Rail Baltica: Preparation of the Operational Plan of the Railway

Final Study Report

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Abbreviations list

AADT	Annual Average Daily Traffic
AAWDT	Annual Average 2-Way Daily Traffic
AC	Alternating current
BEN	Beneficiaries of Rail Baltica project (3 Baltic states)
CBA	Cost-Benefit Analysis
CCS	Control Command System
CD	Commencement Date
CEF	European Union's Connecting Europe Facility
CIS	Commonwealth of Independent States
CPTD	Consolidated Preliminary Technical Design
ERA	European Union Agency for Railways
EoA	End of Authority
ERTMS	European Rail Traffic Management System
EE	Estonia
ETCS	European Train Control System
EY	Ernst & Young
EU	European Union
FinEst link	Railway link between Finland and Estonia (Helsinki – Tallinn)
FTE	Full Time Equivalents
GDP	Gross Domestic Product
GSM-R	Global System for Mobile Communication – Railway
GVA	Gross Value Added
HHT	Hand Held Terminal
HST	High Speed Train
IM	Railway Infrastructure Manager
IT	Information technology

km/h	Kilometres per hour
kV	Kilovolt
LDz	Latvijas dzelzceļš (Latvian Railways)
LT	Lithuania
LV	Latvia
MA	Movement Authority
m	Meter
mill	Million
MoM	Minutes of Meeting
NIEC	National Incident and Emergency Management Centre
NT	Night Train
OCC	Operations Control Centre
SOCC	Satellite Operations Control Centre
OCL	Overhead contact line
OD or O/D	Origin-Destination
PIC	Parcel Intercity
PL	Poland
PLK	PKP Polskie Linie Kolejowe S.A. (national railway line infrastructure manager)
PKP	Polish Railway Lines S.A.
PSC	Public Service Contract
RB	Rail Baltica railway
RBC	Radio Block Centre
RBDG	Rail Baltica Design Guidelines
RBILC	Rail Baltica Intermodal Logistics Centre (RBILC) located in Salaspils (LV)
RBR	RB Rail AS
RE	Regional Express Train
SWOT	Strengths - Weaknesses - Opportunities - Threats analysis
TEN-T	Trans-European Transport Network

TMS	Traffic Management System
ToR	Terms of Reference
TP	Time Period
TPS	Traction Power Supply
TSI	Technical Specifications for Interoperability
TSI ENE	Technical Specifications for Interoperability – energy subsystem; Regulation (EU); Regulation (EU) No 1301/2014
TSI INF	Technical Specifications for Interoperability – infrastructure subsystem; Regulation (EU) 1299/2014
TSI OPE	Technical Specification for Interoperability relating - operation and traffic management; Regulation (EU) 995/2015
TWG	Technical Working Group
WP	Work Package

0. Introduction

0.1. Operational Plan for Rail Baltica

The Rail Baltica project aims at the provision of a new standard gauge railway corridor connecting the three Baltic States Estonia, Latvia and Lithuania directly to the Central European railway network and providing a new quality of transport for the region. The new railway will be designed as an electrified (25 kV AC) double track line with a design speed of up to 249 km/h. The proposed railway line will be part of the North Sea – Baltic corridor of the European TEN-T core network.

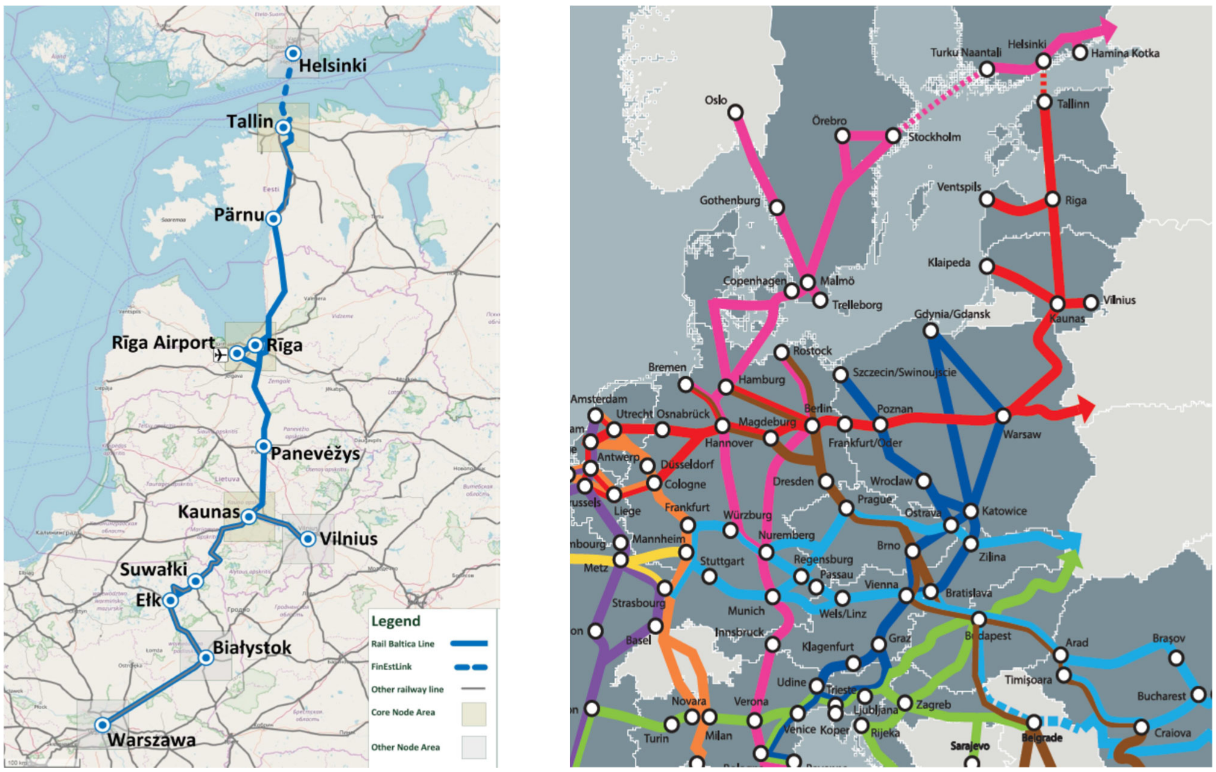


Figure 1: Map of study area and location of Rail Baltica within TEN-T core network

The total investment cost for Rail Baltica project is currently estimated at 5.8 billion Euros. In addition, the potential and feasibility of a future extension of the railway to Helsinki, the so called FinEst link is being investigated as a separate project.

RB Rail AS was established by the Republics of Estonia, Latvia and Lithuania to coordinate the development and construction of the proposed new standard gauge railway.

As part of on-going planning and construction preparation activities, RB Rail AS, the Client, hired the association consisting of ETC Transport Consultants GmbH (Berlin, DE), COWI AS (Lyngby, DK) and IFB – Institut für Bahntechnik (Berlin, DE) for the development of the Rail Baltica Operational Plan Concept of the railway.

The Operational Plan concept is a comprehensive set of documents describing the future structure of train traffic and operational processes on the railway line, outlining capacity of the railway, establishing operational requirements with regard to the infrastructure and rolling stock and outlining the related effort for maintenance of the infrastructure and rolling stock. The respective contract between the Client and the Contractor was signed on February 22nd, 2018 (Contract No A1.1.2.).

The project and the setup of the Operational Plan of the railway are co-financed by the European Union's Connecting Europe Facility (CEF), Action 2014-EU-TMC-0560-M, financing agreement No INEA/CEF/TRAN/M2014/1045990.

0.2. Scope and methodology of the Operational Plan concept

The aim of the study is the provision of the overall Operational Plan concept for the Rail Baltica corridor on a short, medium and long term perspective (from 2026 to 2056). The Operational Plan concept is the proposed organisation for the transport offer, which will be realised on the Rail Baltica standard gauge railway. Transport offer in this context is to be understood as the provision of sufficient capacity and capability of the infrastructure to handle the future transport demand most efficiently and providing an infrastructure and organisation which is attractive to railway undertakings and their customers thus revealing the full potential of rail transport.

0.2.1. General Planning Principles

By integrating a market-oriented offer (timetable) into the long-term planning process an optimal infrastructure planning and realisation is possible:

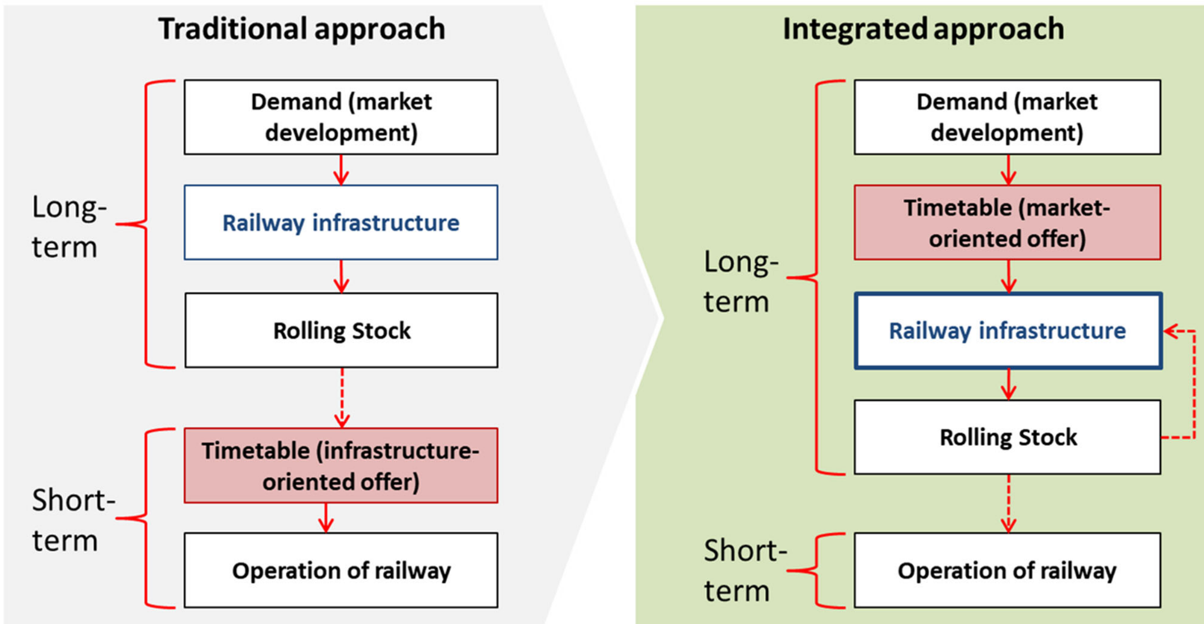


Figure 2: Integrated approach of timetable and infrastructure planning

Within the integrated approach of operational and infrastructure planning an iterative optimisation process is crucial. The starting point for this process within this study has been the Preliminary Design for Rail Baltica. The initial time table on this infrastructure helps to determine infrastructure bottlenecks with insufficient capacity. In the next iteration an improved infrastructure will be implemented into the timetable model. At the end of the study and optimised infrastructure with improved capacity and operational flexibility should be the basis for the further infrastructure design.

This Operation Plan is not the final planning document on future operation and time tabling on Rail Baltica but the initial basis for improving infrastructure design and the integration of Rail Baltica in the overall spatial structure of the region. Hence in the following planning and design phases of Rail Baltica the Operational Plan has to be further developed considering i.e. updated infrastructure design and the decision on regional traffic on Rail Baltica.

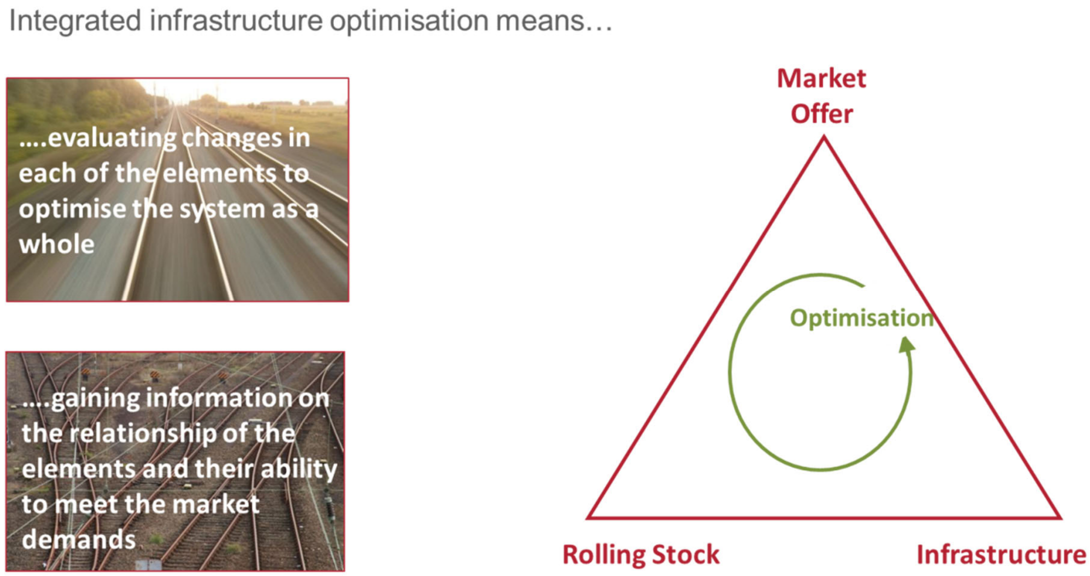


Figure 3: Integrated approach of timetable and infrastructure planning – optimisation process

0.2.2. Main Components of the Operational Plan

In order to reach that goal of integrated planning the Operational Plan concept does include three main components:

- The future transportation demand is depicted in the traffic study. Therefore all traffic flows which shall employ Rail Baltica have been considered, namely freight transport, which is mainly cross-border-traffic as well as long-distance and regional passenger transport.
- The Operational Plan defines the service pattern for train operation of Rail Baltica and will establish the operational requirements on the infrastructure and the related traffic organisation and management, incl. interfaces with 1520 mm gauge.
- The maintenance plan depicts how the infrastructure and rolling stock are to be maintained and what resources will be needed to maintain the infrastructure and what facilities will be required to maintain the rolling stock. Furthermore the related costs will be depicted.

The components of the Operational Plan concept and the related results for each of the three components are depicted in Figure 4 below.

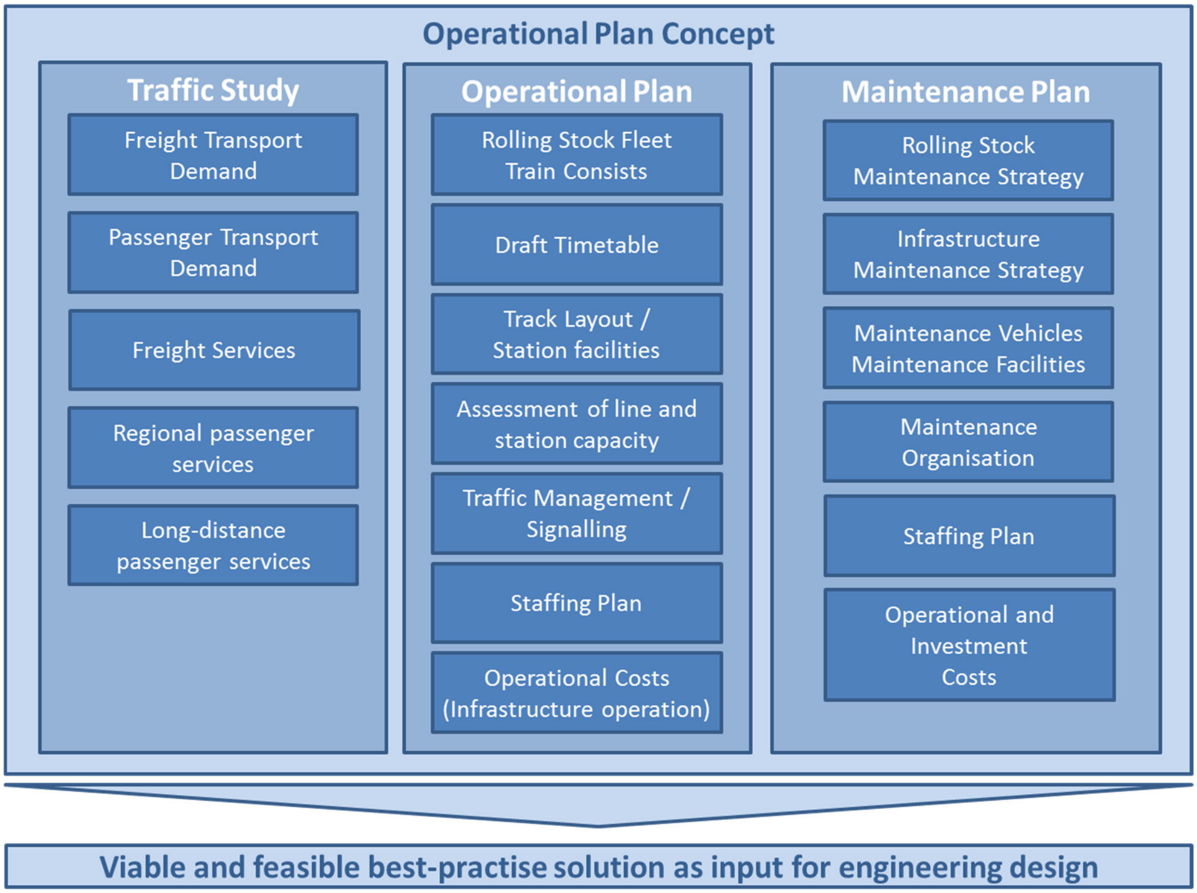


Figure 4: Expected outcome of the study – components of the Operational Plan concept

1. Transportation Demand and Transport Services (WP 1)

1.1. Scope and methodology

The scope of this task is to carry out a detailed analysis of the existing traffic studies, consolidating and supplementing them in order to propose an overview of the passenger and freight flows for each time horizon. The consolidated traffic flows form the basis for the definition of the train programme on the new railway line.

The scope includes the screening of existing studies of passenger traffic and freight traffic respectively. The latest study from 2017 named "Rail Baltica Global Project Cost-Benefit Analysis (CBA)" is considered the best basis for this Operational Plan. The FinEst study 2018 supplements the Global Study addressing a railway tunnel between Finland and Estonia and a potential extension of Rail Baltica to Finland after 2050. Other studies are screened as summarised below.

The main challenge for the consolidation is that regional passenger traffic which could create additional socio-economic benefit in the catchment area of Rail Baltica has not been considered in the existing studies accordingly. In the CBA for passenger traffic only 7 long-distance stops have been analysed in the three Baltic countries (Tallinn, Pärnu, Riga, Riga Airport RIX, Panevėžys, Kaunas and Vilnius). Smaller locations along the alignment including mid-size cities as e.g. Rapla in Estonia (~8,000 inhabitants within a 5 km radius), Bauska in Latvia (~8,000 inhabitants) or Marijampolė in Lithuania (~45,000 inhabitants) have not been considered. In the consolidation additional regional stations as proposed by the Technical Working Group have been assessed.

The transport demand includes information received from the Client and the Technical Working Group members. This information refers in differing detail to the section from Tallinn to the Lithuanian-Polish border as well as the Kaunas – Vilnius link and FinEst tunnel from Tallinn to Helsinki. By contrast no reliable information has been received so far for the Polish section from the Lithuanian-Polish border to Warsaw. Initial meetings with the Polish stakeholders (mainly the infrastructure manager PKP PLK S.A.) have been held. However, required information on the infrastructure, passenger demand, planned train services and travel times have not been received. Hence the Polish section has not been assessed in addition to the CBA within the Traffic Studies (WP 1) but assumption will be made as part of the Operational Plan (WP 4).

1.2. Long distance passenger transport

1.2.1. Screening of existing studies (WP1.1)

1.2.1.1. Rail Baltica Global Project Cost-Benefit Analyses

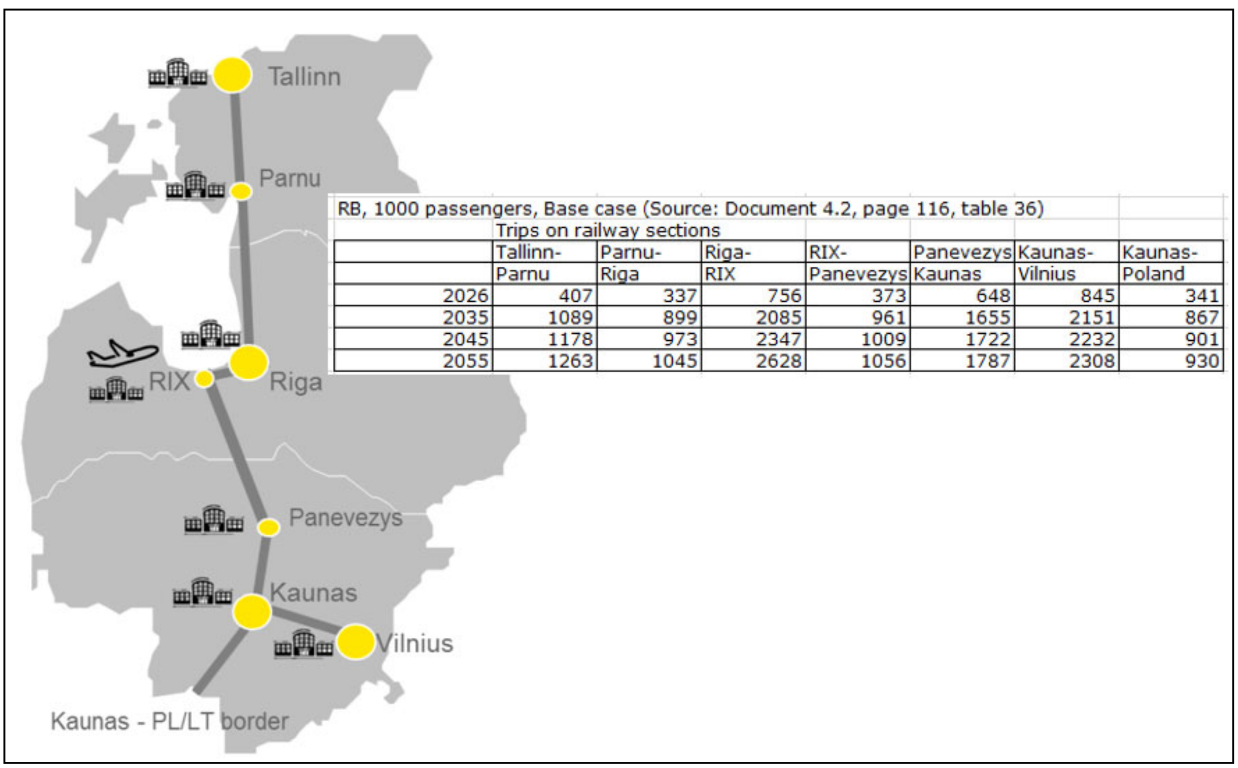
The documents

- Rail Baltica Global Project Cost-Benefit Analysis, Executive summary, 24 April 2017 (Document 4.1)
- Rail Baltica Global Project Cost-Benefit Analysis, Final Report, 30 April 2017 (Document 4.2)

include passenger forecasts, description of methodology and assumptions how passenger forecasts for future passenger traffic has been prepared by EY.

The Rail Baltica Global Project Cost-Benefit Analysis (the CBA) as prepared by EY and as documented in the two reports mention above is considered to be the main source for preparation of the Operational Plan for Rail Baltica. The passenger forecasts and assumptions in the CBA are summarised below.

The passenger numbers between Tallinn, Pärnu, Riga, Riga Airport, Panevėžys, Kaunas, Vilnius and Poland as forecasted in the base case in the CBA are shown in Figure 5.



RB, 1000 passengers, Base case (Source: Document 4.2, page 116, table 36)

	Trips on railway sections						
	Tallinn-Parnu	Parnu-Riga	Riga-RIX	RIX-Panevezys	Panevezys Kaunas	Kaunas-Vilnius	Kaunas-Poland
2026	407	337	756	373	648	845	341
2035	1089	899	2085	961	1655	2151	867
2045	1178	973	2347	1009	1722	2232	901
2055	1263	1045	2628	1056	1787	2308	930

Figure 5: Passenger forecasts from CBA 2017 for the base case (1,000 passengers/year, two-way)1

The forecasting approach applied by EY is a growth factor approach including the following steps:

- Step 1: Existing transport movement in 2015 between relevant origins and destinations by all existing modes (car, bus, train, air etc.) collected from statistical databases e.g. Eurostat.
- Step 2: Forecast on basis of general expectation and historic trends (GVA forecasts and elasticities).
- Step 3: Forecast and redistribution (mode and route choice) on basis of estimated generalised future travel costs with Rail Baltica and with other mode of transport (car, bus, other trains, air etc.).
- Step 4: Reducing forecast in the first years of operation as passengers are assumed to adapt to the new possibility to use Rail Baltica gradually over a 5-year period.

The existing (2015) daily passenger traffic including all modes (car, bus, train etc.) except air traffic are illustrated in Figure 6. The figure does not include air traffic, because air traffic cannot be assigned and illustrated meaningful on sections as road and railway traffic. However, the CBA does consider existing air traffic and competitiveness with Rail Baltica in the forecast model[2]. The question if air traffic was considered in a realistic way in the CBA was raised in the Technical Workshop in Vilnius 2nd – 3rd of May 2018. For an in-depth assessment see the analysis of the latest air statistics and an assessment if air traffic is handled in a realistic way in the CBA on page 38 in Chapter 1.2.2 with the consolidated passenger forecast.

[1] Source: Executive summary, page 6, figure 2 and CBA Cost-Benefit Analysis, page 116 table 36
[2] See more details in Cost-Benefit Analysis , page 38, page 39 and table 12

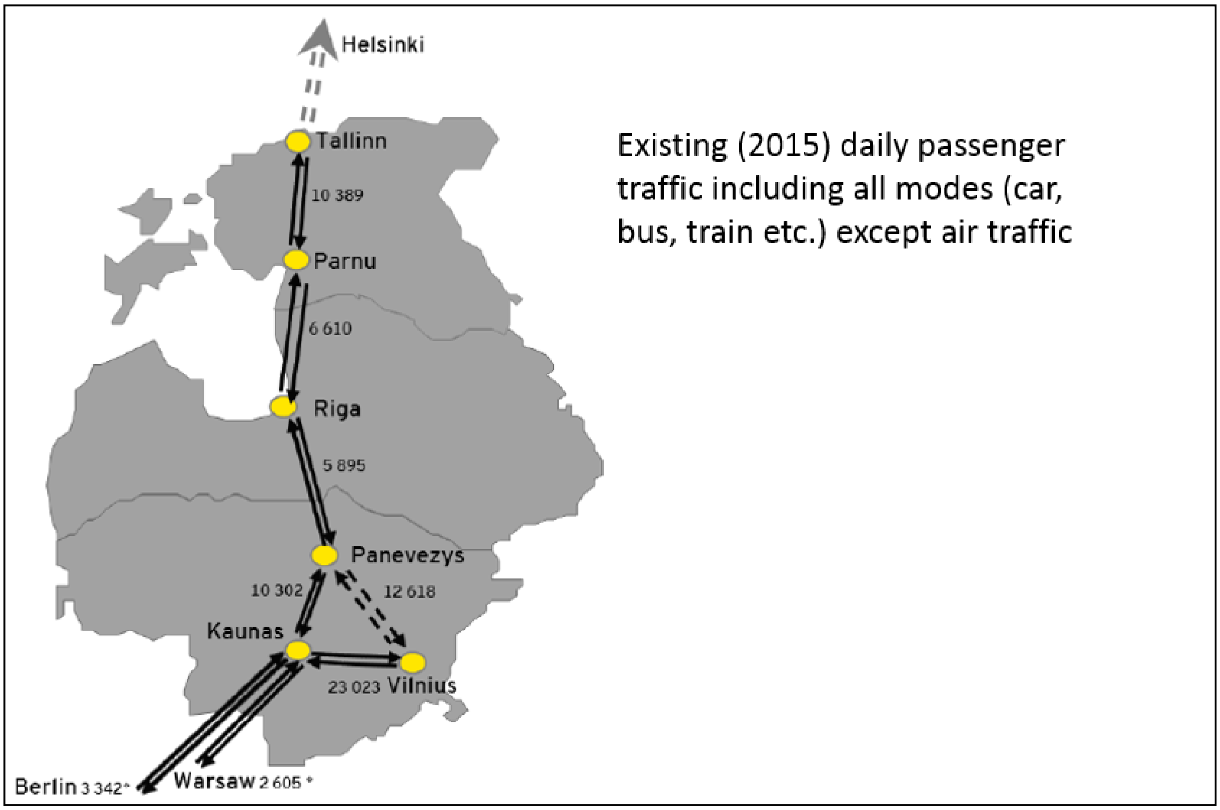


Figure 6: Estimate of daily passenger movements in 2015 between relevant nodes for Rail Baltica (passengers/day in both directions together)3

Regarding Step 3 – mode and route choice –this is dependent in the forecast model of travel time and travel cost in a reference scenario corresponding to the existing situation and in a project scenario with Rail Baltica. Assumed travel times between nodes are illustrated in Figure 7. The reader should be aware that air travel time includes check in, security, waiting and boarding time (but not travel time to and from the airports which are located rather close to the city centres in the analysed examples); this time is assumed to add 1 hour to the flight time per direction.

In terms of travel time Rail Baltica has an advantage over cars and buses between Rail Baltica nodes as shown in Figure 7. For example the travel time Vilnius – Kaunas is 00:36 with Rail Baltica compared to 01:39 by car or Riga – Tallinn 01:55 with Rail Baltica compared to 04:05[4] by car. Travel times in the figure are between Rail Baltica nodes corresponding to capitals and areas with high generation and attraction of passenger transport. However, many trips have an origin or destination elsewhere making the car more competitive depending on the origin and final destination. Rail Baltica has an advance over the car for many combinations of door to door origin and destination

[3] Source: Cost-Benefit Analysis, page 37, figure 17
[4] Source: CBA Final Report page 42 figure 21

for long-distance trips but the car could still have an advance over Rail Baltica and other public transport for many combinations of door to door origin and destinations if shorter regional trips prevail.

The competitiveness of Rail Baltica will depend to a great extent on the final location of the stations and their connection to the urban and regional residences, work places, educational institutions and other attractions. This relates e.g. significantly to the location of Panevėžys stations and its connection to the 1520 mm railway network.

Travel time by Rail Baltica and air is estimated to be similar for the shorter trips between Vilnius and Riga and between Riga and Tallinn. However, traveling longer distances by air do provide time savings compared to Rail Baltica[5].

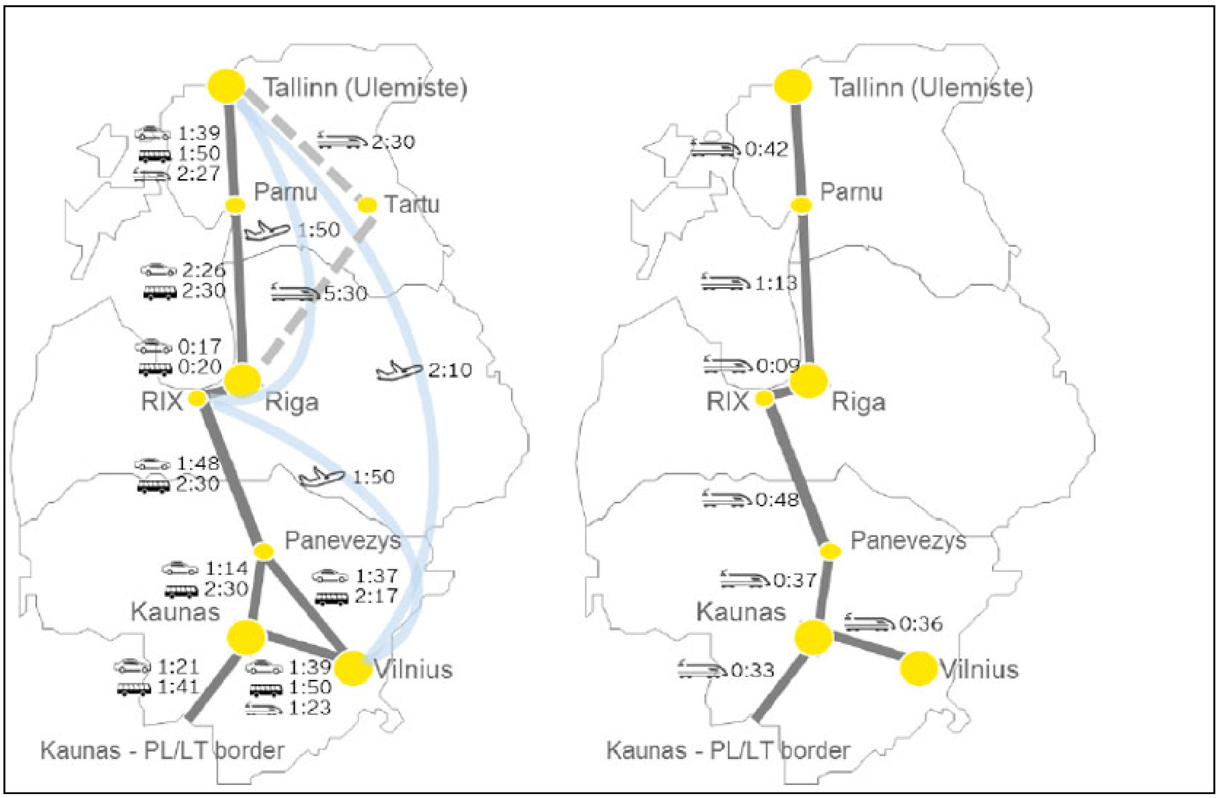


Figure 7: Schematic map of passenger travel time (existing - left, Rail Baltica only – right)6

Step 3 – mode and route choice - depends on generalised travel costs from door to door including travel time and direct monetary out of pocket travel costs. Assumed direct costs are e.g. Rail Baltica ticket price at 10.4 €/100 km and out of the pocket costs for private car at 22 €/100 km.

[5] For more details refer to Cost-Benefit Analysis, page 38, page 39 and table 12

[6] Source: Cost-Benefit Analysis, page 42, figure 21

Traffic forecasts addressing major changes in train service and addressing scenarios until 2055 in the CBA are estimates based on a number of assumptions:

- how attractive passengers will find the Rail Baltica service,
- how other public transport service will change in the future,
- how private transport will change and how socioeconomic parameters will change until 2055.

The CBA includes a base case as summarised above and as assumed to be the central estimate. The CBA include also a low case with 20% less passenger traffic and a high case with 20% more passenger traffic (Source: Executive summary, page 8, figure 5 and text next to figure 5).

Based on the passengers forecast for the base case the following train offer has been assumed in the CBA:

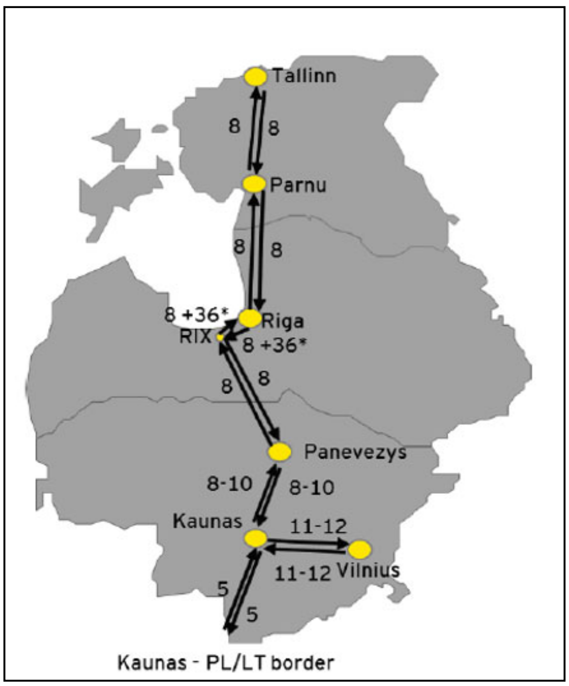


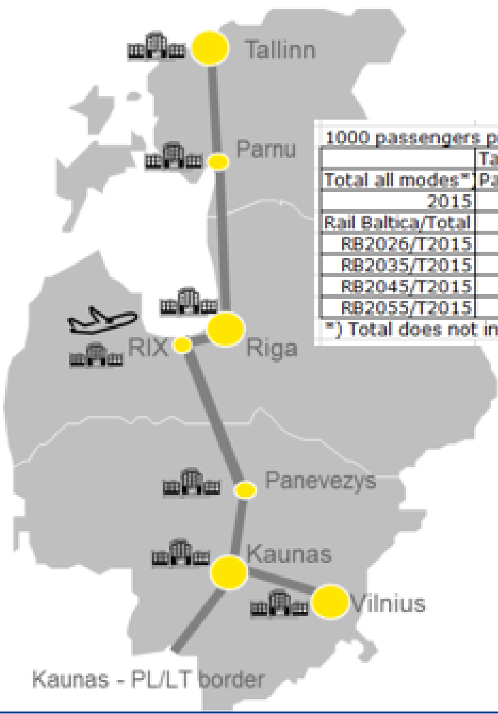
Figure 8: Schematic map of assumed passenger trains/day and direction (* shuttle to and from the airport)7

The question is if the forecasts made are realistic. The answer is that the method is state of the art, and the input data available seems realistic. Alas it was not possible to check the details in-depth, because not all important data was made available, required if a detailed quality assurance would have to be conducted. Unavailable data are e.g. origin-destination (OD) tables with number of passenger trips and travel cost elements in the reference and Rail Baltica scenarios.

[7] Source: Executive summary, page 10, figure 8

Comparison with the present car traffic does indicate that the forecasts conducted by EY are not out of scale. The forecasted long-distance railway passenger traffic in the main sections of Rail Baltica in 2026 is estimated to be between 11% and 17% of the present total road, railway and air passenger traffic which seems not to be unrealistic. For further details see table in Figure 9.

Passenger service



1000 passengers pr. year Total all modes*)	Tallinn-Parnu	Parnu-Riga	Riga-RIX	RIX-Panevezys	Panevezys Kaunas	Kaunas-Vilnius	Kaunas-Polen
2015	3792	2413		2152	3760	8403	2171
Rail Baltica/Total							
RB2026/T2015	11%	14%		17%	17%	10%	16%
RB2035/T2015	29%	37%		45%	44%	26%	40%
RB2045/T2015	31%	40%		47%	46%	27%	42%
RB2055/T2015	33%	43%		49%	48%	27%	43%

*) Total does not include passengers travelling by air

Figure 9: Comparison of present long-distance passenger traffic and Global Project forecasts[8]

Demand forecasting is not a straight forward process. Uncertainties are considered in the Global Project with a low and high demand forecast case with 20% less and 20% more traffic than the base case. Some of the uncertainties are raised and addressed below.

The proposed location of Panevėžys RB station is not optimal from a passenger's point of view. The station is located approximately 10 km from the centre and from the existing railway station. It is not clear if this was assumed in the Global Project and this might reduce passenger traffic compared to estimate in the Global Project CBA.

Passenger traffic by air was discussed at the Technical Workshop in Vilnius 2nd – 3rd of May 2018, as the question was raised if the potential diversion of air traffic to Rail Baltica has been considered or underestimated in the CBA.

[8] Source: Consultant calculation on basis of Cost-Benefit Analysis , page 116, table 36 and Cost-Benefit Analysis, page 37 figure 17

New information regarding air traffic has therefore been collected from EuroStat as shown in Table 1. Be aware the figures in Table 1 are two-way traffic; because of that OD combinations between Baltic Airports in the two directions should not be added. Figures not available (e.g. to and from Kaunas) is because of no regular traffic between the OD combinations.

Even if air traffic is not mentioned in Figure 6, it is mentioned elsewhere in the Global Project CBA and air passenger traffic is considered in the Global Project passenger forecast model[9]. The registered air traffic in 2016 as shown in Table 1 is in the same order of magnitude as the 2014 figures in the CBA[10]. Data of air traffic with regard to the competitiveness between air and Rail Baltica as well as the way it is incorporated in the CBA demand model is realistic and well justified. In conclusion the CBA seem to consider the diversion from air to Rail Baltica in a realistic way.

	TALLINN	RIGA	KAUNAS	VILNIUS
HELSINKI-VANTAA airport	639	716	-	256
LENNART MERI TALLINN airport	-	558	-	176
RIGA airport	558	-	-	454
KAUNAS INTL airport[11]	-	-	-	-
VILNIUS/INTERNATIONAL airport	176	454	-	-
WARSZAWIA/CHOPINA airport	127	259	-	332
BERLIN-SCHOENEFELD/TEGEL airport	78	633	-	-

Table 1: 2-way average daily air passengers in 2016 (Source: Eurostat, passengers carried, all airlines)

[9] See details in Cost-Benefit Analysis, page 38, page 39 and table 12

[10] See Cost-Benefit Analysis, table 12

[11] Flights Kaunas – Warszawa started in 2017, currently 6 flights weekly per direction.

1.2.1.2. FinEst link final report 2018

The FinEst link is a railway tunnel option connecting Helsinki and Tallinn with a 1435 mm gauge railway for direct passenger and freight train services via Rail Baltica connecting to the European Railway Network. The figure below gives an overview of the proposed alignment of the tunnel option and railway link (Source: FinEst link final report 2018). All forecast results are taken directly from the above mentioned FinEst link final report.

Figure 10: FinEst link map

The distance Helsinki-Tallinn is approximately 100 km.

Travel time is assumed to be reduced from the present two hours (fastest connection) to 30 minutes with train service via the potential tunnel.

Passenger growth the past 10 years has been +4%/year between Tallinn and Helsinki Assumed growth 2016-2030 in the 0+ scenario without a tunnel is +2%/year. Assumed growth 2030-2050 in 0+ scenario is +1% /year.

Passenger forecast 2050 in the scenario with the tunnel is estimated to be 23 million in total between Helsinki and Tallinn of which 12.5 million using the tunnel and 10.5 million on using the ferry services.

The 12.5 million railway passengers forecasted for the tunnel is approximately 10 times as high as the forecast for passengers on Rail Baltica on the section between Tallinn and Pärnu.

Three passenger trains per hour and direction were assumed in the study per working day in the morning and afternoon peak periods. No night passenger traffic was foreseen.

The report does not indicate to what extend the passengers have Tallinn as their final destination and to what extend passengers are supposed to continue further south with Rail Baltica.

1.2.1.3. Other earlier Rail Baltic passenger studies

Other earlier Rail Baltic studies have been screened including:

- AECOM 2015 focusing on optional alignments between Vilnius and Kaunas;
- AECOM 2012 feasibility study addressing optional alignments of the main line;
- COWI 2007 pre-feasibility study.

The above mentioned earlier studies have all a broader perspective as the Rail Baltic Global Project CBA. The above mentioned studies address e.g. alignment options not considered realistic anymore. The earlier studies have been important as a basis for the many choices and decisions made before the Rail Baltic Global Project Analysis and assumptions made in the Rail Baltic Global Project. The Rail Baltic Global Project CBA is therefore considered as the best basis for the Operational Plan including earlier decisions and based on newer data than the earlier studies.

1.2.1.4. Conclusion of passenger traffic studies

The EY CBA method is state of the art, and the input data available seems realistic. The approach from methodology to the results is not documented in detail. Results are not out of scale considering the potential for change of mode from mainly car traffic.

The CBA and the other passenger traffic studies as available and as screened did not consider regional traffic as it is part of this Operational Plan study. The CBA addresses only the 7 international stations as shown on Figure 5 above. The present Rail Baltica ambition is to serve 37 regional stations in addition to the 7 international long-distance stations as listed in Table 13, Table 14 and Table 15 below. The CBA and the other passenger studies do not specifically address regional stations and regional passenger traffic.

The CBA does not mention and specific address 1435 regional passenger traffic as part of the Rail Baltica Global project. The CBA does mention extended projects and wider projects including potential regional passenger station not taken into account in CBA calculations of cost as well as benefits. Introducing regional and local railway service in between high speed service might or might not add to net benefit. The primary aim of Rail Baltica is – according to the CBA – to serve international connections. The CBA does not include recommendations if and how to integrate regional and local passenger traffic at the Rail Baltic 1435 railways.

The CBA does not mention and specific address how to integrate regional and local 1520 railway service into Rail Baltic service. If regional passenger service are introduced at the 1435 Rail Baltic project as assumed in this Operational Plan there is an intrusive need to plan how the 1520 service are integrated the best way. The recommendation is to initiate, detailed studies on regional passenger transport including the planned service pattern and the transport offer on feeding and competing 1520 railway lines and other public passenger transport.

The recommendation is therefore to initiate detailed studies of regional railway traffic demand and operational plans in Estonia, Latvia and Lithuania in cooperation with the Railway Authorities and Transport Ministries in each of the 3 countries to address the potential regional passenger traffic along Rail Baltica including trans-border traffic. These should consider as well how to integrate the regional traffic with the existing and future 1520 mm gauge railway transport offer.

It is recommended to include the following subtasks in each of the 3 detailed studies:

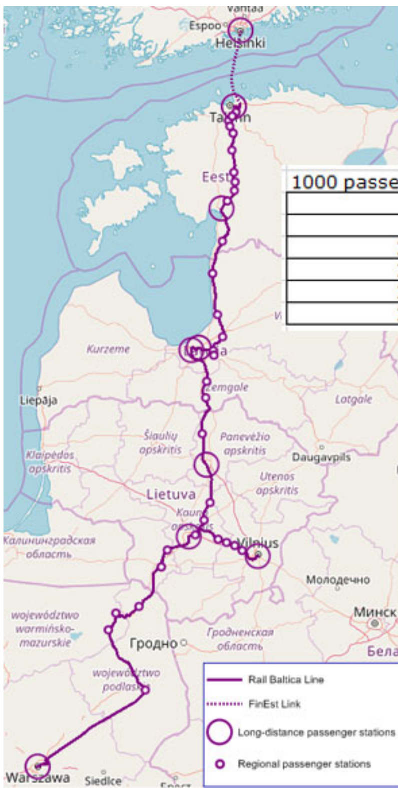
- Currently there is neither comprehensive and comparable traffic model nor OD matrix on a national and regional level in Baltic countries. All transport authorities plan in their own way, in most cases without embedding other transport modes and possible modal shifts. Thus, first, there is a need for ambitious data gathering to establish OD relations, mode choice criteria, etc.;
- It is necessary to identify and screen existing passenger statistic as available with relevant authorities in Estonia, Latvia and Lithuania on 1520 mm railway lines, for other public transport modes and passenger car traffic along the Rail Baltica corridor and integrate them into the traffic model;
- It is necessary to identify and screen existing development plans for passenger transport and for land-use as available with relevant authorities in each of the 3 countries and integrate them into the traffic model;
- It is necessary to consolidate and supplement existing plans as needed to reconsider location of regional railway stations and potential regional passengers along Rail Baltica and relevant future 1520 mm railway lines as input to the on-going optimisation of the Rail Baltica project.

Within this work package of the Operational Plan the initial elements of these studies have been analysed in order to determine the potential for regional passenger transportation and the consequent train service pattern on Rail Baltica. However additional assessment should be conducted in order to determine the economic feasibility and the spatial integration of the regional stops in detail.

Chapter 1.3 on regional passenger transportation is based on the available information on the proposed locations of the stations and according socio-economic data as well as best practice from similar projects in Europe. In this regard, the trip generation for the 37 regional stations and the consequent traffic flows has been assessed in order to prepare a realistic service pattern of regional trains as required to prepare the Operational Plan and the technical feasibility of the proposed regional stops.

1.2.2. Consolidated demand forecast for long distance traffic (WP1.3)

The consolidated demand forecast is based on the CBA and includes an assessment of the future demand along the entire Rail Baltica alignment before and after the opening of the FinEst tunnel. In addition, the annual demand has been broken down into daily figures as they determine the future train service pattern. The following figure shows the Rail Baltic alignment and location of long distance stations as well as the consolidated forecast based on the Rail Baltic Global Study without FinEst tunnel.



1000 passenger trips (Source: Consultants estimate based on the CBA)

	Tallinn-Parnu	Parnu-Riga	Riga-RIX	RIX-Panevezys	Panevezys Kaunas	Kaunas-Vilnius	Kaunas-Poland
2026	407	337	756	373	648	845	341
2036	1098	906	2111	966	1662	2159	870
2046	1187	980	2375	1014	1729	2240	904
2056	1272	1052	2656	1061	1794	2316	933

Figure 11: Rail Baltica passenger demand p.a. for long distance passenger trains without FinEst tunnel

The forecasts for 2026, 2035, 2045 and 2055 are based on socio-economic data, as e.g. GVA and GDP for the relevant urban nodes and country pairs within Rail Baltica catchment area as described in general in the CBA reports. Parameters are established on basis of comprehensive survey of historic and present transport and transport cost with all relevant modes in all of Europe. The approach takes advantage of the experience from similar projects and forecast models as e.g. TRANS-TOOLS. A similar approach has been used by WTO.

The consolidated demand forecast above is based on interpolations and minor extrapolations to cope with the time periods 2036, 2046 and 2056 as required in the Operational Plan. The relevant question is if assumptions and results are in line with Rail Baltica requirements and following a realistic approach.

The locations of main stations as documented as the basis for the Operational Plan and assumed to be served with long-distance passenger train service correspond with the Global Project except for the optional extension to Helsinki and Finland.

The annual long distance passenger traffic has been consolidated to daily traffic in Table 2 below to justify the proposed train service in the Operational Plan (WP 4). Long distance passenger traffic is assumed to be considerable in weekends and holiday periods as well as on working days. Shorter regional passenger traffic – especially next to major conurbations - is usually higher on working days than on non-working days because of relative more home-work trips than compared to long distance traffic. The daily long distance traffic in Table 2 is simply estimated as yearly traffic divided by 365 resulting in annual average daily traffic.

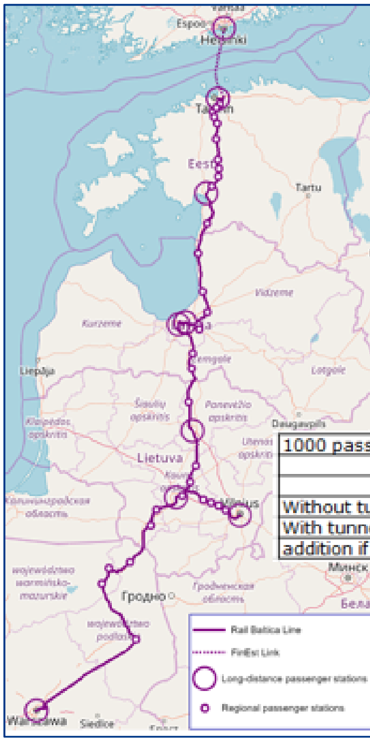
The average working day traffic is assumed to be in the same range, as weekend traffic and holiday traffic are assumed to be considerable. The extreme maximum of daily long distance passenger traffic is likely to be next to a holiday.

	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Kaunas-Vilnius	Kaunas-Poland
2026	1,115	923	2,071	1,022	1,775	2,315	934
2036	3,008	2,483	5,784	2,646	4,553	5,915	2,385
2046	3,251	2,685	6,507	2,777	4,736	6,136	2,476
2056	3,484	2,883	7,277	2,906	4,914	6,344	2,556

Table 2: Long-distance passenger trips per day (AADT Annual Average Daily Traffic, both directions) without FinEst tunnel

The FinEst tunnel is to be considered in the Operational Plan as required by the ToR, but no decision has been made yet if and how to finance the project. The project is considered in the Operational Plan for 2056, but it is uncertain if the tunnel option will be realised as foreseen today.

Passenger demand of long-distance passenger traffic are assumed to vary from 7%-10% of AADT per hour in the morning peak from 7:00 to 9:00 and in the afternoon peak from 15:00 to 18:00. Passenger demand in the rest of the daytime and the early evening is typically in the range of 4-7% of AADT. Passenger demand in the late evening and night time is typically in the range of 0-2% per hour. Peaks could be higher – up to 15% in critical direction - if regional and local traffic dominated of commuter traffic next to major cities with considerable directional split.



If FinEst tunnel open 2050, it could rise demand considerable:

FinEst link Helsinki-Tallinn			
1000 passenger trips			
	2017	2050	2050
Scenario		Without tunnel	With tunnel
In tunnel	0	0	12500
On ferries	9000	14000	10500
Total	9000	14000	23000

If 10% of the above tunnel passengers are long-distance Helsinki-Warsaw and further:

1000 passenger trips 2056 (Source: Consultants estimate assuming 10% long-distance)							
2056	Helsinki Tallinn	Tallinn-Parnu	Parnu-Riga	RIX-Panevezys	Panevezys-Kaunas		Kaunas-Poland
Without tunnel	0	1272	1052	1061	1794		933
With tunnel	13250	2597	2377	2386	3119		2258
addition if tunnel		104%	126%	125%	74%		142%

A doubling of long-distance passengers and long-distance train every hour probably required in 2056 if a FinEst tunnel

Figure 12: Rail Baltica passenger demand p.a. for long distance passenger trains with FinEst tunnel

Figure 12 gives the passenger forecast in the FinEst tunnel as well as an indicative forecast how the tunnel potentially could increase passenger demand on Rail Baltica. The influence of the tunnel on the overall demand is significant with 74% - 142% of additional traffic on the relevant sections.

Table 3 shows the resulting long-distance passenger trips with daily two-way passenger traffic in the scenario where the FinEst tunnel is assumed to open in 2050.

	Helsinki-Tallinn	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Kaunas-Vilnius	Kaunas-Poland
2026	0	1,115	923	2,071	1,022	1,775	2,315	934
2036	0	3,008	2,483	5,784	2,646	4,553	5,915	2,385
2046	0	3,251	2,685	6,507	2,777	4,736	6,136	2,476
2056	36,300	7,114	6,513	10,907	6,536	8,544	9,974	6,186

Table 3: Long-distance passenger trips per day (AADT Annual Average Daily Traffic, both directions) with FinEst tunnel

Comments have been received at the TWG meeting in Tallinn on June 13th, 2018 that a more detailed assessment of distribution of passengers south of Tallinn would be required. The recommended adjusted assumptions are:

- 90% of the passenger in the tunnel to go to and from the Tallinn region,
- 3% of the passenger in the tunnel to go to and from the Riga region,
- 1% of the passengers in the tunnel to go to and from the Vilnius region,
- 1% of the passengers in the tunnel to go to and from the Kaunas region,
- 5% of the passengers to go further south of Kaunas to and from Poland and further south and west.

The revised forecast means less passenger traffic towards Poland and more passenger traffic towards Vilnius. This will be considered in the train service pattern as part of Operational Plan (WP 4).

Concerns were expressed in the TWG meeting not to invest too much effort in planning for long-term scenarios as e.g. the FinEst scenario that might not turn out to be realised. However, 2056 is the time horizon for the Operational Plan and the required infrastructure includes FinEst tunnel, with opening assumption in 2050. Earlier stages (2026 – 2046) will be developed from the 2056 situation in such a way that the infrastructure can be extended step by step by step (no sunk costs for previous investments).

General OD tables with passengers between all stations are not available in the CBA. Availability of OD tables would be helpful to address realism and to consolidate if major changes in the assumptions are being made. OD tables are not needed to justify recommendation of train service pattern and capacity utilisation on most sections. The only exception is the triangle next to Kaunas where there are optional routes and a need to consider the split of passengers between the sections Vilnius – Kaunas, Kaunas including stations south of Kaunas and Panevėžys including stations north of Panevėžys.

The daily passengers on main sections in the table above have been translated into OD tables below with number of passengers between origins and destinations addressing the planned triangle next to Kaunas allowing train and passengers between Vilnius and the northern part of Rail Baltica including Panevėžys, Riga etc. to bypass Kaunas. The OD tables are based on passenger volumes in the CBA and information in the CBA distinguishing between point to point trips, intra-Baltic trips and extra-Baltic trips[12].

The reader should be aware that the format are OD tables and figures in each cell are one direction from-to and that "Kaunas" includes Kaunas as well as all stations south of Kaunas in Lithuania and Poland where "Panevėžys" include Panevėžys as well as all stations north of Panevėžys in Latvia, Estonia and Finland in 2056.

from to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.

[12] See CBA, Executive summary, page 9, figure 7

Vilnius	0	809	349
Kaunas, Poland etc.	809	0	539
Panevėžys, Riga etc.	349	539	0

Table 4: Indicative OD passenger trips per day 2026 in the Kaunas triangle (AADT)

From/to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius	0	2,065	892
Kaunas, Poland etc.	2,065	0	1,384
Panevėžys, Riga etc.	892	1,384	0

Table 5: Indicative OD passenger trips per day 2036 in the Kaunas triangle (AADT)

From/to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius	0	2,141	927
Kaunas, Poland etc.	2,141	0	1,441
Panevėžys, Riga etc.	927	1,441	0

Table 6: Indicative OD passenger trips per day 2046 in the Kaunas triangle (AADT)

From/to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius	0	3,476	1,511
Kaunas, Poland etc.	3,476	0	2,761
Panevėžys, Riga etc.	1,511	2,761	0

Table 7: Indicative OD passenger trips per day 2056 in the Kaunas triangle (AADT) including FinEst tunnel

In order to get more information on the origin-destination relations a pragmatic approach has been applied to establish OD tables corresponding to Table 3 adding assumptions of distributions of southbound traffic from each station as shown in Table 8.

From/to	Tallinn	Pärnu	Riga	RIX	Panevėžys	Kaunas	Vilnius	Poland	Total
Tallinn		25%	30%	20%	5%	10%	6%	4%	100%
Pärnu			35%	35%	7%	12%	7%	4%	100%
Riga				80%	6%	7%	4%	3%	100%
RIX					25%	40%	30%	5%	100%
Panevėžys						50%	44%	6%	100%
Kaunas							80%	20%	100%
Vilnius								100%	100%

Table 8: Assumed distribution of southbound traffic from each station

Adding the assumption from in Table 8 to the passenger volumes in Table 3 the results will be as shown in OD tables below.

From/to	Tallinn	Pärnu	Riga	RIX	Pane-vėžys	Kaunas	Vilnius	Poland	Total
Tallinn		139	167	112	28	56	33	22	558
Pärnu	139		15	15	3	5	3	2	183

Riga	167	15		605	45	53	30	23	939
RIX	112	15	605		52	83	62	10	939
Panevėžys	28	3	45	52		252	222	30	633
Kaunas	56	5	53	83	252		575	144	1,168
Vilnius	33	3	30	62	222	575		231	1,158
Poland	22	2	23	10	30	144	231		462
Total	558	183	939	939	633	1,168	1,158	462	6,039

Table 9: 2026 long-distance passenger trips per day (AADT Annual Average Daily Traffic)

From/to	Tallinn	Pärnu	Riga	RIX	Pane-vėžys	Kaunas	Vilnius	Poland	Total
Tallinn		376	451	301	75	150	90	60	1,504
Pärnu	376		40	40	8	14	8	5	490
Riga	451	40		1,713	128	150	86	64	2,632
RIX	301	40	1,713		121	194	145	24	2,538
Panevėžys	75	8	128	121		643	566	77	1,619
Kaunas	150	14	150	194	643		1,466	366	2,983
Vilnius	90	8	86	145	566	1,466		597	2,958
Poland	60	5	64	24	77	366	597		1,193
Total	1,504	490	2,632	2,538	1,619	2,983	2,958	1,193	15,917

Table 10: 2036 long-distance passenger trips per day (AADT Annual Average Daily Traffic)

From/to	Tallinn	Pärnu	Riga	RIX	Pane-vėžys	Kaunas	Vilnius	Poland	Total
Tallinn		406	488	325	81	163	98	65	1,626
Pärnu	406		43	43	9	15	9	5	530
Riga	488	43		1,953	147	171	98	73	2,973
RIX	325	43	1,953		114	183	137	23	2,778
Panevėžys	81	9	147	114		665	585	80	1,681
Kaunas	163	15	171	183	665		1,517	379	3,092
Vilnius	98	9	98	137	585	1,517		625	3,068
Poland	65	5	73	23	80	379	625		1,250
Total	1,626	530	2,973	2,778	1,681	3,092	3,068	1,250	16,997

Table 11: 2046 long-distance passenger trips per day (AADT Annual Average Daily Traffic)

From/to	Tallinn	Pärnu	Riga	RIX	Pane-vėžys	Kaunas	Vilnius	Poland	Total
Tallinn		711	889	711	142	178	178	747	3,557
Pärnu	711		144	144	29	49	29	16	1,122
Riga	889	144		2,584	194	226	129	97	4,263
RIX	711	144	2,584		313	502	376	63	4,693

From/to	Tallinn	Pärnu	Riga	RIX	Pane-vėžys	Kaunas	Vilnius	Poland	Total
Panevėžys	142	29	194	313		841	740	101	2,361
Kaunas	178	49	226	502	841		2,009	502	4,307
Vilnius	178	29	129	376	740	2,009		1,526	4,987
Poland	747	16	97	63	101	502	1526		3,052
Total	3,557	1,122	4,263	4,693	2,361	4,307	4,987	3,052	28,342

Table 12: 2056 long-distance passenger trips per day (AADT) including FinEst tunnel

The long distance passenger demand (PAX1) is mainly in the daytime including morning and afternoon peaks and in the evening. Passenger demand of long-distance passenger traffic vary typically from 7%-10% of AADT per hour in the morning peak from 7:00 to 9:00 and in the afternoon peak from 15:00 to 18:00. Passenger demand in the rest of the daytime and the early evening is typically in the range of 4-7% of AADT. Passenger demand in the late evening and night time is typically in the range of 0-2% per hour.

The demand for night time long distance (international) express passenger service (PAX2) is limited. Throughout Europe, the number of night train services has greatly reduced over the past 50 years. After the World War II, the advent of air travel, high-speed rail services and the rise of private car ownership have collectively phased out night trains from circulation. As of last year, only 11 EU Member States retain their domestic night train services.

An example of a corridor similar to Rail Baltica is Stockholm – Copenhagen – Hamburg connecting to the Central European Network in Germany and beyond. There used to be night train service from Stockholm to Hamburg via Copenhagen, and there used to be night train service from Copenhagen via Hamburg to other major cities in Germany and beyond. Night train service Stockholm – Copenhagen - Hamburg was closed down in 1990. The last night train from Copenhagen via Hamburg to other destinations in Europa run in 2014.

Recently, European Parliament's Committee on Transport & Tourism published a report titled "Passenger night trains in Europe: the end of the line?", which looks in detail at the financial, economic, social and environmental viability of night train services[13].The report found that night trains still contribute to the mobility needs of European citizens, but deemed it "unlikely that the night train sector will grow beyond a small niche". However there is market potential – especially in the light of climate change and the need to reduce continental flights.

In some countries a first small renaissance of night trains can be observed; especially Austrian national operator ÖBB who e.g. took over in 12/2016 all night trains in Germany cancelled by DB. ÖBB is now expanding its international night train network covering in 2018 already Croatia, Germany, Hungary, Italy, Poland, Slovakia, Slovenia and , Switzerland. Further connections are announced after according rolling stock purchase.

In addition the current situation in the Baltic countries differs from travel patterns in other parts of Europe and travelling at night times – also historically –is of much higher importance. For example in the current long distance bus time tables courses at night times usually account to 10-25% of all offered courses. It is difficult to forecast how

[13] Source: www.europarl.europa.eu/RegData/etudes/STUD/2017/601977/IPOL_STU(2017)601977_EN.pdf

these travel patterns will develop in the future however a higher significance than in other parts of Europe of night time travelling can be assumed.

The total demand for night time passenger traffic in the 6 hour period from 24:00 to 6:00 is assumed to be in the range of 5-10% of the daily 24 hour traffic if a train service as in the daytime.

The forecast for the FinEst tunnel does not assume night time express passenger service between Helsinki and Tallinn. Slow freight trains are prioritised in the tunnel in the night time not allowing express passenger service. However, night trains could be operated – probably at lower speed – also during night times, e.g. as an extension of night train services from Warsaw to Tallinn (comp 4.5.4).

1.3. Regional Passenger Transport

1.3.1. Screening and review of existing studies (WP1.1)

The studies and reports made available for the consultant as basis for this Operational Plan study do not address regional passenger transport. The studies made available and screened include:

- EY CBA 2017 – Rail Baltic Global Project,
- AECOM 2015 focusing on optional alignments between Vilnius and Kaunas,
- AECOM 2012 feasibility study addressing optional alignments of the main line,
- COWI 2007 pre-feasibility study.

The earlier studies from 2007 and 2012 do consider optional alignments of Rail Baltic from Warsaw via Kaunas and Riga to Tallinn without the section Vilnius – Kaunas. The 2015 study addresses the section Vilnius – Kaunas studying optional alignments of the standard gauge railway also to some extend touching how to integrate each optional standard gauge option with the existing railway. None of these studies seem to address regional stations on the main line or on the section Vilnius – Kaunas.

The latest Rail Baltic Global Project focus on a Rail Baltic project including the section Vilnius – Kaunas, but the study considers only long distance passenger traffic and freight traffic. The level of detail regarding the railway alignment and location of passenger stations are as shown on Figure 5 above.

The reports made available including

- Rail Baltica Global Project Cost-Benefit Analysis, Executive summary, 24 April 2017 (Document 4.1),
- Rail Baltica Global Project Cost-Benefit Analysis, Final Report, 30 April 2017 (Document 4.2)

as well as appendices do not show and address further details of alignment and do not address other passenger stations than the long distance passenger stations shown in Figure 5 above.

1.3.2. Assessment of potential regional passenger stations (WP1.3)

1.3.2.1. Introduction

None of the earlier studies and the 2017 CBA considers regional passenger service as part of Rail Baltica. Thus, there is no starting point for consolidating demand forecast for regional services based on these reports. An assessment of passenger demand for regional passenger services has been prepared as described below based on the information received for possible regional stations from the respective Transport ministries of Estonia, Latvia and Lithuania. The aim of this assessment in this first iteration is to check if the regional passenger stations are feasible from an economic (sufficient number of passengers) and technical (available slots and influence on overall Rail Baltica capacity) point of view.

Regional stations in and next to Helsinki are not available yet. 3 stations are indicated and shown in "FinEst Helsinki-Tallinn Transport Link Feasibility Study Final Report". The report state that number of stations in Helsinki will be studied later (see page 42 in the report).

The analysed stations as received from the Technical Working Group are shown in the following tables for the main alignment, Riga bypass and the section Vilnius – Kaunas. The tables are generated in the RailSys model and correspond to the track layout in 2018. The long distance passenger stations correspond to the stations considered in the EY Global Project CBA 2017.

Station no.	Station name	Station type
1	Tallinn	Long distance
2	Assaku	Regional
3	Luige	Regional
4	Saku	Regional
5	Kurtna	Regional
6	Kohila	Regional
7	Rapla	Regional
8	Järvakandi	Regional
9	Kaisma	Regional
10	Tootsi	Regional
11	Kilksama	Regional
12	Pärnu	Long distance
13	Surju	Regional
14	Häädemeste	Regional
15	Salacgrīva	Regional
16	Skulte	Regional
17	Vangaži	Regional
18	Saurieši	Regional
19	Acone	Regional

Station no.	Station name	Station type
20	Slāvu tilts (Akropole)	Regional
21	Riga Central	Long distance
22	Torņakalns	Regional
23	Imanta	Regional
24	Riga airport (RIX)	Long distance
25	Janunmārupe	Regional
26	Olaine	Regional
27	Ķekava	Regional
28	Iecava	Regional
29	Bauska	Regional
30	Joniškelis	Regional
31	Panevėžys	Long distance
32	Kedainiai	Regional
33	Jonava	Regional
34	Palemonas	Regional
35	Kaunas main station	Long distance
36	Kazlų Rūda	Regional
37	Marijampolė	Regional
38	Šeštokai	Regional

Table 13: Passenger station at the main line

Station no.	Station name	Station type
101	Salaspils	Regional
102	Baldone	Regional

Table 14: Passenger station at Riga bypass

Station no.	Station name	Station type
201	Kaišiadorys	Regional
202	Vievis	Regional
203	Lentvaris	Regional
204	Vilnius	Long distance

Table 15: Passenger station on the section Vilnius – Kaunas

The locations of stations and the alignment of the new Rail Baltica railway were not finally fixed as a starting point for this Operational Plan study. Options were discussed i.e. at the Technical Workshop in Vilnius 2^{nd} – 3^{rd} of May

2018. New information has been made available to the consultants also after that meeting, i.e. for the section Kaunas – Vilnius and Vilnius – LT/PL border. No information has been received for the Polish sections[14].

There is an obvious dilemma if Rail Baltica is to be utilised for regional passenger traffic as well as for long distance high speed traffic (and freight traffic) looking at the suggested and planned location of stations along the corridor. For being attractive for regional passenger traffic the stations shall preferably be located in centre of the regional cities next to residences, next to activities and next to existing public railway and bus service. On the other hand, it is not attractive with long distance high speed train passing through the centre of the regional cities next to residences and activities with a speed of up to 249 km/h regarding the required alignment and the resulting noise emissions.

Rail Baltica alignment and location of stations are optimised to serve long distance high speed trains. In general, the alignment bypasses regional cities and proposed regional stations are located several km away from residential areas needed for generating traffic and activities attracting traffic. See examples below on Figure 13, Figure 14 and Figure 15. All figures include an overview map to the left and more detailed maps to the right.

Station location as shown on the figures are typical looking optimal for long distance and high speed train serving long distance passenger trips, but not optimal for serving shorter regional passenger trips. The long distances from the stations to centres of regional cities is not attractive for regional passenger adding access and egress time to the travel time making it difficult to compete with car traffic and other public transport modes (i.e. regional bus transport).

[14] There are several upgrade options analysed in Poland mainly as modernisation of the existing lines. However the location of several stations could change after modernisation.

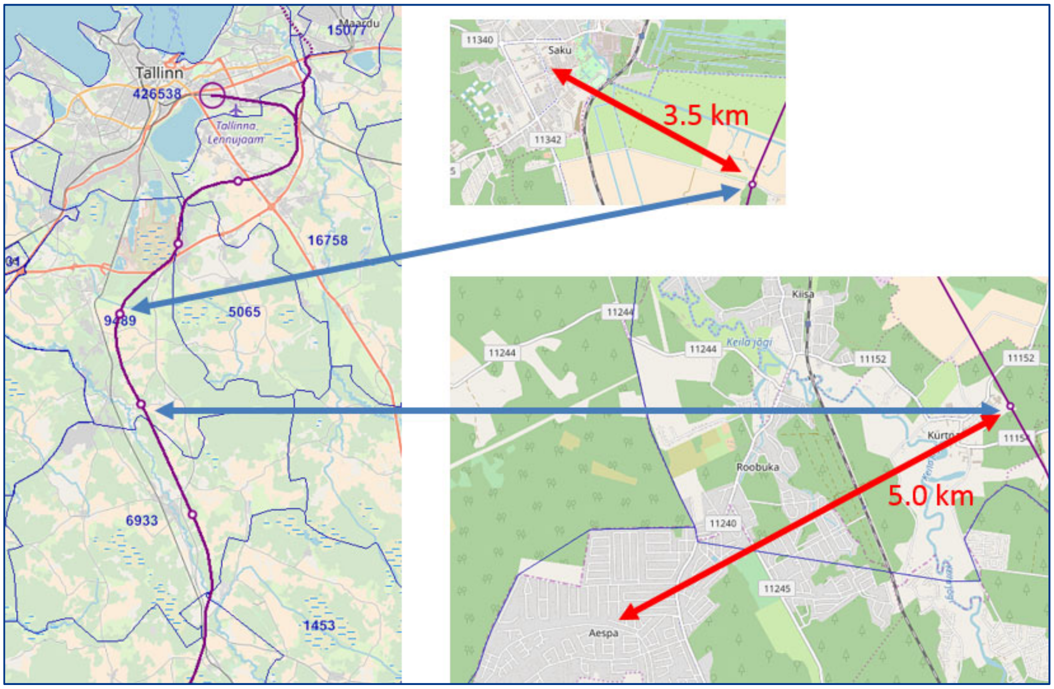


Figure 13: Location of Saku and Kurtna stations in Estonia

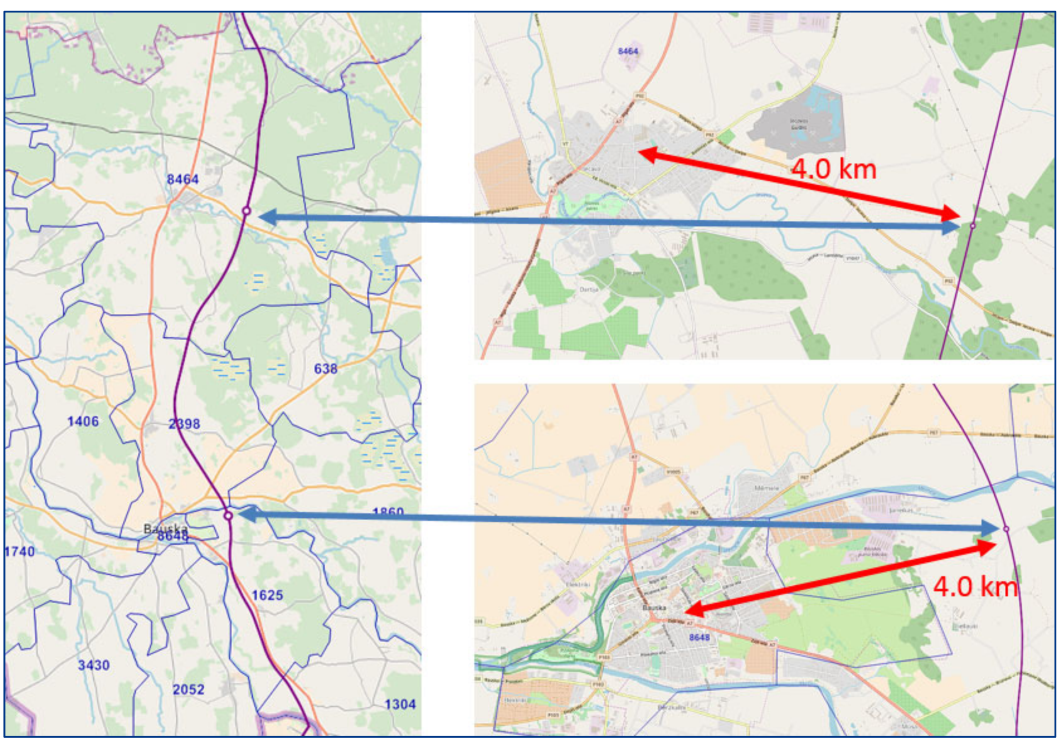


Figure 14: Location of Iecava and Bauska stations in Latvia

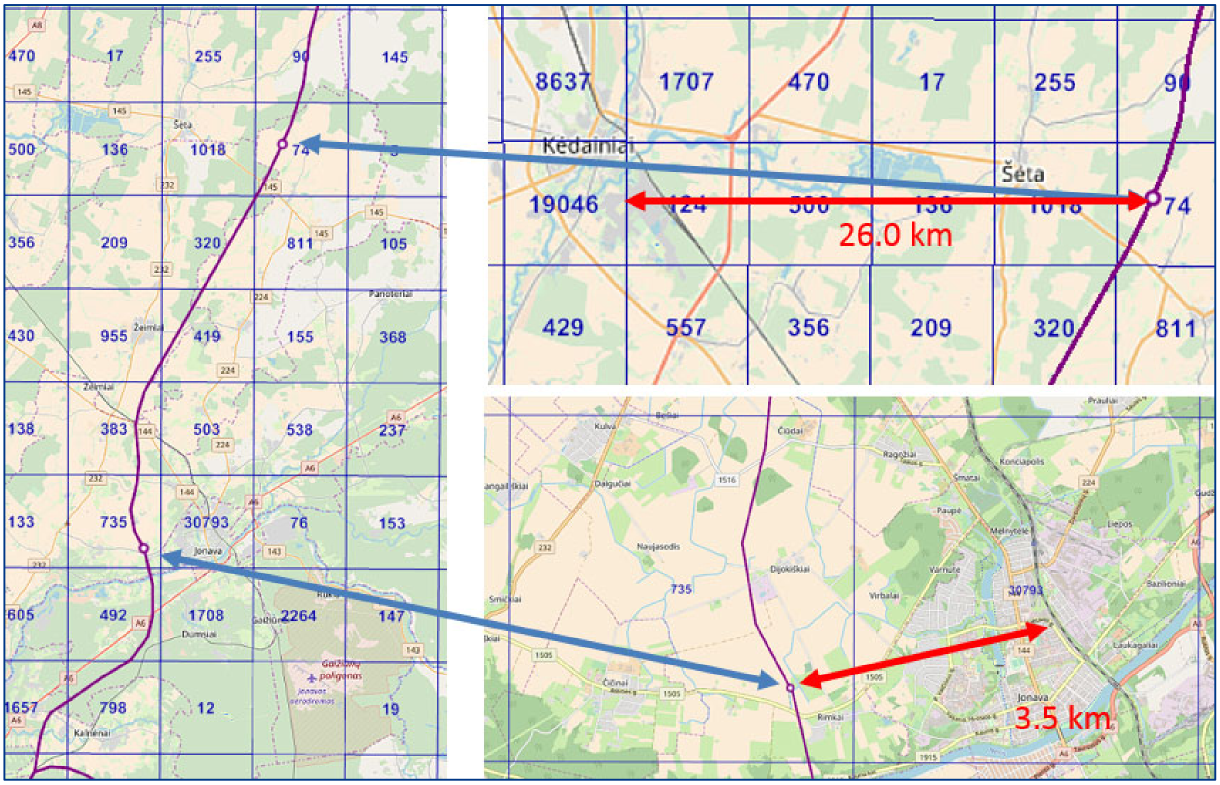


Figure 15: Location of Kedainiai and Jonava stations in Lithuania

Estimation of passenger demand on each of the regional stations is a complex task depending on future population and development activities next to the stations, information on planned supporting public transport to get to and from the stations, information of alternative public transport with 1520 mm gauge network, regional bus services and information of the optional mode and route to utilise the car. Detailed modelling and estimation of future passenger demand is outside the scope of the Operational Plan. An indicative assessment of potential trip generation for each of the regional stations has been made as described below.

