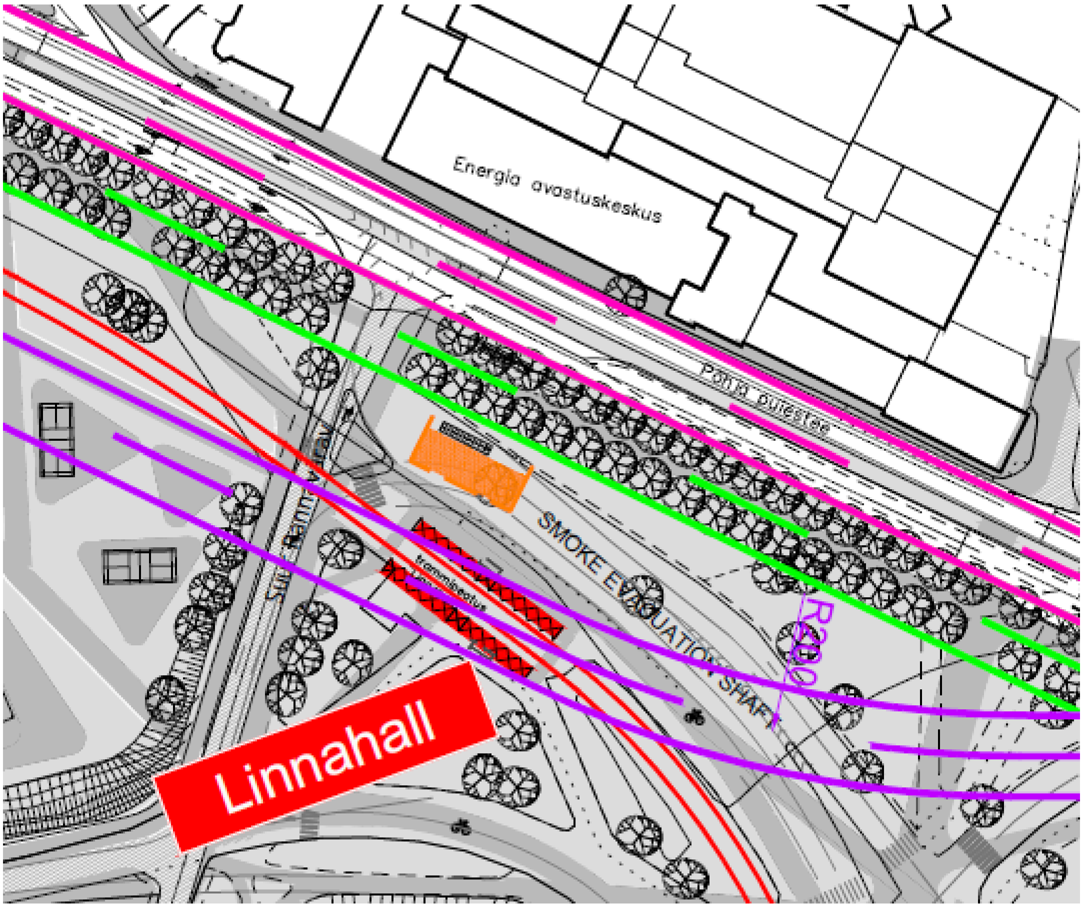


Figure 92 : Train option - smoke evacuation shaft (orange) - Egis

4.3.6 Utilities constraints

Two main public utilities network exist under the Sadama Street and Pohja Puiestee, there are the gas network and heating pipeline. Diversion of these both networks represents a major issue. Utilities contractors need to be suitably informed and managed to allow their diversion of utility networks on the train route could be relocated by the constructor. Achieving these diversions in phase with works progress can be cause of serious works delay and can present an important cost.

Next maps from "A comprehensive plan of Paljassaare and Russalka beach area" (www.tallinn.ee) present the heating system and gas network.

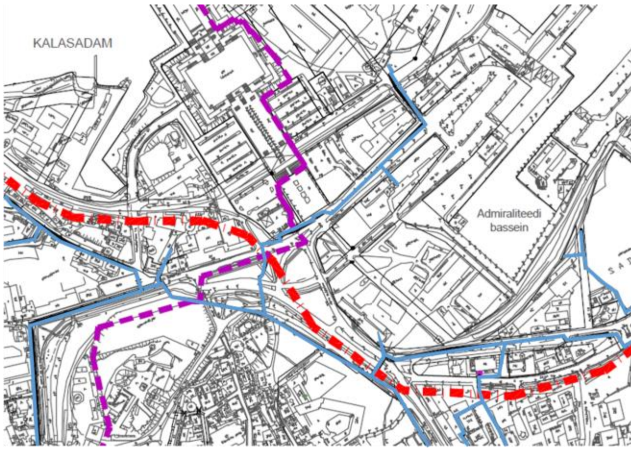


Figure 93 : gas network (blue lines)

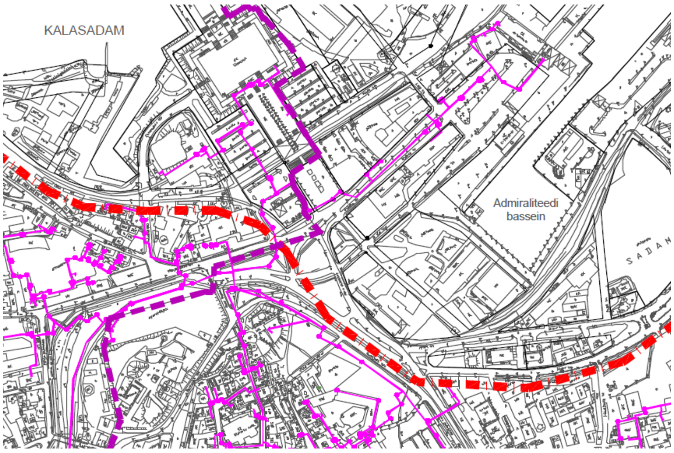


Figure 94: heating pipeline network (pink lines)

4.3.7 Conclusion

All these options are technically feasible but the former two do not interfere in the preservation of the heritage perimeter of the older city. The option running under Pöhja Puiestee minimizes the impact on the existing trees, thus becoming the favorable option. The stations are well positioned, next to the existing stations and modes in order to propose efficient intermodal polarities.

4.4. Project costing and implementation schedule

4.4.1 Investment costs

Methodology and main hypothesis

The cost estimates are determined on the basis of unit prices applied to quantities:

- The quantities are at feasibility study level of details, they are based on the cross sections and the systems conception presented in the previous sections of the report.
- The costs are Estonian costs for civil works and buildings, and French costs for systems. The Estonian civil works costs are taken as being 75% of the French civil works costs. For the items that mix civil works and systems like "Rail systems" and "Power supply equipment", their price has been taken as 90% of the French costs.

These prices are expressed in euro exclusive of taxes (both internal taxes like VAT, and import taxes) as of their January 2018 value.

Contingencies and uncertainty costs are added on top of these costs. The contingencies amount is intended to ensure that the project cost does not exceed the overall budget on a constant program basis. At the current level of study, they are included at the level of 15 %.

Detailed hypothesis

The cost of the project has been broken down into different items which limits are described here below and which description shall always be shown together with the final synthesis table.

Client's direct costs / Consultancy services

This item contains the costs of project management, consultancy services and complementary studies or services (such as detailed project, legal assistance, insurance, communication, consultation, public surveys, archaeological excavations, and topographical, noise and soil surveys, compensation for inconvenience or loss of business during works etc.).

These costs are estimated to be 10% of the total project cost excluding rolling stock.

Land acquisition

Land acquisition is not included in the cost estimates.

Utilities diversion

This involves the costs of diversion of the underground utilities in order to keep independent the operation of the transport system and the maintenance of utilities, whether funded by the organizing authority or otherwise.

For the feasibility study, costs of utilities diversion are difficult to estimate in details. The cost of diversion of utilities diversion are estimated according a ratio per kilometer based on from previous international experience in tramway construction excepted for the main utilities as main pipe of gas or main pipe of heating pipe which are estimated specifically.

Preparatory works

This item includes all the preparatory works for work completion on public property, such as: release of right-of way, cutting down of trees, road diversions, temporary lighting, work site facilities, temporary roads for traffic diversions, etc.

No particular hypothesis has been taken into account.

Civil Engineering works

This item includes all major civil engineering works like tunnels, underpasses, bridges.

It includes cost of underground sections in cut and cover

Track system

This item includes the track system adapted to the train. In tunnel, concrete track system is proposed.

This items includes the main track and all the facilities that have to be equipped with tracks, turnouts required to operate the line (main line and other facilities), which are estimated to 4.

The track is 2000 m long

Signaling system and train control and telecommunication

The signaling system includes all the wayside fixed equipment along the new section.

This item also includes the Implementation of optic fiber required for the signaling system and operations control;

Roads and public spaces

It includes the roadway and public spaces works required for restoring the public space above cut and cover: earthworks, structural works, pavements and coverings.

The estimate takes into account 5 000 m² of renewed streets.

Urban Facilities

It includes the urban equipment located along the line: planting, urban furnishings, benches, fences and guard rails.

The following hypotheses are taken into account: 50 trees are planted, 20 000 m² of green land is laid out, 500 m of public lightning are renewed.

Stations /platforms

This item includes the civil engineering: structural work and finishing work. It also includes the station equipment: station furnishings including shelters, benches, fences, lighting.

- *2 new shallow stations are implemented, it includes* civil engineering woks only

Power supply equipment

This item includes all the facilities needed to distribute power to the electric traction vehicles:

- Traction power supply for the main line and train operations.
- Overhead catenary system (OCS).
- Low voltage and UPS system (stations, signaling, SCADA, communication system…).

*The estimate take into account 0 substation. The whole line is equipped with an o*verhead catenary system.

Workshop & Depot

For the project, no investment on the depot has been taken into account.

Rolling Stock

In addition to the vehicles themselves, this item includes the cost of testing and commissioning equipment.

3 new EMUs is required (3-carriages).

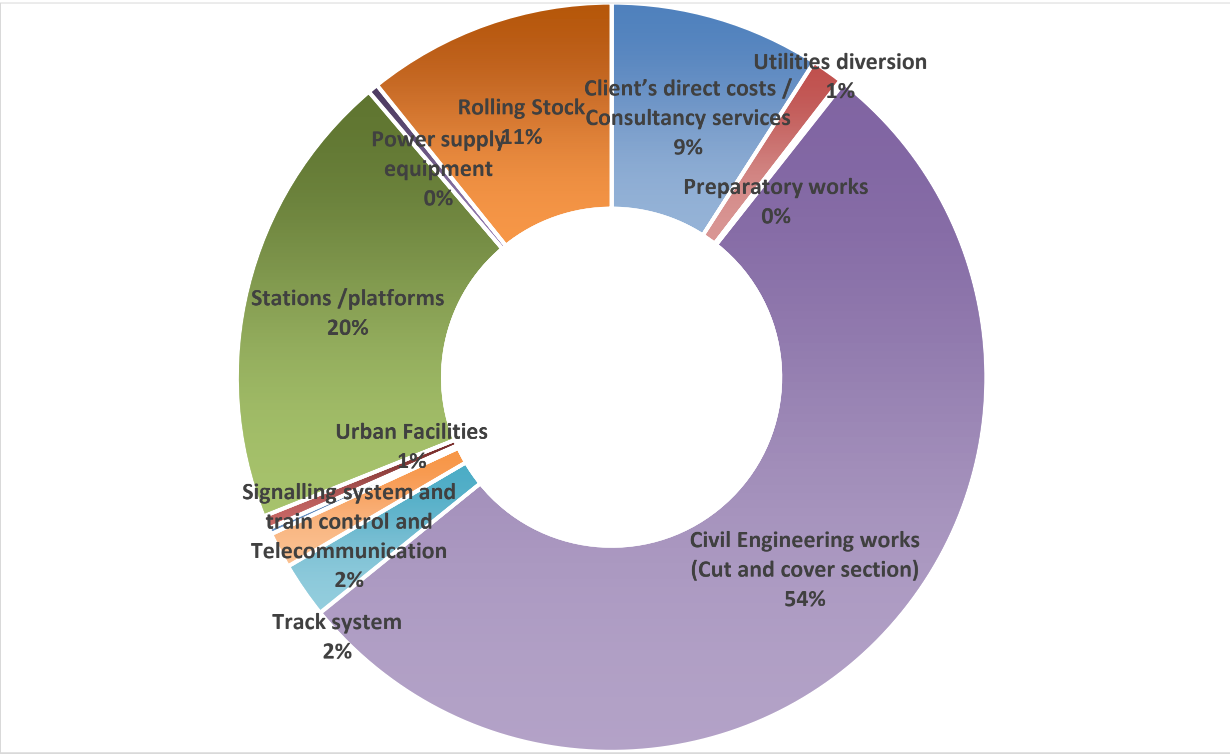
Results

With these assumptions, the cost of the extension is estimated of 184 million euros (2018 cost excluding taxes, without land acquisition and utilities diversion).

The synthesis table is presented according to the above mentioned cost breakdown:

Table 4 : Investment costs for the train option

Client's direct costs / Consultancy services	**16 896 k€**
Land acquisition	**0 k€**
Utilities diversion	**2 539 k€**
Preparatory works	**319 k€**
Civil Engineering works (Cut and cover section)	**99 523 k€**
Track system	**4 462 k€**
Signaling system and train control and Telecommunication	**2 875 k€**
Roads and public spaces	**480 k€**
Urban Facilities	**1 043 k€**
Stations /platforms	**36 879 k€**
Power supply equipment	**828 k€**
Workshop & Depot	**0 k€**
Rolling Stock	**20 010 k€**
Total	**185 854 k€**



4.4.2 Implementation schedule

Overview

After the approval of the current feasibility study, the main elements that have to be taken into account in the implementation schedule are:

- The preliminary and detailed design, followed by the tendering process for the rolling stock and the main line.
- The administrative procedures including the land acquisitions, if any.
- The works and the manufacturing of the rolling stock.
- The testing and commissioning of the system.

All these tasks have to be supervised by a strong project implementation unit and/or a general consultant.

The hypothesis taken here is that the project will be implemented through traditional public procurement.

Detailed design

The detailed design will be the basis for the tender documents. This study requires an approved preliminary design and some public consultation to make sure that the project will be granted public approval.

The experience of past tram lines show that this phase is one of the most critical study phase: it is the stage when all decisions have to be taken and finalized. As the detailed design maps will be used by the contractors performing the works in order to draft their shop drawings, they should be as close as possible to the final project.

Administrative procedures

This task includes all the administrative procedures required to get the necessary permits for starting the construction works and performing the land acquisitions.

Rolling stock

The rolling stock studies, made by the manufacturer, have to start after the approval of the detailed design so that all project options have been decided.

It takes about 24 months for the manufacturer to perform its studies, build and deliver the first rolling stock unit.

Main line works phasing

After the tendering process, the works of the main line start on all sections simultaneously and take about 37 months. Civil works start first followed by the system implementation. Civil works for the station and the cut and cover takes about 31 month.

During works (about 12 month), the tramway line 1 and 2 will be stopped entirely.

Bus services will have to be set up as alternative transport. If this option is chosen, it could be interesting to include some buses in the cost of the project so that sufficient alternative services can be provided.

The diversion of the heating pipe located under the future extension have to be diverted before the beginning of the civil works.

Testing

After completion of works on the main line, testing can start. Full testing of a tram line takes about 6 months.

Results

With the hypotheses considered here, the extension of train line until the port can open for revenue service as soon as possible at the beginning of the year 2025.

This opening is adapted to the Rail Baltica opening.

The summary planning is shown below and the detailed planning after.

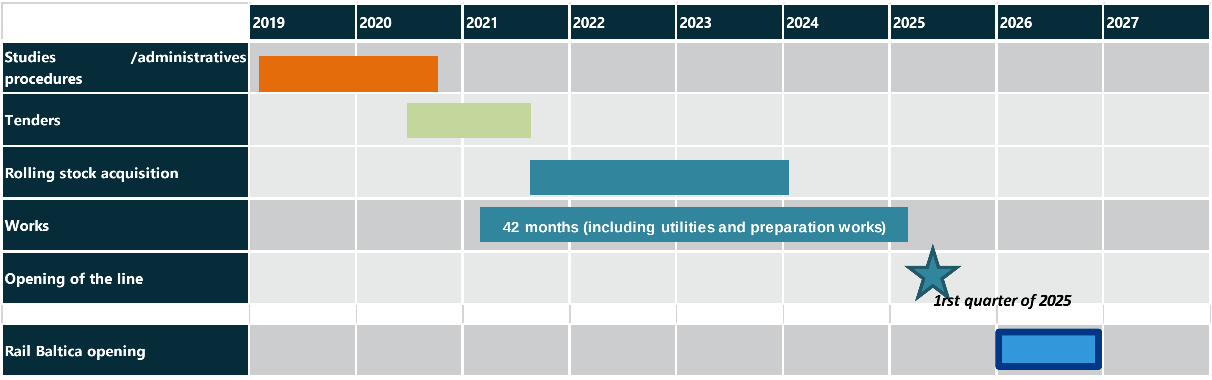


Figure 95 : Train option - Summary implementation schedule

However, according the **opening of Rail Baltica, it is proposed to take 2026 for the beginning of the commercial operation of the project between Ülemiste and Vanasadam.**

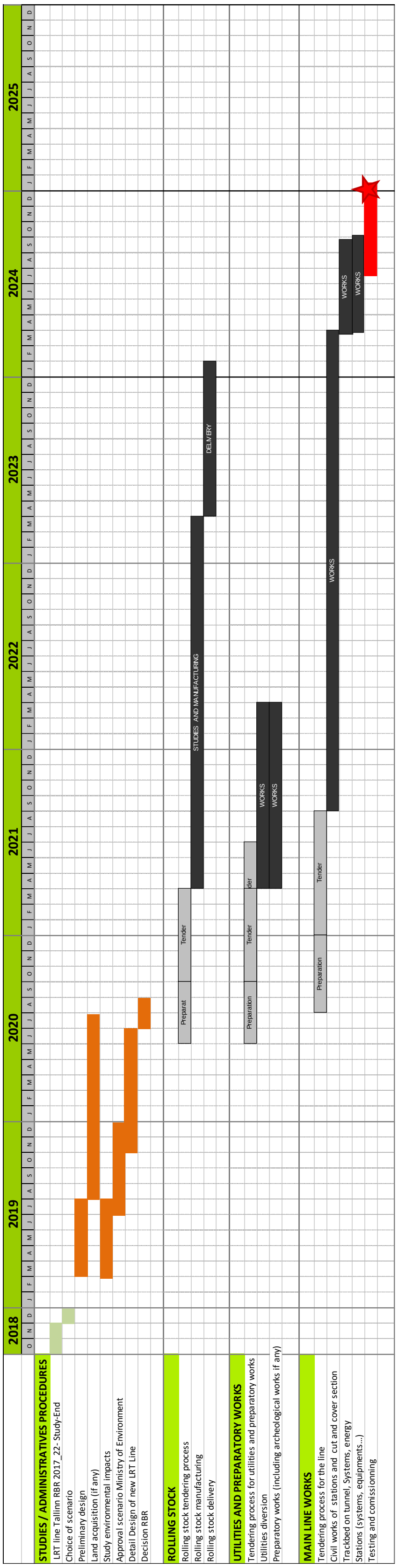


Figure 96 : Train option - Detailed implementation schedule

5. Tram in tunnel option

5.1. Description of the option

This alternative proposes to connect Ülemiste to Vanasadam Port by creating a new infrastructure.

The first idea of this alternative was to use partially the railway network until crossing bridge over Tartu Mnt. After the bridge could begin the ramp to the tunnel before Peterburi Tee. The distance of the ramp is too short to be at the right depth to begin the tunnel.

Another issue was the feasibility to insert new services on the railway infrastructure in Ülemiste Railway station.

According to these difficulties, the option is studied in tram.

Original concept is maintained,

- Partially underground (deep underground or in cut and cover) between Ülemiste and Liivalaia
- And at grade on the city center between Liivalaia and Vanasadam.

The line will be connected to the tram network at the intersection with line 1 and 3. This connection could enable fleet injections and withdrawals from and to the depot

The following map shows schematically the route of the new tram line.

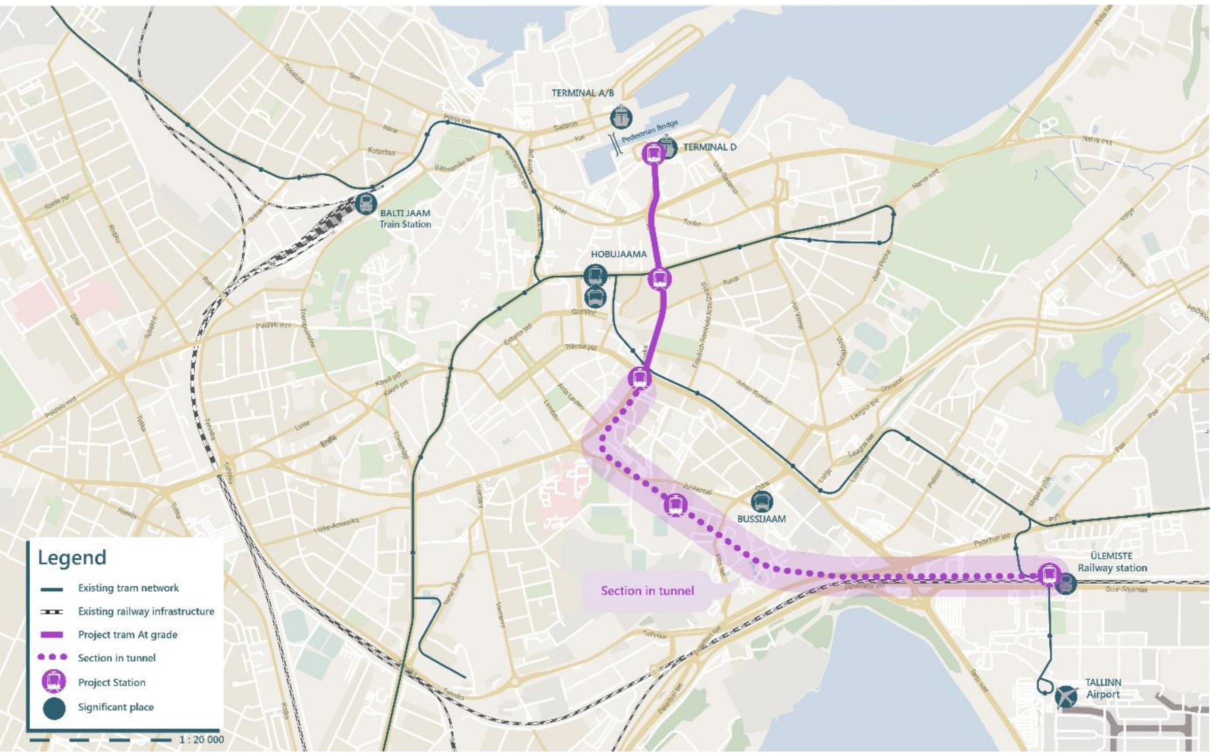


Figure 97 : schematic route of the new tram line

According to the time table of the ferry (1 or 2 per hour), the proposed headway is 15 minutes.

The new line become the **tram line 5** of the network of Tallinn:

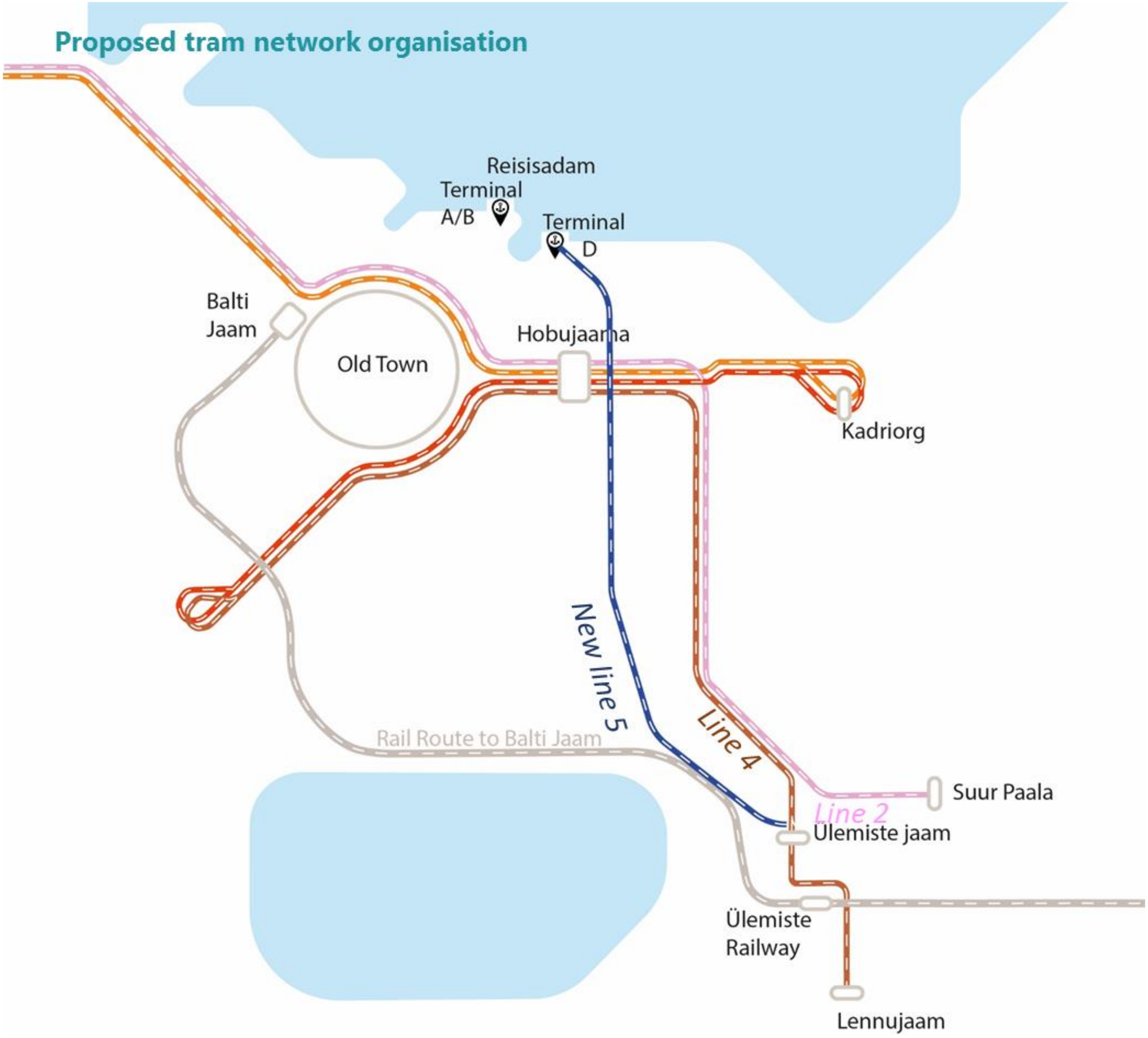


Figure 98 : schematic tram network

5.2. System conception

In addition to the chapter 3.2 System conception (tram option), rolling stock and tunnel construction are detailed in this chapter.

5.2.1 Rolling stock

According to the unfeasibility to integrate a reverse loop at Ülemiste terminus, the proposed rolling stock is bidirectional.

Figure 99 : Citadis 302 in operation in Lyon

Most of modern tramway have 100% low floor, a modularity concept, and lower horizontal curve requirements, is specifically designed for easy integration into the urban landscape and in narrower streets. Even in cases for which the low floor is not integral and may imply a step inside the vehicle (limitation for physically challenged people); it can still allow for direct low access to areas directly facing doors.

Length

The rolling stock currently available in the market provides two main options for the length of the vehicles: long vehicles (~ 40m) and short vehicles (~ 30m). The latter are extendable to 40 m. Very few 60 m tram vehicles are available but it is easily possible to reach a length of about 60 m, using 30 m vehicles operating in multiple units. I

Width

The rolling stock currently available in the market provides two main options for the width of the vehicles: 2.30m and 2.65 which is the standard maximum width available with all constructors. The latter enables not only more capacity during peak hours but also better comfort during off-peak periods, with more comfortable corridors between seats for example.

> The proposed option is to operate with 30 meters long and 2.3 meters wide vehicles to keep the caracteristics of current rolling stock.

5.2.2 Tunnel configuration

Four configurations are considered for the underground sections:

- Deep underground section
- Cut-and-cover for the entrance to the tunnel.

Deep underground section

Two methods can be considered for the construction of the tunnel: tunnel boring machine (TBM) or "conventional methods" such as Drill & Blast (D&B) or New Austrian Tunnelling Method (NATM). We don't have enough outputs to confirm the choice of the method. But the main outputs are that the TBM is a safer method for the adjacent buildings and allows a much less deep alignment than conventional methods. TBM are more versatile, capable of boring through any rock under high pressures and through hydraulic soils at any depth. **It is therefore recommended to use the TBM method.**

For all TBM sections, the recommended minimal cover over the tunnel is 1.5 diameter under building foundations and 1 to 1.5 under a wide avenue.

For the study, single tube 1 level is considered for the deep underground section. The single tube 1 level option is the most common / classical configuration for recent metro lines.