The potential trip generation is assessed on basis of current population in catchment areas around the regional stations, multiplying population with assumed trip rates for train passenger trips depending of distance between residence and station.

Train transport becomes less attractive than e.g. the car if a long distance to the train station has to be taken into account. There are several studies how trip rates for railway passengers decrease depending on distance to stations. See an example from Sørlandet region in Norway in Table 16 below[15].

The study is based on information of 144,626 train passenger trips and distance from the residence (from origin of the trip) to the train station. See distances and no. of passenger trips in column 1 and 2. See also the corresponding total population and trip rate (train trips/population) in column 5 and 6. See the estimated modal split (train trips/total trips) in the last column (column 8).

Car traffic is the dominating mode hard to compete with when it comes to regional trips. Students are often a surprisingly high share of train passengers and of other public transport passengers.

1	2	3	4	5	6	7	8
Distance from residence to station	Passenger trips pr. working day	%	Aggregate	Population	Railway passenger trip rate (trips/population)	Weight	Modal Split (train trips/all modes)
< 500 m	26,673	18%	18%	162,294	0.1643	1.00	8%
0.5 - 1 km	39,549	27%	45%	373,384	0.1059	0.64	5%
1 - 2.5 km	50,064	35%	80%	819,383	0.0611	0.37	3%
2.5 - 5 km	18,269	13%	93%	480,534	0.0380	0.23	2%
5 - 10 km	7,299	5%	98%	256,245	0.0285	0.17	1.4%
10 - 25 km	2,772	2%	100%	203,032	0.0137	0.08	0.7%
Total	144,626	100%		2,294,872	0.0630		3%

Table 16: Trip rates (train passenger trips/population) as registered in regional train traffic in Norway16

Danish experience shows the same as illustrated in Figure 17. The Danish figures distinguish between the capital area (green columns) with dense train network and high frequencies and high share of train passengers, and rural areas (red columns) with low share of train passengers.

[15] Sørlandet is a rural area in Southern Norway with a low population density (comparable to Zemgale in LV)
[16] Consultants estimate based on a study of regional train passengers in Sørlandet in Norway.

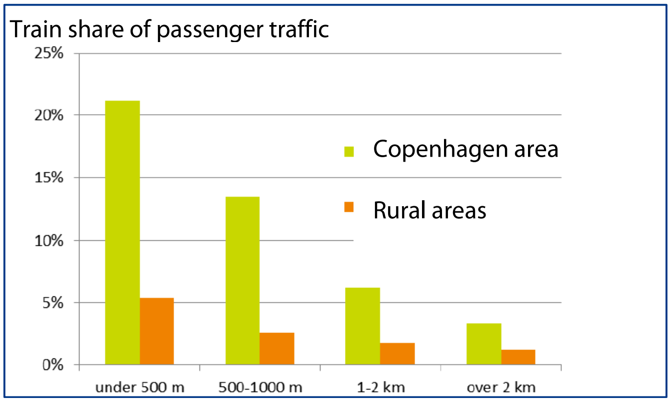


Figure 16: Train share depending of distance to train station17

The potential trip generation is assessed for each of the proposed Rail Baltic regional stations multiplying population in the catchment area with the trips rates in Table 16.

Other parameters do influence the number of passenger trips, but the simple assessment of potential trip generation does give an indication of the potential. These simple assessments are at least useful if to rank stations assuming other parameters as e.g. train frequencies are equal.

The unit of trip generation is trips per working day. Trip rates are based on the situation in regional traffic in Norway and might turn out to be different in Rail Baltica regional traffic depending on e.g. frequencies. Trip rates applied are based on average train frequencies as in regional traffic in Norway in the range of 20-50 departures a day. The uncertainty of absolute trip generation figures is higher than the uncertainty on relative trip generation figures. The level of detail of available data differs for each of the Baltic countries.

Thus it is recommended to initiate detailed studies of regional railway traffic demand and operational plans in Estonia, Latvia and Lithuania in cooperation with the Railway Authorities and Transport Ministries in each of the 3 countries to address the potential regional passenger traffic along Rail Baltica in more detail. These studies should be elaborated in close coordination with the overall traffic studies on national and regional level (Comp. 1.2.1.4) and should have a special focus on the regional development (including new origins and destinations) and the multimodal integration of the planned stops.

[17] Source: Trafikplan for den statslige jernbane 2017-2032, Trafikstyrelsen, 27. november 2017

1.3.2.2. Estonia

Detailed information of population distribution in Estonia has been received as seen in Figure 17 and has been utilised for the assessment of trip generation in Estonia as illustrated in Table 17. The potential total train trip generation is estimated to be up to 400 trips per working day to and from stations in the outskirts of Tallinn down to Rapla and considerably less to and from stations south of Rapla. It is assumed that the present 1520 mm gauge train service will continue in the future on the section Tallinn – Rapla (-Viljandi[18]) and reduce demand on the Rail Baltic standards gauge more or less. The 1520 mm service is assumed to be more attractive for passengers between Tallinn and the stations on the section Saku to Rapla due to its closer proximity of the stations to the relevant potential. Thus the assumed trips via the standard gauge are reduced as shown in the last column assuming 25% of the passengers travel on the standard gauge and 75% on the 1520 mm gauge railway.

Station name	Population					Trip generation	
	0-500 m	0,5-1 km	1-2,5 km	2,5-5 km	5-10 km	Total	Standard gauge
Tallinn							Long-distance station
Assaku	108	71	3,024			207	207
Luige	214	732	1,014			176	176
Saku	3	0	4,756			286	71
Kurtna	92	284	686			87	22
Kohila	4	1,917	1,937			328	82
Rapla	20	310	3,749	3,472		401	100
Järvakandi	0	800	429	107		118	118
Kaisma	7	26	128	332		25	25
Tootsi	3	20	801	298		63	63
Kilksama	3	63	230	851		55	55
Pärnu				Long-distance station			
Surju	3	26	243	338	628	50	50
Häädemeeste	4	0	44	214	1,355	52	52
Total	461	2,333	2,575	2,143	1,983	1,848	1,021

Table 17: Assessment of regional passenger trips pr. working day to/from regional stations in Estonia

The on-going preparation of the Operational Plan does consider all stops in Table 17. Ideas as expressed on the TWG meeting in Tallinn and later how to improve service on the section Tallinn – Pärnu including a better integration between Rail Baltica and the existing 1520 mm line, e.g. in Rapla are still being discussed and might be considered later after finalisation of this study.

[18] No more 1520 mm train services are expected on the section Rapla – Lelle – Pärnu

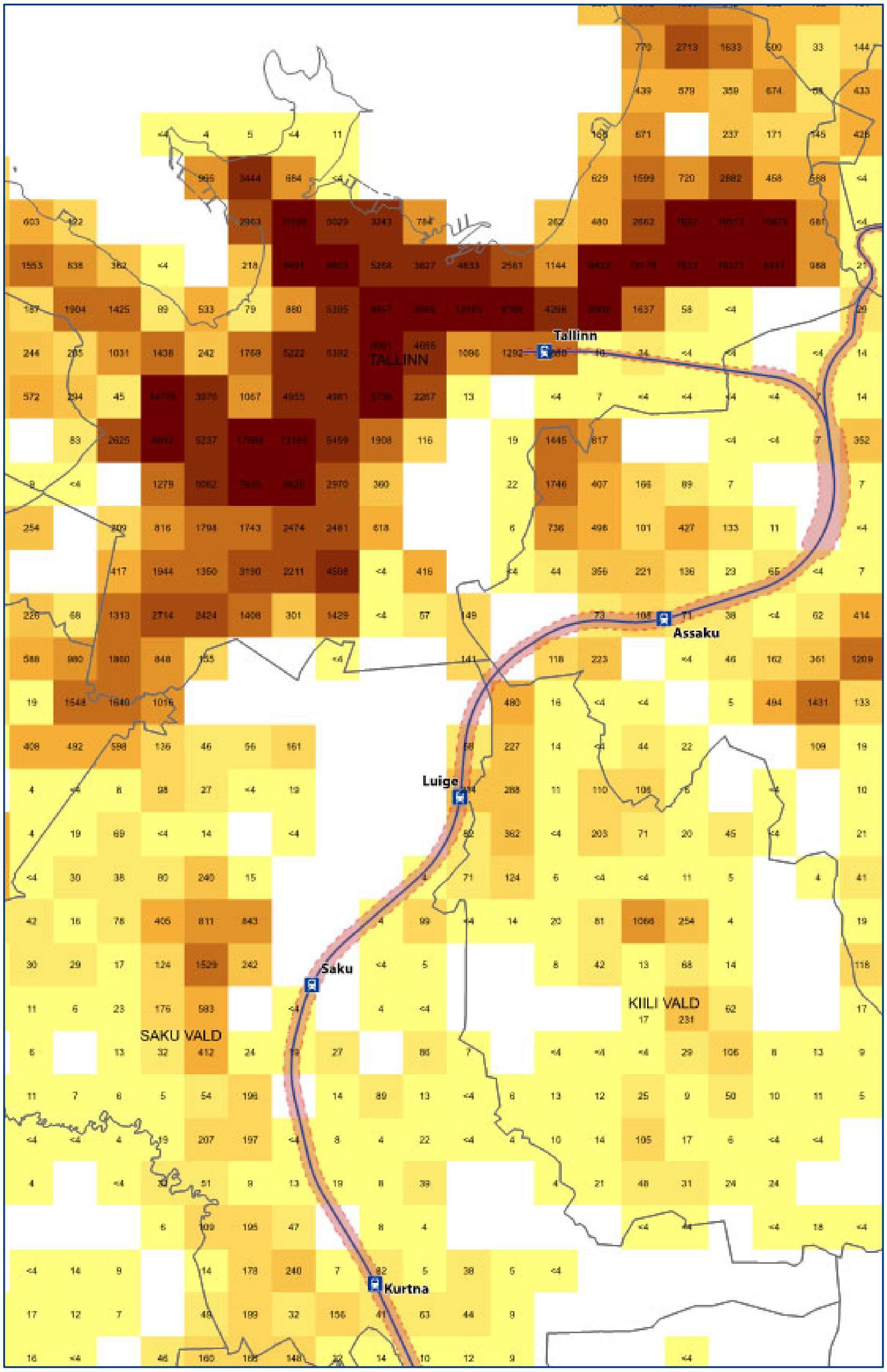


Figure 17: Part of detail population distribution in the Rail Baltic corridor in Estonia

1.3.2.3. Latvia

Trip generation for stations in Latvia has been assessed as show in Table 18 and Table 19. The level of detail of population is a starting point for administrative areas as shown to the left on Figure 14. Further break down of population are based on visual assessment of general maps as the one to the right on Figure 14. The uncertainty on the resulting trip generation is therefore considerable, but the results are valid enough to give an indication of the relative potential of each of the stations.

Total trip generation is the result of multiplying population with trip rates. Figures in the last column are reduced for e.g. stations in and next to Riga with other public transport modes providing direct competing services to many destinations in Riga, mainly 1520 mm railway services but also bus services. The uncertainty of population figures and trip generation are high, as no detailed information is available of population and alternative public transport in Riga for 2026 - 2056. Skulte station has a minor trip generation, but Skulte could be attractive for passenger from the north of Riga interchanging to local public transport to and from other destinations in Riga. Torņakalns and Imanta are located in dense areas in Riga, for this reason trains to Riga Airport should also serve these stations.

It is recommended to do a more detailed study of potential regional traffic in cooperation with relevant authorities because of the deficiencies in the available studies. See conclusions in section 1.2.1.4 above.

	Population					Trip generation	
Station name	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Salacgrīva	200	200	1,000	1,500	2,000	234	234
Skulte	200	200	1,000	2,000	2,000	254	64
Vangaži	200	3,400	5,000	5,000	0	906	227
Saurieši	500	1,000	3,000	500	0	390	98
Acone	500	1,000	3,000	500	0	390	98
Akropole	1,000	2,000	6,000	1,000	0	780	195
Riga Central	Long-distance station with predominant trip attraction						
Torņakalns	20,000	20,000	60,000	0	0	9,000	2,250
Imanta	20,000	20,000	60,000	0	0	9,000	2,250
Riga Airport (RIX)	Long-distance station with predominant trip attraction						
Janunmārupe	500	1,000	5,000	3,500	0	630	158
Olaine	1,000	1,000	3,000	5,000	10,000	950	238
Ķekava	100	200	1,700	5,000	5,000	490	123
Iecava	100	400	1,000	6,000	2,500	435	435
Bauska	100	400	1,000	6,000	2,500	435	435
Total	2,442	1,449	151	1,035	24	5,912	2,310

Table 18: Initial assessment of regional passenger trips to/from regional stations on the main line in Latvia

Station name	Population					Trip generation	
	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Salaspils	100	100	1,000	18,000	10,000	1,107	277
Baldone	100	100	500	4,000	2,000	277	69
Total	200	200	1,500	22,000	12,000	1,384	346

Table 19: Assessment of regional passenger trips to/from regional stations on the Riga bypass

1.3.2.4. Lithuania

Trip generation for stations in Lithuania has been assessed as show in Table 20, Table 22 and Table 23. The 5x5 km grids as shown to the left on Figure 15 are the starting point for the level of detailisation for population data. Further break down of population are based on visual assessment of general maps as the one to the right on Figure 15. The uncertainty on the resulting trip generation is therefore considerable, but the results are valid enough to give an indication of the relative potential of each of the stations.

Station name	Population					Trip generation	
	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Joniskelis	100	500	1,500	500	500	196	196
Panevėžys	Long-distance station with predominant trip attraction						
Kedainiai	100	200	400	500	800	106	106
Jonava	100	200	2,000	12,000	20,000	1,238	1,238
Kaunas Airport (KUN)						800	0
Palemonas	200	400	600	10,000	10,000	812	812
Kaunas	Long-distance station with predominant trip attraction						
Kazlu Rūda	500	2,000	5,000	1,000	1,000	670	670
Marijampolė	2,000	3,000	20,000	20,000	1,000	2,680	2,500
Šeštokai	400	400	400	1,000	2,000	232	232
Total	3,500	6,900	30,900	49,000	85,300	7,692	7,692

Table 20: Assessment of regional passenger trips to/from regional stations on the main line in Lithuania

Kaunas International Airport Station is added to the design (to the track layout) as a regional station in a late phase of the operational plan project. The total number of air passengers to and from Kaunas International Airport was 1.18 million in 2017 according to EusoStat. The 1.18 million correspond to 3,200 in average per day. 25% of the air passengers corresponding to 800 trips per day are assume to use the railway to and from the airport[19].

[19] According to the 2nd iteration travel times with RE from Kaunas to KUN will be 12 minutes and from Vilnius to KUN 40 minutes. The potential travel time of non-stop HST between Vilnius and KUN is approx.30 minutes.

Population figures and resulting trip generation for Marijampolė – the biggest city along the alignment without a long-distance stop – have been questioned in the TWG meeting in Tallinn on 13 June 2018. The argument was that the real population in Marijampolė is less than stated in Table 20. Population in Marijampolė has therefore been re-estimated on basis of 500*500 m and 1*1 km grids (see part of the 500*500 m grid on Figure 18 and the re-estimated population and trip generation in Table 21). The result was that the re-estimated population and trip generation is a bit higher than in the first assessment, but overall in the same range. The re-estimated population will be used for the Operational Plan (WP 4).

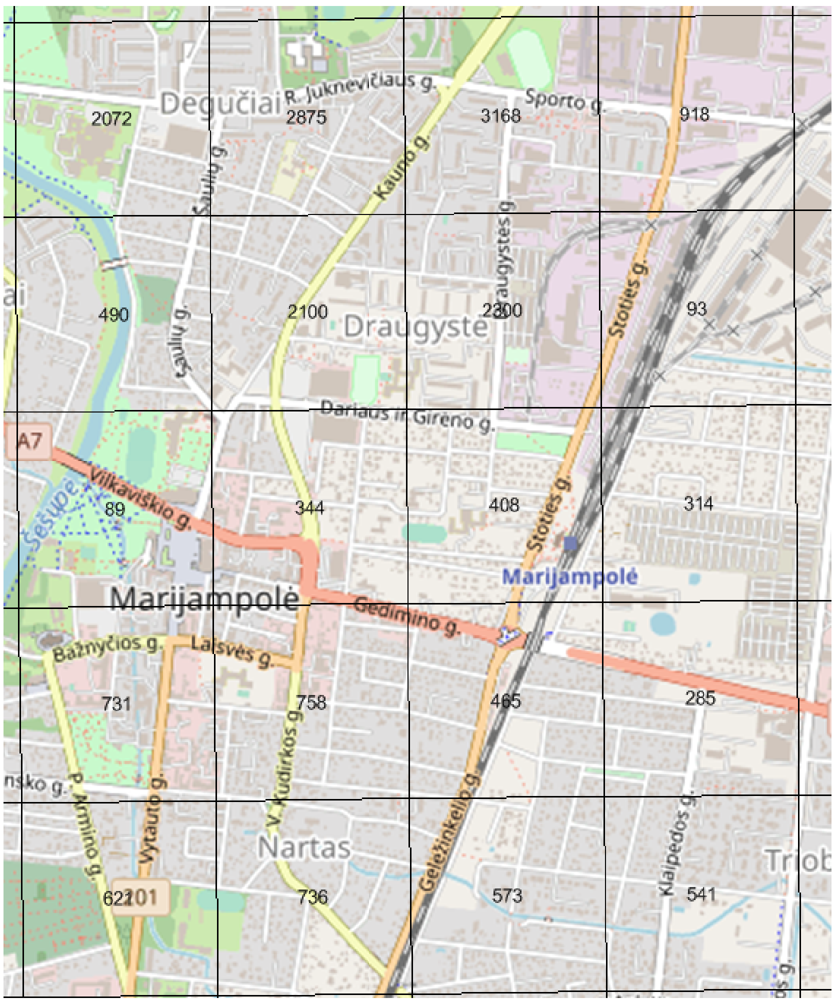


Figure 18: Population in central Marijampolė 500*500 meter grids (Source: Statistic Lithuania)

Station name	Population					Trip generation	
	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Marijampolė	1,500	8,200	30,600	4,800	3,800	3,280	3,000

Table 21: Re-estimated population and trip generation in Marijampolė (Source: Consultants estimate)

Several options regarding the regional stations are still considered on the section Vilnius – Kaunas as illustrated in Figure 19. Trip generation in Table 22 corresponds to an option with locations of the 3 stations outside the regional cities on a direct high speed track bypassing the 3 regional cities.

Trip generation in Table 23 correspond to an option with high speed train bypassing the cities and separate regional tracks alignments passing the centre of the 3 cities and regional stations in the centre of the 3 regional cities. Due to the location of the stations closer to the city centres and urban activities in the second option the trip generation is significantly higher.

In conclusion there is a high potential and market for regional public transport next to Vilnius and Kaunas. The proposed red and blue alignments and station locations does not serve all major regional cities in the area and it is not possible to serve all major regional cities with a single railway line. It is recommended to do a more detailed study of potential regional traffic in cooperation with relevant authorities because of the deficiencies in the available studies also considering the possibilities to maintain the 1520 mm service and other public transport modes. See conclusions in section 1.2.1.4 above.

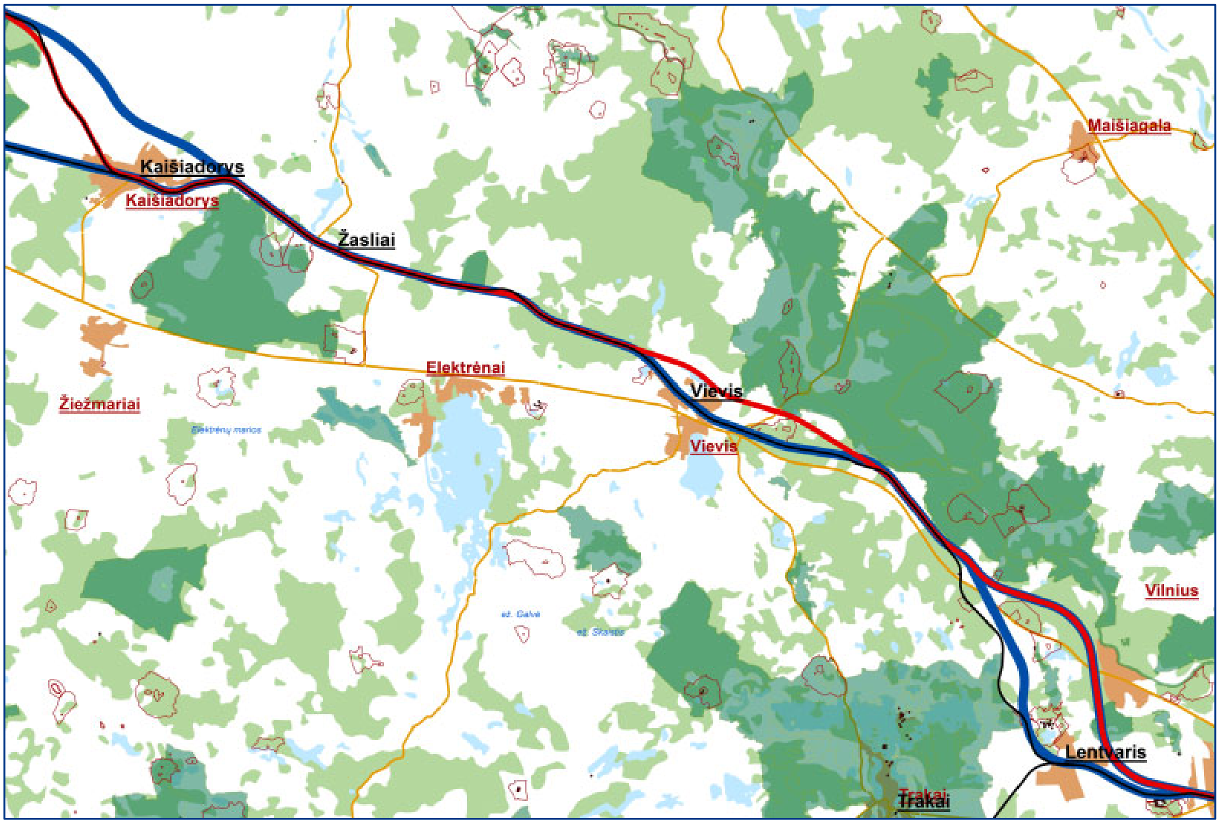


Figure 19: Optional alignments and location of stations on the section Vilnius – Kaunas

Station name	Population					Trip generation	
	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Kaišiadorys	1,000	3,000	5,000	5,000	5,000	1,140	800
Vievis	100	200	2,500	4,500	5,000	518	518
Lentvaris	1,000	1,000	2,000	20,000	10,000	1,490	1,490
Total	2,100	4,200	9,500	29,500	20,000	3,148	3,148

Table 22: Regional passenger trip generation on the section Vilnius – Kaunas (red alignment)

Station name	Population					Trip generation	
	0-500 m	0.5-1 km	1-2.5 km	2.5-5 km	5-10 km	Total	Standard gauge
Kaišiadorys	4,000	4,000	4,000	3,000	4,000	1,560	1,560
Vievis	2,500	3,000	3,000	2,000	2,000	1,050	1,050
Lentvaris	2,000	10,000	2,000	10,000	10,000	2,240	2,240
Total	8,500	17,000	9,000	15,000	16,000	4,850	4,850

Table 23: Regional passenger trip generation on the section Vilnius – Kaunas (blue alignment)

1.3.3. Consolidated demand forecast for regional passenger traffic (WP 1.3)

The above assessment of the trip generation of potential regional passenger stations has been translated into an indicative trip load for the sections of Rail Baltica as seen in the following tables. Regional trips are mainly working day trips including home to work trips, home to education trips and trips for buying goods for the household. Primary attraction points are therefore assumed to be Tallinn, Riga, Kaunas and Vilnius.

Trip generation and trip loads are indicative as described above, because the earlier Rail Baltica studies do not address regional traffic and do not provide a basis for consolidation. The uncertainties are especially high for local traffic in and around Riga, Kaunas and Vilnius because of considerable other public transport offers as well as the overall train offer and pricing on Rail Baltica. Thus, the following tables are starting point for the future determination of demand for regional passenger trains to be updated in the following Rail Baltica project phase after determining i.e. the final location and realisation of the stations, train offer at the according stations, integration with other transport modes, pricing, etc.

The demand forecast for the regional passenger traffic in the following tables correspond to a traffic offer with two departures per hour in the morning and afternoon peak hours, without traffic offer in the night time and with one departure per hour in the rest of the day and evening.

Passenger traffic demand depends of the traffic offer. Elasticities observed around Europe vary in the range between -1.0 and -3.5. An elasticity of -3.5 means that if the generalised transport cost is reduced by 1% the transport demand increases by 3.5%.

Generalised transport costs are defined as a function of in-vehicle time, waiting time (frequencies), direct transport cost (ticked price) etc. Short trips as e.g. local trips in Riga does therefore depend very much of frequency. Longer regional trips, as e.g. trips between Pärnu and Riga depend less of frequency. Optimal and minimum train frequencies do therefore depend of passenger trip lengths. The minimum train frequency to effectively attract passengers into regional trains is considered to correspond to one train departure every second hour all day along the corridor including evening hours. A reasonable transport offer outside peak periods is important to offer a reasonable service for one day passenger trips where the time of the return trip can be difficult to foresee and where long waiting time for the return trip often are annoying adding very much perceived travel time and generalised travel costs.

Section		2026	2036	2046	2056
Tallinn	Assaku	900	2,100	2,250	2,400
Assaku	Luige	750	1,650	1,800	1,800
Luige	Saku	450	1,200	1,350	1,350
Saku	Kurtna	450	1,050	1,050	1,200
Kurtna	Kohila	450	1,050	1,050	1,050
Kohila	Rapla	300	750	900	900
Rapla	Järvakandi	300	600	600	600
Järvakandi	Kaisma	150	450	450	450
Kaisma	Tootsi	150	450	450	450
Tootsi	Kliksama	300	600	600	600
Kliksama	Pärnu	300	600	750	750

Table 24: Indicative 2-way daily regional passengers on regional trains section Tallinn – Pämu (AAWDT)

Section		2026	2036	2046	2056
Pärnu	Surju	200	500	500	500
Surju	Häädemeste	200	300	300	300
Häädemeste	Salacgrīva	200	300	300	300
Salacgrīva	Skulte	300	800	900	900
Skulte	Vangaži	500	1,100	1,100	1,100
Vangaži	Saurieši	600	1,500	1,700	1,700
Saurieši	Acone	800	1,800	2,000	2,000
Acone	Slāvu tilts	900	2,100	2,300	2,300
Slāvu tilts	Riga Central	1,100	2,600	2,700	2,900

Table 25: Indicative 2-way daily regional passengers on regional trains section Pämu – Riga (AAWDT)

Section		2026	2036	2046	2056
Riga Central	Torņakalns	2,400	5,600	5,900	6,200
Torņakalns	Imanta	1,800	4,200	4,500	4,700
Imanta	Riga airport	1,100	2,600	2,700	2,900
Riga airport	Janunmārupe	1,700	4,000	4,200	4,400
Janunmārupe	Olaine	1,600	3,800	4,000	4,200
Olaine	Ķekava	1,100	2,600	2,700	2,900
Ķekava	Iecava	1,100	2,500	2,600	2,800
Iecava	Bauska	900	2,100	2,300	2,400
Bauska	Joniskelis	500	1,300	1,300	1,400
Joniskelis	Panevėžys	600	1,400	1,500	1,500

Table 26: Indicative 2-way daily regional passengers on regional trains section Riga – Panevėžys (AAWDT)

Section		2026	2036	2046	2056
Riga Central	Salaspils	200	400	500	500
Salaspils	Baldone	100	200	200	200
Baldone	Riga Central	100	300	300	300

Table 27: Indicative 2-way daily regional passengers on regional trains Riga bypass and a Riga loop (AAWDT)

Section		2026	2036	2046	2056
Panevėžys	Kedainiai	800	1,800	1,900	2,000
Kedainiai	Jonava	700	1,700	1,800	1,900
Jonava	Palemonas	1,100	2,700	2,800	3,000
Palemonas	Kaunas main s	1,500	3,600	3,900	4,100
Kaunas main	Kazlų Rūda	2,500	5,800	6,200	6,500
Kazlų Rūda	Marijampolė	2,500	5,800	6,200	6,500
Marijampolė	LT/PL border	400	1,000	1,100	1,200

Table 28: Indicative 2-way daily regional passengers on regional trains section Panevėžys – Kaunas – LT/PL border (AAWDT)

Section		2026	2036	2046	2056
Kaunas	Kaišiadorys	1,000	2,400	2,500	2,700
Kaišiadorys	Vievis	800	1,900	2,000	2,200
Vievis	Lentvaris	900	2,100	2,300	2,400
Lentvaris	Vilnius	1,700	3,900	4,200	4,400
Vilnius	Vilnius Airport	1,500	3,000	3,300	3,500

Table 29: Indicative 2-way daily regional passengers on regional trains section Vilnius – Kaunas (AAWDT)

Vilnius International Airport Station is added to the track layout as a regional station. The total number of air passengers to and from Vilnius International Airport was 3.76 million in 2017 according to EusoStat. The 3.76 million correspond to 10,000 in average per day. 25% of air passengers corresponding to 2,500 trips per day are assume to use the railway to and from the airport in 2017 level corresponding to 3,000 in 2026.

The indicative passenger forecasts in Lithuania in Table 28 and Table 29 do assume the existing 1520 mm service parallel to the proposed new Rail Baltic 1435 mm service will stop if and when the Rail Baltic regional passenger service starts. In the Design Parameters Workshop on 2nd – 3rd of May 2018 in Vilnius a continuation of regional passenger services on the 1520 mm line has been discussed but without a clear definition of the future service pattern. In the sensitivity analyses the following assumptions for the 1520mm services have been made:

- Only limited number of 1520 mm service south of Kaunas
- 16 train pairs (hourly service) between Kaunas and Vilnius on the 1520mm line with stops at all stations with a travel time of 1:30. Regional trains on the 1435 mm line will stop only KUN airport, Kaišiadorys, Vievis and Lentvaris with a travel time between Kaunas and Vilnius of less than 1:00.

Section		2026	2036	2046	2056
Panevėžys	Kedainiai	700	1,800	1,900	2,000
Kedainiai	Jonava	700	1,700	1,800	1,900
Jonava	Palemonas	1,100	2,700	2,800	3,000
Palemonas	Kaunas main s	1,500	3,600	3,800	4,000
Kaunas main	Kazlų Rūda	2,400	5,700	6,100	6,400
Kazlų Rūda	Marijampole	2,400	5,700	6,100	6,400
Marijampole	LT/PL border	1,000	2,500	2,600	2,800

Table 30: Indicative 2-way daily regional passengers on regional trains section Panevėžys – Kaunas – LT/PL border assuming no 1520 service in the corridor (AAWDT)

Section		2026	2036	2046	2056
Kaunas	Kaišiadorys	500	1,600	1,700	1,800
Kaišiadorys	Vievis	400	1,300	1,300	1,500
Vievis	Lentvaris	450	1,400	1,500	1,600
Lentvaris	Vilnius	850	2,600	2,800	2,900

Table 31: Indicative 2-way daily regional passengers on the section Vilnius – Kaunas on regional trains assuming hourly 1520 service in the future serving local stations (AAWDT)

1.4. Integration with 1520 mm railway network and other modes – Panevėžys example

As described above the actual passenger demand will depend not only of the future spatial structure around the planned long-distance and regional passenger stations and the realised transport offer on Rail Baltica and its tariffs but also on the integration with the existing 1520mm railway network and other public and individual transport modes. In the following elaborations for Panevėžys, exemplary solutions with the existing and planning transport network are demonstrated.

1.4.1. Currently planned location of Panevėžys station

The currently planned Rail Baltica station is located approx. 10 km west of Panevėžys centre. At this planned location there is no existing transport infrastructure.

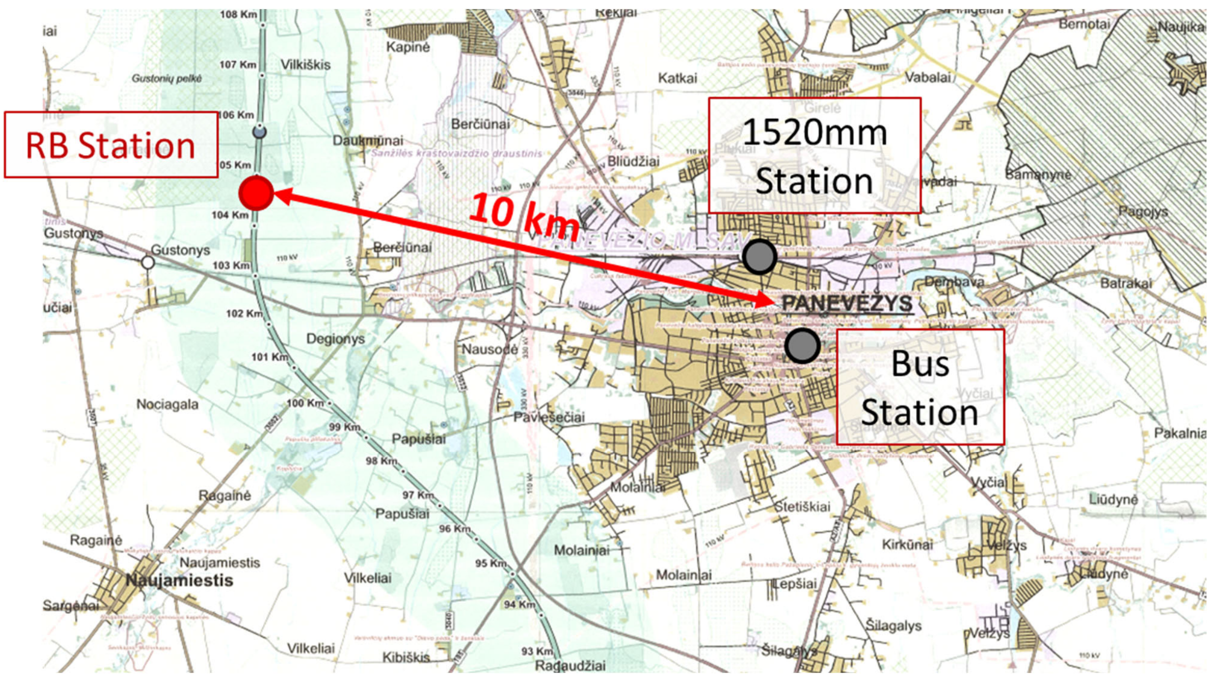


Figure 20: Location of planned Panevėžys Rail Baltica station

New transportation infrastructure with additional investment costs has to be developed for public transportation as well as car and (e-) bicycle users to connect Rail Baltica station with the city centre and other origins and destinations.

Taking into account the transportation network structure the distance between the planned Rail Baltica station and the urban centre is about 15 km as shown in the following figures:

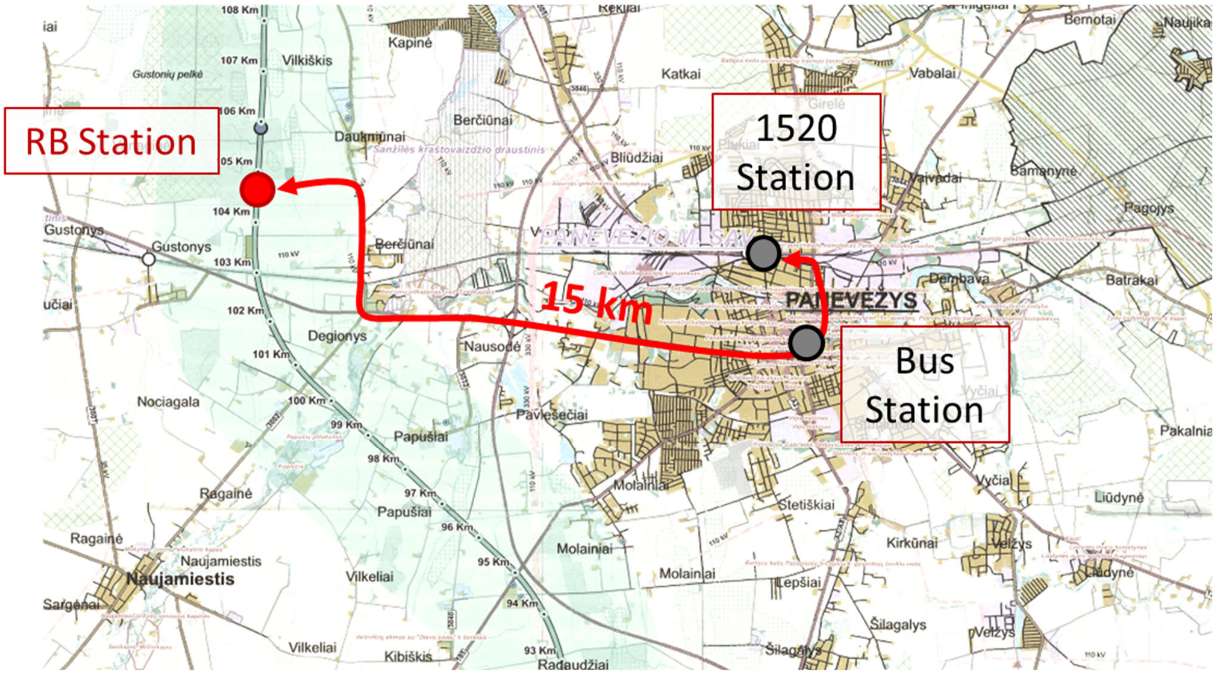


Figure 21: Location of planned Panevėžys Rail Baltica station and road network distance to city centre.

To connect the planned Rail Baltica station with the city centre additional public transportation has to be offered. This will require additional public sources for the operation of these shuttle services.

The additional travel time between the city centre and the planned Rail Baltica station (incl. transfer time) of approx.

- 20 - 30 minutes by bus/car,
- 30 - 60 minutes by (e-)bike

will make door-to-door travel times unattractive, especially on the relation Vilnius – Panevėžys:

- Rail Baltica: 1:30 – 2:00,
- Car: 1:40.

In order to reduce door-to-door travel times and to make Rail Baltica more competitive a better integration with the city centre is required. The following examples show possible solutions to be further analysed in the following planning phases.

A better integration with the city centre should consider the existing 1520mm railway network being an essential part of possible solutions as it is located not only in the city centre but also only 1.5 km south of the planned Rail Baltica station:

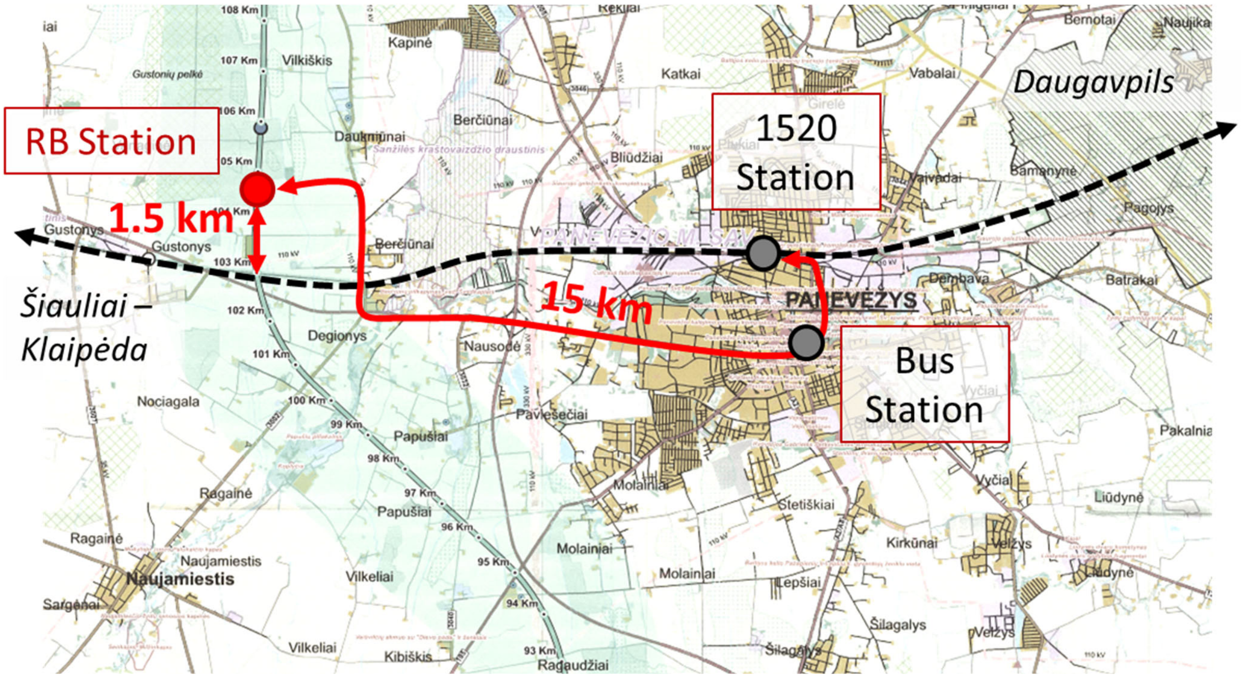


Figure 22: Existing 1520mm railway line Šiauliai – Panevėžys – Daugavpils in Panevėžys area

Taking into consideration the spatial and transportation structure in Panevėžys area as well as international benchmarks (e.g. the additional railway connection to Avignon TGV station in France) there are four major solutions for a better integration:

A) Additional railway connection (1435 or 1520mm)between Rail Baltica station and Panevėžys centre;

B) Tower station on top of the existing 1520mm line;

C) Change Rail Baltica alignment closer to the city centre;

D) Additional 1435mm connection to Panevėžys centre.

1.4.1.1. Additional railway connection to Panevėžys centre

To reduce door-to-door travel time a railway shuttle could be operated on an additional railway line between the existing 1520mm railway station in the city centre and the planned Rail Baltica station. The railway infrastructure could be both realised as 1435 mm or 1520mm where the 1520mm solution would require less additional infrastructure and thus less investment costs.

Figure 23: Additional railway connection to Panevėžys centre

The major pros and cons of this solution are shown in the following table:

PROS	CONS
▪ Shorter travel times compared to a bus shuttle due to faster and more reliable railway shuttle and shorter transfer times in Rail Baltica station (Vilnius – Panevėžys approx. 25 min faster).	▪ Additional railway infrastructure (CAPEX) required (but less road infrastructure) ▪ Additional OPEX for operation of the railway shuttle. ▪ No direct connection to Šiauliai – Daugavpils railway line.

Table 32: Pros and cons of an additional railway connection to Panevėžys centre

1.4.1.2. Tower station on top of the existing 1520mm line

To reduce door-to-door travel time the planned Rail Baltica station could be moved apporx. 1.5 km to the south on top of the existing 1520mm railway line Šiauliai – Daugavpils where additional platforms in a tower station could enable direct transfers.

Figure 24: Panevėžys tower station 1435/1520mm

The major pros and cons of this solution are shown in the following table:

PROS	CONS
▪ Shorter travel times compared to a bus shuttle due to short transfer times in the tower station and short travel times on the existing 1520mm line to/from the city centre. (Vilnius – Panevėžys approx. 30 min faster). ▪ Direct connection to Šiauliai – Daugavpils railway line (no isolated shuttle required). ▪ Less road infrastructure required.	▪ Additional complex infrastructure for the tower station (CAPEX) required (but less road infra-structure).

Table 33: Pros and cons of a tower station on top of the existing 1520mm line

1.4.1.3. Change Rail Baltica alignment closer to the city centre

Shorter door-to-door travel times could be also realised by shifting Rail Baltica alignment eastwards closer to the city centre with a 1435mm station either on top of the existing 1520mm railway line Šiauliai – Daugavpils or the A9 highway.

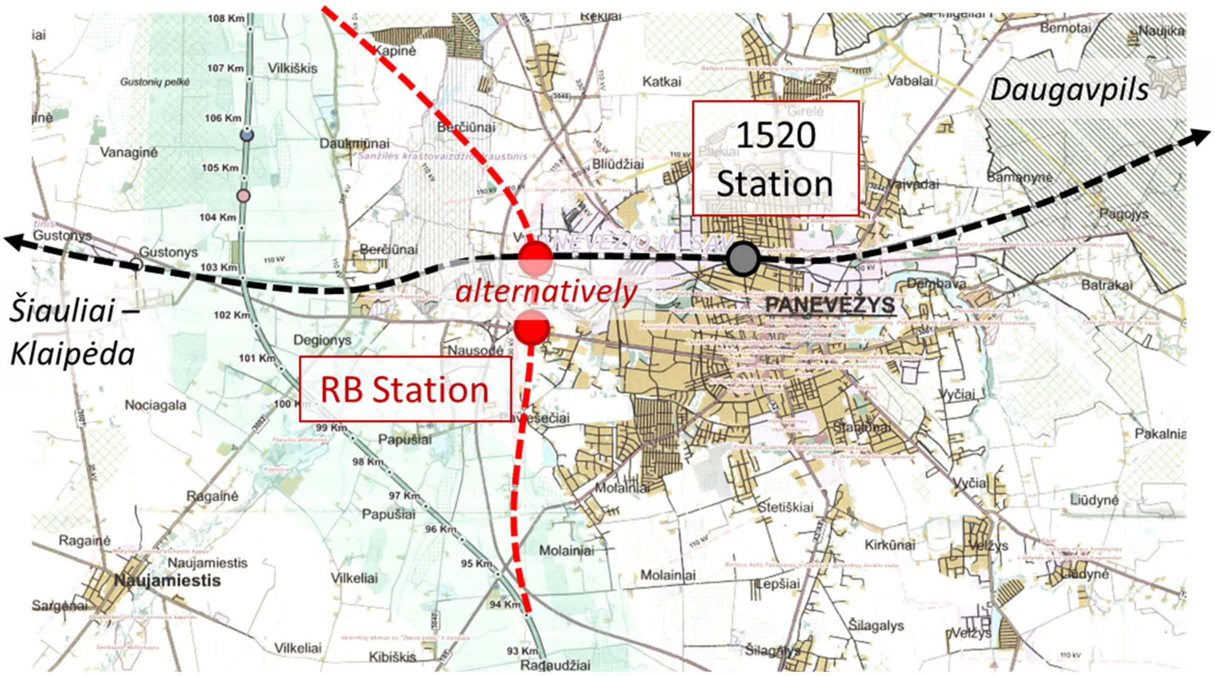


Figure 25: Rail Baltica alignment closer to the city centre

The major pros and cons of this solution are shown in the following table:

PROS	CONS
▪ Shorter travel times compared location outside then urban fabric. (Vilnius – Panevėžys 15 - 30 min faster depending of rail or road solution). ▪ The station could be much better integrated into urban structure and transportation system. ▪ Direct connection to Šiauliai – Daugavpils railway line if located on top of the 1520mm railway line.	▪ New alignment planning required. ▪ More people affected by noise emission and construction works.

Table 34: Pros and cons of Rail Baltica alignment closer to the city centre

1.4.1.4. Additional 1435mm connection to Panevėžys centre

Common solutions for new high-speed lines for cities of different sizes is a bypassing alignment and additional connection to the city centres, as e.g. in Le Mans, Lyon, Paris, Portiers or Tours in France, Toledo or Zaragoza in Spain or Coburg, Freiburg, Leipzig or Stendal in Germany. For Panevėžys such a solution could look like as follows where sprinter trains bypass the city non-stop and selected high-speed and all regional trains stop in the city centre:

Figure 26: Additional 1435mm connection to Panevėžys centre

The major pros and cons of this solution are shown in the following table:

PROS	CONS
▪ Shortest door-to-door travel times of all solutions (Vilnius – Panevėžys approx. 40 min faster). ▪ No isolated shuttle required. ▪ Direct connection to Šiauliai – Daugavpils railway line, gauge-changing possibility at Panevėžys station.	▪ Partly new alignment planning required. ▪ More people affected by noise emission and construction works.

Table 35: Pros and cons of additional 1435mm connection to Panevėžys centre

1.5. Freight Transport

1.5.1. Review of existing studies (WP1.2)

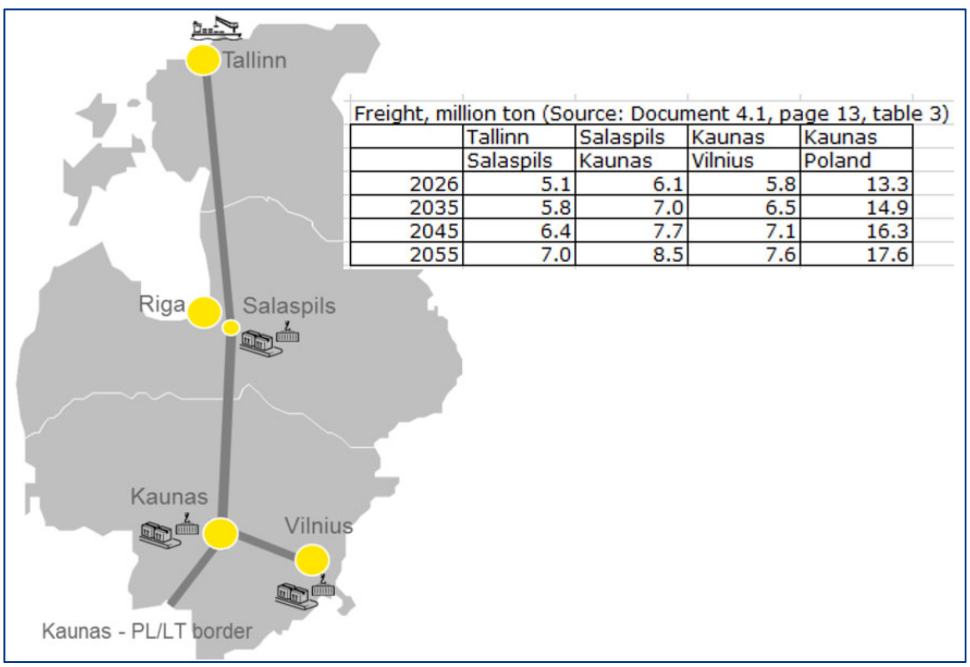
1.5.1.1. Global Project Cost-Benefit-Analysis (EY 2017)

The documents

- Rail Baltica Global Project Cost-Benefit Analysis, Executive summary, 24 April 2017 (Document 4.1)
- Rail Baltica Global Project Cost-Benefit Analysis, Final Report, 30 April 2017 (Document 4.2)

include freight forecasts, the description of methodology and assumptions how freight forecasts for future freight traffic has been prepared by EY. The Rail Baltica Global Project Cost-Benefit Analysis (the CBA) as prepared by EY and as documented in the two reports mentioned above is considered to be the main source for preparation of the Operational Plan of Rail Baltica. The freight forecasts and assumptions in the CBA are summarised below.

The freight service volume between Tallinn, Salaspils (Riga), Kaunas, Vilnius and Poland as forecasted in the base case in the CBA is shown in Figure 27.



Freight, million ton (Source: Document 4.1, page 13, table 3)

	Tallinn Salaspils	Salaspils Kaunas	Kaunas Vilnius	Kaunas Poland
2026	5.1	6.1	5.8	13.3
2035	5.8	7.0	6.5	14.9
2045	6.4	7.7	7.1	16.3
2055	7.0	8.5	7.6	17.6

Figure 27: Freight forecasts from CBA 2017 for the base case (million tonnes/year, both directions)

The overall forecasting principles for freight are the same as for the passenger traffic including the 4 steps described below. The fundamental difference is that the focus is on freight not on passengers, that origins and destinations differ, that transport modes differ, that costs are different etc. as addressed in more detail below:

- Step 1: Existing transport movement in 2015 between relevant origins and destinations by all existing modes (truck, train, ship etc.) collected from statistical databases as e.g. Eurostat
- Step 2: Forecast on basis of general expectation and historic trends (GDP forecasts and elasticities)
- Step 3: Forecast and redistribution (mode and route choice) on basis of estimated generalised future transport costs with Rail Baltica and with other mode of transport (truck, RB train, 1520 mm trains, ship etc.)
- Step 4: Reducing the forecast in the first years of operation as freight operators are assumed to adapt to the new possibility to use Rail Baltica gradually over a 7-year period (compared to passengers the freight industry is expected to adapt the new possibilities with a two years lag resulting in 7-year in total for the freight marked adaption period) The existing (2015) freight volumes (step 1) are an important input for the forecast model. The freight flows are not documented in the CBA in the same level of detail as the passenger flows addressing Rail Baltic main nodes. Freight transports potentially moving to Rail Baltica are long distance transport more difficult to illustrate as passenger transport. Existing freight transport potentially moving to Rail Baltica is a mix of truck transport, 1520 mm train transport and short sea shipping feeder services served by trucks and 1520 mm train transport as illustrated in Figure 28.

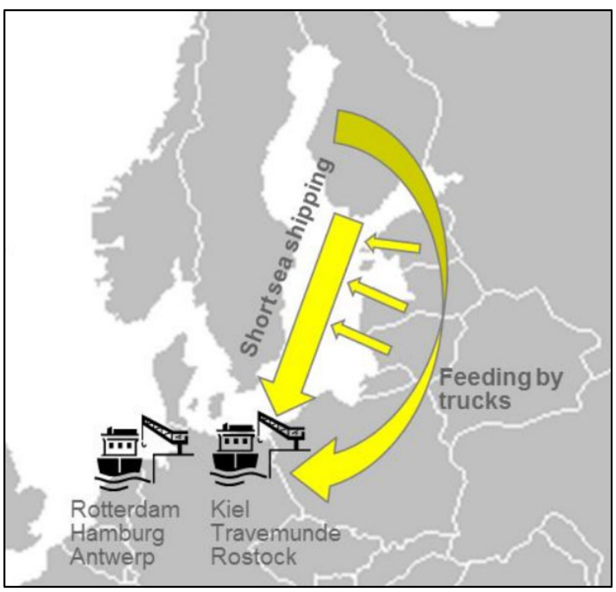


Figure 28: Existing freight flows in the region potentially attracted of Rail Baltica

Regarding Step 3 – mode and route choice – this is depending in the forecast model on the travel time and travel cost in a reference scenario corresponding to the existing situation and in a project scenario with Rail Baltica.

Regarding Step 4 – reducing the forecast in the first years – this is often assumed in transport forecasts for major transport infrastructure projects. The reason is that changes seldom occur from day to day. Change of route for passenger car traffic and truck traffic might occur more or less immediately when new improved roads and routes are available. Change of mode for freight traffic from e.g. sea shipping to railway shipping require major changes of logistic for the freight operator as well as for the customers. Generation of new freight traffic caused by reduced transport costs requiring relocation of production facilities is likely to evolve slowly and could continue for decades.

Rail Baltica freight forecasts assume fundamental changes in the use of transport mode from ship and truck requiring major changes for the operators as well as the customers that probably will require several years to reach a new balance in the freight transport market. Other project as e.g. FinEst and Fehmarn Belt connecting Denmark and Germany require less fundamental changes. FinEst assume a big share of freight on truck shuttle service (70% of the freight on trucks) that does only require minimal logistic changes for the freight operators and costumers compared to the existing mode with the use of ferries. The Fehmarn Belt is mainly a change of route for the railway freight providing a more direct route. The Fehmarn Belt forecasts assume a 4-year "ramp-up" period.

In conclusion it is realistic that the "ramp-up" period of Rail Baltica is longer than for the Fehmarn Belt projects. The 7 year period as assumed in the CBA seems realistic, but uncertainty is considerable.

For freight the complexity is rather high depending on type of freight, volume of each shipment, origin and destination etc. The complexity is illustrated in the CBA by a number of case studies. Time and price estimates provided in the EY Global Project CBA documentation are indicative only as they do not represent permanent combination of the best prices or fastest duration as prices and time are subject to numerous variations. Details of how transport prices and transport times are weighted and combined in the freight forecast model is not available. See indicative price per ton and time as provided in the CBA on Figure 29.

Baltic States	Finland	Baltics	Poland	Germany	BeNeLux	Adriatic	CIS	China
	€ / km | day	€ / km | day	€ / km | day	€ / km | day	€ / km | day	€ / km | day	€ / km | day	€ / km | day
RB		0,75 1 d.						
Existing rail**	- *	- *	0,97 | 5 d.	0,70 | 6 d.	0,73 | 6 d.	0,9 | 6 d.	0,91 | 3 d.	0,44 | 15 d.
Road	1,07 | 1 d.	0,72 | 1 d.	0,80 | 1 d.	1,08 | 2 d.	0,94 | 3 d.	1,05 | 3 d.	0,82 | 3 d.	0,42 | 15 d.
Sea	0,47 | 2 d.	- *	0,50 | 2 d.	0,50 | 2 d.	0,50 | 3 d.	0,39 | 5 d.	- *	0,18 | 30 d.
Air	140 | 1 d.	117 | 1 d.	48 | 1 d.	- *	140 | 1 d.	20 | 1 d.	107 | 1 d.	6,78 | 1 d.

* Denotes that the connection with this destination has either been considered as a non-competitive alternative, or direction connections are not possible based on the presented assumptions.
** Existing rail has been calculated based from the perspective of cargo transportation with Finland.

Figure 29: Indicative price and time estimates (Source: CBA Final Report, page 75, figure 44)

Figure 30 illustrates the results from the CBA in number of freight trains per direction and day for the base case scenario.

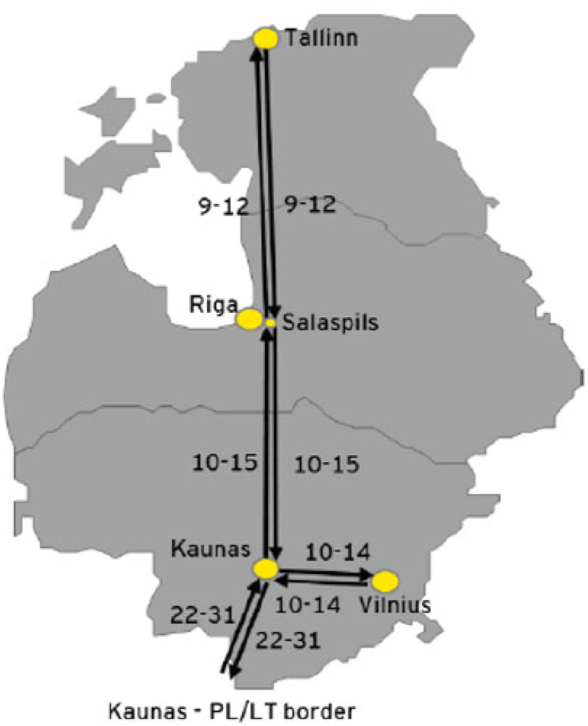


Figure 30: Schematic map of assumed freight trains/day and direction (base case 2030-2050)

Traffic forecasts addressing major changes in train service and addressing scenarios until 2055 in the CBA are estimates. It can turn out otherwise than forecasted. The CBA include a base case as summarised above and as assumed to be the central estimate. The CBA include also a low case with 20% less freight volumes and a high case with 20% more freight volumes (Source: Executive summary, page 13, table 3).

The question is if the forecasts made are realistic. The answer is that the method is state of the art, and the input data available seems realistic. Alas it was not possible to check in details in-depth. Important data in between description of the method and final results is not available in the documents. Other sources illustrate how difficult it is to forecast future freight flows of Rail Baltica. See also the assessment of other sources below.

1.5.1.2. FinEst link final report 2018

The FinEst link is a railway tunnel option connecting Helsinki and Tallinn with a 1435 mm gauge railway for direct passenger and freight train services via Rail Baltica connecting to the European Railway Network. For information on alignment and general information see chapter 1.2.1.2 on screening of existing passenger transport studies.

The FinEst link final report 2018 estimates the future freight traffic between Helsinki and Tallinn in 2050 in the scenario with the tunnel to be 8 million tonnes/year in total of which 4 million tonnes are carried on the railway through the tunnel and 4 million tonnes are carried on the ferry services.

Railway freight is assumed to be partly by truck shuttle service between Helsinki and Tallinn and partly conventional freight train service. 70% of the freight is assumed to move by truck shuttle and 30% of freight is assumed to move by conventional freight trains.

The study estimates the operation of 19 truck shuttle trains per day and direction with a speed of up to 160 km/h to allow truck shuttle trains to move in between passenger trains in off-peak day time traffic.

Conventional freight trains are estimated to be 3 trains per day and direction with a speed of up to 120 km/h. These trains are assumed to run at night time not to delay passenger trains.

The report does not indicate to what extend the freight have Tallinn as the final destination and to what extend freight are supposed to continue further south potentially via Rail Baltica.

1.5.1.3. Other freight studies

Earlier feasibility studies

Other earlier Rail Baltic studies have been screened including:

- AECOM 2015 focusing on optional alignments between Vilnius and Kaunas
- AECOM 2012 feasibility study addressing optional alignments of the main line

- COWI 2007 pre-feasibility study

The above mentioned earlier studies have all a broader perspective as the Rail Baltic Global Project Cost Benefit Analysis. The above-mentioned studies address e.g. alignment options not considered realistic anymore. The earlier studies have been important as basis for the many choices and decisions made before the Rail Baltic Global Project Analysis and assumptions made in the Rail Baltic Global Project. The Rail Baltic Global Cost Benefit Analysis Study is therefore considered the best basis for the Operational Plan including earlier decisions and based on newer data than the earlier studies.

1.5.1.4. Specific Terminal studies

Other studies and documents specifically addressing freight traffic having been screened include:

- Rail Baltic Muuga Multimodal Terminal Study: preview of the results, Meelis Niinepuu, Civetta Estonia, April 10, 2018
- Rail Baltic / Rail Baltica Intermodal Logistics Centre in Latvia - Development of Operational and Technical solutions, 2016 (Source: Revised final report, Rev. no. 4 27.01.2016)
- Development of Kaunas Public Logistics Centre (PLC) and infrastructure under its influence

The focus of these studies is the logistic processes and infrastructure in the terminals situated in Muuga, Salaspils and Palemonas (Kaunas PLC) as well as Tallinn and Riga and Kaunas area. Details of logistic processes and the conceptual design of the terminals are addressed here. The Rail Baltica Muuga Multimodal Terminal Study does specifically address freight forecasts between Tallinn and Pärnu stating that they are "more optimistic about the Finnish share of Rail Baltica" than the EY CBA. The Muuga study estimates 9.2 million tonnes freight in total for 2045 to be realistic on the Estonian section between Tallinn and Pärnu. The 9.2 million tonnes is 42% more freight than estimated in the EY CBA[20].

[20] Source: Analysis of Muuga MMT technological and spatial needs

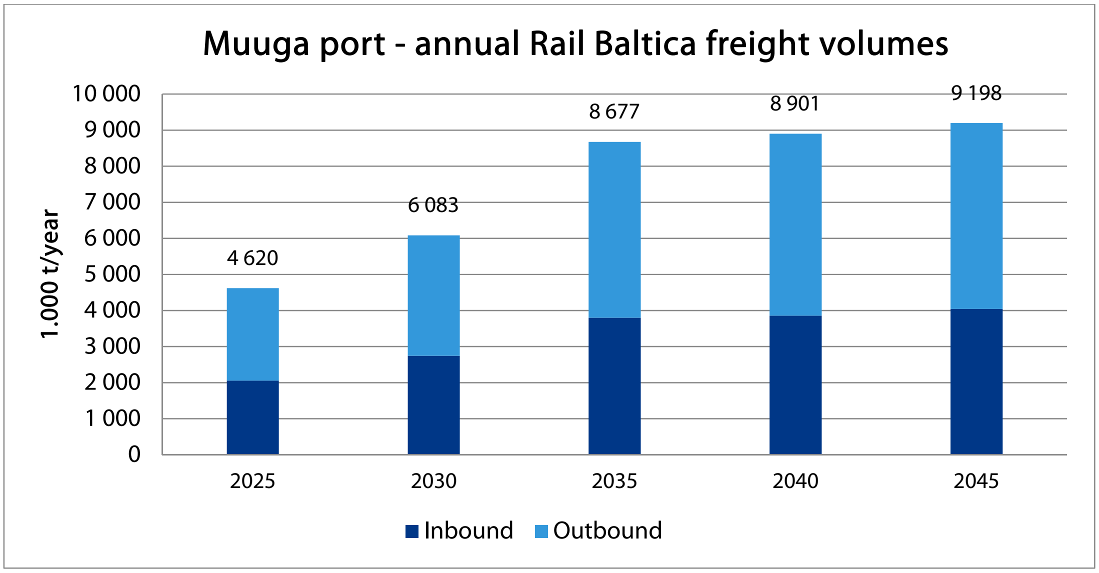


Figure 31: Muuga port - annual turnover of Rail Baltica freight

The distribution of in- and outbound flows shows that more freight is to be transported in the North-South direction towards Latvia, Lithuania and further (see Figure 31).

According to the study the share of containerised freight in the overall tonnage handled in Muuga port will increase from approx. 20% in 2025 to approx. 46% in 2045. Thus, most of the traffic can be expected to be intermodal. Though the majority of RoRo cargo would arrive or leave the port on the land side by road, the authors of the study expect the share of rail also to increase in this market segment (0.39 million tonnes in 2025 to 1.48 million tonnes in 2045).

The volume of bulk freight to and from Rail Baltica is expected to be much lower (approx. 160 wagons in total in- and outbound in 2026 per day which corresponds to an average total traffic volume of approx. 2.3 wagonload train pairs per day).

The Rail Baltica Intermodal Logistics Centre study from Latvia recommends that the Rail Baltica Intermodal Logistics Centre for Latvia (RBILC) is to be located in Salaspils. The estimated market share of RBILC is estimated at 1% of the national freight volume in 2040 including import and export. The expected freight to be handled in the Logistics Centre is estimated to be 1.6 million tonnes in 2040 corresponding to 5 freight train pairs per day (bulk and intermodal together).

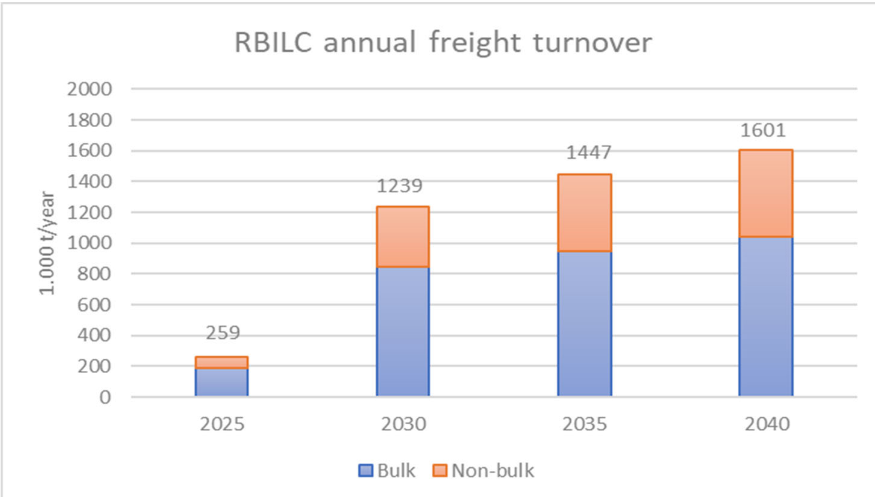


Figure 32: RBILC annual freight turnover[21]

The freight volumes are estimated for a number of different commodity types, and logistics in the terminal as well as expectation of level of containerised transport are considered in detail. According to the study approx.2/3 of the freight volume is bulk freight. It was expected that majority of this freight could be containerised, in addition it was recommended to foresee facilities for bulk handling and loading.

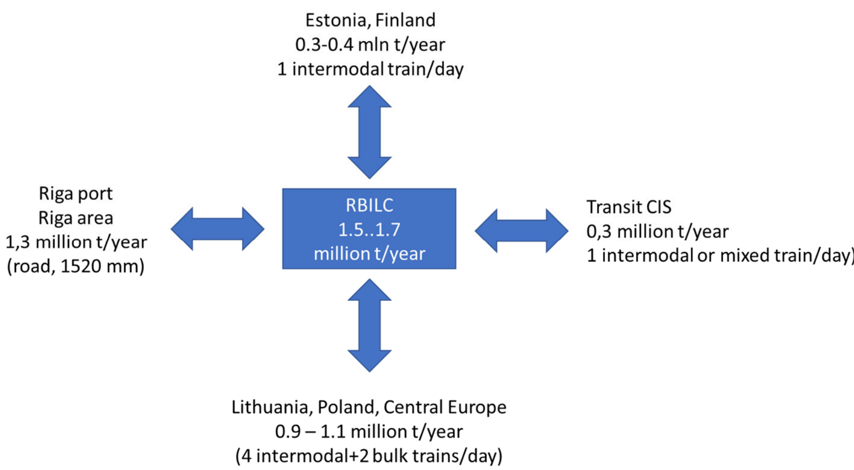


Figure 33: RBILC main relations and freight distribution (2040, own depiction based on RBILC study)

[21] Source: Rail Baltica Intermodal Logistics Centre in Latvia - Development of Operational and Technical Solutions, Identifications, Final Report AECOM 2016

It is expected that most of the freight moves to and from origins and destinations in Latvia and on international relations to Central Europe. While it is expected that most of the goods will have their origin or destination locally in the Riga area there is a realistic chance that the terminal will serve as interconnecting point with the East-West-traffic from and to Russia. The RBILC study concludes that containerisation in Eastern Europe is still at a modest level, but probably to increase to reduce cost. Flexibility is concluded to be important to be able to incorporate the rapidly emerging technologies and types of intermodal services.

Regarding the study on "Development of Kaunas Public Logistics Centre ", it is expected that Kaunas intermodal terminal shall be designed to handle approx.107,000 TEU by 2040, which corresponds to approx. 1,2 million tonnes of annual freight in 2040.

1.5.2. Consolidated demand forecast (WP1.4)

In conclusion the uncertainty about future volumes of freight traffic is considerable as well as how to handle the freight traffic in the future. The Muuga study foresees considerably more freight than the CBA did. The Latvian study is in line with the CBA. The FinEst tunnel could change the demand considerably. The recommendation for the Operational Plan is therefore to base the Operational Plan on the CBA forecasts as the central estimate.

Figure 34 shows the overall annual rail freight volumes per line section as the consolidated forecast based on the Rail Baltica Global Study CBA. The consolidated demand forecast above is simply interpolations and minor extrapolations of the EY CBA base case forecast to cope with the time periods required in the Operational Plan.

The question is if assumptions and results are realistic. Demand forecasting is not a straight forward process. Uncertainties are considered in the Global Project CBA with a low and high demand forecast case with 20% less and 20% more traffic than the base case. The Muuga study indicates it could be higher but the study focuses on very specific terminal and not on the overall corridor. The EY CBA includes a number of cases and examples and indicative parameters. All well documented and realistic, but the comprehensive final forecast model is not documented and made available to the consultant. Nevertheless, the EY CBA is assumed to be realistic and to be the best basis for the Operational Plan if FinEst tunnel is not taken into consideration.

Freight, million tons

	Tallinn	Salaspils	Kaunas	Kaunas
	Salaspils	Kaunas	Vilnius	Poland
2026	5.1	6.1	5.8	13.3
2036	5.9	7.1	6.6	15.0
2046	6.5	7.8	7.2	16.4
2056	7.1	8.6	7.7	17.7

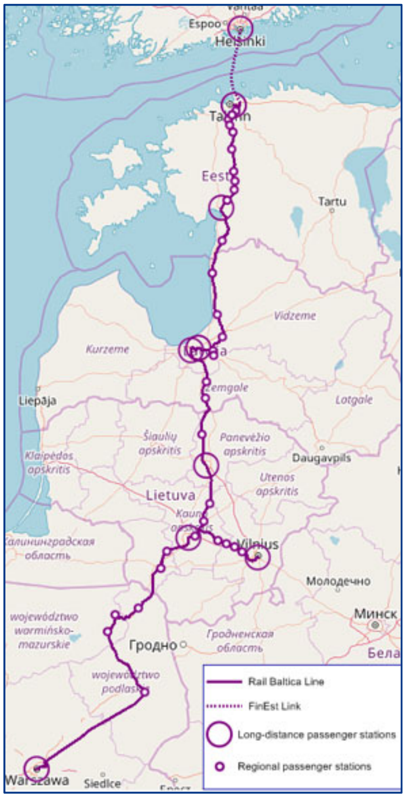
(Source: Consultants estimate based on the CBA)

Figure 34: Rail Baltic 1' iteration demand forecast for freight traffic without realisation of FinEst tunnel (both directions, based on CBA base case)

The FinEst tunnel is to be considered in the Operational Plan as required by the ToR, but no decision has been made yet if and how to finance the project. The project is considered in the Operational Plan for 2056, but it is uncertain if the tunnel option will be realised as foreseen today.

The FinEst scenario is tested to address uncertainty regarding future traffic growth and incorporate flexibility in the Operational Plan. See the forecast of freight transport in the FinEst tunnel on Figure 35 as well as an indicative forecast how the tunnel potentially could increase freight transport on Rail Baltica.

The assumption for the indicative forecast is that 4 million tonnes corresponding to half of the total freight between Helsinki and Tallinn continue south of Tallinn and Estonia via Rail Baltica to Poland, the Rail Baltica terminals and into Europe by rail. See consultants estimate how the additional freight are distributed in Figure 35. This would result to significant growth of demand on the different sections of Rail Baltica (+57% (Tallinn – Salaspils), +35% (Salaspils – Kaunas), +7% (Kaunas-Vilnius) and +11% (Kaunas – Poland) compared to the base case without realisation of FinEst link as indicated in Figure 35.



Freight, million ton 2056 (Source: Consultants estimate)					
	Helsinki	Tallinn	Salaspils	Kaunas	Kaunas
2056	Tallinn	Salaspils	Kaunas	Vilnius	Poland
Without tunnel	0.0	7.1	8.6	7.7	17.7
Additional if tunnel	8.0	4.0	3.0	0.5	2.0
With tunnel	4.0	11.1	11.6	8.2	19.7
addition if tunnel	n.a.	57%	35%	7%	11%

Figure 35: Rail Baltic 1st iteration of estimate of freight with realisation of FinEst tunnel (both directions)

The estimate in Figure 35 is on the safe side addressing operational plan and is to be seen as optimistic scenario, not only because of FinEst link, but also because of other influence factors, e.g. economic boost. The assumption of 8.0 million ton in total between Helsingki and Tallinn of witch 4.0 million ton in the tunnel correspond to the estimates in the FinEst link final report. The assumption of 4.0 million ton via Rail Baltica between Tallinn and Salaspils corresponds also to estimates in the FinEst final report.

The estimates in Figure 35 are on the safe side, because not all of the above mentioned freight flows are additional. More or less of theise freight flows can also be expected in the scenarios without the FinEst tunnel served with ferries between Helsinki and Tallinn. More or less freight are counted twice. The question is how much that are counted twice.

The CBA reports does not include any details how ferry service are assumed in the future and no information of how much freight are estimated to be transferred between Rail Baltica and ferries to and from Finland.

The FinEst final report address a 0 scenario assuming ferry service as today and sketch optional 0+ scenarios. The 0+ scenarios address improvement of current port facilities, new port facilities in Vuosaari and Muuga as well as modern technologies to optimise freight ferry service between Tallinn and Helsinki. The final report concludes, that investments in optimisation of ferry service are likely in the without tunnel scenarios, and that the potential transfer of freight between ferries and Rail Baltica is 1.8 million ton in 2050. The freight counted twice on the section Tallinn-Salaspils in Figure 35 could therefor be up to 1.8 million ton between Tallinn and Salaspils and less south of Salaspils.

The consolidated forecast of daily freight volumes to be transported on the different main sections of Rail Baltica is shown in Table 36 taking into account the annual volumes without FinEst link for the time horizons 2026 – 2046 and the annual demand with FinEst link operational for 2056.

The following table with the final consolidated daily freight transport is used as the basis for the Operational Plan assuming the FinEst tunnel opens in 2050. Conversion from per year to per working day is based on an assumption of 310 working days a year (taking into account weekly traffic distribution due to reduced loading/unloading activities at the ports and terminals and at the origins and destinations).

	Tallinn Salaspils	Salaspils Kaunas	Kaunas Vilnius	Kaunas Poland
2026	16	20	19	43
2036	19	23	21	49
2046	21	25	23	53
2056	36	37	26	64

Table 36: Consolidated freight transport forecast, 1,000 tonnes per working day (both directions)

OD tables (balanced and unbalanced) with volumes of freight are not available in the studies as mentioned in ToR and as screened. OD table would be of advantage to consider consistency in more detail in the future.

OD tables are not needed to justify recommendation of train service pattern and capacity utilisation on most sections. The only exception is the triangle next to Kaunas where there are optional routes and a need to consider the split of freight between the section Vilnius – Kaunas, Kaunas including stations south of Kaunas and Panevėžys including stations north of Panevėžys.

The daily freight volume on the main sections in the table above have been translated into OD tables shown below with estimated freight volume between origins and destinations addressing the planned triangle next to Kaunas allowing freight trains between Vilnius and the northern part of Rail Baltica including Panevėžys, Riga etc. to bypass Kaunas. The OD tables are based on freight volumes in Table 36 and the additional assumptions that 30% of the freight to/from Poland is from/to Kaunas and that 77% of the freight to/from Vilnius is from/to direction Kaunas (including Poland and the rest of Europe). The reader should be aware the format are OD tables and figures in each cell are one direction to and from Kaunas includes Kaunas as well as all stations south of Kaunas in Lithuania and Poland. Panevėžys include Panevėžys as well as all stations north of Panevėžys in Latvia, Estonia and Finland in 2056.

from to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius		7.3	2.2
Kaunas, Poland etc.	7.3		7.8
Panevėžys, Riga etc.	2.2	7.8	

Table 37: Indicative OD freight volumes pr. day 2026 in the Kaunas triangle (1,000 tonnes per working day)

from to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius		8.1	2.4
Kaunas, Poland etc.	8.1		9.1
Panevėžys, Riga etc.	2.4	9.1	

Table 38: Indicative OD freight volumes pr. day 2036 in the Kaunas triangle (1,000 tonnes per working day)

from to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius		8.9	2.6
Kaunas, Poland etc.	8.9		9.9
Panevėžys, Riga etc.	2.6	9.9	

Table 39: Indicative OD freight volumes pr. day 2046 in the Kaunas triangle (1,000 tonnes per working day)

from to	Vilnius	Kaunas, Poland etc.	Panevėžys, Riga etc.
Vilnius		9.2	3.8
Kaunas, Poland etc.	9.2		14.7
Panevėžys, Riga etc.	3.8	14.7	

Table 40: Indicative OD freight volumes pr. day 2056 in the Kaunas triangle (1,000 tonnes per working day)

1.5.3. Freight services considerations (WP 1.4)

In this section the market potentials, typical loading units and special requirements regarding rolling stock and terminal facilities will be analysed as basis for working out requirements for the Operational Plan.

According to the ToR the following freight services shall be facilitated by Rail Baltica.

- FRT1: Freight service for containers (intermodal)
- FRT2: Freight service for trucks or lorry transport (piggyback)
- FRT3: Freight service for dry bulk materials
- FRT4: Freight service for liquid bulk materials
- FRT5: Freight service for dangerous goods (chemicals etc.)
- FRT6: Freight service for transport of new passenger cars and trucks transport (automotive rail logistics)
- FRT7: Freight service for transport of passenger cars of passengers travelling by day or night express service
- FRT8: Freight service for temperature controlled goods
- FRT9: Freight service for express mails, post, parcels
- FRT10: Freight service for dangerous goods (chemicals etc.)
- FRT11: Project Cargo exceptional oversize service

1.5.3.1. Freight Service for intermodal containers (FRT1)

Current market situation and demand forecasts indicate that most of the Rail Baltica freight will be transported using containers. This is especially related to the services from and to the northern terminus of Rail Baltica - Muuga port as well as to the transit services on 1520 mm in East-West-direction from and to the CIS and other Asian countries. Transhipment of containers will take place in the dedicated terminal facilities at Muuga port, Salaspils terminal, Kaunas terminal and Vilnius terminal and, if implemented, Pärnu freight terminal.

Since loading gauge GC will be applied all types of standard ISO containers, including high cube containers can be transported. Given the relative low average payload per container (avg. approx. 10- 14 t/TEU depending on load mix) intermodal services are likely to utilise a track length of 740 m and will also benefit from maximum train length of 1,050 m with increase of transport volumes. Utilisation of train length will also depend on the operating conditions in the terminals, especially in Poland and the maximum permitted train length in Poland and central Europe.

To provide a sufficient departure frequency a significant share of train services will run from and to intermodal terminals in Poland, where loads will be consolidated with loads for other services.

To shorten transport times to be competitive, establishment of direct services going further west, e.g. to Southern and Western Poland or to Germany will be likely. To reach the critical train utilisation it might be necessary to reconsolidate the loads from/to Estonia / Latvia and Lithuania en route. Best location for this in the Baltic states would be the Kaunas node (Palemonas yard or Karmelava freight station), which also is a major source and destination and interconnecting point to the section Kaunas - Vilnius. Best location on the on the Polish side would be Ełk railway node, which will be the access point to the northern route of RFC 8 via Iława to Poznań.

If necessary change of train formation in a separate facility located more closely to the border might also be an option but would not be as efficient as Kaunas or Ełk, where there are more synergies.

Especially for Salaspils, but also for Kaunas, the option of an intermediate stop of through trains might be considered to provide a flexible usable service with regular departures. Track layout in Salaspils would allow trains to go directly to the loading track (coasting or bimodal traction). The whole train would then stop until all intermodal units are loaded or unloaded. Depending on terminal processes exchange of wagons in the reception sidings might be faster.

With the currently planned track layout for Palemonas exchange of wagon groups in the reception sidings would be necessary to achieve the same functionality for Kaunas Intermodal Terminal, since the length of the terminal tracks under crane will only provide for half train size (approx. 450 m).

1.5.3.2. Freight services for trucks and lorry transport (FRT2)

Accompanied transport of trucks ("Rolling Motorway" services)

Accompanied transport of trucks on railways is carried out as block train shuttle service using dedicated low-floor wagons which allow transport of trucks as well as horizontal loading and unloading by movement of the trucks onto the wagons in longitudinal direction. The truck drivers will be carried in dedicated passenger wagons on one end of the train.

Currently most of the services in Europe are provided in situations where there is a natural barrier (mountain transit, waterway crossing by rail tunnel) and/or bottleneck on the road side or for selected long distance transport relations (e.g. Perpignan / Le Boulou – Bettembourg with 985 km road distance). Typical example for the current state of development in Europe area the services provided on the transalpine corridors. Where the framework conditions can be summarised as follows:

- Core services for transport of trucks over short distances with frequent departures (e. g. Brenner shuttle Brenner – Wörgl) with frequent departures
- Extended services over medium distances (e.g. 200 - 400 km) as block trains with less frequent departures (usually 1 or 2 departures per working day)
- Framework conditions to force the use of rail mode for environmental reasons (subsidies for railway undertakings, additional restrictions for road transport, e.g. extended night time driving ban, additional road tolls)
- Minimisation of production costs with limited additional service for truck drivers on the train (e. g. limited catering, usage of couchettes for night services)

Given the current road utilisation in the Baltic States and the absence of comparable restrictions for road transport a similar use case for the Baltic States would require a significant policy change in line with the targets formulated in EU White Paper on Transport to shift30% (by 2030) and 50% (by 2050) of road freights carried on distances above 300 km from road to other more environmentally friendly transport modes (e. g. rail, waterways).

One theoretical scenario would be the takeover of a significant share from Baltic Sea RoPax ferries by introducing new rolling motorway services by rail. These ferry services are running on long distances like Travemünde – Liepaja or Kiel – Klaipeda and are also utilised by a significant share of accompanied trucks. Typical size of a RoPax ferry will provide a loading length for trucks of 1,500 to 3,000 lm (loading metre), depending on the size of the vessel. This corresponds to approx. two to five intermodal trains depending on the allowed train length and size of the ship.

There is a variety of on board services (catering, entertainment, and sleeping compartments) available, which could be also used by the truck drivers.

Such a modal shift would be dependent on a policy change regarding truck transport:

- Restrictions for truck usage on long-distance road services (toll, extended bans)
- Enforcement of better working conditions for drivers (working regime, wages), also targeting risk of truck driver shortage in the future[22]

In such cases it is likely that the industry will adapt to more cooperative service models, which will not require the presence of the driver on the long distance run.

The situation might change if FinEst link will be implemented providing a unique transport link with no road alternative. According to the results of the feasibility study truck and car shuttle services between Helsinki and Tallinn are foreseen. The feasibility study indicates that truck shuttles have a share of 70% of the total cargo tonnage to be transported through the tunnel. Loading and unloading of the shuttle trains on the Estonian side will take place in Tallinn area. According to the study the terminal site shall be situated at Soodevahe south east of Tallinn airport.

Unaccompanied transport of semi-trailers

However, unaccompanied transport of semi-trailers will have a significant share of intermodal freight transport and shall be facilitated to support modal shift to rail.

In the Muuga freight terminal study the annual number of semi-trailers to be transhipped from and to Rail Baltica is estimated to grow from approx. 25,000 in 2025 to more than 100,000 in 2045. This corresponds to a share of approximately one third of total intermodal freight. No dedicated forecast is available for other terminals.

Current standard in Central Europe is to use dedicated and codified craneable trailers, which are loaded vertically, e. g by gantry cranes thus not requiring special dedicated terminal facilities. Currently the most commonly used wagons are standard pocket wagons. The low height of the pocket floor of approx. 0.27 to 0.30 m above rail surface will ensure that trailers and mega-trailers can be transported without restrictions on Central European line sections. Currently, the corner height of road vehicles is 4.00 m, with special vehicles even higher). In Finland the allowed maximum corner height is 4.60 m.

According to current version of Rail Baltica Design Guidelines loading gauge GC shall be applied allowing for a maximum height of 4.65 m above rail surface. This is in line with current TSI requirements for freight lines of the highest category (F1). Application of loading gauge GC implicates that for transport of standard road vehicles pocket wagons need to be used. If standard flat deck wagons should be used the total height of the loading gauge required

[22] Example: For Germany it is estimated that around 40% of truck drivers will retire in the next 10-15 years, leading to a driver shortage of 150.000 drivers. Source: https://www.iru.org/what-we-do/network/driver-portal/problem

would be higher (0.94 m for standard flat deck wagon + 4.00 m corner height of road vehicles = 4.94 m). Application of a loading gauge larger than GC is welcomed by TSI regulations, but not mandatory. To use a loading gauge larger than GC for transport from/to Central and Western Europe an implementation plan for the complete corridors, especially Rail Freight corridor 8 would be required. Application of such a loading gauge would mean additional investments in catenary and structures along existing corridors (e. g. in Poland, Germany, and Netherlands). Given the fact that piggyback wagons are constructed of standard components (bogies, wheel sets etc.) and are widely used it can be doubted that such investments will become priority soon. Thus, in the foreseeable future (until 2050) the use of standard flat deck wagons would be limited to services within the Baltic states if a loading gauge larger than GC is applied. For transport from/to Central Europe and Poland the use of piggyback wagons would still be required for a long time. For example, in Poland the current standard is loading gauge G2 restricted (smaller than GC to be applied on Rail Baltica).

Transport of craneable and non-craneable semi-trailers using conventional pocket wagons can be implemented as mixed train configuration (transport together with other intermodal units in the same train) or as dedicated services subject to the final decision of the intermodal operators involved. While conventional pocket wagons are also designed to carry standard ISO containers and without special preconditions for innovative services a dedicated wagon fleet for transport of semi-trailers only would be required.

Several solutions for transport and transhipment of non-craneable trailers have been developed in recent years. Examples are provided in Table 37. Transport of non-craneable trailers would facilitate further modal shift, since most semi-trailers used in road transport are not designed to be lifted by gantry cranes under normal operating conditions.

Most of the systems available on the market require dedicated wagons and loading equipment to be installed at the terminals. Therefore, a corridor approach to ensure utilisation of equipment to be used is an essential precondition for application of these technologies.

System	Short description	Advantages/Disadvantages
Nikrasa	Usage of dedicated terminal and vehicle pallets (to be positioned under trailer) to allow vertical transhipment by conventional gantry crane	Advantages: Can be implemented on short notice using existing equipment (wagons, terminal facilities) Disadvantages: Additional effort for management of pallets required (e. g. return of empty platforms) Additional tare weight of pallets
Modalohr	Usage of dedicated wagons with integrated moveable swinging deck for horizontal transhipment of trailers Simultaneous loading / unloading of complete train possible depending on terminal configuration Movement of trailers by tractor unit	Advantages: Transhipment under overhead wire possible Fast simultaneous transhipment for several wagons or complete train (depending on terminal facilities) Usage of standard wagon components (wheels, bogies) Disadvantages: Dedicated terminal facilities (movement of swinging decks) and dedicated wagons required Additional space in terminals required leading to higher fixed costs
Cargo Beamer	Transport of trailers by special pallets mounted on flat wagons Usage of dedicated wagons Simultaneous loading / unloading of all wagons of a train possible depending on terminal configuration Loading of trailer on moveable pallets Vertical Transhipment of loaded/unloaded pallets possible (crane, reach stacker) Fast transhipment of loaded/unloaded pallets by fixed terminal facilities	Advantages: Better space utilisation in terminals Usage of standard wagon components (wheels, bogies) Fast simultaneous transhipment for several wagons or complete train Transhipment under overhead wire possible Disadvantages: Dedicated equipment (wagon, pallet, terminal installations for fast transhipment) Additional tare weight of pallets

Table 41: Systems for rail-transport and transhipment of non-crane able trailers (typical examples)

For systems depending on fixed terminal installations (e. g. Modalohr, Cargo Beamer) dedicated loading tracks in the terminals will be required, if the full potential of the systems should be used and complete trains are to be handled. The different area needs of the systems on the road side must be considered in terminal design. Nikrasa and Cargo Beamer transhipment facilities could be easier to integrate into conventional terminals.

Given the high cost for terminal installation systems without the need of dedicated fixed installations will be an advantage in the beginning. Nikrasa and Cargo Beamer pallets could be handled by conventional gantry cranes, allowing for smaller amounts of freight (several trailers to half train load) in service start-up phase.

Given the high cost for terminal installation systems without the need of dedicated fixed installations will be an advantage in the beginning.

To cover the higher equipment cost short turnaround times of trains must be provided. Given the need for dedicated wagons in most cases, transport in dedicated shuttle trains will be the more likely use case to ensure short wagon turnaround times. To ensure return of higher investment stable volumes on dedicated relations will be needed. Thus these systems mainly qualify for main relations (e. g. from/to Warszawa or from/to a major German hub like Duisburg).

Another option is to convert-non-craneable trailers to craneable trailers by retrofitting of terminal gripping edges. The additional tare weight of upgrade solutions available on the market will be only approx. 310 kg per trailer. Additional investment will correspond to approx. 10% of the cost of a standard semi-trailer.[23]

Given the high cost for terminal installation, systems without the need of dedicated fixed installations will be an advantage in the beginning.

Most of the systems available on the market require dedicated wagons and loading equipment to be installed at the terminals. Therefore, a corridor approach to ensure utilisation of equipment to be used is an essential precondition for application of these technologies.

1.5.3.3. Freight service for dry bulk materials (FRT3)

Category of dry bulk materials is related to a wide range of products and raw materials. Of special interest for Rail Baltica are grain, fertilisers, mineral products and building materials. This category is traditionally a domain of rail transport in the 1520 mm network. Nevertheless, the results of the terminal studies indicate that dry bulk materials will gain a small but considerable share of the overall freight volumes along Rail Baltica.

Shipment of these kind of cargo is traditionally dependant on local consolidation close to the (natural) production sites and dedicated loading points for transhipment to rail (e. g. grain conveyor) or from private railway sidings while implementation of dedicated facilities is usually initiated by local producers or logistics service providers.

Transport of bulk freight to destinations in the Baltic States is dependent on facilities for transhipment to road which should be situated closely to major O/D sites, e. g. building sites or production sites.

[23] In zwei Tagen fit für die Schiene. *Eurotransport.* June 16 2016. https://www.eurotransport.de/artikel/umruestung-zum-kranbaren-auflieger-in-zwei-tagen-fit-fuer-die-schiene-8028984.html

Studies for intermodal terminals at Muuga and Salaspils (RBILC) indicate demand for dry bulk material to be handled with the following volumes:

- RBILC: up to 300,0o0 t mineral products/building materials, 2 loaded block trains per day expected
- Muuga: approx. 2 block trains inbound, 4 block trains outbound (1435 mm) in 2035.

Regarding the current state of affairs, the design of the intermodal terminals and sidings in Muuga port shall facilitate optional handling of block trains for dry bulk material without interfering with other businesses. This incorporates either transhipment to/from 1520 mm where applicable or transhipment to road.

Another dry bulk business case is production of ammonium nitrate fertiliser in Lithuania with two plants within 25 km reach of the Rail Baltica corridor in Jonava and Kedainiai. The two plants have an annual fertiliser production of 3 million tonnes per year. Most of the production is exported to European destinations via the port of Klaipeda. If Rail Baltica shall take over some of the transport volumes, which might be advantageous for Central and Western European destinations on the inner main land, a dedicated transhipment and storage facility for block trains (first mile by 1520 mm or road), a dedicated branch line or a containerised transport chain would be required.

Smaller business cases for handling of bulk freight at additional intermediate stations are limited and will require more detailed studies, closer to the date of realisation once Rail Baltica is operational. At least for smaller consignments containerisation will also be an option.

For smaller consignments (e. g. chemicals, fertilisers and grain) or for shipments to be transferred between vehicles or distributed to different consignees so called flexible intermediate bulk containers or big bags could be used. These are either suitable for transport in open wagons, which would require lifting each bag separately by cranes or consolidation in standard intermodal containers. The latter possibility allows for integration of bulk cargo in standard intermodal transport chains (rail-rail, rail-sea, rail-road) via the proposed terminals. Precondition is that the shippers and consignees are able to handle this kind of consignments.

1.5.3.4. Freight service for liquid bulk materials (FRT4)

Transport of mineral oil is a traditional domain of the rail freight transport in the Baltic States. Rail is part of the traditional export routes to the West via the Estonian and Latvian ports. This business is East-West oriented and will stay a domain of 1520 mm. Most of the local refineries and tank farms in the Baltic States are currently not planned to be connected to Rail Baltica. Thus, this business will generally remain on 1520 mm gauge. This situation is confirmed by the study for the Muuga terminal. In Muuga liquid bulk handling is expected to decline from 6.3 million ton in 2015 to 2.5m tonnes in 2045. From this still considerably transport volume Rail Baltica is estimated to garner only a small share (might be 1 block train per day), which might be used e. g. for delivering fuel to Riga airport.

A combined transhipment and storage facility for mineral oil has already been implemented adjacent to Šeštokai station. This facility will allow transhipment from 1520 mm to 1435 mm. The majority of Central European mineral oil imports from the CIS is transported by pipeline. Thus, the market potential of such facilities will be more regional oriented e. g. from Lithuanian refineries to Eastern Poland or vice versa.

For other consignments usage of tank containers or piggybacking of semi-trailers will be an option utilising planned intermodal terminals en route. Smaller consignments could also be integrated into the intermodal transport chain using intermediate bulk containers, which are consolidated in standard intermodal containers.

1.5.3.5. Freight service for dangerous goods (FRT5)

Rail Baltica as such does not directly serve any chemical production sites. Therefore, the possibilities to use wagon-load based services are very limited and are mainly applicable for bulk freight to be transported in larger quantities on the same relation (e. g. fertilisers and related raw material). It can be assumed that the majority of freight will be transported in containers, e. g. tank containers. Given the dedicated requirements for transport of the different chemicals this option is also widely applied practise in European chemical industry. Large European manufacturers, e.g. Bayer and BASF enforce and support the establishment of intermodal facilities near the major production sites of the respective production sites. This is also to consolidate freight transport for transhipment to Poland and further on to Eastern Europe and Russia by rail.

For handling of dangerous goods in general the following conditions must be ensured:

- Dedicated storage areas and fire protection measures to ensure safety
- Terminal design must ensure environmental protection (e.g. drainage facilities)

Furthermore, IT infrastructure must ensure that the staffs of the railway undertaking, terminal manager and railway infrastructure provider have consistent and up-to-date information regarding location of consignments with dangerous goods (e. g. location of containers in the train).

Dedicated block train services can only be expected for fertilisers and liquid bulk. Incident handling staff (local fire brigade, train crew, incident managers must be trained to react properly in case of incidents involving dangerous goods on the railway and related communication to staff and local authorities.

1.5.3.6. Transport of new passenger cars and trucks (FRT6)

Regarding transport of manufactured passenger cars and trucks, typically rail mode is used for rather huge consolidated consignments between an origination point (car manufacturer) and destination point (local distribution hub, sea port for major export flows). Due to the high value density of transported goods condition of vehicles must be monitored closely. Special measures for theft and damage protection should be implemented. Currently there is no car manufacturer in the Baltic States, which would trigger significant transport volumes. Remaining functionality to be served by rail would transport to local distribution hubs for serving the Baltic States and export to CIS countries by rail. This functionality could be developed as part of the Rail port functionality of the foreseen intermodal terminals. The critical mass for rail transport could only be reached, if sufficient storage facilities and value-added services can be implemented closely to the terminal sites. If the cars shall be transported in dedicated block trains or wagon groups to the distribution hubs in the Baltic States it is likely that the loads (e. g. cars from different manufacturers) need to be consolidated in a dedicated hub before entering the Rail Baltica corridor (e. g. in Germany or Poland).

Requirements:

- Consolidation of loads before entering Rail Baltica
- Ensuring transport security and punctuality
- Sufficient transhipment and unloading sidings at the terminal locations

1.5.3.7. Freight service for transport of passenger cars of passengers travelling by day or night express service (FRT 7)

Today, main application of transport of road passenger cars by rail is to overcome a natural barrier where no equivalent road service can be provided. In case of Rail Baltica the similar use case would be introducing a dedicated service for passenger cars between Helsinki and Tallinn if FinEst link should be implemented. For this kind of services dedicated wagons need to be developed to allow for tunnel safety and maximum capacity and adequate passenger comfort. To allow maximum capacity utilisation in the tunnel and to minimise waiting time for both passenger cars and trucks the service could be implemented as integrated service with truck transport (either by using same wagons or by using dedicated double stack wagons. Typically drivers and passengers remain in their car so that no separate passenger wagon is provided.

On greenfield solutions like the channel tunnel a special loading gauge and vehicle clearance is implemented. Given the length of the journey toilets and a minimum service needs to be provided on the train as well as provisions for quick evacuation in case of emergency.

Transport of cars could also be possible by attaching car transporters to the night trains. This mode of transport is currently mainly used for leisure purposes. This can be seen as added advantage motivating users to use the night train which is slower than the plane. Typical relations would be the longest legs of the night train run like Vilnius – Berlin/Wien or Tallinn – Warszawa. It is questionable if there will be a business case in the future taking into account on-going changes of mobility patterns (usage of car sharing or rental cars at train origin/destination instead). As with rolling motorway services, the ferry will be the main competitor. So the main market would be to serve inland destinations like Warszawa or Vienna.

For loading and unloading special terminal facilities must be provided. The typical use case is the use of double stack cars for passenger cars, which must be supported by loading and unloading facilities.

In order to shorten waiting and transfer times for passengers the car terminals need to be located at the same place or within short distance of the departure platform of the trains. The currently available design will allow car loading and unloading only from the front of the wagon with fixed installations. To provide for loading and unloading of wagons at intermediate station the currently used technology needs to be improved.

1.5.3.8. Freight Service for temperature controlled goods (FRT8)

Temperature controlled goods are to be transported in semi-trailers or dedicated containers. During rail transport no power can be supplied to the reefers. To maintain required climatic condition two solutions are typical for European rail transport:

- Continuous cooling of reefers by mounted diesel generator sets
- Usage of electrical powered cooling units in combination with thermo isolation suitable for up to several days without powered cooling.

In both cases maintenance of the cooling units must be ensured at the terminal sites. For powering of electrical cooling units dedicated power connections are to be foreseen on the terminal sites. In case of failure repair and replacement of intermodal units or semi-trailers has to be organised. Given the total freight volumes it is unlikely that dedicated train services will be introduced for temperature-controlled goods. In order to ensure short transport time priority services might be used, if available.

1.5.3.9. Express mails, post, parcels (FRT9)

Transport of express mail, post and priority parcels is usually facilitated on overnight connections between consolidation and distribution hubs. To ensure a short transport time these distribution hubs should be located near the Rail Baltica rail freight terminals. Since Rail Baltica serves the capitals of all three Baltic States the chances would be to install the main distribution hubs within short distance to the already planned rail terminals.

Given a freight train avg. speed of approx. 100 km/h (max operating speed = 120 km/h) during night time direct connections between Vilnius – Riga and Riga – Tallinn are relatively easy to implement. Longer connections Vilnius/Kaunas – Tallinn would likely require higher train speeds of more than 120 km/h and a dedicated fleet. The service could be developed as an intermodal service.

To ensure an economic train utilisation, the service shall be opened for other goods, preferably priority freight like temperature-controlled goods. For goods where no overnight connection is required that service can be extended to a suitable distribution hub in Poland, e. g. in Warszawa area.

One example for remaining postal services successfully operating in Central Europe is the Parcel Intercity (PIC) network of DHL operated by DB Cargo. The PIC network consists of a north-south connection Hamburg – Munich and an East-West connection Berlin – Rhine/Ruhr area. To ensure a high train utilisation this network is open for other transports as well. More than 70% of train capacity is used for other cargo. Initially the service was operated with maximum speed of up to 160 km/h using dedicated train sets (intermodal wagons equipped with electronically controlled pneumatic disc brakes but has been cut-down to 120 km/h using traditional equipment due to high operation costs.

Another example of a fast postal service is the Swedish postal train service. These services use dedicated wagons either boxcars or flat cars with special intermodal units, which are operated as dedicated postal block trains and interconnect dedicated postal terminals where the wagons are loaded and unloaded by postal service staff. According to the logistic service provider Postnord approx. 65% of the mail in Sweden is transported by rail. Since end of 2017 the requirement to deliver stamped mail within one business days was replaced by a two day delivery policy. Required overall service punctuality for postal delivery was raised from 95% to 98.9%. This allows replacing air transport by other modes, mainly by rail.

Last but not least transport of mail and parcels could be integrated in passenger services. This would require dedicated space in the trains and a dedicated loading area at the platform. Given that, the most likely option would be to provide small-volume-high-value courier services or mail service. Success of such a solution will also depend on organisation of pre- and post-haulage on road. Distribution centres for mail and parcels are not located any more close to the passenger stations, but in logistics centres outside the city centres.

The need for such services needs to be determined by a separate study addressing the market conditions and requirements in more detail.

1.5.3.10. Project Cargo exceptional oversize service (FRT11)

1.5.3.10.1. Infrastructure

Clearance gauge

The clearance gauge determines which distances (measured from the centre of the track or from the top of the rail) are to be kept clear of installations. The following figure shows these distances for the clearance gauge "GC" used.

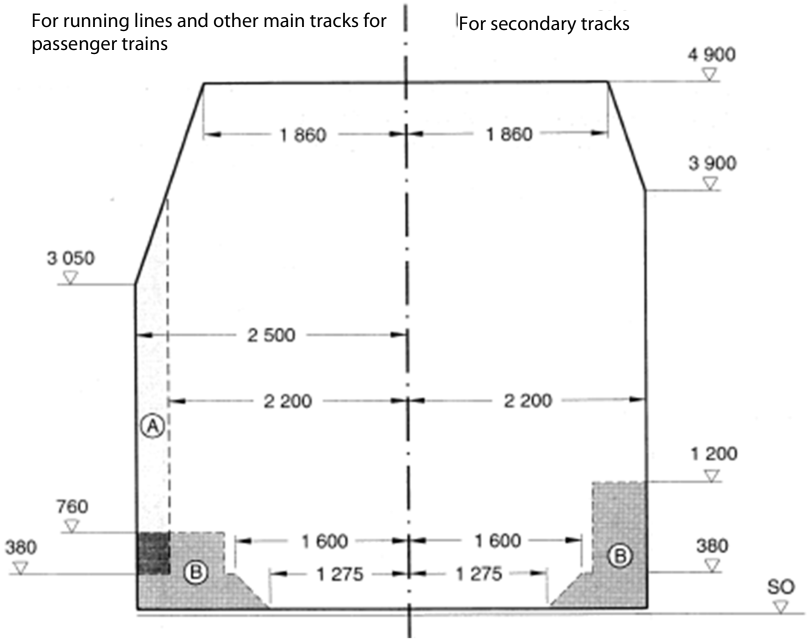


Figure 36: Clearance Gauge "GC"

The clearance gauge results in the required track distances for line tracks and station tracks. Surcharges to the above mentioned distances are required when radiuses of track curves are exceeded, at higher speeds and the existence of rail cant deficiencies (height difference between the two rails).

Loading gauge

The loading gauge determines, which distances (measured from the centre of the track or from the top of the rail) may not be exceed by rail vehicles or their load, so that they may operate within the corresponding clearance gauge without or with specified restrictions. The following figure shows the respective loading gauge dimensions G1 and G2, which correspond to the clearance gauge type "GC".

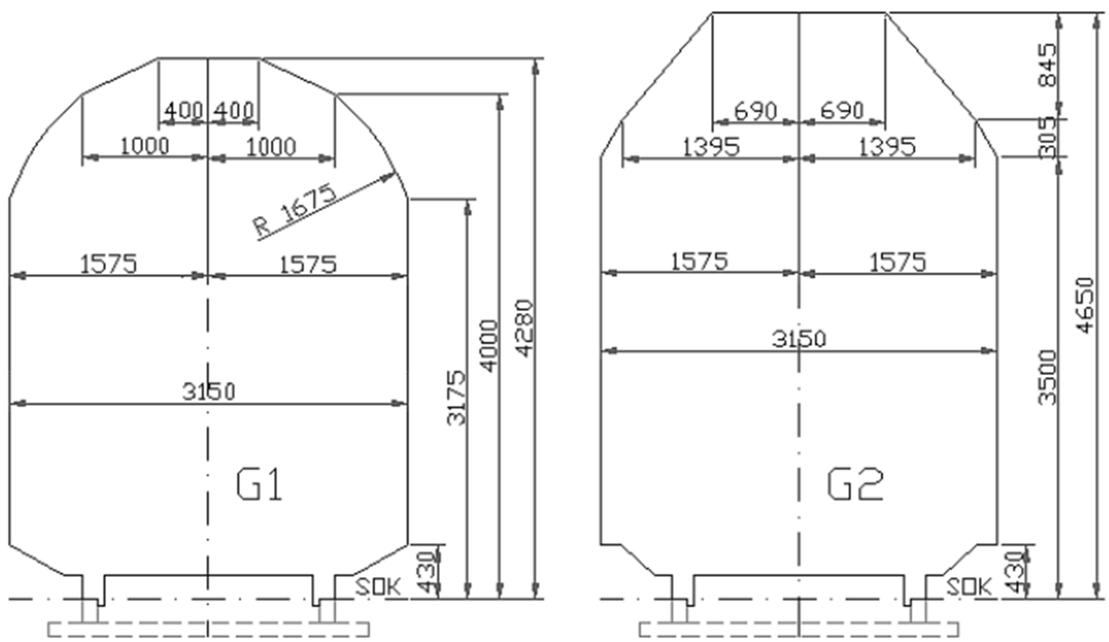


Figure 37: Loading gauge G1 and G2

Vehicles conforming to the international G1 profile (see left figure above) can be used freely in Europe (except in the UK, where an even smaller profile must be respected). The G2 profile is also called the German load gauge (see right picture above). Vehicles with this relatively large profile (e.g., “Hbbills 311” freight wagons) may not, or only by special agreement, operate internationally.

Excursion: Out-of-gauge load / loading (“LÜ”) – German operational rules

The following remarks on out-of-gauge load / loading (“LÜ”) refer to the regulations applied by German Rail [DB AG].

Trains with out-of-gauge load - also referred to as “LÜ” load - have a measurable half of distance between centres of tracks of more than 1,575 mm (minus various surcharges) and must be checked by a qualified technician.

Classification:

a) ”LÜ Alfa“: only height is exceeded, measures for the adjacent track not necessary, for instance double-deck coaches in a normal train (see previous graphic “G2”)

b) ”LÜ Berta“: small exceeding of width, no actions necessary, but see c); allows the passing of regular “LÜ” trains “Alfa” and “Berta” on the adjacent track

c) “LÜ Caesar“: exceeding oft width, exclusion of “LÜ” types “Berta” or “Caesar” on the adjacent track. On that adjacent track only trains with regular loading gauge would be allowed to run. In order to exclude a collision with another “LÜ” train, the operational "offer"[24] of the train is necessary.

d) “LÜ Dora“: Large exceeding of width blocking of the adjacent track(s) is necessary. Due to the extreme exceeding, it is necessary to close the affected adjacent track(s) and keep it clear of all vehicles and persons before these trains can start the journey.

Calculation example for out of gauge load

S corresponds to the average track distance, i.e. measured from the centre of track o track 1 to the centre of track of track 2. 1,750 mm is the regular half width of a rail vehicle consisting of 1,575 mm, which corresponds to the loading gauge of the German Rail [DB AG], plus 75 mm as a supplement for the swing of the vehicle in curves, plus another 100 mm as a surcharge for operating irregularities. A standard loading gauge rail vehicle, but also the “LÜ Alfa” vehicle therefore never has a half width over 1,750 mm. A rail vehicle is called “LÜ Bravo” vehicle, if it has a half width between 1,750 mm and S / 2. The “LÜ Charlie” group includes all vehicles with a half width from S / 2 to S-1,750 mm. Anything that exceeds S-1,750 mm is a “LÜ Delta” vehicle.

The following figure shows an example of the width of vehicles without and with “LÜ” based on a track distance "S" of 4.00 m.

[24] Operational measure which ensures that the train in the opposite / adjacent track (in case of overtaking) is not a train with an inadmissible exceeding of loading gauge also.

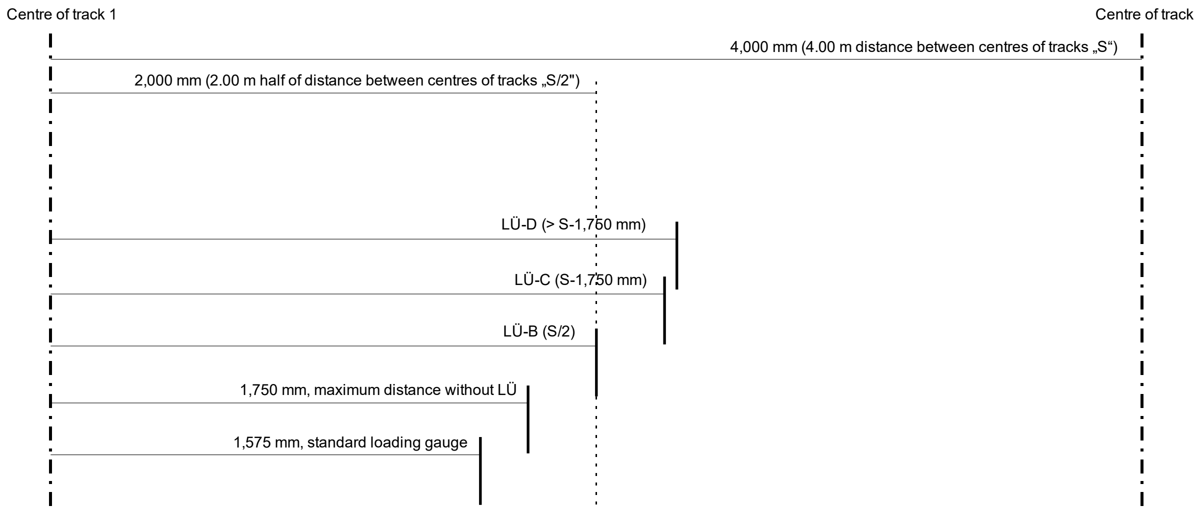


Figure 38: Out of gauge load boundaries for oversized cargo on adjacent tracks – German example

In case of larger or smaller centre of track distances the dimensions change correspondingly. On Rail Baltica the minimum distance between track centres on the main line is 4.50 m. This larger distance compared to conventional lines is mainly provided to avoid impact of unwanted aerodynamical effects between two trains passing each other. To determine the limits for operation of oversized vehicles additional studies need to be carried out to determine the speed limits between to passing trains for oversized cargo.

However, for cross-border transport to Europe the conditions of existing infrastructure have to be taken into account.

Axle load / Load per meter

Rail Baltica is designed for axle load of 25 tonnes. In principle these restrictions need to be complied with. For exceptionally heavy goods special wagons with multiple axles will be used to comply with axle load. If limits are exceeded transports may allowed as special consignments with imposed speed limits and additional empty wagons on both sites of the wagon with overweight subject to individual approval and special calculations by the infrastructure manager.

1.5.3.10.2. Military transport

Load dimensions of combat vehicles

The following table shows the technical data of NATO's combat vehicles, vehicles of the former Warsaw Pact and combat technology under development (PL 01, Poland).

Type	Designation	Length [m]	Width [m]	Height [m]	Mass [t]	"LÜ" 1)
Battle tank	Leopard 2 A4	9.60	3.72	2.80	56.5	B
	Leopard 2 A6	11.27	3.75	3.00	60.1	B
	T-72S	9.54	3.59	2.28	46.5	B
	PT-91	9.53	3.40	2.19	45.5	
	PL-01	7.00	3.59	2.28	46.5	B
Artillery	PzH 2000	11.70	3.56	3.46	55.8	B, H
Armored bridge layer tank	Biber	11.82	4.00	3.55	45.3	B, H
	MZ-55	9.88	3.30	3.35	36.0	H
Infantry fighting vehicle	BMP-1	6.73	2.94	2.07	13.0	
	Marder	6.88	3.38	3.02	35.0	
	Puma	7.60	3.90	3.60	43.0	B, H

1)
B: Exceeding loading gauge in width
H: Exceeding the loading height related to profile G1 and a
height of the car floor of 1.20 m (freight wagon "Samms 489")

Figure 39: Typical Dimensions of combat vehicles

It is obvious that in particular tanks, artillery and armoured bridge layer tanks exceed the loading dimensions: this combat technique can only be transported by rail if the corresponding organisational measures are taken in accordance with point 2.1.1.3.

Layout of loading station for Military transport

The loading of military vehicles requires special facilities and a respectively aligned layout of the track systems. The layout of the track systems must have in consideration the aspects of secrecy. The track systems should not be immediately visible, if this does not result in unreasonably high costs. The special facilities include in particular loading ramps. Only by loading ramps, it is possible to quickly load or unload military vehicles on / from rail wagons. The loading ramps are to be arranged in a manner that the military vehicles can be loaded / unloaded moving forward. However, necessary changes in railway operation can require unloading military vehicles driving backwards. As long as it refers to single military vehicles, this is not a big problem. However, to unload vehicles with trailers by driving-backwards-mode, then the situation is extremely problematic and can lead to accidents very quickly. For such cases, at least one spare ramp should be provided which allows unloading in the other / forward direction. The track layout must enable the handling / loading of such wagon groups. The following figure gives an example of a respective station layout.

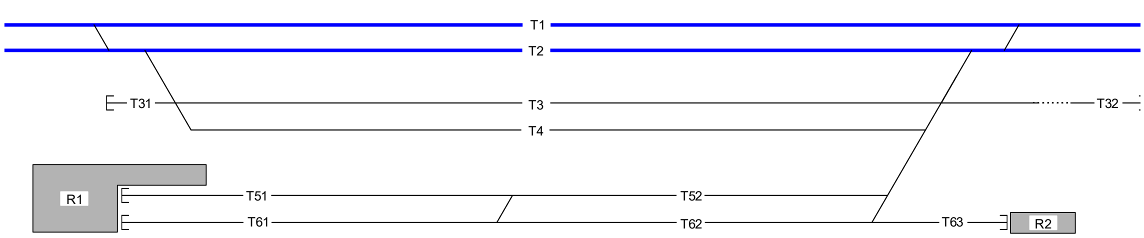


Figure 40: Sample track Layout for military loading point

Legend:

T1/2: Main lines

T3/4: Entry / exit tracks of the military loading station
The distance to the main lines should be chosen in a way that a privacy protection barrier in the form of an earthen wall, a tree strip or a similar installation can be built in between.

T31: Turning track for the locomotive
If a separate shunting locomotive is required, then the respective engine shed can be built on this track.

T32: Turnout track
Preferably the turnout track should have the length of a train plus the length of the train or shunting lo-comotive. The minimum length is half the train length plus the length of the train or shunting locomotive.

T51-63: Loading / unloading tracks
The total length of the tracks T51 / T52 or T61 / T62 should be equal to the train length. The length of T52 or T63 should have such dimension that a wagon group, standing at ramp R2 for loading / unloading, can be bypassed. The length of T63 should have such dimension that at least one wagon can be parked there.

R1: Main loading / unloading ramp
This ramp has to be designed as a combined end-loading and side-loading ramp. The side-loading ramp in its horizontal section must be designed in such a way that cargo can be loaded directly from the wagon onto a truck (different vehicle heights have to be considered).

R2: Spare ramp
The ramp is used to handle / unload military vehicles that have to be unloaded in opposite direction.

1.5.3.10.3. 1520 mm-gauge wagons on standard gauge tracks

If it is envisaged that conventional 1520 mm-gauge vehicles will also be operated on regular gauge tracks (exchange of bogies or vehicles with adjustable wheel sets), then there is also the problem of out-of-gauge load since the dimensions of the 1520 mm loading gauge differ, both in height and in width. Given the width limit of 3.15 m of the relevant loading gauges GC (used on Rail Baltica) and G2 (standard for target countries in central Europe, e.g. Poland, Germany, Netherlands) these wagons have to be transported as oversize transport under special operating conditions. Another interoperability issue are the different braking and coupling systems incorporated (buffers and screw type coupler for 1435 mm trains, central buffer coupler SA-3 coupler without additional buffers for 1520 mm trains). Most common practice is to use adapter cars (fitted with screw type couplers on one end, SA-3 couplers on the other end). This solution requires transport of wagons in a closed group.

Which group of the exceeding of the loading gauge is applicable here depends on the type of wagons actually transported. With proposed minimum track distance of 4500 mm the conditions will be more favourable on Rail

Baltica compared to Central Europe. However, for international transport to Central Europe the condition of TSI (e. g. TSI WAG) and the national infrastructure providers must be met. Due to different brake systems on conventional wagons special operating conditions apply for operation of 1520 mm wagons on 1435 mm.

Regarding distance between track centres it should be ensured that these wagons can be operated without major operational obstacles. Therefore the minimum track distance of 4.00 m must not be compromised.

In stations and especially in freight yards and terminals it must be ensured that vehicles with half width of up to 2.00 m can be safely operated without obstruction of movements on adjacent tracks.

If 1520 mm wagons shall be transported as standard loads without additional operational measures the standards outlined in current TSI INF shall be taken into account. That would mean application of the following infrastructure parameters:

- Minimum track distance for 1520 mm rail system: 4.10 m also to be applied on freight lines and within freight terminals.[25]
- Minimum track distance 4.50 m for lines with speed 200 to 249 km/h as already foreseen in Rail Baltica Design Guidelines. For upgrade to speed higher than 249 km/h in the future a minimum track distance of 4.70 m would be required.[26]
- Application of wider and higher clearance gauge S along the complete line.[27]

1.5.3.10.4. Other oversized cargo

For transport of other oversized cargo the principles outlined above will be applicable. Standard is to agree on every special transport before.

For handling of special oversized cargo a loading track with sufficient space of the road side allowing for heavy lifting equipment (mobile cranes) if needed and for operation of heavy and over dimensioned road vehicles with easy access to main roads shall be provided. In larger terminals loading and unloading should not interfere with normal operation.

To speed up preparation process for oversized/overweight cargo limits and restrictions shall be pre-defined as part of operational rules. Related work by infrastructure manager could be supported by an infrastructure database con-

[25] Commission regulation (EU) No 1299/2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union; clause 4.2.3.2, table 5
[26] Commission regulation (EU) No 1299/2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union; clause 4.2.3.2, table 5
[27] Commission regulation (EU) No 1299/2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union; appendix H.

taining relevant size and dimension of infrastructure elements near the track. This system could be supported with data from building information management systems.

1.5.3.11. Interface to 1520 mm

The majority of freight exchanged between 1435 mm and 1520 mm network is currently transhipped at the border stations. In principle, the same will apply to Rail Baltica freight as long as no innovative technical solutions for a gauge change are used.

The terminals in Muuga, Salaspils, Kaunas (Palemonas) and Vilnius are planned to be served by 1520 mm as well. For the Panevezys terminal this option is also foreseen. The terminal layout will allow direct vertical transhipment of intermodal units (wagon- wagon) if needed and supported by the train timetable, short transfer times can be ensured (min. train or wagon dwell time approx.. 1 hour with respect to necessary checks and time for transhipment of intermodal units).

Additional transhipment of freight between conventional wagons will require considerable time and money. If transhipment of conventional wagons (e. g. pumping of liquids) is practised it might take up to more than an hour per wagon to perform such an operation.

The technologies to overcome these shortcomings are automatic track gauge changeover systems (ATGCS). Prerequisite for the automatic track gauge changeover is that special wagons equipped with variable gauge wheelsets containing a variable gauge axle (VGA). Current solutions for 1435 mm / 1520 mm are on the market for more than a decade now, but are only rarely used:

- .SUW2000 system developed by Poland. This system was used for example for passenger trains between Poland and Vilnius. The related gauge changing facility is situated at Mockava station.
- Dedicated wheelset for freight operation (DBAG–Rafil Type V) developed by German Railways.

Due to the additional costs for the more complex wagons the main application area of such systems would be dedicated shuttle services with short circulation time and regular service intervals. Otherwise the required fleet size or the low fleet utilisation will not allow providing a competitive service. Thus gauge changing facilities will only be needed for a limited number of wagons for special purposes where dedicated fleets can be justified. Currently, it cannot be predicted that these conditions will change significantly due to the overall size of the 1520 mm network, where interoperability needs to be ensured as well and circulation times are long due to the distances from/to relevant destinations for major transit flows.

However, usage of gauge changing facilities and innovative freight wagons would be a means to extend the range of Rail Baltica to railway sidings (e.g. for chemical and fertilizer industry, building material, wood loading, paper industry) within each of the three Baltic states. Furthermore such a solution might be advantageous to quickly deploy military equipment using Rail Baltica. Therefore a separate study to identify future demand and to develop service patterns utilising the rolling stock in a way allowing economic usage of such wagons is recommended.

From the current state of affairs, intermodal transport relying on standard wagons and investment in innovative intermodal loading units will be the more likely and flexible alternative, especially for long distance transport.

1.5.3.12. Conclusions

The studies available only allow a rough estimate of total volumes and no detailed assessment based on OD relations and cargo categories. Given the expected commodity structure, the nearly complete absence of 1435 mm private railway sidings on 1435 mm in the Baltic States and the existing 1520 mm network available for freight service, the main business case for Rail Baltica will be intermodal services.

To provide efficient intermodal services the following preconditions must be fulfilled:

- Handling of intermodal block trains at the major terminals with minimum shunting effort shall be possible
- Terminal design for transhipment of standard intermodal units (containers and swap bodies) and handling of unaccompanied semi-trailers
- Facilitation of intermediate stops of intermodal trains at the terminals, either by direct entrance to the loading tracks or by exchange of groups in the reception sidings

Currently it is uncertain to which extend additional wagonload freight services can be successfully implemented. However, the freight forecasts indicate some demand which shall be supported. Therefore, the terminal facilities shall provide:

- Sufficient space for separate loading tracks, mainly to handle dry bulk and project cargo if required
- Sufficient space for development of rail port functionality to support consolidation of general cargo (warehousing and storage area)
- Support for exchange of wagon groups in the terminal reception sidings to allow transport of wagon groups in intermodal or wagonload block trains

At least for transport of parcels and mail between the Baltic States a high priority express freight service might be established. To cover the full distance between Vilnius and Tallinn during the night (22.00 pm to 6.00 am. the need to provide dedicated wagons and to allow maximum speed to more than 120 km/h (up to 160 km/h) would be advantageous.

For overall estimation of traffic and line capacity the simplified approach with two freight train categories will be sufficient. The currently available information from the CBA and other studies does not provide enough certainty about modal shift potential, local demand distribution along Rail Baltica corridor.

From perspective of business development and to initiate further technical and organisational action to facilitate modal shift to rail the following complementary studies are recommended:

- Detailed analysis of transhipment potential and related service concepts for freight from/to international 1520 mm destinations (CIS, Kazakhstan, China)
- Assessment of regional intermodal and bulk freight potential along the line regarding optional railway terminals for intermodal and bulk freight (Pärnu study is under way, other destinations to follow, e. g. Panevezys, Jonava, Marijampolė)
- Detailed requirements analysis for military transport (origin / destination stations along Rail Baltica route, required terminal facilities)
- Assessment of feasibility to provide direct rail connections to important industrial and logistical sites in the nearer catchment area (e. g. port of Riga, industrial sites in Jonava and Vilnius area) either by gauge change or 1435 mm railway infrastructure)
- Optimisation of the inner harbour interface for intermodal and Ro-Ro cargo at Muuga port (If not already covered in final version of Muuga study)
- Demand analysis and feasibility study for establishing night express rail freight connections between Vilnius and Tallinn and Vilnius – Warszawa for postal and other time critical logistics services, including integration in existing postal logistics network, and with regard to the strong competitive position of Baltic sea ferries
- Integration of Rail Baltica in the paper and wood transport logistic chains: sources and destinations, port transhipment (e. g. Muuga), loading units to be used, collection of raw material along Rail Baltica Future potential of rolling motorway services.

All these studies should be conducted involving stakeholders from the client side as well as from potential logistics service providers. Furthermore, the on-going business plan study and the new market study for RFC 8 covering also the Baltic States and Rail Baltica should provide further information regarding freight market development.

The overall approach should be common, depending on the specific topics to be addressed. Common principles should include:

- Setup of a common scenario framework
- Setup of a common freight transport model
- Inclusion of stakeholders via local advisory groups and closed coordination with RAG / TAG of North Sea Baltic freight corridor
- Closed coordination with national and local authorities and initiatives
- Benchmarking of result with achievments in other regions and on other Rail Freight corridors.

2. Rolling Stock (WP 2)

2.1. Scope and Methodology

The following overall methodology has been applied to conduct the study:

1. Collection of officially available information about locomotives, EMUs and DMUs, passenger and freight wagons that could potentially be used for Rail Baltica train services (includes offered rolling stock by manufacturers in Europe and actual running rolling stock in Germany and Poland),
2. Benchmark of currently available rolling stock,
3. Identification of existing and useful types of rolling stock for RB route by respecting the design requirements to be met,
4. Definition of relevant fleets for different time periods,
5. Additional in-depth analysis on relevant traction characteristics and braking curves, coefficients of rotating mass compared to overall mass of the trains, details about door closing time etc. for RailSys Model (will not be published in the document),
6. Provision of results as input for RailSys modelling (WP 4 and WP8),
7. Proposal for typical fleets for the different time periods to be used on the RB route.

The analysis of the market with respect to actual existing rolling stock types in Poland and Germany as well as offered rolling stock products of the manufacturers, created a comprehensive database of locomotives (diesel, electric, single-system and multi-system locos), wagons and electrical or diesel multiple units (EMU, DMU). Analysis of diesel option for main line operation was required in the ToR as an option for the first years of operation; therefore it is included in this report. This database contains about 560 different vehicles based on an intensive research and market analysis. The IFB database CEMIS reflects the overall market and shows, that from 1990 to 2015 756 electrical multi-system (with 25 kV 50 Hz) locomotives were placed into service in Germany and only 179 in Poland, Romania, Slovenia and Hungary together. All locomotives were built by Bombardier or Siemens, while Bombardier dominates the area for freight locomotives by 70%.

The following chapter starts with a comprehensive enumeration of existing rolling stock and a respective benchmark. In a further step, fleets consisting of new rolling stock of the manufacturers and rolling stock which is already in service in Poland or Germany are proposed and/or analysed as typical train sets for the Rail Baltica route. This is divided into the following parts:

- Long Distance Passenger Service
  - Train Set,
  - EMU,
  - DMU,
  - Night Service;
- Regional Distance Passenger Service
  - Train Set,
  - EMU,
  - DMU;
- Freight Service
  - Locomotives,
  - Intermodal Wagons,
  - Tank Wagons,
  - Bulk Wagons;
- Shunting Locomotives.

According to the proposed supply and the request in the ToR to respect existing vehicles, for each segment, except the Night Service, two sets were defined. One set consisting of currently existing rolling stock and the other set of currently available (new) rolling stock. The basis for the definition criterias are the technical information and the benchmark chapter. At the end of the subchapter for the Long Distance Passenger Service and the Regional Distance Passenger Service a generical train, based on average values, is proposed. The chapter of the Freight Service includes proposals for different kind of freight trains with different lengths, payloads, different total masses and different freight wagons.

The presented fleets consist of technical information for every single piece of rolling stock and for the complete fleet. The existing rolling stock of the Baltic States is excluded due to their wider gauge of 1520 mm. The basis for the compilation is the database of possible rolling stock for the Rail Baltica Route as well as new available rolling stock of the manufacturers. This database is filtered according to the boundary conditions of the Rail Baltica Route and further requirement for the provision of an adequate service.

2.2. Technical design requirements

The following design requirements need to be met by any rolling stock recommended to be used:

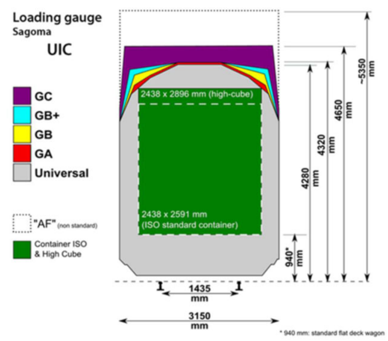
No.	Item	Characteristics
1	Track gauge	1435 mm
2	Clearance / gauge	Specified as GB (passengers) and GC (freight). These 2 values are compliant with INF TSI standards for P2 and F1 traffic category (according to SYSTRA Final Report (Design Guideline from 12.01.2018). The overall clearance / gauge will be GC according to Design Guideline Manual RBDG-MAN-012-0101 from 09.04.2018. This condition requires GC profile in Passenger Train Stations too. 
3	Axle load	25 t – value is in compliance with INF TSI standards for P2 and F1 traffic category
4	Design speed passenger trains	249 km/h
5	Design speed freight trains	100 km/h – 120 km/h
6	Turnout speed	100 km/h
7	Length of passenger trains	up to 200 m with the possibility to extend it to 400 m in the future
8	Length of freight trains	1,050 m

Table 42: Infrastructure parameters as boundary conditions for selection of rolling stock

Especially for the fleet compilation the numbers 1, 2, 3, 4, 5, 7 and 8 are of notable interest. Further requirements are the train control system ERTMS for the Rail Baltica Route and a full compliance to the relevant TSI regulations.

2.3. Benchmark of existing rolling stock

The following enumeration gives a comprehensive list of actual available rolling stock (locomotives, wagons, EMUs DMUs), which are available from different suppliers. The enumeration is an extract from a wide list/table in the Annexes 2 to 6. For the Benchmark only vehicles with known CAPEX were chosen to present in this chapter. It is not the demand for both lists/tables to be exhaustive and complete.

The sources for the indicative prices were mainly official orders and former contracts regarding different amount of rolling stock, personal contacts, official offers and a study from "École Polytechnique Fédérale de Lausanne"[28].

It is part of the required reference for the TSI that for new orders each type of rolling stock must pass the following inspections.

For freight wagons:

- TSI Noise (1)
- TSI Wag (2)

For Locomotives, EMUs and DMUs:

- TSI Noise
- TSO CCS (3)
- TSI OPE (4)
- TSI SRT (5)
- TSI PRM (6)
- TSI CR Loc&Pas (7)

For High-speed-Trains the TSI HS RST (8) has to be fulfilled too.

Further relevant directives are:

- EMC-Directive (2004/108/EC)
- Air Pollution (2004/26/EG).

[28] J.P. Baumgartner, Prizes And Costs In The Railway Sector, EPFL – École Polytechnique Fédérale de Lausanne, LITEP – Laboratoire d'Intermodalité des Transports et de Planification, Bâtiment de Génie civil, Lausanne, January 2001

This enumeration does not claim to be complete due to the extensive and complex homologation process. In ANNEX 2 to this document a table is included, where the TSIs are listed, which at present need to be adhered to by the suppliers. Sometimes only general information exists, that all TSIs are fulfilled with regard to a specific type of rolling stock.

2.3.1. Locomotives

The standard price for a 4-axle or 6-axle locomotives is very similar and in a range of about 3 to 5 million Euro. The price for a single unit depends normally on the amount of locomotives in the order, the extent of country homologations, which are necessary beside the TSI, and especially on the scope of equipment ordered. This scope includes for example the electric current system or the amount of additional train control systems. Especially for freight locomotives, this part is very important due to the international freight services. For example, an AC – Locomotive has 3% and a MS – Locomotive 15% higher investment costs[29] than a DC – Locomotive.

Furthermore, most of the locomotives, especially the passenger locomotives, are 4–axle locomotives with four traction motors and 300 kN haulage capacities. This can be taken as a standard.

For minimizing the production costs, most of the locomotives are based on a modular / platform concept which means, that they could be built as freight or passenger locomotives. The main differences between these modules with regard to freight locomotives are the missing of a power supply line (freight), lower maximum velocities (freight) and a different gearing (gear ratio). Therefore, the use of freight train locomotives with passenger wagons is not possible in regular train service. The other way round the passenger locomotives have a gear ratio for running at higher speeds but not to carry high masses. Use of passenger locomotives in freight service could lead to defects with the gearing in the worst case and to very slow accelerations. At this point a mixed usage is not possible, but as a minimum not recommended.

The following table shows the benchmark of locomotives, for which the indicative prices are known. Very often these prices are given in a certain range. For calculation purposes specific prices were estimated based on collected experiences during the research. The relevant parameters for the benchmark are the indicative price, the power and the starting tractive effort. As a benchmark, the quotient of Power per 1 million Euro and Tractive Effort per 1 million Euro were chosen. Furthermore, it should be mentioned, that the following table consists every locomotive with known CAPEX, even the locomotives without an actual compliance to all relevant TSI regulations. For this question, the annexes 2 – 6 must be considered. It is mentioned at this point, that for new ordered locomotives every manufacturer will offer complete TSI compliance if it is required.

Unfortunately it was not possible to gain the CAPEX for all relevant rolling stock vehicles, so this list/table could only be seen as an extract.

[29] Source : Presentation of Axel Schuppe and Ralf Fleischmann (VDB, Bombardier Transportation) at the Technical University Berlin

Type	Name	Indicative Price	Estimated Indicative Price [mill EUR]	Power (kW)	Start-ing tractive effort (kN)	Power/ Price [kW / 1mill EUR]	Tractive Effort/ Prise [kN / 1mill EUR]
Passenger, Freight	Vectron MS	3-5mill EUR	5	6,400	300	1,280	60
Passenger, Freight	Vectron AC high Power	3-5mill EUR	4.5	6,400	300	1,422.22	66.66
Passenger, Freight	Vectron AC medium Power	3-5mill EUR	4	5,600	300	1,400	75
Passenger, Freight	Vectron DC	3-5mill EUR	3.4	5,200	300	1,529.41	88.23
Passenger, Freight	Vectron DE	3-5mill EUR	3.2	2,400	275	750	85.93
Freight (only Germany)	Smartron	Estimated 3mill EURO	3	5,600	300	1,866.66	100
Freight/Pass enger	EURO 4000	~ 3.3mill EUR	3.3	3,178	400	963.03	121.21
Freight/Pass enger	Eurodual (4-axle)	~ 3.68mill EUR	3.68	4,000	317	1,086.95	86.14
Freight	Eurodual (6-axle)	5.5mill EUR	5.5	6,150	500	1,118.18	90.90
Passenger (Regional), Freight	Traxx 3 (Traxx F160 AC3, MS3, DC3, Traxx P160 AC3)	3.2 - 4.2mill EUR	4.2	5,600	300	1,333.33	71.42
Passenger (Regional), Freight	Traxx Diesel	3mill EUR	3	2,252	300	750.67	100
Passenger and Freight	Prima II	3.75mill EUR	3.75	6,400	320	1,706.66	85.33
Passenger	109E, 109E2, 109E3	ca. 120m CZK, 4.7m Euro	4.7	6,400	275	1,361.70	58.51
Passenger, Freight	Universal-Locomotive	ca. 120m CZK, 4.7m	4.7	6,400	350	1,361.70	74.46
Freight	Dragon DC	15m PLN, ca. 3.51mill EUR	3.51	5,000	450	1,424.50	128.20
Freight	Dragon AC	+ 3% to DC	3.6153	7,200	450	1,991.53	124.47
Freight	Dragon MS	+ 15% to DC	4.0365	7,200	450	1,783.72	111.48
Freight	Dragon diesel	ca. 15m PLN, ca. 3.51mill EUR	3.51	2,300	370	655.27	105.41
Passenger, Freight	Griffin E4DCU/E4DCP	18.35 PLN 4.29mill EUR	4.29	5,600	310	1,305.36	72.26
Passenger, Freight	Griffin E4ACU/E4ACP	+ 3% to DC	4.4187	5,600	310	1,267.34	70.15

Type	Name	Indicative Price	Estimated Indicative Price [mill EUR]	Power (kW)	Start-ing tractive effort (kN)	Power/ Price [kW / 1mill EUR]	Tractive Effort/ Prise [kN / 1mill EUR]
Passenger, Freight	Griffin E4MSU/E4MSP	+ 15% to DC	4.9335	5,600	310	1,135.09	62.83
Shunting	15D/16D	1.83mill EUR	1.83	1,550	372.8	846.99	203.71
Shunting	6DI	3.85mill PLN 0.9 mill EUR	0.9	563	219	625.55	243.33
Passenger	Class SU160 (111Dd Gama)	13.12m PLN 3.07mill EUR	3.07	2,400	300	781.75	97.71
Shunting	G 6	1.4mill EUR	1.4	650	219	464.28	156.42
Shunting, Freight	G 18 / DE 18	3.2mill EUR	3.2	1,800	291	562.5	90.93
Shunting	Butler	2.55mill EUR	2.55	1,500	150	588.23	58.82
Shunting	Prima H4	1.75mill EUR	1.75	2,000	300	1,142.86	171.43

Table 43: Benchmarks for locomotives

Summarizing the quotient "power/price" the 6-axle locomotive Dragon AC from Newag has the best ratio with 1,991.54 kW per 1m Euro. Followed by the 4-axle locomotives Smartron from Siemens, which is at present only produced for the German market and Prima II by Alstom. It is obvious that no diesel-locomotive has a good quotient "power/price".

Summarizing the second quotient "tractive/price" shunting locomotives have the best ratio (Newag 6DI, 243 kN/1 mill EUR; Newag 15D/16D, 203 kN/1mill EUR; Alstom Prima H4 171.43 kN/1mill EUR, Vossloh G6 156 kN/1mill EUR). Beside the shunting locomotives, the 6-axle locomotive Newag Dragon DC and AC (128, 121 kN/1mill EUR) leads this enumeration, followed by Stadler Euro 4000 (121 kN/1mill EUR), Newag Dragon MS and Diesel (111, 105 kN/1mill EUR), Siemens Smartron (100 kN/1mill EUR), Bombardier Traxx Diesel (100 kN/1mill EUR), Stadler Eurodual 6-axle (90 kN/1mill EUR) and Prima II (85 kN/1mill EUR).

Summarizing all known prices, the most expensive locomotive regarding CAPEX is the Stadler Eurodual 6-axle locomotive with 5.5 million Euro. The most likely reasons for this are the low amount of orders and/or the bi-traction principle (diesel-traction / electric traction). It means that this locomotive is the combination of two locomotive types for long distances (no last mile diesel) in one. Furthermore, this locomotive has the highest starting tractive effort with 500 kN and could replace two 4-axle locomotives.

Finally, some specific parameters (power, tractive effort, weight) from all locomotives of the table in Annex 2 (without shunting locomotives) will be averaged by:

- 4-axle electric locomotives,
- 4-axle diesel locomotives,

- 6-axle electric locomotives,
- 6-axle diesel locomotives.

	4-axle electric	4-axle diesel	6-axle electric	6-axle diesel
Average Power [kW]	5475	2046	6000	2702.2
Maximum Power [kW]	6400 (Siemens, Skoda, Alstom)	2900 (CAF)	7200 (Newag)	3178 (Stadler)
Average Tractive Effort [kN]	297	258	458	420.4
Maximum Tractive Effort [kN]	350 (Skoda, 25t axle load) 300 kN (common)	317 (Stadler)	500 (Stadler)	500 (Stadler)
Average Weight [t]	79	85.44	122.6	123.8
Maximum Weight [t]	100 (Skoda 25 t axle load) 90 (Alstom)	90 (Vossloh, CAF)	126 (Stadler), 130 (CAF)	126 (Stadler), 130 (CAF)

Table 44: Average Values for Locomotives

The maximum velocity for actual offered locomotives is 200 km/h. No locomotives with higher velocities are currently supplied on the market at the moment, if the prototype Patentes Talgo TravcaL-9202 with 260 km/h is not be considered. Looking to actual existing/running locomotives the closed Siemens platform Eurosprinter (with ES64P, ES64U2 and ES64U4) has a maximum velocity of 230 km/h. The delivery was closed at 2011 with ES64U4. Especially the car body was designed and built to old standards and outgoing from the actual state of the art, the technical equipment for traction, braking and train control system could also be obsolete. That means that a reactivation of this type for production seems not to be economical, especially with respect to the platform type Vectron (200 km/h).

At the end it is remarked, that all shown locomotives in the benchmark have a maximum axle load of 22.5 t. Although the maximum axle load for the Rail Baltica Route is 25 t, locomotives with 25 t axle loads will be an island solution and seems to be not economical at the moment (interoperatbility) as well as they were not offered standardly by the manufacturers.

2.3.2. Passenger and Freight Wagons

The table in ANNEX 3 gives an overview with regard to the available freight and passenger wagons. Because of the actual low request for this type of rolling stock the list for passenger wagons is rather short. The list for freight wagons can only be taken as an overview, based on information from the two biggest freight wagon suppliers in Europe. These two suppliers offer nearly the complete range of available freight wagons.

Due to a lack of comprehensive information it is not possible to give a complete overview of the actual available freight wagons in Europe. Reason is that there is no dedicated database available comprising all information from all countries, train operation companies, leasing companies and other owners.

According to information provided by the German Parliament ("Bundestag") and the German Federal Railway Agency ("Eisenbahnbundesamt"), in Germany around 180,000 freight wagons are registered, but specific types are not mentioned. Furthermore, PKP Cargo just posted on their website, that they own about 62,500 freight wagons. According to the "FIS Research Information System - Mobility and Transport", the total number of freight wagons in Europe is estimated at 600,000. With German Railway (DB AG) being the owner of about 70,000 – 80,000 freight wagons.

This figure includes a share of the following types of freight wagons:

- 46% flat wagons (UIC Code K,L,R,S,O),
- 1% other wagons (UIC Code U,Z),
- 24% covered wagons (UIC Code G,H,I,T),
- 29% open wagons (UIC Code E,F).

In private ownership are 100,000 to 110,000 freight wagons with:

- 34% flat wagons (UIC Code K,L,R,S,O),
- 45% other wagons (UIC Code U,Z),
- 13% covered wagons (UIC Code G,H,I,T),
- 8% open wagons (UIC Code E,F).

Unfortunately, no information is available concerning the number of freight wagons having the standard UIC coupling or the stronger UIC standard coupling, respective central buffer coupling for 4,000 t heavy transportations.

Passenger wagons:

Concerning the platform heights, especially passenger wagons for public or regional passenger transport have low floor entry with variable entrance height above the top of the rail (ToR). Very often, the entrance heights are optimised to the platform heights and in case of variable platform heights, step treads are used (public, regional passenger transport). Normally, the entrance height in passenger wagons for long distances, or in EMU's, DMU's for long distances is about 1,250 mm above top of the rail.

Model	Supplier	Trans-port Type	Length over	Passenger capacity	Estima-ted	Passen-ger/LoB [-	Seats/ LoB [-/m]	Passen-ger/ Price

			Buffers (LoB) [mm]	Estimated Total Number of Passengers	Estimated Number of Seats	**Indicative Price**	**/m]**		**[-/1mill EUR]**
Sundeck driving Coach 316B	Pesa	Passenger	26,270	229	85	2	8.72	3.23	114.5
Sundeck 416B	Pesa	Passenger	25,800	260	130	2	10.08	5.03	130
Viaggio Classic	Siemens Mobility	Sleeper	26,400	60	60	2	2.27	2.27	30
Viaggio Light	Stadler AG	Passenger	26,400	90	90	1.5	3.40	3.40	60
Viaggio Comfort (Cab Car)	Siemens Mobility	Passenger	26,850	48	48	2.3	1.78	1.78	20.87
Viaggio Comfort	Siemens Mobility	Passenger Bistro	26,500	50	50	2.3	1.88	1.88	21.73
Viaggio Comfort (First Class)	Siemens Mobility	Passenger	26,500	60	60	2.3	2.26	2.26	26.08
Viaggio Comfort (Economy)	Siemens Mobility	Passenger	26,450	90	90	2.3	3.40	3.40	39.13
Viaggio Twin	Siemens Mobility	Passenger	26,800	270	140	2	10.07	5.22	135
Twindexx Vario (Cab Car)	Bombardier Transportation	Passenger	27,270	213	73	1.93	7.81	2.67	110.36
Twindexx Vario (Middle Wagon)	Bombardier Transportation	Passenger	26,800	281	121	1.93	10.48	4.51	145.59
single deck coaches (Cab Car)	Bombardier Transportation	Passenger	27,300	186	78	1.6	6.81	2.85	116.25
single deck coaches (Middle Wagon)	Bombardier Transportation	Passenger	27,300	218	95	1.4	7.98	3.47	155.71
single deck coaches (Auxiliary Power Unit)	Bombardier Transportation	Passenger	27,270	173	69	1.8	6.34	2.53	96.11
168A modernisation	Newag	Passenger	24,500	56	56	1.6	2.28	2.28	35
155A modernisation	Newag	Mixed Passenger and Buf-	26,400	30	30	1.6	1.13	1.13	18.75

Model	Supplier	Transport Type	Length over Buffers (LoB) [mm]	Passenger capacity		Estimated Indicative Price	Passenger/LoB [-/m]	Seats/ LoB [-/m]	Passenger/ Price [-/1mill EUR]
				Estimated Total Number of Passengers	Estimated Number of Seats				
		fet							
134Ac modernisation	Newag	Couchette	26,400	60	60	1.7	2.27	2.27	35.29
WR89 modernisation	Newag	Dining	26,400	39	39	2.2	1.47	1.47	17.72

Table 45: Benchmark Passenger Wagons

The benchmarking of passenger wagons shows, that the public transport double deck wagons have the best ratio with regard to every ratio. For the long distance passenger services, both type of wagons, the new Siemens Viaggio Comfort and the Modernisation by Newag have a similar ratio, with a small advantage for the Siemens economy wagon with 90 seats. It must be considered, that the public transport double deck wagons have the best ratio, but do not deliver the best comfort and are not suitable for long distance passenger transport.

Freight wagons:

The following table gives the benchmarks of the actual available freight wagons by Tatravagonka and Greenbrier. This enumeration can be taken as a common overview for actual available freight wagons. Most of the freight wagons are offered with 22.5 t axle loads and only a few with 25 t axle load. Likewise, the velocity depends very often on axle loads and the total weight - more on this topic see chapter 2.6.

For the respective benchmarking, the consideration of the indicative price is not useful due to the great spread of the different wagon types, even in one wagon class. As parameters for benchmarking the Payload, Payload per Length over Buffers and Capacity per Length over Buffers are chosen.