At this stage of the study, the tunnel dimensions have been determined from the structural clearance and rolling stock characteristics. Tunnel finished internal diameter was fixed to be 9 m as an assumption, i.e. about 10 m for the external diameter, though this value can still be optimized. The following drawing show the typical cross-section. The part filled by concrete under rails can be used for equipments and others facilities if necessary.

The minimum radius of curvature is 200 m.

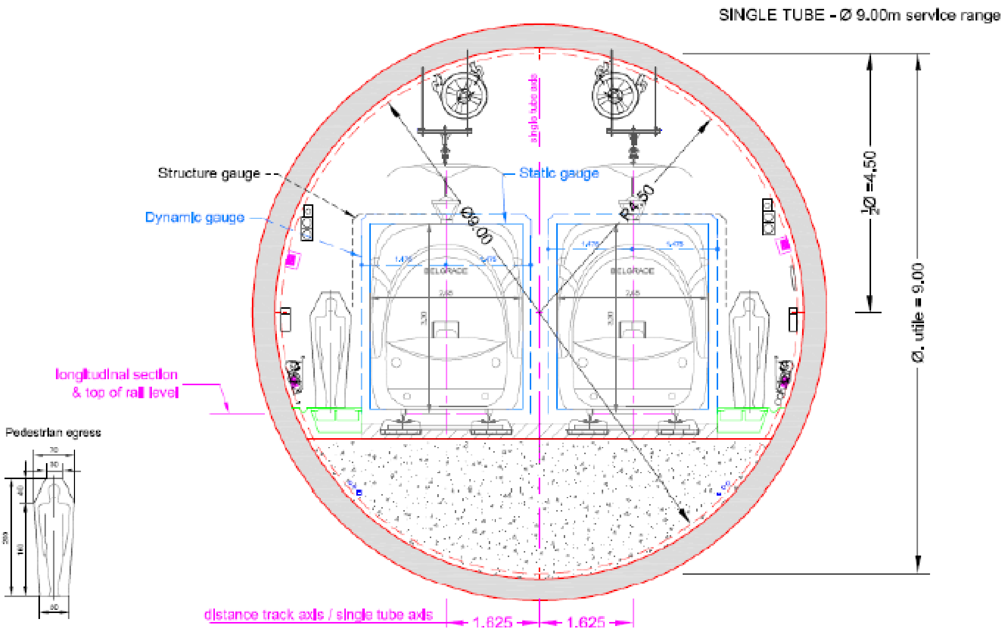


Figure 100 : Typical single tube 1 level tunnel cross section: straight alignment

Cut-and-cover section

Underground sections are constructed with cut-and-cover technology for the tunnel entrance. The impact of the construction stage is maximal, but the technology is simpler and cheaper than with tunnel sections, and it allows shallower alignment and stations.

5.2.3 Tunnel construction stage

A site installation is required to operate the TBM. Required areas for such site installations range generally between 10,000 m² and 20,000 m² according to chosen tunneling techniques and chosen TBM:

- installation: 5,000 – 10,000 m²;
- mucking storage yard: 5,000 – 10,000 m² (to store at least 3 to 7 days of production).

Launching and output shafts of the TBM (Oullins, Lyon, France)

The entrance portal requires the surface 70ml long × 30ml large minimum to assemble the TBM and the backup equipment. Site installations of TBM facilities have to be situated in the center of the line. This localization of the TBM site installation induced a complex organization of the TBM progress. This point will be the entrance portal of TBM, the TBM will progress to Liivalaia. After, it will be transfer the entrance portal and finally TBM could go through the Ülemiste station.

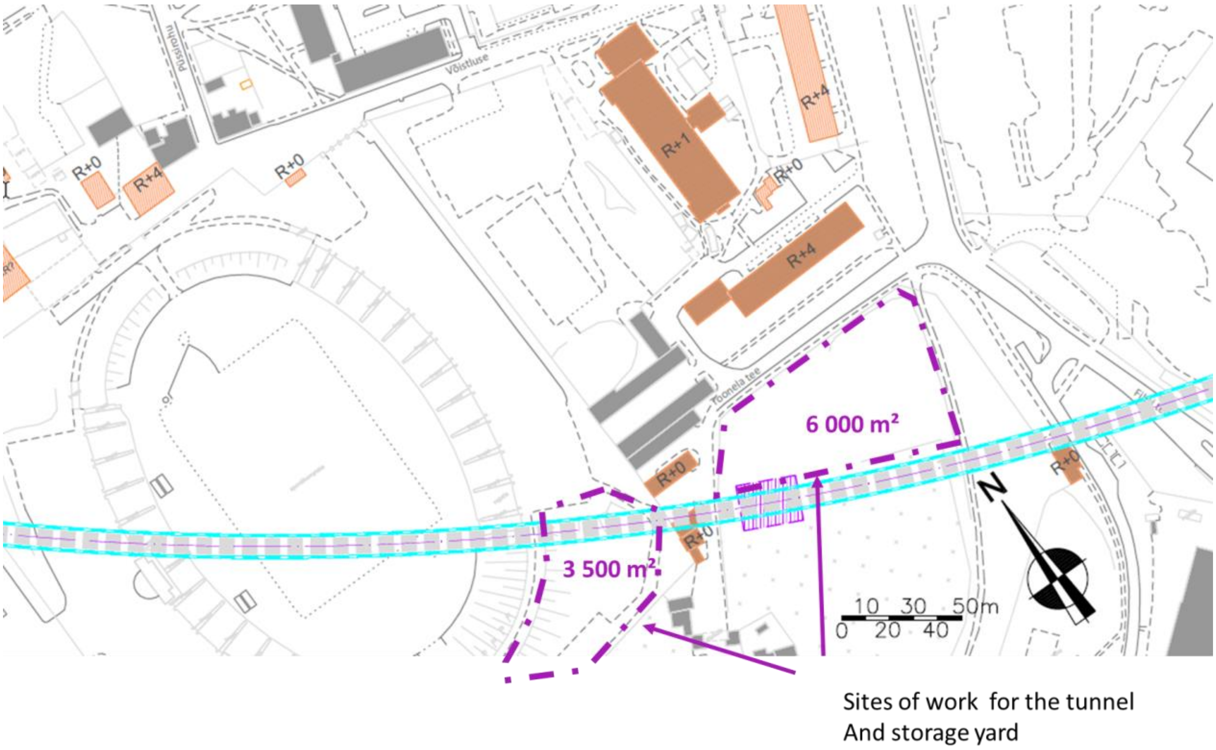


Figure 101 : View to the potential TBM site installation

In addition, the evacuation of the excavated materials from this site (about 800 m3/day) would require dump trucks. Between 25 and 40 trucks per day will required for the evacuation of the excavated materials which will have a direct access to the main route (T1 and T2).

5.3. Identification and analyses of alignment solution

5.3.1 Vanasadam station (Port Terminus)

As explain in the chapter 3.3.4, the conception has been led by letting the maximum space to the drop off in front of the Terminal D and by localized the station in order to be visible from the two terminals. Its situation is in an average equal distance to the two terminals.

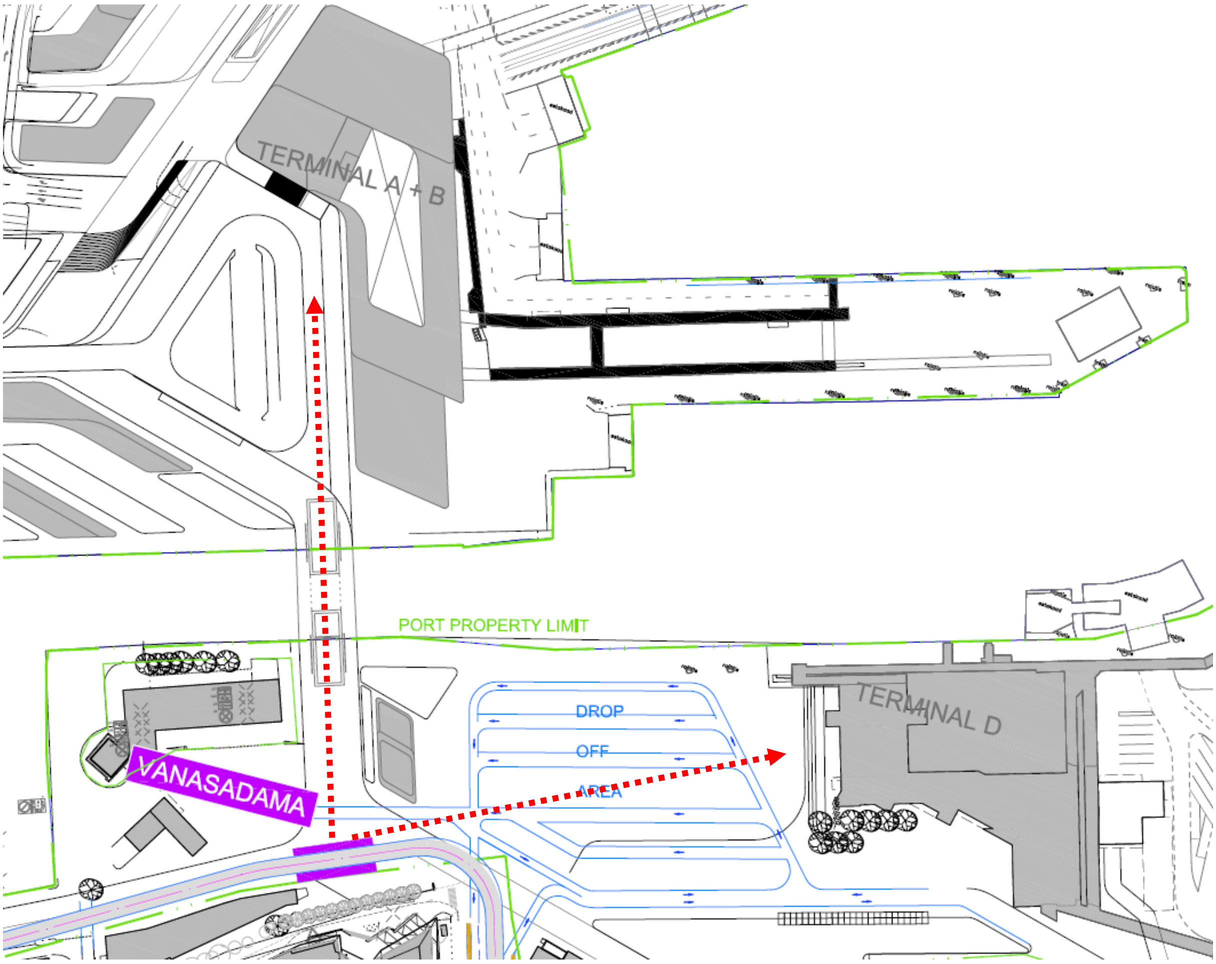


Figure 102 : Tramway in tunnel option - terminus station in Vanasadam - Egis

The terminus station has a two lateral platforms and return of the tramway is operated at the back of the platforms without a loop. The type of rolling stock proposed in this variant is able to turn back that way and also to open the doors on both sides.

The lateral platforms also able to minimize the impact on the pedestrian mall of the new port area.

5.3.2 Jõe Street

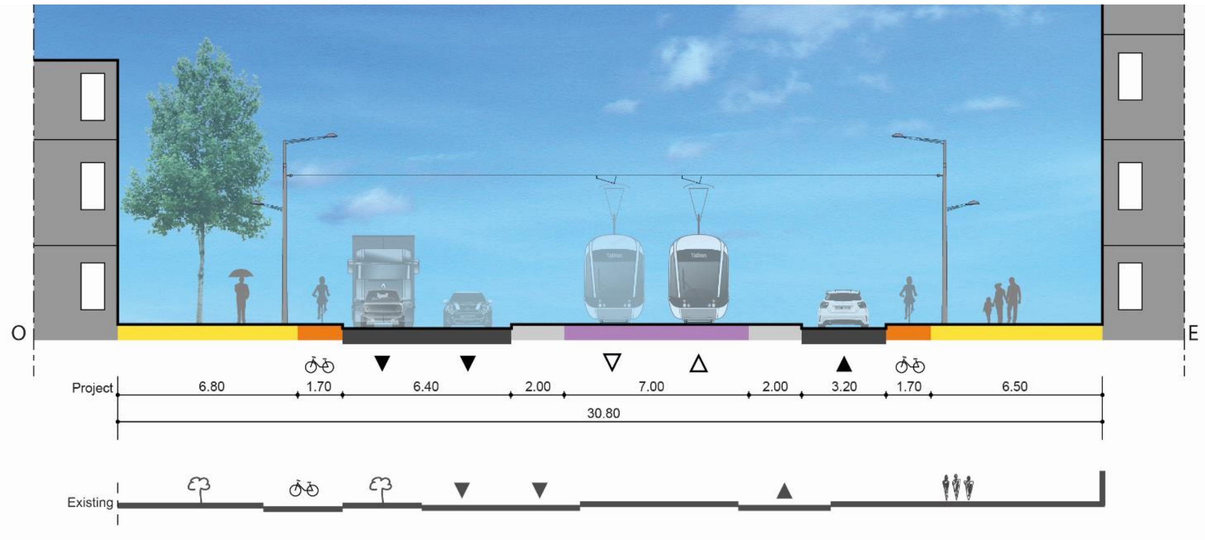


Figure 103 : Tramway in tunnel option - section in Joe's Street - Egis

The urban integration of the tramway in Joe's Street is chosen in axial. This position allow less impact on the delivery of the Norde Centrum Mall. The trajectory of the trucks in the curve crosses the two car lanes and avoids the tramway tracks.

The amenities of the road need to remove trees on the west side of Joe's Street and to remove 1 car lane in South – North direction. This configuration keeps the same number of car lanes as proposed by the project of the new Ahtri Street.

Bicycle lanes are proposed on each side of the street along the pavement.

After the crossroad with Ahtri Street, the alignment is continuing its route to the South. The width of the street is smaller, around 27meters. A double bicycle lane is positioned on the East side of the road. The number of car lanes is reduced from 3 to 2, and from 2 to 1 lane. ***A traffic has to confirm if this capacity is enough***. A car lane could be added is the bicycle lane is removed.

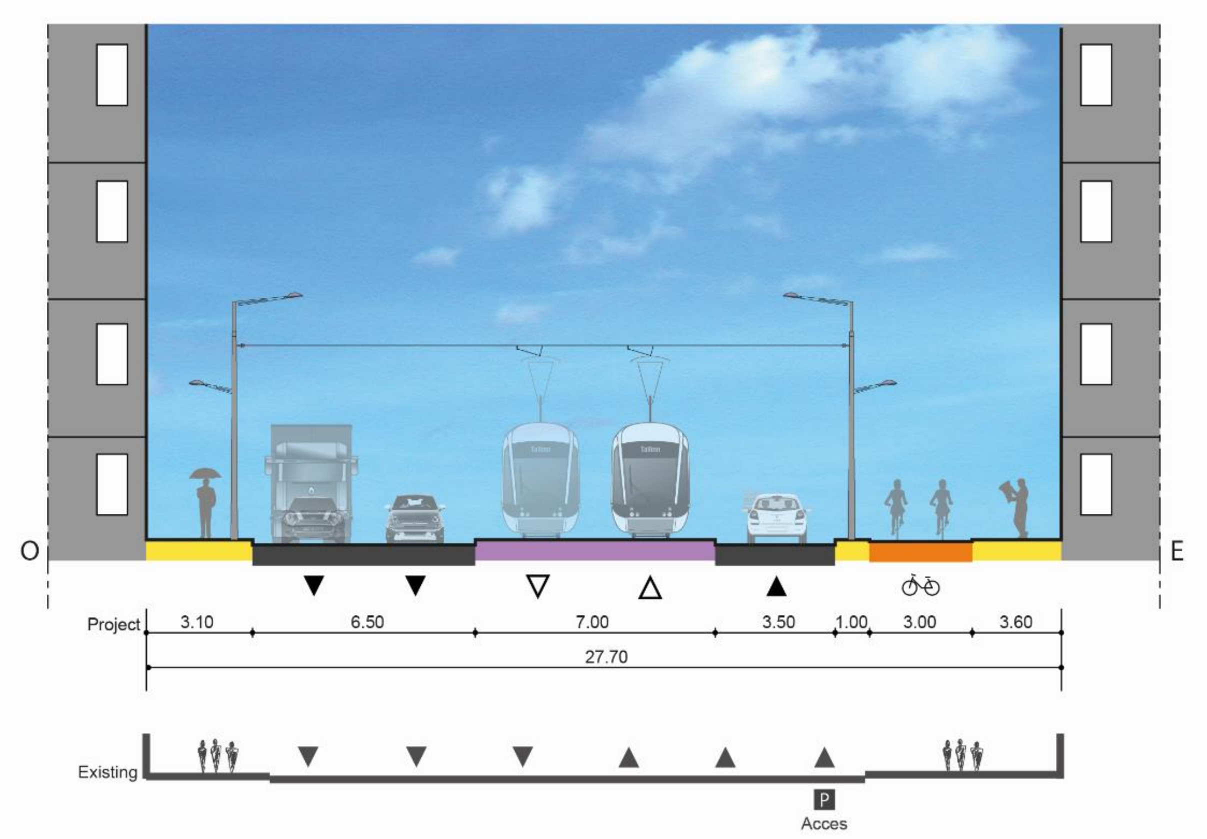


Figure 104 : Tramway in tunnel option - 2nd section in Joe's Street - Egis

5.3.3 Hobujaama station

The crossroad with Narva Mnt is the right place to position another station. Here the road is really narrow, around 29m. The conception is trying to keep the maximum number of car lanes as it exists today. With a specific rolling stock, it is possible to design a central platform. It is more compact and it allows an economy of width in constraint sequences, around 2 or 3m. Here a width of 3m is applied to the central platform. ***This width is not enough***. It could be wider, but it will imply the remove of a car lane. To cope with these constraint and to prevent the risk of overcrowding on simultaneous arrivals of tram a double length platform is proposed. However, it misses also a pedestrian island on each side of the tramway tracks. It means that the fire lights allow pedestrians to cross in one time. In this busy intersection, it could be difficult to organize it.

There is not enough width to add a bicycle lane at the station.

Finally, the feasibility is not verified in this part of the alignment.

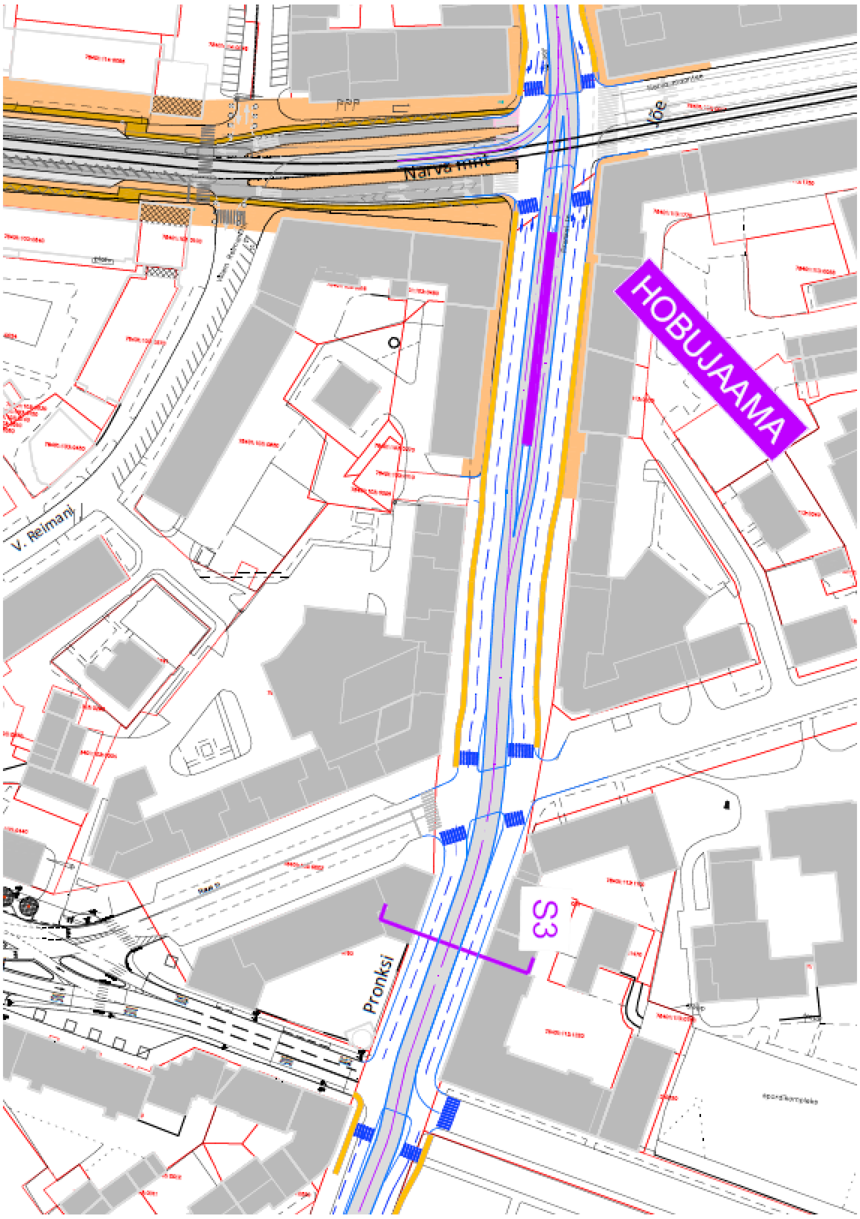


Figure 105 : Hobujaama stop double length platform – Egis

The possibility of detouring to Narva Mantee to connect the depot may be considered with a slight adjustment of the urban plan to accommodate the curve in the intersection by Hobujaama.

This projected crossing and connection requires a specific railway design analysis to check the following points:

- The **vertical alignment** of existing line railtrack should be lightly reshaped to permit new line to be designed properly, without cant in straight alignment.
- As connection turnouts are very close to this crossing, all these railway equipment should be implemented in a **flat and horizontal area**. Despite this constraint, coating efficient drainage should be proposed, for example with grate-covered gutters.

- The **turnout** study must define detailed geometry for each track, because this has operation and maintenance consequences.
- About operation, **tram speed** may be reduced for turnout movements and even straight movement at rail crossing. The transition curve may be implemented, even for train movements without passengers.
- **Arrangements** must be adapted to turnout studies, because for safety and maintenance reasons, pedestrian and road crossings should not be implemented at moving pieces of turnouts. About maintenance, during design stage, the choice should be made of eventual motorized turnout (depending on future use).
- Signaling and overhead line must be studied as well, because this may have an important impact on arrangements and existing utilities especially underground.

The feasibility of this connection need a specific study.

5.3.4 Pronksi Street

After Hobujaama Station and Rävala Pst, Pronksi Street is quite wide, around 34 meters. An axial integration is chosen in order to allow easy car accesses to buildings and to parking lots.

A 2x2 car lanes and a double bicycle lane are designed, except in front of the Estonian Firefighting Museum between Raua Street and Gonsiori Street. In this part, it is not possible to integrate the bicycle lanes, or an additional car lane. The width of the pavement are at their minimum, 2,0m.

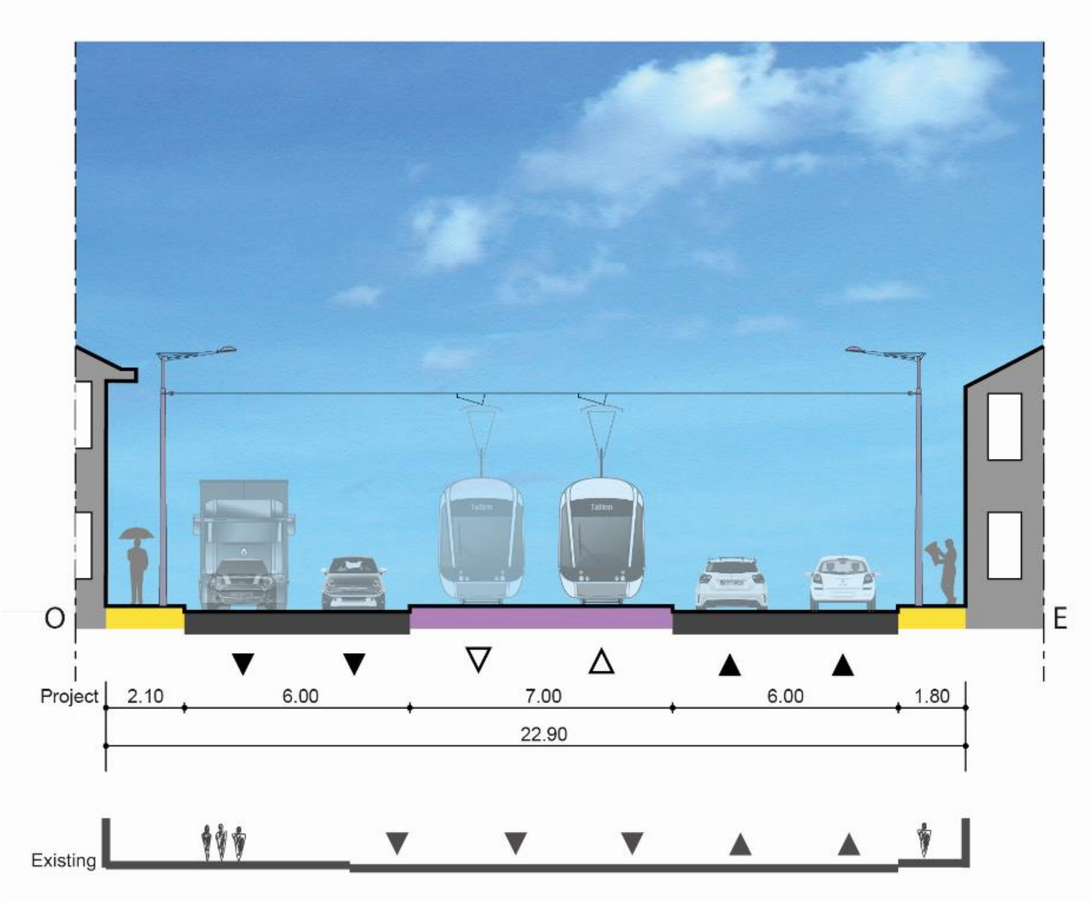


Figure 106 : Tramway in tunnel option - section in Pronksi Street in the narrowest part – Egis

In Rävala crossroad it could be necessary to do a traffic simulation for the traffic light phasing.

5.3.5 Liivalaia Street

Liivalaia Street is a very important avenue in the road network of Tallinn. It is an urban inner ring. The traffic flow is important and its capacity could not be reduce too much. The project proposes another station on Rävala crossroad. Soon after the station the ramp is beginning to go down.

A configuration with axial tramway tracks, 2X2 car lanes and a double bicycle lane is proposed. It reduces the number of car lanes from 3 to 2 car lanes on each side. This projected car capacity must be verified by a traffic study.

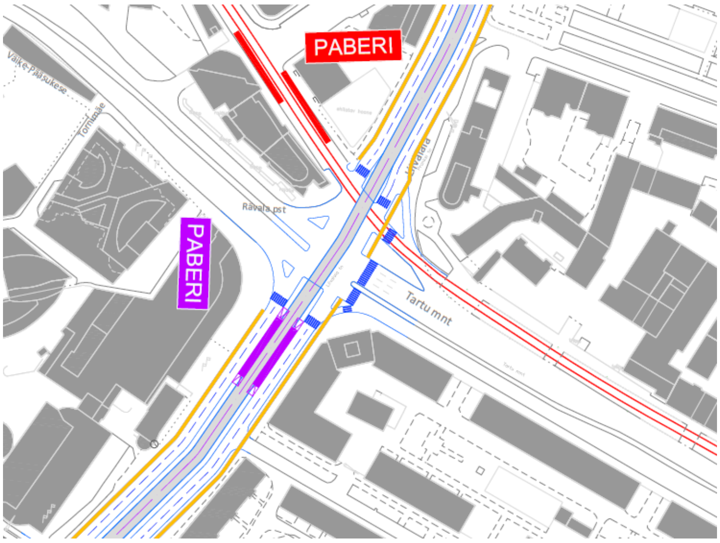


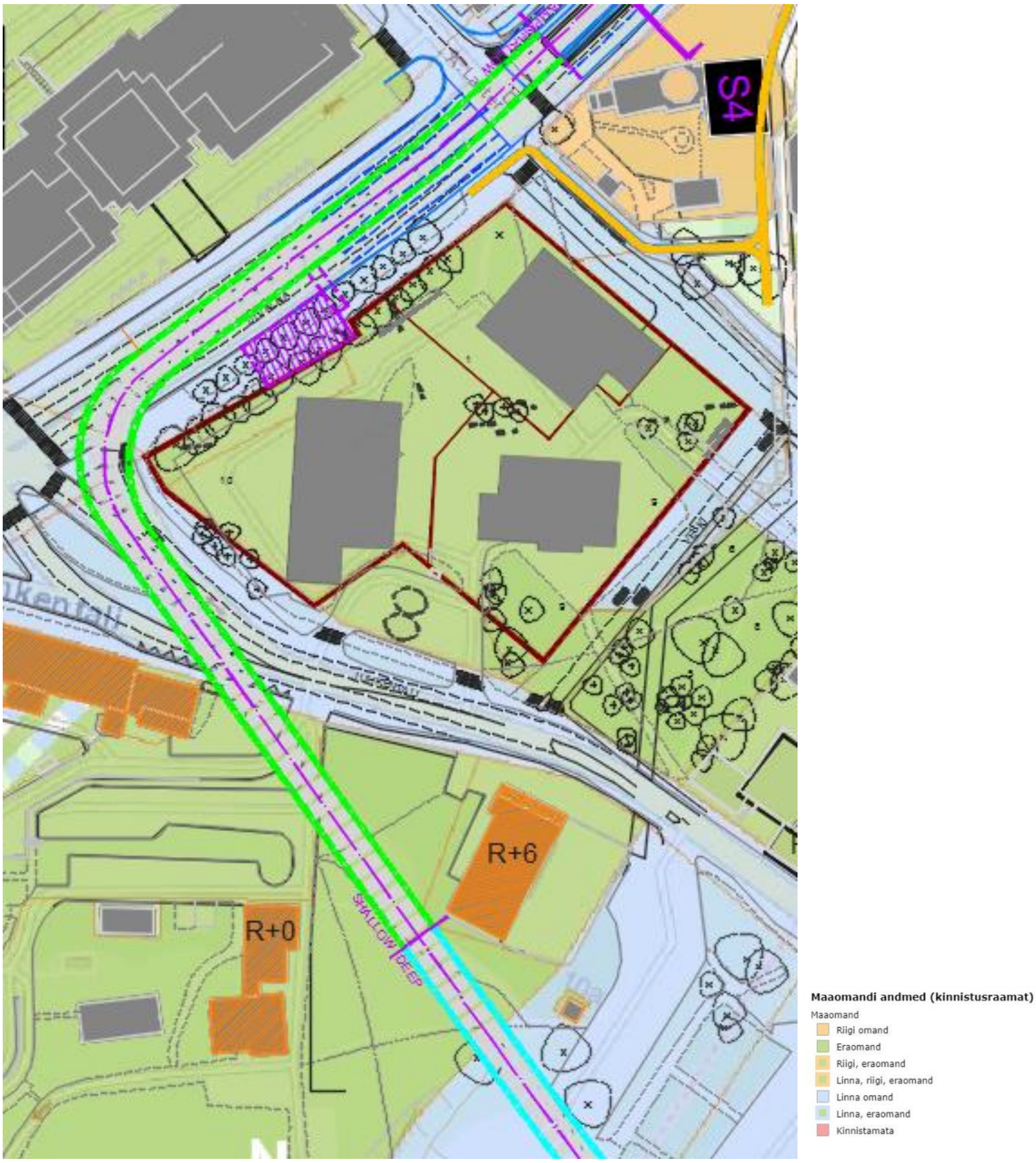
Figure 107 : Tramway in tunnel option - Rävala crossroad - Egis

5.3.6 Tunnel entrance / Olümpia Park

The tunnel entrance began with a long ramp at 6%. After being underground, a 100m radius curve of a cut & cover sequence is passing around the new building project "Lightpark" from Valguspark through the "Olümpia Park" in direction of Ülemiste station. Land acquisitions will be required to accommodate a short part of the shallow alignment. Identified plots are the followings (and picture below):

- 78401:110:0059
- 78401:110:0750
- 78401:110:0011

The inner width of the infrastructure is about 8,2m.


S4
R+6
R+0
SHALLOW
DEEP
Maaomandi andmed (kinnistusraamat)
Maaomand
Riigi omand
Eraomand
Riigi, eraomand
Linna, riigi, eraomand
Linna omand
Linna, eraomand
Kinnistamata

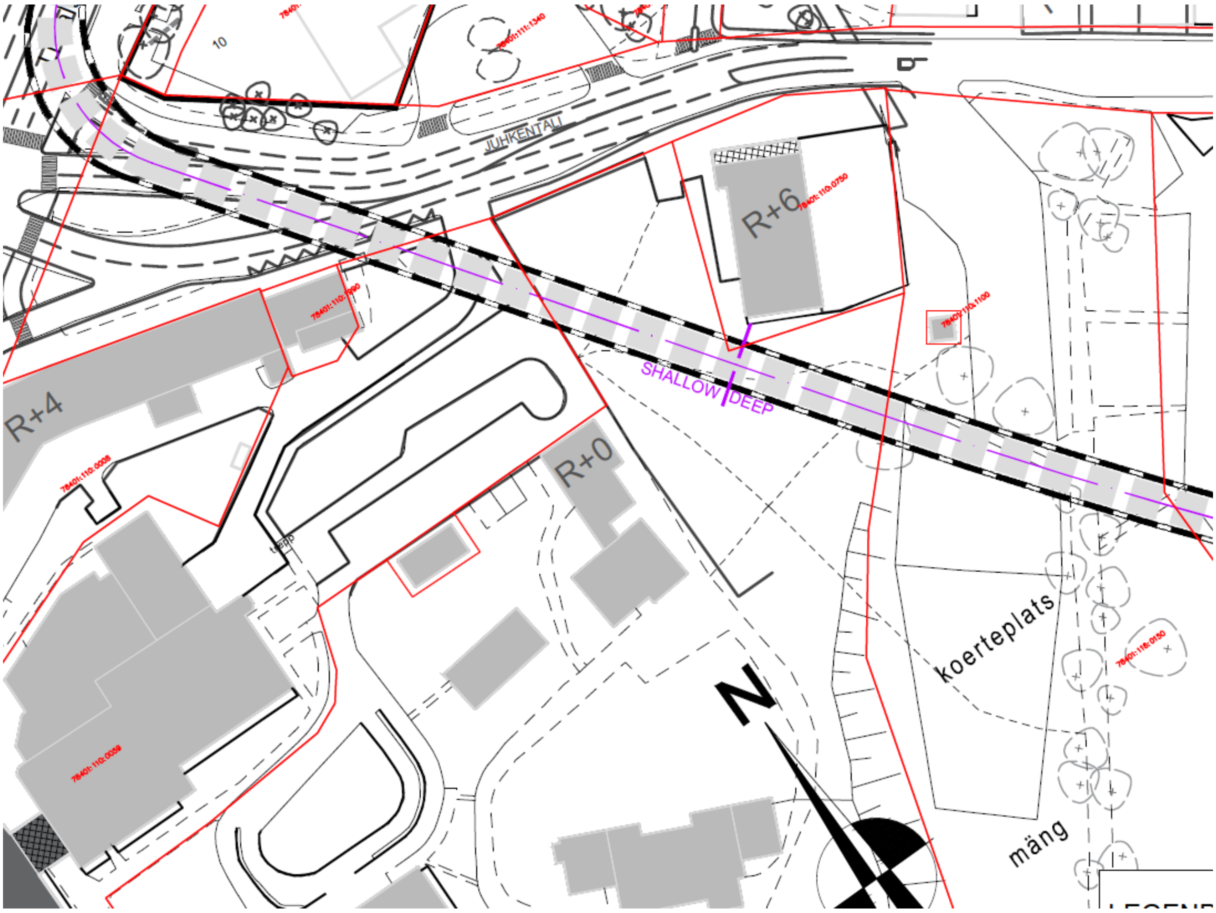


Figure 108 : Land Acquisition required for cut and cover alignment (private property in green)

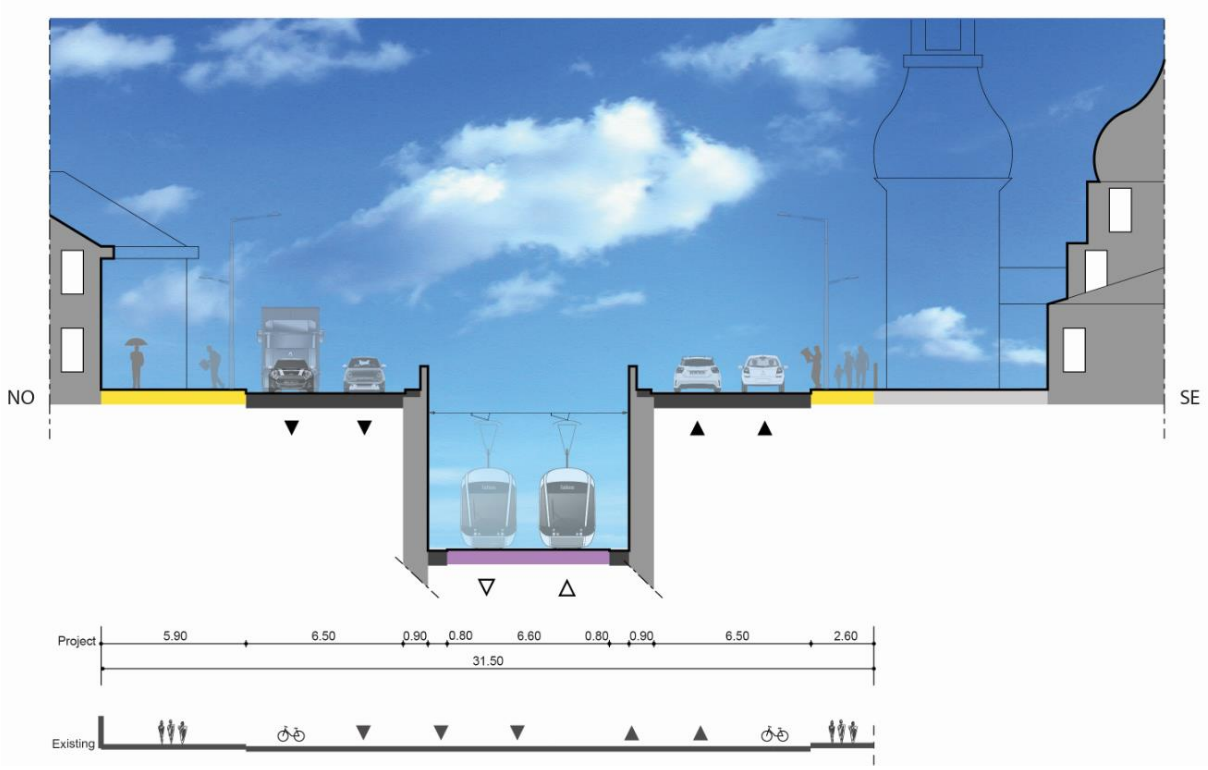


Figure 109 : Tramway in tunnel option - section on the ramp in Liivalaia Street - Egis

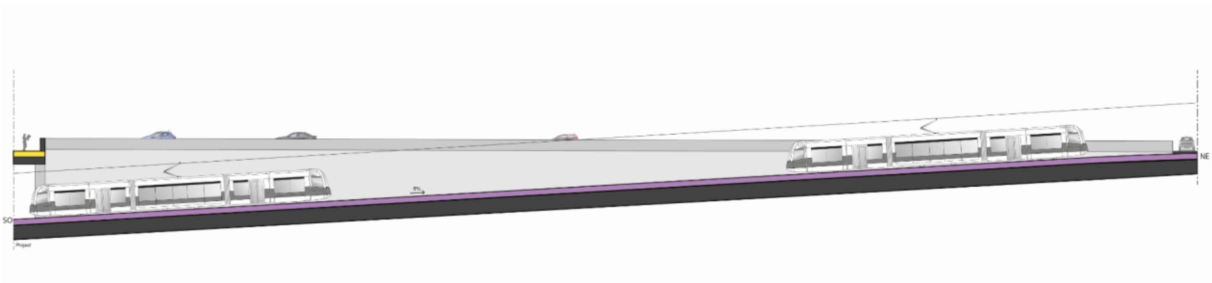


Figure 110 : tramway in tunnel option - longitudinal section on the ramp in Liivalaia Street - Egis

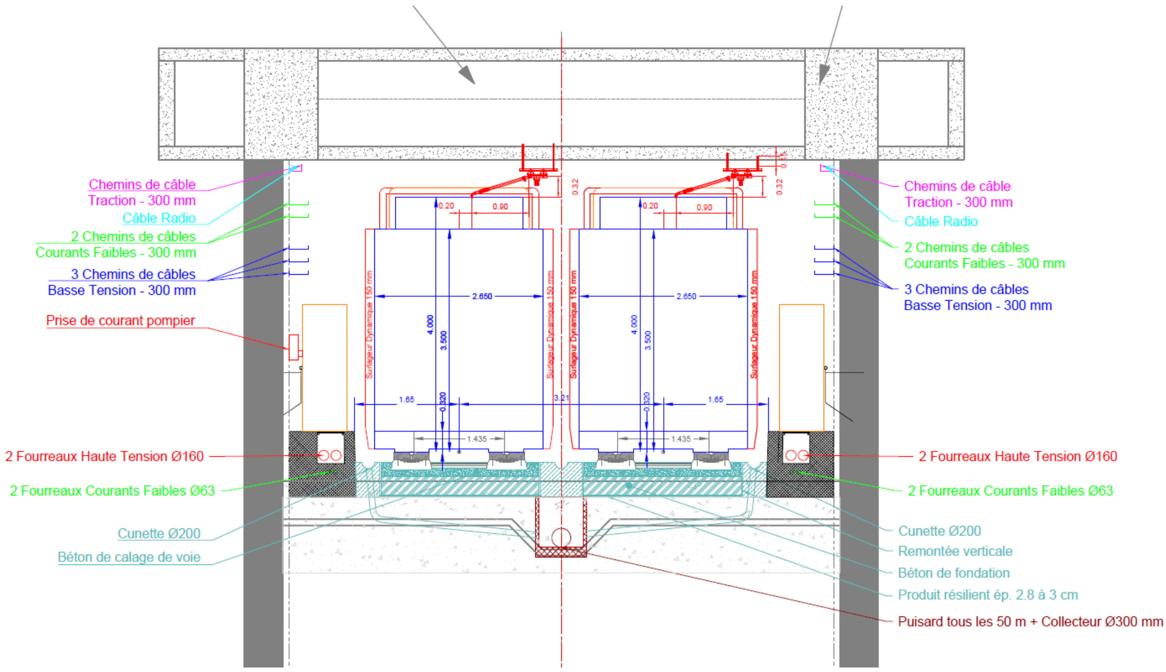


Figure 111 : Example of a cut and cover section - Tramway of Nice – Egis

5.3.7 Tunnel sequence

After a small sequence in cut and cover, a deep underground sequence is necessary in order to pass under buildings and to reach the fastest route to Ülemiste. NATM or TBM would have been the civil works solution.

Following acknowledging that an urban operation is to take place in the corner of Liivalaia and Juhkentali, a revision of the underground section was needed to prevent conflicts with its underground parking as shown in the figure below.

The horizontal alignment is studied so as not to pass under high rise buildings, in order to do so a tight curve is needed on the shallow section in the corner of Liivalaia and Juhkentali, once this curve is completed the underground section begins.

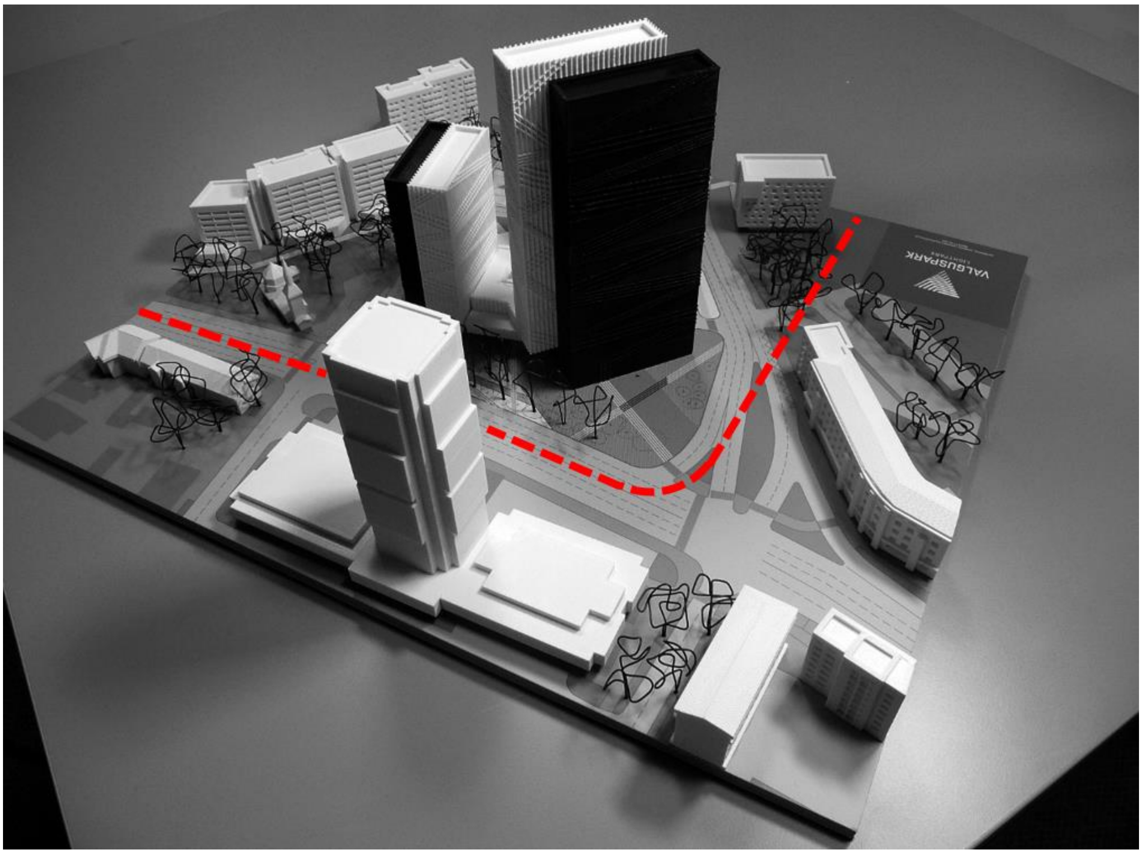


Figure 112 : Scheme showing model of Lightpark complex in relation to the alignment

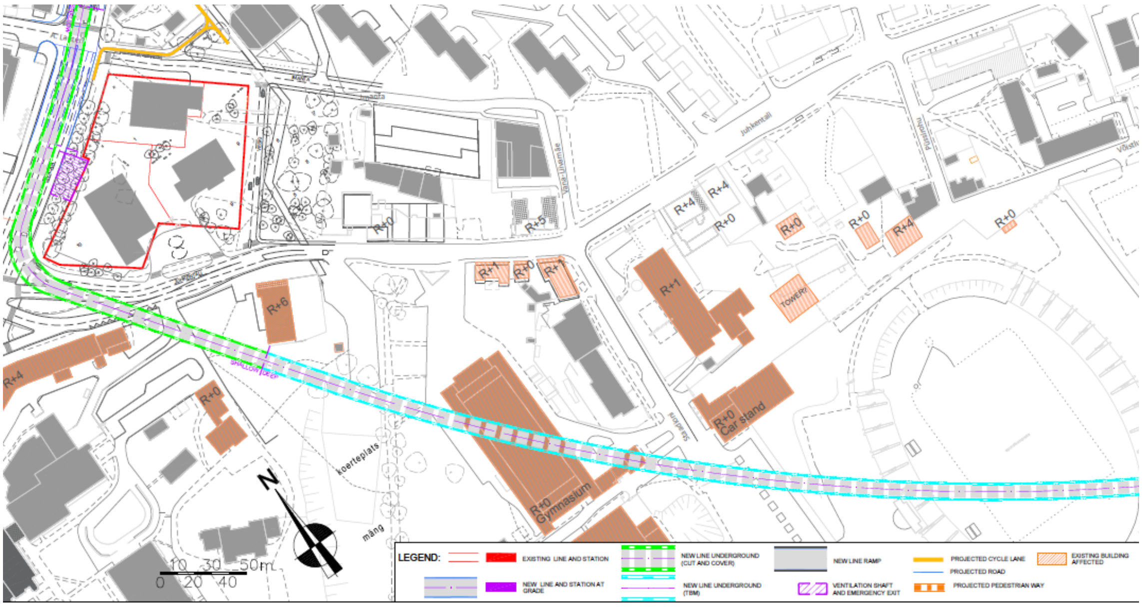


Figure 113 : tramway in tunnel option - West start of the tunnel - Egis

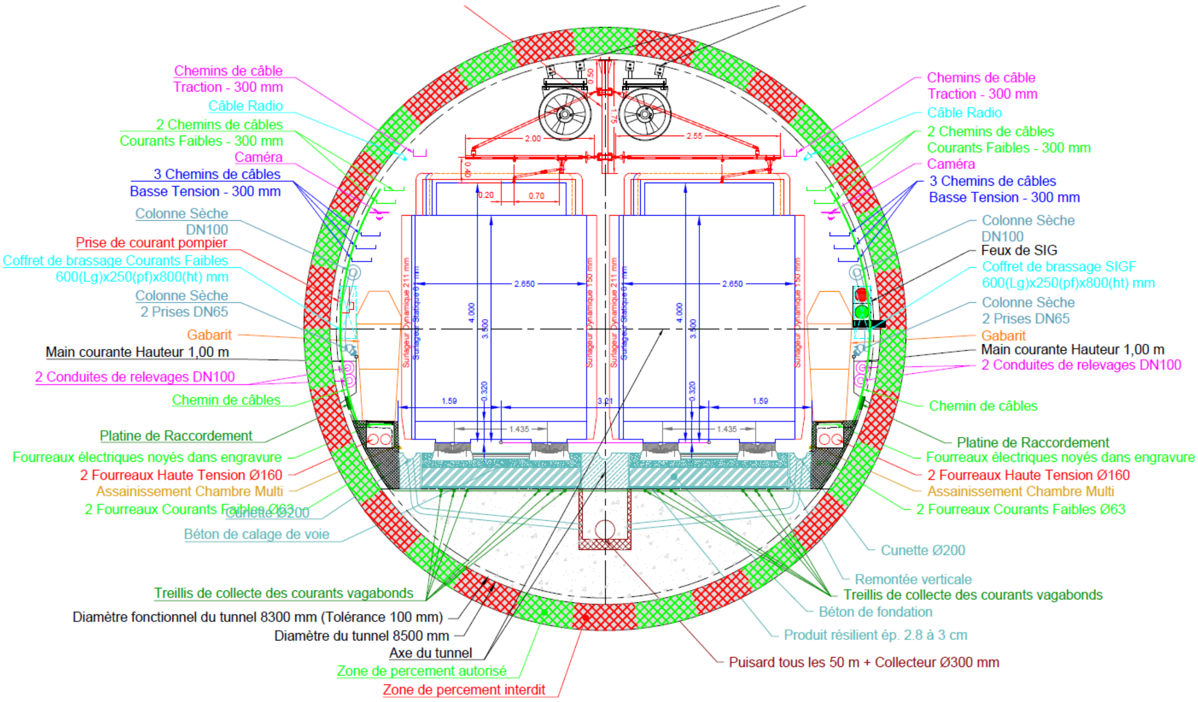


Figure 114 : Example of a TBM section - Tramway of Nice - Egis

The deep underground tunnel sequence is 1919m long, and the tunnel is 2621m long in total. An escape is necessary every 800m maximum. It is also necessary to install smoke evacuation shaft in this point of emergency evacuation. 4 emergencies and smoke evacuation shaft must be installed along the tunnel.

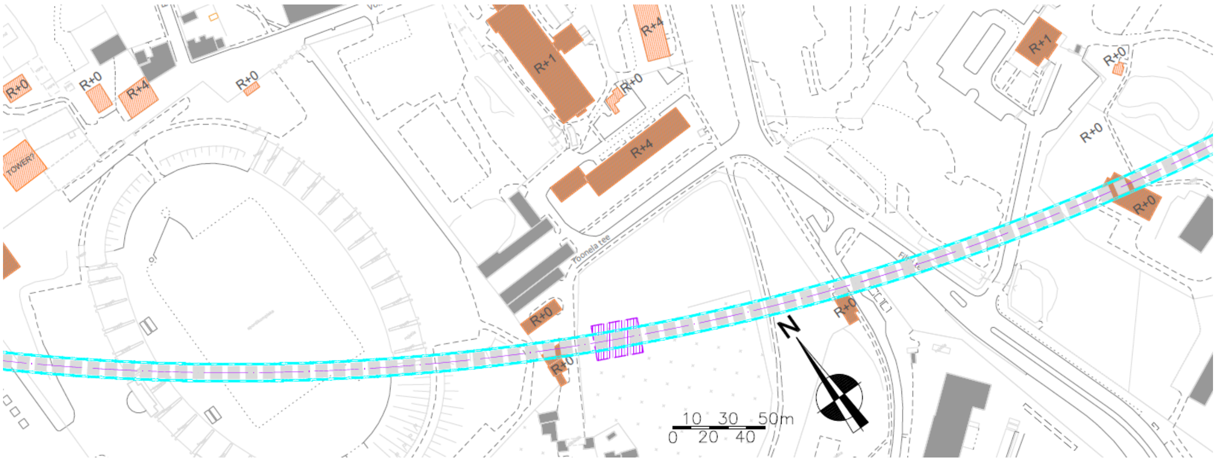


Figure 115 : Tunnel section under Kaalevi Kaaskstaadium - Egis

One of them is located next to the stadium. This area seems to be very active with the construction of new buildings. If needed, it is possible to convert this shaft into a passenger station.

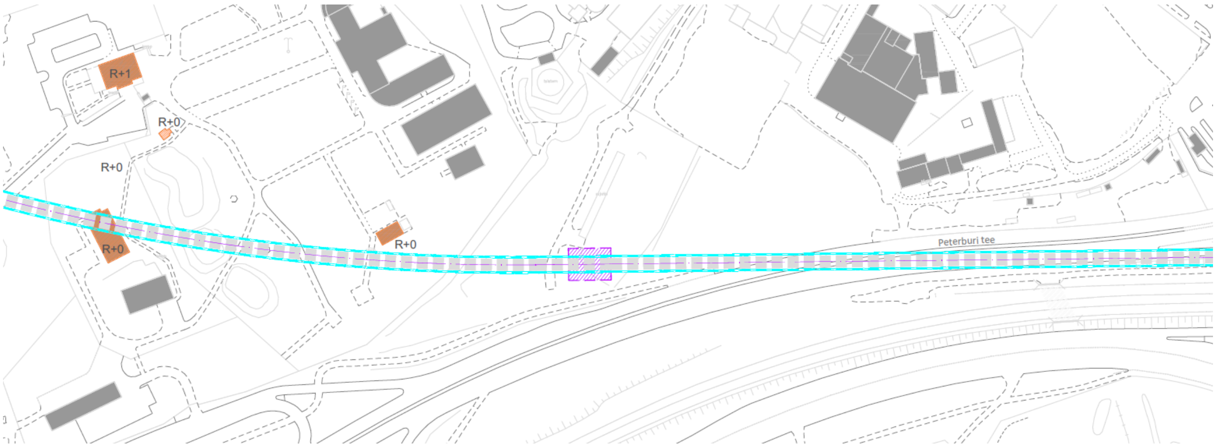


Figure 116 : tramway in tunnel option – Peterburi tee sequence - Egis

After passing under some green fields, the tunnel is passing under Peterburi tee and under Tartu Mnt. This kind of infrastructure allows no impact on the surface during the civil works.

5.3.8 Ülemiste sequence - Ülemiste station

Arriving in Ülemiste tee, the deep underground tunnel build with a TBM is ending on an emergency shaft. Than the tunnel is build till the terminus station in cut and cover.

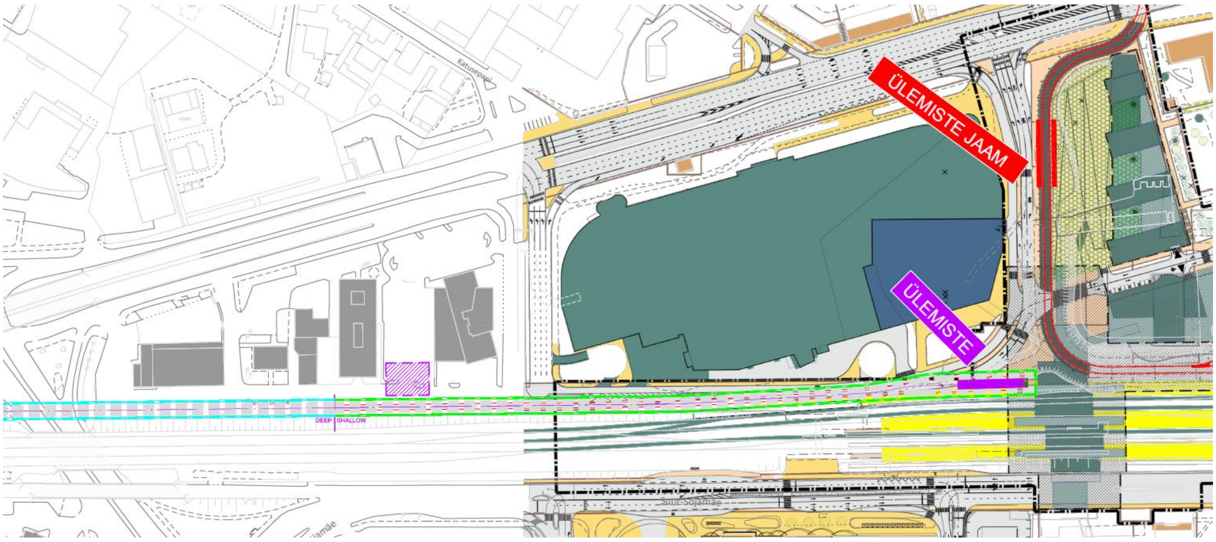


Figure 117 : tramway in tunnel option - Ülemiste sequence – Egis

Ülemiste is an area with many projects: Malls, Rail Baltic station, new pedestrian area, offices, etc. The location is very interesting just close to the international airport.