Model	Supplier	Type	Length over Buffers [mm)]	Weight		Exploitable capacity		Payload [t]	Payload/LoB [t/m]	Cap/LoB [m³/m]
				Tare [t]	total weight [t]	Floor area (m²)	Volumetric capacity (m³)			
Closed Car Transport	Tatravagónka	Car	27,400	35	60			25	0.91	
Open Car Transport	Tatravagónka	Car	27,000	28.5	48.5			20	0.74	
One-Level Open Car Transport	Greenbrier	Car	33,000	30.7	90			59.3	1.80	
Two-Level Open Car Transport	Greenbrier	Car	31,000	34	68			34	1.10	
Flat Wagon	Tatravagónka	Freight	13,200	28.5	135	36		106.5	8.07	2.73
Flat Wagon	Tatravagónka	Freight	19,900	25	90	49		65	3.27	2.46
Flat Wagon	Tatravagónka	Freight	20,150	25.5	90	51.5		64.5	3.20	2.56
Covered 4-axle flat wagon	Greenbrier	Freight	20,000	30	90			60	3.00	0.00
Flat Wagon	Tatravagónka	Freight	16,400	43.8	135			91.2	5.56	0.00
Flat Wagon	Tatravagónka	Freight	13,900	20.8	100	37.2		79.2	5.70	2.68
Flat Wagon	Tatravagónka	Freight	13,900	23.4	100	19.2		76.6	5.51	1.38
Flat Wagon	Tatravagónka	Freight	16,400	29.4	135	46		105.6	6.44	2.80
Flat Wagon Modular Carrier	Tatravagónka	Freight	18,240	23.5	72			48.5	2.66	
Flat Wagon Modular Carrier	Tatravagónka	Freight	25,740	28.5	80			51.5	2.00	
Flat Wagon Timber Transport	Tatravagónka	Freight	29,570	28	100			72	2.43	
Flat Wagon Timber Transport	Tatravagónka	Freight	20,770	22	90			68	3.27	
4-axle Steel Product Wagon	Greenbrier	Freight	12,825	21.5	90			68.5	5.34	
4-axle Steel Product Wagon	Greenbrier	Freight	13,740	22	100			78	5.68	
Transportation of Steel Coils	Tatravagónka	Freight	12,040	24	90			66	5.48	

Model	Supplier	Type	Length over Buffers [mm)]	Weight		Exploitable capacity		Payload [t]	Payload/LoB [t/m]	Cap/LoB [m^3/m]
				Tare [t]	total weight [t]	Floor area (m^2)	Volumetric capacity (m^3)			
Transportation of Steel Coils	Tatravagónka & Greenbrier	Freight	12,040	23	100			77	6.40	
Covered 4-axle Steel Product Wagon	Greenbrier	Freight	12,040	22.7	90			67.3	5.59	
4-axle Steel Product Wagon	Greenbrier	Freight	13,900	20.7	90			69.3	4.99	
Covered Wagon	Tatravagónka	Freight	13,200	34	135			101	7.65	
Covered Wagon	Tatravagónka	Freight	23,270	25.9	90	62.5	168	64.1	2.75	2.69
Covered Wagon	Tatravagónka	Freight	23,270	27.2	90	61.1	164.2	62.8	2.70	2.63
Covered Wagon	Tatravagónka	Freight	18,900	28	100	53.6	162	72	3.81	2.84
Covered Wagon	Tatravagónka	Freight	23,350	27.5	100	62.5	167.8	72.5	3.10	2.68
4-axle sliding wall wagon	Greenbrier	Freight	23,900	27.4	100	63.3	170	72.6	3.04	2.65
Hopper Wag-on 85 m^3	Greenbrier	Freight	13,500	25.6	90		85	64.4	4.77	6.30
Hopper Wag-on 87 m^3	Greenbrier	Freight	13,500	24.9	90	63.6	87	65.1	4.82	4.71
Hopper Wag-on 86.6 m^3	Greenbrier	Freight	12,540	24	90		86.6	66	5.26	6.91
Hopper Wag-on 77 m^3	Greenbrier	Freight	12,540	23.7	66.3		77	42.6	3.40	6.14
Open High Sided Wagon	Tatravagónka	Freight	15,740	28.5	90	38.5	80.5	61.5	3.91	2.45
Open High Sided Wagon	Greenbrier	Freight	15,740	24	90	39.4		66	4.19	2.50
Open High Sided Wagon	Tatravagónka	Freight	15,740	24.6	90	39.4	82.7	65.4	4.16	2.50
Hopper Wag-on 95 m^3	Tatravagónka	Freight	16,000	20.6	90		95	69.4	4.34	5.94
Hopper Wag-on 95 m^3	Greenbrier	Freight	17,170	23.5	90		95	66.5	3.87	5.53
Hopper Wag-on 101 m^3	Tatravagónka	Freight	16,000	21	90		101	69	4.31	6.31
Hopper Wag-on 102 m^3	Tatravagónka	Freight	16,000	21.9	90		102	68.1	4.26	6.38
Hopper Wag-on 102 m^3	Greenbrier	Freight	15,400	20.7	90		102	69.3	4.50	6.62
Hopper Wag-on 103 m^3	Tatravagónka	Freight	16,000	21.2	90		103	68.8	4.30	6.44
Hopper Wag-on 130 m^3	Tatravagónka	Freight	16,000	25	90		130	65	4.06	8.13
Hopper Wag-on 130 m^3	Greenbrier	Freight	20,000	22	90		130	68	3.40	6.50
4-axle Hopper Wagon 90 m^3	Greenbrier	Freight	17,180	24	90		90	66	3.84	5.24
4-axle Hopper Wagon 82 m^3	Greenbrier	Freight	19,040	24.1	90		82.5	65.9	3.46	4.33
Hopper Wag-on	Tatravagónka	Freight	15,740	24.5	90		82.5	65.5	4.16	5.24
4-axle self-unloading Hopper Wag-	Greenbrier	Freight	15,800	23	90			67	4.24	

Model	Supplier	Type	Length over Buffers [mm)]	Weight		Exploitable capacity		Payload [t]	Payload/LoB [t/m]	Cap/LoB [m³/m]
				Tare [t]	total weight [t]	Floor area (m²)	Volumetric capacity (m³)			
on										
Hopper Wag-on	Tatravagónka	Freight	30,170	70	300		140	230	7.62	4.64
Hopper Wag-on 80 m³	Tatravagónka	Freight		25.5	90		80	64.5	-	-
Hopper Wag-on 85 m³	Tatravagónka	Freight	14,040	28.2	100		85	71.8	5.11	6.05
Container - Intermodal Wagon (40')	Tatravagónka	Freight	13,540	16.2	90			73.8	5.45	
Container - Intermodal Wagon (45')	Tatravagónka	Freight	15,140	16.5	90			73.5	4.85	
Container - Intermodal Wagon	Tatravagónka	Freight	17,350	16.5	90			73.5	4.24	
Container - Intermodal Wagon	Tatravagónka	Freight	29,590	29	135			106	3.58	
Container - Intermodal Wagon	Tatravagónka	Freight	29,590	29.35	135.14			105.79	3.58	
Container - Intermodal Wagon	Greenbrier	Freight	29,590	27.3	135			107.7	3.64	
Container - Intermodal Wagon	Tatravagónka	Freight	33,480	30	135			105	3.14	
Pocket Wagon	Tatravagónka	Freight	34,030	35	135			100	2.94	
Pocket Wagon	Tatravagónka	Freight	34,200	35	136			101	2.95	
Pocket Wagon	Tatravagónka	Freight	34,200	36.2	137			100.8	2.95	
Container - Intermodal Wagon	Tatravagónka	Freight	19,830	19	90			71	3.58	
Container - Intermodal Wagon	Greenbrier	Freight	19,640	19	90			71	3.62	
Container - Intermodal Wagon	Tatravagónka	Freight	25,940	21.5	90			68.5	2.64	
Container - Intermodal Wagon	Tatravagónka	Freight	26,390	27.5	135			107.5	4.07	
Container - Intermodal Wagon	Tatravagónka	Freight	26,390	25.3	115.3			90	3.41	
Container - Intermodal Wagon	Greenbrier	Freight	26,390	26.2	135			108.8	4.12	
Container Wagon	Tatravagónka	Freight	21,780	25.5	90			64.5	2.96	
Tank Wagon	Tatravagónka	Freight	11,940	21	90		40	69	5.78	3.35
Tank Wagon	Greenbrier	Freight	14,960	21.6	90		85	68.4	4.57	5.68
Tank Wagon	Tatravagónka	Freight	15,140	21.4	90		88	68.6	4.53	5.81
Tank Wagon	Tatravagónka	Freight	16,880	25	90		95	65	3.85	5.63
Tank Wagon	Tatravagónka	Freight	12,260	19	90		44	71	5.79	3.59
Tank Wagon	Tatravagónka	Freight	13,455	24	90		54	66	4.91	4.01
Tank Wagon	Tatravagónka	Freight	15,110	22.3	90		62	67.7	4.48	4.10
Tank Wagon	Tatravagónka	Freight	16,640	24	90		88	66	3.97	5.29

Model	Supplier	Type	Length over Buffers [mm)]	Weight		Exploitable capacity		Payload [t]	Payload/LoB [t/m]	Cap/LoB [m³/m]
				Tare [t]	total weight [t]	Floor area (m²)	Volumetric capacity (m³)			
Tank Wagon	Greenbrier	Freight	17,000	24.3	90		95	65.7	3.86	5.59
Tank Wagon	Greenbrier	Freight	15,130	21.4	90		87	68.6	4.53	5.75
Tank Wagon	Tatravagónka	Freight	15,000	20.7	90		89	69.3	4.62	5.93
Tank Wagon	Greenbrier	Freight	16,690	22.6	90		97	67.4	4.04	5.81
Tank Wagon	Tatravagónka	Freight	16,400	21.8	90		98	68.2	4.16	5.98
Tank Wagon	Tatravagónka	Freight	15,908	28.9	90		64	61.1	3.84	4.02
Tank Wagon	Tatravagónka	Freight	15,040	24.1	90		73	65.9	4.38	4.85
Tank Wagon	Greenbrier	Freight	15,040	25.4	90		73	64.6	4.30	4.85
Tank Wagon	Greenbrier	Freight	15,860	24	90		79	66	4.16	4.98
Tank Wagon	Tatravagónka	Freight	16,700	26.1	90		80	63.9	3.83	4.79
Tank Wagon	Greenbrier	Freight	16,960	35.7	90		103	54.3	3.20	6.07
Tank Wagon	Greenbrier	Freight	18,000	32	90		112	58	3.22	6.22
Tank Wagon	Greenbrier	Freight	18,000	32.25	90		113	57.75	3.21	6.28
Tank Wagon	Tatravagónka	Freight	18,000	33	90		117	57	3.17	6.50
Tank Wagon	Greenbrier	Freight	19,720	33.4	90		122	56.6	2.87	6.19
Tank Wagon	Tatravagónka	Freight	13,455	25	90		54	65	4.83	4.01
Intermodal Wagon	Greenbrier	Freight	36,440	39	128			89	2.44	0.00
Intermodal Wagon	Greenbrier	Freight	37,720	48	128			80	2.12	0.00
Flat Wagon with Tarpaulin Top	Greenbrier	Freight	16,500	27.6	90	39		62.4	3.78	2.36
Flat Wagon	Greenbrier	Freight	22,350	25	90	55.2		65	2.91	2.47
Flat Wagon	Greenbrier	Freight	19,900	24.6	90	51		65.4	3.29	2.56
Flat Wagon	Greenbrier	Freight	19,640	23.1	90	51		66.9	3.41	2.60
Timber Wagon	Greenbrier	Freight	19,640	22.5	90			67.5	3.44	0.00
Special Hop-per Wagon - 4U	Greenbrier	Freight	51,120	116.5	360		193.5	243.5	4.76	0.00
Special Hop-per Wagon - 6U	Greenbrier	Freight	74,640	167.7	540		298.7	372.3	4.99	0.00
Special Hop-per Wagon	Greenbrier	Freight	15,000	26.2	90		40	63.8	4.25	0.00

Table 46: Benchmark Freight Wagon

For transportation of Containers, flat wagons, intermodal wagons and container intermodal wagons can be used. In this case, the best payload can be realised with a two- part container intermodal freight wagons with 3 bogies, and with up to 108.8 t payload. Also single car flat wagons with 3-axle bogies can support such high payloads and can transport, beside containers, military vehicles too. The total payload for these types of wagons ranges from 48.5 t up to 108.8 t. For the ratio of the Payload/LoB the short 2 bogies (6 axles) flat wagon (13,200 mm LoB) leads this enumeration (8.07 t/m). The first freight wagon just for container transportations (container intermodal wagon) is at position 6 with 4 axles, LoB of 13,540 and a ratio of 5.45 t/m. An evaluation of the ratio Cap/LoB is not useful due to the limited information about the capacity for intermodal wagons. This enumeration shows clearly, that the standard container intermodal wagons are not useful to transport goods with huge weight and that most of the flat wagons, if they can carry containers too, are good all-rounders. The big advantage of container intermodal wagons with 3 bogies is the nearly same transport capacity as of two separate wagons with 4 bogies or one 2 part wagon with 3 bogies.

Benchmarking the different types of tank wagons, their payload is in a range between 54.3 t and 71 t. Herein the best payload has a short 44 m^3 tank wagon, which is very suitable for goods with high densities. The counterpart is the large tank wagon with a volume of about 122 m^3 and a payload of about 56.6 t. The best Payload/LoB ratio has the 44 m^3 tank wagon (5.79 t/m^3). In contrast to these results, the ratio of Capacity (Volume) / LoB is led by the 117 m^3 tank wagon with 6.5 m^3/m.

Benchmarking hopper wagons, their payload range is between 42.6 t and 71.8 t. The highest payload, without respecting double wagon or special wagon, has the 85 m^3 wagon with 25 t axle loads and 71.8 t loading capacity. This wagon is followed by 95 m^3 wagon with 69.4 t, 101 m^3 wagon (69 t) 103 m^3 wagon (68.8 t). The best ratio for Payload/LoB has the 86.6 m^3 wagon with 5.26 t/m^3, followed by the 85 m^3 wagon with 5.11 t/ m^3. The above mentioned 95 m^3 wagon follows at position 6 with 4.34 t/m^3. For the ratio of Capacity (Volume) / LoB the 130 m^3 wagon is in the lead with 16,000 mm LoB and 8.13 m^3/m, followed by the 86.6 m^3 wagon with 12,540 mm LoB and 6.91 m^3/m and the 102 m^3 wagon with 15,400 mm LoB and 6.62 m^3/m.

2.3.3. Multiple-Unit Sets

The following Table 47 shows a list of Multiple-Unit Sets at present available on the European market. This list contains different Multiple-Unit Sets and platforms with electric and diesel traction. Similar to the locomotives, every EMU or DMU has to fulfil several TSIs and can normally be equipped with different train control systems. Due to the huge amount of possible vehicles and the fact that it was not possible to get information about the indicative price for every EMU/DMU, the benchmarking concentrates on vehicles with information about power, total number of passengers and seats per indicative price. It will be split into long distance and regional passenger service sets, while the long distance passenger vehicle contains High Speed Trains and standard Long Distance EMU's like the 8 cars Flirt and the Pesa Dart. Furthermore, for regional passenger service the vehicles can be delivered with different entrance heights above ToR. Details – see ANNEX 4.

Regional Passenger Service					
Type	Supplier	Power (kW)	Indicative Price per Unit	Estimated Indicative Price [mill EUR]	Power/ Price [kW/1mill EUR]
Desiro HC	Siemens Mobility	4,000	13.18mill EUR	13.18	303.49
Desiro ML – 3 car	Siemens Mobility	2,600	5.5mill EUR	5.5	472.73
Flirt3 - 3 car	Stadler AG	2,000	7.5mill EUR	7.5	266.67
Flirt3 - 4 car	Stadler AG	2,000	8.2mill EUR	8.2	243.90
GTW	Stadler AG	600	7.25m Dollar 6.29mill EUR	6.29	95.39
KISS 4 cars	Stadler AG	2000	106mill SEK - 10.04mill EUR (4-Cars)	10.4	192.31
KISS 6 cars	Stadler AG	4000	34,44mill Dollar - 29.84 mill EUR	29.84	134.05
WINK	Stadler AG	1000	7.25m Dollar 6.29mill EUR	6.29	158.98
Coradia Continental - 3 cars	Alstom	2160	5.66mill EUR	5.66	381.63
Elf 27WE (6-car)	PESA	3200	13.6mill EUR	13.6	235.29
Elf 22WE (4-car)	PESA	2500	11.374mill EUR	11.374	219.80
Elf 2 21WEa	PESA	1600	6.73mill EUR??	6.73	237.74
Coradia Polyvalent - 4 cars electric	Alstom	1,700	10mill EUR	10	170.00
Coradia Polyvalent - 6 cars electric	Alstom	2,600	11.76mill EUR	11.76	221.09
Atribo ATR220	Pesa SA	780	3.36mill EUR	3.36	232.14
Link 1 car	Pesa SA	565	2.6mill EUR	3	217.31
Twindexx Vario/Dosto 2010 - 4-Cars	Bombardier	2,300	10mill EUR	10	230.00

Table 47: Multiple-Unit sets – Regional passenger service (1)

Long Distance Passenger Service					
Type	Supplier	Power (kW)	Indicative Price per Unit	Estimated Indicative Price [mill EUR]	Power/ Price [kW/1mill EUR]
ICE 4 (7-cars)	Siemens Mobility	4,950	~ 36mill EUR	36	137.55
ICE 4 (12-cars)	Siemens Mobility	9,900	~ 52mill EUR	52	190.38
Velaro D (8-cars) DC	Siemens Mobility	4200	~33mill EUR	33	127.27
Velaro D (8-cars) AC	Siemens Mobility	8000	34mill EUR	34	235.29
SMILE EC 250	Stadler AG	5400	33.8mill CHF 29.66mill EUR	29.66	182.06
Flirt3 - 8 cars	Stadler AG	4,000	14.75 mill EUR	14.75	271.19
Pendolino 7 cars	Alstom	5,500	21mill EUR	21	261.90
Zefiro 300 - 8 cars	Bombardier Transportation	9,800	30.8mill EUR	30.8	318.18
Euroduplex	Alstom	9400	26.67 mill EUR	26.67	352.46
Dart	PESA	2400	9.65mill EUR	9.65	248.70
Javelin (A Train)	Hitachi Rail	3360	8.6mill brit. Pound 9.59 mill EUR	9.59	350.36
Talgo 350 (2+12 car)	Patentes Talgo, Bombardier	8000	20mill EUR	20	400.00

Table 48: Multiple-Unit sets – Long-distance passenger service (1)

Benchmarking the power for regional passenger service, the Siemens Desiro ML delivers the most power for 1mill EUR (472.73 kW/1mill EUR), followed by the Alstom 3 Cars Coradia Continental and the Siemens Desiro HC. The average power over all regional EMUs is about 2,512 kW and the highest power level is about 4,000 kW for the Siemens Desiro HC and Stadler Kiss 6 cars.

For long distance passenger service the Talgo 350 from Patentes Talgo and Bombardier Transportation has the best ratio of Power/Price (400 kW/1mill EUR). The average power over all long distance EMU's (High Speed and Standard Long Distance) is about 6,243 kW and the highest power level is about 9,900 kW for the long ICE 4, followed by 8,000 kW for the Bombardier Zefiro 300 and Patentes Talgo 350.

For passenger benchmarking of regional transports the total number of passengers is taken into consideration, and for long distance service the number of seats. Unfortunately, the total number of passengers is not available for all vehicle types. In this case, the total number of passengers is the same as the number of seats.

Evaluating the following tables for regional and long-distance passenger service (, the Desiro ML has the best ratio for Passenger/Price (93 Passenger/1mill EUR), followed by the Kiss 4 cars and the Class 490. The average number of passengers per wagon is about 164 passengers per wagon, while the KISS 6 cars have the highest amount of passengers per wagon (342).

For the long distance passenger service the standard long distance train Pesa Dart has the best ratio of 36.47 Seats/1mill EUR, followed by the High Speed Train Javelin (35.45 Seats/1mill EUR) and the Pendolino 7 cars (23.52 Seats/1mill EUR).

Regional Passenger Service					
	Indicative Price per Unit	Estimated Indicative Price [mill EUR]	Total Number of passengers	Seats	Passenger/Price [-/1mill EUR]
Desiro HC	13.18 mill EUR	13.18	400	400	30.34
Desiro ML	5.5mill EUR	5.50	513	252	93.27
Flirt3 - 3 car	7.5mill EUR	7.50	400	181	53.33
Flirt3 - 4 car	8.2mill EUR	8.20	477	219	58.17
GTW	7.25mill Dollar 6.29mill EUR	6.29	200	104	31.79
KISS 4 cars	106mill SEK - 10.04mill EUR	10.04	901	335	89.74
KISS 6 cars	34,44mill Dollar - 29.84 mill EUR	29.84	1373	535	46.01
WINK	7.25mill Dollar 6.29mill EUR	6.29	275	150	43.72
Class 490	5.49mill EUR	5.49	469	190	85.42
Coradia Continental - 3 cars	5.66mill EUR	5.66	302	149	53.35
Elf 27WE (6-car)	13.6 mill EUR	1.,60	900	354	66.17
Elf 22WE (4-car)	11.374 mill EUR	11.37	450	200	39.56
Elf 2 21WEa	6.73 mill EUR	6.73	310	150	46.06
Coradia Polyvalent - 4 cars electric	10mill EUR	10.00	220	220	22
Coradia Polyvalent - 6 cars electric	11.76mill EUR	11.76	354	354	30.10
Atribo ATR220	3.36mill EUR	3.36	159	159	47.32
Link 1 car	2.6mill EUR	2.60	150	70	57.69
Twindexx Vario/Dosto 2010 - 4-Cars	10mill EUR	10.00	608	328	60,8
Coradia Stream - 4 cars	6.11mill EUR	6.11	305	305	49,9181669

Table 49: Multiple-Unit sets – Regional passenger service (2)

Long Distance Passenger Service					
	Indicative Price per Unit	Estimated Indicative Price [mill EUR]	Total Number of passengers	Seats	Seats/Price [-/1mill EUR]
ICE 4 (7-cars)	~ 36mill EUR	36.00	456	456	12.66
ICE 4 (12-cars)	~ 52mill EUR	52.00	830	830	15.96
Velaro D (8-cars) DC	~33mill EUR	33.00	462	462	14
Velaro D (8-cars) AC	34mill EUR	34.00	462	462	13.58
SMILE EC 250	33.8mill CHF 29.66mill EUR	29.66	848	422	14.22
Flirt3 - 8 cars	14.75mill EUR	14.75	354	354	24
Pendolino 7 cars	21mill EUR	21.00	494	494	23.52
Zefiro 300 - 8 cars	30.8mill EUR	30.80	600	469	15.22
Euroduplex	26.67mill EUR	26.67	556	556	20.84
Dart	9.65mill EUR	9.65	352	352	36.47
Javelin (A Train)	8.6mill brit. Pound 9.59mill EUR	9.59	340	340	35.45
Talgo 350 (2+12 car)	20mill EUR	20.00	353	353	17.65

Table 50: Multiple-Unit sets – Long-distance passenger service (2)

2.4. Analysis of Possible Rolling Stock for Long Distance Passenger Service

2.4.1. Locomotive Train Set

In this subchapter a short description about actual running locomotives in Poland follows at first. This short information seems logically because of the nearness from Poland to the Rail Baltica Route and the Idea to probably use actual running rolling stock for a transition time at first.

In Poland a significant number of locomotives exist. But, often they are limited for high-speed services by their maximum velocity. Only a small number of locomotives can reach speeds higher than 159 km/h. These locomotives are:

- Class EU07A (electrical 3kV DC, 160 km/h),
- Class EP09 (electrical 3kV DC, 160 km/h),
- Class EU47 – Traxx P160 DC (electrical 3kV DC ,160 km/h),
- Class EU44 Husarz – Siemens ES64U4 (electrical 1.5 kV, 3 kV DC; 15 kV AC 16.7 Hz; 25 kV AC 50 Hz; 230 km/h),
- Class 111Eb – Pesa 111Eb Gama (electrical 3 kV DC, 160 km/h),
- Class SU160 – Pesa 111Db Gama (diesel-electric, 160 km/h).

Restricted due to the requirement of the electrical multisystem availability, the only two types of existing locomotives at present in Poland are the Class EU44 as an electrical solution and Class SU160 as a diesel-electrical solution. Due to the long distance of the Rail Baltica Route and the boundary condition Number 4, the Class EU44 is the only option available that meets the criteria. A Class EU44 Husarz loco with a power of 6,000 kW at 3 kV DC catenary system can push and pull up to 500 t with a velocity of 200 km/h, has a ETCS train control system and a homologation to at this time actual TSI standards.

For benchmarking the existing passenger rolling stock against the requirements the same approach was used. In Poland an extensive amount of passenger wagons of different types (UIC Y, UIC Z1 UIC Z2 , double deck etc.) are currently in use. A lot of these wagons were built or modernised in the last 10 years. For the Long Term Passenger Service the requirements are:

- RIC compliance,
- Air Conditioning,
- Places for passenger with reduced mobility,
- Minimum velocity of 200 km/h.

At present, in Poland only one Dining car and four Buffet cars with a velocity of 200 km/h are available.

The following available passenger train set with 200 m length could be used:

Nr.	1	2	3	4	5	6	7	8	Total	Without Loco-motive
Name	Class EU44 Husarz	A9mnop uz 158A	Wrmnouz 305Ad	B10bmno uz 156A	B10bmno uz 156A	B10bmno uz 156A	B9mnop uz 159A	B9mnopu z 159A		
Power	6MW									
Tractive Effort [kN]	300 kN (max) 250 kN (cont.)									
Top Speed [km/h]	230	200	200	200	200	200	200	200	200	
Brake Sys-tem	loco: electro-pneu-matic train set: electric, pneu-matic as backup with 8 disc brakes	ep disk brake and em rail brake	ep disk brake and em rail brake	ep disk brake and em rail brake	ep disk brake and em rail brake	ep disk brake and em rail brake	ep disk brake and em rail brake	ep disk brake and em rail brake		
Length [mm]	19580	26,400	26,400	26,400	26,400	26,400	26,400	26,400	204,380	184,800
Passenger	0	54	36	56	56	56	72	72	402	402
Number PRM	0	0	0	2	2	2	0	0	6	6
Weight (tara) [t]	87	50	57	50	50	50	50	50	444	357
Remarks	Locomo-tive, SHP, ETCS, Data Sheet available	First Class	Dining	Second Class + PRM	Second Class + PRM	Second Class + PRM	Second Class	Passen-ger and bike		

Table 51: Passenger train set for locomotive hauled service using existing vehicles

The train set consists of 7 currently available polish passenger wagons (type UIC Z2). The traction is provided by Siemens Taurus Multisystem locomotive and the top speed is limited to 200 km/h by the passenger wagons. The train set has an overall length of about 204.28 m and can transport 402 passengers. The weight of the passenger wagons are about 357 t. Very often a weight of about 500 t is given as a limit for transport with 200 km/h or more. For a longer train set (up to 400 m train length), the train set would consist of 15 passenger wagons, with 369,6 m length, a capacity for 882 passengers and total weight of about 707 t. Due to the type of "second-hand" – vehicles, it is not possible to estimate the CAPEX for this composition.

By using new equipment for a 200 m train set length, the following two push and pull train set configurations (A & B) could be used:

Nr.	1	2	3	4	5	6	7	8	Total	Without Loco-motive
Name	Siemens Vectron MS	Bmpz - Siemens Viaggio Comfort	Bmpz - Siemens Viaggio Comfort	Bmpz - Siemens Viaggio Comfort	Bmpz - Siemens Viaggio Comfort	ARbmpz - Siemens Viaggio Comfort	Ampz - Siemens Viaggio Comfort	Afmpz - Siemens Viaggio Comfort		
Power	6.4 MW	-	-	-	-	-	-	-		
Tractive Effort [kN]	300 kN	-	-	-	-	-	-	-		
Top Speed [km/h]	200	230	230	230	230	230	230	230		
Brake Sys-tem	ed and ep, pneu-matic as backup	ep disk brake (2-3 per wheel-set) and em- rail brake	ep disk brake (2-3 per wheelset) and em-rail brake	ep disk brake (2-3 per wheelset) and em - rail brake	ep disk brake (2-3 per wheelset) and em - rail brake	ep disk brake (2-3 per wheelset) and em-rail brake	ep disk brake (2-3 per wheelset) and em - rail brake	ep disk brake (2-3 per wheelset) and em - rail brake		
Length [mm]	18,980	26,500	26,500	26,500	26,500	26,500	26,500	26,500	204,480	185,500
Passenger	0	72	80	80	80	10	55	27	404	404
Number PRM	0	0	0			3	0	0	3	3
Weight (tara) [t]	90	61	61	61	61	61	61	61	517	427
Costs [mill EUR]	5	2.3	2.3	2.3	2.3	2.3	2.3	2.3	21,1	16,1
Remark	ETCS L2 + 1 nation-al Train Control System	Second Class End car with bike	Second Class	Second Class	Second Class	Buffet Car	First Class	Business Class		

Table 52: Long distance passenger train set A for locomotive-hauled service using new vehicles

Nr.	1	2	3	4	5	6	7	8	Total	Without Loco-motive
Name	NEWAG Griffin E4MSU/E 4MSP	Bdmpz - Siemens Viaggio Light	Bbmpz - Siemens Viaggio Light	Bmpz - Siemens Viaggio Light	Bmpz - Siemens Viaggio Light	ARbmpz - Siemens Viaggio Light	Ampz - Siemens Viaggio Light	Afmpz - Siemens Viaggio Light		
Power	5.6 MW (Conti-nous)	-	-	-	-	-	-	-		
Tractive Effort [kN]	310	-	-	-	-	-	-	-		
Top Speed [km/h]	200	200	200	200	200	200	200	200		
Brake Sys-tem	loco: primary: electric Netbrake dynamic brake with 240 kN backup: pneu-matic 8 disc brakes	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake	ep disk brake (2-3 per wheelset) and em rail brake		
Length [mm]	19,900	26,500	26,500	26,500	26,500	26,500	26,500	26,500	205,400	185,500
Passenger	0	80	80	99	99	25	60	55	498	498
Number PRM	0	0	6	0	0	0	0	0	6	6
Weight (tara) [t]	88	55	55	55	55	55	55	58	476	388
Costs [mill EUR]	4.93	1.5	1.5	1.5	1.5	1.5	1.5	1.5	15.43	10.5
Remark	ETCS L2 + 1 nation-al Train Control System	Second Class End car with bike	Second Class	Second Class	Second Class	Buffet Car	First Class	Business Class		

Table 53: Long distance passenger train set B for locomotive hauled service using new vehicles

The results clearly show that a standard IC-traffic with current available on the Rail Baltica route is possible. With new vehicles and the use of Multisystem-Locomotives the CAPEX – range is between 15.43mill EUR and 21.1mill EUR. If just AC-Locomotives are chosen, the CAPEX for the locomotives can be reduced by about 12%. The overall length of the set is about 205.4 m. The figures presented above present the maximum train length suitable for utilis-ing a 200 m platform. If reasonable, number of wagons could be reduced, e.g. to 6 to comply with requirement to provide a seating capacity of approx. 400 passengers per train for long distance services.

2.4.2. Electrical Multiple Unit (EMU)

For the long term passenger service with EMUs the only currently available EMU in Poland, which complies with the requirements defined above, is the polish ED250 Alstom Pendolino.

Regarding new rolling stock, a high number of high speed trains as EMUs and EMUs for InterCity transport like

- Siemens ICE 4,
- Siemens Velaro D,
- Bombardier Zefiro,
- Stadler SMILE or Flirt 3,
- Alstom Pendolino or AGV,
- Pesa Dart,
- Patentes Talgo Avril,
- Patentes Talgo 350,
- Patentes Talgo 250,
- Patentes Talgo XXI,
- CAF Alstom Oaris,
- Hitachi Rail AT 300 and
- Hitachi Rail A Train

are available. The complete list included in ANNEX 4 and the table in the benchmark chapter show the relevant technical data.

According to the design speed on tracks a lot of the High Speed Trains are overpowered. Furthermore, only the Javeling HST and Pendolino 7 cars have good ratios with regard to the benchmarking. Finally, the Pendolino 7 cars can carry more passengers and is prepared for multisystem use, so that this High Speed Train can travel to other countries with other electric power supply systems.

2.4.3. Diesel Multiple Unit (DMU)

Due to the different track gauge in the UK, the exclude of typical rolling stock vehicles from or for the market in the UK was decided. Generally, no real DMU is currently available for long-distance passenger service. There is one prototype available which might be adaptable for a serial production - the Talgo XXI from Patentes Talgo:

Name:

- Talgo XXI
  - Train Control System: ETCS L1, L2, LZB, ASFA;
  - Power Type: Diesel electric;
  - Track Gauge: 1435/1668;
  - Structure Gauge: GB,
  - Axle arrangement (UIC): Bo'Bo'+variable+Bo'Bo';
  - Power 3000 kW;
  - Max Speed: 220 km/h.

The most relevant facts of this DMU type are not available right now and might change in the future.

Furthermore, an electro diesel dual mode (hybrid) multiple unit exists in Spain. It is called Talgo 250 H and supplied by Talgo and Bombardier Transportation:

Name:

- Talgo 250H
  - Train Control System: ETCS L1, L2, LZB, ASFA;
  - Power Type: Dual Mode, electric, diesel-electric;
  - Track Gauge: 1435/1668;
  - Structure Gauge: GB;
  - Axle arrangement (UIC): Bo'Bo'+2' 1'1'1'1'1'1'1'1'1'2' +Bo'Bo';
  - Power: 2 x 2,400 kW (25 kV 50 Hz), 2 x 1,200 kW (diesel);
  - Max Speed: 250 km/h (AC), 220 km/h (DC), 180 km/h (diesel).

2.4.4. Night Train Service

For the transport of passengers overnight, different wagon types like sleeper (WLA, WLB, WLAB), couchette (BDcm), sleeperette (Bpm) and normal passenger wagons are used. Furthermore, personal cars shall be transported on a respective train, so that car transport wagons (type DDm) are needed. Due to the speed limitation of the car transport wagons to 160 km/h, locomotives with a lower velocity can be used for traction of these services. The analysis of the current vehicle status in Poland shows that for passenger service no locomotives with multi-system requirements exists (except for the Class EU44 Husarz). PKP Cargo owns a lot of multi-system locomotives, but these are only for freight transport and have no connection for an auxiliary power supply line, required for use in passenger train services. According to the proposal, a combination of new vehicles (locomotive and perhaps car transporter) and existing passenger wagons for night service is necessary.

Nr.	1	2	3	4	5	6	7	8	9	10	11	Total	Without Locomotive
Name	Skoda Emil Zátopek Universal MS	WLAB9 bmnou z, 308A	WLAB1 0bmno uz, 306Ab	WLAB1 0bmno uz, 306Ab	Bc10m nouz, 172A	Bc10m nouz, 172A	B5mno puvz, 152Az	B5mno puvz, 152Az	Car trans-porter DDm	Car trans-porter DDm	Car trans-porter DDm		
Power	6.4 MW	-	-	-	-	-	-	-	-	-	-		
Tractive Effort [kN]	274	-	-	-	-	-	-	-	-	-	-		
Top Speed [km/h]	160	160	160	160	160	160	200	200	160	160	160	160	160
Brake System	EP and ED	disc brakes	disc brakes	disc brakes	??	??	ep disc brake and em rail brake	ep disc brake and em rail brake	<R> KE-GPR-A-Mg (D)	<R> KE-GPR-A-Mg (D)	<R> KE-GPR-A-Mg (D)		
Length [mm]	18,000	24,500	26,400	26,400	26,400	26,400	26,400	26,400	26,400	26,400	26,400	280,100	262,100
Passen-ger	0	26	28	28	60	60	48	48	0	0	0	298	298
Number PRM	0	2	1	1	0	0	0	0	0	0	0	4	4
Weight (tara) [t]	88	55	53	53	55	55	55	55	27.7	27.7	27.7	552.1	
Costs [mill EUR]	4.7	2	2	2	1.7	1.7	1.6	1.6	0.1	0.1	0.1	17.6	12.9
Notice	New Lok	Sleep-er	Sleep-er	Sleep-er	Cou-chette	Cou-chette	Sleep-erette	Sleep-erette	10 cars	10 cars	10 cars		

Table 54: Proposed train set for night train service

The overall CAPEX for a typical Night Train Set is about 12.9mill EUR, without the locomotive. Due to the limited maximum velocities of night trains (limiting factor is very often the car transport wagon), a locomotive with a maximum velocity of 160 km/h would be sufficient.

2.4.5. Summary, Average Values and Fleet Proposal for Long Distance Passenger Service

This chapter showed a huge possibility to realize the Long-Distance Passenger Service with different kind of rolling stock like standard Train Sets, EMU's and DMU's. For standard train sets the typical number of passengers with a length over buffers about 202 m is around 400 people. It is possible to increase this number of seats. Therefore, the lower comfort wagons viaggio light could be used and around 500 sears are possible. But with the typical standard Intercity – Comfort a train set with around 205 m length (including locomotive) consists of 8 wagons and carries about 1.97 passengers/m. For the train set case, two cost variants are possible, one with high prize passenger locomotive (5 mill Euro and 2.3 mill Euro per wagon) or one with a low prize passenger locomotive (4 mill Euro and 1.6 mill Euro per wagon). That leads to 17,3 seats/1 mill Euro or 24.0 seats/1 mill Euro. According to chapter 2.2 the relevant velocity for the RailBaltica Route must be 249 km/h. Unfortunately, for a speed of 249 km/h actually no locomotive and passenger wagon are developed, offered or available. Only the Siemens Viaggio passenger wagons and the closed Siemens Eurosprinter locomotive can run up to 230 km/h. Nevertheless, standard train sets are not recommended for the long distance passenger service.

Summarizing the EMU's for Long Distance Passenger Service (including Annex 6) 4 EMU's does not met the design speed of 249 km/h (ICE 4 7 cars, Talgo XXI, Javelin, Intercity Flirt) and 7 EMU's are overpowered with velocities up to 320 km/h and more (Velaro D, Euroduplex, AGV, Talgo 350, Talgo Avril, Oaris, Zefiro 300). In a second step, the ICE 4 12 cars does not met the requirement with the maximum platform length and the list is reduced to

- Stadler SMILE,
- Alstom Pendolino,
- Pesa Dart,
- Patentes Talgo 250,

Based in these 4 typical EMU's for the RailBaltica Route, the range of passenger size is from 299 (Talgo 250) to 422 (Smile EC 250) passengers. According to chapter 2.3.3 and Annex 6 the average number of seats per meter is 2.04 seats/meter, while the Dart has the best ratio with 2.3 seats/meter followed by the Pendolino with 2.15 seats/meter. The average amount of seats/prize is 24.74 seats/1 mill Euro. Due to a pointed averaging of the power (Pesa Dart is excluded at this point) the average power is around 5,300 kW with an average ratio of 230 kW/1 mill Euro.

Like written in chapter 2.4.3 no DMU's are actually available for the long distance passenger service, either as actual available or as actual offered by manufacturers. It is possible to respect hybrid multiple units which consists of electrical traction or diesel traction. However, these multiple units have lower velocities at diesel traction and will not meet the requirement from chapter 2.2.

Comparing the facts between the standard train sets and the EMU's it is shown, that the standard train sets have a similar ratio of seats/prize and power/prize (high prize passenger locomotive) according to the average value for the EMU's. In the same way, the standard train sets perfom with a lower velocity and will not meet the requirements. It is shown on the benchmark chapter that the DMU's have lower ratios than the EMU's and a service will not be suitable and economical at electrified routes. Furthermore the most relevant fact at this point and for this analysis is the required velocity. For this point, standard train sets are not available to reach the required velocity of 249 km/h. With actual offered locomotives, the limitation is at 200 km/h. Based on these results, only EMU's could be proposed for long distance passenger service. And respecting the average values, indicated in chapter 2.2 and Annex 4, a typical generical High Speed EMU has the following key data:

- Length: 200 m,
- Power: 5,300 kW,
- Seats: 408,

- Starting Acceleration: 0.4 – 0.6 (0.5) m/s2,
- Weight: 2.08 t/m; 416.0 t,
- Starting Tractive Effort: 220 kN – 300 kN,
- Prize: Seats/Prize 24.74 seats/1m Euro, 16.5 mill Euro, Power/Prize 230 kW/1m Euro, 23.04 mill Euro.

At this point it is remarked, that the proposed prize is very sensitive to the kind of construction. For EMU's with a high power like the Smile or the Pendolino, the Power/Prize criteria must be chosen. Otherwise, like the Pesa Dart the Seats/Prize could be construction criteria. At the moment, the author proposes to respect the Power/Prize criteria, because the ratio is closer to the other High Speed Trains and perhaps the Pesa Dart EMU is a statistical exemption.

At the end of this summary it is mentioned, that the night train service shall not be ignored, but all relevant information are written in chapter 2.4.4. For a typical Night Train configuration with a medium locomotive, the indicative prize is about 17.6 mill Euro.

2.5. Analysis of Possible Rolling Stock for Regional Passenger Service

Currently, in Poland no regional passenger service is provided with locomotive train sets anymore (except on some branch lines). EMUs and DMUs dominate this area. Unfortunately, these vehicles are only equipped for 3 kV DC electric current and some vehicles only have the Polish train control system SHP. Therefore it can be assumed that for the provision of regional passenger services in the future new train sets need to be acquired and will be analysed in the following.

2.5.1. Locomotive Train Set

Currently, in Poland no Locomotive Train Set is available for transfer to the Rail Baltica Route for regional passenger service. Train sets with double-deck wagons are not possible due to the limitations of the track clearance GB. If it is possible to use vehicles with GC clearance at the RB Route, double-deck wagons can be used too. Currently, the most common supplier for this kind of wagons is Bombardier. Further manufacturers for double-deck coaches are Siemens, Skoda, Transtech and Pesa.

The following list gives an overview about currently available double-deck wagons which are currently in service.

Model/Class	Builder or reconstructor (name)	Track gauge	homologated for track/structure clearance, track/structure gauge	Height	Number of axles	Length over buffers (mm)	Maximum Speed (km/h)
Sundeck 416B	Pesa	1435	G2	4,600	4	25,800	160

Sundeck driving coach 316B	Pesa	1435	G2	4,600	4	26,270	160
Twindexx Vario middle wagon	Bombardier Transportation	1435	GC	4,632	4	26,800 -	160
Twindexx Vario cab car	Bombardier Transportation	1435	GC	4,632	4	27,270	160
Viaggio Twin	Siemens Mobility	1435	G2	4,600	4	26,800	189
Double Deck Push-Pull-Unit	Skoda	1435	GC	4,630	24	161,690	189

Table 55: Double deck passenger wagons

Model/Class	Braking System	Tare Weight [t]	Passenger Capacity		Doors	
			Total Number of Passengers	Seats	Number	Width [mm]
Sundeck 416B	Disk brakes and Mg brake	71	260	130	2	1,300
Sundeck driving coach 316B	Disk brakes and Mg brake	74	229	85	2	1300
Twindexx Vario middle wagon	Disk brakes and Mg brake	50	281	121	2	N/A
Twindexx Vario cab car	Disk brakes and Mg brake	58	213	73	2	N/A
Viaggio Twin	Disk brakes and Mg brake	49 - 69		80-130	2	1,400
Double Deck Push-Pull-Unit	N/A	N/A	676 + x	676	12	N/A

Table 56: Double deck passenger wagons

In Germany the standard number of double-deck wagons for regional trains is 5 wagons per train. For the new regional trains in South Germany, delivered by Skoda, the train set includes 6 wagons. The following configurations for double-deck wagons are possible (without locomotive):

Manufacturer	Number of Wagons	Passenger Capacity	Length [mm]
Skoda	6	est. 1250 (676seats)	161,690
Bombardier	5	1,337 (557 seats)	134,470
Pesa	5	1,269 (605 seats)	129,470
Siemens	5	1,250 (600 seats)	134,000

Table 57 Typical double deck train configurations

According to the benchmarking the double-deck wagons from Bombardier have the best ratio with regard to total numbers of passenger per indicative price. Critical limitation, except for Siemens and Skoda double-deck wagons, is the maximum speed of 160 km/h. Summarising the information, it should be stated, that in case of public tenders the double deck wagons shall transport 1,300 passengers in 5 wagons. The locomotive can have a lower power capacity, due to the maximum velocity of 160 km/h.

2.5.2. Electrical Multiple Unit (EMU)

Currently, there are no EMUs in Poland available for regional rail services on Rail Baltica. Obstacles are the electric power supply with 3 KV DC and the missing train control system ERTMS level 2. Looking for other at present existing EMUs with the GB-profile, the train control system ERTMS (ETCS level 2), the 25 kV 25 Hz AC electric current system and a multisystem availability as a preferred option, gave the following results:

- no relevant EMUs could be found in Germany or other West European Countries,
- in Hungary 48 EMUs of Stadler Flirt have ETCS level 2[30].

New possible EMUs are:

- Bombardier Talent 3,
- Stadler Flirt 3,
- Pesa Elf 2,
- Alstom Coradia Stream,
- PESA Acatus,
- Skoda Regiopanter,
- CAF Civity,

[30] Eurailpress.de; Ungarn: MÁV and GySEV bestellen weitere Flirt; 01.03.2013; https://www.eurailpress.de/news/bahnbetrieb/single-view/news/ungarn-mav-und-gysev-bestellen-weitere-flirt.html

- Hitachi AT200 Commuter,
- Siemens Mireo, Desiro without double-deck part.

In the following tables two examples with detailed information are given. The complete enumeration is in the Benchmark chapter 2.3 and in ANNEXES 4 and 5.

Model	Builder	Train Control System	Electric current	Track gauge	Homologated for track/structure clearance, structure gauge	Height	Axle arrangement (UIC classification)	Number of axles
Elf 2 EN62A	PESA	ETCS Level 2, GSM-R	3 kV DC (can be modified to 15 or 25 kV AC)	1435	GB	4280	Bo'2'2'Bo'	8
Flirt3 (3 cars and 4 cars)	Stadler AG	ERTMS + 1 national	Multiple Possibilities	1435	GB	4185	Bo'2'2'Bo' - 3 cars Bo'2'2'2'2'Bo' - 4 cars	8 - 3 cars 10 - 4 cars
Kiss 4 cars	Stadler AG	ERTMS + 1 national	Multiple Possibilities	1435	G2 EBO /GC	4595	Bo'Bo'+2'2'+2'2'+Bo'Bo'	16
Desiro ML	Siemens Mobility		15 kV 16.7 Hz	1435	GB		Bo'Bo'+2'2'+Bo'Bo'	12

Table 58: Example EMUs for regional passenger trains – technical data

Model	Number of axles for traction	Length over buffers (mm)	Power (kW)	Maximum Speed (km/h)	Weight (tonnes)	Max. axle loads	starting acceleration (m/s^2)	Tractive Effort [kN]	Passenger Capacity (Seats)	Passenger Capacity (Total)	Doors
Elf 2 EN62A	4	58950	1,600	160	107,3		1,2	200	161	326	3 per site
Flirt3 (2 cars - 8 cars)	4 – 3 cars up to 8 for 4 cars	58600 - 3 cars 75200 – 4 cars	2,000 More is possible)	Up to 200	100 - 3 cars 131 - 4 cars		Up to 1.2	200 (common)	181 3 cars 219 4 cars	400 3 cars 477 4 cars	Variable
Kiss 4 cars	8	102240	2,000	160	216		0.63 – 1.3	400	335	901	8 per side
Desiro ML	8	unknown	,2600	160	unknown	17	1.1	120	252	513	4 per wagon

Table 59: Example EMU's for regional passenger trains – performance parameters

According to the benchmark chapter, the Desiro ML has the best power/price ratio and passenger/price. Unfortunately, this train set is actual only for 15 kV 16.7 Hz available. But, a transformation to 25 kV 50 Hz should be possible. One disadvantage of the Desiro ML is the low velocity of 160 km/h while the available Stadler Flirt Train set can drive up to 200 km/h. This point allows a better transport flow and a homogenisation between the regional passenger service and the long distance passenger service with High Speed Trains. According to the offered velocities it seems to be realistic, that every EMU could be delivered with 200 km/h velocity, if the demand exists. However, this modification would lead to higher investments costs and possible new TSI homologations, because for 200 km/h other restrictions or limits in the TSI regulations could be responsible.

2.5.3. Diesel Multiple Unit (DMU)

For the Regional Passenger Service in Poland an extensive number of modernised and new Diesel Multiple Units are in service. Unfortunately, all of these DMUs only have the Polish train control system SHP. They are not useable for the service on the Rail Baltica Route. New DMUs for the Rail Baltica Route could be:

- Stadler GTW, Wink,
- Alstom Coradia Lint, Coradia iLint (hydrogen),
- Pesa Link,
- Siemens Desiro,
- CAF Civity.

Technical data and most important performance parameters are exemplarily shown below.

Model	Builder	Train Control System	Power trans-mission	Track gauge	homologated for track/structure clearance, struc-ture gauge	Height	Axle arrange-ment (UIC classification)	Number of axles	Number of axles for traction
Link (1 car - 4 cars)	Pesa SA		MTU 6H 1800 R85L and ZF gearing MAN and Voith gearing	1435	GB	4280	B'2' - 1 car B'2'B' - 2 cars B'2'2'B' - 3 cars B'2'2'2'B' - 4 cars	4 - 1 car 6 - 2 cars 8 - 3 cars 10 - 4 cars	2 - 1 car 4 - 2 cars 4 - 3 cars 4 - 4 cars
Coradia Lint 81	Alstom		diesel-mechanic	1435	GB	4310	B'2'+B'2'+B'B'	12	8

Table 60: Example DMU's for regional passenger trains – technical data

Model	Power (kW)	Maximum Speed (km/h)	Weight (tonnes)	Adhesion mass (tonnes)	Starting ac-celeration (m/s^2)	Tractive Effort [kN]	Passenger Capacity (Seats)	Passenger Capacity (Total)	Doors

Link (1 car - 4 cars)	565 - 1 cars 780 - 2 cars 1130 - 3 cars 1130 - 4 cars	120-160	84.4 - 2 cars	56.3 - 2 cars	0.74		70 - 1 car 124 - 2 cars 180 - 3 cars 220 - 4 cars	150 - 1 car 250 - 2 cars 350 - 3 cars 450 - 4 cars	2 per side - 1 car 2 per side - 2 cars 3 per side - 3 cars 4 per side - 4 cars
Coradia Lint 81	1560	140	138	92			264 - 300	570 - 606	6 per side

Table 61: Example DMU's for regional passenger trains – performance parameters

Unfortunately, for the benchmark chapter it was not possible to get enough information about the different DMUs for an adequate comparison. Nevertheless, the Rail Baltica Route will be completely electrified and in this case a DMU fleet will not be a viable solution. Thus DMUs would be only suitable as interim solution at the very first month of operation.

2.5.4. Summary, Average Values and Fleet Proposal for Regional Passenger Service

Actually the only relevant Regional Passenger Service with train sets is done by a locomotive and double deck wagons. In chapter 2.5.1 is shown, that the typical length and number of double wagons is around 130 m and 5 wagons. One exception is the new composition from Skoda with 6 double deck wagons. Furthermore without the Skoda composition the maximum velocity is about 160 km/h, 189 km/h for the Skoda train set. According to chapter 2.3.2 and Annex 3 the following investment costs and ratios are given (respecting only the numbers of double deck wagons):

Type	Length [m]	Prize [Euro]	Passenger - Seats	Seats/Meter [-/m]	Passengers/Meter] [-/m]	Passenger/Prize [-/1m Euro]
Skoda	161.7	13.62 mill	1200 – 676	4.18	7.42	88.11
Bombardier	134.5	9.65 mill	1337 – 557	4.14	9.94	138.55
Pesa	129.5	10 mill	1269 – 605	4.67	9,80	126.9
Siemens	134.0	10 mill	1250 – 600	4.47	9.33	125.0

Table 62: Table of DD-Wagon-Ratios

On the basis of table 58 it could be seen, that the higher velocity of the Skoda train set reduces the prize ratio significant.

According to the DMU topic it is mentioned, that these type of traction is not seen as ecologically worthwhile. In the benchmark chapter is shown that the diesel traction trains has significant lower ratios than the electrical traction trains and the complete RailBaltica Route will be electrified too. Probably in the beginning, it could be possible that these types of diesel trains or hybrid trains will be an interims solution. But at the moment, this will not be recommended and must be an analysis for further tasks.

Summarizing the EMU's two types of vehicles should be respected, single deck and double deck EMU's. Referencing the ratios Power/Prize in the benchmark chapter, the EMU's Desiro ML – 3 cars, Coradia Continental – 3 cars, Flirt 3 cars and Flirt 4 cars are leading. According to the ratio Passenger/Prize the EMU's Desiro ML 3 cars, KISS 4 cars and Class 490 are leading and in the same range.

Type	Length [m]	Prize [mill Euro]	Passenger - Seats	Seats/Meter [-/m]	Passengers/Meter] [-/m]	Passenger/Prize [-/1m Euro]
Desiro ML - 3 cars	70.93	5.5	513 - 252	3.55	7.23	93.3
Coradia Continental - 3 cars	56.9	5.66	302 – 149	5.31	5.31	53,36
Flirt - 3 cars	58.6	7.5	400 – 181	3.08	6.83	53,3
Flirt - 4 cars	75.2	8.2	477 – 219	2.91	6.34	58,17
Kiss - 4 cars	102.2	10.04	901 – 335	3,28	8.82	89,74
Class 490	66.0	5.49	469 - 190	2.88	7,11	85,42

Table 63: Table of EMU Ratios

For comparing the types train set and EMU a generical EMU, based on the average values is described in the following. Main Basis is the forecast and the operational plan. For this case, the train needs 300 seats as a basis and outgoing from table, the benchmark chapter and Annex 4, the following average ratios/values are calculated:

- Average running weight: 1.85 t/m,
- Average running seats: 3,5 seats/m,
- Average running passenger: 6.94 passenger/m,

- Average Passenger/Prize ratio[31]: 72,22 Passenger/1m Euro,
- Average Power/Prize ratio over vehicles in table 59: 310 kW/ 1m Euro,
- Average Power/Prize ratio over vehicles in Annex 4/chapter 2.3.3: 223 kW/ 1m Euro,
- Average Power[32]: 2152 kW.

According to the average ratios/values the generical train has the following key data:

- Single deck configuration,
- Seats: 300,
- Passengers:595,
- Length: 85.8 m, for infrastructure considerations a maximum length of 90 to 110 m shall be assumed to be on the safe side and to allow length reserves for growing comfort requirements, as well as growing requirements and demand for bike, baggage and toilet facilities and to provide sufficent space to cater for needs of persons with reduced mobility in the train
- Power: 2160 kW,
- Starting Acceleration: 0.9 – 1.1 m/s^2,
- Weight: 158,7 t,
- Prize: 8.24 mill Euro respecting average Passenger/Prize Ratio, 6.94 mill Euro respecting average Power/Prize Ratio.

Comparing to the Long Distance Passenger Service, in this case the average Passenger/Prize Ratio is more critical and should be used for the calculation of the indicative prize for an EMU.

Regardless of the velocity and the track/loading gauge a typical standard locomotive train set would have 3 double deck wagons (2 middle wagons, 1 end wagon) with 315 seats and could transport total 775 passengers (basis for exemplary calculation is the Bombardier Vario Twindexx). The indicative Prize for the 3 wagons is around 5.8 mill Euro and with a standard regional passenger locomotive (around 4 mill Euro) the total costs are around 9.8 mill Euro.

The advantages of the EMU in this case seem to be the estimated lower indicative prize and especially a better traction due to the distributed drive. Furthermore, in the operational plan a velocity of 200 km/h is needed for the Re-

[31] Based on table 59
[32] Based on table 59

gional Passenger Service and actual only a view EMU's are available for these velocities. Disadvantages of the EMU's are the lower total passenger capacity and that a complete EMU have to go into the workshop, if only one wagon has a small defect.

2.6. Analysis of possible Rolling Stock Freight Service

2.6.1. Initial considerations and limiting factors

For freight trains the relevant additional conditions and requirements in comparison to the passenger service are:

- lower velocity of 120 km/h,
- higher structure clearance GC,
- maximum axle loads of 25 t, and
- the allowed length of 1050 m.

For freight services the maximum possible velocity is very sensitive to different aspects. These aspects are:

- running stability of the freight wagons,
- thermodynamic effects during braking,
- maximum brake force,
- track alignment, maximum trailing load, maximum tractive force and power of the locomotive and
- brake arrangement in the train set.

Especially the brake arrangement in the train set allows different settings like:

- setting G/G (loc G, G),
- setting P/P (loc P, P),
- setting G/P (loc G, P),
- setting L L (loc and first 5 wagons in G, rest in P).

In the 1990's research analyses showed **[Stieler]** that for freight train velocity higher than 90 km/h the brake setting P is necessary. Otherwise it would not be possible to brake within 1,000 m pre-signalling distance. In 2010 DB Netz

AG published the guidelines Ril 402.0202[33] and Ril 408.0721[34] with more detailed information regarding the brake setting. The most relevant information is:

- Freight trains at standard routes with standard signalling system (like ETCS level 1), are allowed to drive in brake setting G up to 100 km/h, at routes with LZB (which is similar to ETCS level 2) up to 140 km/h,
- Freight trains at standard routes with standard signalling system (like ETCS level 1), are allowed to drive in brake setting P up to 120 km/h, at routes with LZB (which is similar to ETCS level 2) up to 140 km/h,
- Freight trains at standard routes with standard signalling system (like ETCS level 1), are allowed to drive in brake setting R up to 140 km/h, at routes with LZB (which is similar to ETCS level 2) higher than 140 km/h.

A second limitation is the 25 t axle load for the Rail Baltica Route, which currently is an isolated application of this standard along the route. In many other countries, which are relevant for the TEN-V corridors (Poland, Germany, etc.), a maximum axle load of 22.5 t is currently the standard.

The third limitation is the actual standard 85 tons screw coupler system used for train coupling in freight trains. Since the last TSI WAG[35] all new freight wagons must have screw couplers with a minimum breaking load of about 850 kN, and for stronger couplings of about 1,350 kN. For the calculation of the allowed maximums trailing load, a maximum traction force of 450 kN for the standard UIC-screw coupler and 500 kN for the stronger UIC-screw couplers will be used[36]. The limitation to the tractive force is lower in comparison to the minimum breaking load to resist the dynamic longitudinal effects. In standard operations, this limitation is only one of several, which need to be taken into account. Normally, for every route section the infrastructure company sets so called load limits. These limits are directly connected to the coupling system used, the grade, the separate resistances, the maximum tractive force of the locomotive and the required minimum velocity. These calculations are very complex and extensive and it is not part of work package or proposal to develop such a calculation tool and to analyse the complete Rail Baltica Route. Hence the following information must be seen as a good given orientation. For standard screw couplers Swiss Rail (SBB) published in its document[37] an exemplary table for maximum trailing loads as a function of the gradient. The limitation for this case is the breaking load of the screw couplers. At the end the relevant infrastructure manager is responsible for the allowed maximum trailing loads. It is possible to transport higher trailing loads at flat areas with a maximum gradient of 5 ‰ or lower. But at the moment the Rail Baltica Route could consists of gradients up to 12 ‰ and the following table should be re observed.

[33] DB Netz AG; Richtlinie 402 „Trassenmanagement“, Modul 0202A04 „Planungsprocedere; Trassenanmeldungen, Bremsstellung der Züge“; Frankfurt am Main; Ausgabe mit Gültigkeit ab 13.04.2010.
[34] DB Netz AG; Richtlinie 408 „Züge fahren und Rangieren“, Modul 0721 „Bremsen im Zug, Bremsen einstellen“; Frankfurt am Main; Ausgabe mit Gültigkeit ab 13.12.2009.
[35] Europäische Union; Verordnung (EU) Nr. 321/2013 der Kommission vom 13. März 2013 über die technische Spezifikation für die Interoperabilität des Teilsystems "Fahrzeuge – Güterwagen" des Eisenbahnsystems in der Europäischen Union - TSI WAG; Brüssel; 13.03.2013
[36] DB Netz AG; Technische Netzzugangsbedingungen (TNB) - Gültig für die Infrastruktur der DB Netz AG, DB Netz AG, Frankfurt am Main, 31.07.2017
[37] Regelwerk SBB; R P 20000800; Betriebsvorschrift SBB Verkehr [5.2a] Normallasten; 2013

Gradient [‰]	Trailing Load [t]
0-12	2,500
14	2,200
16	2,100
18	1,900
20	1,700
22	1,600
24	1,500
26	1,400
28	1,300

Table 64: Trailing load limitation for different gradients – SBB example

Further Information included in this document, are the relationships between gradient, specific locomotive tractive force and trailing load. For new 4-axle locomotives with 300 kN tractive force the limitation for the trailing load at a gradient of 12 ‰ is 1,340 t. This exemplary limitation is written by SBB and considers a required minimum velocity at gradients up to 12 ‰, the limitation factor in this case is the tractive force.

To get more reliable information on which type of locomotive (4-axle or 6-axle) should be used, a more detailed analysis was conducted using RailSys. This analysis included gradients with 12.5 ‰ and 9 ‰. The results showed that gradients lower than 9 ‰ are not critical for freight trains with 1,600 t or 2,500 t. These weight classes are chosen as typical freight train sets for the Rail Baltica Corridor (due to limiting factors of the screw couplings and brake arrangement). In the simulations the typical freight train locomotives used were 4-axle and 6-axle locomotives based on the findings from the tables in the chapter before. Furthermore, adhesion coefficients for normal-dry (=0.34) and normal-wet (=0.25) conditions were considered. For each locomotive type the following tests were made with 1,600 t and 2,500 t train set weight.

1. Passing a 10 km long 12.5‰ gradient.
2. Starting in front of a 10 km long 12.5‰ gradient. The train is stopped on 0‰ before start.
3. Starting in the middle of a 12.5‰ gradient. The entire train is stopped on the gradient.
4. Starting on top of the gradient. The entire train is stopped on the gradient.
5. Passing a 10 km long 9‰ gradient.
6. Starting in front of a 10 km long 9‰ gradient. The train is stopped on 0‰ before start.
7. Starting in the middle of a 9‰ gradient. The entire train is stopped on the gradient.
8. Starting on top of the gradient. The entire train is stopped on the gradient.

For the 9 ‰ gradient it was estimated, that both train configurations pass the tests at wet and dry conditions (see Table 65).

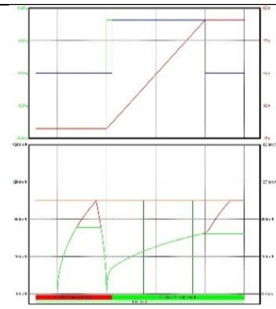
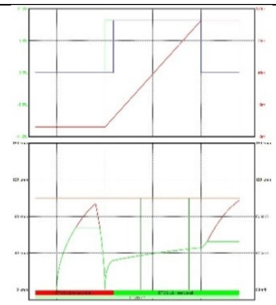
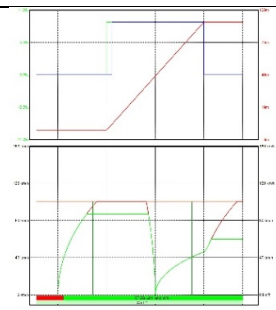
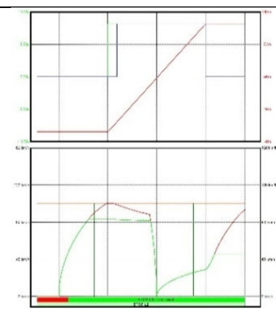
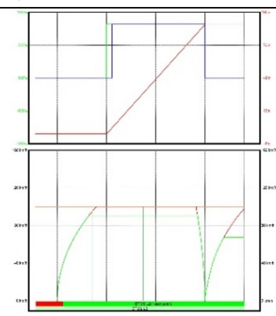
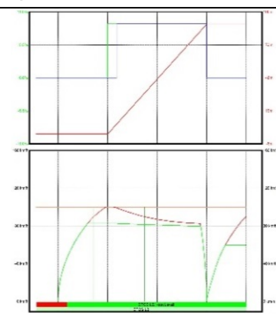
9‰	μ=0.25		μ=0.34	
	87t loc + 1,600t	125t loc + 2,500t	87t loc + 1,600t	125t loc + 2,500t
Passing	Ok	Ok	Ok	Ok
Starting in front of gradient	 Ok	 Ok	Ok	Ok
Starting in the middle of gradient	 Ok	 Ok	Ok	Ok
Starting on top of the gradient	 Ok	 Ok	Ok	Ok

Table 65: Simulation Results for 9 ‰ gradient

Maximum gradient for starting up freight trains

The Rail Baltica alignment has been screened for steep gradients where there could be problems for freight trains to start from. As calculated and documented above, gradients lower than 9‰ and under the assumed conditions will not cause any problems for freight trains to start from.

Maximum gradients for 4-axle locomotives with 1,600 tons load and 6-axle locomotives with 2,500 tons load:

According to the following tests of 4-axle locomotives with 1,600 tons load and 6-axle locomotives with 2,500 tons load, it has to be considered very carefully where to place the signals or other components (e.g. traction power sectioning point) which can stop the train near gradients, which exceed 9‰.

Maximum trailing load on 12.5‰:

The 6-axle locomotive is able to start up and accelerate with a maximum load of 1,930 tons in wet condition on a gradient with 12.5‰. If it is needed to increase the load a calculation of the specific scenario (alignment and rolling stock) should be provided to determine if it is possible to run the freight train or not.

Starting up freight trains from Muuga:

Both tested freight train types: the 87 tons locomotive +1,600 tons load and the 125 tons locomotive + 2,500 tons load are able to pass the line on wet rails (μ=0.25).

It has to be considered very carefully where to place the signals or other components (e.g. traction power sectioning point) which can stop the train near gradients under regular operating conditions, if gradients exceed 9‰. Special attention to three gradients in the alignment should be made:

- EST 01: 12.0‰ Section 09 km 4,937,
- EST 02: 10.0‰ Section 09 km 7.537 and
- EST 03: 10.0 ‰ Section 09 km 11.790

According to the special analysis of these gradients maximum size freight trains can't start again if they are forced to stop at the top of the gradient.

Reducing the maximum load for the 87 tons 4-axle locomotive to 1,530 tons load and the maximum load for the 125 tons 6axle locomotive to 2,400 tons both trains sizes are able to pass, stop in front and stop at the top on wet rails (μ=0.25) and start again.

Starting up freight trains from Palemonas:

Both tested freight train types: the 87 tons locomotive + 1,600 tons trailing load and the 125 tons locomotive + 2,500 tons trailing load are able to pass the line on wet rails (μ=0.25).

It has to be considered very carefully where to place the signals or other components (e.g. traction power sectioning point) which can stop the train near gradients, if they exceed 9‰. Special attention should be made to the following gradients in the alignment with this regard:

- LT 3: 10.0‰ Section Bypass (Palemonas - Kaunas dam - Jesia) km 6.000,
- LT 4: 10.0‰ Section Bypass (Palemonas - Kaunas dam - Jesia) km 6.800

Especially at wet conditions the reduction of the trailing load of the 6-axle locomotive with the 2,500 t freight train sets to 1,930 t leads to acceptable results in the four test cases. Finally, it should be mentioned that the simulations are done for a 5 km/ 10 km gradient. That means, that the results are relevant as basic principle researches, and at the real Rail Baltica route a 12 ‰ gradient with 5 km length does not exist.

Brake rating and resistance against high thermodynamic brake energy

Another limitation is the brake rating and resistance against the high thermodynamic brake energy. In many cases, the freight wagons can run up to 120 km/h or even higher. The difference is in the braking system, which is calculated for 80 km/h, 100 km/h or 120 km/h and for loaded or empty operations. Nevertheless freight wagons exist, especially intermodal wagons, for velocities up to 120 km/h, which can be fully utilised. Limitations are the maximum payload for the different freight wagons based on the braking system. This means, if a standard 4-axle container wagon like the type Sgnss 704 with a weight of 19.8 t (unloaded) shall travel with a speed of up to 120 km/h, the payload is limited to 60 t (below 20 t axle load), and for 100 km/h it is limited to 70 t payload (below 22.5 t axle load). For a six-axle pocket car (articulated freight wagon) like Sdggmrss 738, the limitations for axle load and the velocity are the same.

Regarding the fleet assumptions for Rail Baltica these limitations mean:

- maximum trailing load of 2,500 t (85 tons standard screw couplers) and 4,000 t (with automatic couplings) or maximum train length 1,050 m can be achieved depending on traction power provided,
- 1,600 t with respect to the brake arrangements (important for international traffic outside of the Rail Baltica Route),
- 1,340 t with respect to the grade specifications and new 4-axle locomotive,
- 2,400 t with respect to the grade specifications and new 6-axle locomotive,
- maximum axle load of 22.5 t for international services, due to the limitations through other countries,

- targeted top speed of 120 km/h can be applied, e.g. for intermodal trains services,
- for liquid and dry bulk services with heavy wagons and a maximum speed of 120 km/h is not realistic if wagons are fully loaded utilizing max. 22.5 t or 25 t axle load.

2.6.2. Freight Locomotives

For freight service along Rail Baltica currently two different types of locomotives are available. First one is the standard 4-axle freight locomotive with around 90 t weight and 300 kN maximum tractive force. The second one is the 6-axle freight locomotive with a weight of up to 135 t and a maximum tractive force up to 450/500 kN. Especially the information about the weight is based on actual offered locomotives by manufacturers. All these locomotives have axle loads of about 22.5 t. It is known, that at the RailBaltica Route the axle load limit is 25 t, but these locomotives are not offered yet. Possible new locomotives which are available in the market are:

- 4-axle: Siemens Vectron, Siemens Smartron, Bombardier Traxx, Skoda universal locomotive Emil Zátopek, Newag Griffin, Pesa 111 Ed, Alstom Prima II, Stadler Euro 3000, Stadler EuroLight,
- 6-axle: Stadler Euro 4000, Stadler EuroDual, Newag Dragon, Newag 15D/16D, Newag 311D, Alstom Prima II.

The following table gives short exemplarily overview for two typical freight locomotives.

No.	Model/Class	Builder (name, country)	Motive power type	Type		Axle arrangement (UIC classification)
				Electric current (electric locomotives	Power transmission (diesel locomotives)	
1	Vectron MS	Siemens Mobility	electric	25 kV AC 50 Hz 15 kV AC 16.7 Hz 3 kV DC 1,5 kV DC		Bo'Bo'
6	Eurodual	Stadler AG	electric / diesel	25 kV AC 50 Hz 15 kV AC 16.7 Hz	diesel-electric	Co'Co'

Table 66: Freight locomotive examples – technical data

No.	Number of axles	Number of axles for traction	Length over buffers (mm)	Power (kW)	Maximum Speed (km/h)	Weight (tonnes)	Starting tractive effort - short-term (kN)	Fuel tank volume (l)	standard braking rate in service brake
1	4	4	18,980	6,400	160/200	87	300	-	150kN (optional 240kN)
6	6	6	23,020	3000/708 (diesel), 7000/4000 (electric)	120/160	126	500	3500	??

Table 67: Freight locomotive examples – performance parameters

Available freight locomotives are described in Table 68. Herein the range for the indicative price is from 3 mill EUR for low-powered One-System-Locomotives (4-axle) up to high-powered Multi-System-Locomotives with 6 axles and / or with Bi-Traction-System with a price of 5 mill EURO.

	4-axle electric	4-axle diesel	6-axle electric	6-axle diesel
Average Power [kW]	5,475	2,046	6,000	2,702.2
Maximum Power [kW]	6,400 (Siemens, Skoda, Alstom)	2,900 (CAF)	7,200 (Newag)	3,178 (Stadler)
Average Tractive Effort [kN]	297	258	458	420.4
Maximum Tractive Effort [kN]	350 (Skoda, 25t axle load) 300 kN (common)	317 (Stadler)	500 (Stadler)	500 (Stadler)
Average Weight [t]	79	85.44	122.6	123.8
Maximum Weight [t]	100 (Skoda 25 t axle load) 90 (Alstom)	90 (Vossloh, CAF)	126 (Stadler), 130 (CAF)	126 (Stadler), 130 (CAF)

Table 68: Available Locomotives for Freight Services

2.6.3. Intermodal wagon fleet

The proposal for the Intermodal freight wagons is based on several assumptions. Regarding payload it is assumed that average axle load for the freight wagons is about 17 t (similar to the results of the EU-founded research project SUSTRAIL[38] and independent of the brake arrangement. Only new freight wagons will be used and due to the train control system ETCS level 2, 120 km/h as top speed for loaded wagons is possible. It means that the brake system of the wagons can resist the high brake energy for stopping the train. One further assumption is the maximum number of loaded freight wagons with 80%.

[38] SUSTRAIL Concluding Technical Report; Editor: Beagle, Adam; International Union of Railways (UIC); July 2015; Paris

The following types of container wagons are articulated for the different intermodal freight services:

- articulated container wagon, Sggmrs 714/715, 6 axles, length 33940 mm, weight tare 31 t,
- Container wagon for High-Cube-Container, Sgk(k)ms(s) 698, 4 axles, length 19130 mm, weight tare 18 t,
- articulated container wagon, Sggrss 733 or Sggrs 757, 6 axles, length 26700 mm, weight tare 28 t,
- articulated pocket wagon, Sdggmrs(s) 738 for transport of truck trailers or container, 6 axles, length 34200 mm, weight tare 35 t and
- 80’ container wagon, Sggns(s) 80’, 4 axles, length 25,940 mm, weight tare 22.5 t.

<u>Mixed Intermodal Fleet</u>

The first fleet proposal for Intermodal Freight Service consists of a mixed train set with 80% utilisation grade for the payload. With a length of 1,050 m as limitation in this case, the total weight for the trailing load is about 2,840 t with a payload of about 1,852 t. With 100% utilisation grade, the trailing load is about 3,264 t with a payload of about 2,276 t. In both cases, a standard operation with only one 4-axle locomotive and standard screw couplers is not feasible due to the limitations mentioned above.

No.	1	2	3	4	5	6	Total without loco-motive	Total	Pay-load [t]
Type	Loco-motive	Sggmrs 714	Sgk(k)ms(s)	Sggrss 733	Sdggmrs(s) 738	Sggns(s) 80’			
Description	Siemens Vectron MS	Articulator container wagon	High-Cube-contain-er wag-on	Articulated container wagon	Articulated pocket wagon	80’ contain-er wagon			
No. Wagons (loaded)	1	6	6	7	5	6	30	31	
No. Wagons (empty)	0	2	1	1	1	2	7	7	
No. Axles	4	6	4	6	6	4	192	196	
Length [m]	18.9	33.94	19.13	26.7	34.2	25.94	1,031.75	1,050.65	
Weight tare [t]	87	31	18	28	35	22.5	988	1,075	1,852
Weight loaded/ weight loaded & empty wagons (total)[t]	87	102	68	102	102	68	2,840	2927	
Costs [mill EUR]	5.0	0.66	0.66	0.77	0.55	0.6	3.24	8.24	

Table 69: Mixed intermodal fleet - exemplary train configuration (1.050 m train length)

With a limitation value to the total weight of the trailing load of 2,500 t, the following freight train set could be used. With 80% utilisation grade, it consist a total length of about 876.8 m, 4 empty wagons and 27 loaded wagons. The total amount of axles is 164. The total mass without locomotive is about 2,479.5 t and the payload is about 1,657 t.

No.	1	2	3	4	5	6	Total without loco-	Total	Pay-load [t]
Type	Loco-motive	Sggmrs 714	Sgk(k)ms(s)	Sggrss 733	Sdggmrs(s) 738	Sggns(s) 80’			

Description	Siemens Vectron	articulated Container	High-Cube-Container	Articulated Container	Articulated pocket	80' Container	motive		
No. Wagons (loaded)	1	5	5	6	5	6	27	28	1,657
No. s (empty)	0	1	1	1	0	1	4	4	
No. Axles	4	6	4	6	6	4	160	164	
Length [m]	18.9	33.94	19.13	26.7	34.2	25.94	857.9	876.8	
Weight tare [t]	87	31	18	28	35	22.5	822.5	909.5	
Weight loaded/ weight loaded & empty wagons (total)[t]	87	102	68	102	102	68	2,479.5	2,566.5	
Costs [mill EUR]	5.0	0.55	0.55	0.66	0.55	0.6	2.91	7.91	

Table 70: Mixed intermodal fleet - exemplary train configuration (2.500 t trailing load)

With a limitation value to the total weight of the trailing load of 1,600 t, the payload of the mixed intermodal fleet is about 1,089 t (100% utilisation grade). The freight train consists of 19 wagons and 94 axles. The total length of the train set is 556.96 m.

No.	1	2	3	4	5	6		Total	Pay-load [t]
Type	Loco-motive	Sggmrs 714	Sgk(k)ms(s)	Sggrss 733	Sdggmrs(s) 738	Sggns(s) 80'			
Description	Siemens Vectron MS	2 part container wagon	High-Cube-container wagon	2 part container wagon	2 part pocket wagon	80' container wagon			
No. Wagons (loaded)	1	2	2	2	5	8	19	20	1,089
No. Wagons (empty)	0	0	0	0	0	0	0	0	
No. Axles	4	6	4	6	6	4	94	98	
Length [m]	18.9	33.94	19.13	26.7	34.2	25.94	538.06	556.96	
Weight tare [t]	87	31	18	28	35	22.5	509	596	
Weight loaded/ weight loaded & empty wagons (total)[t]	87	102	68	102	102	68	1,598	1,685	
Costs [mill EUR]	5.0	0.22	0.22	0.22	0.55	0.8	2.01	7.01	

Table 71: Mixed intermodal fleet - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of the trailing load of 1,340 t, the payload of the mixed intermodal fleet is about 902.5 t (100% utilisation grade). The freight train consists of 15 wagons and 78 axles. The total length of the train set is 510.50 m.