However we do not have the exact altimetry of the projected road and the plans of Rail Baltica station.

The project proposes to position the station out of the future platforms of the train station. Due to the future road close to the train station, the tramway station has to be underground under the road. The road would be at +39.0m. The tramway platform would be at +31.0m.

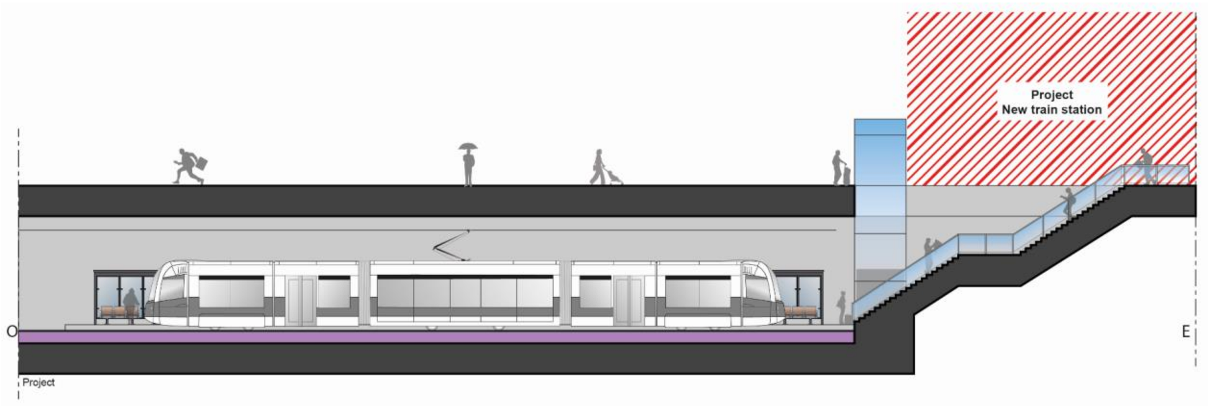


Figure 118 : Tramway in tunnel option - longitudinal section in Ülemiste Station - Egis

5.3.9 Ülemiste station - Variant

An interesting option could be to localize the tramway station at grade under the northern train platform to avoid an underground station and to reduce the interconnection time.

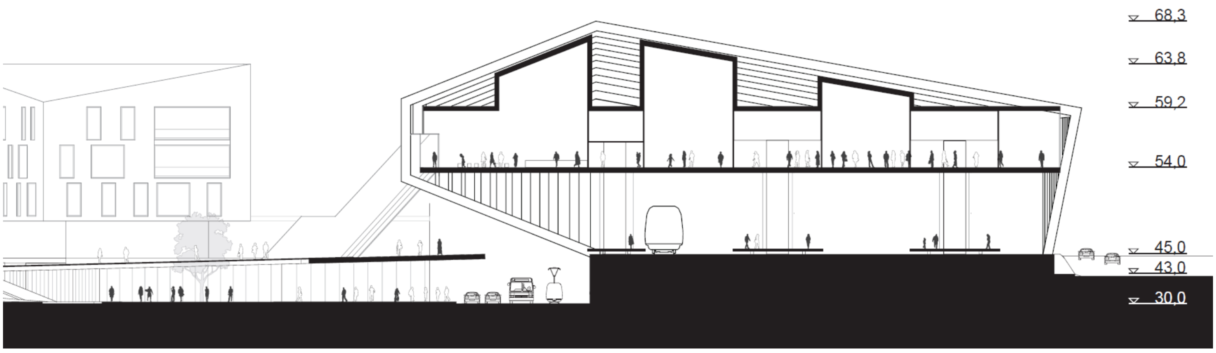


Figure 119 : architectural section of the future Ülemiste Station

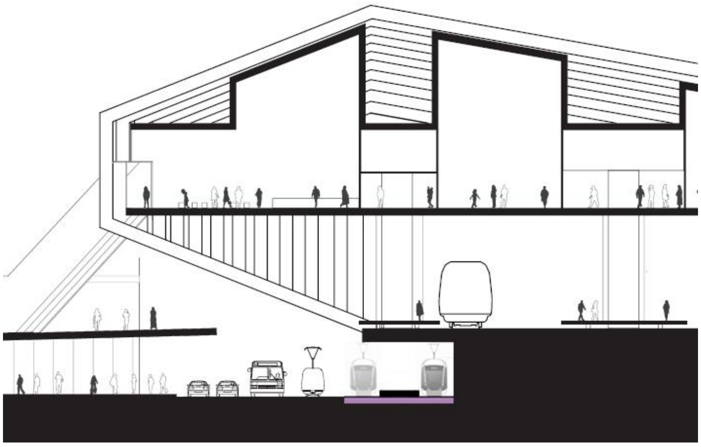


Figure 120 : proposition of a tramway station under the train platform - Egis

Another positive aspect is that this line of tramway could interconnect with the existing line. It gives the possibility to reach the airport station and/or to use the turn back loop. If a loop is also install at the terminal D in Vanasadam, it implies that the rolling stock could be in the current standard.

This option could be verified during the development of the new station with precise plan of the projects around (roads and platforms).

5.3.10 Utilities constraints

Gas network exists under Joe (between Gonsiori and Ahtri), Diversion of these kind of pipeline represents a major issue. Utilities contractors need to be suitably informed and managed to allow their diversion of utility networks on the train route could be relocated by the constructor. Achieving these diversions in phase with works progress can be cause of serious works delay and can present an important cost.

Next map from "Tallinn comprehensive map" (www.tallinn.ee) presents gas network.

Figure 121 : gas network

5.3.11 Conclusion

This solution is passing through very busy avenues of Tallinn: Liivalaia Street, Pronksi Street and Joe Street. ***A traffic study needs to confirm that the integration of a tramway line does not produce traffic jam in the peak hour.***

Hobujaama station is not feasible as it is drawn in the plans. The width of the streets are too narrow in this area.

An alternative option could be to realize a shallow underground tunnel all the long of the alignment, except maybe at the stations and in the north part of Joe Street.

5.4. Operational characteristics

5.4.1 Round trip time calculation

Round trip time calculation

The calculation is made with the same hypothesis explained for the tram option.

The complete commercial travel time for the new line 5 is about 8 minutes in both directions and the commercial speed is about 28,1 km/h to south which is better than modern tramways operating in a urban environment.

The travel time between Vanasadam and Ülemiste is about 8 minutes

Tableau 14 : simulation of total travel time new line 5 Ülemiste RB station - Vanasadam

line 5 Ülemiste - RB station - Harbour - Vanasadam	Distance	Stations dwelling time	Number of roads intersections (with lights)	Commercial travel time	Regulation time	Arrival (h:m:s)	Departure (h:m:s)
Ülemiste - RB station	0	0	0	0			00:00:00
Station Liivalaia	2686	20	0	240		00:04:00	00:04:20
Station Pronksi	559	20	2	105		00:06:05	00:06:25
Harbour - Vanasadam	543	20	2	90		00:07:55	

Fleet size calculation

Line	Way	Itinerary (O/D)	Commercial Speed	Travel time commercial	Time at terminus (stop + change direction)	Regulation time	Round trip duration	Minimal interval (peak hour)
line 5	↑	Ullemiste - RB station - Harbour - Vanasadaam	28,71	07:55	01:20	03:00	00:24:30	15:00
	↓	Harbour - Vanasadaam - Ullemiste - RB station	28,71	07:55	01:20	03:00		

With 15 minutes headway and about 25 min round trip time for the new line 5, only 2 trainsets are needed in operation during peak period.

Line	Rolling stock (bidirectionnal)			
	in line (peak hour)*	in reserve for maintenance *	in reserve for operation*	TOTAL
line 5	2,00	1	1	4

A reserve fleet for maintenance and operation has to be considered in addition to the fleet for peak period operation a maximum of 15% reserve for maintenance, depending on the maintenance strategy (number of daily and weekly shifts…) and for operation reserve.

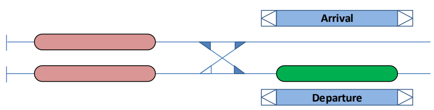
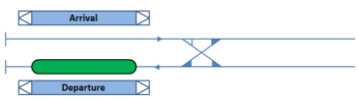
Our simulation resulted in a total fleet size of 4 trainsets for the new line 5. There will be no impact on the depot (8 new tram could be stabled in current depot).

Minor technical modifications could be required on the depot for the maintenance and the stabling of new bidirectional trams.

5.4.2 Track plan layout

There are two main types of terminus, based on the localization of the turnback:

- Turnback behind the station;
- Turnback in front of the station.

Terminal station configuration	Turnback behind the station  	Turnback in front of the station 
Benefits	Operation flexibility: the train can stop and wait at 3 different positions	Limited area, facilitated insertion

	(arrival platform, turnback point and departure platform). Turnback behind the station can offer a shorter headway The length of crossovers is reduced, and so is the maneuvering time	Platform located at the end of the line. (best connections, and better accessibility)
Consequences	In general, this terminal station configuration requires more space than the turnback in front of the station	There is only one stopping position, at the platform itself. Less operating flexibility (Turnback) during the commercial service (discomfort for passengers)

Turnback behind the station is preferred for operation flexibility and stabling positions.

For the new line, the terminus stations of Ülemiste is suggested to be configured with a turnback in front of the station according to limited area and terminus stations of Vanasadam station is suggested to be configured with a turnback behind the station.

A turnback is required at the connection between the line 1/3 to enable fleet injections and withdrawals from and to the depot.

5.5. Project costing and implementation schedule

5.5.1 Investment costs

Methodology and main hypothesis

The cost estimates are determined on the basis of unit prices applied to quantities:

- The quantities are at feasibility study level of details, they are based on the cross sections and the systems conception presented in the previous sections of the report.
- The costs are Estonian costs for civil works and buildings, and French costs for systems. The Estonian civil works costs are taken as being 75% of the French civil works costs (excluding the TBM cost). For the items that mix civil works and systems like "Rail systems" and "Power supply equipment", their price has been taken as 90% of the French costs.

These prices are expressed in euro exclusive of taxes (both internal taxes like VAT, and import taxes) as of their January 2018 value.

The following items are not included in the cost estimates: land acquisition (no acquisition have not identified) and utilities diversions.

Contingencies are added on top of these costs. The contingencies amount is intended to ensure that the project cost does not exceed the overall budget on a constant program basis. At the current level of study, they are included at the level of 15 %.

For the section of infrastructure, the main hypotheses are the following:

Table 5 : Characteristics of the different sections of infrastructure

	New tram line
Line length *Included underground section*	3 880m *2 500 m*
Nb of new stations	4
Nb of rolling stock units	4

Detailed hypothesis

The cost of the project has been broken down into different items which limits are described here below and which description shall always be shown together with the final synthesis table.

Client's direct costs / Consultancy services

This item contains the costs of project management, consultancy services and complementary studies or services (such as detailed project, legal assistance, insurance, communication, consultation, public surveys, archaeological excavations, and topographical, noise and soil surveys, compensation for inconvenience or loss of business during works etc.).

These costs are estimated to be 10% of the total project cost excluding rolling stock.

Land acquisition

This item contains the land acquisition, Land acquisition is not included.

Few acquisitions are identified on the shallow section in the corner of Liivalaia and Juhkentali

Utilities diversion

This involves the costs of diversion of the underground utilities in order to keep independent the operation of the transport system and the maintenance of utilities, whether funded by the organizing authority or otherwise.

For the feasibility study, costs of utilities diversion are difficult to estimate in details. The cost of diversion of utilities diversion are estimated according a ratio per kilometer based on from previous international experience in tramway construction excepted for the main utilities as main pipe of gas or main pipe of heating pipe which are estimated specifically.

Preparatory works

This item includes all the preparatory works for work completion on public property, such as: release of right-of way, cutting down of trees, road diversions, temporary lighting, work site facilities, temporary roads for traffic diversions, etc.

For the underground sections, preparatory works are included directly on Civil Engineering works.

No particular hypothesis has been taken into account.

Civil Engineering works

This item includes all major civil engineering works like tunnels, underpasses, bridges.

It includes cost of underground sections:

- Drilling TBM
- TBM (single tube about 10m diameter)
- Installation TBM
- TBM shaft (for emergencies and smoke evacuation)
- Cut and cover (tunnel entrance near Olümpia Park and Ülemiste)
- Ülemiste shallow station (civil engineering woks only)

Track way

This item contains the excavation and concrete required to support the rail systems, it also includes the multitubular works.

In the at grade section, 9 550 m² of track way are taken into account.

Rail systems

This item includes the track system adapted to the tramway (sleepers, tracks, water drainage embedded concrete) and track points and crossings located along the line or at the stations backyards.

The track is 3 880 m long (underground and at grade sections).

Track way cover

This includes the right-of-way covering: filling between rails, surface covering and separators of right-of-way.

The separator in made of concrete all along the line. The covering is 100% concrete.

Roads and public spaces

It includes the roadway and public spaces works required for restoring the public space: earthworks, structural works, pavements and coverings.

The estimate takes into account 16 800 m² of renewed streets and 12 800 m² of renewed sidewalks and bicycle lanes.

Urban Facilities

It includes the urban equipment located along the line: planting, urban furnishings, benches, fences and guard rails.

The following hypotheses are taken into account: 500 m² of grass is laid out, 1 400 m of public lightning are renewed.

Road traffic signaling

It includes the road signaling:

All the major junctions are equipped with traffic lights.

Stations

This item includes the civil engineering: structural work and finishing work. It also includes the station equipment: station furnishings including shelters, benches, fences, lighting.

4 new stations are implemented included the shallow station of Ülemiste.

Power supply equipment

This item includes all the facilities needed to distribute power to the electric traction vehicles: substations, power instrumentation and control system, connection to the distribution networks, overhead line and its poles and anchors.

The estimate take into account 3 substations for this project. The whole line is equipped with an overhead contact line. Standard support masts are implemented.

Low voltage and OCC

This item includes all the low voltage equipments of the systems (especially stations equipment). It also includes tramway signaling and the OCC equipment required for the centralized management of the system. The OCC building is part of the next item.

The low voltage equipments are listed in chapter 3 - section "System conception" of this report. The estimation don't take into account of new OCC. The turnouts at intersections with the existing infrastructure are equipped with signaling.

Workshop & Depot

This item includes all the elements of the depot and workshop, including buildings and equipments: internal tracks, overhead lines and poles, signaling, washing and maintenance equipments…

For the project, no investment on the depot has been taken into account.

Rolling Stock

In addition to the vehicles themselves, this item includes the cost of testing and commissioning equipment.

The estimate take into account 4 new rolling stocks.

Results

With these assumptions, the cost of the extension is estimated of 200 million euros (2018 cost excluding taxes, without land acquisition and utilities diversion).

The synthesis table is presented according to the above mentioned cost breakdown:

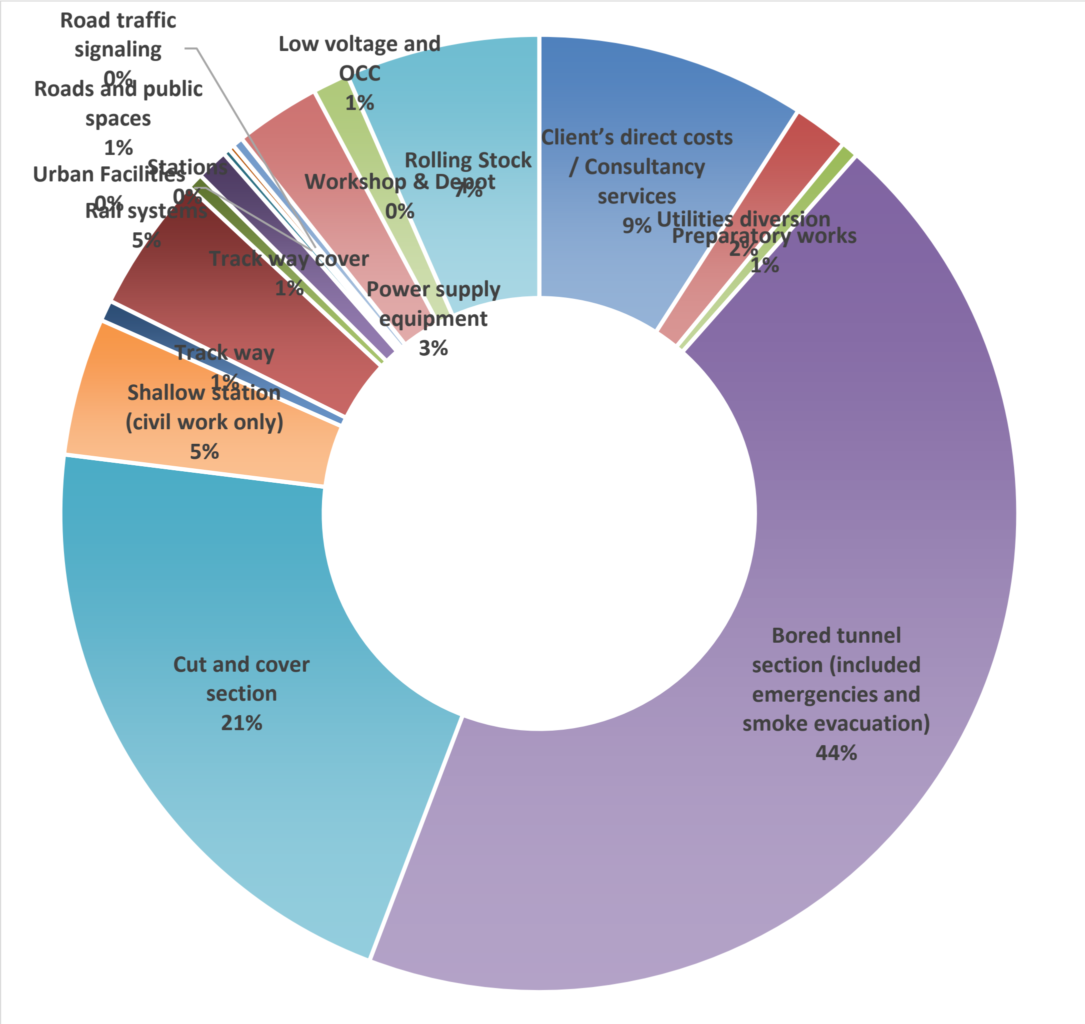


Table 6 : Investment costs for the new tram line in tunnel

Client's direct costs / Consultancy services	**19 946 k€**
Land acquisition	**0 k€**
Utilities diversion	**4 070 k€**
Preparatory works	**1 279 k€**
Civil Engineering works	
Bored tunnel section (included emergencies and smoke evacuation)	**97 080 k€**
Cut and cover section	**46 500 k€**
Shallow station (civil work only)	**10 201 k€**
Track way	**1 551 k€**
Rail systems	**10 145 k€**
Track way cover	**1 171 k€**
Roads and public spaces	**2 338 k€**
Urban Facilities	**495 k€**
Road traffic signaling	**411 k€**
Stations	**796 k€**
Power supply equipment	**6 335 k€**
Low voltage and OCC	**2 681 k€**
Workshop & Depot	**0 k€**
Rolling Stock	**14 412 k€**
Total	**219 409 k€**

5.5.2 Implementation schedule

Overview

After the approval of the current feasibility study, the main elements that have to be taken into account in the implementation schedule are:

- The preliminary and detailed design, followed by the tendering process for the rolling stock, the depot and the main line.
- The administrative procedures including the land acquisitions, if any.
- The works and the manufacturing of the rolling stock.
- The testing and commissioning of the system.

All these tasks have to be supervised by a strong project implementation unit and/or a general consultant.

The hypothesis taken here is that the project will be implemented through traditional public procurement.

Detailed design

The detailed design will be the basis for the tender documents. This study requires an approved preliminary design and some public consultation to make sure that the project will be granted public approval.

The experience of past tram lines show that this phase is one of the most critical study phase: it is the stage when all decisions have to be taken and finalized. As the detailed design maps will be used by the contractors performing the works in order to draft their shop drawings, they should be as close as possible to the final project.

Administrative procedures

This task includes all the administrative procedures required to get the necessary permits for starting the construction works and performing the land acquisitions.

Rolling stock

The rolling stock studies, made by the manufacturer, have to start after the approval of the detailed design so that all project options have been decided.

It takes about 24 months for the manufacturer to perform its studies, build and deliver the first rolling stock unit. At that point, the depot and the test track have to be available so that on site rolling stock testing can begin.

Main line works phasing

Tunnel construction takes about 39 months, the location of the TBM site installation required to progress the TBM in two phases, first between the site installation to Liivalaia, and second between the site installation to Ülemiste. The following period have to be taken into account:

- TBM procurement (procure, manufacture, deliver and assembly TBM): about 18 month
- TBM progress from entrance portal to Liivalaia : about 4 months
- TBM Disassembly, transfer and reassembly : about 6 months
- TBM progress rate from entrance portal to Ülemiste : 6 months

After system equipment and stations are implemented.

Testing

After completion of works on the main line, testing can start. Full testing of a tram line takes about 6 months.

Results

With the hypotheses considered here, the extension of train line until the port can open for revenue service as soon as possible at the beginning of the year 2025.

This opening is adapted to the Rail Baltica opening.

The summary planning is shown below and the detailed planning after.

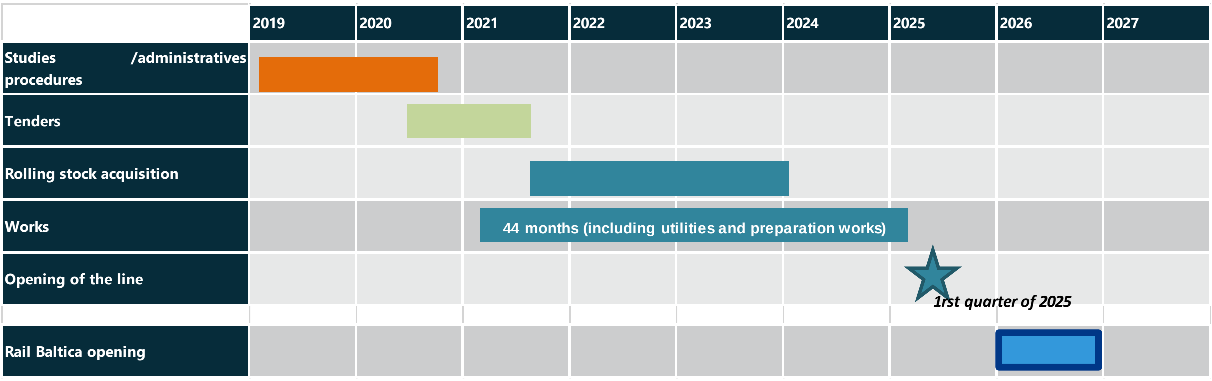


Figure 122 : Train in tunnel option - Summary implementation schedule

However, according the **opening of Rail Baltica, it is proposed to take 2026 for the beginning of the commercial operation of the project between Ülemiste and Vanasadam.**

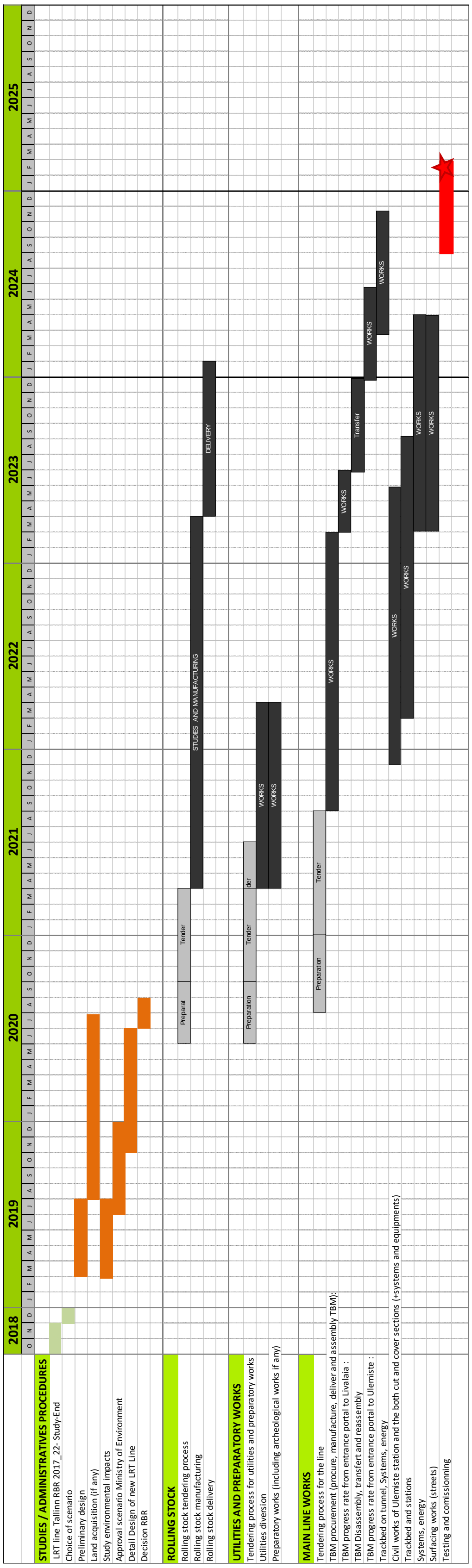


Figure 123 : Tram in tunnel option - Detailed implementation schedule

6. Cost-Benefit Analysis

6.1. Ridership analysis and forecast

6.1.1 Methodology

The ridership forecast and analysis is based on the traffic modelling which is composed of following steps:

- Step 1: estimation of current public transit demand
- Step 2: reference situation modelling in 2026
- Step 3: project scenarios modelling

I.1.1.1 Estimation of current public transit demand

The current public transit demand is based on two input data:

- The Harju public transit model which is provided by North Estonian Public Transport Center
- The Tallinn commuting and home-school matrix which is provided by Tallinn Transport Department.

The Harju public transit model involves the whole territory of Harju County, based on a zoning system of 444 zones. The model refers to the situation of April 2017, 6 public transit modes and 204 public transit lines are included in the model. As to the public transit demand, three demand of a typical working day from 5 am to 2 pm are estimated, basing on the ticket sales system: single ticket user; regular traveler and student.

- Single ticket user: 2610
- Regular traveler: 5762
- Student: 2610

Although the model is only focus on the travel between Tallinn and others cities in Harju and doesn't contain the demand inside Tallinn.

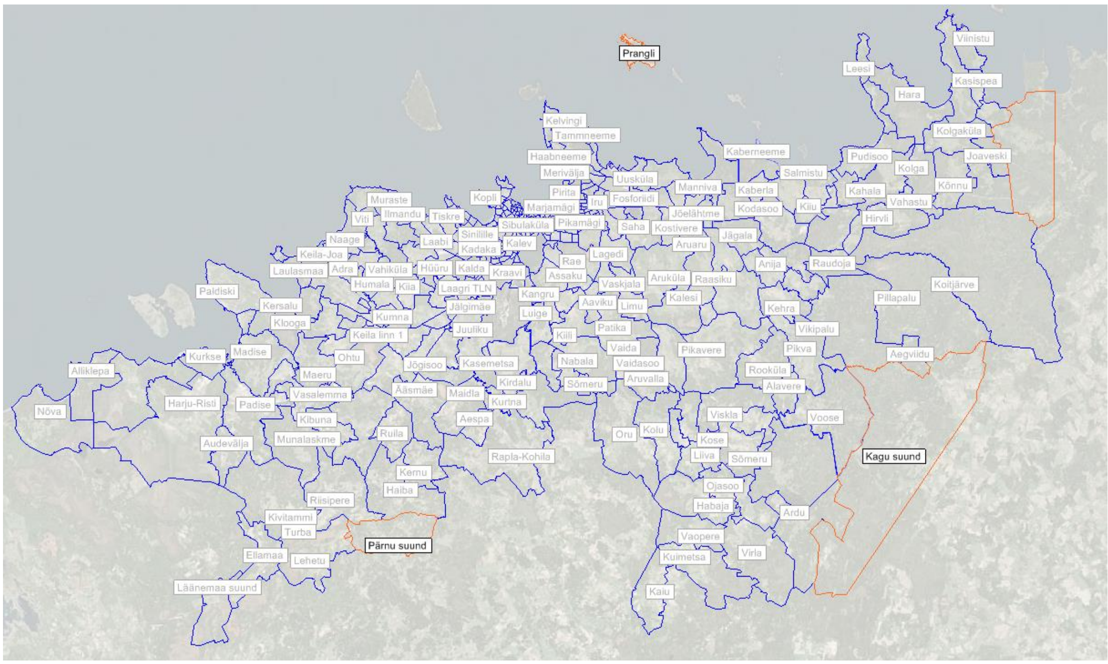


Figure 124: the zoning system of Harju public transit model

To obtain the current public transit demand, the three demand of the Harju model have been combined to one unique matrix, then the matrix has been completed by Tallinn commuting and home-school matrix, provide by Tallinn Transport Department.

According to the Tallinn commuting and home-school matrix, there are 177 679 trips from home to work and 61 850 trips from home to school on an ordinary working day. Although the transport mode and travel period are not specified, the following hypothesis has been used to obtain the public transit demand from 5 am to 2 pm:

- The appearance ratio at school/work place : 90%
- The mode split of public transit : 62% (ref. page 9)

And we consider the travel other than home-work/home–school travel occupy a negligible part for our specific project

As the zoning systems of two input data is different, an additional work to aggregate the Tallinn commuting matrix to the zoning system of Harju public transit model has been done. Then we combine the two matrix and obtain the current public transit demand in Harju County: 128 106.