No.	1	2	3	4	5	6	Total without loco-	Total	Pay-load [t]
Type	Loco-motive	Sggmrs 714	Sgk(k)ms(s)	Sggrss 733	Sdggmrs(s) 738	Sggns(s) 80'			

Description	Siemens Vectron MS	2 part container wagon	High-Cube-container wagon	2 part container wagon	2 part pocket wagon	80' con-tainer wagon	motive		
No. Wagons (loaded)	1	2	1	2	5	5	15	16	
No. Wagons (empty)	0	0	0	0	0	0	0	0	
No. Axles	4	6	4	6	6	4	78	82	
Length [m]	18.9	33.94	19.13	26.7	34.2	25.94	441.11	460.01	
Weight tare [t]	87	31	18	28	35	22.5	423.5	510.5	902.5
Weight loaded/ weight loaded & empty wagons (total)[t]	87	102	68	102	102	68	1,326	1,413	
Costs [mill EUR]	5.0	0.22	0.11	0.22	0.55	0.5	1.6	6.6	

Table 72: Mixed intermodal fleet - exemplary train configuration (1.340 t trailing load)

Intermodal Fleet Pocket Wagon

The second fleet proposal for Intermodal Freight Service consists of a train set for the transport of truck trailers with pocket wagons and 80% utilisation grade. With a length of 1,050 m as a limitation in this case, the total weight for the trailing load is about 2,745 t with a payload of about 1,608 t. With a 100% utilisation grade, the trailing load is about 3,147 t with a payload of about 2,010 t. In both cases, a standard operation with only one 4-axle locomotive and standard screw couplers is not feasible due to the limitations mentioned above.

No.	1	5	Total without locomotive	Total	Payload [t]
Type	Locomotive	Sdggmrs(s) 738			
Description	Siemens Vectron MS	2 part pocket wagon			
No. Wagons (loaded)	1	24	24	25	1608
No. Wagons (empty)	0	6	6	6	
No. Axles	4	6	180	184	
Length [m]	18.9	34.2	1,026	1,044.9	
Weight tare [t]	87	35	1,050	1,137	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	2,658	2,745	
Costs [mill EUR]	5	2.64	2.64	7.64	

Table 73: Intermodal Fleet Pocket Wagon - exemplary train configuration (2,745 t trailing load)

With a limitation value to the total weight of the trailing load of 2,500 t, the following freight train set could be used. With 80% utilisation grade, it consist a total length of about 908.1 m, 3 empty wagons and 23 loaded wagons. The total amount of axles is 160. The total mass without locomotive is about 2,451 t and the payload is about 1,541 t.

No.	1	5	Total without locomotive [t]	Total [t]	Payload [t]
Type	Locomotive	Sdggmrs(s) 738			
Description	Siemens Vectron MS	2 part pocket			
No. s (laden)	1	23	23	24	1541
No. s (empty)	0	3	3	3	
No. Axles	4	6	156	160	
length [m]	18.9	34.2	889.2	908.1	
weight tare [t]	87	35	910	997	
weight loaded / weight load-ed & empty s (total) [t]	87	102	2451	2538	
Costs [mill EUR]	5	2.53	2.53	7.53	

Table 74: Intermodal Fleet Pocket Wagon - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of the trailing load of 1,600 t, the payload of the pocket wagon fleet is about 1,005 t (100% utilisation grade). The freight train consists of 15 wagons and 90 axles. The total length of the train set is 531.9 m.

No.	1	5	Total without locomotive	Total	Payload [t]
Type	Locomotive	Sdggmrs(s) 738			
Description	Siemens Vectron MS	2 part pocket wagon			
No. Wagons (loaded)	1	15	15	16	1005
No. Wagons (empty)	0	0	0	0	
No. Axles	4	6	90	94	
Length [m]	18.9	34.2	513	531.9	
Weight tare [t]	87	35	525	612	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	1,530	1,617	
Costs [mill EUR]	5	1.65	1.65	6.65	

Table 75: Intermodal Fleet Pocket Wagon - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of the trailing load of 1,340 t, the payload of the pocket wagon fleet is about 871 t (100% utilisation grade). The freight train consists of 13 wagons and 78 axles. The total length of the train set is 463.5 m.

No.	1	5	Total without locomotive	Total	Payload [t]
Type	Locomotive	Sdggmrs(s) 738			
Description	Siemens Vectron MS	2 part pocket wagon			
No. Wagons (loaded)	1	13	13	14	871
No. Wagons (empty)	0	0	0	0	
No. Axles	4	6	78	82	
Length [m]	18.9	34.2	444.6	463.5	
Weight tare [t]	87	35	455	542	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	1,326	1,413	
Costs [mill EUR]	5	1.43	1.43	6.43	

Table 76: Intermodal Fleet Pocket Wagon - exemplary train configuration (1,340 t trailing load)

Intermodal Fleet Container Wagon

The third fleet proposal for Intermodal Freight Service contains the transport of standard containers with standard articulated-part container wagons and 80% utilisation grade. For the proposal very short articulated container wagons, which can be used up to 120 km/h fully loaded, were chosen. With a length of 1,050 m as limitation in this case, the total weight for trailing load is about 3,358 t with a payload of about 2,294 t. With 100% payload, the trailing load is about 3,876 t with a payload of about 2,812 t. In both cases, a standard operation with only one 4-axle locomotive and standard screw couplers is not feasible due to the limitations mentioned above.

No.	1	5	Total without locomotive	Total	Payload [t]
Type	Locomotive	Sggrss 733			
Description	Siemens Vectron MS	2 part container wagon			
No. Wagons (loaded)	1	31	31	32	2294
No. Wagons (empty)	0	7	7	7	
No. Axles	4	6	228	232	
Length [m]	18.9	26.7	1,014.6	1,033.5	
Weight tare [t]	87	28	1,064	1,151	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	3,358	3,445	
Costs [mill EUR]	5	3.41	3.41	8.41	

Table 77: Intermodal Fleet Container Wagon - exemplary train configuration (3,876 t trailing load)

With a limitation value to the total weight of the trailing load of 2,500 t, the following freight train set could be used. With 80% utilisation grade, it consist a total length of about 686.4 m, 2 empty wagons and 23 loaded wagons. The total amount of axles is 154. The total mass without locomotive is about 2,402 t and the payload is about 1,702 t.

No.	1	5	Total without locomotive [t]	Total [t]	Payload [t]
Type	Locomotive	Sggrss 733			
Description	Siemens Vectron MS	2 part Container			
No. wagons (loaded)	1	23	23	24	1702
No. wagons (empty)	0	2	2	2	
No. Axles	4	6	150	154	
length [m]	18.9	26.7	667.5	686.4	
weight tare [t]	87	28	700	787	
weight loaded / weight loaded & empty s (total) [t]	87	102	2,402	2,489	
Costs [mill EUR]	5	2.53	2.53	7.53	

Table 78: Intermodal Fleet Container Wagon - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of the trailing load of about 1,600 t, the payload of the container wagon fleet is about 1,110 t (100% utilisation grade). The freight train consists of 15 wagons and 90 axles. The total length of the train set is 419.5 m.

No.	1	5	Total without locomotive	Total	Payload [t]
Type	Locomotive	Sggrss 733			
Description	Siemens Vectron MS	2 part container wagon			
No. Wagons (loaded)	1	15	15	16	1110
No. Wagons (empty)	0	0	0	0	
No. Axles	4	6	90	94	
Length [m]	18.9	26.7	400.5	419.5	
Weight tare [t]	87	28	420	507	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	1,530	1,617	
Costs [mill EUR]	5	1.65	1.65	6.65	

Table 79: Intermodal Fleet Container Wagon - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of the trailing load of about 1,340 t, the payload of the container wagon fleet is about 962 t (100% utilisation grade). The freight train consists of 13 wagons and 78 axles. The total length of the train set is 366 m.

No.	1	5	Total without locomotive [t]	Total [t]	Payload [t]
Type	Locomotive	Sggrss 733			
Description	Siemens Vectron MS	2 part container wagon			
No. Wagons (loaded)	1	13	13	14	962
No. Wagons (empty)	0	0	0	0	
No. Axles	4	6	78	82	
Length [m]	18.9	26.7	347.1	366	
Weight tare [t]	87	28	364	451	
Weight loaded / weight loaded & empty wagons (total) [t]	87	102	1,326	1,413	
Costs [mill EUR]	5	1.43	1.43	6.43	

Table 80: Intermodal Fleet Container Wagon - exemplary train configuration (1,340 t trailing load)

2.6.4. Tank Wagon fleet

For the transport of liquid goods the biggest tank wagon with a space of 120 m^3 and an utilisation grade of 100% is chosen. The length is about 19.4 m and the tare weight is about 34 t. The weight of one fully loaded wagon with 22.5 t axle load is about 90 t. For the indicative Prise the highest standards and safety levels are chosen which leads to a price of about 132,500 EUR per wagon. With a limitation to 4,000 t total weight (which requires central buffer couplings) of the trailing load, the train consists of 44 tank wagons with 176 axles and a total length of 872.5 m. In areas without longer gradients it could be possible to operate this configuration. A locomotive with 6 axles is preferred. The payload is about 2,596 t.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Za…		
Description	Bombardier Traxx MS3	Tank wagon 120 cbm		
No. Wagons	1	44	45	46
No. Axles	4	4	176	180
Length [m]	18.9	19.4	853.6	872.5
Weight tare [t]	86	31	1,364	1,450
Weight loaded [t]	86	90	3,960	4,046
Costs [mill EUR]	4.2	5.83	5.83	10.03

Table 81: Tank Wagon Fleet - exemplary train configuration (4,000 t trailing load)

With a limitation value to the total weight of 2,500 t, the payload is about 1,593 t. The freight train consists of 27 wagons and 108 axles. The total length of the train set is 542.7 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Za…		
Description	Bombardier Traxx MS3	Tank 120 cbm		
No. Wagons	1	27	27	28
No. Axles	4	4	108	112
Length [m]	18.9	19.4	523.8	542.7
Weight tare [t]	86	31	837	923
Weight loaded [t]	86	90	2,430	2,516
Costs [mill EUR]	4.2	3.5775	3.5775	7.7775

Table 82: Tank Wagon Fleet - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of 1,600 t, the payload is about 1,003 t. The freight train consists of 17 wagons and 68 axles. The total length of the train set is 348.7 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Za…		
Description	Bombardier Traxx MS3	Tank wagon 120 cbm		
No. Wagons	1	17	17	18
No. Axles	4	4	68	72
Length [m]	18.9	19.4	329.8	348.7
Weight tare [t]	86	31	527	613
Weight loaded [t]	86	90	1,530	1,616
Costs [mill EUR]	4.2	2.2525	2.2525	6.4525

Table 83: Tank Wagon Fleet - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of 1,340 t, the payload is about 885 t. The freight train consists of 15 wagons and 60 axles. The total length of the train set is 309.9 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Za…		
Description	Bombardier Traxx MS3	Tank wagon 120 cbm		
No. Wagons	1	15	15	16
No. Axles	4	4	60	64
Length [m]	18.9	19.4	291	309.9
Weight tare [t]	86	31	465	551
Weight loaded [t]	86	90	1,350	1,436
Costs [mill EUR]	4.2	1.9875	1.9875	6.1875

Table 84: Tank Wagon Fleet - exemplary train configuration (1,340 t trailing load)

2.6.5. Bulk wagon fleet

Transport of ore, coal

For the transport of bulk freight like ore, coal etc. it is possible to use 4-axle bulk carrier like Fals or Falns or for very heavy transport 6-axle bulk carrier like Falrrs. The last one uses automatic couplings instead of screw couplers realizing a heavier trailing load of up to 6,000 t. At the current state it is recommended to use the screw coupler system and limit the bulk wagon fleet to types similar to Falns or Fals. A typical Falns 180 has a volume of 85 m^3 with a length of 12.54 m and a tare weight of 25 t.

With a limitation to 4,000 t total weight of the trailing load, the train consists of 44 wagons with 176 axles and a length of 572.56 m.

In areas without longer gradients it could be possible to operate this configuration. A locomotive with 6 axles is preferred. The payload is about 2,860 t.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Falns		
Description	Stadler Eurodual	Bulk Carrier 85 cbm		
No. Wagons	1	44	44	45
No. Axles	6	4	176	182
Length [m]	20.8	12.54	551.76	572.56
Weight tare [t]	126	25	1,100	1,226
Weight loaded [t]	126	90	3,960	4,086
Costs [mill EUR]	5.5	3.96	3.96	9.46

Table 85: Bulk Wagon Fleet - exemplary train configuration (4,000 t trailing load)

With a limitation value to the total weight of 2,500 t, the payload is about 1,593 t. The freight train consists of 27 wagons and 108 axles. The total length of the train set is 359.38 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Falns		
Description	Stadler Eurodual	Bulk Carrier 85 cbm		
No. Wagons	1	27	27	28
No. Axles	6	4	108	114
Length [m]	20.8	12.54	338.58	359.38
Weight tare [t]	126	25	675	801
Weight loaded [t]	126	90	2,430	2,556
Costs [mill EUR]	5.5	2.43	2.43	7.93

Table 86: Bulk Wagon Fleet - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of 1,600 t, the payload is about 1,105 t. The freight train consists of 17 wagons and 68 axles. The total length of the train set is 233.98 m.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Falns		
Description	Stadler Eurodual	Bulk Carrier 85 cbm		
No. Wagons	1	17	17	18
No. Axles	6	4	68	74
Length [m]	20.8	12.54	213.18	233.98
Weight tare [t]	126	25	425	551
Weight loaded [t]	126	90	1,530	1,656
Costs [mill EUR]	5.5	1.53	1.53	7.03

Table 87: Bulk Wagon Fleet - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of 1,340 t, the payload is about 975 t. The freight train consists of 15 wagons and 60 axles. The total length of the train set is 208.9 m.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Falns		
Description	Stadler Eurodual	Bulk Carrier 85 cbm		
No. Wagons	1	15	15	16
No. Axles	6	4	60	66
Length [m]	20.8	12.54	188.1	208.9
Weight tare [t]	126	25	375	501
Weight loaded [t]	126	90	1,350	1,476
Costs [mill EUR]	5.5	1.35	1.35	6.85

Table 88: Bulk Wagon Fleet - exemplary train configuration (1,340 t trailing load)

Transport of grain, cereals, animal feed

For the transport of grain, cereals or animal feed typical 4-axle swing roof wagon (like Tadgs(-v) 959, Tads 960) can be used. The wagons have length of about 21.64 m, tare weight of about 24.4 t and a payload of about 65.6 t at 22.5 t axle load.

With a limitation to 4,000 t total weight of the trailing load, the train consists of 44 wagons with 176 axles and a length of 972.96 m. The payload is about 2,886.4 t.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Tads 960		
Description	Stadler Eurodual	swing roof wagon 80 cbm		
No. Wagons	1	44	44	45
No. Axles	6	4	176	182
length [m]	20.8	21.64	952.16	972.96
weight tare [t]	126	24.4	1,073.6	1,199.6
weight loaded [t]	126	90	3,960	4,086
Costs [mill EUR]	5.5	3.96	3.96	9.46

Table 89: Swing Roof Wagon Fleet - exemplary train configuration (4,000 t trailing load)

With a limitation value to the total weight of 2,500 t, the payload is about 1,771.2 t. The freight train consists of 27 wagons and 108 axles. The total length of the train set is 605.8 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Tads 960		
Description	Stadler Eurodual	swing roof wagon 80 cbm		
No. Wagons	1	27	27	28
No. Axles	6	4	108	114
length [m]	20.8	21.64	584.28	605.08
weight tare [t]	126	24.4	658.8	784.8
weight loaded [t]	126	90	2,430	2,556
Costs [mill EUR]	5.5	2.43	2.43	7.93

Table 90: Swing Roof Wagon Fleet - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of 1,600 t, the payload is about 1,115.2 t. The freight train consists of 17 wagons and 68 axles. The total length of the train set is 388.68 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Tads 960		
Description	Stadler Eurodual	swing roof wagon 80 cbm		
No. Wagons	1	17	17	18
No. Axles	6	4	68	74
Length [m]	20.8	21.64	367.88	388.68
Weight tare [t]	126	24.4	414.8	540.8
Weight loaded [t]	126	90	1,530	1,656
Costs [mill EUR]	5.5	1.53	1.53	7.03

Table 91: Swing Roof Wagon Fleet - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of 1,340 t, the payload is about 918.4 t. The freight train consists of 14 wagons and 56 axles. The total length of the train set is 323.76 m.

No.	1	2	Total without locomotive	Total
Type	Locomotive	Tads 960		
Description	Stadler Eurodual	swing roof wagon 80 cbm		
No. Wagons	1	14	14	15
No. Axles	6	4	56	62
Length [m]	20.8	21.64	302.96	323.76
Weight tare [t]	126	24.4	341.6	467.6
Weight loaded [t]	126	90	1,260	1,386
Costs [mill EUR]	5.5	1.26	1.26	6.76

Table 92: Swing Roof Wagon Fleet - exemplary train configuration (1,340 t trailing load)

Transport of powder-shaped materials

For the transport of powder-shaped materials like cement, lime, sand, dust etc. 4-axle powder products wagons (Uacs, Uacns) can be used. A typical 82 cbm Uacns wagon with 22.5 t axle load has a length over buffer of about 16.24 m, 17.8 t tare weight and a payload of about 72.2 t.

With a limitation to 4,000 t total weight of the trailing load, the train consists of 44 wagons with 176 axles and a length of 735.36 m. The payload is about 3,176.8 t.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Uacns		
Description	Stadler Eurodu-al	Powder Products Wagon 82 cbm		
No. Wagons	1	44	44	45
No. Axles	6	4	176	182
length [m]	20.8	16.24	714.56	735.36
weight tare [t]	126	17.8	783.2	909.2
weight loaded [t]	126	90	3,960	4,086
Costs [mill EUR]	5.5	5.83	5.83	11.33

Table 93: Powder Products Wagon Fleet - exemplary train configuration (4,000 t trailing load)

With a limitation value to the total weight of 2,500 t, the payload is about 1,949.4 t. The freight train consists of 27 wagons and 108 axles. The total length of the train set is 459.28 m.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Uacns		
Description	Stadler Eurodu-al	Powder Products Wagon 82 cbm		
No. Wagons	1	27	27	28
No. Axles	6	4	108	114
length [m]	20.8	16.24	438.48	459.28
weight tare [t]	126	17.8	480.6	606.6
weight loaded [t]	126	90	2,430	2,556
Costs [mill EUR]	5.5	3.5775	3.5775	9.0775

Table 94: Powder Products Wagon Fleet - exemplary train configuration (2,500 t trailing load)

With a limitation value to the total weight of 1,600 t, the payload is about 1,227.4 t. The freight train consists of 17 wagons and 68 axles. The total length of the train set is 296.88 m.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Uacns		
Description	Stadler Eurodu-al	Powder Products Wagon 82 cbm		
No. Wagons	1	17	17	18
No. Axles	6	4	68	74
length [m]	20.8	16.24	276.08	296.88
Weight tare [t]	126	17.8	302.6	428.6
Weight loaded [t]	126	90	1,530	1,656
Costs [mill EUR]	5.5	2.2525	2.2525	7.7525

Table 95: Powder Products Wagon Fleet - exemplary train configuration (1,600 t trailing load)

With a limitation value to the total weight of 1,340 t, the payload is about 1,010.8 t. The freight train consists of 14 wagons and 56 axles. The total length of the train set is 247.16 m.

No.	1	2	Total without loco-motive	Total
Type	Locomotive	Uacns		
Description	Stadler Eurodu-al	Powder Products Wagon 82 cbm		
No. Wagons	1	14	14	15
No. Axles	6	4	56	62
Length [m]	20.8	16.24	227.36	248.16
Weight tare [t]	126	17.8	249.2	375.2
Weight loaded [t]	126	90	1,260	1,386
Costs [mill EUR]	5.5	1.855	1.855	7.355

Table 96: Powder Products Wagon Fleet - exemplary train configuration (1340 t trailing load)

2.6.6. Conclusion for the freight train chapter

Summarising the investigation results it is obvious, that there are a lot of restrictions and complicated exceptions for the freight trains to the total weight or a train speed higher than 120 km/h. Two of the main limitations are the maximum trailing load of 2,500 t (due to 85 tons standard screw couplings) and 1,600 t (due to brake arrangement and 120 km/h).

For the transport of these two trailing load types it was demonstrated, that the 4-axle locomotive is able to carry the 1,600 t freight train and the 6-axle locomotive the 2,500 t freight train. But in both cases, an additional locomotive seems to be necessary for providing the pulling power at 12.5 ‰ gradient at wet conditions. The RailSys simulations of the 6-axle locomotive with the 2,500 t trailing load at a gradient with 12.5 ‰ showed, that even in the passing case, when the train is not stopped, the velocity will be reduced below 40 km/h after 5 km on the gradient. That means, that for the heaviest configuration with 4,000 t the traction with the strongest 4-axle locomotive is not possible and even a double header with two 6-axle locomotives could get problems to handle trains with this configuration on such a gradient.

In the previous sub-chapters, for different transport goods different train configurations were listed and calculated with an indicative price, based on the benchmark chapter. For the locomotive, different possibilities are available in a range from 3 to 5.5 mill EUR.

According to the technical requirements, a total train length of 1,050 m shall be possible. In the analyses for the freight train configurations it was shown, that it is not possible to create such long train sets. The limitation factor is the trailing load limit of 2,500 t, if the loading limit table by SBB will be respected. If a trailing load with more than 2,500 t is possible (central buffer couplings, or sections with lower gradients at the Rail Baltica Route), the intermodal fleets can reach such long train sets with a trailing load up to 2,840 t with payload of 1,852 t. For a final summary, Figure 41 shows and overview of the train length and trailing load of the proposed exemplary freight trains.

Over all configurations the price range for 1,600 t trailing load (just freight wagons) is between 1.53 up to 2.25mill EUR. For 2,500 t trailing between 2.43 up to 3.58ill mill EUR, for 4,000 t trailing load (central buffer couplings, just bulk materials) between 3.96 up to 5.83 mill EUR and for 1,050 m intermodal fleet length (with central buffer couplings) between 2.64 and 3.41 mill EUR.

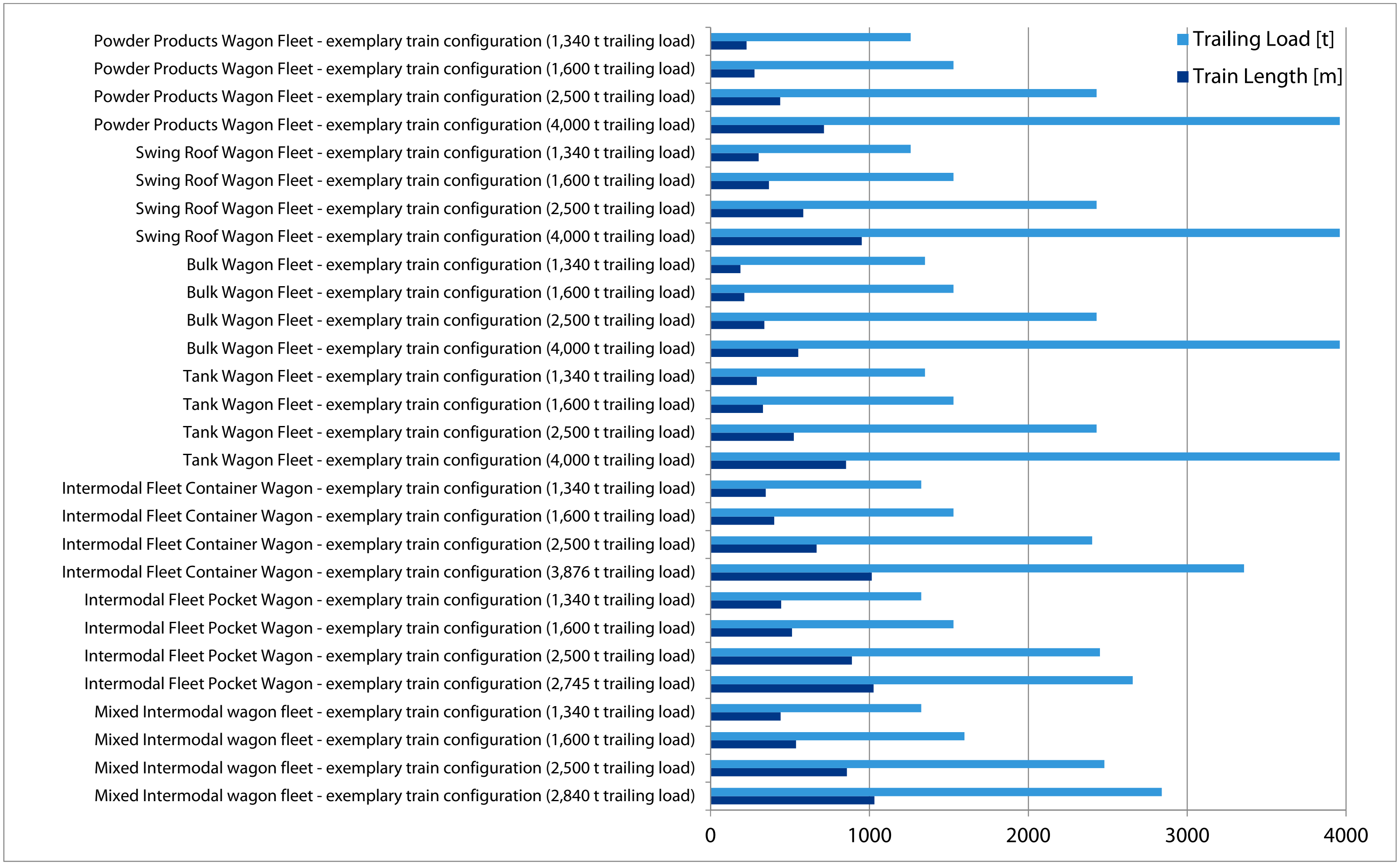


Figure 41: Overview of train length and trailing load for proposed exemplary freight trains

2.7. Shunting Locomotives

The actual market of available shunting locomotives or shunting locomotives in service is very big. An extensive number of vehicle types exist. In many cases the shunting locomotives are not built by one of the big manufacturers, rather by smaller specialised companies. Furthermore most of the shunting locomotives are very old, but due to their simply construction they can be modernised easily. In general two ways for new shunting locomotives exist:

- The development and mounting of new shunting locomotives, or
- the rebuild, modernization of existing shunting locomotives.

For RailBaltica both ways must consider the actual TSI homologations too. This point could lead to an exclusion of the rebuild, modernization of existing shunting locomotives due to (for example) missing crash zones etc.

Due the huge amount of different manufacturers, it is not possible to know every small manufacturer for shunting locomotives. Furthermore the following enumeration only lists new available shunting locomotives.

Model	Builder	Power Unit	Electric current	Motor Type	Track gauge	Homolo-gated for clearance gauge	Height	Axcel arrange-ment (UIC classifica-tion)	Number of axles
15D / 16D	Newag	diesel-electric	-	V12 diesel	1435	GB		Co'Co'	6
6DI	Newag	diesel-electric	-	C18 diesel	1435	GB		Bo'Bo'	4
18D	Newag	diesel-electric	-	C18 diesel	1435	GB		Bo'Bo'	4
G 6	Vossloh	diesel-hydraulic	-	Cummins, MTU, Caterpil-lar, diesel-hydraulic	1435	GB	4225	C	3
G 12 / DE 12	Vossloh	diesel-hydraulic and diesel-electric	-	MTU 8V 4000 R43(L) G 12 dieselhyd-raulic DE 12 die-selelectric	1435	GB	4310	B'B' - G 12 Bo'Bo' - DE 12	4
G 18 / DE 18	Vossloh	diesel-hydraulic and diesel-electric	-	MTU 12V 4000 R43(L) G 12 dieselhyd-raulic DE 12 die-selelectric	1435	GB	4310	B'B' - G 12 Bo'Bo' - DE 12	4
Butler	Stadler	diesel and electric	25 kV AC 50 Hz 15 kV AC 16.7 Hz	diesel-electric	1435	GB	4306	Bo	2

Model	Builder	Power Unit	Electric current	Motor Type	Track gauge	Homolo-gated for clearance gauge	Height	Axcel arrange-ment (UIC classifica-tion)	Number of axles
D25 B	Gmeinder Locomotive	diesel - N/A	-	MB OM424, Deutz BF12L513	1435	GB	3960	B	2
D60 C	Gmeinder Locomotive	diesel-hydraulic	-	MTU 12V 1600 R50	1435	GB	4255	C	3
D75 BB	Gmeinder Locomotive	diesel - N/A	-	CAT 3412 E DI-TTA	1435	GB	4240	B'B'	4
D75 BB Hybrid	Gmeinder Locomotive	diesel - N/A	-	N/A	1435	GB	4260	Bo'Bo'	4
MMT-S-400-BDE (2-axle)	Schalker Eisenhütte	diesel-electric	-	N/A	1000-1600	GB	4250	Bo	2
MMT-S-400-BDE (4-axle)	Schalker Eisenhütte	diesel-electric	-	N/A	1000-1600	GB	4250	Bo'Bo'	4
Prima H3	Alstom	Hybrid	Battery Locomo-tive 600 kW	One Diesel 1000 kW, 2 Diesel à 350 kW, Hybrid Diesel 350 kW and Battery	1435	GB	N/A	A'A'A'	3
Prima H4	Alstom	DUAL Mode	15 kV AC 16.7 Hz	CAT C18	1435	GC	4476	Bo'Bo'	4
Effishunter 300	CZ Loko	diesel-electric	-	CAT C13	1435	GB	3460	Bo	2
Effishunter 600	CZ Loko	diesel-electric	-	CAT C18	1435	GB	4290	Bo'Bo'	4
Effishunter 1000	CZ Loko	diesel-electric	-	CAT C32	1435	GB	4280	Bo'Bo'	4
Effishunter 1600	CZ Loko	diesel-electric	-	CAT 3512 C-HD	1435	GC	4640	Bo'Bo'	6

Table 97: Shunting locomotives – main parameters

Model	Number of axles for traction	Length over buffers (mm)	Power (kW)	Maximum Speed (km/h)	Weight (tonnes)	Adhesion mass (tonnes)	Tractive Effort [kN]	Fuel tank volume (l)	Indicative Price
15D / 16D	6	16,970	1,550	100	116	116	372.8	6,000	1.83mill EUR
6DI	4	14,240	563	90	70	70	219	6,000	887,700 EUR
18D	4	14,240	563	90	70	70	219	6,000	N/A
G 6	3	10,790	650	80	67.5	67.5	219	1,800	1.4mill EUR
G 12 / DE 12	4	1,700	1,200 (max)	100-120	90	90	291	4,100	N/A
G 18 / DE 18	4	1,700	1,800 (max)	100-120	90	90	291	4,100	3.2mill EUR
Butler	2	9,132	1,500 (elec.) 290 (diesel)	120	45	45	150	N/A	~2.55mill EUR
D25 B	2	8,240	380	15	45	45	145	1,200	N/A
D60 C	3	10,760	690	40	67.5	67.5	218	2,200	N/A
D75 BB	4	12,400	571	25	80	80	240	1,900	N/A
D75 BB Hybrid	4	1,300	600	60	80	80	260	1900	N/A
MMT-S-400-BDE (2-axle)	2	8,000	390	50	45	45	150	N/A	N/A
MMT-S-400-BDE (4-axle)	4	1,700	1,800	60	90	90	290	N/A	N/A

Model	Number of axles for traction	Length over buffers (mm)	Power (kW)	Maximum Speed (km/h)	Weight (tonnes)	Adhesion mass (tonnes)	Tractive Effort [kN]	Fuel tank volume (l)	Indicative Price
Prima H3	3	12,800	600 - 1000	100	67,5	67,5	240	2200	N/A
Prima H4	4	18,750	2,000	120	80	80	300	3,000	1.73mill EUR
Effishunter 300	2	7,940	328	60	36	36	90	700	N/A
Effishunter 600	4	13,820	563	80	72	72	222	4,000	N/A
Effishunter 1000	4	16,400	895	100	80	80	267	4,000	N/A
Effishunter 1600	6	17,420	1550	90	115.2	115.2	383	5,000	N/A

Table 98: Shunting locomotives – technical performance

Very often shunting locomotives were sold to private companies with own railway infrastructure. Due to that reason, it was not possible to collect information about the indicative price for every shunting locomotive. Nevertheless, it must be calculated, that for locomotives, only for shunting, the indicative price is around 1.4 mill Euro or below. For locomotives suitable for shunting and long distance service higher prices up to 3.2 mill Euro must be paid.

2.8. Fleet Size Proposal

2.8.1. Passenger Transport

At the current status of the Operational Plan for the proposed train service pattern the following fleet size would be required:

Train type	Line	Turnarounds and fleet size			
		2026	2036	2046	2056
HST	11 Warszawa - Tallinn/Helsinki	4	6	6	8
	12 Vilnius - Tallinn/Helsinki	3	5	5	7
	13 Warszawa - Vilnius	5	3	3	5
	14 Kaunas - Vilnius	3	6	6	5
	Total	15	20	20	25
	Reserve (15%)	3	3	3	4

Train type	Line	Turnarounds and fleet size			
		2026	2036	2046	2056
	Total with reserve	**18**	**23**	**23**	**29**
NT	41 Warszawa - Tallinn/Helsinki	0	2	2	2
	42 Warszawa - Vilnius	0	2	2	2
	Total	0	4	4	4
	Reserve (15%)	0	1	1	1
	Total with reserve	**0**	**5**	**5**	**5**
RE/RIX/HEL	21 RIX - Tallinn	3	3	3	4
	22 Pärnu - Tallinn	1	2	2	2
	24 Bauska - Salacgrïva	1	2	2	2
	25 Bauska - Skulte	1	1	1	2
	26 Marijampolé - Riga	3	3	3	4
	27 Vilnius - Panevezys	3	3	3	4
	28 Bialystok - Vilnius	3	3	3	4
	29 Kaunas - Vilnius	1	1	1	1
	31 Riga - RIX	1	1	1	2
	51 Helsinki - Tallinn	0	0	0	4
	Total	17	19	19	29
	Reserve (15%)	3	3	3	5
	Total with reserve	**20**	**22**	**22**	**34**

Table 99: Preliminary Study fleet size dimension for passenger trains

Based on the developed CAPEX for the generical EMU's and the CAPEX for the night train, the following overall CAPEX over 4 time periods are calculated:

Train Type	Single CAPEX [mill Euro]	2026		2036		2046		2056	
		No of new trains [-]	Total Capex [mill Euro]	No of new trains [-]	Total Capex [mill Euro]	No of new trains [-]	Total Capex [mill Euro]	No of new trains [-]	Total Capex [mill Euro]
HST	23.04	18	414.72	5	115.20	0	0.00	24	552.96
NT	17.6	0	0.00	5	88.00	0	0.00	0	0.00
RE/RIX/HEL	8.24	20	164.8	2	16.84	0	0.00	32	263.68

Table 100: Total CAPEX for Passenger Fleet

The calculations in the table above assume that the lifetime of one train is about 30 years. That means, that for the year 2056 the number of trains from 2026 must be reinvested. Summarizing the calculations, in 2026 a total CAPEX of 579.52 mill Euro, in 2036 220.04 mill Euro, in 2046 0 mill Euro and in 2056 816.64 mill Euro were calculated.

2.8.2. Freight Transport

The calculation of fleet size is based on the average train configuration for trailing load of 1,600 t. Therefore, the number of freight trains has been calculated based on the forecast in WP 1. For further details please refer to the Operational Plan. Fleet size is calculated for the total train run, including circulation on line sections outside Rail Baltica. Therefore the following assumptions are made:

- To represent freight trains going to other major destinations in Poland (e. g. Poznan, Southern Poland) 300 km are added to overall travelling distance between the border and Warszawa.
- 30% of the trains are going further to destinations in other countries (mainly Germany). For these trains 750 km additional distances are incorporated in the calculation of travel time.

To incorporate the time share for loading and unloading a layover time of 12 hours at each terminal is added to the overall circulation time of wagon fleet. For locomotive circulation this average time is reduced to 6 hours to represent the share of locomotives picking up another train in opposite direction. With respect to regularity of the timetabled departures and long travelled distances, the overall circulation time is rounded up to full operating days.

The calculation of fleet size and CAPEX is based on the assumption of trains with maximum payload of 1,600 t. This is in line with the traffic forecast assuming an average payload of 1,000 t per freight train. If heavier trains are operated, the number of required locomotives will be lower, and the size of the wagon fleet will be more or less the same depending on departure frequency.

Regarding circulation of cargo trains an average speed of 70 km/h is assumed. This is in line with results of timetabling freight services on the Rail Baltica as outlined in chapter 4.5.5.3.

It is taken into account that most trains will be operated as block trains from origin to destination, and that the majority of the services will be intermodal. For single wagonload additional layover times of the freight wagons at the hubs of the network would apply. Due to the low of single wagonload assignments to be expected this is not considered in the calculation.

The results of the calculation of the number of required train sets are presented in the tables below. The fleet size does include a maintenance reserve of 5% (freight wagons) and 10% (freight locomotives).

Relation	km	km/h	h	Layover at terminal	Travel Time	Circulation time	Days
Muuga-Warszawa	1,460	70	20.90	12.00	32.90	89.80	4
Salaspils - Warszawa	1,130	70	16.10	12.00	28.10	80.20	4
Vilnius - Warszawa	690	70	9.90	12.00	21.90	67.80	3
Tallinn - Vilnius	660	70	9.40	12.00	21.40	66.80	3
Salaspils - Vilnius	320	70	4.60	12.00	16.60	57.20	3
Kaunas - Warszawa	890	70	12.70	12.00	24.70	73.40	4
Extended service to other EU countries	*750*	*70*	*10.70*	*2.00*	*12.70*	*29.40*	*2*

Table 101: Overall fleet size calculation of freight wagon fleet for different operating periods (basics)

	2026		2036		2046		2056	
Relation	***Train pairs per day***	***No of trainsets***	***Train pairs per day***	***No. of trainsets***	***Train pairs per day***	***No. of trainsets***	***Train pairs per day***	***No. of trainsets***
Muuga-Warszawa	9	36	9	36	10	40	17	68
Salaspils - Warszawa	1	4	1	4	2	8	2	8
Vilnius - Warszawa	9	27	11	33	12	36	12	36
Tallinn - Vilnius	1	3	3	9	4	12	4	12
Salaspils - Vilnius	1	3	1	3	1	3	1	3
Kaunas - Warszawa	8	32	9	36	10	40	11	44
Extended service to other EU countries	*8*	*16*	*9*	*18*	*10*	*20*	*13*	*26*
Sum	29	**121**	34	**139**	39	**159**	47	**197**
Maintenance Reserve		7		7		8		10
Total		**128**		**146**		**167**		**207**

Table 102: Overall fleet size calculation of freight wagon fleet for different operating periods (results)

Locomotive calculation:

Relation	km	km/h	h	Layover at terminal	Travel Time	Circulation time	Days
Muuga-Warszawa	1,460	70	20.90	6.00	26.90	65.80	3
Salaspils - Warszawa	1,130	70	16.10	6.00	22.10	56.20	3
Vilnius - Warszawa	690	70	9.90	6.00	15.90	43.80	2
Tallinn - Vilnius	660	70	9.40	6.00	15.40	42.80	2
Salaspils - Vilnius	320	70	4.60	6.00	10.60	33.20	2
Kaunas - Warszawa	890	70	12.70	6.00	18.70	49.40	3
Extended service to other EU countries	*750*	*70*	*10.70*	*2.00*	*12.70*	*29.40*	*2*

Table 103: Overall fleet size calculation of freight train locomotives for different operating periods (basics)

	2026		2036		2046		2056	
Relation	***Train pairs per day***	***No. of trainsets***	***Train pairs per day***	***No. of trainsets***	***Train pairs per day***	***No. of trainsets***	***Train pairs per day***	***No. of trainsets***
Muuga-Warszawa	9	27	9	27	10	30	17	51
Salaspils - Warszawa	1	3	1	3	2	6	2	6
Vilnius - Warszawa	9	18	11	22	12	24	12	24
Tallinn - Vilnius	1	2	3	6	4	8	4	8
Salaspils - Vilnius	1	2	1	2	1	2	1	2
Kaunas - Warszawa	8	24	9	27	10	30	11	33
Extended service to other EU countries	*8*	*16*	*9*	*18*	*10*	*20*	*13*	*26*
Sum	29	**92**	34	**105**	39	**120**	47	**150**
Maintenance reserve		10		11		12		20
Total		**102**	34	**116**	39	**132**		**170**
Trains PL-VIL	27		30		34		42	
Trains per week	162		180		204		252	

Table 104: Overall fleet size calculation of freight train locomotives for different operating periods (results)

For the operation of the forecasted freight trains a fleet of a size between 100 (first years of operation) and 170 (optimistic case with FinEst link) freight train locomotives would be required.

The expected CAPEX are indicated based on a price range per unit. For more details about indicative unit prices please refer to ANNEXES 2 to 4.

CAPEX for freight train fleet:

Rolling Stock Type	Case	Indicative price (mill EUR per unit)	CAPEX for fleet required in operating period			
			2026	2036	2046	2056
Locomotives	Low Case	3,00	306.0	348.0	396.0	510.0
	High Case	5,50	561.0	638.0	726.0	935.0
Freight Wagons (complete train sets)	Low Case	1,53	185.1	212.7	243.3	301.4
	High Case	2,25	272.3	312.8	357.8	443.3
Total	Low Case		491.1	560.7	639.3	811.4
	High Case		833.3	950.8	1.083.8	1.378.3

Table 105: CAPEX for required freight train fleet

At the end it shall be considered, that very often the freight transports are done by third party companies, which operate all over Europe and uses their own or rented freight locomotives and freight wagons.

2.9. Train resistance

2.9.1. Passenger Transport

The area of the calculation of train resistances is very complex and in the literature an extensive number of different equations are given. Unfortunately no supplier wanted to hand out any information about the train resistance. For that case, a manual calculation based on literature is done. For the calculation of the EMUs and DMUs, the equation of *Rappenglück*[39] is used, which is similar to the Davis-Formula.

$$F_{WZ} = F_{WZO} + F_{WZ1}\left(\frac{v}{v_{00}}\right) + F_{WZ2}\left(\frac{v+\Delta v}{v_{00}}\right).$$

In the following, the train resistance F_{WZ} in kN is given for the separate Multipe-Units, if all necessary information is available. However, in some cases, estimations had to be done. These estimations were:

- periphery of the outer dimensions in driving direction, estimated from width and height of the train set,
- length between two car ends (passenger transit area from car to car) with 0.5 m,
- front area, as standard value 10 m² and
- contrary wind addition with 15 km/h.

The final calculations are done for a velocity of 100 km/h to compare all Multiple-Units (HST, IC, and Regional trains) and at the separate maximum velocity respectively the maximum velocity 249 km/h. Furthermore, in some cases not all information about a train set for calculations was available. In this case, the train sets were not considered and deleted. The separate velocity classes are:

- 120 km/h,
- 130 km/h,
- 140 km/h,
- 160 km/h,
- 200 km/h,
- 225/230 km/h,
- 249 km/h.

In every case it can be seen, that short Multiple-Units have a low train resistance. For the proposal in the chapter before, the 5-cars FLIRT has a lower train resistance than the 4-cars KISS. For the HST-Train sets the Talgo-Trains have the lowest train resistances, followed by the Alstom Pendolino.

[39] In: D. Wende, Fahrdynamik des Schienenverkehrs, Vieweg+Teubner, Springer Fachmedien, Wiesbaden, 2003

Model	Supplier	Maximum velocity (km/h)	Calculation for reference velocity 100 km/h [N/kN]	Calculation for maxi-mum velocity km/h [N/kN]
Coradia Lint 27	Alstom	120	7.86353695	10.1937757
GTW 2/6	Stadler	120	6.72074103	8.62444332
Class SA137 Type 220M	Newag	120	5.53960622	7.05300924
Coradia Lint 41	Alstom	120	6.43761582	8.25134575
Class SA137/SA138 Type 220M/221M	Newag	120	5.39174082	6.8410832
Type 222M/222Ma	Newag	130	5.28072355	7.50001858
Atribo ATR220	Pesa SA	130	5.58350714	7.92964524
19WE	Newag	130	4.92151601	6.86029517
Coradia Lint 54	Alstom	140	5.61017969	8.85561132
Class 490	Bombardier Trans-portation	140	5.51508251	8.62511413
Coradia Lint 81	Alstom	140	5.42838295	8.49611335
Link (2-cars)	Pesa SA	160	5.56725585	10.7922576
Impuls 37WE (2-car)	Newag	160	6.00613673	11.7801168
Elf 34WE (2-car)	PESA	160	5.93001635	11.6224557
Elf 2 34WEa	PESA	160	5.93001635	11.6224557
Acatus Plus (2 cars)	PESA	160	5.86130604	11.4748068
WINK	Stadler	160	7.44195348	14.9178095
Desiro HC	Siemens Mobility	160	3.58497372	6.11860063
Acatus Plus (3 cars)	PESA	160	5.46507965	10.6235154
Impuls 36WEa (3-car)	Newag	160	5.52512677	10.6790164
Impuls 36WE (3-car)	Newag	160	5.13244764	9.83959399

Model	Supplier	Maximum velocity (km/h)	Calculation for reference velocity 100 km/h [N/kN]	Calculation for maxi-mum velocity km/h [N/kN]
Elf 21WE (3-car)	PESA	160	5.67520619	11.0092308
Elf 2 21WEa	PESA	160	5.67520619	11.0092308
Elf 2 EN62A	PESA	160	5.67520619	11.0092308
Coradia Polyvalent (3-cars)	Alstom	160	4.253602	7.97125653
Impuls 31WE (4-car)	Newag	160	5.09140589	9.71095984
Elf 22WE (4-car)	PESA	160	5.40814954	10.3953639
Coradia Polyvalent (4-cars)	Alstom	160	4.08772204	7.58712997
Twindexx Vario/Dosto 2010 (3-Cars)	Bombardier	160	4.55194982	8.51980242
Impuls 45WE (5-car)	Newag	160	5.26001606	10.0392034
Coradia Continental (5-cars)	Alstom	160	5.09392212	9.69290598
Elf 27WE (6-car)	PESA	160	5.1052686	9.69950123
Impuls 35WE (6-car)	Newag	160	5.01927089	9.52352616
Elf 27WEb (6-car)	PESA	160	4.91231392	9.23069258
Twindexx Vario/Dosto 2010 (3-Cars, 4-Cars)	Bombardier	160	4.42793921	8.21882335
Coradia Polyvalent (6-cars)	Alstom	160	3.76634061	6.84291021
Flirt3 (3-cars)	Stadler	200	5.94418431	16.4955263
Flirt3 (4-cars)	Stadler	200	5.50346557	15.0189441

Model	Supplier	Maximum velocity (km/h)	Calculation for reference velocity 100 km/h [N/kN]	Calculation for maximum velocity km/h [N/kN]
Flirt3 (5-cars)	Stadler	200	5.84711402	15.8845443
Kiss (4-cars)	Stadler	200	4.79393786	12.5791316
Flirt3 (8-cars)	Stadler	200	5.02944092	13.3360374
Dart	PESA	200	3.69833101	9.32157486
Kiss (6-cars)	Stadler AG	225	4.80611946	12.5037942
Javelin (A Train)	Hitachi Rail	230	4.7512325	14.6030493
ICE 4 (7-cars)	Siemens Mobility	249	4.47668107	14.3325725
Talgo 250 (2+11 car)	Patentes Talgo, Bombardier	249	4.68898359	17.6539843
Talgo 350 (2+12 car)	Patentes Talgo, Bombardier	249	4.67226271	17.5939315
Pendolino (7-cars)	Alstom	249	4.26477364	15.2665759
SMILE EC 250	Stadler	249	4.44867518	16.4187751
Euroduplex	Alstom	249	4.10813023	14.7704337
Zefiro 300 (8 cars)	Bombardier Transportation	249	4.22683202	15.0132803
Velaro D (8-cars)	Siemens Mobility	249	4.2645393	15.2119984
ICE 4 (12-cars)	Siemens Mobility	249	4.32374819	15.4878407

Table 106: Train resistances of EMU and DMU in the straight

2.9.2. Freight Transport

The calculations of the train resistances for the freight trains has not been done for every single freight wagon, but instead for three typical trailing loads (4,000 t, 2,500 t and 1,600 t), for three different axle-loads (17 t, 22.5 t and 25 t) and for a 4-axle locomotive (87 t weight) and a 6-axle locomotive (125 t weight). The configurations are based on the freight wagon information in chapter 2.6. In the course of this analysis a 17 t axle-loads means the intermodal container freight trains, and therefore a train set with 4,000 t trailing load is not possible. The 17 t axle-loads are based on the average weight of standard ISO-container which leads to the lower axle-loads. That means that with intermodal transport more volume of good is transported than mass of goods. The axle-load of 22.5 t is the actual standard, and for a comparison a calculation with 25 t axle-loads has been done too.

For the train resistance the equation for freight trains by Jentsch and Preysing[40] was used. The base formula is similar to the Davis formula, with other ways to calculate the coefficients. In Table 107 the train resistances for the 4-axle locomotive and in Table 108 for the 6-axle locomotive is shown. It is clear that a higher axle-load leads to lower train resistances. Unfortunately, an axle-load of 25 t is currently a solution only for Rail Baltica. In other countries in Europe, the 22.5 t maximum axle-loads is still the standard.

Axel Load for 100 km/h with 4-axle Loco [t]	4,000 t trailing load	2,500 t trailing load	1,600 t trailing load
17 t	-	5.724 N/kN	5.809 N/kN
22.5 t	4.467 N/kN	4.608 N/kN	4.710 N/kN
25 t	4.117 N/ kN	4.256 N/kN	4.361 N/kN

Table 107: Freight train resistance with 4-axle locomotive in the straight

Axel Load for 100 km/h with 6-axle loco [t]	4,000 t trailing load	2,500 trailing load	1,600 t trailing load
17 t	-	5.887 N/kN	5.842 N/kN
22.5 t	4.579 N/kN	4.761 N/kN	4.769 N/kN
25 t	4.227 N/kN	4.404 N/kN	4.427 N/kN

Table 108: Freight train resistance with 6-axle locomotive in the straight

[40] In: D. Wende, Fahrdynamik des Schienenverkehrs, Vieweg+Teubner, Springer Fachmedien, Wiesbaden, 2003

3. Infrastructure studies (WP 3)

3.1. Scope and methodology

As basis for the Operational Plan the existing planning stage of the infrastructure was analysed with following aims:

- Collection and consolidation of source data for the draft timetable and the capacity analysis as part of preparation of the Operational Plan;
- Identification of improvement potential of planned infrastructure to meet the requirements set out in the Operational Plan;
- Identification of interoperability issues with impact on operations and rolling stock;
- Analysis of alignment parameters relevant for train configuration for freight and passenger services.

One main result is a consolidated overview of the intended infrastructure as schematic track layout indicating the location of all operational points (stations, passing loops, emergency crossovers, junctions, passenger stops) and the related track layout.

The consolidated track plan is the basis for development of the Operational Plan and the related working timetable. Based on the outcome of the operational assessment and the requirements highlighted in the Operational Plan the track layout will be amended step by step to highlight the operational requirements and to show impact of further traffic growth as basis for further planning work to be undertaken.

In addition to that relevant technical parameters of the line have been analysed to provide the necessary basis for the Operational Plan.

3.2. Route Overview

Rail Baltica is a new 1435mm railway line and will connect the three Baltic countries with Poland and Central Europe. In a later stage a railway tunnel between Tallinn and Helsinki will extend Rail Baltica to Finland. The following figure gives an overview of the planned alignment:

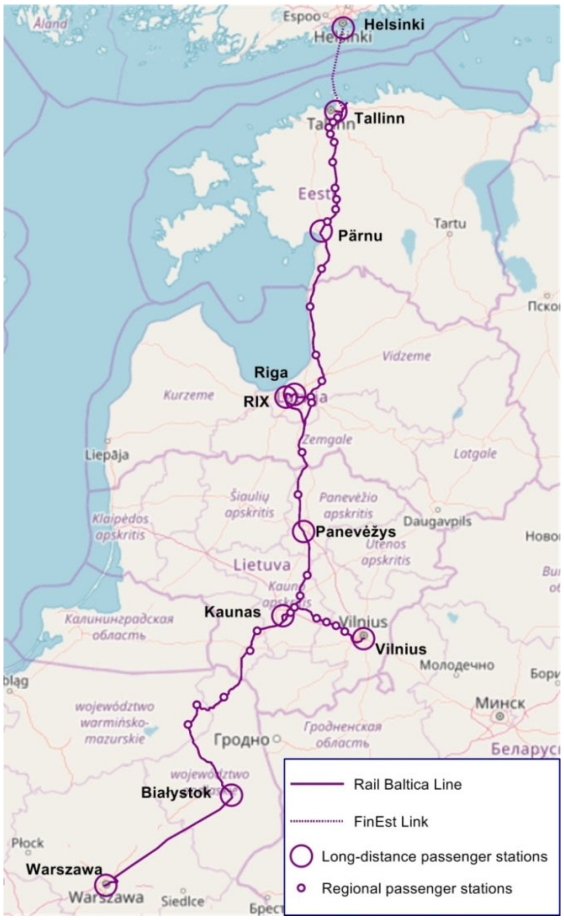


Figure 42: Route overview

The planned alignment can be subdivided into three major parts (from north to south):

- FinEst link (Tunnel from Helsinki to Tallinn);
- New high-speed line from Tallinn via Riga and Kaunas to the Lithuanian-Polish border with 6 long-distance stops (Tallinn, Pärnu, Riga, Riga Airport, Panevėžys and Kaunas);
- Upgraded (and partly new) line from the Lithuanian-Polish border via Ełk and Białystok to Warszawa.

In addition to the main line two additional lines will extend the direct catchment area of Rail Baltica:

- Kaunas – Vilnius link to connect the Lithuanian capital;
- Riga Bypass (east of Riga) for direct freight trains bypassing the urban area of Riga.

In total Rail Baltica has a length of approx. **1,265 km** (total distance Helsinki – Warszawa). Total length 1435 mm lines to be constructed in the three Baltic states is 848 km (including all branches and bypasses, but excluding FinEst link).

The following table gives an overview of the Rail Baltica sections in the individual countries and their length.

Section	Length
FI – EE: FinEst Tunnel Helsinki – Tallinn	107.40 km
EE: Rae Junction - Muuga	*16.70 km*
EE: Tallinn (Ülemiste) – Pärnu – Border EE/LV	200.76 km
LV: Border EE/LV – Riga – RIX – Border LV/LT	234.87 km
LV: Riga Bypass	*28.55 km*
LT: Border LT/LV – Kaunas – Border LT/PL[41]	249.00 km
LT: Kaunas Triangle East Junction – Vilnius	93.43 km[42]
LT: Kaunas Bypass (Palemonas – Jiesia)	*15,52 km*
LT: Vaidotai branch (Junction – Vaidotai freight station)	*8,98 km*
PL: Lithuanian-Polish-border – Suwałki – Ełk – Białystok – Warszawa	~379 km
Total distance (Helsinki – Warszawa)	~1,265 km
Total length of alignment sections (Baltic states)[43]	847,81

Table 109: Length of the alignment sections

[41] Length according to alignment option 3 of Kaunas – border PL/LT feasibility study
[42] Length according to option 3B of Kaunas – border PL/LT feasibility study (status 05/2018)
[43] Including all line sections, excluding FinEst link

3.3. Schematic track plan

This track plan is based on the Preliminary Design for the Rail Baltica alignment in the three Baltic countries and includes in addition all information received from the Technical Working Group (TWG) members as of 28 05.2018 and discussed in three TWG meetings on 12th of April 2018 in Tallinn and 2nd/3rd of May 2018 in Vilnius and on 13th of June 2018 in Tallinn. The received information includes the required information for the track layout with all operating points, gradients, speed limits, etc.

In contrast to the Preliminary Design the track plan of the Operational Plan also includes planned regional stops in the three Baltic countries which are assessed as part of this study. This assessment will show the socio-economic benefit of these stations (passenger potential, comp. chapter 1.3) and operational feasibility of additional stops ([Wp4]).

Infrastructure planning stages along Rail Baltica corridor are slightly different with planning activities going on in parallel. The different planning stages and main data sources for the consolidated track map are described below.

One main result is a consolidated overview of the intended infrastructure as schematic track layout indicating the location of all operational points (stations, passing loops, emergency crossovers, junctions, passenger stops) and the related track layout.

Section Muuga/Tallinn Ülemiste – State Border EE/LV

For this section preliminary design and spatial planning is completed. Preliminary design is the main source for the track layout. Regional stations have not been part of Preliminary Design therefore the position of the regional stations to be assumed for demand forecast was agreed between Rail Baltica and the Technical Working Group. Further amendments and justifications might be needed in the future.

Due to limited platform capacity at Tallinn Ülemiste the improved solution provided by RB Rail has been incorporated as basis for the Operational Plan. Further details and justification about required platform capacity will be discussed in chapter [WP4.1/8.1] of this report.

Muuga station layout was derived from preliminary design. It has to be noted that the track layout depicted is simplified only depicting the main tracks and the general layout principle.[44]

Assumed line speeds for Estonian sections were provided by RB Rail based on an analysis of infrastructure parameters (curve radii).

Line Sections Latvia

[44] Tracks used by train movements

For line sections in Latvia the track layout and alignment of the Preliminary Design forms the basis for infrastructure analysis where environmental impact analysis is completed. For track layout of Riga main station and Riga airport station RIX the newest proposals provided by EDzL are considered. In line with newest proposals the complete passenger line from Upeslejas triangle to Misa triangle is assumed to be double track. Regarding track layout and feature of RBILC intermodal terminal located at Salaspils the results of the related study on operational and technical solutions[45] formed the basis for analysis and depiction of the terminal on the track map.

Location of local passenger stations was discussed and clarified with the Technical Working Group.

For Upeslejas triangle – Skirotava the results of the Consolidated Preliminary Technical Design (CPTD) process were incorporated in the track map.

Assumed line speeds for Latvian sections were provided by RB Rail based on an analysis of infrastructure parameters (curve radii). Results of abovementioned CPTD process between Upeslejas triangle and Skirotava only were included in the RailSys timetable resulting in higher speed and shorter travel time on that section.

Current status of CPTD at the time of writing the report (10/2018) was incorporated in the final version of the RailSys model to investigate impact on travel time and to calculate energy consumption.

Line sections in Lithuania

For line sections state border LV/LT – Palemonas the alignment as per Spatial Plan were considered; speed limits were provided by RB Rail. Line sections south of Palemonas to the Polish border are still at Feasibility Study level. Speed profile and gradients for Kaunas bypass (Palemonas – Jiesia) and Palemonas – Kaunas Central – Jiesia are based on data provided by LG.

For Kaunas – Vilnius the current planning stage of horizontal and vertical alignment was provided by RB Rail (planning stage 05/2018). Gradients and speed profiles were derived from this alignment. The track layout of Vilnius station is not fixed yet, thus only the tracks indicated in the provided documents are indicated.

At the time of writing the report track layout for Kaunas triangle was not fixed completely, therefore the current stage of discussion as understood by the consultant is depicted. Final layout will depend on final decision to develop Kaunas Airport station, on results of further optimisation to provide maximum speed for HST trains on both western legs of the triangle (Kaunas- Vilnius, Riga – Vilnius) and on decision on development of Karmelava freight station.

Selection of final alignment of section Jiesia – border PL/LT is subject to spatial planning, two options are currently discussed based on the results of the Feasibility Study:

[45] "Rail Baltica Intermodal Logistics Centre in Latvia - Development of Operational and Technical Solutions", Identifications, Final Report AECOM 2016 were considered.

- Option 6: separated alignment west of the existing 1520 mm railway,
- Option 3: alignment closer to existing railway.

Both options will be considered in the Operational Plan, for calculation and RailSys modelling option 3 was chosen based on initial discussion in the TWG.

For Kaunas bypass two options are under consideration:

- Scheme 1: Jiesia – Palemonas single track,
- Scheme 2: Jiesia – Palemonas double track except Kaunas dam.

Alignment for Jiesia junction and Kaunas bypass is based on recommendations of the Feasibility Study to implement scheme 3 (grade separated junction and double track on Kaunas bypass, single track on Kaunas dam).

The Layout of Palemonas station is based on the agreed draft solution between RB Rail and LG incorporating no gauge crossings on the passenger main line.

The Location of regional passenger stations to be assumed for the operational plan were discussed and agreed during Technical Workgroup meetings. For Marijampolė it is assumed that the existing passenger station will be served by 1435 mm trains using a separate diversionary line for regional trains. Track layout (1435 mm), speeds and are based on assumptions of the consultant to highlight the operational issues. Further alignment study will be needed in the future to determine the final routing options as basis for spatial planning.

The Status of CPTD for section Border LV/LT – Palemonas as per 10/2018 was incorporated in the final version of the RailSys model to investigate impact on travel time (speed) and to calculate energy consumption (gradients).

FinEst link

Currently FinEst link is at early feasibility stage (see the available map in Figure 10). If information is missing, available data is combined with own assumptions by the consultant regarding line speed, station locations and layout, junction layout and distances between operational points.

Line sections in Poland

As no detailed information on the planned infrastructure in Poland as required for the RailSys modelling has been received from PKP PLK S.A. assumptions have been taken within this study. The entire line from the LT/PL state border to Warszawa is assumed as double track electrified line with a maximum speed of 160 km/h with an optional increased speed to 200/250 km/h.

For the section LT/PL state border – Ełk a shortened alignment has been assumed due to the planned straightening and bypasses in Suwałki and especially Olecko. In total this section has a length of 86,6 km compared to almost 100 km today. According to the ongoing Feasibility Study by PLK three options are analysed with maximum speed of 160, 200 and 250 km/h. This section is implemented in the RailSys model including the simulation of all Rail Baltica trains.

For the section Ełk – Białystok – Warszawa only the distances and the possible travel times have been considered.

3.4. Operational points

3.4.1. Passing loops and crossovers

Passing loops will be used for the overpass of a slow train by another train to be compliant with the timetable. They can also be used as crossovers in order to reduce the investments. The standard layout recommended in the Rail Baltica Design Guidelines does provide one passing loop on each side of the main line. This will allow trains in either direction to reach a loop track without interference with traffic in contraflow direction. For maximum flexibility it is recommended to provide two crossovers at either end of the passing loop such that both loop lines can be reached from both running lines.

To avoid passenger platforms on the running lines, platforms shall be located at the loop lines. From the timetabling study it can be concluded that this layout principle will work in most locations. On mixed traffic sections with dense regional train services (Kaunas – Vilnius, Kaunas – Panevėžys) additional passing loops and/or additional loop lines shall be provided as depicted in the track map in annex 1 to allow for sufficient waiting capacity for freight, while passenger trains occupy the loop lines with platforms.

In order to allow parking of defective rolling stock which cannot be moved to a depot or suitable station without repair a separate emergency/maintenance siding shall be provided. Therefore it is recommended to allocate one maintenance/emergency siding at every passing loop. This siding can also be used to rail/derail road-rail vehicles and to for short-term parking of maintenance rolling stock to ensure short possession times. This siding shall be accessible by road for handling of incidents and maintenance purposes. For maximum operational flexibility it is proposed that this siding shall be provided alternating on the up and down line site of the loop. Where feasible this siding shall be placed such, that defective wagons can be pushed into the siding without the need to shunt the locomotive to the other end of the train. Length of the loop track shall be at least 210 m (corresponding to parking of a multiple unit for passenger service and need to park selected freight wagons).

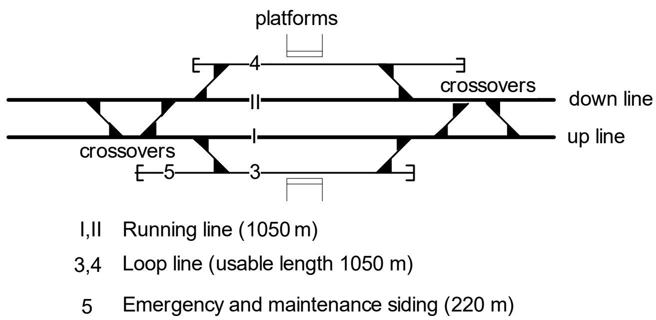


Figure 43: Standard layout of passing loop (example with platform for regional trains)

Passing loops allow one faster train to pass slower trains, Passing loops shall be designed to provide usable track length of 1050 m. 1050 m according Design Guidelines. On the track plan, all passing loops are with this standard length, except in some particular cases in some passenger stations with specific constraints, where it is limited to 410 m.

Crossovers are implemented on longer line sections to support bidirectional working on one running line, when the other line is blocked or closed for maintenance. According to considerations outlined in Rail Baltica Design Guidelines based on international benchmarking of high-speed lines the following maximum distances between passing loops are recommended in RBDG:

- 25 km between adjacent crossovers
- 50 km between adjacent passing loops

Overall these conditions are fulfilled in most cases, with following exceptions:

- Missing crossover between Skulte station and Salacgrīva station (approx. line km 238)
- Long distance between Skulte station and Salacgrīva station (56 km)
- Missing crossover between Misa triangle South junction and Bauska station
- Missing crossover between Bauska station and Joniškėlis station
- Missing crossover between Kėdainiai station and Jonava station

Further need for relocation or adding passing loops was assessed based on train service pattern as result of 2nd iteration of Operational Plan.

Recommended location and dimensioning of passing loops and crossovers is depicted in the track map in annex 1. For further details and related justifications please refer to chapter 3.1.

Regarding single track line capacity between crossovers it can be estimated, that over a single track distance of 25 km approx. two passenger train pairs (1 HST and 1 RE per direction) and one freight train could be operated. Maximum capacity for freight train only operation can be estimated at 3 trains (2 trains in one direction, 1 train in the other). Design Guidelines for double track lines railways with same standard recommend for with mixed traffic a maximum spacing between crossovers and passing loops of 20 km. Given the proposed train service pattern it is recommended to opt for a crossover distance around 20 km from the beginning. Additional crossovers are recommended on line sections with dense passenger traffic (Kaunas triangle – Vilnius, Kaunas triangle – Panevėžys, Jiesia – Marijampole taking into account freight requirements).

3.4.2. Passenger stations

There are two types of passenger stations along the Rail Baltica network.

International passenger stations have been introduced where high speed trains shall stop. Planning, design and implementations of these stations are co-financed by European Union and these stations are agreed among the three Baltic States. Platforms and stations tracks shall be designed to provide for 200 m long HST trains, with option to extend platform length to 410 m to provide for coupling of two HST EMUs at a later stage.

These stations are Tallinn, Pärnu, Riga, Riga Airport (RIX), Panevėžys, Kaunas and Vilnius.

All other stations not mentioned above are considered as **regional passenger stations**. These stations serve mainly local and national needs. Currently it is not foreseen, that these stations are served by long distance trains. Implementation of these stations will depend on final decision regarding implementation of a regional train service, which is not yet decided.

For safety reasons it shall be avoided that platforms are situated on high speed tracks due to aerodynamic situation near the platform edge. However, for small regional stations this requirement can be replaced by sufficient barrier solutions allowing passenger access to the platform only, when no high-speed train is running. In many cases passenger stations also serve as passing loop and provide crossover facilities (e. g. Skulte and Salacgrīva station north of Riga).

According to Rail Baltica Design Guidelines platforms for regional trains shall designed for 100 m length. In principle this requirement is confirmed by rolling stock studies. A typical EMU corresponding to 100 m platform length will provide a seating capacity of approx. 300 passengers. Forecast of passenger traffic indicates that in peak-hours passenger demand in the areas around Tallinn, Riga and Kaunas (sections Tallinn – Rapla, Skulte – Bauska, Vilnius – Kaunas - Marijampole might reach the capacity limit taking into account proposed service frequencies as outlined in this operational plan. If the service frequency remains unchanged double traction would be required. With exception of peak hour services in Riga area most of regional train services cover larger distances. Train coupling and sharing does add additional complexity to the operation and increases travel time. Thus it is recommended to initially provide 100 m platforms, but to design for an option to extend platform length to 200 m at a later stage for all regional stations, in case needed. Providing 200 m platforms would also be advantageous for evacuation of HST train sets in case of line closure or train failures.

3.4.3. Freight terminals and access to private railway sidings

Freight terminals are foreseen at locations where sufficient volumes can be expected. Currently all planned terminals will be designed as intermodal facilities. The following stations are currently planned:

- Muuga freight station to provide access to Tallinn area and Tallinn harbour
- RBILC intermodal terminal at Salaspils to serve the Riga area incl. Riga port and to provide a gateway to Russia, Belarus
- Riga airport cargo yard to provide an option to serve Riga airport (fuel, air cargo) and to interconnect local businesses and logistics service providers to Rail Baltica, if needed, e.g. Latvian post.
- Kaunas intermodal terminal
- Vilnius intermodal terminal to serve the Vilnius area and provide interlink to Belarus

Further optional terminals and local freight stations might be added in the future if justified by market potential, e.g.

- Pärnu intermodal terminal (separate study currently under way)
- Panevėžys intermodal terminal
- Marijampolė freight station
- Jonava freight station.

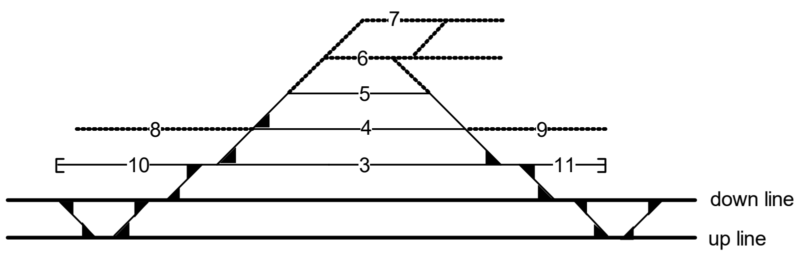
The aforementioned options are marked in the schematic track plan. Provision of access tracks has been considered in the recommended the track layout. Exact location and needs for parking, shunting operation, as well as arriving and departing trains need to be determined by later studies.

As basis for station design a general concept of a freight station is provided in Figure 44 below. This concept does consider the following operational requirements:

- Arrival and departure of trains in a separate passing loop. If not needed for arriving and departing trains, this loop can also be used for other services.
- Possibility to separate shunting operation at loading areas from main line operation.

- Necessity to park wagons after arrival and departure in order to allow short stop turnaround time of trains which deliver or pick up wagons. This does also include option.
- Necessity of long head shunts to sort wagons and reach sidings (rule of thumb ½ train length).

In addition to that it might be sensible to divide longer sidings into shorter sections by providing additional track connections.



I,II	Running line
3	loop line (arrival and departure of through train)
4	Wagon exvchange (arriving)
5	Wagon exchange (departing)
6,7	Loading/unloading siding
8,9	Potential access to industrial siding
10,11	Head shunt

Figure 44: General concept layout for freight station

3.5. Technical Infrastructure parameters

3.5.1. Maximum line speeds

According to the current Design Guidelines the maximum design speeds for infrastructure are as follows:

- Passenger trains: 249 km/h (according to line category P2 TSI-INF)
- Freight trains: 120 km/h. This corresponds to line category F1 of TSI-INF.

According to Design Guidelines the lines the operational speed of the high speed trains will be restricted to 234 km/h considering the necessary margin for ERTMS speed measurement, train location accuracy and intervention speed for driver warning and emergency brake in case of exceeding permitted speed. By this approach it is secured that the maximum line speed is not exceeded under any circumstances. Technical design parameters for railway lines contain a safety margin for exceeding design speed.

Typically trial runs prior to inauguration of public services are performed with speed exceeding line speed by 10%. This approach was also applied in recent infrastructure projects, e.g. Erfurt – Nuremberg high speed line in Germany or LGV Est européenne line in France. To maximise commercial speed for passenger services it is recommended to follow the conventional approach (249 km/h+10% speed margin) also on Rail Baltica, which would allow operational speed of up to 249 km/h for passenger trains. Therefore, the technical Design Guidelines should be clarified to ensure that the necessary margins are provided on the infrastructure side. Final decision on operational speed should be subject to provision of final testing and homologation strategy also taking into account possibilities of ERTMS to provide for safe speed supervision of trial runs.[46]

Analysis of maximum speed allowed by infrastructure as per preliminary design reveals that maximum permitted speed of 249 km/h is available on approx. 85% of overall route length (main route for passenger train. Given the current planning stage the following restrictions are remaining:

[46] Separate speed profile for test runs to allow safer trial runs. Current practise is not to apply train protection system for non-public trial runs exceeding operational speed for testing purposes.

Country	Section	Total length of restrictions (km)	Speed	Line Usage (main purpose)
Estonia	Ülemiste- Rae Junction	12,4	150..200	Passenger Traffic
Estonia	Rae Junction – Kurtna Station	23,6	200..210	Mixed Traffic
Estonia	Kohila Station – Rapla Station	8,0	210	
Estonia	Rapla Station – Järvakandi Station	1,9	210	
Estonia	Järvakandi Station – Kaisma Station	6,0	230	
Estonia	Kaisma Station – Tootsi Station	1,7	230	
Estonia	Pärnu – Surju Station	4,4	230	
Latvia	Upeslejas – Riga Central	4,4	60..110	Passenger Traffic
Latvia	Riga Central – Riga Airport	12,8	90..150	
Latvia	Riga Airport – Jaunmārupe Station	5,6	140 ..200	
Latvia	Olaine Station – Kekava Station	0,6	170	
Lithuania	Border LV/LT - Joniškėlis Station	15,2	210	Mixed Traffic
Lithuania	Jonava – Palemonas	4,5	130…230	
Lithuania	Palemonas - Kaunas Central – Jiesia	17,5	70..130	
Lithuania	Palemonas – Jiesia (Kaunas bypass)	8,7	110..150	Freight Traffic
Lithuania	Kaunas triangle – Kaišiadorys (Kaunas – Vilnius)	3,6	160..190	Mixed Traffic
Lithuania	Kaišiadorys – Paneriai Junction (Kaunas – Vilnius)	1,2	140..160	
Lithuania	Paneriai Junction – Vilnius main station (Kaunas – Vilnius)		110..210	

Table 110: Speed restrictions due to alignment of main line according to preliminary technical design[47]

Detailed maps indicating maximum speed allowed by infrastructure as per preliminary design are provided in annex 10.

[47] Status as of May 2018 without CPTD

Part of these remaining speed restrictions may be removed with further alignment improvements which are under study as part of CPTD process, and that shall be confirmed during detailed design phase. Improved speed profiles resulting from CPTD (status December 2018) are provided in annex 10. Results of CPTD indicate that overall travel time could be reduced by 14 minutes. One example, in Riga area the results from CPTD show that the situation on Upeslejas – Šķirotava section can be significantly improved to allow for maximum line speed. Thus reducing travel times by more than 4 minutes.

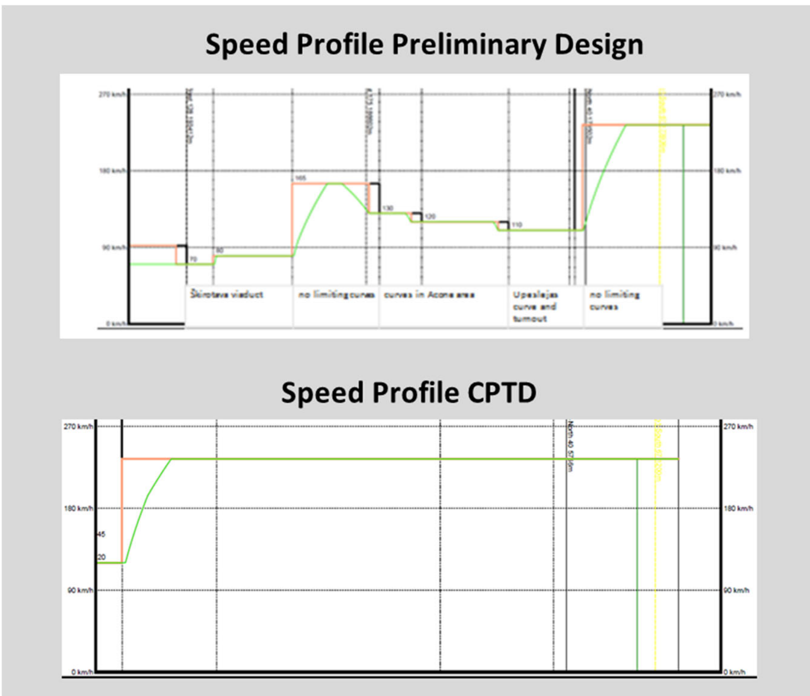


Figure 45: Comparison of speed profiles Upeslejas – Šķirotava[48]

3.5.2. Gradients

Distribution of gradients is an important boundary condition, especially for operation of long and heavy freight trains. Rail Baltica will allow operation of freight trains with total length of up to 1,050 m. To get an overview of current planning stage the alignment as per Preliminary Design was analysed considering line capacity, smoothness of future operation and safety aspects.