I.1.1.2 Reference situation modelling in 2026

The reference situation modelling in 2026 contains the demand projection and the public transit offer in 2026.

The demand estimation in 2026 takes various factors into account:

- The population growth
- The modal share evolution

- The development project in port area
- The Rail Baltica project
- The ferry passengers

The population growth

The population growth of Harju County has been analysis in Tallinn and in Harju without Tallinn. In Tallinn, we observe an increase of population since 2008 with a mean annual growth rate of 1.2%.

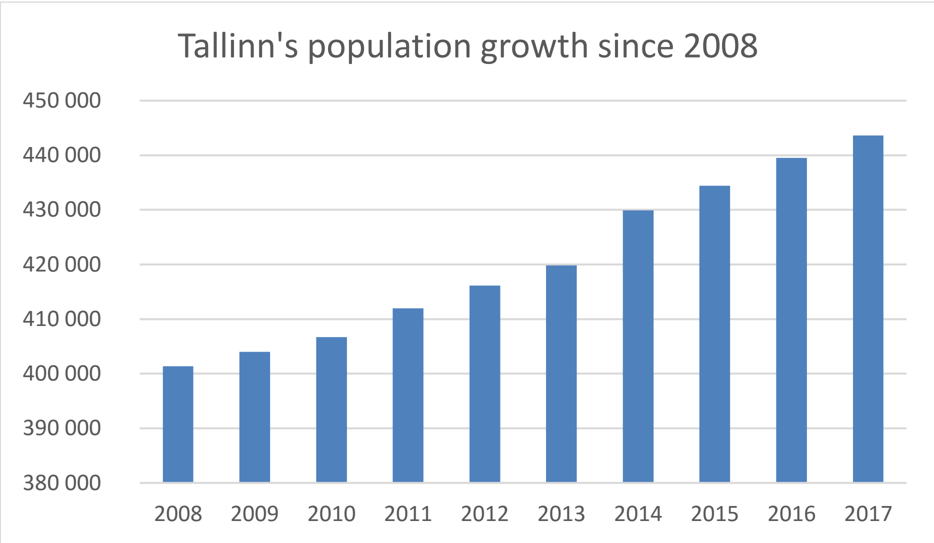


Figure 125: Tallinn's population growth since 2008 (source: statistical yearbook "Tallinn avedes", 2017)

As to others cities of Harju County than Tallinn, we apply an average increase rate of population in Harju, following the observation of the population growth between 2006 and 2011.

Année	Harju population
2006	521 313
2007	522 147
2008	523 277
2009	524 938
2010	526 505
2011	528 468

Table 7 : the population growth in Harju from 2006 to 2011

Consider the population growth in Tallinn and in Harju outside Tallinn, the hypothesis of the population growth from 2017 to 2026 we took are as following:

- In Tallinn : 1.105
- In Harju outside Tallinn: 1.025

The modal share evolution

The public transport in Tallinn holds a large part to work, school or other main destination in the division of modes of travel (53-62%, figure 4). With the free public transport in Tallinn since January 2013 and the policy of promote the use of public, cycling and walking, we consume that the part of public transport will be improved in 2026:

- Public transport : 63%
- Car : 25%
- Walking : 9%
- Cycling : 2%
- Other: 1%

	2008	2010	2012	2013	2014
TC	61	55	55	62	53
Car	34	31	32	29	31
Walking		12	12	7	14
Cycling		1.8	0.7	0.7	0.5
Other	0.6	0.6	0.8	0.9	1.3

Table 8 : main mode of travel to work, school or other main destination on working day (source: satisfaction of residents with public service of Tallinn, 2014)

<u>The development project in port area</u>

In the masterplan of Tallinn, a lot of urban projects are planned in the port area. In stage 4, there would be 2043 residents and 428 university students more in port area. We take the trip generation of those projects into account in our demand estimation in 2026.

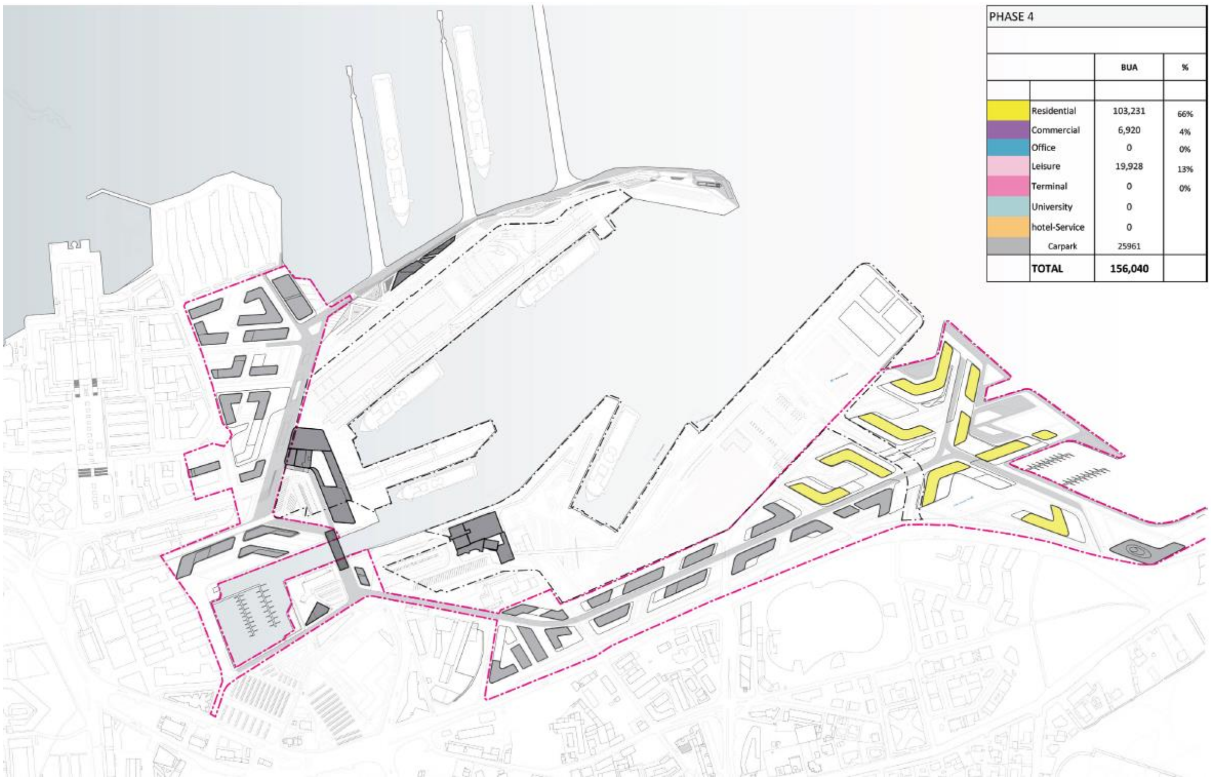


Figure 126 : program (Source: Tallinn masterplan 2030; stage 4 report)

The Rail Baltica project

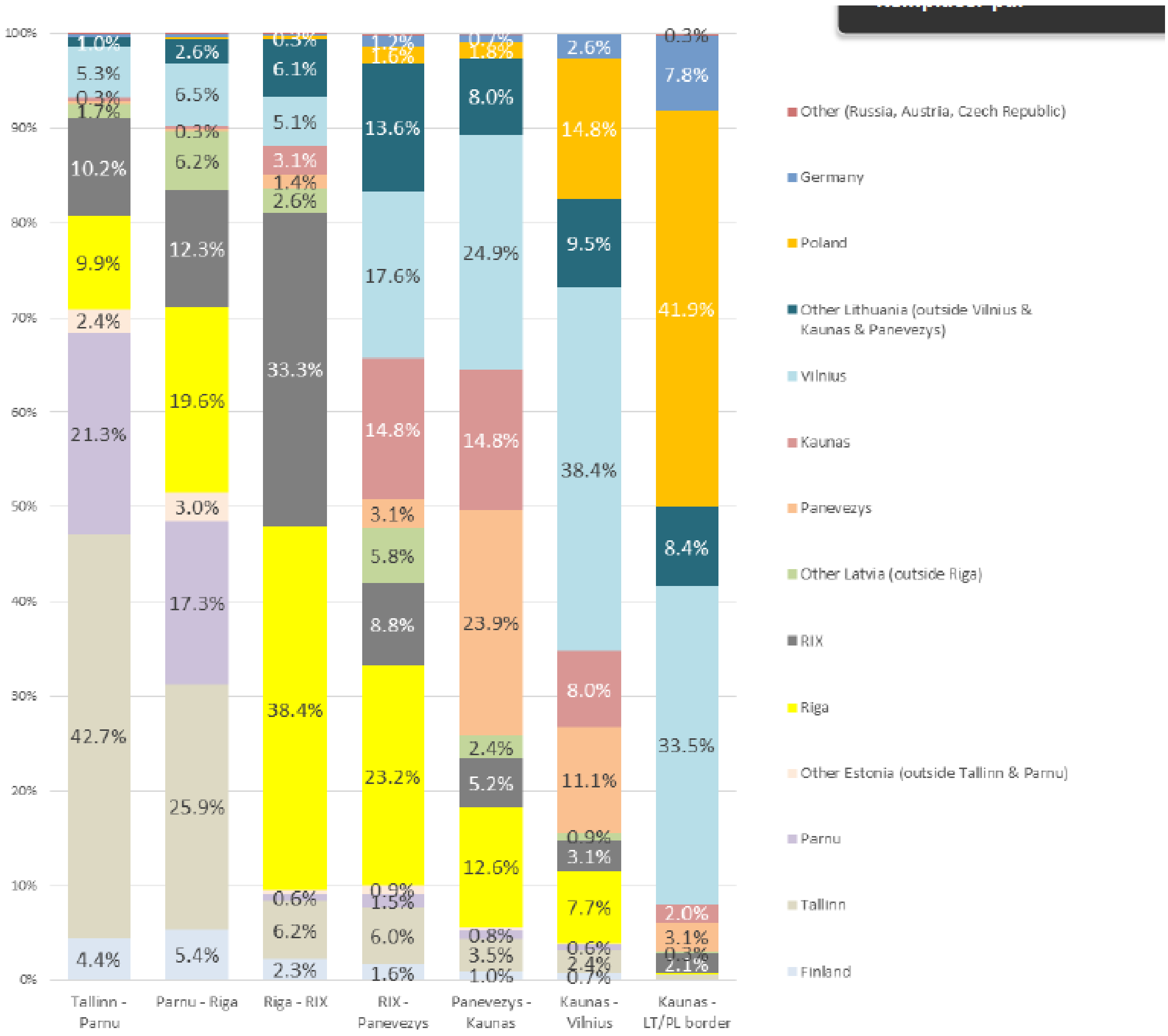
With the Rail Baltica project in service, Ülemiste station would have 428 000 new passengers per year carried by the new railway. That means there would be 118 new passengers in the peak hour on working day.

The ferry passengers

Meanwhile, according the potential passengers analysis of the Rail Baltica project, around 73779 passengers per year come from Finland. We suppose those people use the public transit to join Ülemiste station, and have been taken into account in the demand estimation in 2026.

Table 9 : Rail Baltica - passengers forecasts (thousand passengers) source: Rail Baltica Global Project Cost-Benefit Analysis – EY - 2017

	2025	2026
Tallinn-Parnu	0	428
Parnu - Riga	0	354
Riga-RIX	0	794
RIX-Panevezys	0	392
Panevezys - Kaunas	0	680
Kaunas - Vilnius	0	887
Kaunas - PL/LT border	0	358
Trips	**0**	**1 920**



In 2016, according to FinEst link, there were about 8.5 million passengers between Tallinn and Helsingi per year, among those about 1.3 million are in cars and 86 000 are in tourist buses. We suppose there are 2.5 passengers in a car, and a tourist bus carried 30 passengers, thus we deduce there are 2.8 million passengers who need choose their travel mode when they arrive at Tallinn. We suppose that 40% of those passengers choose to use the public transport to travel in Tallinn which means 1694 passengers who took public transport in the peak hour on a working day. If we apply the population growth ratio of Helsingi (1%), in 2026, there would be 1871 additional passengers from ferry who would take the public transit to travel. This passengers from ferries are mainly attracted by the city centre and the old city centre thus, we assumed that it will only take on the tram option.

Nbre of passengers	2010	2011	2012	2013	2014	2015	2016	2017
Tallinn-Helsingi	6 646 289	6 982 723	7 264 264	7 573 674	7 959 688	8 186 320	8 476 942	8 798 048
Tallinn-Stockholm	860 805	917 963	936 459	934 966	955 492	931 346	963 572	1 012 588
Tallinn-Vuosaari	0	0	0	0	0	27 489	38 904	38 514
Stockholm-St.Peterburg	0	110 928	182 175	184 280	146 971	124 639	163 478	7 072
St.Peterburg-Stockholm	0	0	43	0	0	0	0	0
Helsingi-St.Peterburg	0	3 085	2 135	0	0	0	0	0
Helsingi-Stockholm	0	0	0	0	0	0	0	76 328
Muuga-Helsinki	0	4 073	0	0	0	0	0	0
Muuga-Vuosaari	0	0	0	0	0	0	0	0
Paldiski-Kapellskär	15 097	15 487	13 423	15 975	18 152	17 605	18 753	17 441
Kruiisilaevad	391 765	443 172	441 624	525 775	486 624	504 245	509 730	608 513
Kauba- ja muud laevad	1 290	1 498	1 556	1 759	2 386	1 405	1 918	1 608
Liin	7 915 246	8 478 929	8 841 679	9 236 429	9 569 313	9 793 049	10 173 297	10 560 112

Figure 127 : ferry passengers since 2010 (source: FinEst link)

<u>Public transport demand in 2026</u>

Thus, the public transit demand in 2026 is estimated to 160 229 for a period from 5am to 2pm on a working day.

As to the public transit offer in 2026, we suppose the current service (April 2017) will continue to work, with tram line 4 extended to Lennart Meri Tallinn Airport.

I.1.1.3 Scenario modelling in 2026

Four scenario modelling have been carried out:

- Scenario 1: Tram option
- Scenario 2: Train option
- Scenario 3: Tram in tunnel option
- Scenario 4: Tram option with improvement of commercial speed of Tram solution (3.6.1 Reduce number of station)

The public transit service of each scenario has been built in the Harju public transit model. As to measure the induced traffic of each scenario due to the improvement of public transit service, a generalized time-based elasticity method has been used:

(Demand project – Demand reference) / Demand reference = - 0.7 * (GT project – GT reference) / GT reference

If GT project > GT reference

(Demand project – Demand reference) / Demand reference = - 1.4 * (GT project – GT reference) / GT reference

If GT project < GT reference

Here, GT refers to Generalized Time. Reference refers to reference scenario, and Project refers to Project scenario.

6.1.2 Results

In general, we estimate an increase of 12% of the public transit demand in 2026 from 5 am to 2 pm, comparing the demand of 2017. Between the reference situation in 2026 and the scenarios, we observe a low induced traffic.

Matrices 2026	2017	Reference	Scenario 1*	Delta/Ref	Scenario 2	Delta/Ref	Scenario 3	Delta/Ref	Scenario 4*	Delta/Ref
Total	143 246.6	160 229.0	162 643.1	2 414.1	160 288.8	59.7	160 320.5	91.5	162 452.5	2 223.5
Growth/Ref.			1.5%		0.0%		0.1%		1.4%	

I.1.1.4 Reference situation modelling results in 2026

In the reference situation in 2026, as the model's perimeter covers the Harju County, the bus traffic (passengers.kilometers) is the most important, representing 76.7%, and the tram represent 5%.

Figure 128: estimated traffic in the reference situation in 2026 from 5am to 2pm

If we focus on the train and tram lines, the tram lines 2 and 4 captured 59% of passengers.

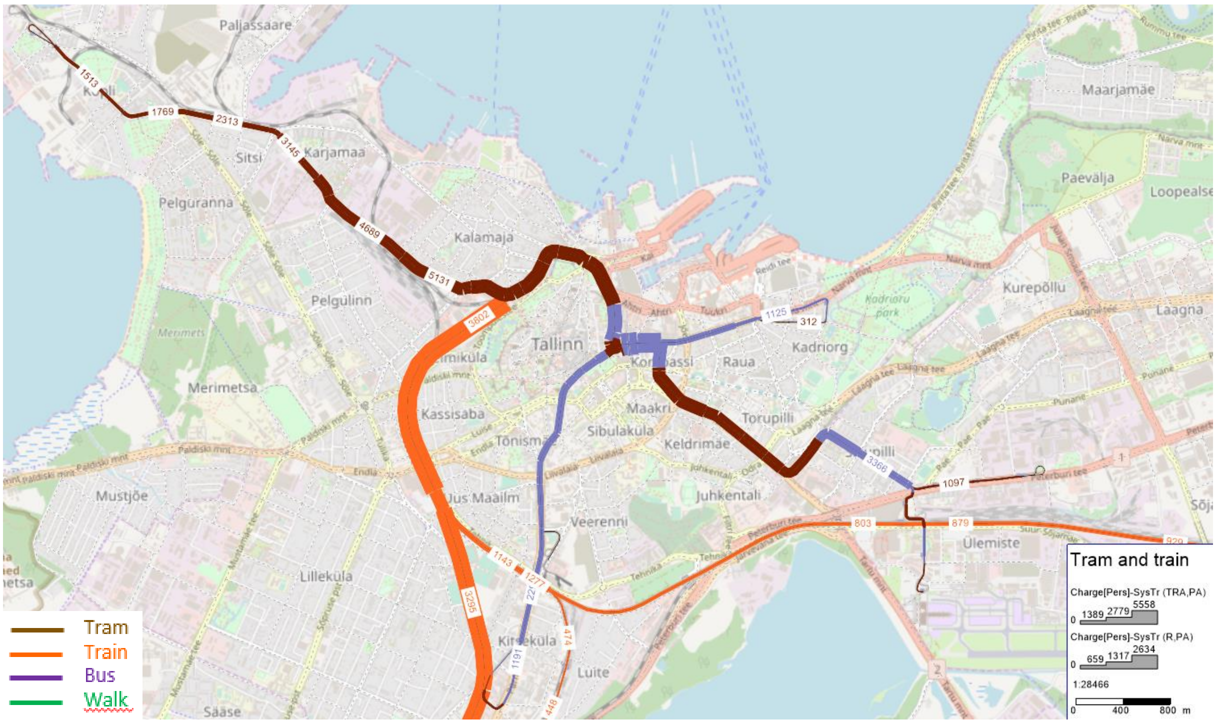


Figure 129: train and tram traffic in the reference situation in 2026 from 5am to 2pm

Among the stations the most important, Tallinn Railway station support the most traffic, we count 1 168 boarding and 2 634 alighting, and the second station is Balti Jaam with 696 boarding and 1 118 alighting.

The following table shows the number of boarding and alighting analysis of main stations. Number includes all the public transit lines of this station. Here it is a global analysis indicator.

	Model code	Boarding	Alighting
Tallinn Railway station	21106-1	1 168	2 634
Balti Jaam (Tram 1, 2)	10801-1	696	1118
Paberi	12302-1	202	191
Kadriorg	11901-1	551	312
Kopli	09005-1	110	490
Majaka põik	14901-1	188	838
Lennujaam	50005-1	635	65
Tondi	07406-1	1 151	404
Suur Paala	14701-1	11	908
Ülemiste railway station	13411-1	64	188
Ülemiste railway station Tram 5	50009-1	-	-
Keskturg	11702-1	326	752

Table 10: passengers boarding and alighting analysis of main stations

I.1.1.5 Scenario 1 modelling results

Compare to the reference situation, an increase of 1.4% of passengers has been observed to use of the public transport in the scenario 1. The bus lines hold a share less important than in the reference situation. We observe an increase of using the tram lines by 1.1%. A part of the increase comes from the modal shift from bus to tram, and a more important part comes from the modal shift from cars to the tram lines. As to the passengers of mains lines (train and tram), we estimate an increase of 42.6% of the tram line 2. As consequence, the station of the tram line 2 support a traffic more important, and have more boarding/alighting movements.

According to the simulation results, the tram lines carried on more than 8000 passengers.kilometers, compare to the reference situation.

Figure 130: estimated traffic in scenario 1 in 2026 from 5am to 2pm

Figure 131: train and tram traffic in scenario 1 in 2026 from 5am to 2pm

Pax	Reference scenario	Modal share	**Scenario 1***	**Modal share**
Bus	135 313	75.8%	135 735	74.9%
Train	7 227	4.0%	7 188	4.0%
Tram	15 507	8.7%	17 718	9.8%
Troll	20 492	11.5%	20 479	11.3%
Total	**178 539**	**100.0%**	**181 120**	**100.0%**

Table 11 : passengers per transport mode

Pax	Reference scenario	**Scenario 1***	**Delta/Ref**
ELR_Aegviidu	1 131	1 097	-3.0%
Tramm 1	3 703	3 442	-7.0%
Tramm 2	5 554	7 919	**42.6%**
Tramm 3	1 991	2 007	0.8%
Tramm 4	4 260	4 350	**2.1%**
Tramm 5	0	0	0.0%
Total	**16 639**	**18 815**	**13.1%**

Table 12 : passengers of main lines

	Model code	Boarding	Alighting
Tallinn Railway station	21106-1	1181	2608
Balti Jaam	10801-1	802	1483
Paberi	12302-1	256	296
Kadriorg	11901-1	553	307
Kopli	09005-1	111	481
Majaka põik	14901-1	190	945
Lennujaam	50005-1	718	99
Tondi	07406-1	1196	422
Suur Paala	14701-1	22	898
Ülemiste railway station	13411-1	61	171
Ülemiste railway station Tram 5	50009-1	-	-
Keskturg	11702-1	394	1069
Harbour Vanasadam	50006-1	1069	242

Table 13: passengers boarding/alighting of main stations

I.1.1.6 Scenario 2 modelling results

Compare to the reference situation, we keep a stable level of passengers who use of the public transport in the scenario 2, as well as the share of each public transport mode. The train on tunnel solution allows an increase of about 300 passengers, mainly in Aegviidu-Tallinn line.

The traffic on passengers.kilometers keep a stable level as well, compare to the reference situation.

Figure 132: estimated traffic in scenario 2 in 2026 from 5am to 2pm

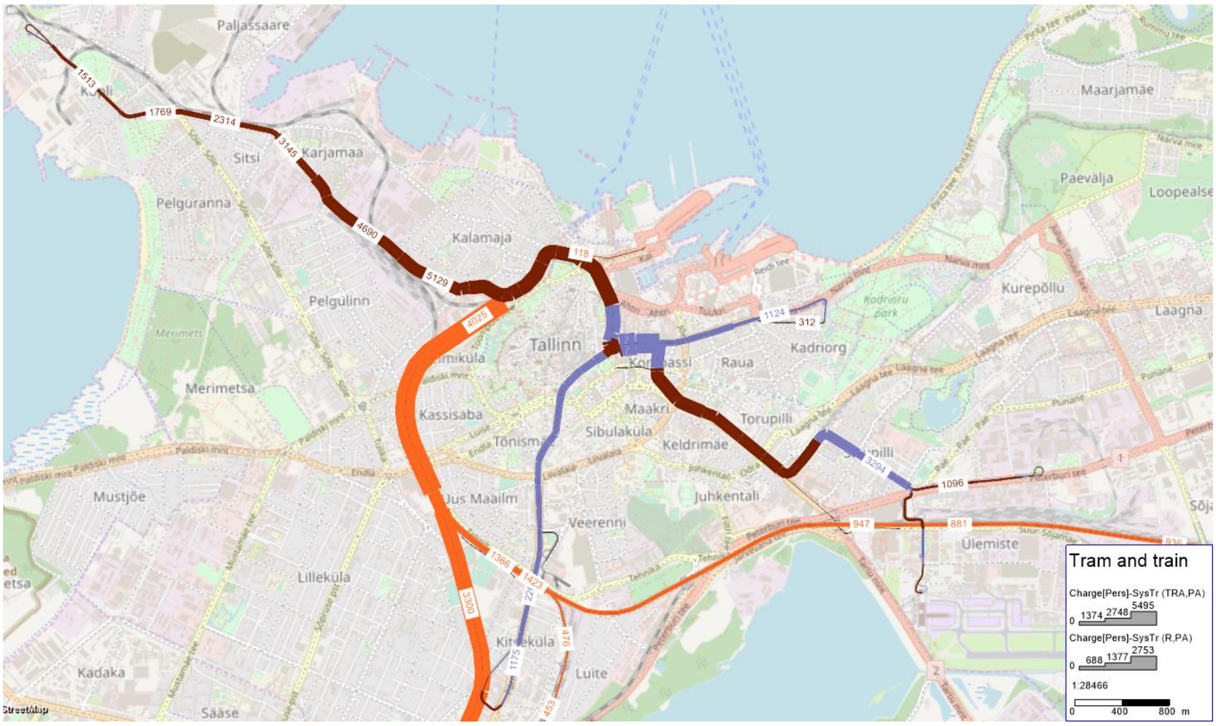


Figure 133: train and tram traffic in scenario 2 in 2026 from 5am to 2pm

Pax	Reference scenario	Modal share	**Scenario 2**	**Modal share**
Bus	135 313	75.8%	135 151	75.7%
Train	7 227	4.0%	7 527	4.2%
Tram	15 507	8.7%	15 392	8.6%
Troll	20 492	11.5%	20 491	11.5%
Total	**178 539**	**100.0%**	**178 561**	**100.0%**

Table 14 : passengers per transport mode

Pax	Reference situation	**Scenario 2**	**Delta/Ref**
ELR_Aegviidu	1 131	1 444	**27.7%**
Tramm 1	3 703	3 689	-0.4%
Tramm 2	5 554	5 528	-0.5%
Tramm 3	1 991	1 982	-0.5%
Tramm 4	4 260	4 193	-1.6%
Tramm 5	0	0	0.0%
Total	**16 639**	**16 836**	**1.2%**

Table 15 : passengers of main lines

	Model code	boarding	alighting
Tallinn Railway station	21106-1	1 293	2 682
Balti Jaam (Tram 1, 2)	10801-1	681	1 116
Paberi	12302-1	201	191
Kadriorg	11901-1	551	312
Kopli	09005-1	110	490
Majaka põik	14901-1	174	821
Lennujaam	50005-1	633	64
Tondi	07406-1	1 136	404
Suur Paala	14701-1	11	908
Ülemiste railway station	13411-1	99	293
Ülemiste railway station Tram 5	50009-1	-	-
Keskturg	11702-1	326	752
Harbour Vanasadam (Rail)	50006-1	12	106

Table 16: passengers boarding/alighting of main stations

I.1.1.7 Scenario 3 modelling results

Compare to the reference situation, we keep a stable level of passengers who use of the public transport in the scenario 3, as well as the share of each public transport mode. We observe a slight increase of train and tram lines.

The traffic (passengers.kilometers) keep a stable level as well (+0.1%), compare to the reference situation.

Figure 134: estimated traffic in scenario 3 in 2026 from 5am to 2pm

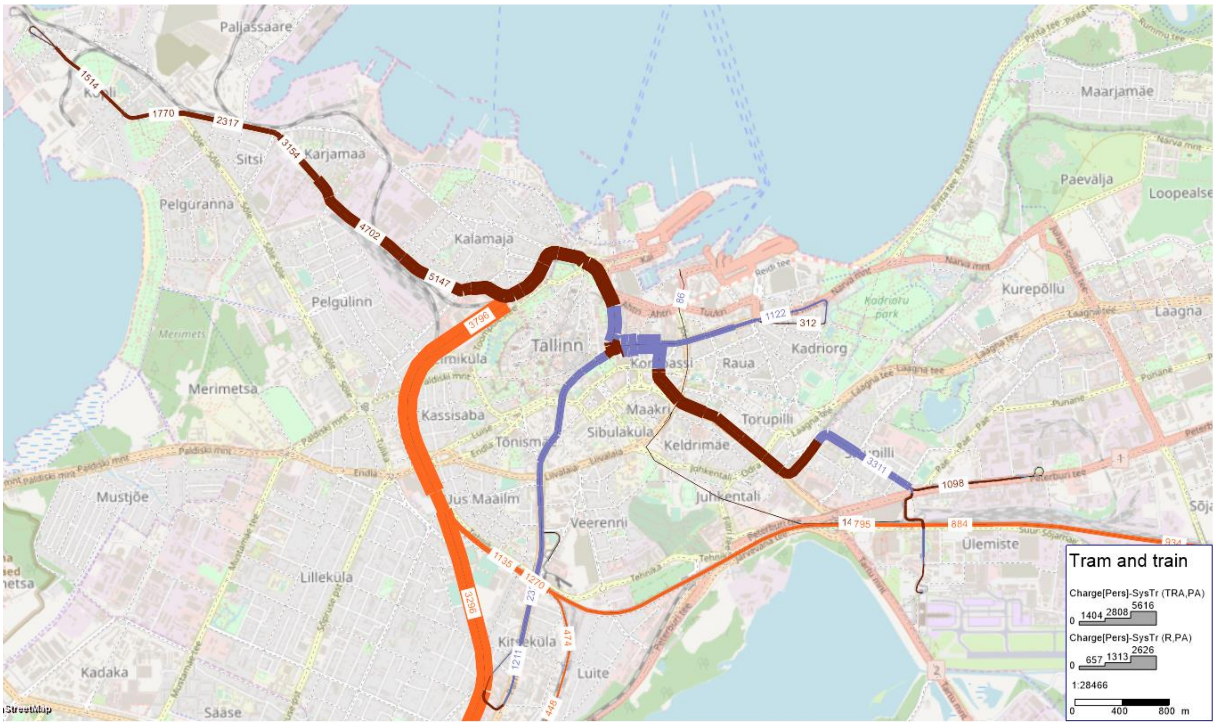


Figure 135: train and tram traffic in scenario 3 in 2026 from 5am to 2pm

Pax	Reference scenario	Modal share	**Scenario 3**	**Modal share**
Bus	135 313	75.8%	135 142	75.7%
Train	7 227	4.0%	7 235	4.1%
Tram	15 507	8.7%	15 776	8.8%
Troll	20 492	11.5%	20 488	11.5%
Total	**178 539**	**100.0%**	**178 641**	**100.0%**

Table 17 : passengers per transport mode

Pax	Reference scenario	**Scenario 3**	**Delta/Ref**
ELR_Aegviidu	1 131	1 137	**0.5%**
Tramm 1	3 703	3 692	-0.3%
Tramm 2	5 554	5 597	0.8%
Tramm 3	1 991	1 984	-0.4%
Tramm 4	4 260	4 269	0.2%
Tramm 5	0	**234**	0.0%
Total	**16 639**	**16 913**	**1.6%**

Table 18 : passengers of main lines

	Model code	boarding	alighting
Tallinn Railway station	21106-1	1 170	2 626
Balti Jaam (Tram 1, 2)	10801-1	697	1 120
Paberi	12302-1	223	277
Kadriorg	11901-1	550	312
Kopli	09005-1	110	490
Majaka põik	14901-1	188	825
Lennujaam	50005-1	640	64
Tondi	07406-1	1 168	406
Suur Paala	14701-1	11	909

Ülemiste railway station	13411-1	64	204
Ülemiste railway station Tram 5	50009-1	33	112
Keskturg	11702-1	324	753
Harbour Vanasadam (Tram 5)	50006-1	51	35

Table 19: passengers boarding/alighting of main stations

I.1.1.8 Scenario 4 modelling results

Compare to the reference situation, the tram lines have a share more important in the scenario 4. The simulation results show an increase of 1% for the modal share of the tram lines, mainly because of the tram line 2 and 4 which support a more important traffic.

Figure 136: estimated traffic in scenario 4 in 2026 from 5am to 2pm

Figure 137: train and tram traffic in scenario 4 in 2026 from 5am to 2pm

Pax	Reference scenario	Modal share	**Scenario 4***	**Modal share**
Bus	135 313	75.8%	135 734	75.0%
Train	7 227	4.0%	7 178	4.0%
Tram	15 507	8.7%	17 519	9.7%
Troll	20 492	11.5%	20 491	11.3%
Total	**178 539**	**100.0%**	**180 922**	**100.0%**

Table 20 : passengers per transport mode

Pax	Reference scenario	**Scenario 4***	**Delta/Ref**
ELR_Aegviidu	1 131	1 096	-3.1%
Tramm 1	3 703	3 328	-10.1%
Tramm 2	5 554	7 782	**40.1%**
Tramm 3	1 991	2 000	0.5%

Tramm 4	4 260	4 409	**3.5%**
Tramm 5	0	0	0.0%
Total	**16 639**	**18 615**	**11.9%**

Table 21 : passengers of main lines

	Model code	boarding	alighting
Tallinn Railway station	21106-1	1176	2615
Balti Jaam (Tram 1, 2)	10801-1	806	1481
Paberi	12302-1	252	290
Kadriorg	11901-1	554	312
Kopli	09005-1	110	480
Majaka põik	14901-1	242	897
Lennujaam	50005-1	660	103
Tondi	07406-1	1188	419
Suur Paala	14701-1	20	900
Ülemiste railway station	13411-1	61	170
Ülemiste railway station Tram 5	50009-1	-	-
Keskturg	11702-1	392	1116
Harbour Vanasadam	50006-1	1094	232

Table 22: passengers boarding/alighting of main stations

6.2. Economic analysis

6.2.1 Introduction

The purpose of the economic analysis is to estimate the socio-economic viability of the project by comparing project costs and project benefits for the whole society. This differentiates the economic analysis from the financial one that takes only into account agents involved in the financing and operation of the project. The economic evaluation process has followed standard evaluation methodology for transport project investments. That is, the situation forecasted with the project of rail bound (light rail or tram) connection from RB Ülemiste passenger terminal to TEN-T core network Tallinn passenger port, has been compared with the situation expected if the present public transport system is maintained, the "base case".

The process takes into account factors which can be quantified, such as the construction and maintenance costs, forecasted volumes of traffic and passenger numbers, road user costs, that is vehicle operating costs and passenger time costs, as well as emission reduction and safety improvements.

This analysis provides measures of the overall returns obtainable from the project for society considered as a whole. The benefit for each of the three main actors or group of actors is computed, these actors are shown in the following schemes for the tramway options (tramway option or tramway in tunnel option) and for the train option. There are the State institution, the public transport operators and the public transport users and citizens. This highlights the economic flows between these actors (such as taxes, fare costs and operating subsidies) that do not appear in the overall analysis.

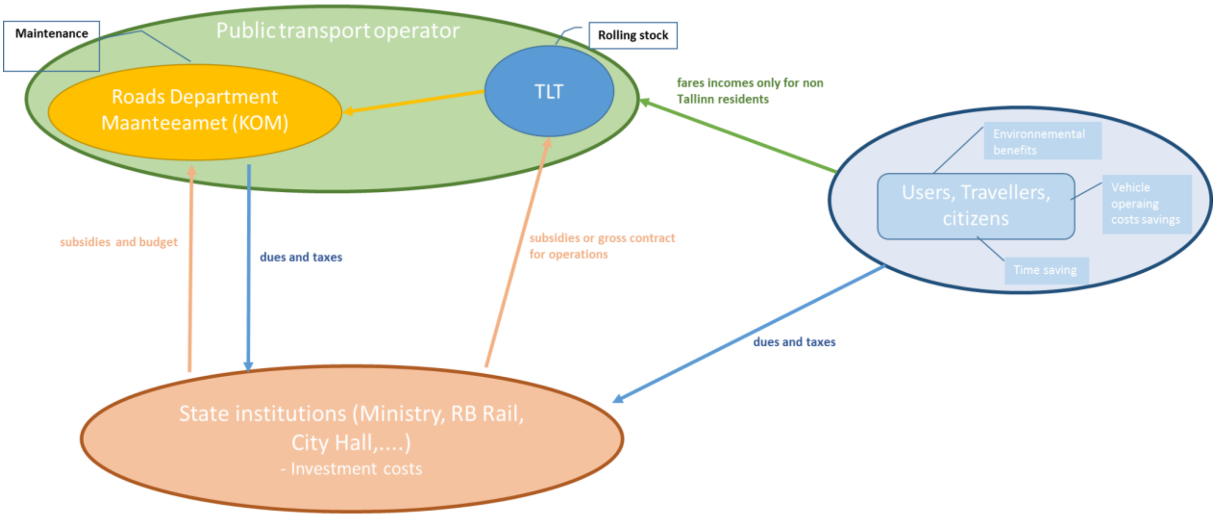


Figure 138: benefit for the three main actors (tram or tram in tunnel option)

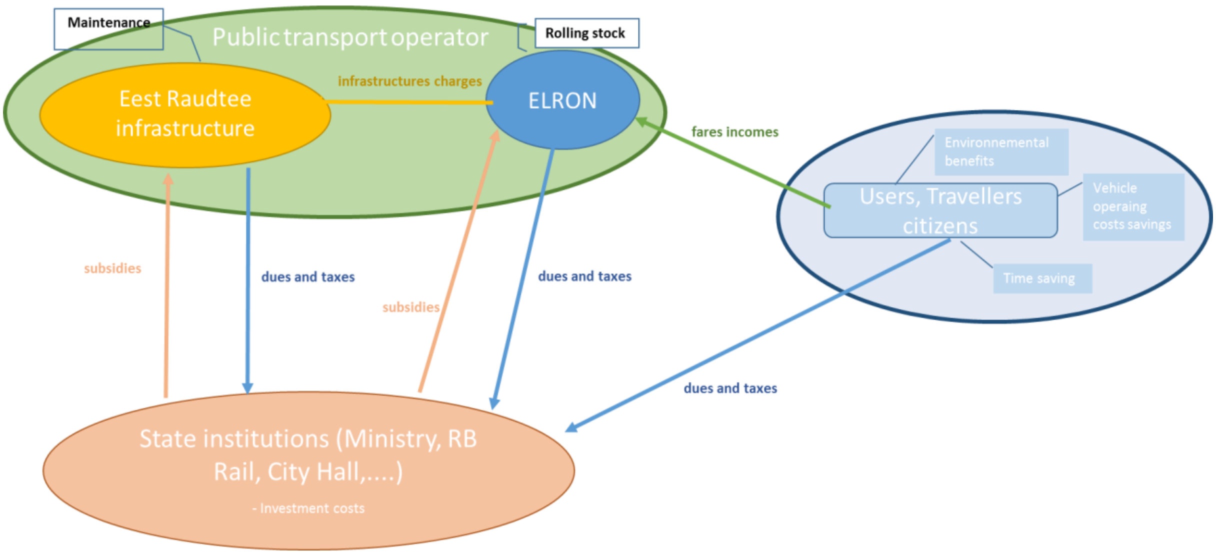


Figure 139 : benefit for the three main actors (train option)

6.2.2 Methodology

The socio-economic evaluation is established based on investment costs, the variation of the operating expenditures and the benefits due to the project in comparison with a reference scenario, which is the scenario without the project.

The components of the evaluation are:

- The project investment costs and operating costs
- The net variation of private vehicle operating costs. It corresponds to the monetary savings of current car users who switch to the new infrastructure.
- The economic surplus corresponding to the time savings gained by passengers using the new infrastructure that used before either public transportation or private cars.
- The economic surplus of the induced users of public transportation. Induced passengers are those that did not travel before, and which do travel after the project because of the attractivity of the new infrastructure.
- The benefits due to the reduction in the in the number of road accidents, and therefore the reduction of accident-related costs.
- The environmental and social benefits, which are non-monetary benefits but that can be "monetarized": the reduction of air pollution, noise and greenhouse gases emissions due the modal shift toward public transportation.

The methodology is based on the "*Guide to Cost-Benefit Analysis of Investment Projects*" by the European Commission.

6.2.3 Main assumptions

"Base case" and "with project case"

The socio-economic evaluation is carried out by comparing a "base case" to a "with project case". The "base case" corresponds to the most probable situation in the absence of the new infrastructure due to the project.

The "with project case" is characterized by the investments for the realization of the project and all its related impacts. In both cases, no other public transports projects are implemented. The evaluation will only focus on the benefits provided by the new infrastructure.

Evaluation period

The following economic assessment will be performed on the 2018-2056 period. It corresponds to a period of studies and work between 2019 and 2025. The start of operation is assumed to take place in 2026 in line with the opening of Rail Baltica followed by a 30-year operation period from 2026 to 2056. This duration corresponds to the lifetime of the system.

Macroeconomic assumptions

All prices, costs and benefits are expressed in Euros, excluding taxes, at 2018 economic conditions, in constant 2018 Euros, excluding inflation.

Annual inflation rates used to update values before 2018 originate from "Statistics Estonia" (www.stat.ee). The growth rate in 2018 is based on the consumer price index growth rate between august 2017 and august 2018.

The following table shows the rates used in the study:

Table 23: Inflation growth rates 2015 /2018 in Estonia

	2015	2016	2017	2018
Inflation rate	-0,5%	0,1%	3,4%	3,7%

Macroeconomic assumptions for Estonia are as follows:

Gross Domestic Product (GDP)

The GDP of Estonia in 2016 is 20.9 bln EUR. The growth of the GDP in 2017 is established at 2.2 %.

Evolution of the population

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Population	401732	404005	406703	411980	416144	419830	429899	434426	439517	443623

Source: Statistical yearbook "Tallinn arvudes" (Tallinn in numbers), 2017

The annual growth rate between 2008 and 2017 is 1.2 %.

The population growth in Tallinn between 2017 and 2025 is 1.093 inhabitants.

Gross Domestic Product per capita

Based on the *Rail Baltica Global Project Cost-Benefit Analysis Final Report (source Oxford Economics)*, the following forecasts have been used for the economic analysis of the CBA:

	2018	2019	2020	2021	2022	2023	2024	2025
GDP per capita % change	4,2%	4,2%	4,2%	4,2%	4,2%	4,0%	3,9%	3,5%
	2026	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
GDP per capita % change	3,3%	2,9%	2,7%	2,7%	2,7%	2,80%	2,80%	2,80%
	2034	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**
GDP per capita % change	2,70%	2,60%	2,50%	2,40%	2,40%	2,40%	2,40%	2,40%
	2042	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**
GDP per capita % change	2,30%	2,30%	2,40%	2,30%	2,30%	2,30%	2,30%	2,30%
	2050	**2051**	**2052**	**2053**	**2054**	**2055**	**2056**	
GDP per capita % change	2,30%	2,30%	2,30%	2,30%	2,30%	2,30%	2,30%	

Figure 140 : GDP per capita assumptions between 2018 and 2056

Discount rate

According European commission recommendation, the discount rate for an economic analysis is 5 % (source: *Guide to Cost-Benefit Analysis of Investment Projects)*.

6.2.4 Annual demand

These variables have been calculated from the model in 2026.

The model provides the numbers of passengers the public transit demand from 5 am to 2 pm. The conversion of morning peak period data in daily and annual data is made using of the following factors:

- From peak hour to day 2,5
- From day to year 250

Traffic forecasts for the "base case" and "with project case" have been extrapolated from 2025 to 2056 by applying an annual growth of 1 % (average annual growth for public transport demand from 2017 to 2025).

6.2.5 Project economic cost assumptions

The economic analysis considers the economic costs and benefits of the project rather than its financial ones. The economic value of an item is its opportunity cost (benefit) for the whole society, i.e. the unitary value that society places on this item when using it for the project.

Ticket sales revenue, as they are an internal transfer of money between members of the society (the operating company on the one hand, and the users on the other hand), are not taken into account in the economic benefit.

Induced passengers are people that in the "with project case" travel between and origin and a destination and which did not perform this trip in the "base case". Thus, for induced passengers, it is not possible to assess the difference of cost between the "base case" and the "with project case", because in the reference scenario, there is no trip and then no cost. As a consequence, the economic surplus for induced passengers, which comes from the well-being earnings between a situation where they travel and one where they did not, is assessed according to the economic theory: it is equal to half of the economic surplus of the former public transport users.

The economic theory shows that, when there are no market distortions such as price subsidies or quantitative supply restrictions, the economic cost to society of a traded good can be considered equal to its market price without taxes (import duties, VAT, other taxes, etc.). The economic analysis presented in this current document is based on a "no distortions assumption" in order to simplify the analysis.

Investment costs

Project economic costs include investment costs and operating and maintenance costs for the new equipment deduced by the residual value of investments at the end of the evaluation period. These investments are detailed before.

The investment costs are excluding taxes so that they are considered similar to economic costs.

According the Rail Baltica opening date in 2026, the start of investment on the tram line is expected in 2021. An investment schedule was established as follows:

- 2021: 1% (studies),
- 2022: 1% (tendering),
- 2023: 20% (construction period),
- 2024: 35% (construction period),
- 2025: 43% (construction period).

Residual value

The economic evaluation runs up to 2056 (after 30 years of operation). The lifespan of some investments will extend beyond this date. Thus there is a residual value of investments in 2051. To compute this figure, it has been considered that the value of each component will decrease linearly over its lifespan.

For each component, the following lifespans will be considered:

Type of works	Lifespan

Civil works	50 years
Track way, stations and rail systems	30 years
Systems	20 years
Rolling stock	30 years

Figure 141 : lifespans for type of works

Operation and Maintenance costs

According to *Tallinna Linatranspordi AS* data, operating and maintenance costs for the current public transport network are :

- For tramway :
  - 2.9121 EUR/km for old ones
  - 3.1752 EUR/km for the new ones
- For buses : 2.1573 EUR/km

For tramways options, the operating cost assumption taken is the new tramway cost (3,17€).

According Elron data, the operating cost for the train is 7,0 EUR/km, including infrastructure charges of 2,8 EUR/km.

To reflect the raise in material and salary costs (excluding inflation) over the 30-year period, it is considered an annual cost "drift" (growth rate) of 1% per year.

For the 3 options, bus network reorganization is limited to the bus line 2 adaption. It is assumed to keep the line between current terminus south in Moigu to Bussijaam to preserve the public transport service for the resident of Moigu (connection to the tram line 2 and 4).

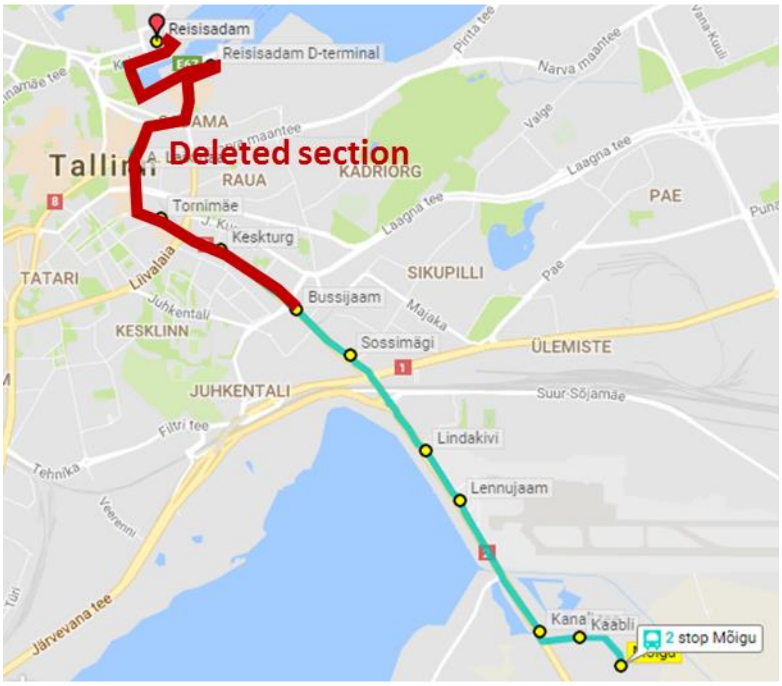


Figure 142 : bus line 2 maintained between Moigu and Bussijaam

This modification represents an economy of 70 000 km.bus per year (based of the current time table).

6.2.6 Project economic benefits assumptions

The monetized benefits of the project, compared to the reference situation, included in the following economic analysis are:

- **Vehicles operating costs savings** => Reduction of private cars operating costs
- **Passenger travel time savings** => Reduction of travel time for public transport and others users (private car), there are no reduction of congestion due to the project, modal shift is too low to reduce the congestion car in the city.
- **Environmental and social benefits** => Reduction of pollution and greenhouse gases, improvement of road safety and noise reduction.

Vehicles operating costs savings

With the implementation of the new public transport equipment, cars users will be transferred to the project. It will lead to a reduction of vehicle operating costs due to the transfer of existing car users to the new transport system.

In the *Rail Baltica Global Project Cost-Benefit Analysis Final Report,* the adopted unit for the Vehicle Operating system is 0.30 EUR/car veh-km (in 2018 prices).

Operating cost is based on national statistics and takes into account fuel costs and wear and tear of vehicles.

Travel time

As time travel savings are a major benefit arising from investments in transport infrastructure for every user, it is essential to first present the value of time which enables to transform time savings into an economic benefit.

The gain on travel time is calculated for:

- Current users of public transports
- Induced passengers after the project travelers from ferries are taken as induced passengers
- And for old car users.

Impacts on travel time are calculated based on the information provided by the traffic model on door-to-door travel time.

Values of time for each mode have been already been estimated in phase 1 report:

- 0.21 EUR/min (in 2018 prices) for commuters (home to work) Source : Rail Baltica Global Project Cost-Benefit Analysis Final Report
- 0.084 EUR/min (in 2018 prices) for non-work trip (non-working time usually estimate at 40 % of the work time).

It is assumed the following share of trips for the Tallinn public transport: 35 % of work trip and 65 % for non-work trip.

With these assumptions, the value of time (VoT) is estimated of 7.6 EUR.hour (in 2018 prices).

Based on the *EU CBA guidelines*, it is assumed that the value of time will increase like GDP per capita with an elasticity of 0.7.

Environmental and social benefits

The environmental and social benefits related to the project of a rail bound connections between Rail Baltica station and the port include factors such as the decrease in the number of road accidents or the decrease in air pollution. These benefits, while significant, are nonetheless difficult to quantify. The estimation of the monetary values of these benefits is based on the "Rail Baltica Global Project Cost-Benefit Analysis Final Report" EY in 2017. These monetary values are coherent with EU CBA Guideline

Road safety

The traffic diversion from cars to public transport is expected to reduce the number of accidents on the roads because of the reduction of distance travelled by road (reduction of vehicle-km).

The average cost of one life in 2015, is 1 351 947 EUR (Source: *Rail Baltica Global Project Cost-Benefit Analysis Final Report)* and 1 478 559 EUR in 2018 prices.

In Estonia, number of fatalities is 5.1 per billion of vehicle – km in 2014 (source: Statistical pocketbook 2016 of European Union – Mobility and transport statistics).

According this assumptions, the unitary cost is 0.0163 € 2018 per vehicle.km.

It is assumed that the unit security cost increases at the same rate as the projected annual increase of GDP per capita. Accident rates are constant

Noise

Noise cost associated with the project has to be estimated. It takes into account the difference in noise levels due to transport activity related to tram, bus and individual cars.

In urban area, noise cost is 0.0095 EUR/vkm for cars and 0,047 EUR/vkm in 2018 prices (source: *Rail Baltica Global Project Cost-Benefit Analysis Final Report)*

Air pollution

A reduction of the environmental burden is expected due to traffic diversion from cars to the new project, which generate a reduction of fuel consumption and generate less air pollutant emissions.

The cost of the local pollution produced by motor vehicles includes two factors:

- The cost of sicknesses caused or aggravated by pollution,
- The cost of pollution damage to buildings and infrastructures.

The cost of local pollution in Tallinn is calculated from the *Rail Baltica Global Project Cost-Benefit Analysis Final Report*.

Local pollution costs for private car is 0.02 € 2018 per vehicle.km ,

It is assumed that the local pollution will increase like GDP per capita with an elasticity of 0.7 (based on the CBA methodology).

Climate change

The production of pollution containing greenhouse gases has long-term consequences on a planetary level. This type of pollution is measured in terms of tons of carbon dioxide emitted.

The costs of greenhouse gases production are the following:

- Private car: 0.02 € 2018 per vehicle.km
- Bus : 0.08 € 2018 per vehicle.km

It is assumed that the greenhouse gases will increase like GDP per capita with an elasticity of 0.7 (based on the CBA methodology).

6.2.7 Definition of economic indicators

Definition of economic indicators

From a socio-economic perspective, the profitability of a project can be expressed by the economic net present value (ENPV) or the economic internal rate of return (EIRR).

The ENPV is a measure of the absolute welfare gain over the whole life of a project. This absolute gain is discounted at a compound rate (also called a discount rate), which is a reflection of the preference for the present and of the opportunity cost of capital. The economic analysis uses a 5% discount rate.

The economic internal rate of return is the discount rate at which economic benefits are made following an initial transport investment (it is the rate at which the net present value is reduced to zero).

In order for the project to be considered acceptable, its EIRR must be greater than the discount rate. In this case the criteria for acceptability is EIRR > 5%.

Calculation

The Economic Net Present Value is calculated as follows:

$$NPV = \sum_{i=0}^{N} \frac{B_i - C_i}{(1+r)^i}$$

Where:

- N is the number of years on which the analysis is carried out, starting from reference year
- Bi are the benefits made during year i
- Ci are the costs associated to year i
- r is the discount rate

The internal rate of return is as previously mentioned, the discount rate corresponding to a net present value equal to zero:

$$\sum_{i=0}^{N} \frac{B_i - C_i}{(1+EIRR)^i} = 0$$

6.3. Financial analysis

6.3.1 Introduction

The financial analysis must be included in the Cost-Benefit Analysis to compute the project's financial performance indicators. It is carried out in order to:

- Assess the consolidated project profitability
- Assess the project profitability for the project owner and some key stakeholders
- Verify the project financial sustainability, a key feasibility condition for any kind of project
- Outline the cash flows which underpin the calculation of the socio-economic costs and benefits

6.3.2 Methodology

The methodology is based on the "Guide to Cost-Benefit Analysis of Investment Projects" by the European Commission.

The financial analysis methodology used is the Discounted Cash Flow (DCF) method. The following rules should be adopted:

- Only cash inflows and outflows are considered in the analysis, i.e. depreciation, reserves, price and technical contingencies and other accounting items which do not correspond to actual flows are disregarded.
- Financial Analysis should be carried out from the point of view of the infrastructure owner
- A Financial Discount Rate (FDR) is adopted in order to calculate the present value of the future cash flows.
- The number of years for which forecasts are provided should correspond to the project's time horizon
- When the analysis is carried out at constant prices, the FDR will be expressed in real terms. When the analysis is carried out at current prices, a nominal FDR will be used.
- The analysis should be carried out net of VAT, both on purchase (cost) and sales (revenues).

6.3.3 Main assumptions

Discount rate

Based on the *Rail Baltica Global Project Cost-Benefit Analysis Final Report*, the discount rate for a financial analysis is 4 %.

Revenue projections

Ticket price is a crucial and sensitive assumption for the overall profitability of the project. In Tallinn, public transport is free for the Tallinn Resident which are registered as a resident. Only visitors, including those from other parts of Estonia, and tourists have to pay to use Tallinn's network of buses, trams, trains and trolley buses.

There was 142,5 Millions trips in Tallinn public transport in 2017. The number of trips with tickets was 7 220 566, it represents 5,1% from total number. Ticket revenue was 4,1 M euros. The average revenue from one trip with ticket is about 56,8 cents.

It is assumed that new public transport users (from modal shift and induced traffic) keep this part of 5,1% which paid a ticket.

For the new public transport users from the ferries it assumed that a part of passengers is already in the public transport in base case and therefore has already paid their tickets (50%).

For the train option, Average ticket revenue for trips within Tallinn is estimated of 0,67 EUR/trip.

6.3.4 Definition of financial indicators

Definition of economic indicators

The financial profitability of a project can be expressed by the financial net present value (FNPV) and by the financial rate of return (FRR). These indicators are estimated:

- financial net present value – FNPV(C) - and financial rate of return – FRR(C) - on investment;
- financial net present value – FNPV (K) - and the financial rate of return - FRR (K) - on national capital.

Return on investment

The financial net present value of investment (FNPV(C)) and the financial rate of return of the investment (FRR(C)) compare investment costs to net revenues and measure the extent to which the project net revenues are able to repay the investment, regardless of the sources or methods of financing.

The **Financial net present value on investment (FNPV (c))** is defined as the sum that results when the expected investment and operating costs of the project (discounted) are deducted from the discounted value of the expected revenues.

$$Financial\ Net\ Present\ Value\ (C) = -Investment\ cost + \sum_{i=1}^{system\ life\ time} \frac{Income_i\ - Annual\ cost_i}{(1+i)^n}$$

With i the financial discount rate

The **financial rate of return on investment** (**FRR(C))** is the discount rate at which the financial net present value FNPV(C) is reduced to zero.

Return on national capital

The objective of the return on national capital calculation is to examine the project performance from the perspective of the assisted public entities in Estonia (after the EU grant).

It is assumed that the EU co-financing rate will be of 81 % as the rate assumed for Rail Baltica project in Estonia.

The return on national capital is calculated considering as outflows: the operating costs; the national capital contributions to the project; the financial resources from loans at the time in which they are reimbursed; the related interest on loans. It is assumed that the investment remaining after the EU co financing is entirely state funding.

The inflows are the operating revenues only and the residual value.

The **financial net present value of capital (FNPC (K))** is the sum of the net discounted cash flows of the national beneficiaries due to the implementation of the project.
The **financial rate of return on capital** (**FRR(k))** is the discount rate at which the financial net present value on national capital FNPV(k) is reduced to zero.

6.4. Results for the Tram option

6.4.1 Annual demand

Traffic forecasts are performed with the model for the year 2025. This results in the following annual data:

	Base case	With project case
Passengers year (public transport network))	100 143 125	101 651 938
included Old car passengers		106 275
included Induced PT + Ferry passengers		1 402 538
PT Passengers PT.km year	714 056 875	719 414 375
PT Passengers.hour	56 613 716	56 914 874
PT Passengers.hour saved year	-	- 150 874
Average distance (km)	7,1	7,1
Average time (min)	33,9	33,6

Table 24: Public transport ridership in 2025

With project case there are more than 1 million new public transport users. 93% come from ferries or induced traffic and 7% correspond to modal shift from private car. An induced user of public transportation is a person who makes a trip in the "with project case", but who would not travel in the "base case".

6.4.2 Capex

The investment cost for the tram option is 26 360 k€ (Rävala option).

The residual value amounts to 3 461k€ which represents 13% of the initial investment costs. It must however be noted that some equipment with a lifespan of less than 30 years have been renewed before 2056. For example, it is the case for the system which are renewed entirely in 2046.