Due to the topography and the initial standards to be applied for design of Rail Baltica there is only a limited share of line sections with considerable gradients, which might impact operating conditions on the railway line.

According to the Design Guidelines for Rail Baltica the following maximum vertical gradients are applicable:

[48] Consolidated Preliminary Technical Design Upeslejas – Šķirotava Section, RB Rail AS, 2018

- Nominal gradient limit is 8‰.
- Gradient higher than 8‰ should be avoided nearby stations and passing loops.
- Gradient up to 10‰ is accepted and shall not be exceeded as an average value over 1 km length of track.
- Maximum gradient limit is 12.5‰.

For stations additional restrictions do apply to ensure operational safety (avoid unwanted movement of standing vehicles and run away of wagons and ensuring platform safety):

- The nominal gradient limit is 0‰.
- The maximum gradient limit is 1.5‰.
- The exceptional gradient limit is 2.5‰.
- For regional stations where platform is located at the main track and no coupling operation is possible, gradient limit is 5 ‰.

The shares of sections with considerable gradients (> 5‰, >8‰, >10‰ and > 12.5‰) are presented in the tables below. Overall the number of line sections with gradients > 5‰ is limited. Many of the sections with gradients > 5‰ are rather short, with many of them not exceeding the maximum length of freight trains.

The most critical sections as per preliminary design are:

- Incline towards Tallinn from Muuga freight terminal with gradients up to 10.5 ‰. Here the situation might get worse than depicted since an additional overpass is to be implemented if the reception sidings will be placed north of the 1520 mm tracks.
- Riga passenger line with short incline sections of up to 12.6…29.6 ‰. According to the current version of TSI INF for passenger line category P1 up to 35 ‰ are allowed on short track sections. The individual lengths of all sections concerned are shorter than the boundary conditions stated in the TSI. Thus, interoperability for passenger trains will not be compromised. If it is intended, that freight trains are to be diverted over this section additional operational rules may have to be applied.
- Kaunas bypass with gradients up to 12 ‰. According to the currently proposed track layout trains might be forced to stop in front on the gradient in order to wait to for a passing train on the single-track section over Kaunas dam.
- Planned underpass to Kaunas main station on the south side of Palemonas station (gradient up to 25‰). Same conditions as for Riga passenger line apply. This solution is in line with current Design Guidelines and not critical for operation of the proposed passenger services. It will not limit possibilities to divert freight

trains via Kaunas main station in case of line closures on Kaunas bypass, as a specific track with normal gradient will be included in the design of Palemonas station.

Resulting from ongoing CPTD process the longitudinal profile of the line is also under review. Current results indicate that gradients can be even further reduced. For example the maximum gradient on section Tallinn – Muuga is now only 8.5‰. This will allow for longer and heavier freight trains. Impact of critical section on maximum trailing weight of freight trains is assessed in chapter 2.6.1 as part of rolling stock studies.

For Kaunas – Vilnius section the maximum gradient does not exceed 12.5 ‰. Sections with incline of more than 5 only rarely reach a length of slightly more than 1.500 m. Thus required tractive power and impact on freight train speed is comparable to conditions on other sections of Rail Baltica line. Most critical section is the incline after Paneriai junction, where freight trains have to restart. Given the remaining low gradients after CPTD for section Palemonas – Tallinn provisioning of lower gradients (<9 ‰) shall be further studied also for this line section during next planning stages.

Estonia

Border to Latvia - Rae Junction

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	171.3	22.2	0.0	0.0	0.0
Share on total Length [‰]	88.5	11.5	0.0	0.0	0.0
max Lenght [km]	6.1	2.3	0.0	0.0	0.0

Muuga branch (freight line)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	4.4	4.2	2.1	0.6	0.0
Share on total Length [‰]	38.6	37.5	18.5	5.4	0.0
max Lenght [km]	1.6	1.5	1.2	0.6	0.0

Tallinn Ülemiste station - Rae Junction

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	5.6	1.5	0.0	0.5	0.0
Share on total Length [‰]	74.3	19.6	0.0	6.0	0.0
max Lenght [km]	1.3	0.8	0.0	0.5	0.0

Table 111: Share of gradients along rail Baltica main line – Estonia

Latvia

Main Line (Border to Estonia – Upeslejas triangle / Misa triangle - Border to Lithuania)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	154.7	8.0	1.7	0.0	0.0
Share on total Length [‰]	80.5	4.1	0.9	0.0	0.0
max Lenght [km]	5.5	1.4	1.1	0.0	0.0

Riga Bypass (Upeslejas triangle – Misa triangle)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	23.6	4.3	0.0	0.0	0.0
Share on total Length [‰]	84.5	15.5	0.0	0.0	0.0
max Length [km]	2.7	1.0	0.0	0.0	0.0

Riga (Upeslejas triangle - Riga Central Station – Misa triangle)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	52.8	10.9	1.4	1.8	3.2
Share on total Length [‰]	75.3	15.6	2.0	2.6	4.6
max Length [km]	3.9	1.0	0.7	0.6	0.5

Table 112: Share of gradients along rail Baltica main line - Latvia

Lithuania

Border LV/LT - Palemonas

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	153.0	14.1	0.0	0.0	0.0
Share on total Length [‰]	91.5	8.5	0.0	0.0	0.0
max Length [km]	8.8	2.7	0.0	0.0	0.0

Kaunas Bypass (Palemonas - Kaunas dam - Jiesia)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	6.7	5.0	1.3	0.3	0.0
Share on total Length [‰]	50.5	37.7	9.5	2.3	0.0
max Lenght [km]	0.9	0.7	0.4	0.3	0.0

Kaunas (Palemonas – Kaunas Central Station - Jiesia)

Distribution of Gradients					
Gradients [‰]	< 5	>= 5	> 8	> 10	> 12.5
Length [km]	11.6	2.3	0.0	0.0	0.0
Share on total Length [‰]	83.7	16.3	0.0	0.0	0.0
max Lenght [km]	1.3	0.5	0.0	0.0	0.0

Table 113: Share of gradients along rail Baltica main line – Lithuanian line sections

3.5.3. Loading gauge

According to the Design Guidelines, Rail Baltica will be implemented to provide for loading gauge GC on all tracks. Main advantage of this gauge profile compared to loading gauges still used in Central Europe is the additional space in the upper part of the profile. While international transports are limited to smaller loading gauge G2, e.g. for existing line sections in Poland, transports between stations in the Baltic States will benefit from this loading gauge. This is especially relevant for piggybacking and exceptional oversized cargo. For further details about oversized transport please refer to section 3.5.5.

From current perspective loading gauge GC is sufficient with respect to interoperability for traffic from and to central Europe. To provide more advantageous conditions for transport of trucks and semi-trailers and for transport of 1520 mm a higher loading gauge might be considered (equivalent to clearance gauge S for transport of 1520 mm wagons, loading gauge AF with total height of static profile of 5.35 m for truck transport on standard instead of piggyback wagons). This loading gauge is not compatible to foreseen P1 line category according to TSI-INF. However, from current state of affairs this would only be an advantage for traffic within the Baltic States and to Finland since there are no currently plans to upgrade of TEN-T railway corridors for loading gauges higher than GC. Opting for a higher loading gauge like AF will restrict line speed to 250 km/h since the maximum contact wire height as defined in TSI-ENE is limited to 5,30 m.

To conclude, benefits of provisioning loading gauge higher than GC in medium and short term are uncertain considering the intended usage of the line (international freight traffic from/to Western Europe). Thus, loading gauge GC compatible to contact wire height recommended in RBDG could remain. For transport of 1520 mm wagons on Rail Baltica a dedicated fleet suitable for automatic gauge change and fitting into GC envelop seems to be more realistic.

3.5.4. Electrification

3.5.4.1. Traction Power Supply

According to Rail Baltica Design Guidelines power supply will be provided using **2x25 KV AC** electrification systems. If justified by local conditions or by a technical-economic study 1x25 kV traction power supply system may be implemented.

3.5.4.2. Changeover at the Polish/Lithuanian border

Traction power for railway line in Poland is 3 kV DC. As stated above on Rail Baltica 25 KV AC electrification system will be provided. Therefore, a power system changeover facility between 3 KV DC and 25 KV AC has to be implemented. Technical needs and location for these facilities are not yet defined and will be subject of a separate study. For provision of traction power changeover there are two alternatives:

a) Implementing power system **changeover on the open line**, e.g. at a suitable location very closed to the Polish/Lithuanian border. This solution will require multiple systems locomotives.

b) Implementing power system **changeover at a station**. Therefore the station is divided into two power supply sections (3 KV DC and 25 KV AC). In principle this could be a dedicated border station or any other station suitable for that purpose from infrastructure and rolling stock perspective. This station could be also reached by single voltage locomotives from either side. Exchanging single voltage locomotives will require additional shunting effort and costs time.

Implementation examples for traction power changeover on North-Sea-Baltic Rail Freight Corridor

Solution a) traction power supply on the open line is currently applied on all the newer implementations on cross-border sections on Rail Freight Corridor North Sea-Baltic. This shall be illustrated by the following examples:

- Between Germany and the Netherlands the voltage change (15KV 16,33 Hz /25 KV 50 Hz AC) was relocated from Emmerich station to the border between Germany and the Netherlands since 2017.
- Between Germany and Poland the voltage on the newly upgraded cross-border line section Horka – Węgliniec is also located on the open line at the state border.
- On the Aachen – Montzen route between Germany and Belgium traction power supply changeover is provided on the Moresnet, which is located in Belgium a few kilometres west of the state border. This solution is provided despite the fact that many freight trains have to stop at Aachen West to change direction.
- Traction power changeover at stations is implemented in Aachen main station at the border between Belgium and France since the 1960's and in Frankfurt Oderbruecke at the Polish/German state border (since 1990). In Aachen main station traction power of three station tracks can be switched between 3 KV DC and 15 KV AC.

Operation on Rail Baltica will require modern TSI compliant rolling stock equipped with ETCS. Provision of traction power changeover at a station is mainly beneficial if there are single voltage locomotives to be used for freight operation in the Baltic States and in Poland at the same time and for the same trains, so that traction power change on the open line would be an obstacle. Usage of multiple systems locomotives is now common standard and a variety of locomotives is available on the market for sale, rent or lease. Regarding more information on current availability of rolling stock, please refer to chapter 2.

For passenger trains need to change locomotive is rather unattractive since it costs additional travel time. At least it should be implemented at a location where passenger trains are planned to stop (e.g. Ełk). Therefore multiple systems locomotives and EMUs are to be used for passenger service anyway.

Thus it can be concluded from operational and market perspective that in case of Rail Baltica changeover of traction power supply at a station does not bring significant benefits but is adding technical (two power systems in stations), commercial (e.g. energy tax issues in different countries), and operational (shunting) and technical complexity (dual voltage tracks, different power supply areas) complexity to the project.

Based on this, multiple systems locomotives and EMU need to be used for cross-border operation from and to Poland.

3.5.4.3. Contact wire height

According to the Design Guidelines, nominal height of contact wire above rail top shall be 5.00 m to 5.30 m. The minimum and maximum height of the contact wire is in this case determined by the limits stated in European TSI ENE for lines with maximum speed above 250 km/h. This would allow for potential speed increase in the future using standard pantographs.

Regarding freight transport the possibilities for transport of oversized cargo (height dimensions) and to introduce piggyback services will be limited by the height of the contact wire and restricted to envelope of loading gauge GC. Given the conditions in Central Europe opting for higher loading gauge than GC would be mainly relevant for cargo to be transported within the Baltic States and for import/export flows of transit cargo from/to CIS and (in long term perspective) from/to Scandinavia. Having these limits in mind contact wire height of 5.30 m shall be kept as specified in current version of RBDG (5.30 m).

Latest investigations show that for dual gauge operation in Kaunas tunnel and at the remaining gauge crossings the minimum contact wire height must be at least 5,555 mm to allow interoperability with electrification system for 1520 mm. It must be ensured that rolling stock operating on gauge crossings and in Kaunas tunnel is compatible with required contact wire height on this lower speed sections. Further details about the proposed solution for Kaunas tunnel can be found in the upgrade study for the line section Polish / Lithuanian State Border – Kaunas – Palemonas.[49]

3.5.5. Platform height

According to current version of Rail Baltica Design Guidelines the platform height shall be 550 mm. This height is in accordance with the nominal standard platform heights stated in the TSI-INF. Furthermore this height this is also the nominal platform height on the 1520 mm network in the Baltic States as required by TSI-INF. The selected platform height is coherent with TSI requirements and will allow introduction of common platforms 1435 mm and 1520 mm without compromising safety and passenger comfort on the platform (usage of 760 and 550 mm on the same platform would require steps or inclined profile of the platform, if both track surfaces are on the same height level). According to the current planning stage, a common platform is foreseen in Tallinn Ülemiste station[50].

According to the current planning stage and already implemented upgrade solutions on the line sections in Poland (Warszawa – Bialystok) the chosen platform height will be 760 mm. This platform height is also allowed by TSI-INF[51].

Typical entrance situation of high-speed trains is depicted in the following figure.

[49] Study on Rail Baltica Section "Polish / Lithuanian State Border – Kaunas – RRT Palemonas" Upgrade, Draft final report, 10th July 2018 submitted by Ardanuy

[50] RB Rail proposal with longer platforms and 3rd dead end track

[51] Regulation ((EU) No 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union

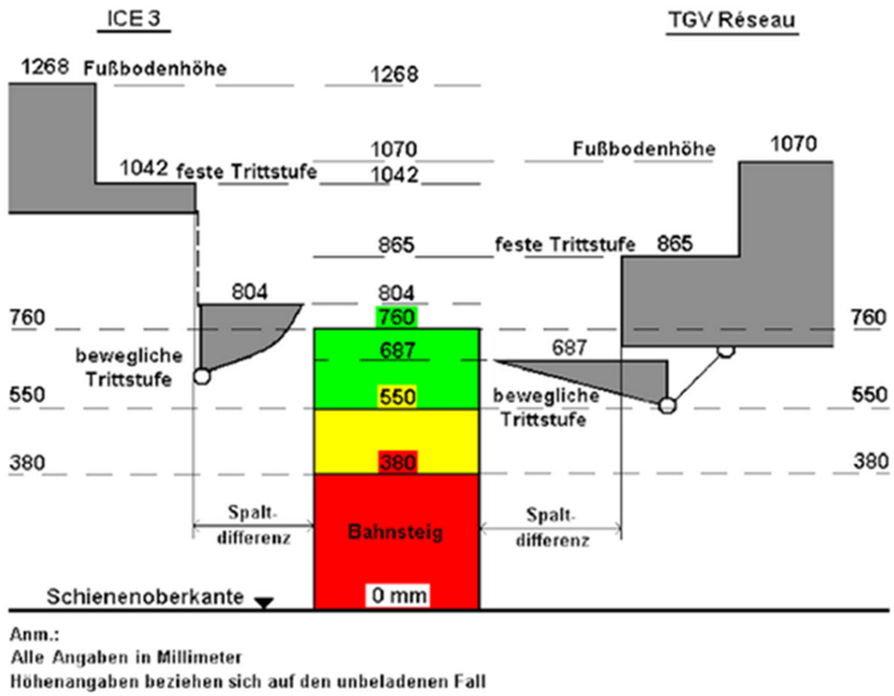


Figure 46: Entrance and floor height situation ICE3/TGV Reséau52

This illustrates, that the height gap to a typical HST floor height will be lower, if a platform height of 760 mm is implemented. Due to the lower height difference solutions aiding persons with reduced mobility will require less space to be implemented (e.g. dimensions of mobile ramps). Most of the single high-speed trains currently in service have floor heights not allowing this. Depending on bogie and drive configuration, lower floor height can be provided at the entrance area, but not throughout the complete train. One example of such a configuration is the Stadler EC 250. The situation is depicted in Figure 47. In that case the lower entrance area is provided, but the floor height above the bogies is higher.

Provision of different platform heights along the same line or in the same train would lead to more difficulties to create a barrier free entrance situation allowing persons with reduced mobility to enter and leave the train conveniently without steps.

Usually the floor height and entrance area of regional trains is optimised for one platform height (either 550 mm or 760 mm) providing the most convenient entrance. If such a train does stop at a platform with different height more steps or larger gaps will be the result.

The concept of Stadler Smile shall serve as an example to depict the design conflicts, which need to be addressed:

[52] Schulte, M. Ermittlung eines kostengünstigen und zuverlässigen Fahrgast-Einstiegstürsystems für Hochgeschwindigkeitstriebzüge der DB AG

- It is difficult to provide step-less access to the complete train, if the entrance height is lower due to the minimum floor height.
- Stepless access to different platform heights might require different solutions for different sections along the train or separate entrances needed additional space.

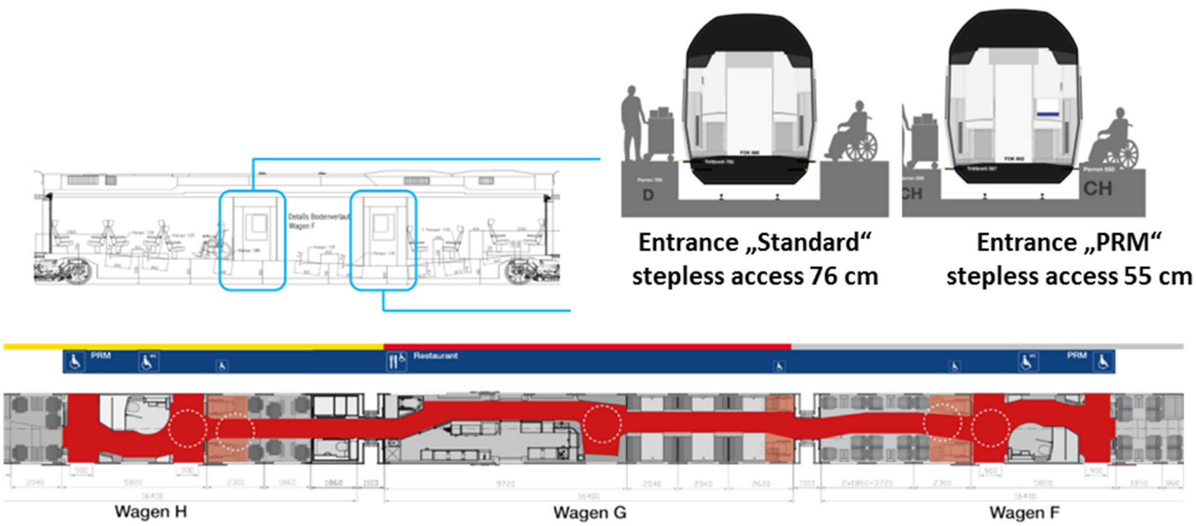


Figure 47: Entrance and floor height situation Stadler Smile 250 / Giruno53

From operational and customer viewpoint 760 mm platform height does provide for a more convenient entrance situation in the short term (lower height difference between platform and train floor for HSTs). As illustrated by the Talgo example and by Stadler Smile chances are higher that a wider selection of next generation HST will support facilitating step-less entrance and step-less access to larger areas in the train without losing floor space to provide separate solutions for persons with reduced mobility.

To implement 1520 mm and 1435 mm on the same platform the height level of the tracks has to be adjusted accordingly (lowering 1435 mm track or lifting 1520 mm track).

Due to similar situation and uncertainties, e. g. on the German market, solutions have been developed by the railway industry which could be converted from 550 mm to 760 mm. This might be an option for later conversion of station tracks from 1520 mm to 1435 mm. This option might be interesting for stations with limited space (Riga Central, Kaunas Central). Based on this it can be recommended to change the current Design Guidelines to 760 mm nominal platform height.

[53] Starlinger/Bühl/Legler: Das Zulassungskonzept für den EC 250 / Giruno Hochgeschwindigkeitszug, 43. Schienenfahrzeugtagung, Graz, 05.04.2016

If 760 mm platforms are chosen needs for transport of oversized cargo which is placed low above the rail top (e. g. transformers) should to be checked in detail since the higher 760 mm platforms close to the standard clearance profile might limit in certain circumstances possibilities to run such transports, while passing of 550 mm platforms would have been possible.[54]

Taking into account all circumstances,

- Interoperability with 76 cm platform height on line secti0ns in Poland,
- compatibility to vehicle concepts for long distance trains (higher floor height than local trains in most cases),
- difficulty and added technical complexity to provide convenient entrance situation on the same train for different platform heights,
- technical possibility to provide 55 cm (for 1520 mm) and 76 cm (1435 mm) platform height on adjacent tracks of the same platform, and
- availability of regional service rolling stock for 76 cm platform height

the final recommendation from operational perspective is to provide **0.76 m platform height** along Rail Baltica.

3.5.6. Maximum train length

Freight trains

According to Rail Baltica Design Guidelines all tracks used by freight trains shall be designed for a freight train length of 1,050 m to accommodate for future traffic growth.

The majority of services operated on Rail Baltica will cross the border to Poland. A significant share of trains will run from and to other destinations, especially along RFC 8. Current infrastructure situation on RFC 8 will provide for 600 … 650 m train length in Poland and up to 740 m train length in Germany. Target maximum train length for upgrade of the line sections in Poland (border PL/LT – Ełk – Białystok – Warszawa) is 740 m.

Generally, seamless application of a train length of 1,050 m on international corridors west of the Polish / Lithuanian border is currently not realistic for at least the next 20 years since it is not part of current TEN-T standards.

Minimum requirement to apply 1,050 m train length for international services to Poland would be to allow for operation of 1,050 m trains to nearest consolidation point attractive to the market (from current perspective e. g. Ełk station, Białystok in medium term, in the long term more "remote" terminals and freight stations, e.g. in Warszawa

[54] Das Bahnsteighöhenkonzept der DB AG, Eisenbahntechnische Rundschau, 05/2014, Eurailpress

area) where trains will be split up or intermodal loads can be consolidated accordingly. If this is not foreseen the consolidation point shall be a hub on the Lithuanian side. From market perspective location nearest larger consolidation point would then be the located around Kaunas (Palemonas, Karmelava freight station). This would mean the section most heavy occupied with freight trains will likely see only very limited benefit of 1,050 m long freight trains.

Furthermore provision of track capacity in Kaunas area to split up and form longer trains from/to Riga and Tallinn will be an option.

Another important precondition for longer freight trains is to provide sufficient loading tracks at the terminals in order to minimise amount of shunting as well as reception sidings with 1,050 m usable track length.

Passenger trains

Maximum length of passenger trains is determined by length the platforms.

In RBDG the following requirements are established regarding platform length:

- Passenger platforms for long-distance trains shall be designed with initial physical length of 200 m with the option to accommodate 400 m long passenger trains in the future, if needed (design length). This requirement is in-line with requirements of TSI-INF for traffic code P2.[55]
- For regional stations the length of the platform shall be at least 100 m.[56] For regional stations the length of the platform could be adjusted to the length of rolling stock.[57]. As minimum requirement

Regarding long distance trains, analysis of rolling stock and traffic forecast reveal that this length will be sufficient to operate long distance and regional services as required and rolling stock fitting to platform length with sufficient seating capacity is available on the market.

To allow train coupling and sharing of two train-sets up to 2x200 m length shall be supported to allow e.g. to split up trains from Poland in Kaunas for Vilnius and Riga. Furthermore, some rolling stock available on the market is slightly longer than 200 m. Therefore it is advisable to design platform tracks for a usable track length of 420 m (long distance trains) to provide for safety margins, if needed.

The regional trains proposed in this operation plan shall provide for a seating capacity of approx. 300 seats and will have a maximum length between 90 and 110 m depending on finally chosen configuration. This corresponds to a platform length of 110 m. As shown in section 1.3.3 there will be a need to operate longer trains in the peak time according to the traffic forecast for regional trains. This corresponds to a platform length of up to 220 m. The pro-

[55] RBDG-MAN-025-0101 Design guidelines Infrastructure facilities, section 1.1
[56] RBDG-MAN-025-0101 Design guidelines Infrastructure facilities, section 1.1
[57] RBDG-MAN-025-0101 Design guidelines Infrastructure facilities, section 1.2

posed service pattern will require that all stations can be fitted later for double traction, if needed, though the highest peak hour demand will be around the city centres.

Thus for regional trains a platform track length of 110 m with future option to extend to 220 m shall be provided. This applies to all platforms at regional stations and – subject to final considerations on track layout dedicated platforms for regional trains at international passenger stations.

3.5.7. Turnout Speeds

The current version of Rail Baltica Design Guidelines does suggest turnout speeds of 80/100 km/h for passing loops and crossovers, as well as for access to depots subject to final consideration in the operational plan.

A higher turnout speed will result in additional investment and maintenance cost (additional point machines, moveable frog) and requires additional development space for the track layout.

Regarding definition of turnout speeds the following aspects need to be considered:

- Impact on runtimes for passenger trains,
- Avoiding unnecessary energy consumption due to speed limits at turnouts,
- Minimisation of obstructions at operational bottlenecks and conflict areas,
- Speed on adjacent line sections (e. g. junctions on open line),
- Length of stations tracks and passing loops and resulting speed profile of arriving or departing trains,
- Development length of switch area, which might impact needed time for shunting operations,
- Ease of maintenance, providing least possible number of standardised types of turnouts across the railway line.

To determine the effects of using faster turnouts several turnout configurations for stations and junctions on the open line have been tested by RailSys simulation. The results are provided below.

From the RailSys simulations the following conclusions can be drawn:

- Turnout speed at junctions on the open line is critical for run time of high speed trains. Therefore, junction shall be designed such that the majority of high speed trains can use the straight track without speed limit. If this is not possible the speed of the diverging track shall be at least 170 km/h, if the junction is passed by high speed trains. From global viewpoint the additional costs for higher speeds will be partly repaid by energy savings within the lifetime of the turnouts.

- For passing loops a speed of 100 km/h is suitable, further improvement does not payoff. According to RBDG (Rail Baltica Design Guidelines) the currently proposed turnout speed for passing loops is 100 km/h, subject to further justification and modification in the Operational Plan. The analysis done in the RailSys model show, that this is sufficient for most cases. Even for long passing loops (1,050 m) there is only a minor advantage for passenger trains if turnout speed is raised above 100 km/h, see example provided in Table 114 below.

- Crossovers between the running lines are mainly used in case of track closures. Reason for most track closures will be regular maintenance, which is carried out during night time possessions, when only few passenger trains are running. During daytime the possibilities to use crossovers for overtaking of slower trains are limited due to line occupation. If applicable the freight train could use the diverging track. Therefore benefits of speed of more than 100 km/h are limited.

The aforementioned turnout speeds are also in line applied for construction of new lines in Europe, e. g. design standards by line category of Deutsche Bahn (turnout speed for passing loops: 80..100 km/h; for crossovers: 100 km/h).[58]

Example Calculation - Improvement of turnout speed at passing loops

In Table 114 the saved runtimes for improvement of turnout speed in a passing loop are provided for speed improvement 80-100 and 80-130 km/h as examples based on RailSys modelling of a typical passing loop at a regional passenger station with platforms. The following assumptions have been implemented into the underlying model:

- Regional train (Train length 200 m, Braking rate 0.8 m/s^2,
- Acceleration rate 0- 60km/h: 0.96m/s^2, 60 -200 km/h: 0.96m/s^2 – 0.21m/s^2,
- Distance from turnout to stop 1,280 m,
- Speed at the main line 200 km/h,
- Distance from stop to turnout 180 m.

Initial turnout speed	Improved Turnout Speed	Runtime saved per station stop [s]
100	130	11
80	130	28

Table 114: Speed improvement of turnouts at passing loops – runtime savings for passenger trains

[58] DB AG: Example design standard for mixed traffic lines with max. line speed up to 161..230 km/h – Ril 402.0301A03, version valid from 01.01.2002

Example Calculation - Improvement of turnout speeds at junctions and crossovers

To study the effects of different turnout speeds at junctions and crossovers it is analysed how much running time and energy a high speed train can "save" in a situation where the assumed speed in the crossover is upgraded from 100 km/h to 130, 170 or to line speed 234 km/h. The running time calculations are based on the following assumptions:

- High speed train,
- Train length 400 m,
- Braking rate 0.5 m/s2,
- Regenerating of energy by braking is not assumed,
- Acceleration rate 0- 60km/h: 0.64m/s2, 60 -249km/h: 0.64m/s2 – 0.12m/s2,
- Speed at the main line 234 km/h.

In the analysis are assumed a 234km/h speed profile on both sides of the crossover and a restriction in the middle depending on the dimensions of the crossover, which is determined by turnout radius to be foreseen, see Table 115 below.

Speed restriction in the fast crossover	Turnout Radius	Length of speed restriction
170 km/h	3,000 m	470 m
130 km/h	2,500 m	390 m
100 km/h	1,200 m	180 m
80 km/h	750 m	1.178 m

Table 115: Speed restrictions in turnouts and related parameters

The results of the calculation are provided in Table 116. According to calculation results speed at junctions should be as high as possible to avoid lost runtime and energy consumption. 170 km/h can be considered as lower bound. If the diverging track turnout is passed regularly by scheduled high speed trains. In case the line speed of the line section ahead or in rear of the junction is lower, turnout speed can be lowered to line speed of the neighbouring sections.

The principle straight track for high speed trains should be applied to all junctions of the open line (Rae junction, Upeslejas triangle, Misa triangle, Kaunas triangle (route to Vilnius), Palemonas and Jiesia, Marjampole north and south). For Kaunas triangle the application of reduced speed is foreseen for trains from/to Kaunas/Warszawa. Junction speed shall depend on final decision regarding line speed on section Palemonas – Kaunas triangle (speed limit 160 km/h...130 km/h starting section km 4,495 to Palemonas station according to preliminary design, might be higher resulting from ongoing CPTD process it will be approx. 220 km/h).

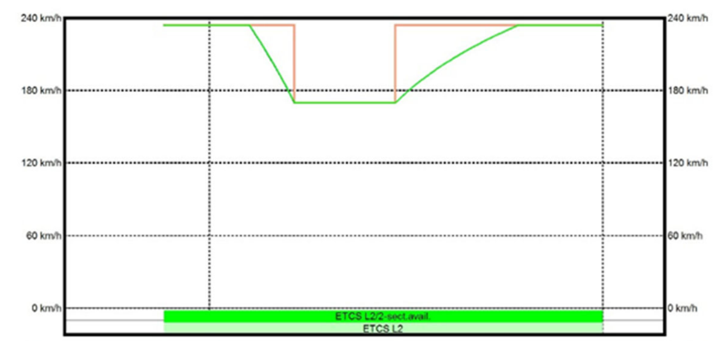
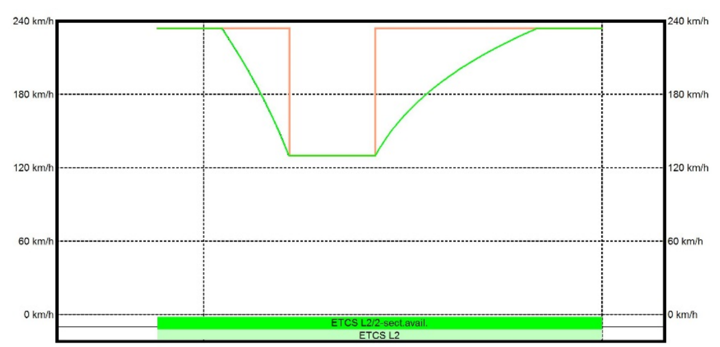
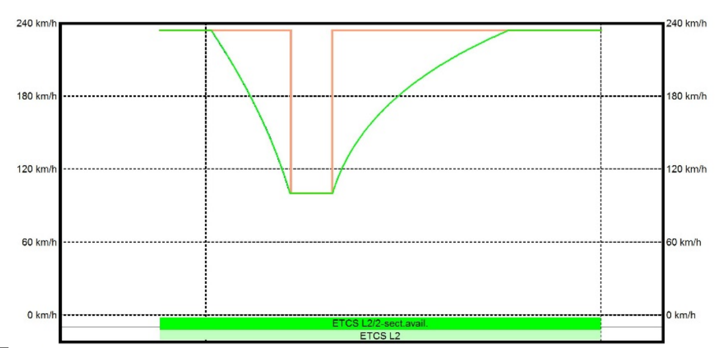
	Crossover speed	170 km/h
	Additional energy consumption run time compared to continuous speed running time at 234 km/h[59]	47 sec
	Additional energy consumption compared to continuous speed at 234 km/h[60]	94 kWh
	Crossover speed	130 km/h
	Additional energy consumption run time compared to continuous speed running time at 234 km/h[61]	1 min 34 sec
	Additional energy consumption compared to continuous speed at 234 km/h[62]	138 kWh
	Crossover speed	100 km/h
	Additional run time compared to running time at 234 km/h	1 min 42 sec
	Additional energy consumption compared to continuous speed at 234 km/h[63]	170 kWh

Table 116: Runtime and energy consumption for various turnout speeds

[59] Provision of tractive force at wheelset, regeneration not considered
[60] Provision of tractive force at wheelset, regeneration not considered
[61] Provision of tractive force at wheelset, regeneration not considered
[62] Provision of tractive force at wheelset, regeneration not considered
[63] Provision of tractive force at wheelset, regeneration not considered

Recommended turnout speeds

A complete overview of the recommended turnout speeds is presented in Table 117.

As indicated in this table only four types of switches are to be applied on Rail Baltica, which will ease maintenance and contributes to overall reliability. These recommendations are to be seen as more general guidelines. Other solutions might be applied in case of limited space to develop the track layout of passenger and freight stations. Usually at such location providing an additional track or track connection is more beneficial than only using one of the four standard types. This could be the case e. g in Kaunas Central station or Riga Central station.

Use case	Turnout speed (diverging track)	Use case
Junctions on the open line	Passenger tracks (regional and long distance): >=170 km/h 230km/h Freight only tracks not used by passenger trains: 120 km/h.	Guaranteeing short travel times and avoiding unnecessary energy consumption. Speed should be adjusted to speed on adjacent track sections. Design of junctions should support straight track can be used for High speed trains.
Passing loops	100 km/h	Advantageous for passenger trains, light engines, maintenance trains because of high length of loop track. Fast clearance of mainline will have positive impact on capacity. RailSys analysis shows only minimal benefits for passenger trains if higher speeds than 100 km/h would be used.
Standard Crossover (between running lines)	100 km/h	limiting negative impact of wrong direction working. Allow for flying overtaking (freight train is using diverging track). Same turnout type as in passing loops can be used.
Main tracks of international passenger stations (all passenger trains stopping)	100 km/h (station tracks > 1.000 m) 80 km/h tracks < 1.000 m length	RailSys model shows only minor advantage for 130 km/h. Advantage of higher speed only in case of long distances between turnout and stopping point of the train.
Main tracks of freight stations	80 km/h	Provide for fast arrival and departure of light trains and light engine movements. Limit required path length for shunting movements.
Other Sidings	40 km/h	Max. speed for signalled shunting operation with track occupancy detection: up to 40 km/h.

Use case	Turnout speed (diverging track)	Use case
		Limit required path length for shunting movements.
Access to depots and terminals (from main line)	100 km/h 80 km/h (distance to stopping point < 1.000 m)	Subject to length of reception sidings and ERTMS mode transition.

Table 117: Recommended turnout speeds and related justification

3.5.8. Block section length

Rail Baltica will be operated applying ETCS, level 2 train control system without fixed main signals. For this system track vacancy detection by axle counters or track circuits is still needed and fixed block working is to be applied. However ETCS and operation without lineside signals allows for additional flexibility regarding length of block sections due to lower investment costs compared to installation of fixed signals. ETCS level 2 does provide cab signalling and the speed curve to safely stop in ahead of an occupied block section is calculated by the on-board computer individually for each ttrain based on the movement authorities sent from the Radio Blocking Centre (RBC) and brake distance to be applied. Thus the minimum headway between two consecutive trains passing a block section will be determined by

- Speed of first train
- Brake distance of second train under regular operating conditions
- Length of block section
- Clearing time of block section (Safety overlap at the end of the block section, length of first train, reaction time until clearance of block section received by on-board unit of following train).

Optimisation of block secti0ns aims to provide equal occupation times for all block sections.

Minimum headway between two consecutive trains is determined by the critical block section. Rail Baltica shall be designed for mixed traffic. The best results can be achieved if travel time of the trains is harmonized between block sections. On lines with mixed traffic and necessity of passing critical sections are:

- The length of the last section before a train entering a passing loop clears the main line. Occupation time of the section is determined by the braking process.
- The length of the first section after the passing loop will determine when the following train is able to start from the passing loop.

Based on the above stated consideration the following parameters are proposed:

- In front and rear of stations, passing loops and junctions the maximum block section length shall be restricted to 1,500 m for two consecutive block sections.
- The first/last section at entry/exit of stations, junctions, passing loops shall be as short as possible and designed such that length of section to be travelled with restrictive speed is minimized.
- Signalling system shall provide for bidirectional running on all lines. Block sections provided could be used wherever possible for both directions.
- Taking into account above stated principles for block sections around stations, junctions and crossovers the maximum length of a block section on the open line shall not exceed:
    - 1,500 m on heavy occupied line sections Kaunas triangle south – Palemonas – Kaunas Central – Jiesia and Riga loop (Acone – Riga Central – Riga airport – Jaunmārupe).
    - 4,000 m on all other line sections.
    - On lower occupied cross-border sections Pärnu – Salacgriva and Bauska - Panevėžys the maximum block section length could be extended to 6,000 m.

These principles are illustrated in the figure below. Information is only provided for the up track (running from left to right in the picture.

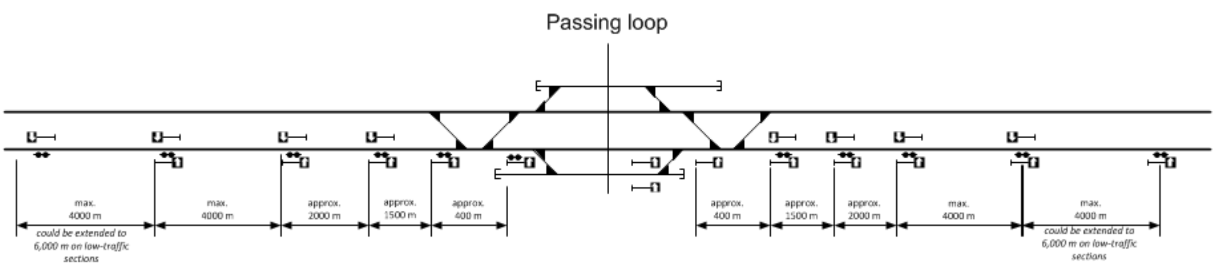


Figure 48: Recommended block section lengths

Example blocking time stairways for the recommended configuration around passing loops are provided in the figure below. As can be seen shortening of block sections around passing loops will contribute to shorter train headways.

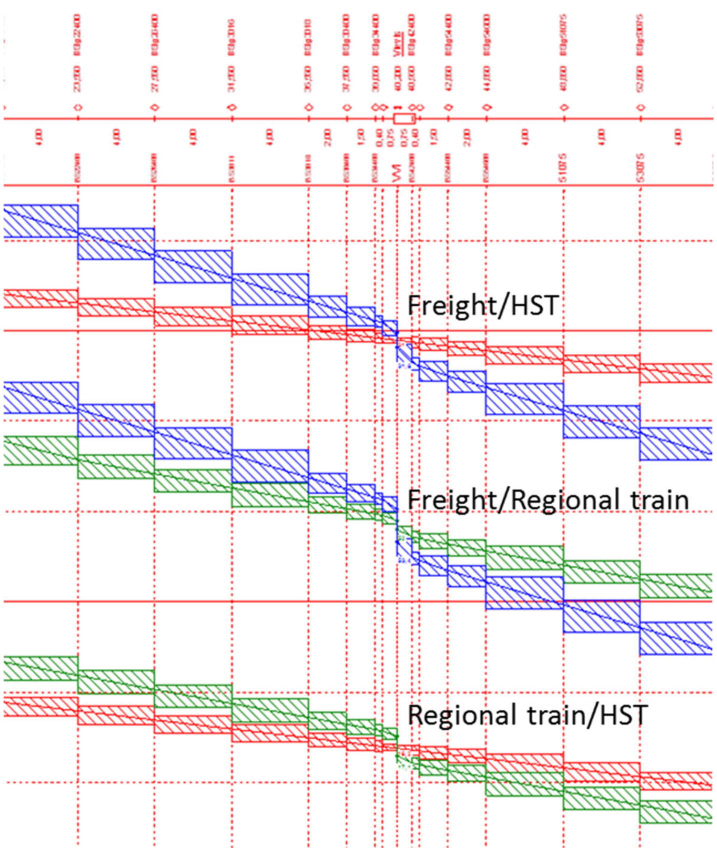


Figure 49: Blocking time stairways for two trains following each other with recommended block section length

The proposed block section lengths are proposed to allow harmonized minimum train headways such that waiting times of regional passenger trains and freight trains at passing loops can be minimized and fast trains are not slowed down by slower trains ahead entering the passing loop or passing a crossover or junction at reduced speed. This will allow to fully expose functionality of ERTMS with the aim to minimize possible train headways. From overall capacity viewpoint block section length on open line could be higher but this will lead to more restrictions on operation and additional waiting times at passing loops and in case of disturbed operation, if a train is forced to stop or slow down.

The maximum block section length of 4,000 m is be also confirmed by international benchmarking. The design guidelines of Deutsche Bahn foresee this block section length for comparable conditions (mixed traffic lines standard M230 with total 60 trains per day per direction).[64]

[64] Deutsche Bahn Ril 413.0301A03

4. Operation Plan(WP 4+WP8)

4.1. Scope and methodology

Compilation of operation plan is following an integrated approach strongly oriented on market requirements. In the operation plan the future train service is defined by means of operational timetables for the TP 2026, 2036, 2046 and 2056. The requirements derived from this timetable are then mapped onto the proposed railway infrastructure and also applied to rolling stock following an iterative approach to ensure infrastructure and rolling stock will be compatible to the market requirements laid out in the timetable. Basis for that work are the market requirements regarding freight and passenger traffic condensed in the traffic forecast as output from WP 1, for which the results were presented in the 1st interim report. Main outcome of operational analysis based on the developed timetable is to indicate how the infrastructure will be utilised. On the grounds of infrastructure utilisation, remaining operational bottlenecks can be identified. To overcome operational bottlenecks solutions will be developed following an iterative approach. The first recommendations towards changes in the infrastructure layout are provided in this report. This work will be continued as part of WP 7.

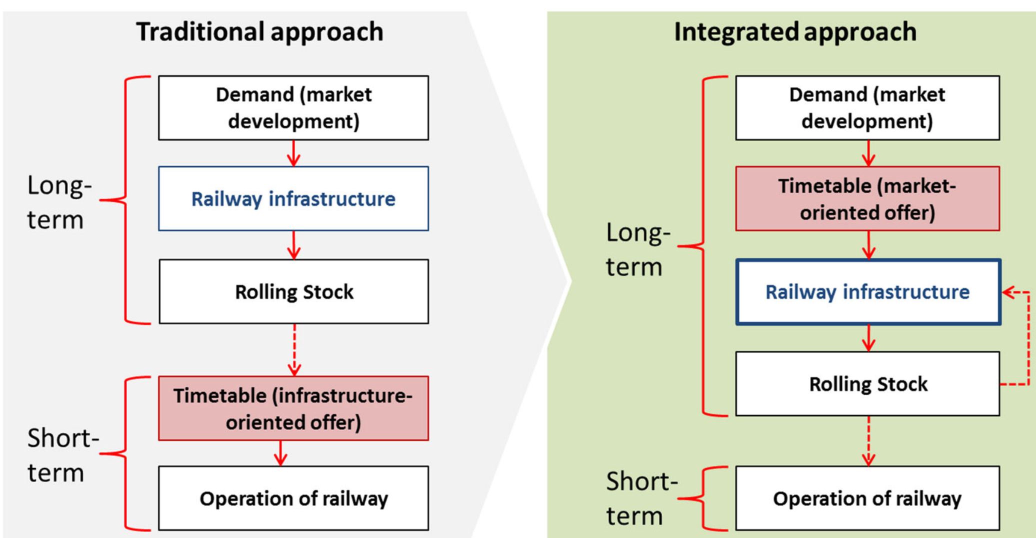


Figure 50: Integrated long-term planning approach for railway operation

The current version of the operation plan is focused on the Rail Baltica sections in Latvia, Lithuania, and Estonia together with future extension to include the FinEst link tunnel section as well as the Helsinki node. As far as available the information on develelopment of Rail Baltica corridor in Poland have been included in the operation plan.

Regarding travel times and infrastructure conditions the current and future situation in Poland is considered as far as data is available.

The operation plan was developed in an iterative process taking into account updated information on infrastructure and refinement of passenger and freight forecast. The first version of the operational plan was provided in the 2nd interim report. For second iteration of the operational plan the updated passenger and freight transport forecasts and the updated train service pattern as well as the resulting draft timetable were provided in the preliminary study report. Recommendations and considerations presented in this report are based on the 2nd iteration of the operation plan, which includes final recommendations regarding infrastructure development according to the various time horizons and also considering completed requirements regarding rolling stock and infrastructure maintenance.

4.2. Considered Track Layout

Track layout considered so far is mainly based on preliminary design. Optimisations proposed by RB Rail as part of the on-going Consolidated Preliminary Technical Design (CPTD) work and as results of other discussion, e.g. with Operational Plan Concept study ad hoc Technical Working Group (TWG) is incorporated step by step into this study.

The currently assumed track layout is provided in Annex 1 of this report. Assumptions regarding track layout and used data sources are outlined in 3.3 of this report. Any assumed changes to the track layout required to run the developed timetable are documented in this report together with first recommendations regarding optimisation and further development of track layout in stations and nodes.

In annex 1 the recommended changes to the original track layout will be provided on separate track maps for time horizons 2026, 2036/46 and 2056.

4.3. Maximum Speed allowed by infrastructure

According to the current Rail Baltica Design Guidelines the maximum speeds for infrastructure are as follows:

- passenger trains: 249 km/h (according to line category P2 TSI-INF),
- freight trains: 120 km/h. This corresponds to line category F1 of TSI-INF.

Since railway alignment is likely to remain for more than a century, the design of track geometry shall include reserve to allow future speed increase (e. g. to 300 km/h) where possible without significant additional CAPEX.

According to Design Guidelines the lines the operational speed of the high speed trains will be restricted to 234 km/h considering the necessary margin for ERTMS speed measurement, train location accuracy and intervention speed for driver warning and emergency brake in case of exceeding permitted speed. By this approach it is secured that the maximum line speed is not exceeded under any circumstances, which is a safe but new approach since technical design parameters for railway lines usually contain a safety margin for exceeding design speed. Typically trial runs prior to inauguration of public services are performed with speed exceeding line speed by 10 %.

Timetables and indicated travel times in the current version of the operational plan are based on maximum operational speed 234 km/h. However, it is recommended to check whether the conventional principle (operational speed 249 km/h) shall be applied on Rail Baltica subject to the final strategy for test runs.

According to preliminary design the maximum line speed can be reached on 85 % of overall route length (main route for passenger train). Remaining restrictions and further details are outlined in chapter 3.5.1. As part of ongoing Consolidated Preliminary Technical Design (CPTD) possibilities to further increase speed by optimisation of railway alignment are evaluated by RB Rail.

Since CPTD was carried out by RB Rail parallel to development of the operational plan the speed as per preliminary design was considered for timetabling and capacity analysis.[65] As a last step the current results of CPTD were incorporated into the Railsys model to show effect on travel time, to calculate energy consumption and to provide a basis for further traffic modelling after completion of this study.

4.4. Train service pattern

4.4.1. Passenger Train Service

The passenger train service pattern is developed from the consolidated demand forecast and forms the basis for the operational programme on Rail Baltica together with the freight train service pattern. For evaluation of capacity limits of the line for passenger traffic the train service pattern required during peak hours – and not by the daily number of trains is important. Furthermore, the required train service in peak hours will determine number of vehicles and required stabling capacity at depots and stations.

In general, there are four types of passenger trains:

- High-Speed Trains (HST) with a maximum speed of 249 km/h[66] and few stops to realise a high travel speed.
- Night Trains (NT) for long-distance international overnight services with few stops (Vmax = 200 km/h) and arrival in the final destination in the early morning.
- Regional Express (RE) trains to connect regional centres with additional stops along the alignment (Vmax =160/200 km/h[67]).

[65] Exception: CPTD for section Upeslejas – Šķirotava, which was finalized at the time of conducting the study, for further details see chapter 3.5.1.
[66] Maximum operating speed is limited to 234 km/h
[67] In this Operation Plan RE trains are operated with a maximum speed of 200 km/h requiring dedicated rolling stock. As travel time difference of RE trains with a high number of stops between a maximum speed of 200 and 160 km/h

- RIX shuttle trains between Riga Central and Riga Airport (Vmax = 160/200 km/h[68]) and HEL shuttles between Tallinn and Helsinki[69].

The train service pattern should be increased with the growing demand after opening of Rail Baltica in 2026. The general forecast horizon of the train service pattern was set to 2056 in order to meet the required capacity of both the operated trains (seating capacity) and the line capacity considering FinEst link. The integration of the potential FinEst link and regional passenger service into the Operation Plan are the reason why the number of passengers and the offered trains are significantly higher compared to the CBA which did not consider both services.

The following figure shows the passenger train service pattern in 2056 which forms the basis for the offered passenger trains in all time horizons:

is rather limited, authorities and operators could decide to use vehicles with a maximum speed of 160 km/h in order to reduce costs.

[68] On the short section Riga Central – Riga Airport trains will hardly use a maximum speed of 160 km/h or even 200 km/h. In order to unify the vehicle fleet the same vehicles as for RE trains are chosen.

[69] Compare chapter 4.5.10 on FinEst link

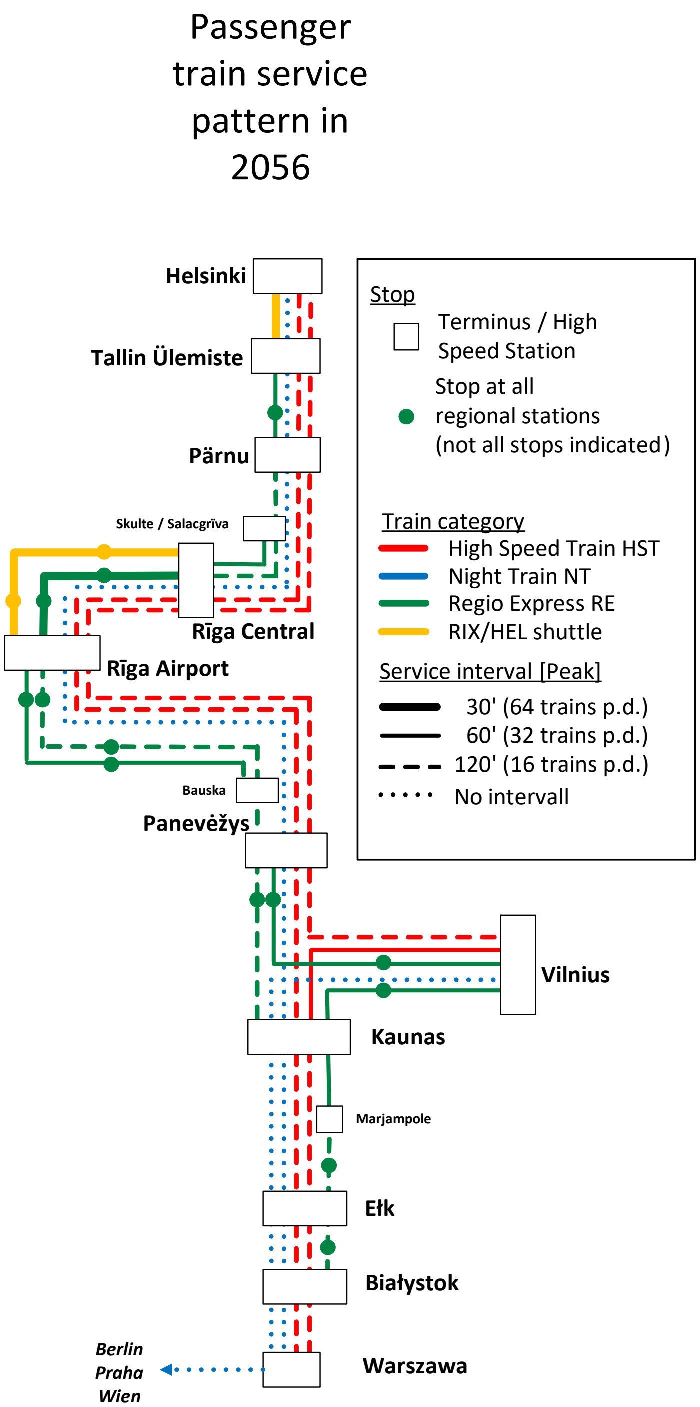


Figure 51: Graphical train service pattern and headways in 2056 (with FinEst tunnel)

In 2056 on most sections both HST and RE trains are operated in an hourly service (together 2 trains per hour and direction) where in areas with a higher demand as on the section Kaunas – Vilnius or around Riga the number of trains is higher. Individual lines with certain headway are combined on common sections to the half headway, e.g. HST lines Tallinn – Warszawa and Tallinn – Vilnius are both operated in a 120′ headway and combined to a 60′ headway on the section Tallinn – Panevėžys.

The routing and frequency of the individual lines can be taken from the following figure (forecast horizons:

Train Category / Line No.		Service Interval [Minutes] Peak	Off Peak	Train pairs/day	Warszawa	Bialystok	Ełk	Suwałki	Marjampole	Kaunas	Vilnius	Panevėžys	Bauska	Riga Airport	Riga Central	SKulte	Salacgriva	Pärnu	Rapla	Tallin Ülem.	Helsinki
HST	11	120	120	8	●	●		●		●		●		●	●			●		●	●
	12	120	120	8							●	●		●	●			●		●	●
	13	120	240	6	●	●		●		●	●										
	14	120	120	10						●	●										
HEL	51	30	60	24																●	●
NT	41			1	●	●		●		●		●		●	●			●		●	●
	42	To BER/ VIE		1	●	●		●		●	●										
RIX*	31	30	60	16										●	●						
RE	21	120	120	8										●	●	●	●	●	●	●	
	22	120	120	8														●	●	●	
	24	120	20	8									●	●	●	●	●				
	25	120	120	8									●	●	●	●					
	26	120	120	8					●	●		●	●	●	●						
	27	60	60	16							●	●									
	28	120	120	8		●	●	●	●	●	●										
	29	120	120	8						●	●										

Legend:
● stop at station / terminus
(RE/RIX stop at all intermediate stations

*Basic offer in a 30‘ headway between Riga Central and RIX will be offered by RE trains (4 lines in 120‘ headway).
RIX shuttles will be operated in a 30‘ headway as additional trains during peak hours . The resulting train offer will be a 15‘ headway during peak hours. RIX shuttles could also run in an hourly service during night periods without RE trains.
3 RE trains (3 x 120’ headway) could be a too extensive train offer north of Riga hence some trains could end closer to Riga.

Figure 52: Passenger train service pattern in 2056 with FinEst tunnel

In long-distance traffic next to the three HST lines Helsinki – Tallinn – Riga – Kaunas – Warszawa, Helsinki – Tallinn – Riga – Vilnius and Vilnius – Kaunas (– Warszawa) two night train pairs are included in the service pattern, one between Warszawa and Tallinn with a possible extension to Helsinki and one between Vilnius via Warszawa to another capital in Central Europe (e.g. Berlin, Praha or Vienna).

In regional traffic all services have been developed in an integrated way. This means that RIX shuttles are not considered as a separate service in fact they will be integrated in the entire time table and passengers can either go by a RE or RIX in Riga metropolitan area. Between Riga Central and Riga Airport the highest number of passenger trains is operated – 32 HST trains and 96 RE/RIX trains in 2056.

The realisation of regional passenger service (both the required infrastructure as stations + intermodal facilities and the PSC-based train operation) will depend of the political willingness and financial means of national and regional authorities. At the current stage there has been no decision by the authorities how and when to develop and introduce such services.

All proposed regional stations have been considered in the Operational Plan to demonstrate the operational feasibility of the related services and stops. In the further process the national and regional authorities have to develop a programme to realise the proposed stations and to implement them accordingly in the regional structures and socio-economic activities to improve the attractivity of these stations. This relates especially, but not only, for the 11 stations with less than 100 forecasted passengers daily. The integration in the (future) urban and regional structures (settlements and transportation network) will have a significant impact of the passengers demand at all stations. This relates to all stations, from a regional stop to international stations, e.g. in Panevėžys, where the number of passengers could be increased significantly with a better location as well as urban and regional integration including connection to the 1520 mm network.

In the earlier time horizons 2036/2046 and 2026 the train service patterns based on the 2056 pattern in such a way that individual (but possible) slots in the time table construction are not used before 2056 due to the lower passenger demand. With such an approach additional trains can be introduced easily without a complete new time table construction if the passenger demand growth will be faster than expected (comp WP 1).

The following figures give an overview of the proposed train service pattern in 2026 and 2036/2046 respectively with a reduced number of used slots compared to the full programme in 2056. All lines are operated already in earlier stages with the exceptions of HEL shuttles between Tallinn and Helsinki as the FinEst tunnel will not be realised before 2056.

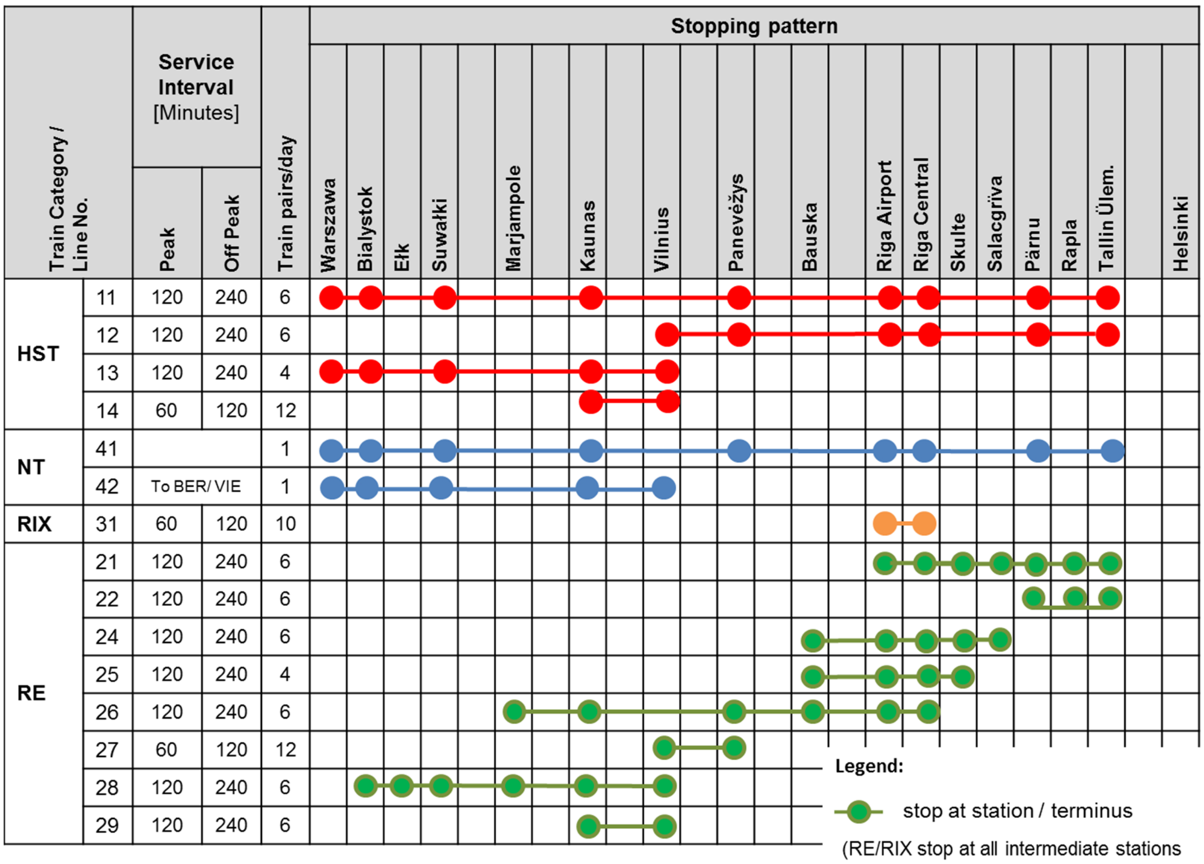


Figure 53: Passenger train service pattern in 2036/2046

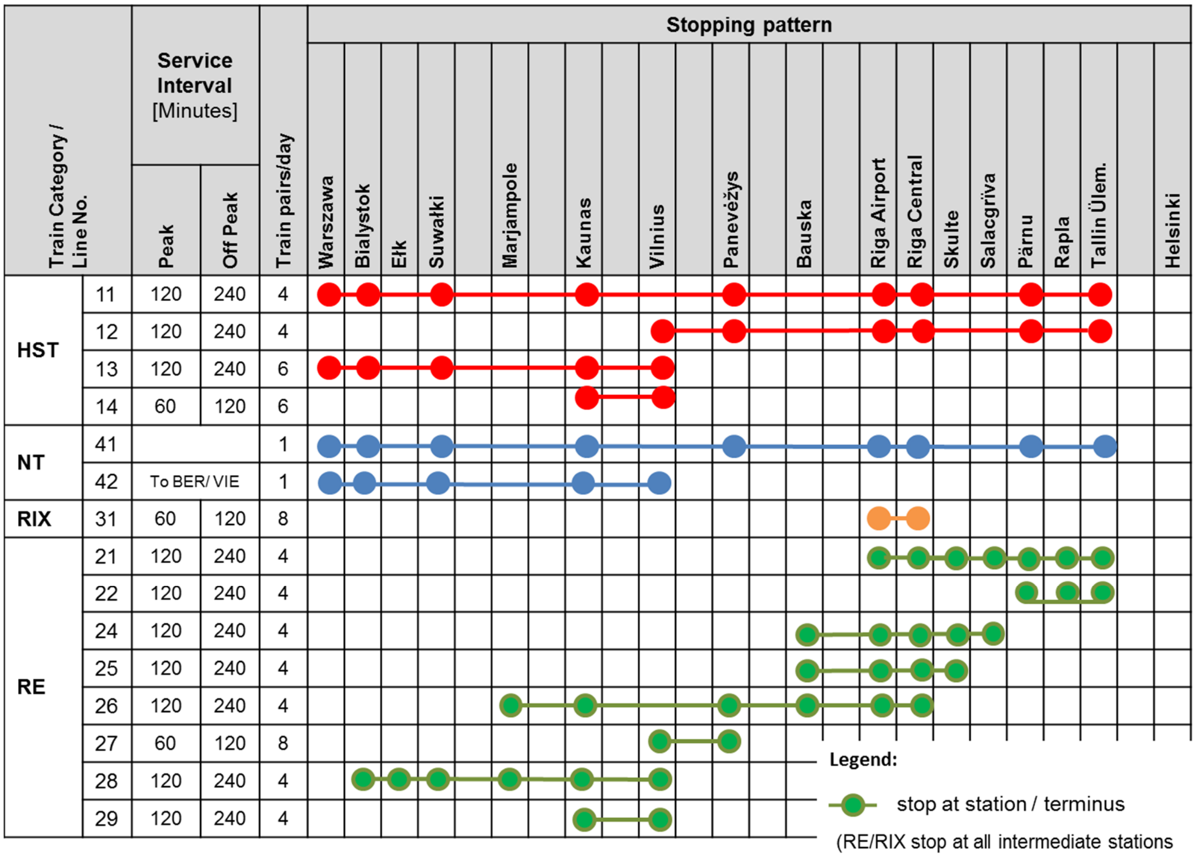


Figure 54: Passenger train service pattern in 2026

When comparing the train service pattern with the forecasted passengers numbers the following average train utilisation will occur in long-distance trains:

	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Panevėžys-Vilnius	Kaunas-Vilnius	Kaunas-Poland
2026	70	58	95	64	135	87	67	78
2036	125	103	152	110	231	149	129	119
2046	135	112	162	116	240	155	134	124
2056	222	204	242	204	345	189	217	221

Table 118: Average number of passengers in long-distance trains (ø passengers/train); capacity: 400 seats

	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Panevėžys-Vilnius	Kaunas-Vilnius	Kaunas-Poland
2026	17%	14%	24%	16%	34%	22%	17%	19%
2036	31%	26%	38%	28%	58%	37%	32%	30%
2046	34%	28%	40%	29%	60%	39%	33%	31%
2056	56%	51%	60%	51%	86%	47%	54%	55%

Table 119: Average train utilisation in long-distance trains (ø seat occupation); capacity: 400 seats

In the starting year 2026 the utilisation of long-distance trains will be comparably low but due to the phasing in. However after few years train utilisation on all section will be on an economically feasible level. The highest utilisation will be on the section Panevėžys – Kaunas where the lowest number of trains is operated within the three Baltic States. If the FinEst tunnel will be realised additional seating capacity will be required in 2056 on that section, i.e. by double traction during peak hours.

During peak hours the utilisation will be higher. According to international benchmark the usual peak hour share amounts to 10-15% of daily transport demand. Assuming a 10% share of peak hour for long distance transport on total daily number of passengers the utilisation of the trains in peak hour will be as follows:

	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Panevėžys-Vilnius	Kaunas-Vilnius	Kaunas-Poland
2026	112	92	152	102	108	70	162	93
2036	301	248	365	265	277	178	413	239
2046	325	269	388	278	288	185	428	248
2056	711	651	774	654	552	302	695	619

Table 120: Number of passengers in long-distance trains during peak hours; capacity: 400 seats

	Tallinn-Pärnu	Pärnu-Riga	Riga-RIX	RIX-Panevėžys	Panevėžys-Kaunas	Panevėžys-Vilnius	Kaunas-Vilnius	Kaunas-Poland
2026	28%	23%	38%	26%	27%	17%	40%	23%
2036	75%	62%	91%	66%	69%	45%	103%	60%
2046	81%	67%	97%	69%	72%	46%	107%	62%
2056	178%	163%	193%	163%	138%	76%	174%	155%

Table 121: Train utilisation in long-distance trains during peak hours; capacity: 400 seats

During peak hours train utilisation will be above 100% in 2056 horizon after opening of FinEst tunnel requiring double traction on all sections. On the section Vilnius – Kaunas already from 2036 double traction will be required.

For regional trains the average train utilisation will be as follows:

	Tallinn-Rapla	Rapla-Pärnu	Pärnu-Salacgrïva	Salacgrïva-Skulte	Skulte-Riga	Riga - RIX (with shuttles)	RIX-Bauska	Bauska-Panevėžys
2026	56	19	25	19	46	50	71	75
2036	88	25	42	33	81	105	125	117
2046	96	33	42	38	84	116	131	125
2056	75	25	31	28	60	85	92	94
	Bauska-Panevėžys	Panevėžys-Kaun./Viln.	Kaunas-Pan./Viln.	Vilnius-Pan./Kaun.	Kaunas-Marijampolė	Marijampolė-LT-PL border		
2026	75	46	63	53	156	50		
2036	117	75	100	81	242	83		
2046	125	78	108	85	258	92		
2056	94	63	85	69	203	75		

Table 122: Average number passengers per RE train (ø passengers/train); capacity: 300 seats

	Tallinn-Rapla	Rapla-Pärnu	Pärnu-Salacgrïva	Salacgrïva-Skulte	Skulte-Riga	Riga - RIX (with shuttle	RIX-Bauska	Bauska-Panevėžys
2026	19%	6%	8%	6%	15%	17%	24%	25%
2036	29%	8%	14%	11%	27%	35%	42%	39%
2046	32%	11%	14%	13%	28%	39%	44%	42%
2056	25%	8%	10%	9%	20%	28%	31%	31%
	Bauska-Panevėžys	Panevėžys-Kaun./Viln.	Kaunas-Pan./Viln.	Vilnius-Pan./Kaun.	Kaunas-Marijampolė	Marijampolė-LT-PL border		
2026	25%	15%	21%	18%	52%	17%		
2036	39%	25%	33%	27%	81%	28%		
2046	42%	26%	36%	28%	86%	31%		
2056	31%	21%	28%	23%	68%	25%		

Table 123: Average train utilisation in RE trains (ø seat occupation); capacity: 300 seats

During peak hours the utilisation will be higher. Assuming a 15% share of peak hour on total daily transport demand[70] the peak hour utilisation of the proposed train (seating capacity 300 seats) will be as indicated in Table 124

[70] Higher share of commuters in morning and evening peak than in long disctance trains.

	Tallinn-Rapla	Rapla-Pärnu	Pärnu-Salacgrïva	Salacgrïva-Skulte	Skulte-Riga	Riga - RIX (with shuttles)	RIX-Bauska	Bauska-Panevėžys
2026	135	45	30	45	165	360	255	90
2036	315	90	75	120	390	1005	600	210
2046	345	120	75	135	405	1110	630	225
2056	360	120	75	135	435	1230	660	225
	Bauska-Panevėžys	Panevėžys-Kaun./Viln.	Kaunas-Pan./Viln.	Vilnius-Pan./Kaun.	Kaunas-Marijampolė	Marijampolė-LT-PL border		
2026	90	165	225	255	375	60		
2036	210	405	540	585	870	150		
2046	225	420	585	615	930	165		
2056	225	450	615	660	975	180		

Table 124: Number of passengers in RE trains during peak hours; capacity: 300 seats

”

	Tallinn-Rapla	Rapla-Pärnu	Pärnu-Salacgrïva	Salacgrïva-Skulte	Skulte-Riga	Riga - RIX (with shuttle	RIX-Bauska	Bauska-Panevėžys
2026	45%	15%	10%	15%	55%	60%	85%	30%
2036	105%	30%	25%	40%	130%	168%	200%	70%
2046	115%	40%	25%	45%	135%	185%	210%	75%
2056	120%	40%	25%	45%	73%	103%	110%	75%
	Bauska-Panevėžys	Panevėžys-Kaun./Viln.	Kaunas-Pan./Viln.	Vilnius-Pan./Kaun.	Kaunas-Marijampolė	Marijampolė-LT-PL border		
2026	30%	55%	75%	85%	125%	20%		
2036	70%	68%	90%	98%	290%	50%		
2046	75%	70%	98%	103%	310%	55%		
2056	75%	75%	103%	110%	325%	60%		

Table 125: Train utilisation in RE trains during peak hours; capacity: 300 seats

By contrast to long-distance traffic FinEst link does not have a significant impact on the passenger numbers in regional traffic. However commuting patterns dominate regional traffic. From the current initial state of analysing regional traffic train utilisation will be very high in the suburban areas around Tallinn, Riga, Vilnius and Kaunas requiring double traction and higher capacity during peak hours. The actual demand in regional trains will depend on several indicators to be further analysed as described above.

As described above the passengers demand forecast and the operation of regional trains will depend not only of the socioeconomic development but also significantly of political decisions on the train service and spatial development. At the current stage the proposed train service is comparably high (and train utilisation low) on the section north of Riga. The capacity might not be sufficient in single-traction on the section Kaunas – Marijampolė. As the passenger demand might differ from this forecast in the following project phases of Rail Baltica detailed analysed of the planned regional passenger services should be conducted. This refers to all sections but mainly to the sections in Lithuania as they have a significant influence of the design requirements for Kaunas node. These studies should analyse in details i.e.:

- Final determination of the location of regional stops,
- Minimum transport offer of RE trains (should not be < 2 hourly service),
- Planned spatial structure and infrastructure around these stops (New settlements / traffic generators),
- Planned transport infrastructure and offer at and around the planned stops including possible parallel busses; intramodal connectivity,
- Planned tariff system (RE trains and entire public transport) and pricing on parallel roads.

4.4.2. Freight train service

Required Services

According to the identified market demand for the different freight services, the operational plan shall focus on two to three main service types:

- Standard intermodal trains (container and semi-trailers)
- Standard Wagonload trains
- High priority intermodal service (container, dedicated postal units, semi-trailers, if required)

Containerisation in Eastern Europe and the Baltic countries is currently still moderate but likely to increase in the future to reduce cost. Thus, most of freight trains on Rail Baltica will be intermodal trains. These trains could be either operated as:

- shuttle train services: fixed train configuration for the whole journey between two terminals and uniform wagon type
- block train services: train formation will be adjusted to transport demand by varying train length and mix of wagon types within the train, thus requiring additional shunting at the origin and destination terminals, e. g. adding piggyback wagons depending on demand

Terminals on the other end of intermodal train run will be major hubs in Poland (where units might be reconsolidated to go further west or south), Germany and Western Europe, e. g. terminals in the regions Katowice, Warszawa, Poznan, Ludwigshafen, Duisburg, Hamburg/Bremerhaven, and, subject to distribution of intermodal volumes among harbours and development of short sea shipping potentially and hinterland consolidation also Antwerpen/Rotterdam).

This mainly depends on the OD relations to be served by the different operators. Transport of semi-trailers will have a significant share of the overall transport volumes. From current state of affairs special provisions for transport of non-craneable semi-trailers shall be made. At least in the first years of operation systems without need for dedicated transhipment facilities in the terminals will be advantageous.

Wagonload services will be mainly provided as shuttle block trains terminal – terminal with minimum change of train formation en route. For smaller wagonload consignment it shall be possible to add a wagon group to an intermodal train provided this operation takes places in or nearest to the terminal to avoid additional shunting stops en route. From currently available data no further distinction about wagonload services for different freights can be made in sufficient detail. Thus, no distinction between different block train types can be made in the operational plan. Thus, terminal space shall provide for at least one loading track with road access (train length or half train length), implementation of cargo warehouse (up to 300 m loading length to minimise shunting).

Based on these assumptions and the consolidated forecasts provided as results of WP 1 (see chapter 1.5.2) the number of required freight trains per working day to be operated on the different line sections was estimated. The results are shown in Table 126and Table 127.

OD Train Relations	Train pairs / day			
	2026	2036	2046	2056
Muuga-Poland	8	9	12	17
Muuga – Salaspils	1	1	1	2
Muuga – Vilnius	3	3	3	5
Salaspils – Poland	2	2	2	2
Salaspils – Vilnius	1	1	1	1
Vilnius – Poland	9	11	12	12
Kaunas – Poland	8	9	10	11

Table 126: Consolidated freight transport forecast, train pairs per OD relation

Line section	Total number of trains [train pairs / day]			
Year	2026	2036	2046	2056
Muuga – Salaspils	12	13	16	24
Salaspils - Kaunas triangle	14	15	18	25
Vaidotai - Kaunas triangle	13	15	16	18
Kaunas Triangle – Palemonas	19	22	26	31
Palemonas - border PL/LT	27	31	36	42
Kaunas Triangle East - Kaunas Triangle North	*4*	*4*	*4*	*6*
Kaunas Triangle North - Kaunas Triangle South	*10*	*11*	*14*	*19*
Kaunas Triangle South - Kaunas Triangle East	*9*	*11*	*12*	*12*
Line section	Thereof wagonload trains [train pairs / day]			
Year	2026	2036	2046	2056
Muuga – Salaspils	2	3	3	5
Salaspils - Kaunas triangle	2	2	2	4
Vaidotai - Kaunas triangle	1	1	1	1
Kaunas Triangle – Palemonas	1	1	1	3
Palemonas - border PL/LT	3	3	4	5
	Thereof intermodal trains [train pairs / day]			
Year	2026	2036	2046	2056
Muuga – Salaspils	10	10	13	19
Salaspils - Kaunas triangle	12	13	16	21
Vaidotai - Kaunas triangle	12	14	15	17
Kaunas Triangle – Palemonas	18	21	25	28
Palemonas - border PL/LT	24	28	32	37

Table 127: Consolidated freight transport forecast, train pairs per working day per line section

This calculation is based on following assumptions and considerations taking into account available information on freight flows:

- Daily freight volumes only available for both directions from consolidated forecast, incl. distribution of freight flows around Kaunas triangle
- Distribution of overall annual volume on 310 working/days per year, this assumption does also reflect seasonal and weekly imbalance of freight flows
- Avg. train utilisation 70 % as assumed in CBA. Taking into account high share of intermodal services this assumption seems to be realistic.