6.4.3 Opex

Based on the current time table of the tram line 2 and 4, the additional annual number of kilometres run by the trams extension amounts to 57 000 km.

The operating costs are made in euros 2018, excluding taxes. Next table presents the operating cost change included the reduction of the amount of km.bus (bus line 2 modification) and the additional kilometres due to the tramway extension:

	€ per year
Additional tramway cost	*180 387*
Bus cost reduction	- *151 661*
Total OPEX change	**28 726,0**

Figure 143 : Opex change per year

6.4.4 Revenues

Following tables presents the additional revenues to be generated by the extension to the port.

	2026
Total trips with tickets	*460 000*
Total Revenues	*261 000 €*

Figure 144 : additional revenues from non-resident trips

6.4.5 Results of the socio-economic analysis

User economic surplus

The number of passenger.km and passenger.hour saved for each mode is provided by the traffic model. For both “base case” and “with project case” the model calculates the average speed and the average length for all trips and all modes. By comparing “base case” and “with project case” we can compute savings brought by the tram project extension to the port, especially users time savings.

The modal transfer of users from private cars towards the tram generates a reduction of the vehicle-km covered by these modes, and savings in operating costs as a result of this reduction.

It is assumed the trip from the ferries passengers are included on the induced public transport users.

Total savings on operating costs due to modal transfers were then computed using unitary costs per mode.

Savings	
Passenger.km saved (year)	**757 779**
Private car	*757 779*
Passenger.hour saved (year)	**155 000**
From car to public transport users (modal shift)	*300*
Induced public transport users	*3 800*
Public transport users in base case	*150 900*

Table 25: Tram option - Savings in 2026 ("with project case" compared to "base case")

Socio economic Benefits

The table below shows the share of the benefits, for 2026 and for the 2026-2056 period. It indicates that the main benefits come from time savings and operating costs savings for public transport.

	2026		2026 to 2056	
	K EUR 2018	%	K EUR 2018	%
Vehicle Operating Costs benefits	**210,5**	***13,3%***	**7 776**	***11,9%***
Road user costs	*210,5*	*13,3%*	*7 776*	*11,9%*
Time savings	**1 317,7**	***83,4%***	**55 134**	***84,7%***
From car to public transport users (modal shift)	*2,5*	*0,2%*	*110*	*0,2%*
Induced public transport users	*32,4*	*2,0%*	*1 361*	*2,1%*
Public transport users in base case	*1 282,9*	*81,2%*	*53 663*	*82,5%*
Pollution and greenhouse gases	**45,9**	***2,9%***	**1 670**	***2,6%***
Safety benefits	**5,5**	***0,3%***	**201**	***0,3%***
Noise impacts reduction	**8,9**	***0,6%***	**292**	***0,4%***
Total benefits	**1 579,6**	**100%**	**65 072**	**100%**

Table 26: Tram option - Annual benefits in 2026, global benefits from 2026 to 2056 (K EUR 2018) undiscounted

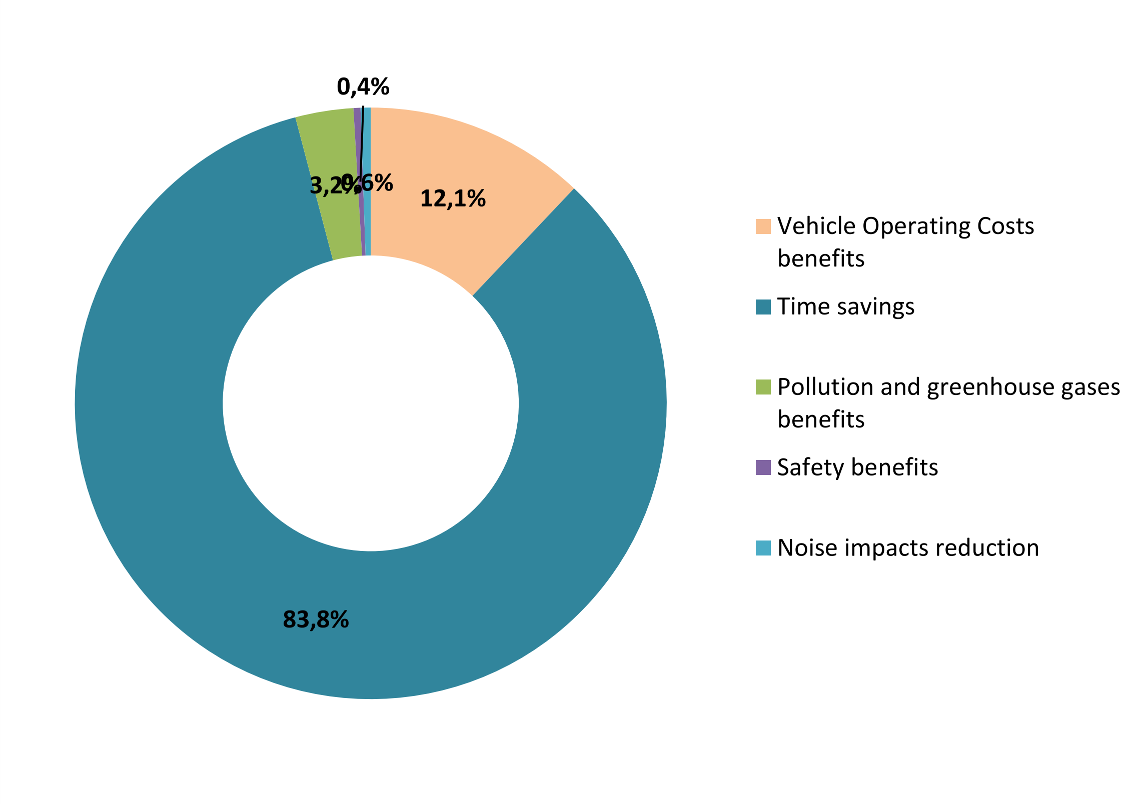


Figure 145: Share of global benefits from 2026 to 2056

Most of the benefits are provided by time savings.

Economic appraisal main results

As a reminder, the economic assessment led in the study aggregates CAPEX, OPEX and economic benefits such as time savings, vehicle operating costs and other positive impacts for the society as a whole. The discount rate for the tram project is held at 5%.

The following table presents the two main economic indicators needed to assess the viability of the project, the Net Present Value (NPV) and the Economic Rate of Return (ERR).

Table 27: Tram option - main economic indicators–discounted values

	K EUR 2018
Project economic cost	
Investment cost CAPEX, including residual values	*-27 932,6*
Operating cost OPEX	*-502,7*
Project economic benefits	
Road user costs	*3 763,8*
Time savings	*25 934,7*
Pollution and greenhouse gases	*974,4*
Safety benefits	*117,3*

Noise impacts reduction	*171,6*
Economic NPV (in thousands of euros 2018)	**2 526,5**
Economic Rate of Return (ERR)	**5,7%**

The ERR being above 6%, the project is then considered economically viable.

The figure displayed below presents the annual evolution of the balance sheet over the period considered for the assessment. It also includes the cumulative account of the project. All values are discounted at an 5% rate from year 2025.

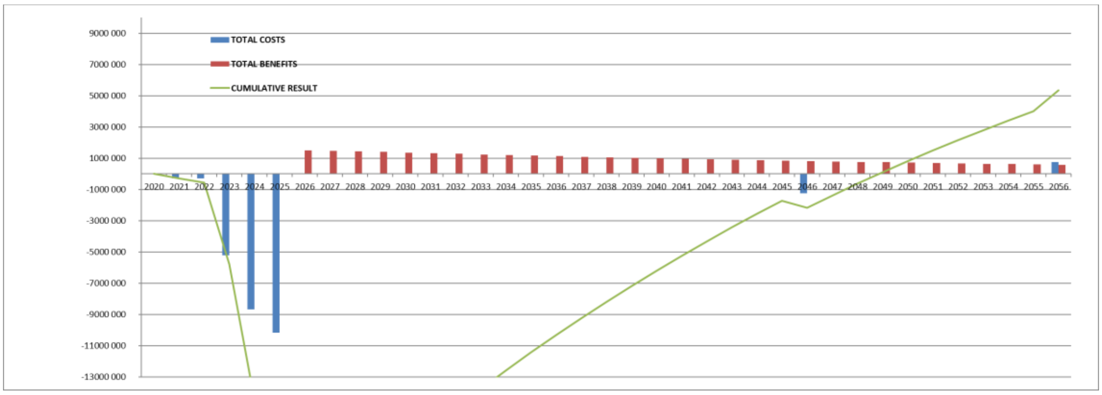


Figure 146: Evolution of the annual and cumulative economic balance sheet – Discounted value

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	EIRR
"with project case"	***5,7%***
Investments costs +10%	4,9%
Investments costs -5%	6,0%
GDP growth -2%	3,3%
Aditionnal passenger trafic -20 %	5,3%

Table 28: Sensitivity analysis

A variation of investment costs (+20%) or operating costs (+20%) for the Tram “with project case” does not have a significant impact on the EIRR.

GDP growth -2% reduces the EIRR because of the slower growth of the value of time.

Except for the GDP growth, in all sensitivity tests, the EIRR stays higher than 5% or very close. This sensitivity analysis confirms the feasibility of the project on socio-economic grounds.

6.4.6 Results of the financial analysis

Following table shows the financial analysis of the project of tram extension to the port.

These elements show that the project is not profitable from a strictly financial point of view. Throughout the world, it is very common that such public transport project are not profitable financially speaking.

Table 29 : Tram option - main financial indicators on investment (FNPV (c) and FRR (c))

	K EUR 2018
Expenses	
Investment cost CAPEX	*-27 236,7*
Operating cost OPEX	*-571,1*
Renewable infrastructure	*-1 510,4*
Residual value	*1 026,1*
Revenues	
Additional revenues	*5 188,8*
Financial Net Present Value (c)	**-23 103,4**
Financial Rate of Return (c)	**-4,5%**

Next table shows the financial analysis on national capital, excepted the EU contribution, the project appears almost profitable from a financial point of view.

Table 30 : Tram option - main financial indicators on national (FNPV (k) and FRR (k))

	K EUR 2018
Expenses	
Estonian contribution	*-5 175,0*
Operating cost OPEX	*-571,1*
Renewable infrastructure	*-1 510,4*
Residual value	*1 026,1*
Revenues	
Additional revenues	*5 188,8*
Financial Net Present Value (k)	**-1 041,7**
Financial Rate of Return (k)	**2,6%**

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	FIRR (c)	FIRR (k)
"with project case"	***-4,5%***	***2,6%***
Investments costs +10%	-4,9%	2,1%
Investments costs -5%	-4,4%	2,9%
GDP growth -2%	-4,5%	2,6%
Aditionnal passenger trafic -20 %	-5,2%	1,2%

Table 31: Sensitivity analysis for financial analysis

6.4.7 Risk analysis

The following table presents a qualitative risk analysis identified for the tramway extension until the port. It presents potential impact and risk of the project, during the construction and the operation

Risk description	Probability	Severity	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Administrative risks					
Land acquisition on Laeva street : (Nota, all the future necessary functionality to the future building will be restitute with the tramway project)	*B*	*I*	*low*	*initiate the negotiation to acquire this land as soon as possible*	*low*
Dependence on the Rail Baltica project	*B*	*II*	*low*	*The project of extension to the port remains relevant without the Rail Baltica project.* *However, the funding could be dependent on the RB project.*	*low*
Financing risk (Insufficient financing resources for the project or very expensive financing)	*A*	*I*	*low*	*Investment costs are limited*	*low*

Construction risks					
Underestimated costs	*B*	*II*	*low*	*Sensitivity analysis have been made with a CAPEX increases by 20 %*	*low*
Archeological constraints	*A*	*I*	*low*	*Civil works are limited on the heritage area*	*low*
Utilities constraint	*A*	*I*	*low*	*Utilities diversion limited for the extension of tram until the port*	*low*
Environmental and social risks					
Public opposition	*A*	*I*	*low*	*it will be important to do a public consultation*	*low*
impact on environment (Urban spaces, green spaces and street trees)	*A*	*I*	*low*	*Limited impact on environment*	*low*
Operational risks					
Increase of operating cost	*B*	*II*	*low*	*The operating costs have been given by TLT, they reflected the current operating cost for tramway and buses,* *However the proposed reorganization of bus line 2 could be more limited*	*low*

6.5. Results for the train option

6.5.1 Annual demand

Traffic forecasts are performed with the model for the year 2025. This results in the following annual data:

	Base case	With project case
Passengers year (public transport network))	100 143 125	100 255 500
included Old car passengers		14 950
included Induced PT + Ferry passengers		97 425
PT Passengers PT.km year	714 056 875	719 414 375
PT Passengers.hour	56 613 716	56 627 051
PT Passengers.hour saved year	-	- 22 624
Average distance (km)	7,1	7,2
Average time (min)	33,9	33,9

Table 32: Public transport ridership in 2025

With project case there only are 100 000 new public transport users. 87% come from ferries or induced traffic and 13% correspond to modal shift from private car. An induced user of public transportation is a person who makes a trip in the "with project case", but who would not travel in the "base case".

6.5.2 Capex

The investment cost for the tram option is 185 854 k€.

The residual value amounts to 43 745k€ which represents 24% of the initial investment costs. It must however be noted that some equipment with a lifespan of less than 30 years have been renewed before 2056. For example, it is the case for the system which are renewed entirely in 2046.

6.5.3 Opex

The additional annual number of kilometres run by train extension and new train services between Ülemiste and the port is estimated at 57 000 km.

The operating costs are made in euros 2018, excluding taxes. Next table presents the operating cost change included the reduction of the amount of km.bus (bus line 2 modification) and the additional kilometres due to the train extension and new services:

	k€ per year
Additional train cost	*449 456*
Bus cost reduction	- *151 661*
Total OPEX change	**297 795,0**

Figure 147 : Opex change per year

6.5.4 Revenues

Following tables presents the additional revenues to be generated by the extension to the port from non-resident trips.

	2026
Total trips with tickets	*61 000*
Total Revenues	*41 000 €*

Figure 148 : additional revenues from non-resident trips

6.5.5 Results of the socio-economic analysis

User economic surplus

The number of passenger.km and passenger.hour saved for each mode is provided by the traffic model. For both "base case" and "with project case" the model calculates the average speed and the average length for all trips and all modes. By comparing "base case" and "with project case" we can compute savings brought by the tram project extension to the port, especially users time savings.

The modal transfer of users from private cars towards the tram generates a reduction of the vehicle-km covered by these modes, and savings in operating costs as a result of this reduction.

It is assumed the trip from the ferries passengers are included on the induced public transport users.

Total savings on operating costs due to modal transfers were then computed using unitary costs per mode.

Savings	
Passenger.km saved (year)	**106 599**
Private car	*106 599*
Passenger.hour saved (year)	**22 600**
From car to public transport users (modal shift)	*0*
Induced public transport users	*0*
Public transport users in base case	*22 600*

Table 33: Train option - Savings in 2026 ("with project case" compared to "base case")

Socio economic Benefits

The table below shows the share of the benefits, for 2026 and for the 2026-2056 period. It indicates that the main benefits come from time savings and operating costs savings for public transport.

	2026		2026 to 2056	
	K EUR 2018	%	K EUR 2018	%
Vehicle Operating Costs benefits	**29,6**	***13,1%***	**1 094**	***11,7%***
Road user costs	*29,6*	*13,1%*	*1 094*	*11,7%*
Time savings	**192,4**	***85,0%***	**8 068**	***86,3%***
From car to public transport users (modal shift)	*0,0*	*0,0%*	*7*	*0,1%*
Induced public transport users	*0,0*	*0,0%*	*8*	*0,1%*
Public transport users in base case	*192,4*	*85,0%*	*8 053*	*86,2%*
Pollution and greenhouse gases	**3,7**	***1,6%***	**134**	***1,4%***
Safety benefits	**0,7**	***0,3%***	**25**	***0,3%***
Noise impacts reduction	**0,8**	***0,3%***	**26**	***0,3%***
Total benefits	**226,4**	**100%**	**9 347**	**100%**

Table 34: Train option - Annual benefits in 2026, global benefits from 2026 to 2056 (K EUR 2018) undiscounted

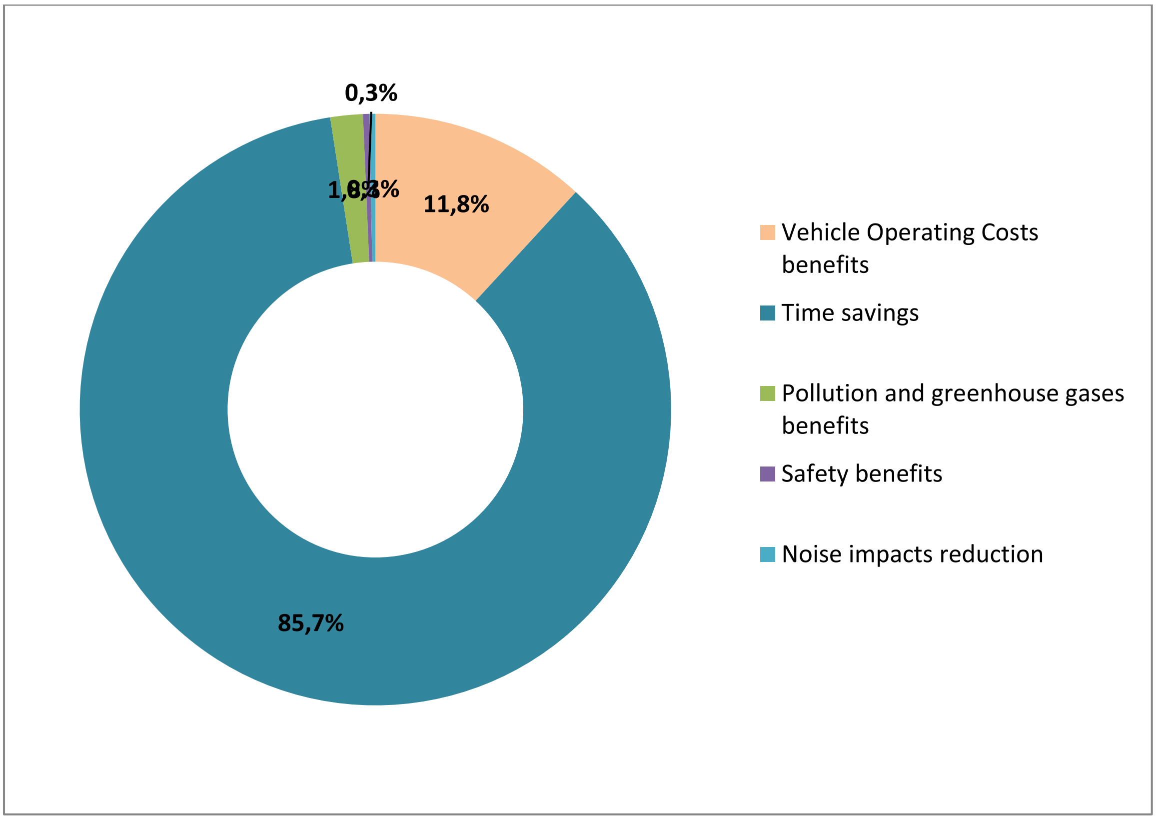


Figure 149: Share of global benefits from 2026 to 2056

Most of the benefits are provided by time savings.

Economic appraisal main results

As a reminder, the economic assessment led in the study aggregates CAPEX, OPEX and economic benefits such as time savings, vehicle operating costs and other positive impacts for the society as a whole. The discount rate for the tram project is held at 5%.

The following table presents the two main economic indicators needed to assess the viability of the project, the Net Present Value (NPV) and the Economic Rate of Return (ERR).

Table 35: Train option - main economic indicators–discounted values

	K EUR 2018
Project economic cost	
Investment cost CAPEX, including residual values	*-185 376,9*
Operating cost OPEX	*-5 211,6*
Project economic benefits	
Road user costs	*529,5*
Time savings	*3 793,5*
Pollution and greenhouse gases	*78,1*
Safety benefits	*14,7*
Noise impacts reduction	*15,1*
Economic NPV (in thousands of euros 2018)	**-186 157,5**
Economic Rate of Return (ERR)	**-5%**

The train option is forecasted to have negative 5% economic rate of return and negative economic net present value, the project is then considered economically not viable.

The figure displayed below presents the annual evolution of the balance sheet over the period considered for the assessment. It also includes the cumulative account of the project. All values are discounted at an 5% rate from year 2025.

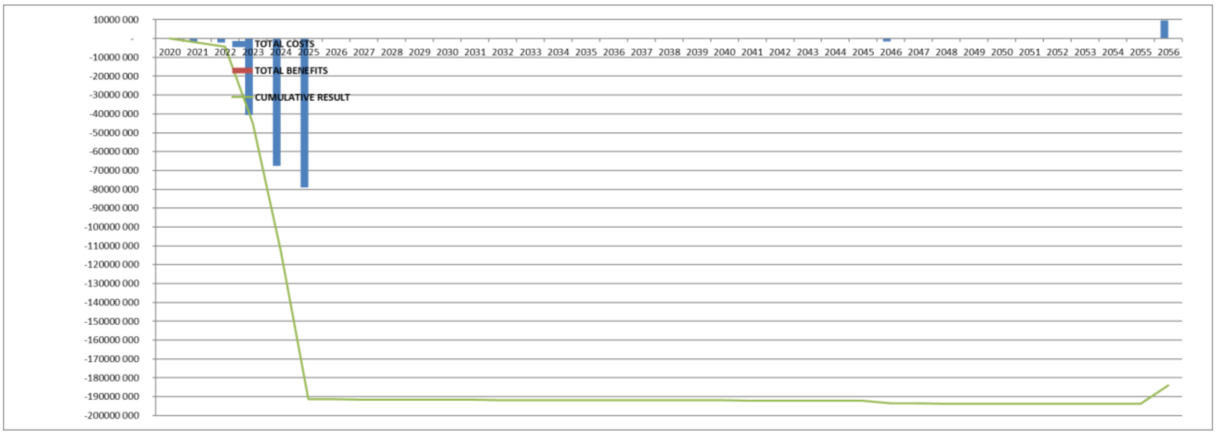


Figure 150: Evolution of the annual and cumulative economic balance sheet – Discounted value

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	EIRR
"with project case"	***-4,7%***
Investments costs +10%	-4,9%
Investments costs -5%	-4,5%
GDP growth -2%	-4,8%
Aditionnal passenger trafic -20 %	-4,7%

Table 36: Sensitivity analysis

In all sensitivity tests, the EIRR stays non viable.

6.5.6 Results of the financial analysis

Following table shows the financial analysis of the project of tram extension to the port.

These elements show that the project is not profitable from a strictly financial point of view. Throughout the world, it is very common that such public transport project are not profitable financially speaking.

Table 37 : Train option - main financial indicators on investment (FNPV (c) and FRR (c))

	K EUR 2018
Expenses	
Investment cost CAPEX	*-192 037,0*
Operating cost OPEX	*-5 920,4*
Renewable infrastructure	*-1 719,5*

Residual value	*12 968,7*
Revenues	
Additional revenues	*402,9*
Financial Net Present Value (c)	**-186 305,3**
Financial Rate of Return (c)	**-5,0%**

Next table shows the financial analysis on national capital, excepted the EU contribution, the project stays not profitable from a financial point of view.

Table 38 : Train option - main financial indicators on national (FNPV (k) and FRR (k))

	K EUR 2018
Expenses	
Estonian contribution	*-36 487,0*
Operating cost OPEX	*-5 920,4*
Renewable infrastructure	*-1 719,5*
Residual value	*12 968,7*
Revenues	
Additional revenues	*402,9*
Financial Net Present Value (k)	**-30 755,3**
Financial Rate of Return (k)	**-0,5%**

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	FIRR (c)	**FIRR (k)**
"with project case"	***-5,0%***	***-0,5%***
Investments costs +10%	-5,3%	-0,7%
Investments costs -5%	-4,9%	-0,3%
GDP growth -2%	-5,0%	-0,5%
Aditionnal passenger trafic -20 %	-5,0%	-0,5%

Table 39: Sensitivity analysis for financial analysis

6.5.7 Risk analysis

The following table presents a qualitative risk analysis identified for the tramway extension until the port. It presents potential impact and risk of the project, during the construction and the operation

Risk description	Probability	Severity	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Administrative risks					
Land acquisition on Laeva street : (Nota, all the future necessary functionality to the future building will be restitute with the tramway project)	*B*	*I*	*low*	*initiate the negotiation to acquire this land as soon as possible*	*low*
Dependence on the Rail Baltica project	*C*	*III*	*Moderate*	*The project of extension to the port is completely dependent of the project of Rail Baltica However, the funding could be dependent on the RB project.*	*Moderate*
Financing risk (Insufficient financing resources for the project or very expensive financing)	*C*	*III*	*Moderate*	*Investment costs are important*	*Moderate*
Construction risks					
Underestimated costs	*B*	*II*	*low*	*Sensitivity analysis have been made with a CAPEX increases by 10 %*	*low*
Archeological constraints	*B*	*III*	*Moderate*	*Civil works are important on the heritage area. Archeological excavations could be require*	*Moderate*
Utilities constraint	*B*	*III*	*Moderate*	*Main utilities diversions are require*	*Moderate*
Environmental and social risks					

Public opposition	*A*	*I*	*low*	*it will be important to do a public consultation*	*low*
impact on environment (Urban spaces, green spaces and street trees)	*B*	*III*	*Moderate*	*impact on trees alignment on Pohja pst*	*Moderate*
Operational risks					
Increase of operating cost	*B*	*II*	*low*	*The operating costs have been given by Elron they reflected the current operating cost for tramway and buses, However the proposed reorganization of bus line 2 could be more limited*	*low*

6.6. Results for the tram in tunnel option

6.6.1 Annual demand

Traffic forecasts are performed with the model for the year 2025. This results in the following annual data:

	Base case	With project case
Passengers year (public transport network))	100 143 125	100 275 313
included Old car passengers		22 875
included Induced PT + Ferry passengers		109 313
PT Passengers PT.km year	714 056 875	719 414 375
PT Passengers.hour	56 613 716	56 627 051
PT Passengers.hour saved year	-	- 12 904
Average distance (km)	7,1	7,2
Average time (min)	33,9	33,9

Table 40: Public transport ridership in 2025

With project case there only are more 100 000 new public transport users. 83% come from ferries or induced traffic and 17% correspond to modal shift from private car. An induced user of public transportation is a person who makes a trip in the "with project case", but who would not travel in the "base case".

6.6.2 Capex

The investment cost for the tram option is 219 400 k€.

The residual value amounts to 64 861k€ which represents 30% of the initial investment costs. It must however be noted that some equipment with a lifespan of less than 30 years have been renewed before 2056. For example, it is the case for the system which are renewed entirely in 2046.

6.6.3 Opex

The additional annual number of kilometers run by tramway on the new tramline 5 is estimated at 149 000 km.

The operating costs are made in euros 2018, excluding taxes. Next table presents the operating cost change included the reduction of the amount of km.bus (bus line 2 modification) and the additional kilometers due to the train extension and new services:

	k€ per year
Additional tramway cost	*473 689*
Bus cost reduction	- *151 661*
Total OPEX change	**322 028,1**

Figure 151 : Opex change per year

6.6.4 Revenues

Following tables presents the additional revenues to be generated by the new line to the port from non-resident trips.

	2026
Total trips with tickets	*30 000*
Total Revenues	*17 000 €*

Figure 152 : additional revenues from non-resident trips

6.6.5 Results of the socio-economic analysis

User economic surplus

The number of passenger.km and passenger.hour saved for each mode is provided by the traffic model. For both “base case” and “with project case” the model calculates the average speed and the average length for all trips and all modes. By comparing “base case” and “with project case” we can compute savings brought by the tram project extension to the port, especially users time savings.

The modal transfer of users from private cars towards the tram generates a reduction of the vehicle-km covered by these modes, and savings in operating costs as a result of this reduction.

It is assumed the trip from the ferries passengers are included on the induced public transport users.

Total savings on operating costs due to modal transfers were then computed using unitary costs per mode.

Savings	
Passenger.km saved (year)	**163 107**
Private car	*163 107*
Passenger.hour saved (year)	**12 912**
From car to public transport users (modal shift)	*2*
Induced public transport users	*10*
Public transport users in base case	*12 900*

Table 41: Tram in tunnel option - Savings in 2026 ("with project case" compared to "base case")

Socio economic Benefits

The table below shows the share of the benefits, for 2026 and for the 2026-2056 period. It indicates that the main benefits come from time savings and operating costs savings for public transport.