- Avg. achievable payload per freight train 1,000 t. This corresponds to max. gross train weight 1.530 t with single locomotive, interoperable train length outside the Baltic states of 740 m and possibility to operate heavier trains (e. g. bulk wagonload) with double traction.

Requirements on distribution of freight trains over the day cannot be derived yet in detail and may change subject to overall train path restrictions, also in other countries like Poland. To provide the necessary flexibility for timetabling at least the number of train paths per hour as indicated in Table 128 shall be considered in the operational plan.

Line Section	Year			
	2026	2036	2046	2056
Year	Freight train paths per hour per direction			
Muuga – Salaspils	1	1	1.5	2
Salaspils - Kaunas triangle	1.5	1.5	1.5	2
Vaidotai - Kaunas triangle	1	1.5	1.5	1.5
Kaunas Triangle – Palemonas	1.5	2	2	3
Palemonas - border PL/LT	2	3	3	3

Table 128: Required freight train paths to be provided on individual line sections

This table indicates train paths per hour per direction. 1.5 means 3 paths per direction are to be provided within a 2 hour period.

This requirement is based on following considerations:

- Possibilities to coordinate train paths between different operators to avoid peaks are limited and is complicated since several parties are involved (e.g. infrastructure provider, railway undertaking, terminal operator, logistics service provider)
- Collection and distribution of freight during daytime will lead to morning and evening peaks
- Train Path regime must allow to compensate the higher level of delays of freight trains compared to passenger services
- Utilisation of offered paths by required freight trains of significantly more than 60% is considered as insufficient regarding flexibility provided (too many timetabling restrictions and no reserve for special trains on short notice).

For capacity considerations in the operational plan a typical representative train with dimensions corresponding to average payload will be considered. As outlined in chapter 2.6, for significantly longer and heavier trains double traction leading to comparable acceleration and deceleration will be the likely case. Average payload per train also respects that not all services will utilise the maximum train length and/or weight, depending of the service concepts of the train operators. During first years of operation establishing sufficiently frequent transport connections to be competitive with road transport will be the priority, thus train utilisation will be increased step by step.

4.4.3. Dedicated FinEst link services

According to results of the feasibility study for FinEst link the following train services shall be introduced:

- Passenger trains (shuttle traffic) from Helsinki Vantaa Airport (via Pasila and Helsinki central) to Tallinn Ülemiste station.
- Truck shuttles Tallinn - Helsinki, recommended max. speed 160 km/h
- Car shuttles Tallinn – Helsinki with dedicated fleet, recommended max. speed 160 km/h
- Conventional freight trains with speed of up to 120 km/h and closed or intermodal wagons

Initial proposal is to use the same type of train set for car and truck shuttle services. One train set consists of two locomotives and approx. 720 meters of wagon set, whereof three wagons for passengers. The terminals for car and truck shuttles are planned to be located north of Helsinki airport. On the Estonian side the terminal is currently assumed to be located southwest of Tallinn airport (track access from Rae Junction).

Based on the traffic related traffic forecast the following train service pattern is assumed forecast in the FinEst link feasibility study for the first years of operation of the tunnel.

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Trains per direction
Train type		Maintenance																							
Passenger Trains 200 km/h	1					2	2	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2	1	1	40
Car shuttle						1	1	1	1	1	1							1	1	1	1	1			11
Truckshuttle						2	2	2	2	1	1								1	2	2	2	1	1	19
Conventional cargo trains	1																						1	1	3

Figure 55: Initial demands based train service pattern from FinEst link feasibility study

This will be the basis for the operational plan with following modifications:

- extension of Rail Baltica high speed trains as proposed in 4.4.1 to Helsinki replacing some of the shuttle trains proposed in the FinEst link study between Tallinn Ülemiste and Helsinki airport
- integration of a higher number of freight trains (in total 9 train pairs per day) than proposed considering that transhipment in Tallinn will cost additional time and money weakening the competitive position of rail in this market segment. Additional freight trains will run in hours with reduced service where sufficient capacity might be expected.

All passenger services will be operated to Helsinki airport. Regarding existing shuttle service between Helsinki main station and Helsinki airport, it is assumed that this will remain on 1524 mm gauge using the existing infrastructure. Truck and car shuttles are to be operated between dedicated terminals located north of Helsinki airport and at Tallinn Rae.

	Service pattern (Trains per hour per direction)																								Daily trains per
Time (hour)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	direction
Train Type																									
High Speed Train RB							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			16
Night train RB							0.5															0.5			1
Passenger Shuttle	1					2	1	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	24
Car shuttle						1	1	1	1	1	1							1	1	1	1	1			11
Truck Shuttle						2	2	2	2	1	1								1	2	2	2	1	1	19
Cargo train	2											1		1	1								2	2	9
Total	3	0	0	0	0	5	5.5	6	5	4	4	3	2	3	3	3	3	3	4	5	5	5.5	4	4	80

Table 129: FinEst link – modified service pattern for Rail Baltica operational plan

4.4.4. Train movements for operational purposes

In addition to the required paths as described above additional movements will be required for operational purposes:

- Light engine and empty rolling stock movements between the terminals and depots

- Train movements required for infrastructure maintenance (ballast transport, movement of rolling stock to possession sites)
- Movements of emergency train to reach incident sites

These movements are not considered separately. It is assumed that these movements can use the spare additional freight train paths and/or remaining capacity.

4.5. Results of Study Area Software Modelling (WP 4.2)

4.5.1. Infrastructure Modelling

Infrastructure is based on the base track map (see annex 1) with the following simplifications and modifications:

- Station layouts only contain main tracks. Requirements on sidings will be established separately where needed.
- Latest design of Kaunas triangle is considered.
- Line section to as indicated on track map.
- Additional passing loop on Kaunas – Vilnius section as outlined in 4.6.1.
- Assumption regarding separate line as on track map.
- Track layout for Vilnius station as outlined in 4.7.10.1.
- Track layout for Kaunas Central station according to minimum requirements established in 4.7.6.4.
- Track layout Riga Central station based on current solution, with modification as outlined in 4.7.4.3, picture Figure 81.
- Track layout Jaunmarupe passing loop as outlined in Figure 82 to allow turnaround of regional express line 21.

For alignment of line section Jiesia – border PL/LT alternative 3 (alignment closer to existing line) as provided in the ongoing feasibility study is assumed (alignment closer to existing railway).

Speed profile on the main tracks is modelled in detail. Assumed speed profile for high speed train is provided in annex 7 (maximum permitted operational speed).

Regarding block section length the following assumptions are implemented in the current version of the RailSys model:

- Block section length on line sections with low or homogeneous traffic 2,000 – 5,000 meters,
- Block section length before a station 1,200 – 1,500 meters,
- Short block sections on line sections with dense traffic 700 – 1.200 meters.

4.5.2. Model Timetables

Timetabling does reflect the requirements of the proposed train service patterns.

According to ToR the timetables shall be separate for each time horizon 2026, 36, 46, 56. The results of the traffic study show there are only little differences in demand between 2036 and 2046. Furthermore, the line concept for passenger service is nearly identical between all traffic periods. Traffic in peak time is nearly identical. Thus the fundamental structure of the timetable (departure minutes, run times etc.) used will be the same, with growing path utilisation towards the end of the investigation period.

Therefore, the consultant proposes to model three timetables:

- 2026 (start of operation)
- 2036/46 (demand potential fully exploited)
- 2056 (further traffic growths due to FinEst link)

Derived from the traffic pattern for the operational plan all three timetables will be constructed from the same base timetable varying only the number of trains. For 2056 the additional traffic for FinEst link is taken into consideration.

As most important for dimensioning of the final state of the infrastructure and the maximum amount of paths to be considered, timetable 2056 has been implemented in the RailSys model, first to derive the maximum requirements.. Based on this timetable the timetables 2026 and 2036/46 have been developed on the basis of timetable 2056, by successively reducing the number of trains in the timetable according to the needs for each traffic period.

4.5.3. Timetable construction principles

Construction of the timetable in Railsys was done in an iterative process. The final model timetables provided in this report constructed based on the following principles:

1. **Timetabling Priority[71] at the line sections.** At the line sections the trains are prioritised as follows:
    1. High speed trains,

[71] Timetabling priority: stepwise modification of timetable according to priority of the trains. For daily operation, other principles may apply.

2. Regional trains, including airport shuttle
3. Night trains,
4. Freight trains.

The prioritizing is activated when a high priority train during the timetable construction process catch up a lower priority train: The lower priority train will be planned to stop at a passing loop before the higher priority train catch up to it and let the high priority train pass without delay.

2. **Fixed interval timetable.** Passenger trains will be operated in fixed interval timetables according to the service intervals required according to requirements established in chapter 4.4.1.

3. **Timetable construction based on Kaunas node** in order to utilise the capacity in Kaunas node and the 8 km single track sections on both side of Kaunas Central station:

   a) The Kaunas node defines the slots in the entire Rail Baltica network for all the high speed trains which are calling at Kaunas Central station.

   b) The through running high speed trains Tallinn – Warszawa and Vilnius – Warszawa meet in minute 00 in Kaunas - Central station

   c) The terminating high speed train of line 14 (Kaunas - Vilnius) arrives at Kaunas Central station 32 minutes before minute 00 and departs every hour at minute 30. This means the train has to be parked at Kaunas Central station for at least nearly one hour, which would allow time for cleaning and other illustrated by the red lines in Figure 56

   d) In order to utilise the capacity on the single-track section *and to give connection to the high speed trains* the regional trains arrive short before the high speed trains arrivals to Kaunas. Shortly after the high speed trains departs from Kaunas the regional trains depart. This is illustrated by the green lines in Figure 56 and Figure 57.

4. **Alternating passenger train services (Kaunas node):** To avoid/minimize the number of situations where high speed trains need to overtake regional trains, the lines to/from Kaunas are alternating served by high speed trains every second hour and by regional trains every second hour:

   - In hours where the high speed train runs in direction Kaunas - Vilnius. The regional train runs in direction Kaunas - Riga.
   - In hours where the high speed train runs in direction Kaunas – Riga. The Regional train runs in direction Kaunas – Vilnius.

5. **Services at Riga node.** The high speed trains towards Helsinki stop in Riga with approximately one hour interval, every two hours arriving from Warszawa, and every two hours from Vilnius. Regional trains will be placed between the slots for the high speed train. In order to keep the symmetrical timetable two regional trains paths via Riga Central are provided two consecutive high speed trains. For trains of line 28 (Marijampole Kaunas – Riga Central) turn-around at Acone is assumed.

6. **No trains are overtaken in Riga Central.** As long as above stated principles for HST and regional train service permit, there shall be regular departure intervals between regional passenger services on Riga loop. Therefore the regional trains will be complemented by the airport shuttle trains between Riga Central and Riga Airport to provide the required departure between Riga Central station and Riga airport station intervals (up to 4 regional train departures per hour per direction in peak time, depending on restrictions on regional train timetable). Further smoothening of departure intervals is subject to further optimisation of timetable at a later stage (stopping pattern, final travel times after implementation of infrastructure).

7. **Freight train timetable.** Freight timetable is constructed based on the number of required paths on the individual line sections taking into account different demand on major OD relations. Since paths need to be adjusted to passenger timetable they mainly run in fixed intervals. Time distance between successive paths may vary depending on stops at passing loops. To provide the final timetables and to calculate capacity utilisation according to UIC 406, number of trains in the timetable is reduced in a second step to the number of freight trains as required to model demand for the respective time horizon. Therefore a random approach was chosen.

8. **No fixed maintenance downtime:** there is none predefined time window for track closures. Most of the maintenance work carried out will only require temporary closure of one running line of the double track sections. This work will be mainly done by night or at least outside the passenger traffic peak hours. Number of required freight train paths is calculated on the basis of 22 operating hours. The spare paths will ensure that there is the needed flexibility to cope with delays and timetable alterations for maintenance work.

9. **Variation of train service pattern for different time horizons:** To model different traffic demand the number of trains and train paths needs is different. For all time horizons (2026, 20036/46 and 2056) the same base timetable is used. Therefore timetable 2056 was constructed first. For the other time horizons, where demand is lower, service pattern is modelled by taking by deleting not required trains from the timetable.

10. **Infrastructure:** All timetables are modelled on identical infrastructure.

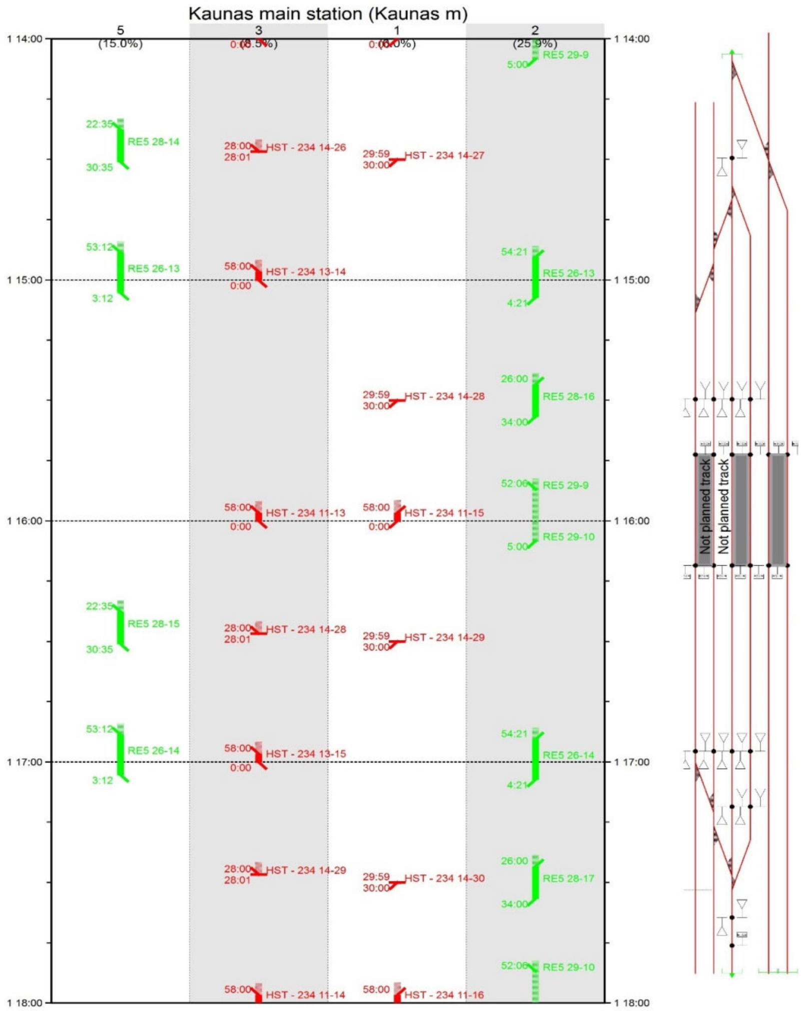


Figure 56: Timetabling principles applied in Railsys model – meeting of trains in Kaunas Central station[72]

[72] Red lines: High speed trains; green lines regional trains; brown lines freight trains

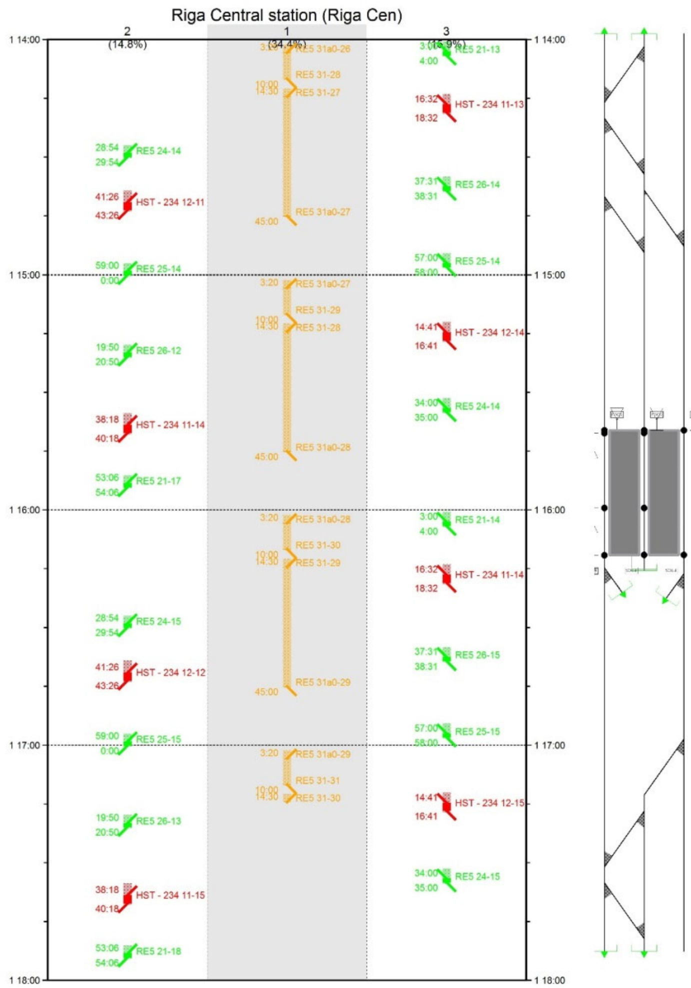


Figure 57: Track occupation diagram Riga Central station

4.5.4. Train Services

Passenger Trains

Train services are modelled according to the traffic pattern on a line-based concept. That means each passenger train relation stated is modelled as a separate line with similar departure minutes and similar run times throughout the complete day as needed.

Freight trains

For modelling the freight timetable a modular pathing concept is followed. To reflect the requirements from the forecasted service, the service in the Baltic States is split up into 5 “virtual lines” on Rail Baltica corridor (see Table 130). If other O/D relations are required, paths modelled could be combined to provide the necessary train routes. If there is a need to stay longer at an intermediate station (e.g. Salaspils) for exchange of a wagon group etc. the train would jump to the next free slot. The spare paths included in the timetable will ensure that such principles would work. Freight services are nearly evenly distributed over the complete day with following minor exceptions:

- Freight line 85 is modelled to run from late evening until early morning
- Several freight trains are cancelled due to operation of the night trains
- For car and truck shuttles on FinEst link an hourly service is assumed. Main reason for this is the speed difference between the different train types, which limits the capacity in the tunnel. This will be addressed in related recommendations.

Related infrastructure bottlenecks at the passing loops are addressed in this report.

For Kaunas node this operational procedure is modelled in Palemonas freight station. If implemented, Karmelava freight station would be a more suitable location for trains not carrying wagon groups for Kaunas intermodal terminal due to space limitations in Palemonas freight station.

The overall line concept and the number of train paths in the model for 2056 are presented in Table 127 below.

Service Type	Line	Relation	Timetable 2056	Running time [hh:mm]	Energy consumption per train [kWh][73]
HST	11	line 11 High speed Warszawa-Tallinn Ülemiste / (Helsinki airport)	8 train pairs	6:52 (7:50)	8446
HST	12	line 12 High speed Vilnius-Tallinn -(Helsinki airport)	8 train pairs	3:51 (4:51)	6352
HST	13	line 13 High speed Warszawa-Vilnius	6 train pairs	4:02	3570
HST	14	line 14 High speed Kaunas - Vilnius	12 train pairs	0:41	873
RE	21	line 21 Regional train Riga airport-Tallinn	8 train pairs	3:07	2227
RE	22	line 22 Regional train Pärnu-Tallinn	8 train pairs	1:13	973
RE	24	line 24 Regional train Bauska-Salacgrïva	8 train pairs	1:48	1262
RE	25	line 25 Regional train Bauska-Skulte	8 train pairs	1:26	990
RE	26	line 26 Regional train Marijampolé-Riga Central	8 train pairs	3:04	1931
RE	line 27/27 b	line 27/27b Regional train Vilnius-Panevezys	16 train pairs	1:30	1117

[73] Energy consumption on wheelset

Service Type	Line	Relation	Timetable 2056	Running time [hh:mm]	Energy consumption per train [kWh][73]
RE	28	line 28 Regional train Bialystok-Vilnius	8 train pairs	3:04	1604
RE	29	line 29 Regional train Kaunas-Vilnius	8 train pairs	0:52	583
RIX	31/31a	RIX shuttle Riga Central-Riga Airport	24 train pairs	0:11	79
NT	41	Night train Warszawa-Tallinn /(Helsinki)	1 train pair	9:10	14577
NT	42	line 42 Night train Warszawa-Vilnius	1 train pair	4:21	6967
Passenger Shuttle	line 51/51a /51b	Helsinki - Tallinn	24 train pairs	0:46	962
Freight	61	Freight Helsinki-FinEst	1 slots per 2 hours per direction	1:17	2276
Truck/Car Shuttle	71/71a	Tallinn FinEst terminal - Helsinki Cargo terminal	1 slot per hour per direction	0:53	1466
Freight	81/81 b/81c	Ełk-Vilnius	3 slots per 2 hours per direction	4:28	4987
Freight	82/82a /82b	Ełk-Salaspils	3 slots per 2 hours per direction	6:20	7194
Freight	83/83a /83b	Muuga-Salaspils	3 slots per 2 hours per direction	4:55	5327
Freight	84	Palemonas-Salaspils	1 slots per 2 hours per direction	3:59	4105
Freight	85	Vilnius-Salaspils	5 trains per day per direction	9:10	10218

Table 130: Train services implemented in the RailSys model for timetable 2056

The slots indicated above confirm that all required services could be implemented into the timetable as required. Foll0wing bottlenecks limit the full provision of all required paths:

- Possibility to operate freight services is determined by the availability of passing loops. Basically there are two issues:
  - Missing passing loops at certain stations in the original layout (Marijampole passing loop, passing loop between Kaišiadorys and Kaunas triangle, additional passing loop between Järvakandi station and Häädemeeste station).

- Number of tracks at regional passenger stations with passing loops. Here a separate freight train passing loop would ease operation. In situations with long distance between the passing loop concerned and adjacent passing loops provision of additional passing loop could be considered to shorten stopping time of freight trains to be overtaken. This was considered as part of final optimisation process.

- Necessity to cross contraflow track at junctions and stations will also reduce timetabling flexibility. For example, the currently proposed at grade design of Jiesia junction (1435 mm at-grade) will limit flexibility for freight train pathing for trains going from Kaunas bypass towards Poland in time periods with passenger traffic.

- Single-track line to Vaidotai in interrelation with at-grade design of Paneriai junction will reduce flexibility for freight train pathing on the Kaunas – Vilnius line.

- During day time, when regional train service is provided according to the train service pattern outlined in Table 130, freight traffic will have to spend longer time periods (more than 30 min) at passing loops. Resulting from that the average speed of the freight train is approx. 70 km/h.

Service Type	Relation			Train pairs per day	Max. Speed		Rolling Stock parameters
	From	Via	To		FinEst tunnel	Rail Baltica	
HST	Helsinki	Tallinn Ülemiste	Vilnius / Warszawa	16	200	234	Pendolino ED 250
Passenger Shuttle	Helsinki	Tallinn Ülemiste		24	200	200	Stadler 8 car
Car shuttle	Helsinki		Soodevahe (FinEst terminal)	11	120	120	Train length: 740 m; 2400 t; Double traction
Truck Shuttle	Helsinki		Soodevahe (FinEst terminal)	19	120	120	Train length: 740 m; 1600 t; Double traction
Cargo train	Helsinki		Poland	9	120	120	Train length up to 1050 m; 1600 t; Single traction

Table 131: Train services FinEst link to be implemented into the timetable

The daily distribution of trains is based on the final report for FinEst link with following changes:

- Introduction of cargo trains between Helsinki freight terminal and destinations further south served by Rail Baltica outside peak hours

- Extension of long distance passenger services from Tallinn Ülemiste to Helsinki airport replacing slots of passenger shuttles foreseen in the FinEst link study

4.5.5. Train Parameters

The calculated running time is determined by the performance parameters for each train type and parameters for dwell time and run time allowance.

Run time supplements for different services are handled differently by the individual infrastructure managers. For the purpose of this study the following assumptions are made:

- For regional train the run time allowance is set to 5%, which is added to the technical minimum running time.
- For high-speed train and freight trains the run time allowance is set to 6% which is added to the technical minimum running time.

These values are in line with recommendation outlined in UIC leaflet 451-1 OR.

Regarding station dwell times the following values will be used throughout the model:

- Long distance train: 2 min (this value is in line with international practice)
- Regional express train: required time for station stops is initially set to 1 min (also typical value, which might be shortened for small stations with few passengers boarding or alighting). Need for prolonged dwell time but might also be extended for larger stations e.g. Riga main station, Kaunas main station. In the latter case it is likely that overall running time indicated will not be compromised since longer dwell times can be covered by shorter stops on small stations.
- Minimum turnaround time for terminating trains and direction change is set to at least 9 min.

4.5.5.1. High Speed Trains

For high speed trains a typical train set available on the market is modelled (Pendolino ED 250). Main parameters are as follows:

- Seating capacity: 402 passengers
- Train length: 187,40 m
- Tractive Power: 5.664 KW
- Starting acceleration: 0,49 m/s^2 (0-60 km/h)
- Max. train speed: 250 km/h

- Braking performance: 0.5 m/s^2.

Run time of high speed trains is calculated on the basis of a maximum speed of 234 km/h.

In Figure 58 acceleration over speed diagram is presented for level gradient and wet conditions. The run times for different train relations is provided in the tables below the diagram.

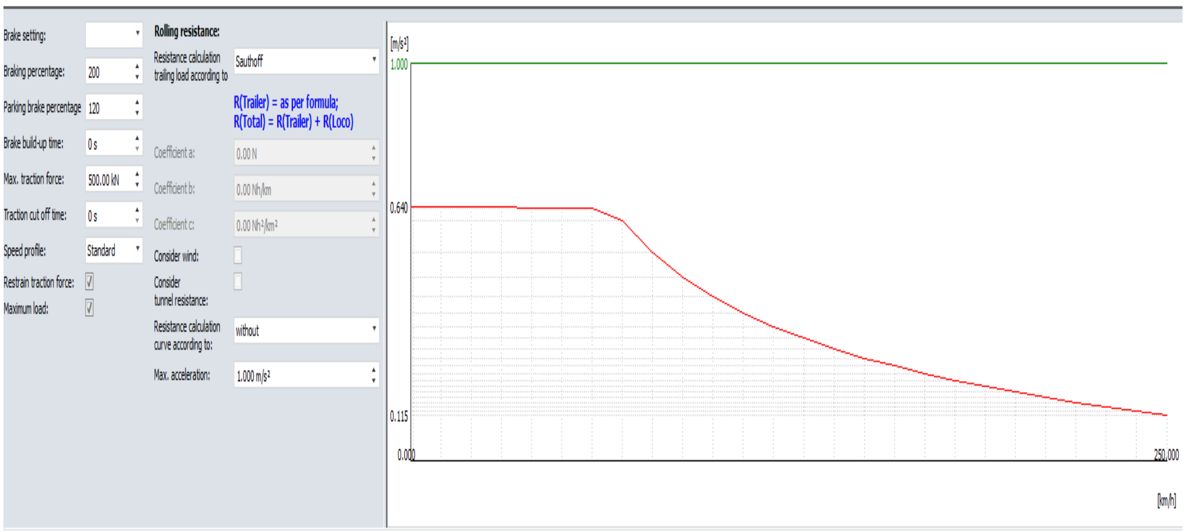


Figure 58: Acceleration-speed profile high speed train

4.5.5.2. Regional trains

For regional trains a homogeneous fleet with a max. seating capacity of approx. 300 passengers per train is suitable and hence used for the model timetables. This corresponds to the forecasted traffic flows and the derived service pattern. In the RailSys model timetable regional trains stop at all intermediate stations indicated in the track map. The train parameters and

- Train length 90 meters
- Number of seats 300
- Maximum acceleration 0-60 km/h: 0.963 m/s^2.

The graph shows the speed-acceleration profile on level gradient under wet conditions (μ=0.25).

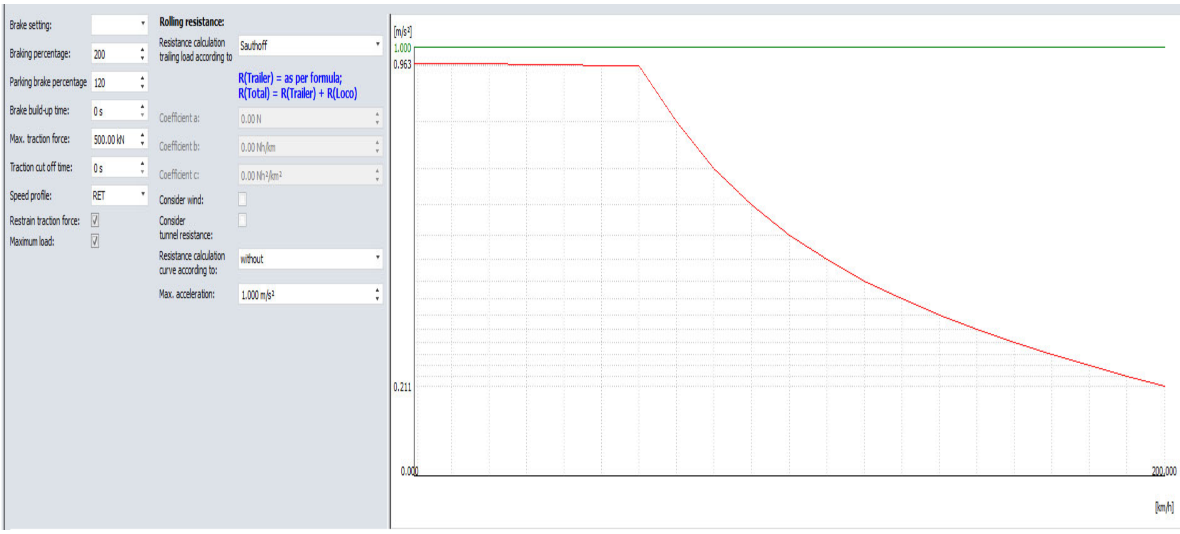


Figure 59: Acceleration-speed profile regional train

The minimum travel times of selected regional train relations are provided in Table 132. The comparison shows that for all proposed regional train lines a maximum speed of 200 km/h is advantageous due to higher distances between stops outside of the city surroundings. Exception is the Riga airport shuttle services which will be operated at a lower maximum speed due to short distances between stops and speed and maximum speed allowed by infrastructure between Riga Central station and Riga Airport station.

In the model timetables all regional trains are modelled with a maximum speed of 200 km/h.

A comparison of minimum travel times for 200 km/h and 160 km/h for selected regional services is provided below. These runtimes are based on stopping at all stations and include a runtime allowance of 5%.

Train relation		Minimum travel time [min]		
From	**To**	**200 km/h**	**160 km/h**	**Difference**
Tallinn Ülemiste	Riga Airport	184.9	202.1	17.30
Tallinn Ülemiste	Pärnu	70.7	77.1	6.50
Bauska	Salacgriva	105.4	115.7	10.30
Bauska	Vangazi	73.9	78.5	4.60
Kaunas Central	Riga Central	133.7	147.7	14.00
Panevėžys	Vilnius	85.2	95.1	9.90
Kaunas Central	Vilnius	52.3	57.2	4.80

Table 132: Comparison of runtimes for regional trains

4.5.5.3. Freight trains

For RailSys modelling a unified standard model train with single traction is assumed. Main parameters are:

- Train weight 1530 t corresponding to approx. 1000 t payload as in the traffic forecast
- Max. speed 100 km/h taking into account that not all trains will utilise the maximum freight trains speed (typical reasons: braking conditions, energy consumption, rolling stock parameters)

Heavier trains would be able to operate with double traction if needed. Trains equipped to fully utilise operational speed would be slightly faster.

Typical minimum run times for freight trains on different line sections are provided in Table 130. The stated run times include the waiting times at the passing loops.

4.5.6. Travel Times HST services

As a result of this Operational Plan travel times have been calculated based on the current and optimised track lay-out and considering the updated service pattern, i.e. including FinEst link and regional traffic. In general travel times after the 2nd iteration only slightly differ from the CBA.

The travel time difference on Kaunas – Vilnius section is partly related to assumed speeds around Kaunas triangle and Kaišiadorys station. It can be expected that with ongoing further design work initially assumed speed re-strictions will be removed, thus travel times level according to CBA for Kaunas – Vilnius section is still realistic target for further planning work.

Section	Travel Time		Difference Operational Plan to CPTD (Preliminary design)	
	CBA	Operational Plan (prelimi-nary design speeds[74])	[min]	[%]
Tallinn - Pärnu	00:39	00:42	+00:03	7.6%
Pärnu - Riga	01:13	01:06	-00:07	-10%
Riga - RIX	00:09	00:08	-00:01	-11%
RIX - Panevėžys	00:48	00:47	-00:01	-2%
Panevėžys - Kaunas	00:37	00:41	+00:04	+11%
Kaunas - LT/PL border	00:33	00:38	+00:05	+15%
Kaunas - Vilnius	*00:36*	*00:41*	*+00:05*	*+14%*

[74] Status June 2018

Section	Travel Time		Difference Operational Plan to CPTD (Preliminary design)	
	CBA	Operational Plan (prelimi-nary design speeds[74])	[min]	[%]
Total Tallin – LT/PL border (without stops)	04:02	04:01	+00:05	+2%

Table 133: Comparison of travel times according to CBA and after 2nd iteration of Operational Plan (OP)

Newest results from ongoing Consolidation of Preliminary Technical Design (CPTD) carried out by RB Rail as per December 2018 for line section Tallin Ülemiste – Riga Central - Palemonas indicate that travel times for HST from Estonia to the Polish border could be further reduced by 14 minutes. This corresponds to improvement of travel time by 5.8% (without stops).

Section	Travel Time		Travel Time Improvement	
	Preliminary Design[75]	Improved Speed (CPTD)	[min]	[%]
Tallinn - Pärnu	00:42	00:40	2	5.0%
Pärnu - Riga	01:06	01:00	6	10.0%
Riga - RIX	00:08	00:08	0	0.0%
RIX - Panevėžys	00:47	00:45	2	4.4%
Panevėžys – Kaunas	00:41	00:37	4	10.8%
Kaunas - LT/PL border	00:38	00:38	0	0.0%
Total (without stops)	**04:02**	**03:48**	**14**	**5.8%**

Table 134: Travel times resulting from improved speed profile after Consolidated Preliminary Technical Design

4.5.7. Total Power Consumption

The individual power consumption for each train is calculated based on the required tractive effort on the wheelset as outlined in Table 130 (chapter 4.5.4).

The daily power consumption of all trains will increase from 0.85 million of kWh in 2026 to 1.64 million of kWh in 2056 according to the increased train service pattern. Details and summary on the power consumption (at wheel-set) per line in the four time horizons can be taken from the following table:

[75] Status June 2018

Train type	Line	No of train pairs				Power consumption [kwh]				
		2026	2036	2046	2056	per train	Total per day			
							2026	2036	2046	2056
HST	11 Warszawa - Tallinn/Helsinki	4	6	6	8	8.609	68.872	103.308	103.308	137.744
	12 Vilnius - Tallinn/Helsinki	4	6	6	8	6.568	52.544	78.816	78.816	105.088
	13 Warszawa - Vilnius	6	4	4	6	3.364	40.368	26.912	26.912	40.368
	14 Kaunas - Vilnius	6	12	12	10	1.041	12.492	24.984	24.984	20.820
	Total						176.302	236.056	236.066	306.076
NT	41 Warszawa - Tallinn/Helsinki	0	1	1	1	13.296	0	26.592	26.592	26.592
	42 Warszawa - Vilnius	0	1	1	1	7.043	0	14.086	14.086	14.086
	Total						0	40.678	40.678	40.678
RE/RIX/HEL	21 RIX - Tallinn	4	6	6	8	2.234	17.872	26.808	26.808	35.744
	22 Pärnu - Tallinn	4	6	6	8	977	7.816	11.724	11.724	15.632
	24 Bauska - Salacgrïva	4	6	6	8	1.271	10.168	15.252	15.252	20.336
	25 Bauska - Skulte	4	4	4	8	1.006	8.048	8.048	8.048	16.096
	26 Marijampolé - Riga	4	6	6	8	1.952	15.616	23.424	23.424	31.232
	27 Vilnius - Panevezys	8	12	12	16	1.127	18.032	27.048	27.048	36.064
	28 Bialystok - Vilnius	4	6	6	8	1.624	12.992	19.488	19.488	25.984
	29 Kaunas - Vilnius	4	6	6	8	630	5.040	7.560	7.560	10.080
	31 Riga - RIX	8	10	10	24	86	1.376	1.720	1.720	4.128
	51 Helsinki - Tallinn	0	0	0	24	962	0	0	0	46.176
	Total						96.960	141.072	141.072	241.472
FT	61 Tallinn - Helsinki (Shuttle)	0	0	0	9	2.276	0	0	0	40.968
	71 Tallinn - Helsinki (RB)	0	0	0	11	1.451	0	0	0	31.922
	81 Elk - Vilnius	9	11	12	12	5.461	98.298	120.142	131.064	131.064
	82 Elk - Riga (Salaspils)	18	20	24	30	7.380	265.680	295.200	354.240	442.800
	83 Muuga - Riga	12	13	16	24	5.326	127.824	138.476	170.432	255.648
	84 Palemonas - Riga	0	1	2	3	4.045	0	8.090	16.180	24.270
	85 Vilnius - Riga	4	4	4	6	10.606	84.848	84.848	84.848	127.272
	Total						576.650	646.756	756.764	1.053.944
Total (passenger and freight)							849.912	1.064.562	1.174.580	1.642.170

Table 135: Power consumption of the proposed train service pattern [kWh per day]

4.5.8. Graphical timetables

Graphical timetables are provided in annex 6 of this document for time horizon 2056.

4.5.9. Evaluation of Line Capacity Utilisation

General approach and methodology

Evaluation of utilisation of line capacity is based on three study elements:

- Construction and evaluation of a sample timetable
- Analysis of station track occupation and related conflicts during timetable construction
- Evaluation of line capacity utilisation based on constructed timetable applying UIC 406 method

Capacity of stations and junctions will be evaluated separately based on constructed timetable for 2056. Results are presented in chapter 4.7.

The sample timetable implements the proposed service pattern for the operating periods 2026, 2036/46 and 2056 as described in chapter 4.1. This will illustrate that sufficient amount of paths can be constructed for both freight and passenger services utilizing the same infrastructure. For passenger services the timetable is constructed according to the service needs as outlined in the proposed train service pattern. That means the number of passenger train paths modelled for the passenger services and the departure frequency will be identical to proposed number of trains in the train service pattern.

For freight services the uncertainties about distribution of demand over the day is higher. Therefore the number of paths will be based on the requirements outlined in the train service pattern. The number of required paths is higher than number of trains expected to run resulting from traffic forecast. By this approach it is demonstrated, that the needed flexibility to operate freight services and other special services (empty rolling stock movements not part of regular operation, maintenance trains) can be provided in the daily timetabling and dispatching practise according to expected market requirements.

Experience from construction of sample timetable will also reveal operational bottlenecks leading to additional constraints for the timetable.

Evaluation of line capacity utilisation is aimed to check and illustrate that the proposed services can be operated with sufficient operational quality respectively overall train punctuality will be acceptable. If utilisation of line capacity is beyond recommended boundaries train punctuality will not be sufficient. Example: A small original delay of one train (e.g. delayed departure at a passenger station after minor incident) will lead to significant delays of other trains since there are no sufficient buffer times available to compensate this original delay in the course of the operating day.

For the purpose of the operational plan the line utilisation will be evaluated applying UIC 406 method for the individual line sections. Therefore, the paths of the constructed sample timetable will be used to provide a realistic train sequence as input.

Assumed Line Availability / Maintenance time windows

Except in Riga and Kaunas node there are no diversionary routes available to handle Rail Baltica traffic in case of necessary line closures. The complete maintenance approach needs to ensure that the line can be operated without service interruption on a 24 hrs/ 7 days a week basis. On double track line sections this is ensured by provided infrastructure for bidirectional running. If the line needs to be closed down for maintenance, this shall be done during night time, whereever possible. To check wether sufficient time windows can be provided in the number of scheduled trains at night (00:00 – 06:00 was analysed) for timetable 2056 for the sections with most freight traffic (Kaunas triangle - Panevėžys and Jiesia – border PL/LT). Closing down the line for six hours during night time on these line sections will require

- Retiming of nightly freight services to day time

- Cancellation of night trains (2 train pairs)
- Rescheduling or bus replacement of first and last regional or HST depending on timetable, in example case 1 HST train was concerned.

Analysis of timetable 2056 reveals that the scheduled freight trains could be retimed to daytime slots using spare paths already constructed as part of the timetabling scheme assumed for timetable 2056.

Section	HST	Freight	Regional express	Night train	Total
Jiesia - Marijampolė north junction	1	7	0	2	10
Panevėžys - Kaunas triangle north	1	2	0	1	4

Table 136: Example for traffic demand in night time: Number of trains 00:00 hrs to 6:00 hrs on section Kaunas triangle - Panevėžys and Jiesia – border PL/LT (direction north-south)

This case study illustrates that a complete closure of the line could be scheduled for up to 6 hours. As can be seen by the example providing such a possession the first and last passenger trains would also have to be retimed or cancelled. Furthermore, night trains services would have to be cancelled.

This confirms that there will be sufficient capacity reserves available to handle expected amount of traffic in case of required maintenance work or major incidents. Precondition for that is scheduling of regular maintenance work such, that impact of required line closures for maintenance and renewal is minimised and short reaction times in case of incidents can be ensured.

From current state of affairs no fixed maintenance downtime to be applied on the complete line shall be applied. This can be supported by the following evidence:

- The maintenance plan as outlined in WP 7 indicates that the expected amount of regular inspections work which requires track closures can be handled mainly during night time when only freight services are running.
- With fixed nightly downtime operation of a night train passenger service will be difficult, if not be possible at all if there is a fixed maintenance downtime window during the night.
- For regular inspection of double track line sections simultaneous closure of both running lines will not be required.
- The timetable does provide for sufficient reserve capacity to handle night time closures of one running line at certain locations as necessary.
- If closure of single-track sections in Kaunas node is required a diversionary route will be available. Same applies to single-track curves in Upeslejas and Misa triangle.

- The timetable does provide sufficient reserve capacity to balance amount of freight services such, that closure of the line due to emergencies can be handled by adjusting the working timetable (number of required paths calculated based on 22 hours operating day, 40% of the paths reserve, maximum train length not utilised).

Regarding application of nightly possessions, it shall be concluded:

- Whereever possible on double track line sections, single-track possessions are to be preferred to avoid major retimings and to minimize impact on passenger and freight service.
- For single track section (Palemonas – Kaunas Central Jiesia, remaining single track section on Kaunas dam) the line needs to be closed down completely to provide maintenance possessions. On these sections maintenance time windows shall be limited to 4 hours to minimize negative impact on passenger and freight service.
- Overall line capacity for freight will allow to provide possession time window of up to 6 hours (nightly closure of the line), but possession time shall be restricted to 4 hours wherever possible to minimize interference with passenger train service.
- For FinEst link a maintenance time window as outlined in 4.4.3 is modelled into the timetable (no services between 01.00 and 05.00).
- At the passenger lines with tunnel sections (Riga loop; Palemonas – Kaunas Central station) additional maintenance time windows can be provided during the night when no passenger trains are running, these shall be restricted to 4 hours.

Evaluation of results

The current version of the RailSys timetable for 2056 illustrates that a conflict-free timetable can be constructed incorporating the required number of passenger trains and the required amount of freight train paths to provide for operational flexibility and additional services not considered in detail (maintenance trains, light engine movements etc.).

Based on the constructed timetable overall line capacity utilisation is assessed by means of timetable compression according to UIC 406.

UIC406 is a guideline for capacity calculation. The approach is to calculate capacity consumption by compressing the timetable to evaluate the number of possible train paths for the line.

The compressing method provides information on the capacity usage of the infrastructure. It requires only existing data in the timetable.

Table 137 taken from the UIC leaflet 406 provides a general summary indication regarding acceptable Concatenated Occupancy Rates to provide sufficient operational quality according to the main characteristics of the elaborated timetable. These values should be used as upper boundaries on capacity utilisation when applying the compression method. For evaluation of operational quality utilisation rates in peak time and for 24 hours are provided. During night time nearly only freight trains services are operated for which sufficient reserve capacity to compensate for closures due to regular maintenance is built into the timetable used as basis for the calculation. Therefore, no additional maintenance time window is considered when calculating UIC 406 utilisation for complete day. For the purpose of this study only the interlinked occupation time is taken into account since the purpose of the study is to cross-check for operational quality of constructed timetable on the given infrastructure.

Type of line	Occupancy time rate	
	Peak hour	Daily period
Dedicated suburban passenger traffic	85%	70%
Dedicated high-speed line	75%	60%
Mixed-traffic lines	75%	60%

Table 137: Upper boundaries, not suggested to be exceeded for total occupancy time according to UIC 406

For timetable compression different methods are available in RailSys. (marked as A, B, C, D in Figure 60 below):

- Method closest to the original UIC406-method is shown on the figure below as "B". This method seems not "fair" because time used for overtaking has a negative impact to the UIC406 utilisation; the utilisation can be well over 100%.
- RailSys and has another method which is more sufficient to cope with overtaking at passing loops. The method is shown on figure below as "C".
- This method takes into account overtaking and seems more realistic. Depending on how the method is implemented the utilisation should not be more the 100% but in some special cases the utilisation can exceed 100%.

For calculation in this report the method shown on picture "C" is used. The fourth method shown on the figure below as "D" is not used in this analysis.

Utilisations will increase depending on how many line sections are included in the UIC406-calculation. The utilisation of the line sections between the big nodes: Tallinn, Riga and Vilnius higher than recommended by UIC406.

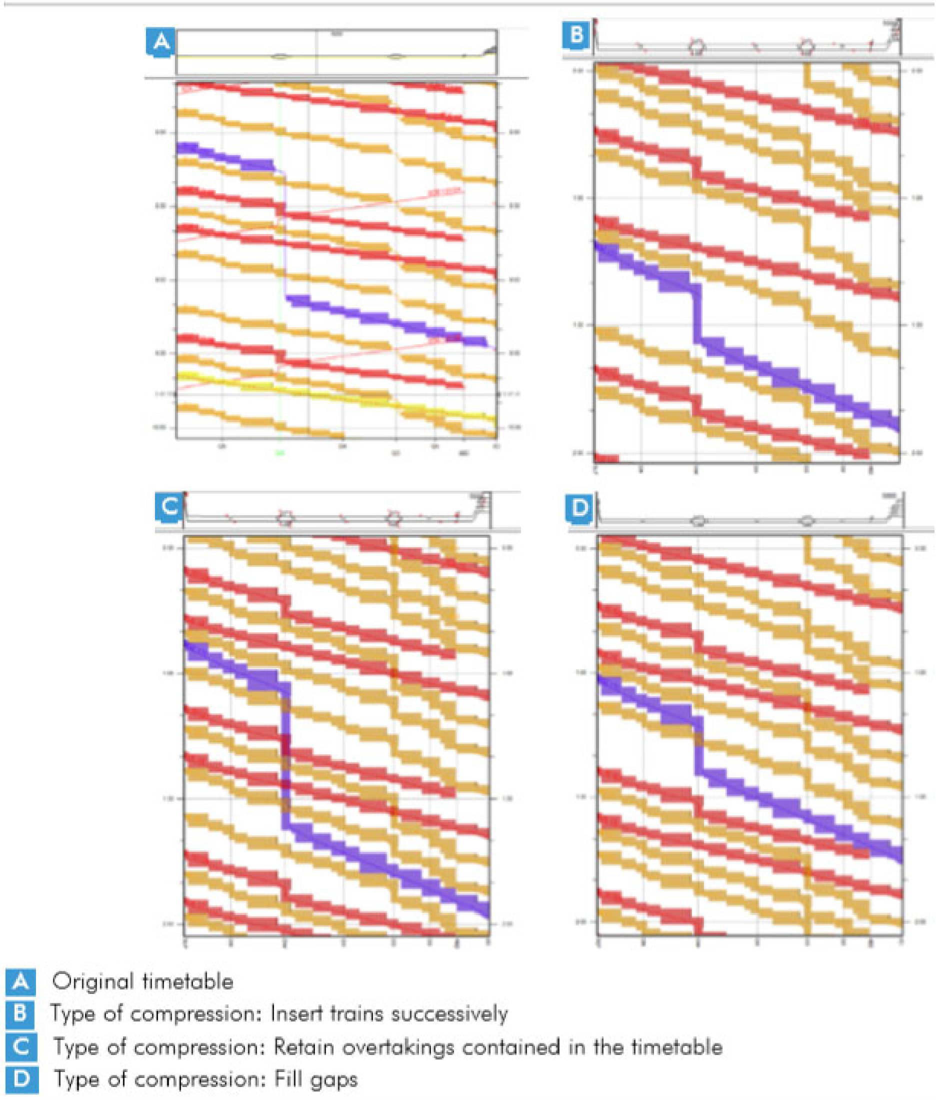


Figure 60: Timetable compression methods available in RailSys[76]

A first estimate of concatenated occupation time rates based on the existing timetable is provided in Table 138 below. When comparing the figures against the recommended maximum values, it has to be stated that the values are to be interpreted as first indicators of potential problems. For double track lines only the line utilisation for one direction is calculated (up track). For single-track line sections, trains in both directions are included in the calculation.

[76] Source: RailSys manual

	Capacity utilisation according to UIC 406 method (concatenated occupation time rates)									
	Time horizon	2056			2046			2026		
	Line sections	4 hours (06:00-10:00)	24 hours	Trains	4 hours (06:00-10:00)	24 hours	Trains	4 hours (06:00-10:00)	24 hours	Trains
	Recommended maximum occupation rate	75	60		75	60		75	60	
0	Helsinki-Tallinn	62.9	45.8	74						
1	Tallin-Pärnu	63.3	49.5	53	45.7	43.7	47	44.7	29.7	29
2	Pärnu-Salacgrïva	43.2	36.1	46	69.0	36.6	41	29.2	22.1	25
3	Salacgrïva- Riga Central Station	70.5	55.3	70	**98.4**	50.0	57	52.7	31.8	37
4	Riga Central Station - Bauska	43.0	39.6	95	46.0	34.3	72	48.8	23.8	53
5	Bauska-Panevezys	35.9	33.2	48	40.1	34.2	46	42.9	24.1	33
6	Panevezys - Kaunas Central	**89.0**	58.9	158	**93.7**	**61.0**	140	**90.4**	48.5	100
7	Kaunas Central – Marijampolė	**73.2**	**63.5**	93	**81.7**	49.3	81	**81.7**	37.1	64
8	Marijampolė - Ełk[77]	48.6	44.8	61	48.8	43.9	57	46.0	37.6	44
9	Vilnius-Vievis	29.9	24.9	68	29.8	21.9	59	26.2	24.9	68
10	Vievis - Kaunas Central	62.9	50.7	152	29.8	45.9	135	69.9	37.9	107

Table 138: Line capacity utilisation for timetable 2056 (concatenated occupation time rate)

As it can be expected for a double track line and the proposed train service pattern with approx. 100 – 130 trains per day (equiv. to 50-60 trains per direction), overall capacity utilisation for the complete day is in most cases far below the recommended upper-boundary utilisation in UIC 406 guidelines. Thus, stable operation on the line can be expected on the provided infrastructure.

In peak hours UIC 406 utilisation is above the recommended limits on line sections:

- Panevėžys – Kaunas Central Station
- Kaunas Central Station – Marijampolė
- Salacgrïva- Riga Central Station
- Vievis - Kaunas Central Station

[77] On this line section only cross-border Rail Baltica trains are included in the analysis.

This trend can be observed in all time horizons due to following reasons:

- identical line concept and fixed interval passenger timetable for all time horizons,
- high level of peak hour passenger service from the beginning, variation of passenger train numbers mainly outside peak,
- provision of freight train paths throughout the complete day without exception in peak time.

The spacing of line sections to Kaunas Central was chosen, to investigate overall capability of the system taking the interdependencies between different line sections and into account, e.g. single-track section Palemonas – Kaunas Central –Jiesia, necessity to cross contraflow track at junctions. These interdependencies are reflected by the resulting high concatenated occupation time rates in peak time. Based on results of this analysis it is recommended to check the capapility of the system to compensate delays, at least around Kaunas node, by multi-simulation to gain a more detailed picture on potential bottlenecks.

As can be seen in Table 138 the occupation time rates in peak time differ for timetables 2046 and 2056. Surprisingly the occupation time rates for timetable 2046 are higher than for time horizon 2056. This is due to the different structures of the timetables with more freight trains in the peak time for timetable 2046. To test out the system a random approach to select the freight train paths which should be utilised based on the same conflict free timetable was chosen. One practical solution would be to change the freight timetable accordingly (less freight trains in peak time). However, this example illustrates the limited flexibility of the system to provide freight train paths during day time. To add additional operational flexibility, the spacing and layout of the passing loops needs to be checked and further optimised. Furthermore, the station layouts can be optimised to avoid conflicts. Results of this analysis are presented in chapter 4.6 and 4.7.

There is still room to grow at the end of the forecasting period. It must be noted that such assessment is based on preconditions already implemented in the Railsys model:

- Sufficient platform capacity at stations
- Sufficient track capacity at the passing loops implemented in the model
- No single track sections on Kaunas bypass (except Kaunas dam)
- Implementation of Riga loop as double track on all sections
- Grade separated junctions (Kaunas triangle, Palemonas station[78], Jiesia, Upeslejas triangle, Misa triangle)

[78] Except connection to freight sidings

- Operation until normal operating conditions without need for single track operation on a certain line section

It also has to be noted that train runs for operational purposes (maintenance, light engine runnings etc.) are not directly modelled in the timetable.

4.5.10. Line utilisation FinEst link

Regarding line utilisation of FinEst link the results of the timetabling study do confirm the difficulties to operate a long tunnel section with different speed categories (120 km/h for freight, 200km/h for passenger service inside the tunnel) without passing loop. The capacity consumption to be expected is illustrated by results of the timetabling study for the afternoon peak hours, see Figure 67. While speeds of HST services and passenger shuttles are homogeneous, speed is much lower for conventional car and truck shuttles and conventional freight trains. This leads to a high amount of capacity consumption.

In order to utilise the tunnel up to expected level it is recommended to limit speed of passenger services to 160 km/h. This will provide for the necessary harmonisation of speed profiles.

In the current version of the timetable the passenger trains are modelled to terminate at Helsinki Airport. According to current early considerations no capacity for turning and stabling of the trains is provided at this station. In the further curse of the study it will be assumed that trains go to the depot facilities north of Helsinki airport station.

Maintenance of the trains shall be done at dedicated facilities provided on the Finnish side of the tunnel (north of Helsinki airport. For further details regarding needed facilities and assumed infrastructure at the Estonian side please refer to chapter 4.7.2.4.

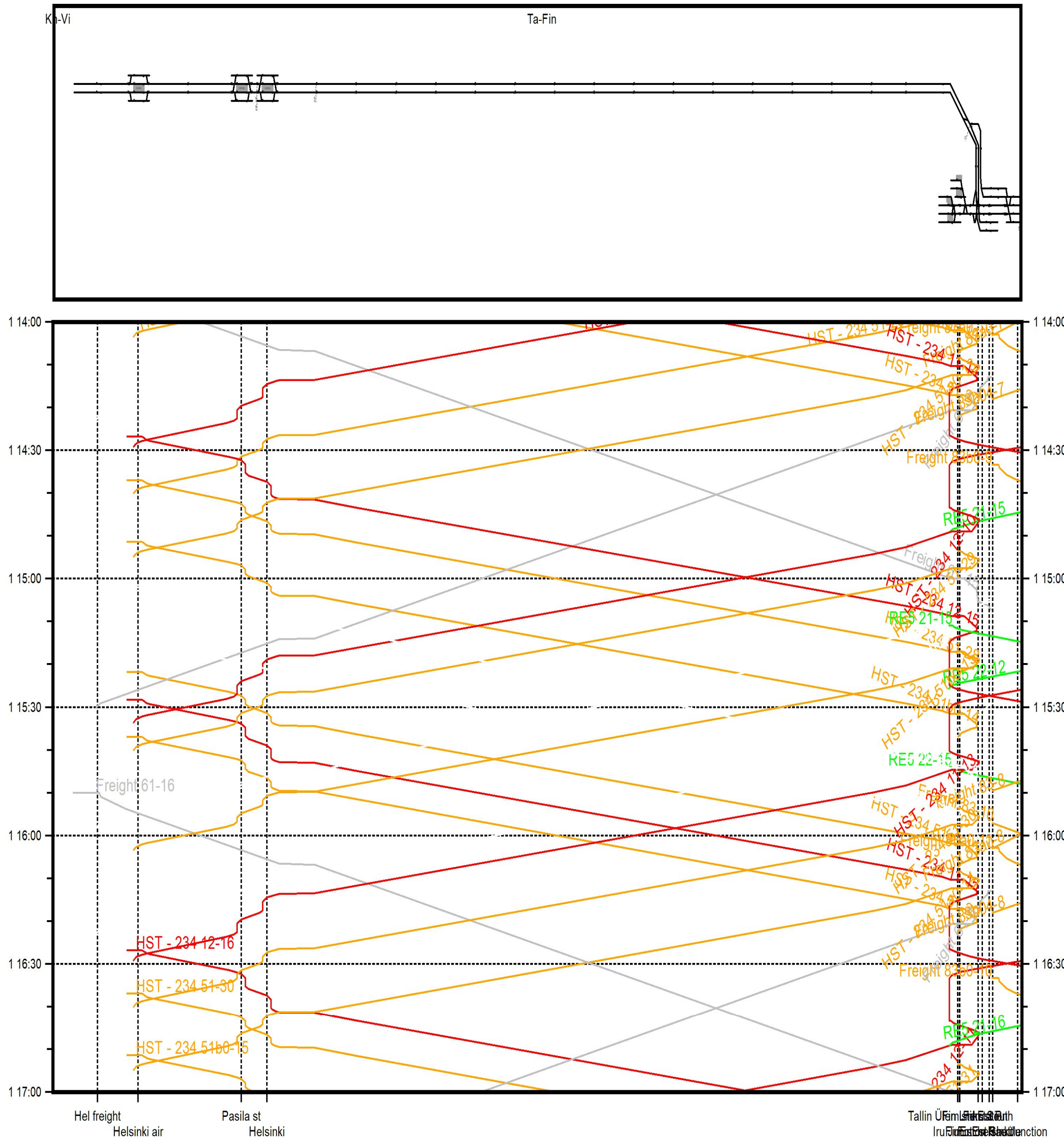


Figure 61: Timetable FinEst link – traffic flows 2026 (trains per day)

4.6. Further optimisation of passing loop and crossover locations

Given the intended usage of the line as mixed traffic line the question is to be solved how the line can be adapted to provide sufficient timetabling flexibility for mixed traffic. Results of timetabling study indicate (all intended paths could be implemented, acceptable UIC 406 utilisation), that overall the line has sufficient capacity under normal operating conditions. However, timetabling study reveals that several pasing loops are missing either by missing station tracks or by longer waiting times of the freight trains. Layout of passing loops as per preliminary design does provide only two loop lines (one for each direction). If possible platform tracks are to be placed away from the running lines at the loop lines. Timetabling studies reveal that this arrangement is not sufficient on line sections with higher passenger train path demand (Kaunas – Vilnius, Kaunas triangle north – Panevėžys, Bauska – Salacgriva. In addition to that it has to be ensured that a decent service level can also be operated in case of necessary single line working due to incidents or construction works.

Several European design guidelines for double track lines with mixed traffix state, that the recommended distance between passing loops and crossovers on lines with mixed traffic and comparable amount of traffic should not exceed 20 km.[79] [80] Currently proposed spacing between passing loops as per preliminary design exceed this limit.

Therefore further improvement of infrastructure is recommended. There are several options to be taken into account:

- Provision of additional passing loops
- Provision of additional tracks at existing stations
- Provision of facilities for flying overtaking (fast crossovers or dedicated third track on the open line)
- Provision of additional crossovers to provide more capacity in fallback mode (single line operation in case of incidents or construction work)

Taking all these factors into account, it is recommended to optimise the spacing and layout of the passing loops and crossovers. Related recommendations are presented below. It has to be noted that not all improvements are needed from the beginning but with growing traffic on the individual line sections, namely:

- Introduction of hourly passenger services instead of initial two-hourly services
- Growing freight traffic

Overall target is to provide even spacing between passing loops at a distance of approx. 20 to 25 km as target stage. This will not only allow for regular operation but also allow regulating train sequence more flexibly in case of single line working. On sections with lower traffic, passing loops can be replaced by crossovers. On sections with higher amount of traffic additional crossovers are proposed to shorten length of single track sections. Regarding spacing of passing loops the location of the passenger stations is considered first. Additional passing loops without passenger station are only added, if there is a need. Additional facilities are proposed to be introduced in stages in line with

[79] DB Ril 413, recommended distance between passing loops for line category M230 and traffic volume corresponding to approx. 120 trains per day (total for both directions)

[80] Polish "Technical Standards. "Detailed technical conditions for the modernization or construction of railway lines up to a speed Vmax ≤ 200 km / h (for conventional rolling stock) / 250 km / h (for rolling stock with a tilting box) Version 1.1" for lines such as RailBaltica, provide for construction stations allowing overtaking every 8-20 km.

growing traffic. Detailed recommendations regarding layout of larger stations are presented in chapter 4.7. Recommended improvements for each time horizon 2026, 2036/46 and 2056 are depicted on the track maps in annex 1.

4.6.1. Additional and relocated passing loops and crossovers

Line section Tallinn – border EE/LV

On this line section the following improvements are proposed, based on results for timetabling study 2056. Main drivers for optimizing passing loop capacity are growing regional traffic between Tallinn Ülemiste and Pärnu and introduction of hourly HST service (peak times for time horizon 2036/46, complete day in time horizon 2056):

- **Kurtna station**, line km 34.72: This location is intended as regional train station. Recommendation is to implement this station as passing loop (1050 m usable length of loop lines for freight trains) with platforms for regional trains on the loop lines.
- **Kohila station**, line km 39.25: This location is intended as regional train station. It is proposed in the preliminary design to locate the platform at dedicated loop tracks (usable length 420 m). Since the station is situated closed to Kurtna, there is no urgent need to extend the loop tracks to full track length 1,050 m). Recommendation is to implement this station with short loop tracks but to reserve the land for extension to 1,050 m, if needed later.
- **Rapla station**, line km 61.72: According to the current trains service pattern all regional trains from Tallinn are intended to run until Pärnu. Subject to final decisions it cannot be ensured that there is no need to terminate regional passenger trains here. Therefore capacity should be improved by one optional freight loop.
- **Tootsi station**, line km 93.5: This passing loop is introduced as option to harmonize distances between passing loops. The distance between adjacent passing loops (Järvakandi and Pärnu freight station is 48 km. During first years of operation this passing loop could be implemented as crossover.
- **Kilksama station**, line km 126,6: Due to adjacent passing loops and crossovers (Tootsi, Pärnu freight station) there is no need to provide a crossover or passing loop here.
- **Pärnu freight station:** Due to the fact that the provided loop tracks at Pärnu station will be also used by terminating passenger services an additional passing loop will be needed. Distance between currently foreseen passing loops Häädemeste and Järvakandi station is 90.9 km and thus far too long to provide the necessary line capacity. This passing loop shall be introduced from the beginning, also since the local infrastructure maintenance facility shall be based here.

Line section border EE/LV – Upeslejas triangle north

On this line section the following improvements are proposed in order to provide an equal spacing between passing loops and crossovers:

- **Salacgrīva station**, line km 216.86: To allow for terminating trains with layover at the platform one additional loop line for freight traffic shall be added to the layout.
- **Crossover**, line km 241.76: This crossover is introduced due to the long section length between Salacgrīva and Skulte (46 km).
- **Ādaži freight station**, line km 287.36: This station shall be implemented as passing loop from the beginning to ensure freight trains can be overtaken. This does also ensure that there is enough space for maintenance related train reception and preparation at Vangaži.
- **Vangaži infrastructure maintenance depot:** Arrival and departure sidings parallel to the mainline shall be implemented such, that the station can be used as passing loop for freight trains.

Misa triangle – Bauska

Regarding layout of Riga Central station, Riga Airport station and Jaunmarupe station and Bauska station please refer to chapter 4.7. Following additional optimisations are recommended:

- Kekava station, line km 370.70: This station shall provide a crossover due to the distance between Kekava station and Misa triangle to minimise impact of single line working on passenger traffic.
- Iecava station, line km 82.22.: This station is foreseen as regional station. The platform tracks shall be provided as passing loop due to the distance Bauska – Misa triangle.

Line section Bauska – Panevėžys

Compared to neighbouring line section, there is less traffic due to the lower amount of regional traffic on the crossing the border between Latvia and Lithuania. For this section the following alteration is proposed:

- **Vaškai passing loop,** line km 157.0: This passing loop is introduced since distance between passing loops at Bauska station and Joniškėlis station is rather long (46 km). During first years of operation this passing loop could be implemented as crossover.

Line section Panevėžys – Kaunas triangle north

Railsys timetabling study indicates that capacity of existing passing loops will reach the limit until end of forecasting period. Example: Needed additional tracks at Kėdainiaii station in the Railsys model to accommodate for passenger and freight to be overtaken at the same time. Due to the high number of passenger trains (RE line 26 with 2 hourly service, line 27 Vilnius - Panevėžys with hourly service, HST with hourly service) it is advisable to optimize distances between passing loops and crossovers to allow for more flexible (passage of freight trains) and stable (passage trains in case of needed single track working due to construction works or incidents) operation. Therefore the following alterations are proposed:

- **Anciškis passing loop**, line km 538.49, and
- **Uliūnai passing loop**, line km 518.49.

These loops serve as passing loops for freight in order to ensure regional trains can use the platform tracks at Pasrauciai station and Jonava station. Regional train station Kėdainiai station (Ramygala) could therefore be implemented without passing loop.

These passing loops are provided to optimize passing loop distances between Jonava and Panevėžys (approx. distance every 20 km). These loops serve as passing loops for freight in order to ensure regional trains can use the platform tracks at Pasrauciai station and Jonava station. Evenly spacing of passing loops in this section will also improve operational flexibility if one running line is blocked.

Passing loops on line section Jiesia – border PL/LT

According to proposed train service pattern this line section will see a high share of freight trains. If necessary these are to be overtaken by HST and regional trains with highest passenger traffic between • Marijampolė and Jiesia. In order to provide for flexible and stable operation the following optimisations are proposed:

- **Juragiai passing loop,** line km 629.78: This passing loop is introduced to allow to regulate traffic approaching Kaunas node from the south. This would be especially be important if Kaunas bypass would be implemented as single track during first years of operation. In the feasibility study for line section Palemonas – border PL/LT this passing loop was to be placed at section km 69,0. In order to provide above stated functionality it is recommended to relocate this passing loop to section km 78,0 (line km 629,78).

- **Ąžuolų Būda Passing loop,** line km 650.28: This passing loop is introduced to provide evenly spaced passing loops between Marijampolė and Jiesia. During first years of operation this could be implemented as crossover or completely left out (if diversionary route via existing Marijampolė passenger station is introduced. In the current track maps this loop is indicated only for time horizon 2056.
- **Marijampolė passing loop** (Lithuania, line km 672.8): According to current planning stage Marijampole passing loop is to be treated as optional since it was not part of the previous feasibility study "Study on Rail Baltica Section Polish / Lithuanian State Border – Kaunas – RRT Palemonas Upgrade" but was seen as an option to provide additional freight facilities near Marijampole. The timetabling study revealed that this passing loop will be advantageous. Therefore, recommendation is to implement this passing loop from the beginning.
- **Trakiszki passing loop:** Spacing of passing loops should be continued also south of the border on the Polish section. The last passing loop on the Lithuanian side is currently proposed at line km (section km 15,0). Given a distance of approx. 20 km and considering a potential station on the proposed Olecko bypass, this passing loop would have to be provided near Trakiszki. Currently, the alignment in Poland and the handover point are not finalized, thus need and location for this passing loop shall be reconsidered during further studies. According to PLK guidelines passing loops on Polish line sections would have to be placed with maximum spacing every 8-20 km.[81]

Passing loops and crossovers on Kaunas – Vilnius section

According to operational plan Kaunas – Vilnius section will be utilized by up to 3 to 4 passenger trains per hour per direction, subject to final timetable configuration and share of passenger traffic between 1435 mm and 1520 mm. In addition to that the necessary paths to serve Vaidotai terminal need to be provided. Location of regional train is not finalized yet. To ensure smooth and stable operation and to serve the the following stations, passing loops and crossovers are proposed in this operational plan based on results of Railsys timetabling studies:

- **Mikainiai passing loop** (km 86.50 Kaunas – Vilnius section) According to results of timetabling study a passing loop between KaišiadorysKaisiadorys and Kaunas triangle is highly beneficial. Apart from overtaking one additional function is to provide for synchronisation of paths on Kaunas – Vilnius line with adjacent line sectionsnorth-south traffic Palemonas - Panevėžys. Final need will depend on the final layout of Kaunas

[81] As outlined by PLK as comment to preliminary study report Technical Standards. "Detailed technical conditions for the modernization or construction of railway lines up to a speed Vmax ≤ 200 km / h (for conventional rolling stock)" / 250 km / h (for rolling stock with a tilting box) Version 1.1" for lines such as RailBaltica, provide for construction stations allowing overtaking every 8-20 km.

triangle, which is not fixed yet and provision of passing loops at Kaunas airport station (for further details please refer to chapter 5.6.5.1).

- **Kaišiadorys station**, section km 65.50: This station is intended as regional train station and interchange to 1520 mm services from/to Jonava, Kėdainiai, Šiauliai, Klaipeda. In the current model this station serves as passing loop and regional train stop. This should be reconsidered depending on final decision about implementing Kaišiadorys bypass. Depending on final decision about overtaking facilities at Kaunas triangle and **on implementation of** Kaišiadorys bypass optional loop lines dedicated for freight trains shall be foreseen.

- **Žasliai passing loop**, section km 56.50: This passing loop is intended to provide passing for freight trains. Timetable study indicates that this passing loop will be beneficial for pathing flexibility of freight trains.

- **Crossover**, section km 28.0: This crossover is suggested to shorten distance in case of single line working.

- **Vievis station**, section km 40.20: This station is intended as regional train station and passing loop. To provide additional capacity for flexible timing of freight trains, optional dedicated passing lines for freight might be considered.

- **Lentvaris station**, section km 15.40: This station is intended as regional train stop and passing loop. For freight, dedicated loop lines shall be provided. Furthermore, track capacity for proposed local infrastructure maintenance facility has to be foreseen.

4.6.2. Extension and layout optimisation of existing passing loops

According to preliminary design most of the passing loops are located at potential regional stations. Advantage of this approach is that the platforms could be provided on the loop tracks with no need for additional platform security to allow passing of trains at > 200 km/h. In certain constellations it will be required to hold regional or freight trains simultaneously at the loops or to provide capacity for a second freight train.

According to to results of railsys modelling this will be likely the case on line sections with mixed traffic, where the line will be utilised by more than one regional passenger train per direction, namely:

- Kaunas triangle north – Panevėžys, and

- Kaunas triangle - Vilnius

Therefore, the layout of the existing stations could be improved by either:

- Option A: Provision of additional dedicated loop line for freight trains

- Option B: Provision of loop line between the running lines so that they can be used more flexible without need to cross the contraflow track

In case of option A it might be sufficient to provide only one additional track and to provide a second track for the other direction at the neighbouring station. The additional tracks could be implemented at a later stage, but space should be foreseen from the beginning, e.g. in order to place the platforms at the final location from the beginning.

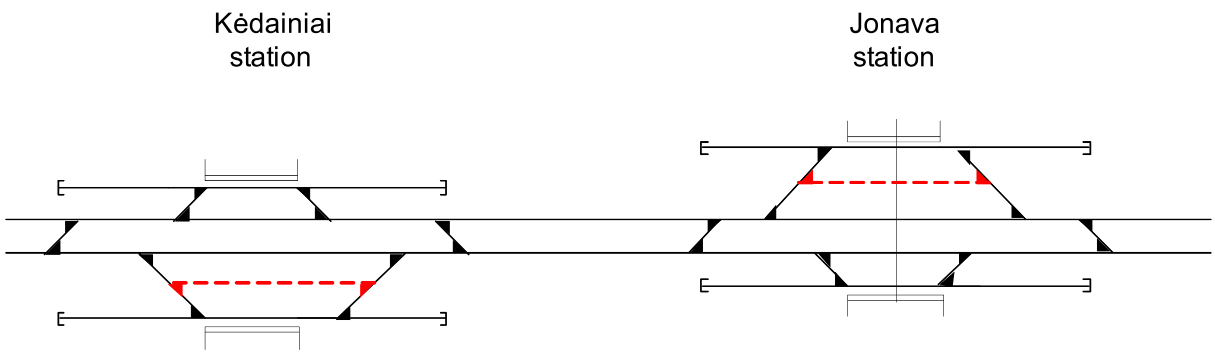


Figure 62: Provision of additional dedicated freight track at passing loops

Same applies to option B, where only one loop track could be implemented in the beginning with option to introduce another loop track (see Figure 64). Disadvantage of option B is more difficult access to platforms, if to be provided between the running lines, and to trains waiting at the loop (e. g. in case of breakdowns or emergencies). Also, at least the embankment between the running lines needs to be prepared from the beginning.

In principle such layout considerations would also ease operation on other line sections, e.g. in case of situatios with disturbed traffic.

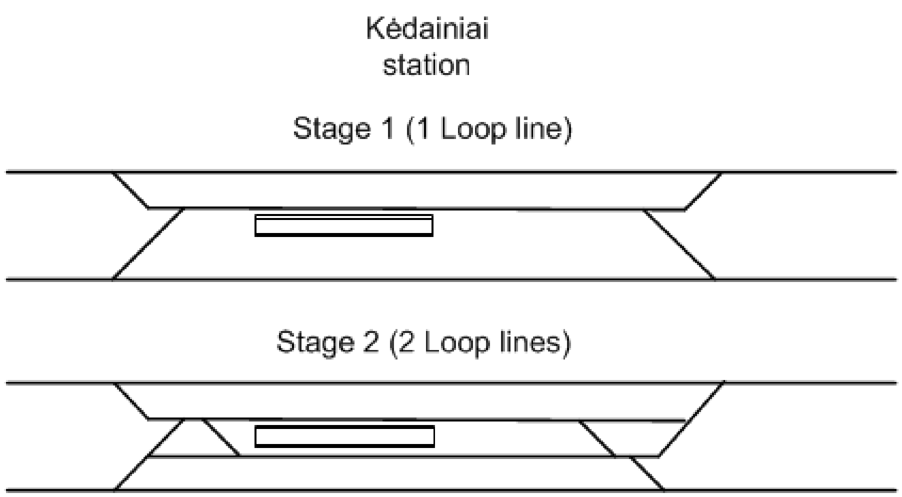


Figure 63: Provision of loop lines between the running lines

In order to provide for a more flexible operation final recommendation is to optimize spacing of passing loops on the line sections instead of providing additional tracks. Where there is special demand to accommodate waiting freight trains additional tracks have been incorporated into the final layout:

- Lentvaris station to accommodate freight trains waiting to enter the the single track line to Vaidotai freight terminal, if needed
- Pärnu station to accommodate freight trains from/to (optional tracks depending on needs to be established by ongoing Pärnu terminal feasibility study)
- Panevėžys station (separation of freight passing loops from passenger tracks)
- Salacgrīva, Bauska, Pärnu station (separation of freight passing loop from passenger tracks to provide for beginning/terminating passenger train runs occupying the platform tracks.