	2026		2026 to 2056	
	K EUR 2018	%	K EUR 2018	%
Vehicle Operating Costs benefits	**45,3**	***21,1%***	**1 674**	***19,0%***
Road user costs	*45,3*	*21,1%*	*1 674*	*19,0%*
Time savings	**109,9**	***51,0%***	**4 614**	***52,4%***
From car to public transport users (modal shift)	*0,0*	*0,0%*	*8*	*0,1%*
Induced public transport users	*0,1*	*0,0%*	*11*	*0,1%*
Public transport users in base case	*109,7*	*51,0%*	*4 596*	*52,2%*
Pollution and greenhouse gases	**57,4**	***26,7%***	**2 091**	***23,8%***
Safety benefits	**2,6**	***1,2%***	**95**	***1,1%***
Noise impacts reduction	**10,0**	***4,6%***	**328**	***3,7%***
Total benefits	**215,2**	**100%**	**8 802**	**96%**

Table 42: tram in tunnel option - Annual benefits in 2026, global benefits from 2026 to 2056 (K EUR 2018) undiscounted

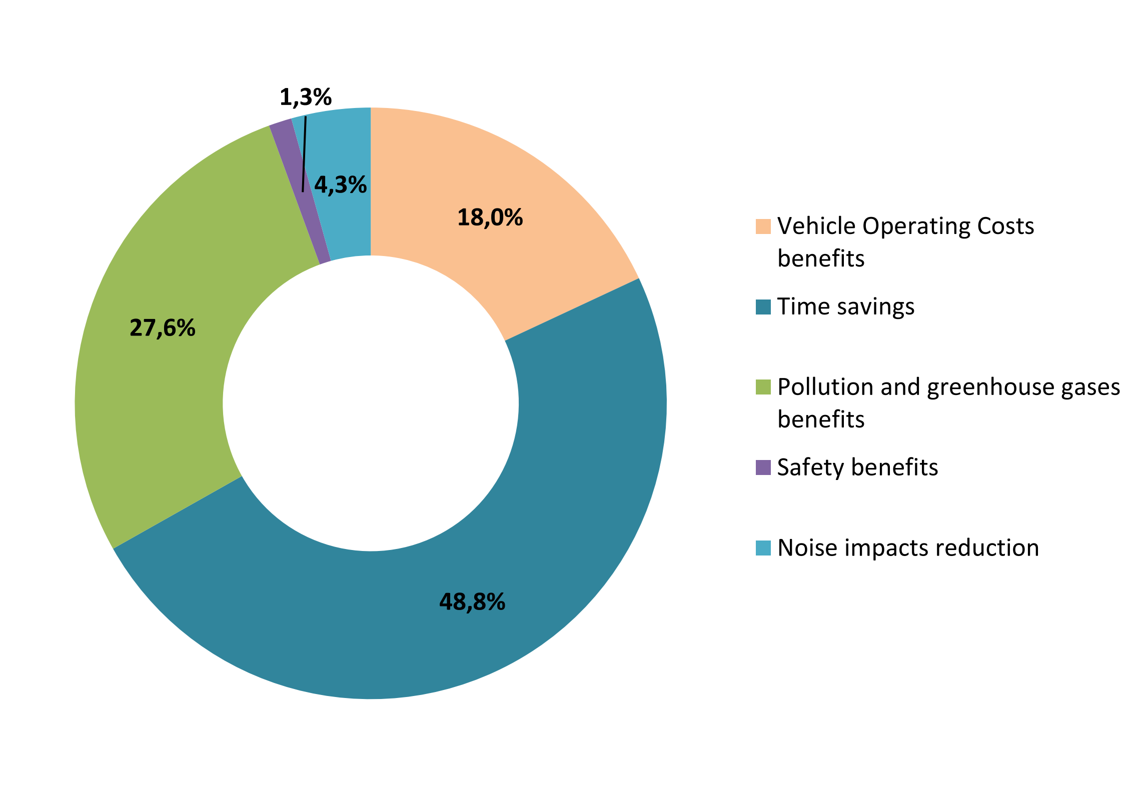


Figure 153: Share of global benefits from 2026 to 2056

Most of the benefits are provided by time savings.

Economic appraisal main results

As a reminder, the economic assessment led in the study aggregates CAPEX, OPEX and economic benefits such as time savings, vehicle operating costs and other positive impacts for the society as a whole. The discount rate for the tram project is held at 5%.

The following table presents the two main economic indicators needed to assess the viability of the project, the Net Present Value (NPV) and the Economic Rate of Return (ERR).

Table 43: Tram option - main economic indicators –discounted values

	K EUR 2018
Project economic cost	
Investment cost CAPEX, including residual values	*-215 559,6*
Operating cost OPEX	*-5 635,6*
Project economic benefits	
Road user costs	*810,2*
Time savings	*2 168,6*
Pollution and greenhouse gases	*1 220,1*

Safety benefits	*55,7*
Noise impacts reduction	*192,7*
Economic NPV (in thousands of euros 2018)	**-216 747,8**
Economic Rate of Return (ERR)	**-4%**

The tram in tunnel option is forecasted to have negative 4% economic rate of return and negative economic net present value, the project is then considered economically not viable.

The figure displayed below presents the annual evolution of the balance sheet over the period considered for the assessment. It also includes the cumulative account of the project. All values are discounted at an 5% rate from year 2025.

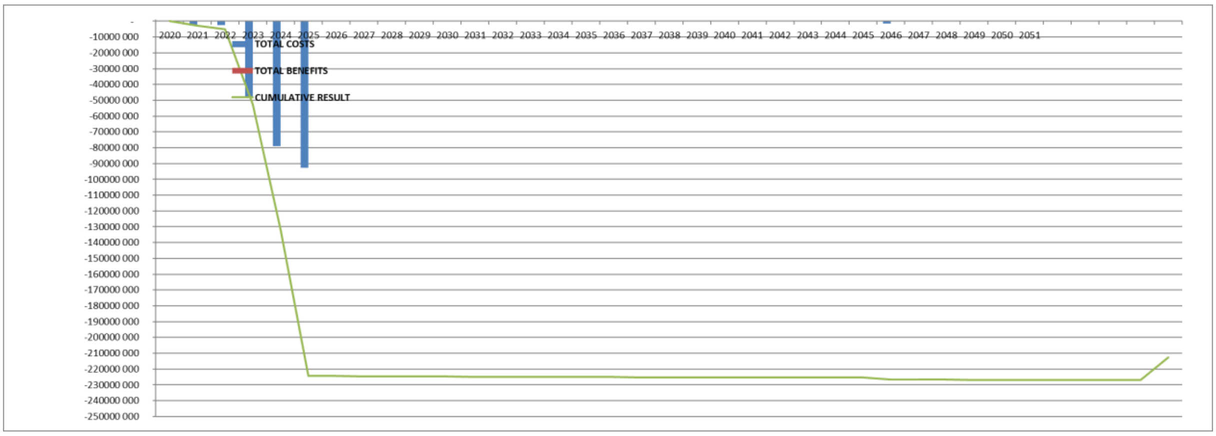


Figure 154: Evolution of the annual and cumulative economic balance sheet – Discounted value

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	EIRR
"with project case"	***-3,9%***
Investments costs +10%	-4,2%
Investments costs -5%	-3,8%
GDP growth -2%	-4,0%
Aditionnal passenger trafic -20 %	-3,9%

Table 44: Sensitivity analysis

In all sensitivity tests, the EIRR stays non viable.

6.6.6 Results of the financial analysis

Following table shows the financial analysis of the project of tram extension to the port.

These elements show that the project is not profitable from a strictly financial point of view. Throughout the world, it is very common that such public transport project are not profitable financially speaking.

Table 45 : Tram option - main financial indicators on investment (FNPV (c) and FRR (c))

	K EUR 2018
Expenses	
Investment cost CAPEX	*-226 707,8*
Operating cost OPEX	*-6 402,1*
Renewable infrastructure	*-1 574,0*
Residual value	*19 228,7*
Revenues	
Additional revenues	*334,2*
Financial Net Present Value (c)	**-215 120,9**
Financial Rate of Return (c)	**-4,2%**

Next table shows the financial analysis on national capital, excepted the EU contribution, the project stays not profitable from a financial point of view.

Table 46 : Tram option - main financial indicators on national (FNPV (k) and FRR (k))

	K EUR 2018
Expenses	
Estonian contribution	*-43 074,5*
Operating cost OPEX	*-6 402,1*
Renewable infrastructure	*-1 574,0*
Residual value	*19 228,7*
Revenues	
Additional revenues	*334,2*
Financial Net Present Value (k)	**-31 487,7**
Financial Rate of Return (k)	**0,5%**

Sensitivity tests

The following table presents a sensitivity analysis taking into account various changes in investment costs, reducing of amount of new passengers or GDP growth.

	FIRR (c)	FIRR (k)
"with project case"	***-4,2%***	***0,5%***
Investments costs +10%	-4,5%	0,3%
Investments costs -5%	-4,1%	0,7%
GDP growth -2%	-4,2%	0,5%
Aditionnal passenger trafic -20 %	-4,2%	0,5%

Table 47: Sensitivity analysis for financial analysis

6.6.7 Risk analysis

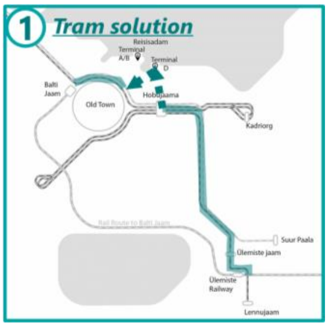
The following table presents a qualitative risk analysis identified for the tramway extension until the port. It presents potential impact and risk of the project, during the construction and the operation

Risk description	Probability	Severity	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Administrative risks					
Land acquisition on Laeva street : (Nota, all the future necessary functionality to the future building will be restitute with the tramway project)	*B*	*I*	*low*	*initiate the negotiation to acquire this land as soon as possible*	*low*
Dependence on the Rail Baltica project	*C*	*III*	*Moderate*	*The project of extension to the port is completely dependent of the project of Rail Baltica However, the funding could be dependent on the RB project.*	*Moderate*
Financing risk (Insufficient financing resources for the project or very expensive financing)	*C*	*III*	*Moderate*	*Investment costs are important*	*Moderate*
Construction risks					
Underestimated costs	*B*	*II*	*low*	*Sensitivity analysis have been made with a CAPEX increases by 10 %*	*low*

Archeological constraints	*A*	*I*	*low*	*Civil works are limited on the heritage area*	*low*
Utilities constraint	*B*	*III*	*Moderate*	*Main utilities diversions are require*	*Moderate*
Environmental and social risks					
Public opposition	*A*	*I*	*low*	*it will be important to do a public consultation*	*low*
impact on environment (Urban spaces, green spaces and street trees)	*A*	*I*	*low*	*Limited impact on environment*	*low*
Operational risks					
Increase of operating cost	*B*	*II*	*low*	*The operating costs have been given by TLT, they reflected the current operating cost for tramway and buses, However the proposed reorganization of bus line 2 could be more limited*	*low*

7. Comparison of alternatives

As described in the previous sections, there are three alternatives : 2 alternatives which will complete the tram network and one alternative on the railway. These three alternatives have the same main objective: to ensure an efficient passenger link between Vanasadam and Rail Baltica Station Ülemiste .

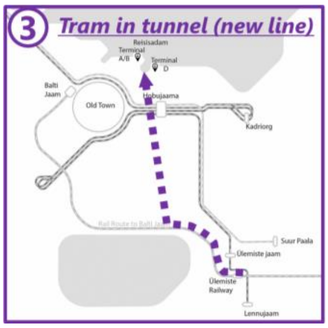


Tram option

The tram option connects Ülemiste station to Vanasadam Port and Balti jaam. The proposed route start at Ülemiste station, uses the tram network until Paberi Stop. At Paberi stop, a new infrastructure is created Rävala pst (after Tartu mnt) to Laikmaa and Hobujaama street to avoid the bottleneck of Hobujaama. Then the route runs along Hobujaama Street, Paddi or Joey (after Ahtri) to arrive at the port. And return by Leava and Pohja street to come back to the existing infrastructure at the Kanuti station. Then the route continues to Balti jaam.

Train option

The train option connects Ülemiste Rail Baltica station to Vanasadam by reusing the existing ring railway infrastructure between Ülemiste and Balti jaam and creating a new underground infrastructure between Balti jaam and Terminal A/B.



Tram in tunnel option

This alternative proposes to connect Ülemiste to Vanasadam Port by creating a new LRT route :

- Partially underground (deep underground or in cut and cover) between Ülemiste and Liivalaia
- And at grade on the city center between Liivalaia and Vanasadam.

A bi-directional rolling stock is necessary for this option.

7.1. Evaluation criteria

Each of the 3 options has been analyzed through different criteria grouped into the following categories.

- Rail Baltica objectives
- Ridership and areas served
- Operation and maintenance
- Feasibility of implementation
- Feasibility of integration and conception
- Cost elements
- Economic and financial analysis

For each of the previous categories, a grade out of 10 is given to the option. The option with the highest grade will be recommended for the following studies.

Ridership, attractiveness and areas served

- Number of users of the line
- Intermodal polarities served by the line
- Connectivity with other public transport networks
- Urban polarities served by the line
- Touristic polarities served by the line
- Opportunity given by the line (ex: serving a new area, etc.)

Quality of service

- Travel time of the line between Ülemiste and the port)
- Headway
- Average travel time

Operation and maintenance

- Operation with the existing network
- Existing Depot and maintenance workshop
- Type of the rolling stock

Feasibility of integration and conception

- Impact on the existing functions (remove of existing car lanes to confirm with a traffic study)
- Impact on existing trees
- Impact on projected bicycle lanes
- Opportunity of enhancing the urban landscape
- Impact on the protected area
- Difficulties of integration on hard spots

- Efficiency of the Vanasadam station
- Efficiency of the Ülemiste station (lisibility, Ease of intermodal transfer in Ülemiste station, etc.)
- Feasibility and efficiency of the other stations

Feasibility of implementation

- Underground stations and infrastructure
- At grade stations and infrastructure
- Complexity of the civil works and risks
- Impact on general traffic during the works
- Acceptability of people (trees, heritage area, trucks and constructions site engines…)
- Land and building acquisitions
- Main utilities constraints

Cost elements

- Investment cost (CAPEX)
- Operating cost (OPEX)
- Needs of land acquisition

Economic and financial analysis

- Socio economic Benefits
- Economic NPV
- Financial NPV

Rail Baltica and Stakeholders objectives for the project

	ANSWER TO THE INITIAL OBJECTIVES	Tramway option	Train option	Tramway in tunnel option
RB objectives by ensuring connection between both Ten-T nodes (Ülemiste and Port)	to provide a sustainable, high quality, high capacity and fast connection	All the items are respected, except the speed which is less efficient than the two others.	All the items are respected, except that the headway is limited by the existing infrastructure of tracks.	all the items are respected
	to integrate urban, suburban and international passenger flows	answer totally to this objective	If the international and suburban passengers are well integrated, urban passengers are not enough integrated.	If the international and suburban passengers are well integrated, urban passengers are not well integrated.
complementary objectives shared by the Stakeholders	to serve Tallinn airport	Yes	only with interconnection with urban tramway	could be possible (to be confirm)
	to serve Tallinn main railway station – Balti jaam	Yes	Yes	only with interconnection with urban tramway
	to serve International Bus station – Bussijaam	Yes	only with interconnection with urban tramway	only with interconnection with urban tramway
	to serve Urban bus station – Hobujaama	Yes	only with interconnection with urban tramway	the Hobujaama station is quite fare from the bus station
	Score (weight of the criteria :10)	***8***	***4***	***6***

Ridership, attractiveness and areas served

Ridership, attractiveness and areas served	Tramway option	Train option	Tramway in tunnel option
Philosophy of the line / Improvement of Tallinn Public transport network	This line is the 2th existing tramway line with a changing of the route in order to decrease the headway in the bottleneck of Hobujaama and to serve the Port. It changes a little the tramway network but it does not create a new service.	This option proposes to realize an underground extension of the regional train lines from Balti Jaam to the Port. It is more an extension than a new line in the public transport network.	This option creates a new express tramway line. It changes and improves the public transport network.
Additional users on the public transport network (morning peak period)	+ 2400	+ 100	+ 100
Connection with other public transport networks	• Regular train lines and Rail Baltica in 2 main railway stations • the 3 other tramway lines • 11 bus lines (67-68-5-1A-34A-3-60-73-72-43-4) • Existing Bussijaam • International Airport • Ferry terminals	• Regular train lines and Rail Baltica in 2 main stations • the 4 tramway lines in Balti jaam, Ülemiste station and Kitseküla station. • 4 bus lines (5-18-36-43) • 2 trolleybus lines (4-5) • Ferry terminals	• Regular train lines and Rail Baltica in 1 station • the 4 tramway lines in Ülemiste, Hobujaama • 8 bus lines (60-68-40-18-3-5-34A-1A) • Ferry terminals
Urban polarities served by the line	Hobujaama, Telliskivi, Rotermanni	Telliskivi,	Hobujaama
Historic and touristic polarities served by the line	The 4 stations Balti Jaam, Kunstiakademia, Linnahall and Kanuti propose a good proximity with the old city, but they do not serve it directly.	The station Balti Jaam proposes a good proximity with the old city, but does not serve it directly. (1 station)	This line does not serve the historical center.
Opportunity given by the line (ex: serving a new area, etc.)	Serve the port area and connect the users of ferries to the old city and the new city center	Serve the port area and connect the users of ferries to the old city and the new city center	Serve the port area and connect the users of ferries to the old city and the new city center Possibility to serve a neighborhood near the stadium of Kesklinn

Opportunity of enhancing the urban landscape	The new route is already included in an urban development of the Port and on the city project of renewal of Narva Mnt and Hobujaama street.	None, the extension is completely underground. However it is a good point due to the heritage area that it passes through.	Medium, the part of the line at grade is around 1,5 km. The renewal of Liivalaia street and Joe street is possible.
Intermodal polarities served by the line	Balti Jaam, the Port, Hobujaama, Bussijaam, Ülemiste RB station, international Airport.	Balti Jaam, the Port, Ülemiste RB station.	The Port, Ülemiste station, Hobujaama (a bit further)
Score (weight of the criteria :10)	***9***	***6***	***5***

Quality of service

Quality of the service	Tramway option	Train option	Tramway in tunnel option
Travel time of the line between Ülemiste and the port)	~ 17 minutes	~13 minutes	~8 minutes
Headway at port	7 minutes	about 30 minutes	15 minutes
Average travel time between RB Ülemiste and The port (include a waiting time)	~ 20,5 minutes include a waiting time of 3,5mn (half headway)	~ 28 minutes include a waiting time of 15 mn (half headway)	~ 15,5 minutes include a waiting time of 7,5 mn (half headway)
Score (weight of the criteria :10)	***7***	***3***	***10***

Operation and maintenance

Operation and maintenance	Tramway option	Train option	Tramway in tunnel option
operation with the existing network	The line is interconnected with the tramway network in several points.	Interconnection with the existing railway network.	The line could be interconnected at the crossroad between Joe street and Narva mnt with the tramway network. If the Ülemiste station is at grade, a second interconnection is possible.
Type of the rolling stock	The existing tramway rolling stock is used.	The existing regional trains are used.	Ülemiste station is underground and a specific rolling stock (bi-directional) is necessary with the possibility to turn back without a loop,
And number of new rolling stock	No new rolling required	3 new electric regional trains are required	4 new bi-directional tramway

Depot and maintenance workshop	Existing depot.	Existing depot.	Existing depot. Necessity of little modifications for the new rolling stock.
Score (weight of the criteria :10)	***10***	***7***	***5***

Feasibility of implementation

Feasibility of implementation	**Tramway option**	**Train option**	**Tramway in tunnel option**
Underground stations	None	No specific problem	No specific problem, but need to realize it in the same time as the Ülemiste train station.
At grade stations	No specific problem	None	Due to the narrowness of the street, the platform Hobujaama station is too small to be operated normally.
Complexity of the civil works and risks	No real complexity. Interfaces with the port project are necessary to validate the location of the different part of the extension. It is also necessary to organize the works in coherence with the works of the new Port neighborhood.	The implementation of Vanasadam station has to be completed before the implementation of the drop off in front of the terminal A-B. A work site has to be find in the park.	Geological inspection are needed to confirm the TBM option. A large work site is necessary to realize the underground part. The time of implementation is potentially longer than the other options. This option is more risky.
Impact on general traffic during the works	The main impact will be the implementation of the new configuration of Ahtri crossroad.	Important impact will be during the civil works of Balti Jaam station under Toompuiestee and Ranamäe Tee and under	Deep underground part: civil works do not impact the general traffic.

	The rest of the project need classical means of work.	Pohjä Pst during the construction of the cut and cover section, A car diversion would be necessary on the pavement.	Shallow part: civil works disturb the traffic on Ülemiste tee. At grade part: civil works disturb a lot the traffic in Liivalaia street and the crossroads (Rävala pst and Ahtri).
Impact on the tramway network	All line will be impacted for the implementation of crossovers on the intersections of the line near Hobujaama (2/3 months).	The tramway line 1 and 2 will be close at less during 12 months between Linnahall to Balti jaam during the civil works of the cut and cover.	All line will be impacted for the implementation of crossovers on the intersections of the line near Hobujaama (2/3 months).
Acceptability of people	Traffic impact in Mere Pst crossroad and in Ahtri crossroad could be problematic.	The evacuation of the waste material could be done by ship with a site work close to the see. The cut of the trees is very problematic. A modification of the alignment could be necessary but it will imply to rebuild 3 small buildings in the heritage area.	The deep excavation need a big amount of trucks to evacuate the waste material by road. Disturb of the traffic in Liivalaia could be problematic.
Land and building acquisitions	Tram option needs to expropriate private lots between two buildings in Laeva Street. These two lands are free of constructions and are used as road.	Land and subsoil acquisitions could be necessary for the zigzag and the ramp in Balti Jaam and in the Port.	Smoke evacuation shaft need land acquisitions. Shaft need accesses for security and maintenance. Few acquisitions are identified on the shallow section in the corner of Liivalaia and Juhkentali. The surface of this land could be restitute after the civil works Underground part need also land acquisition of the subsoils under properties.

Main Utilities constraints	limited impact (no interfaces have been identified with the main utility network : gas and heating network)	Diversion of gas pipeline and heating pipeline are necessary under Sadama Street and Pohja Puiestee	Diversion of gas pipeline and heating pipeline could be necessary under Rävala Pst (between Gonsiori and Ahtri)
Score (weight of the criteria :10)	***8***	***3***	***1***

Feasibility of integration and conception

Feasibility of integration and conception	Tramway option	Train option	Tramway in tunnel option
Impact on the existing functions (remove of existing car lanes → need of circulation study)	**Very small impact** on Joe and Lootsi Street.	**Very small impact** on Balti jam organization and on the future drop off of the terminal A-B.	**Important impact on car traffic** on Liivalaia street with the remove of 2 car lanes (1 per direction). Necessity to make a traffic study on the avenue and on the Rävala crossroad. Reduce of the width of pavements with the creation of bicycle lanes.
Impact on existing trees	Impact on 28 small trees in Joe and Lootsi street.	**Impact on trees** with the cut and cover in the heritage perimeter.	Several old trees in the park near the old church. 7 old trees along Liivalaia street. 10 old trees along Joe street. 28 small trees in Joe and Lootsi street.
Impact on projected bicycle lanes	None	None	It is not possible to implement it in front of the fire station in Tartu-Võru-Luhamaa street and near the tramway stations in Joe and Liivalaia street.
Impact on the protected area	None	Trees and archeological issues (some regulations will have to be observed :Heritage Conservation Act, Planning and Building Act, Tallinn Temporary Building Regulations)	None
Difficulties of integration on certain points	None	The “zigzag” passes between two 7 storeys buildings.	The car traffic has to be checked to confirm the reduce of the number of car lanes.

	Mixt use tramway and car integration on Hobujaama street.	The small radius curve (150m) in front of the tip of the rampart.	
Efficiency of the Vanasadam station	The position of the station allows a good visibility from the two terminals. It is located in front of the footbridge. Good efficiency.	The shallow underground station is next to the terminal A-B. The accesses do not need too much space and are visible from the footbridge. Good efficiency.	The position of the station allows a good visibility from the two terminals. It is located in front of the footbridge. Good efficiency.
Efficiency of the Ülemiste station	The tramway station is located as it is today. It is localized in front of the future train station.	The train platforms will be integrated to the future train station.	The underground tramway station is closed to the train station. Its implementation as to be integrated to the train station one. An integration at grade would be better.
Feasibility and efficiency of the other stations	New Hobujaama station is well located and allows good intermodality with the other tramway lines and with the underground bus station.	Underground Balti Jaam station is well placed, next to the existing train station. It integrates the existing pedestrian underpass in the mezzanine.	New Hobujaama station is a bit far away from the tramway stations and the bus station. It is also too narrow. Keskturg station is well located.
Score (weight of the criteria :10)	***10***	***7***	***5***

Cost elements

Cost elements	**Tramway option**	**Train option**	**Tramway in tunnel option**
Investment cost (CAPEX)	21 M€ / 24 M€	184 M€	215 M€
Additional operation cost (OPEX)	28,7 k€	297,8 k€	322 k€
Needs of land acquisition	limited	limited	important

Score (weight of the criteria :10)	***10***	***2***	***0***

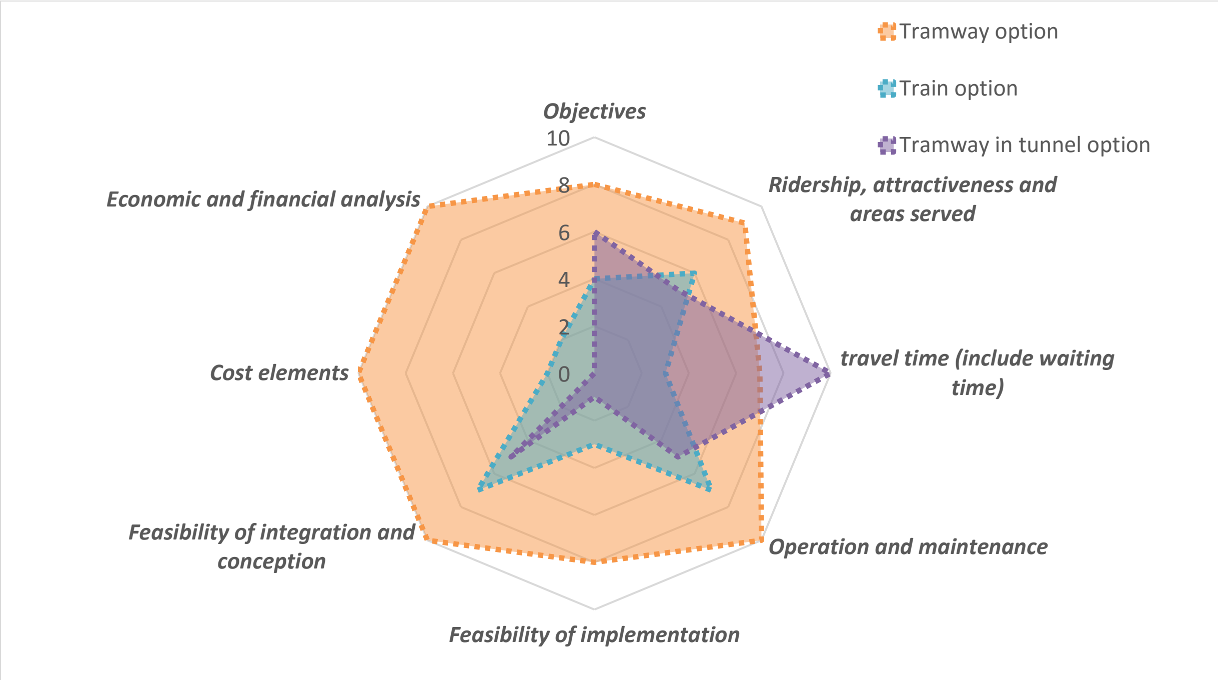
Economic and financial analysis

Economic and financial analysis	**Tramway option**	**Train option**	**Tramway in tunnel option**
Socio economic Benefits (for a year)	1600	200	200
Economic NPV	5 300 k€	-184 000 k€	-211 000 k€
Financial NPV	-20 300 k€	-184 000 k€	-211 000 k€
Score (weight of the criteria :10)	***10***	***2***	***0***

7.2. Conclusions and recommendations

According to the previous analysis, the grades given to each option are the following:

(weight of each criteria : 10)	Tramway option	Train option	Tramway in tunnel option
Objectives	8	4	6
Ridership, attractiveness and areas served	9	6	5
travel time (include waiting time)	7	3	10
Operation and maintenance	10	7	5
Feasibility of implementation	8	3	1
Feasibility of integration and conception	10	7	5
Cost elements	10	2	0
Economic and financial analysis	10	2	0
Total score	***72***	***34***	***32***



As a conclusion, the tram option is recommended for the next steps of the studies rail bound (light rail or tram) connection from RB Ülemiste passenger terminal to TEN-T core network Tallinn passenger port (Old City harbour / Vanasadam).

The choice between Rävala and Gonsiori options have to consider two long term projects, the car tunnel under Gonsiori and a new tram line through Rävala Street planned by Tallinn City. Both project are planned in a long term vision.

In case of these projects would not be confirmed, **option by Gonsiori appears as the most relevant solution because the** impact on car traffic and the investment cost are less important than the Rävala option.

In case of these projects would be confirmed :

- option by Rävala becomes a better option, but it has bigger impact on the car lanes and the traffic flow on big intersections. In this case, it is also interesting to consider a small change of the tramway alignment of the other lines as explained in the chapter "2nd alternative route" in order to simplify the Liivalaia -Rävala Junction.
- option by Gonsiori could be implement with a modification of the ramp access to the car tunnel. In this case, both projects are possible. Option by Gonsiori remains a relevant solution.
- For the both options, the implementation of the tunnel project of the city will seriously impact the new tramway line during the civil works.

Rail Baltica

Co-financed by the Connecting Europe Facility of the European Union

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