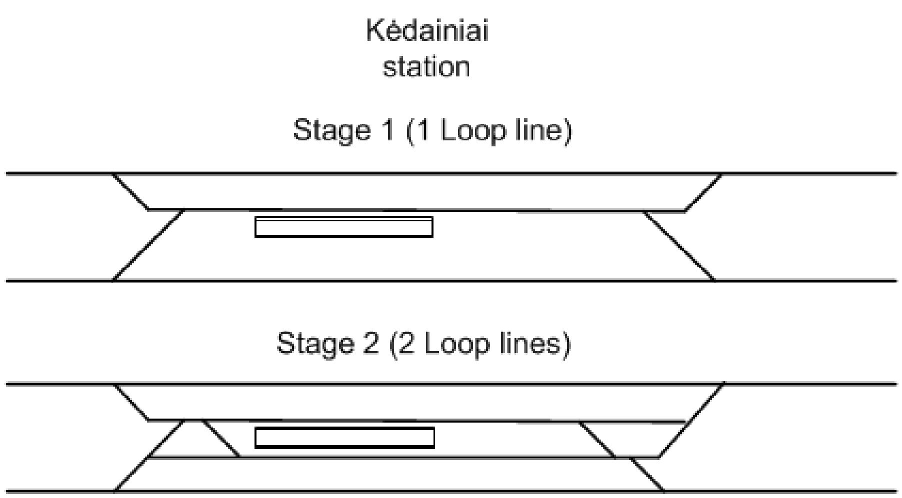


Figure 64: Provision of loop lines between the running lines

In order to provide for a more flexible operation final recommendation is to optimize spacing of passing loops on the line sections instead of providing additional tracks. Where there is special demand to accommodate waiting freight trains additional tracks have been incorporated into the final layout:

- Lentvaris station to accommodate freight trains waiting for the single track line
- Pärnu station to accommodate freight trains from/to (optional tracks depending on needs to be established by ongoing Pärnu terminal feasibility study)
- Panevėžys station (separation of freight passing loops from passenger tracks)

- Salacgrīva, Bauska, Pärnu station (additional passenger tracks to provide for beginning/terminating passenger train runs.

4.6.3. Facilities for flying overtaking

To reduce the load and to add more freight train paths between the passenger trains without needing to stop at passing loops for long time periods a dedicated long freight trains bypass could be added on certain line sections. The bypass must be at least 4 km long, better 10 km long so that the freight trains do not need to stop when high-speed trains overtake them. Another possibility in times with lower traffic is wrong direction working. To reduce blockage of the line for trains in opposite direction, this might require dedicated crossovers with high speed turnouts. If there is a sufficient time window for the freight train to use the left-hand track, the currently proposed crossover speed of 100 km/h will be sufficient.

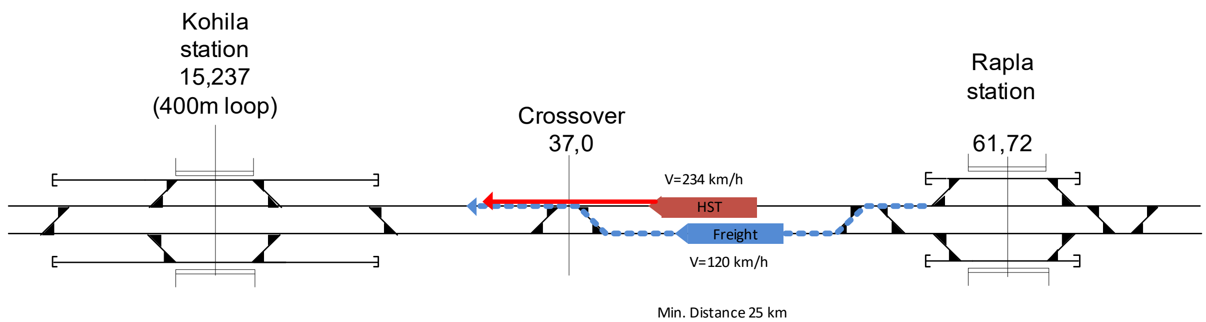


Figure 65: Example "Flying overtaking" by using running existing running line and high speed crossovers

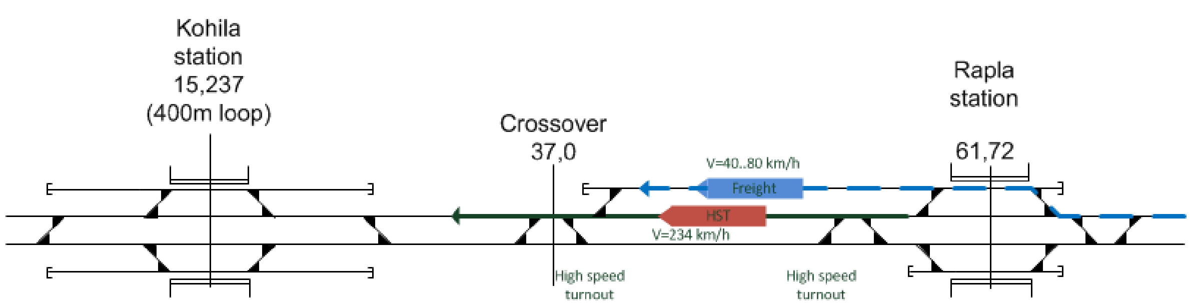


Figure 66: Example "Flying overtaking" by means of dedicated freight bypass track

Recommendation: From current state of affairs a third track for overtaking is costly and thus only a choice for improvement towards the end of the forecasting period, which shall not be considered now. Bidirectional running will be especially useful during first years of operation, when line utilisation is still low. Therefore, the currently proposed turnout speeds at crossovers are sufficient since the diverging track will be mainly used by freight trains.

4.7. Assessment of track occupation and track layout in nodes and selected stations

4.7.1. Scope and methodology

Overall success of Rail Baltica will depend on smoothness of operation in the nodes. Furthermore, sufficient track capacity in the stations is required to ensure that the line can be utilised as required. In the node areas special attention must be paid to interdependencies between the different parts of the network. Therefore, in the following chapter the operational situation in the nodes (Tallinn node, Riga node, Kaunas node, Vilnius area) is analysed. The situation in Helsinki node is outlined in the FinEst link chapter.

The proposed station layouts and track layouts are not always fully sufficient to cope with required traffic. Timetable studies reveal that there is a variety of stations which cannot handle the proposed traffic with the existing track layout. As result from the timetabling study the revealed bottlenecks will be addressed in the following section.

For the nodes, an overview on network structure and expected utilisation of the network will be provided. Based on that, the situation in stations and junctions is discussed to highlight operational bottlenecks.

Analysis is based on infrastructure as per preliminary design (see track map in annex 1), train service pattern as outlined in chapter 4.1 and evidence from the developed RailSys timetable.

4.7.2. Tallinn node

Tallinn node consists of the following facilities:

- Tallinn Ülemiste station as northern endpoint of Rail Baltica. The station is situated in the suburbs of Tallinn within short distance to the airport. City centre can be reached by public transport (tram). Additionally, an interface to 1520 mm suburban network will be provided there incl. connection to existing Tallinn main station, which is located closer to city centre.
- Muuga station – freight station adjacent to Tallinn port area
- Rae junction – diversion of lines to Muuga and Tallinn Ülemiste
- Rae depot – facilities for rolling stock maintenance and stabling of passenger trains.

In Figure 67 and Figure 68 the utilisation of the railway network in Tallinn area is depicted for time period 2026 (traffic volumes to be reached within first 10 years of operation) and 2036/46 (further moderate growth after ramp-up period). The graphic shows the forecasted number of trains in addition to the depicted train movements.

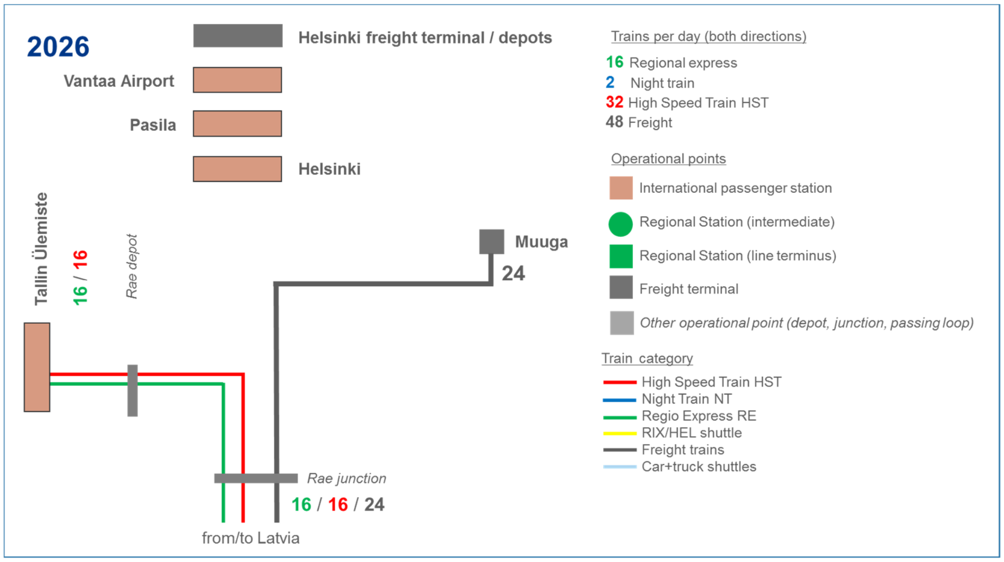


Figure 67: Tallinn node – traffic flows 2026 (trains per day)

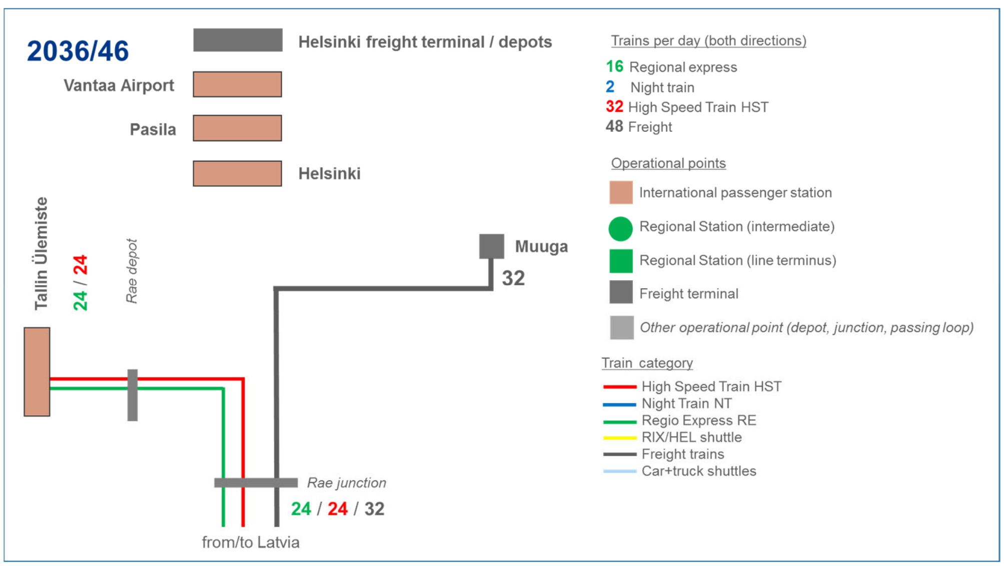


Figure 68: Tallinn node – traffic flows 2036/46 (trains per day)

If FinEst link is introduced, infrastructure situation will change in order to provide the needed operational points

- Additional shuttle terminal for FinEst link car and truck shuttles west of Rae junction
- Iru junction providing connection to southern part of Rail Baltica
- Direct line to Tallinn Ülemiste station

The resulting traffic flows for time horizon 2056 after inauguration of FinEst link tunnel are depicted in Figure 69. Tallinn Ülemiste will then be utilised by up to 146 trains in total arriving or departing. In Muuga freight station 30 freight trains will need to be handled. The FinEst link shuttle terminal has to provide facilities for 30 train pairs per day (car and truck shuttles).

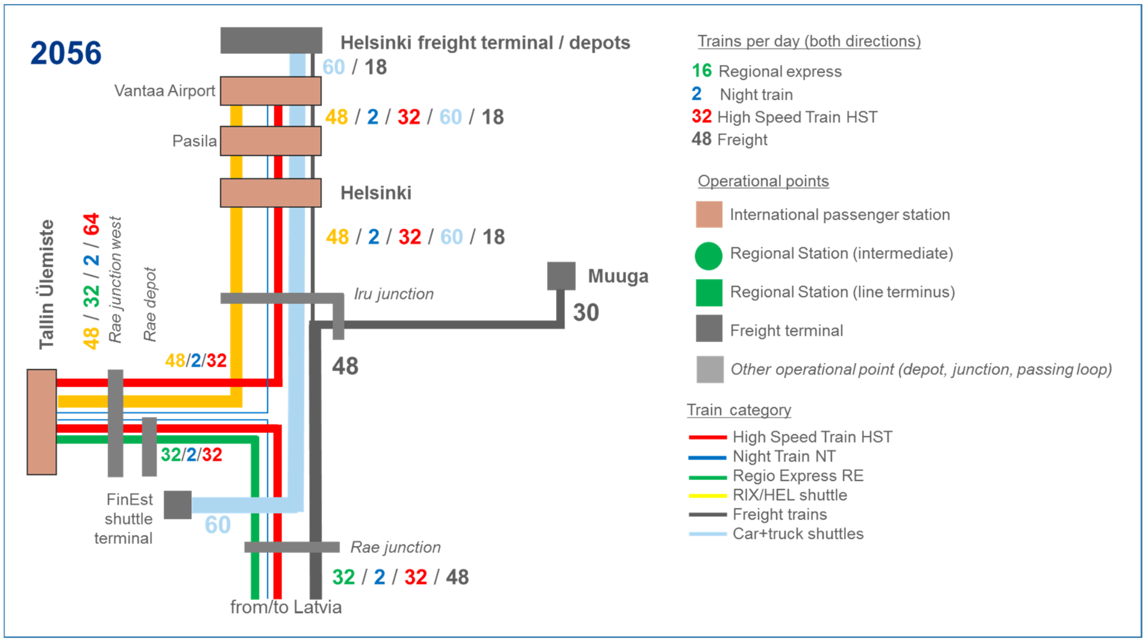


Figure 69: Tallinn node – traffic flows 2056 (trains per day)

4.7.2.1. Tallinn Ülemiste

The current proposal by RB Rail to develop Tallinn Ülemiste station is to construct the station in stages (1-3) in order to cope with growth of traffic. The three stages are depicted in Figure 71 below.

In development stage 1 the layout does provide two long platforms with a scissors crossover in the middle to make best use of available space between the existing 1520 mm tracks (north side) and the road (south side).

In theory this solution would provide for up to four trains to be in the station at the same time. Nevertheless, the layout has the following disadvantages

- long walkways along the platform for the passengers due to the additional platform length required for scissors crossover
- entry speed to tracks will be limited to 30 km/h due to available safety overlap
- interdependencies between arriving and departing services

- limited reserve for intermediate stabling of an arrived or prepared train in the morning or in the evening
- future extension of train length to 410 m will compromise operational flexibility since not all tracks can be provided to accommodate 400 m long trains
- Provision of required platform capacity for handling of night train services having overall longer track occupation times will be more difficult since there is no capacity for additional services with extended dwell times.
- In addition to that the possibilities to enter and leave the station simultaneously are limited in the current track layout.

From current planning stage it can be concluded that Stage 2 will provide sufficient capacity to handle proposed-traffic volumes until time horizon 2036/46. During the first years of operation service pattern will be demand oriented. This will require short departure frequencies of the HST in peak hours (down to hourly departures or arrivals) and less frequent departures outside peek. Therefore dwell times at the station during the day will be longer. Thus it is recommended to start with stage 2 from the beginning. This would also ensure that there is sufficient capacity to accommodate the proposed night train as long as needed in the morning and in the evening to provide a passenger-friendly service (early check-in, late check-out, car shuttle handling). Stage 3 should then be considered.

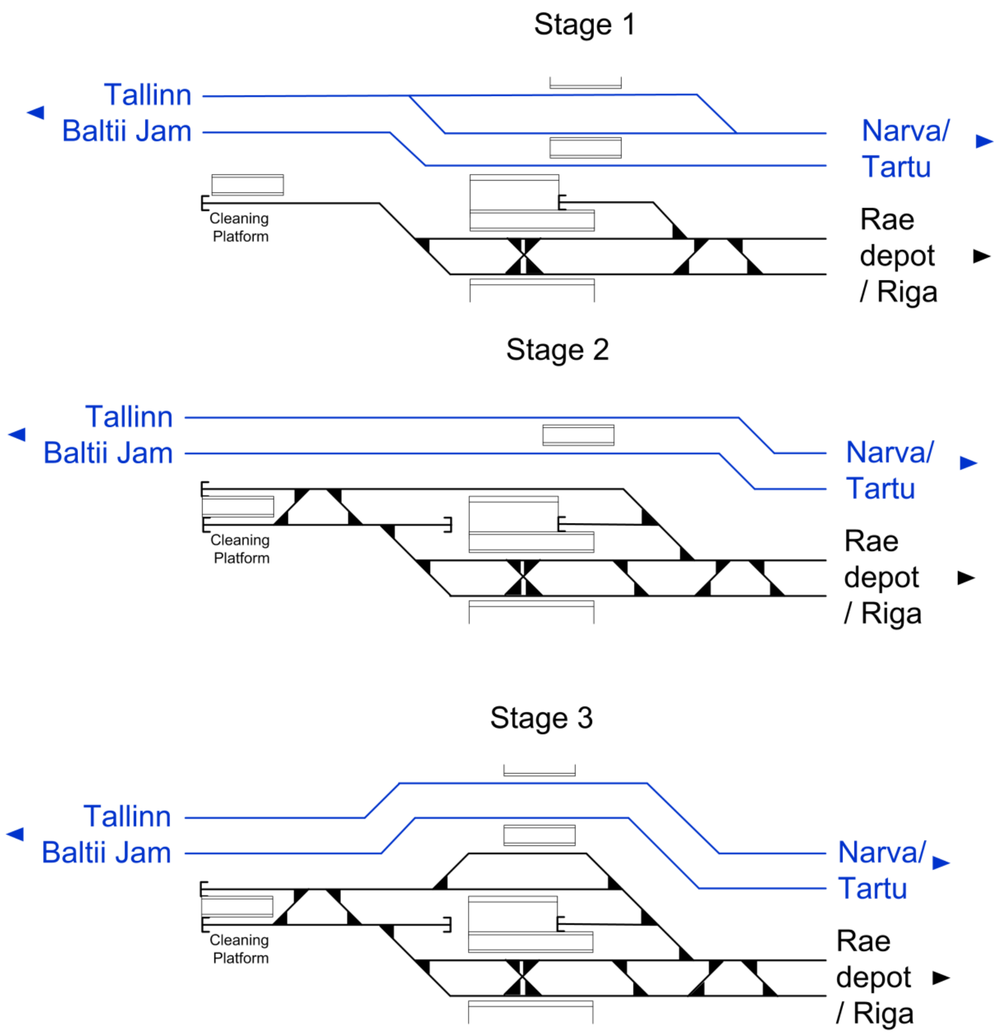


Figure 70: Currently proposed track layout for Tallinn Ülemiste

To illustrate required station capacity the track occupation for timetable 2056 is shown in Figure 71. As can be seen at least 4 platform tracks directly connected to the main line would be needed to handle the expected amount of traffic for the currently proposed timetable 2036/46 and 56.

In 2056 the station shall handle termination of

- Two high speed lines which continue to Finland (red on the track occupation diagram),
- Two regional train lines which ends in Tallinn (green on the track occupation diagram) and
- A night train which continue to Finland (not shown on the track occupation diagram).

The track occupation diagram from 14:00 to 18:00 shows the traffic in 2056

- The high speed trains are handled from arrival, turnaround in 10 minutes to departure.
- The regional line 21 is handled from arrival, turnaround in 21 minutes to departure.
- The regional line 22 is handled from arrival, turnaround in 19 minutes to departure.

For the timetable 2056 it is expected that long distance services will turn around at the station and continue to Helsinki and vice versa. For this procedure approx. 10 min station dwell time are assumed (technical turnaround time + time reserve to cover for minor delays).

However, the platform capacity would not be sufficient for proposed FinEst link passenger shuttle. According to estimate derived from the Railsys model, timetable is that at least three additional tracks would be needed to provide the full FinEst link shuttle service. Given the space constraints in the area, a separate terminal might be needed. One potential location could be north of the 1520 mm line at the current location of the freight yard.

Following improvements to the layout (development stage 2) as depicted in Figure 70 are suggested:

- Introduction of a cleaning platform on the west side of the station. Advantage of this would be that the HST trains can be serviced during daytime without the need to go to Rae depot and back, which in additiona requires direction change at the platform.
- Depending on final requirements for car shuttle services (demand, position of car shuttle wagon in the night train set), providing short dead end track and loading ramp on the west side of the station should be considered. This would allow short access way of the passenger when picking up or delivering their cars.

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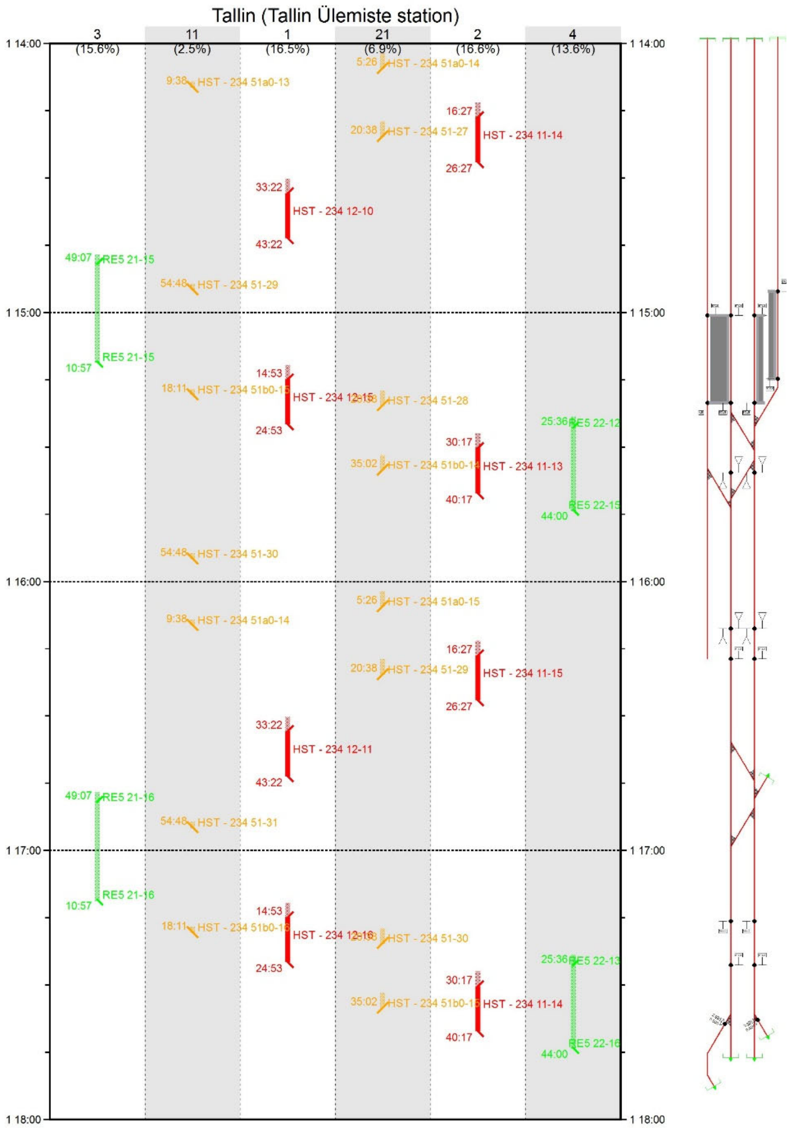

Figure 71: Example track occupation Tallinn Ülemiste – timetable 2056 (Rail Baltica services)[82]

Based on the requirements indicated by the track occupation example depicted in Figure 71 , the required minimum solution for track layout would be to provide at least four platforms with full length accommodating platform stops of 200 m trains from the beginning (with extension option to 410 m). At least two platform tracks should be connected to the head shunt west of the station to provide for run-around of locomotives for wagon hauled services (night train, loco hauled charter services, maintenance trains).

[82] Tracks 11 and 12 depict FinEst link shuttles leaving/entering mainline.

Additionaly, in order to cover the case of major disruption in Tallinn Ülemiste or in Rae junction, which may bring perturbations for operation of the whole corridor, it may be necessary to be able to transfer passengers from HST and regional trains to other transport modes to reach their final destination in Tallinn. Therefore, it is proposed to use Assaku planned regional station as emergency transfer location, equipping it with 200 m (expandable to 410 m) emergency platforms.

4.7.2.2. Loading facility for car services

At the time of writing this report, provision of car transport facilities is under consideration. Such solution would typically be implemented as part of the proposed night trains service. Success criteria for transport of cars in passenger trains are:

- Low operational cost
- Convenient solution for passengers (minimisation of additional waiting time, comfortable waiting, preferably in the train)
- Minimisation of extra time needed for the passengers between car loading/unloading and departure/arrival

Thus, the facilities shall be located as closed as possible to the Ülemiste passenger station; so that the passengers could use the station facilities for their convenience and short transfer times between car loading facility and passenger station could be provided.

Since loading takes place from the head of the piggyback wagons, shunting of the train is required. Necessity of shunting also depends on position of car transport wagons at either end of the train. This also depends from operational conditions on the other end of the train run.

Optimum solution for passenger convenience would be a loading track parallel to an existing platform in Ülemiste. If such solution cannot be provided a shuttle service by train to the loading facility shall be provided until the final destination. In this case passenger shall have a chance to enter/leave the train as close as possible to the loading ramp, so that they can remain in their compartment while the train is prepared and shunted.

Regarding track layout of car loading facility there are two options:

- Option A: Provision of a smaller facility for a dedicated portion of the train (passenger + car wagons).
- Option B: Provision of a facility for the complete train.

Advantage of option B compared to A is that the total shunting effort for the train can be minimised since a split up of the train is not needed. Proper facilities should be provided either as integrated solution at Ülemiste station (variant 1), near the main line east of Ülemiste station (variant 2) or parallel at the Rae depot. The latter option has the advantage that the train can be serviced there with minimum of additional shunting. The general track layout principle of the car loading facility is depicted in Figure 72 for options B.1 and B.2.

One example for application of option B.1 is the dedicated car shuttle terminal near Vienna main station, where night trains start and terminate. Car loading facility is implemented next to the platform. The trains can start directly from the station and terminate there.

If a separate facility near the main line is implemented a separate shunting spur might ease pushing operation without the need to run round the engine (e. g. of arriving train at Ülemiste).

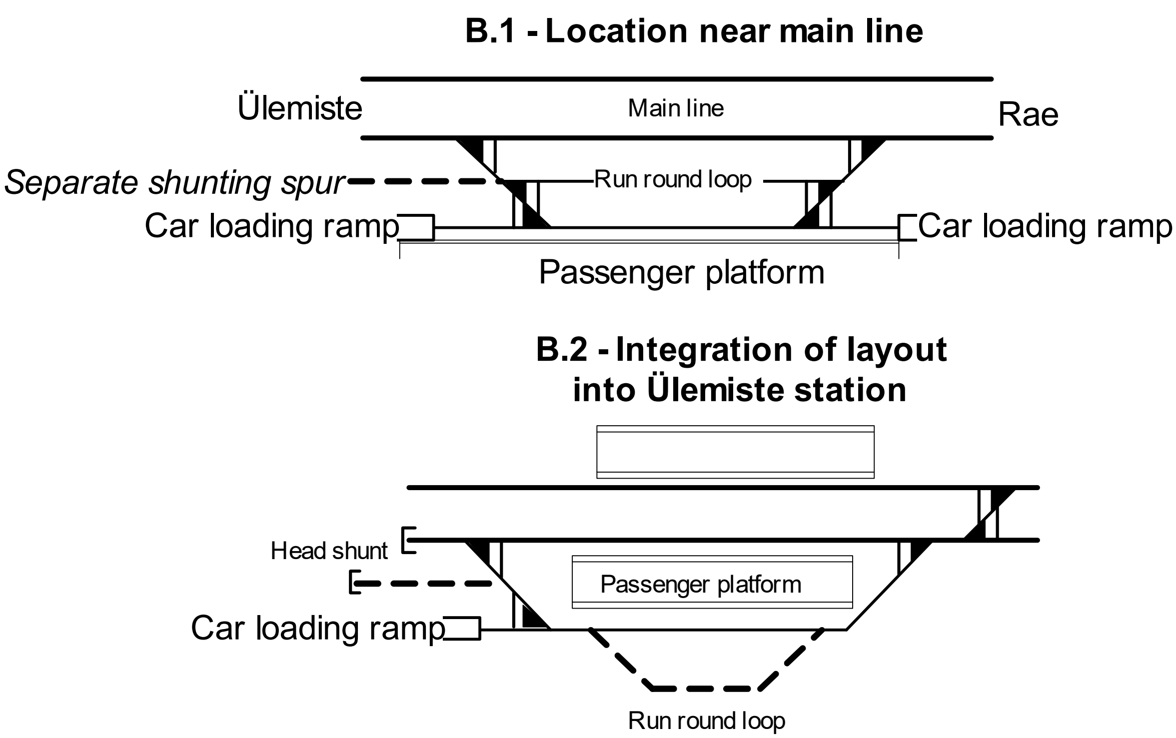

Figure 72: Car loading facility – general track layout principle

Facilities for option A (movement of a portion of the train) would be similar, but with shorter track length (min usable track length approx. 155 m to provide space for at least 2 passenger wagons + 3 car carriers + locomotive).

Due to space constraints at Ülemiste station there is currently no proven solution to implement option B.

4.7.2.3. Rae junction / Rae freight station

According to preliminary design the junction of the lines to Tallinn Ülemiste and Muuga is planned to be at-grade. The foreseen track layout is depicted in Figure 73. If this track layout is implemented as planned southbound freight trains from Muuga have to cross the down track used by all passenger services to Tallinn Ülemiste. According to timetable for time horizon 2056 with maximum traffic the related conflict point is passed by 5 trains per hour (timetable 2056).

Thus, capacity should be sufficient until end of forecasting period. Nevertheless, necessity to pass will reduce flexibility for timing and daily dispatching of freight train paths. Suggestion is to start with the planned layout and consider flyover at a later stage, e.g. when FinEst link will be implemented.

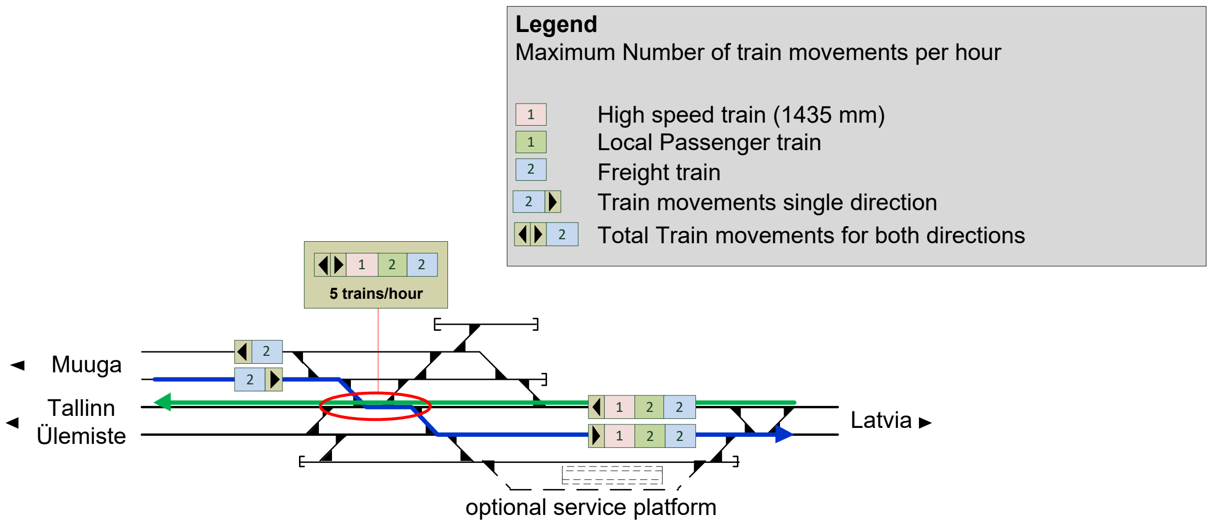

Figure 73: Track layout Rae junction - indication of potential conflict point between freight and passenger traffic

As part of CPTD layout change of track layout was proposed by RB Rail to provide a freight station at Rae in order to serve industry and logistics service providers located nearby. In addition to that it is proposed in the operational plan to locate Infrastructure Heavy maintenance facility also in Rae.

Based on the initial track layout developed by RB Rail the following track layout is proposed. This layout provides for following additional functionalities

- simultaneous freight train traffic from/to Muuga branch as in preliminary design
- facilities for access to maintenance base (also from/to Tallinn Ülemiste by direction change using head shunt

The recommended track layout is shown below.

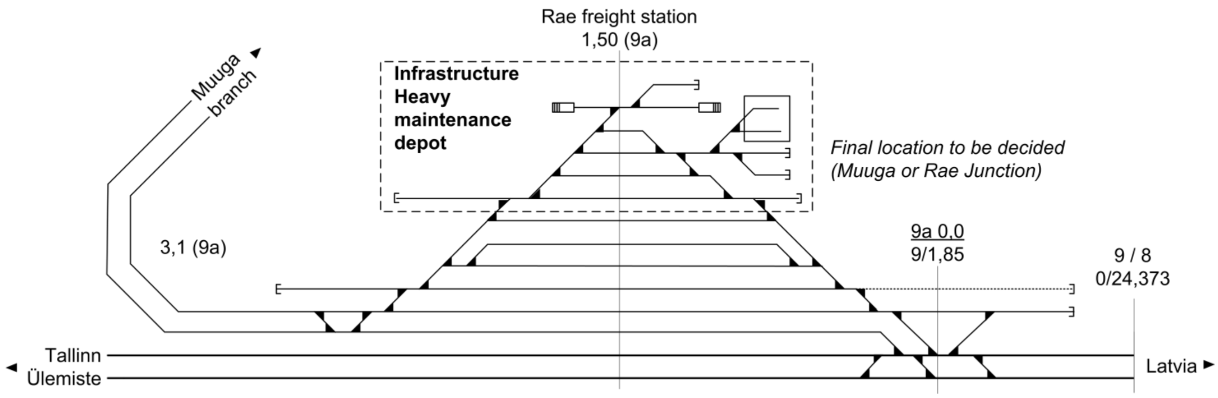

Figure 74: Track layout Rae freight station

4.7.2.4. Facilities for FinEst link

On FinEst link there are several types of traffic for which the Tallinn node needs to be adapted.

- FinEst link shuttle passenger trains (Ülemiste – Helsinki airport)
- FinEst link car and truck shuttle services
- Direct freight services Helsinki freight terminal – Salaspils/Kaunas/Vilnius/Warszawa
- Extended long distance and night trains Helsinki – Ülemiste – Warszawa/Vilnius

Regarding long distance passenger services, it is assumed that these trains will arrive and depart from the Rail Baltica tracks in Tallinn Ülemiste. For turnaround of the HST trains a minimum time of 10 minutes is assumed (technical turnaround time + pathing allowance).

To operate FinEst link passenger shuttle services Vantaa Airport – Tallinn Ülemiste additional platform tracks will be needed. According to the timetabling study carried out at least three additional platform tracks would be required to accommodate the proposed services.

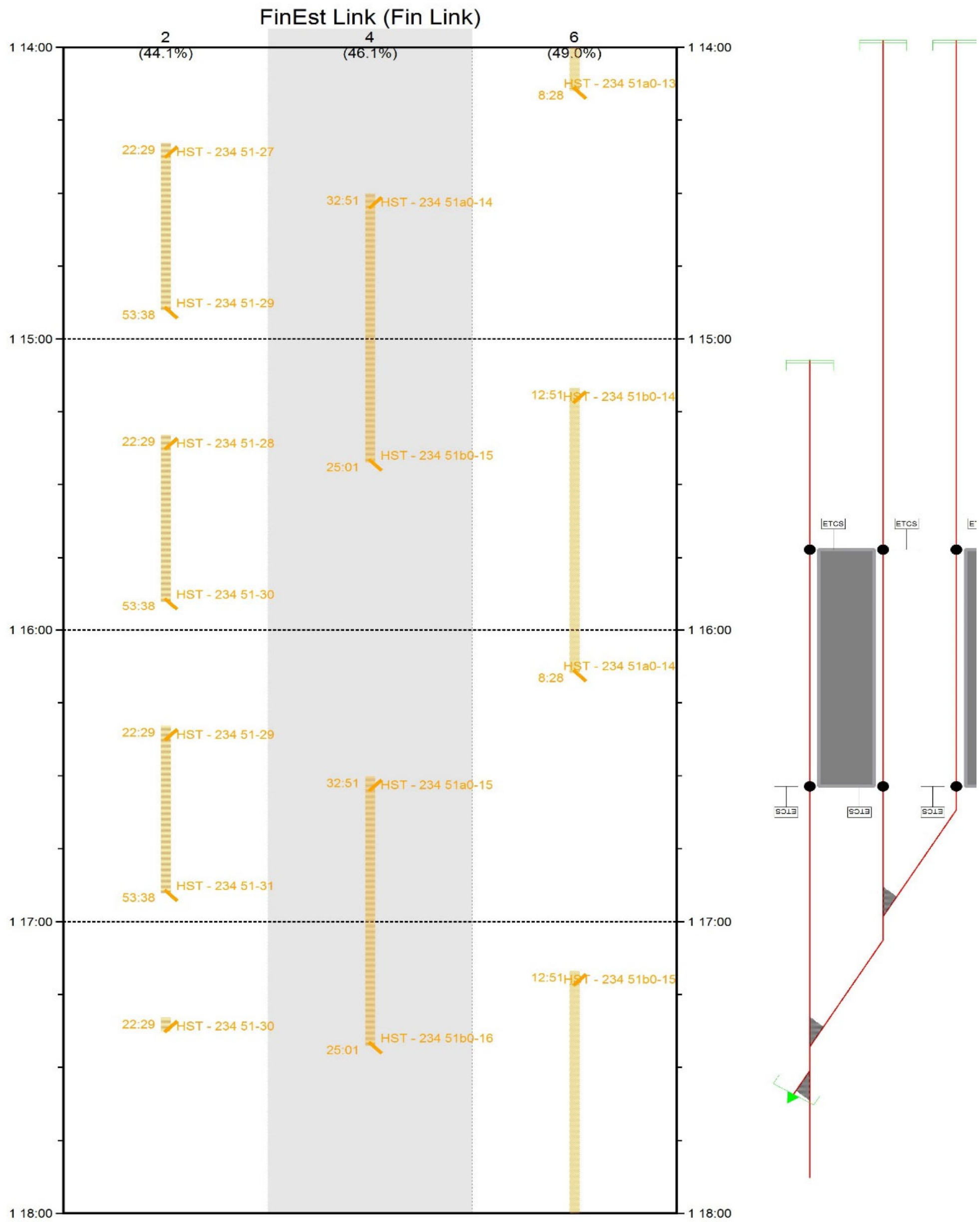

Figure 75: Track occupation Tallinn Ülemiste 2056 – FinEst link tracks

These additional platforms cannot be accommodated on the currently proposed site for Ülemiste station. Potential solutions to provide the required functionalities in Ülemiste might be:

- Provision of a separate station or a dedicated terminal north of the existing 1520 mm railway line

- Introduction of a second level (e. g. FinEst link tracks in a tunnel below the existing platforms). Depending on method of tunnel or structure erection this would lead to severe disruption of services since tracks and platform facilities would need to be closed down at least partly for construction of required facilities.

In line with current planning stage from the feasibility study it is assumed in the operational plan, that FinEst car and truck shuttles will depart from a dedicated terminal facility west of Rae junction. In order to avoid interference with the already dense traffic at Rae junction the terminal should be reached by a separate double track line passing Rae junction grade separated. Due to the very early planning stage the layout of the car and truck shuttle terminal is not considered in detail. If engines or wagons should be serviced at Rae depot a separate single-track connection from the FinEst link terminal to Rae would be needed.

For conventional freight trains (9 train pairs per day) a separate track connection needs to be provided so that they can directly reach the Rail Baltica main line without direction change. Therefore, a separate junction with Muuga branch is foreseen at Iru junction. For the purpose of the operational plan this junction is not completely grade separated due to the low amount of additional freight trains (9 train pairs per day). At this early planning stage, it is assumed that most of the cargo trains will continue further south, therefore no direct connection to Muuga freight station is initially assumed. If there will be a need to reach Muuga directly a triangle is to be provided at Iru junction.

For synchronisation of paths between Rail Baltica main line dedicated waiting tracks should be provided at Rae junction (at least one track for direction to Helsinki, one track for direction to Riga). These tracks would also allow for crew change or additional safety checks and could also be used to reverse conventional freight trains from/to Muuga, if no triangle is provided at Iru junction.

4.7.3. Pärnu station

According to intergovernmental agreement between the three Baltic States this station is an international passenger station. That means HST services will call at the station. According to the train service pattern proposed in this operational plan, regional trains from/to Tallinn Ülemiste are to terminate/begin at the station. Since HST trains will stop at the station the platforms can be implemented as bay platforms between running lines and loop lines, thus four platform edges with length of 210 m and option for upgrade to 410 m shall be provided to allow for overtaking if needed.

For stabling of regional passenger trains at least one stabling sidings for regional train (max. usable length 210 m for parking of two trainsets shall be provided. This track shall be placed southeast of the station. If more space is needed in the long-term additional tracks could be provided at the southwest side of the station. To avoid additional shunting with direction change and fast clearance of the main line by arriving trains these should be placed at the southwest end of the station.

According to preliminary results of feasibility study for Pärnu freight terminal the terminal will be most likely connected to the main line by a separate freight station, which is located approx. km 5.3 km north of Pärnu station. In this case there is no development space for reception sidings next to the terminal foreseen. Therefore, these facilities are to be provided at the freight station closed to the main line. At least one arrival track, one departure track and one run-around for shunting locomotive would be needed. If Pärnu freight terminal is implemented, a local infrastructure maintenance facility with related added tracks as outlined in chapter 6.5 shall be included in the layout of Pärnu freight station.

The resulting recommended track layout is shown below.

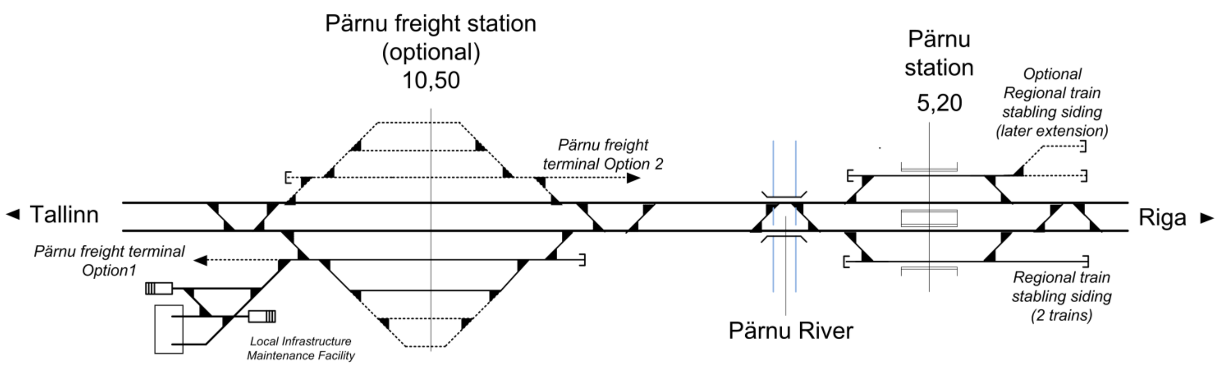

Figure 76: Recommended track layout of Pärnu station and Pärnu freight station

4.7.4. Riga node

The railway network in Riga node consists of two line sections running in parallel:

- Riga loop, which is nearly exclusively used by passenger trains and which will be designed as passenger line. On Riga loop there are two international passenger stations (Riga Central and Riga airport). In addition to that up to nine regional stations on the Riga loop will be served by the regional express trains.
- Riga bypass, which will be nearly exclusively used by freight trains. On the bypass a dedicated freight terminal is planned (RBILC terminal at Salaspils).

The corresponding Junctions in the north are Upeslejas triangle in the north and Misa triangle in the south.

In preliminary design, Misa was only designed as a connection from Riga node to Riga bypass in one (south) direction.

It was proposed by RB Rail AS to add a connection from Riga bypass in direction of Riga airport to be able to send freight trains to Riga Airport Cargo yard, to support diversion of services, if needed, and for maintenance movements. It is recommended to realise this connection since:

- it provides the quickest and fastest access from Salaspils to Riga Airport Cargo yard without need for direction change in Riga airport or Jaunmārupe station

- it avoids the currently proposed incline of 29‰ near Slāvu tilts station (section km 14.394 - 14.796), which is especially beneficial for fuel trains serving Riga airport,
- It contributes to relief of Riga Central station. It allows freight trains to avoid the Centre of Riga thus contributing to minimum noise emission.

If this connection is not realised freight service from and to Riga Airport Cargo yard can only be provided in night hours without passenger services.

Both junctions will be designed grade separated, except for the track connections from the bypass to Riga loop.

Traffic flows in Riga node for the time horizons 2026 and 2056 are depicted in Figure 77 and Figure 79. Initially, there will be approx. 64 passenger trains (16 HST and 16 regional express trains and 16 shuttle services) using Riga loop. In addition, dedicated shuttle trains will be operated between Riga Central and Riga airport. The shuttle and the Regional trains shall be timed such that a service with regular time intervals between Riga Central and Riga airport can be provided (at least half hourly).

With expected growth of traffic the sections on both sides the line section between Riga airport and Riga Central will be utilised by up to 130 daily trains.

According to current version of operational plan Riga bypass is utilised exclusively by freight trains. Demand analysis has shown that there is low demand for passenger services to be extended to stations at Riga bypass. However, in case of major disruption in the Riga urban area, it may be necessary to route HST and regional trains through the Riga bypass. Therefore 200 m (expandable to 410 m) emergency platforms are needed, with possible location between Salaspils intermodal terminal and Daugava river bridge. In emergency case, interchange with 1520 mm trains could be ensured, providing access to Riga central station.

In 2026 there will be approx. 24 trains north of Salaspils and 28 trains per day south of Salaspils. According to consolidated freight forecast outlined in this report 4 trains in 2026 and 5 trains will depart from Salaspils terminal. In addition to that Salaspils terminal will be used for crew change and exchange of wagon groups.

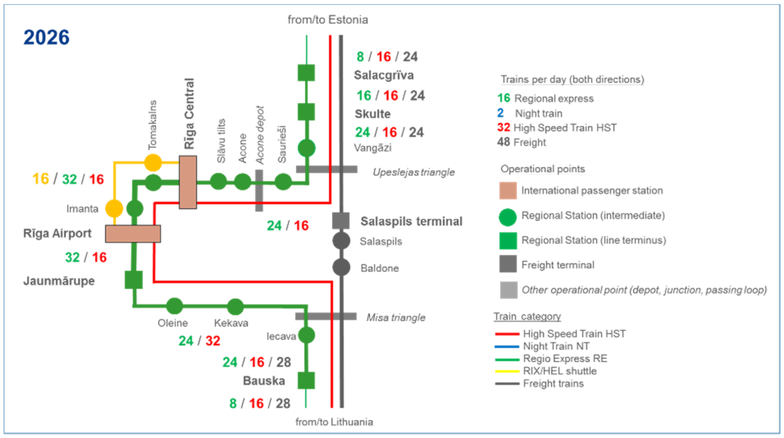

Figure 77: Riga node – traffic flows 2026 (trains per day)

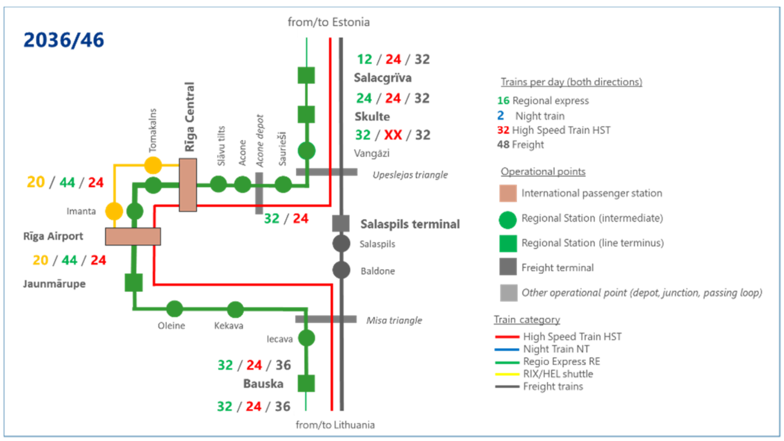

Figure 78: Riga node – traffic flows 2036/46 (trains per day)

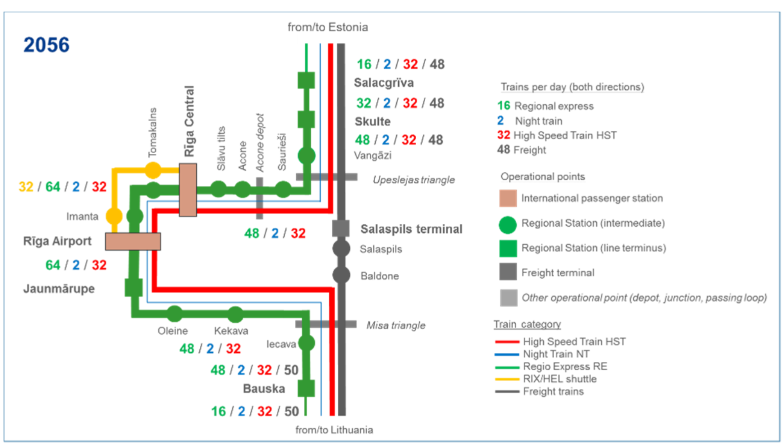

Figure 79: Riga node – traffic flows 2056 (trains per day)

Given the forecasted train service pattern, capacity of the passenger stations and suitability to handle proposed traffic is crucial for overall functionality of Riga node. Therefore, the situation regarding capacity of passenger stations is highlighted in the next chapters.

4.7.4.1. Riga Airport Station

According to the currently proposed layout only through trains and the airport shuttle trains can be handled in the station. This leads to conflict with regional trains from the north which shall also terminate at Riga airport (regional train line 21 Tallinn – Riga airport).

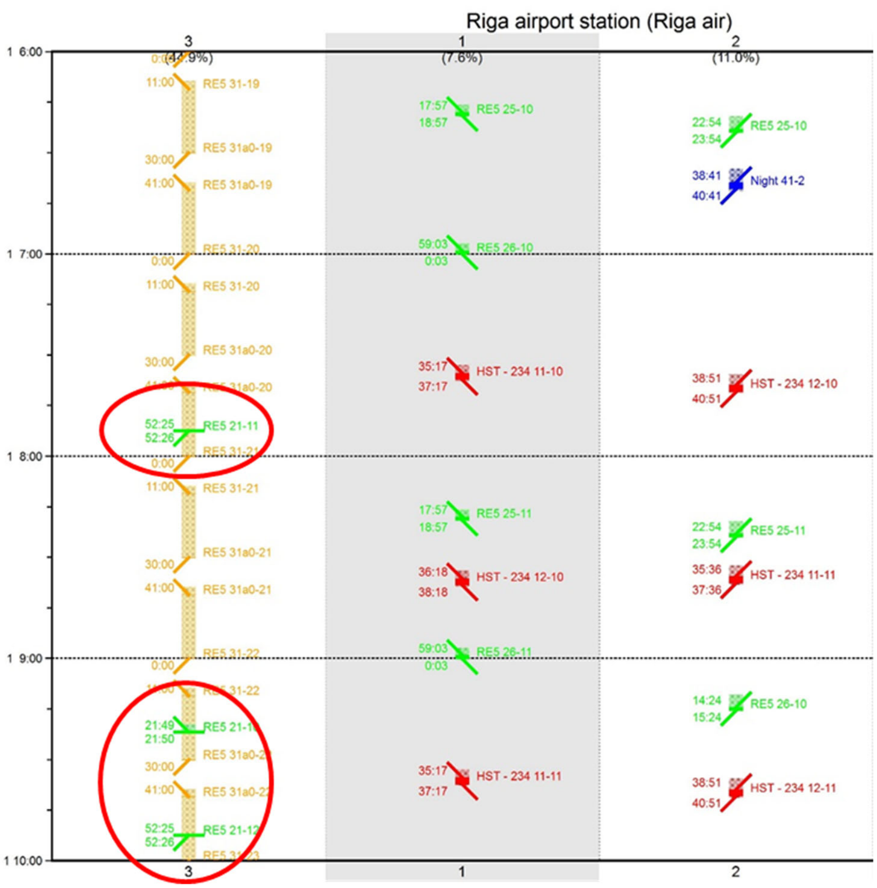

Figure 80: Track occupation Riga Airport station

There are two options to solve this issue:

- Option 1: improve layout of Riga Airport station (preferred solution)
- Option 2: continue line 21 to Jaunmārupe station and provide turning facilities there. These facilities could also be used for other lines. Distance between Riga Airport station and Jaunmārupe station is approx. 6 km.

To provide maximum flexibility for turnaround of trains at Riga airport station layout should be improved as depicted in Figure 81 below. General principle of the proposed layout is turning of terminating trains between the running lines for through traffic. Provision of such track layout would have the following advantages:

- Enough track capacity for turnaround of all trains as required by operational plan
- Possibility to change train sequence at Riga loop in order to prioritise the international HST trains over high speed trains
- Independency of train services in both direction and no additional conflicts due to turning trains needing to cross the running line in opposite direction

If option 2 has to be chosen similar principles could be applied for development of track layout of Jaunmarupe station (see 4.7.4.2).

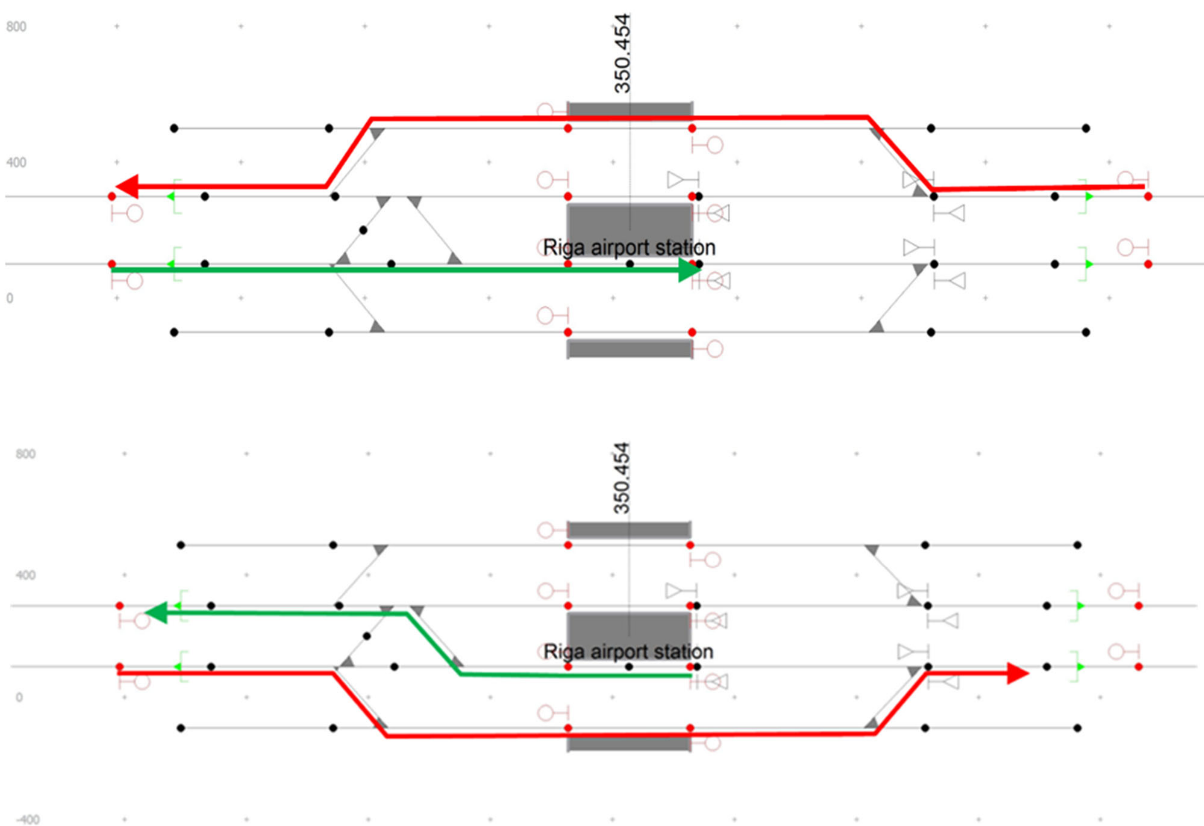

Figure 81: Suggested layout improvement for Riga airport station

4.7.4.2. Jaunmārupe station

Currently Jaunmarupe station is an optional regional passenger station. In case Riga airport station cannot be upgraded Jaunmarupe station shall be upgraded to provide additional turning facilities for regional express line 21 (Tallinn – Riga airport), which would otherwise terminate at Riga Airport station.

In addition to that the station could also be used for turnaround of Riga airport shuttles. To provide for this a total of two turning sidings (platforms for terminating trains) would be needed, which should be placed between the two running lines to minimise impact on traffic in opposite direction.

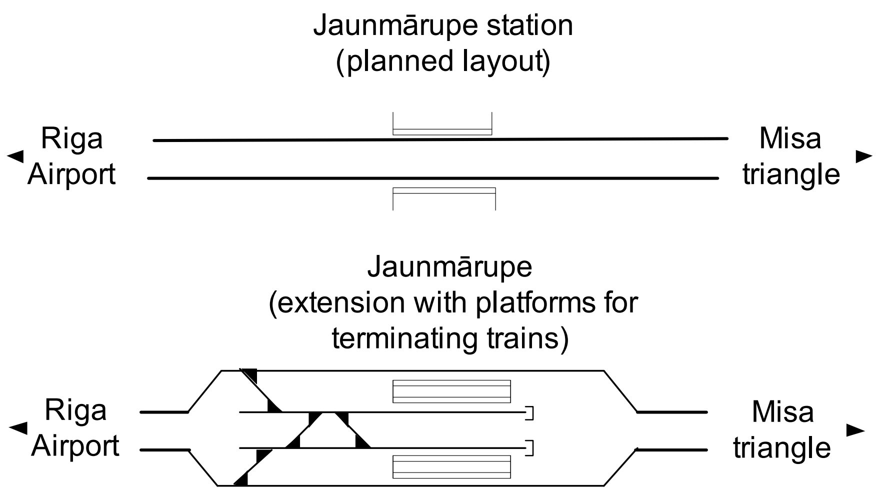

Figure 82: Jaunmārupe station –track layout for terminating trains

As southern destination for Riga airport shuttle and regional express services from the north Jaunmārupe station would be also sufficient location for nightly stabling of trains. Due to space constraints (parallel road) the tracks have to be provided on the north side of the station.

The resulting layout is depicted in Figure 83. For nightly stabling trains of the two lines terminating at Jaunmārupe at least 3 stabling tracks with 210 m length shall be provided allowing for stabling of two trains per stabling track. Jaunmarupe is also potential candidate for provision of depot as an alternative to Acone.

Results from rolling stock maintenance analysis indicate that there is a slight benefit in choosing this location. Trains entering and leaving the storage and depot could be incorporated in early morning late evening service between Riga Central station and Riga airport station. In that case additional space and stabling tracks are to be provided at Jaunmārupe. For further details please refer to chapter 5.1. If a depot is to be provided a second entrance on the East side would be beneficial in order to allow easy access for empty trains from the south, e.g. empty coaching stock from/to Bauska.

Current preliminary design and EIA did not foresee Jaunmarupe as turning, stabling or depot location, thus additional studies need to be carried out to determine whether the necessary space can be provided.

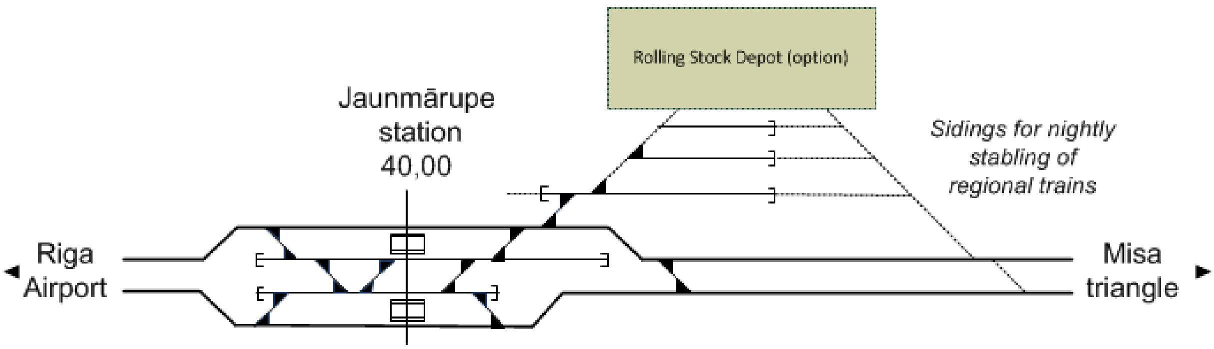

Figure 83: Jaunmārupe station – required changes of track layout for terminating trains and nightly stabling

4.7.4.3. Riga Central station

The currently proposed layout of Riga Central station is depicted in Figure 84.

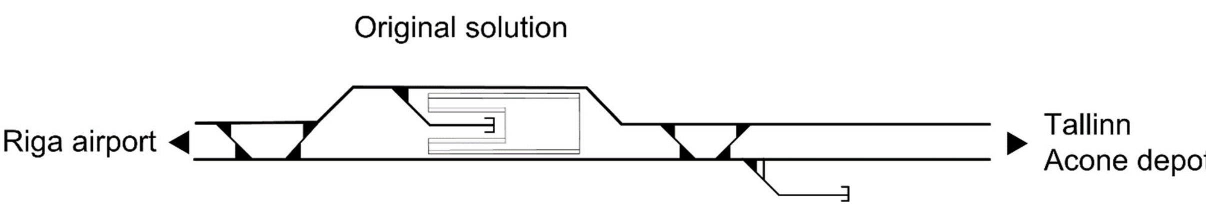

Figure 84: Riga central station – initially proposed layout

The track occupation diagram depicted in Figure 81 shows the peak hour traffic for time period 2056.

According to the operational plan as outlined in chapter 4.1 of this report, in 2056 in total 130 passenger trains per day call, begin or terminate at Riga Central station.

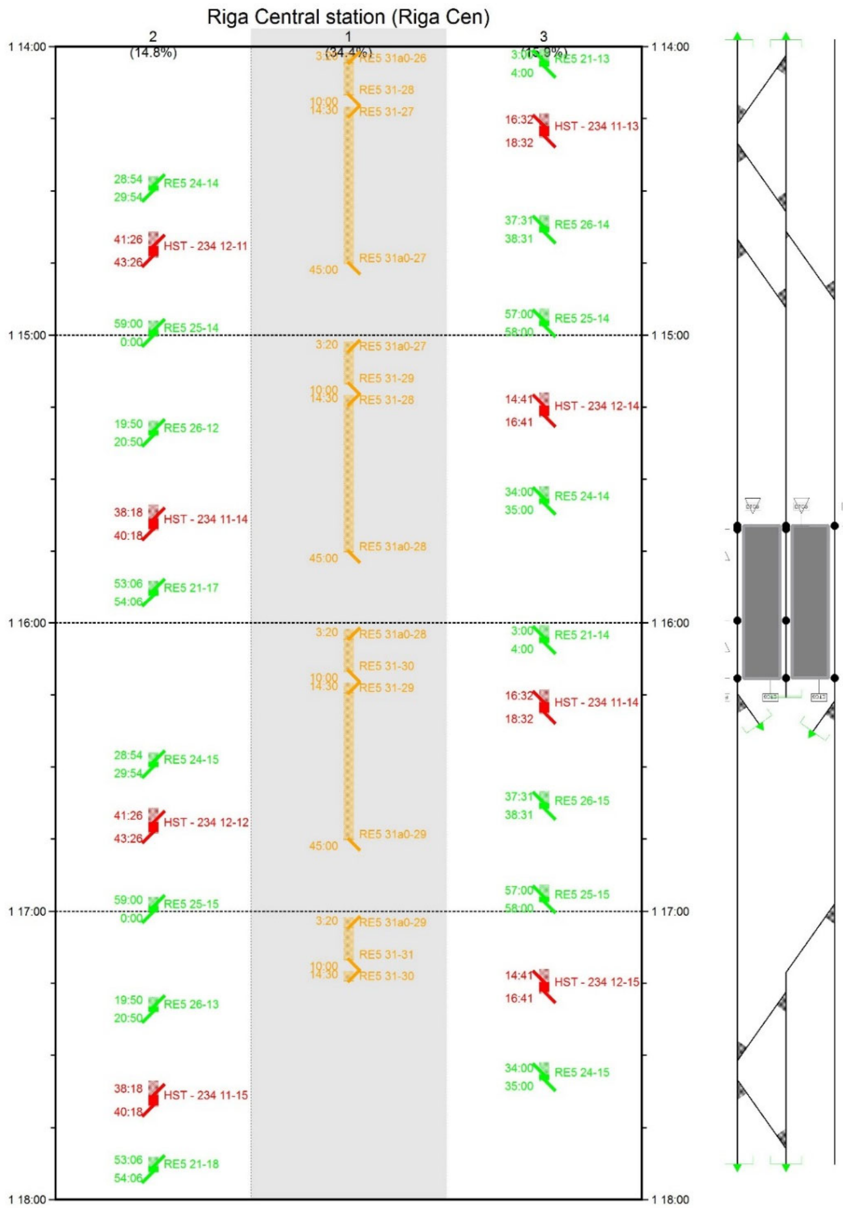

Figure 85: Track occupation diagram Riga Central station 2056

Overall the station shall handle following train services:

- Long distance trains, which will have an intermediate stop at the station (16 train pairs per day; red on the track occupation diagram)
- Regional trains Bauska / Riga airport – Salacgriva/Tallinn having an intermediate stop (24 train pairs per day; green on the track occupation diagram)

- One regional train line from the Marijampolė/Kaunas, terminating at Riga Central (green on the track occupation diagram;2 hourly service)
- Riga Airport Shuttle (16 train pairs per day; brown on the track occupation diagram).

With the currently planned layout resulting from preliminary design Riga Central station has only one island platform between the two running lines and a bay platform in between, which will be needed to handle airport shuttle trains. In addition to that trains entering the dead-end track of thie bay platform at the west side of the station have to cross the running line in contraflow direction. The currently foreseen layout of does provide for one turning facility at the east side of the station to be implemented as dead and track. This turning track is only usable for regional trains (usable length < 200 m).

Consequence of this is that terminating trains from the south would need to proceed as far as Acone depot, which is located 11.6 km away from the main station for turnaround. Trains from the north are required to continue further south to Riga Airport station, which will also have very limited station track capacity, or alternatively to Jaunmārupe.

Looking at the station track occupation diagram for timetable 2056 (Figure 85) it becomes clear that there is no room to handle additional trains during peak hours. In addition to that a change of train sequence is not possible since there is no free waiting track for the train to be overtaken. Thus the long distance services cannot be prioritised over regional express trains as would be needed in case of failures and delays. If a train is held at a platform due to an incident following trains might be delayed since in many cased the second through platform will be needed. Finally there is the necessity to handle terminating and beginning trains in the morning and evening which will increase station dwell time for beginning and terminating services.

To provide an acceptable operational quality and flexibility and to suit the needs stated above, at least 4 through platform tracks (200 m train length with option to accommodate 400 m long trains) would be required. Extension of layout to support four platform tracks will allow for following functionalities, which are difficult to realize with the original layout:

- Overtaking of delayed train in Riga Central station
- Startup and terminating passenger train runs in the morning and in the evening, which might require additional platform occupation time
- Direction change of terminating services at the platform, also for HST services if needed
- Providing interconnectivity between 1435 mm HST and regional trains using adjacent platform edges
- Providing reserve capacity in case one platform tracks needs to be closed down for infrastructure maintenance work or due to a damaged train
- Allowing longer scheduled stops of train services, e.g. to synchronize with 1520 mm timetable

- Providing additional capacity in case of prolonged platform occupation time (e.g. waiting for arrival of delayed 520 mm train service to provide connecting service, handling of damaged train, providing special assistance to passengers in case they need medical help a.s.o.).

Within the space constraints of the current location this is only possible, if three 1520 mm tracks parallel to Rail Baltica could be closed or relocated to free up space for additional 1435 mm tracks (2 platform tracks, 1 track dedicated to passing freight services).

In Figure 86 the recommended layout development is shown. Underlying assumption is that the two southernmost 1520 mm platform tracks and the dedicated freight track of Riga Central station and the 1520 mm freight bypass can be replaced by 1435 mm tracks in the long term. Feasibility of this is not yet proven and thus recommended topic for further investigations. As can be seen the layout could be developed from first stage step by step. Therefore, it is necessary to consider the final layout from the beginning when designing the station tracks for first development stage.

Start of operation with the currently planned layout might be possible due to the lower amount of trains and reduced departure frequency, if following preconditions are met by implementing improvement stage 1

- To allow smooth operation at least the additional track connection to the dead-end platform should be implemented
- The turning siding on the east side of the station shall be implemented, preferably as track which can be reached from Acone direction and from the platform tracks. To allow parking of an HST the length of the turning siding shall be upgraded to at least 220 m.[83]
- Adequate tracks for stabling of regional and long-distance trains need to be provided in Acone and/or Jaunmārupe.

Given the distance between Riga Central station and Acone depot (approx. 11 km) additional stabling tracks at Riga Central station will ease operation and contribute to operational efficiency.

[83] Provision with length over buffers slightly exceeding 200 m length (e. g. 202 m) and reserve for stopping inaccuracy

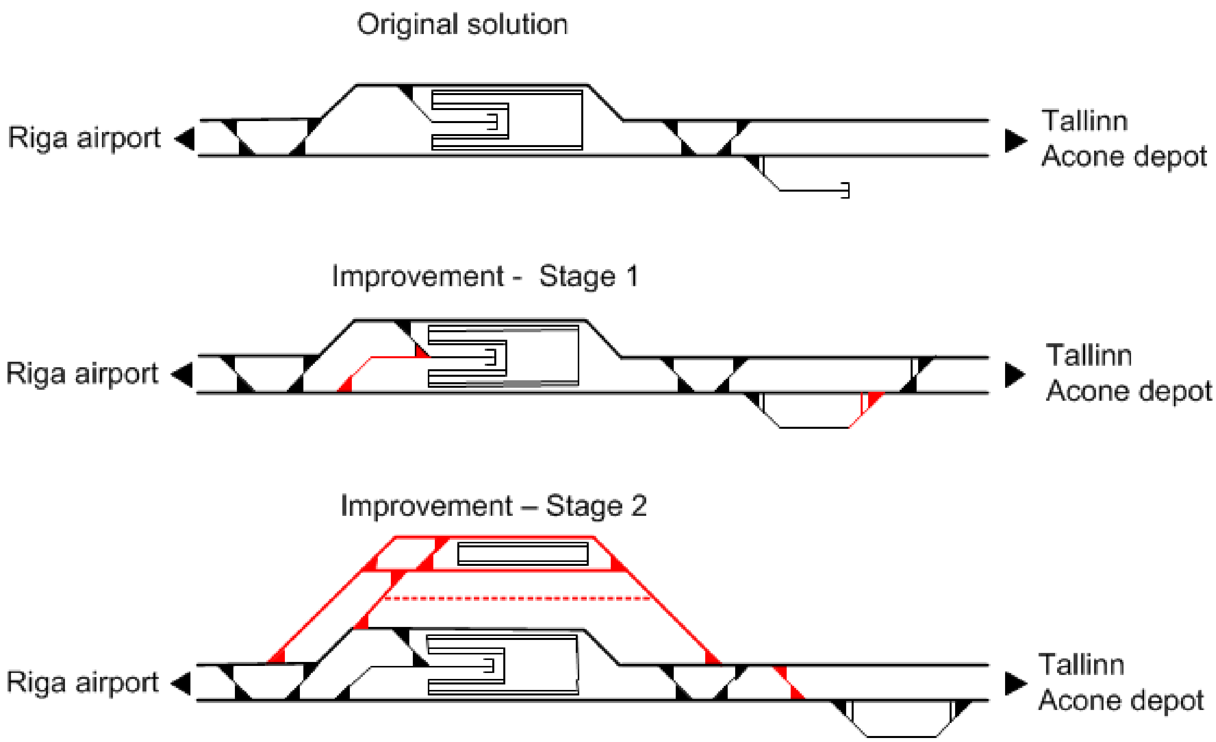

Figure 86: Riga Central station layouts: Original solution, Improvement Stage 1 and longer-term Improvement Stage 2

Departure from the turning siding would require crossing of the down running line. To increase operational flexibility it is recommended to place the turning siding between the two main tracks. This is especially useful for development stage 1 as depicted in Figure 85, where only two platforms are provided. Placing of the turning siding between the running lines will contribute to short platform occupation times since departure from the siding is independent from traffic in other direction. Optimum location of turning siding from operational viewpoint is depicted in Figure 87based on layout for improvement stage 1.

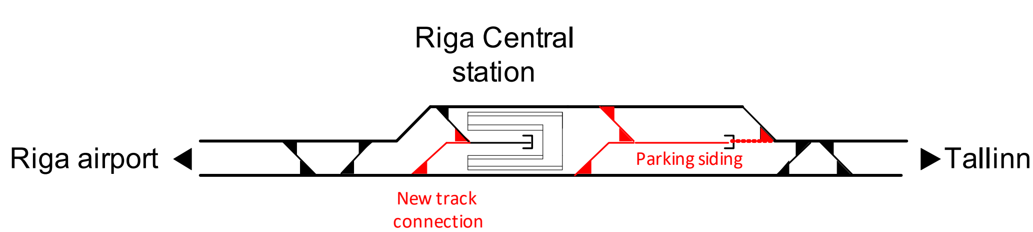

Figure 87: Optimum location of required turning siding

To provide additional turning and stabling capacity closed to the main station provision of turning tracks adjacent to the yard of Vagonu Parks 1520 mm (distance from Riga main station: depot should be considered (distance approx. 2.3 km) as an option, subject to further investigation about available space in the future.

4.7.4.4. Bauska, Skulte and Salacgrīva station

According to the operational plan turnaround of regional trains is also to be considered at the following stations.

- Salacgrīva station (regional trains from/to Riga Airport / Bauska; turnaround of regional train line 24;8 train pairs per day in 2056)
- Skulte station (turnaround of regional train line 25; 8 train pairs per day in 2056)
- Bauska station (turnaround of regional train line 24/25; 16 train pairs per day in 2056)

Currently no additional platforms or parking sidings for turning-around of trains are foreseen at these stations. Therefore, additional facilities shall be foreseen.

According to preliminary design, all of these stations are planned with two passing loop tracks, which were intended also to be used by freight trains. Regarding station layout there are several options to be considered:

- Option 1: use existing platforms and provide dead end track as turning siding. This solution is recommended for low amounts of traffic in the first years of operation.
- Option 2.1: Provide additional platform for terminating off the main line. This solution will require that the train crosses the contraflow track when departing to the mainline. Compared to solution 2.2, the additional platform track can be easily provided at a later stage.
- Option 2.2: Provide additional platform and passing loops between the running lines. From operational viewpoint this is the most flexible alternative. Disadvantage is additional space needed (widening of track distance between running lines at entry and exit of the stations) and more difficult access to passing loop tracks in case of incidents and emergencies (train diverted to passing loop to deal with incident).

Overall recommendation for Salacgrīva and Skulte is to start with option 1 and extend to option 2.1 with growing traffic as needed. Analysis of Railsys timetable indicates that f0r Bauska option 2.2 should be preferred, if hourly service to Bauska will be implemented as indicated for time period 2056.

Taking into account space constraints at this location option 2.1 is recommended.

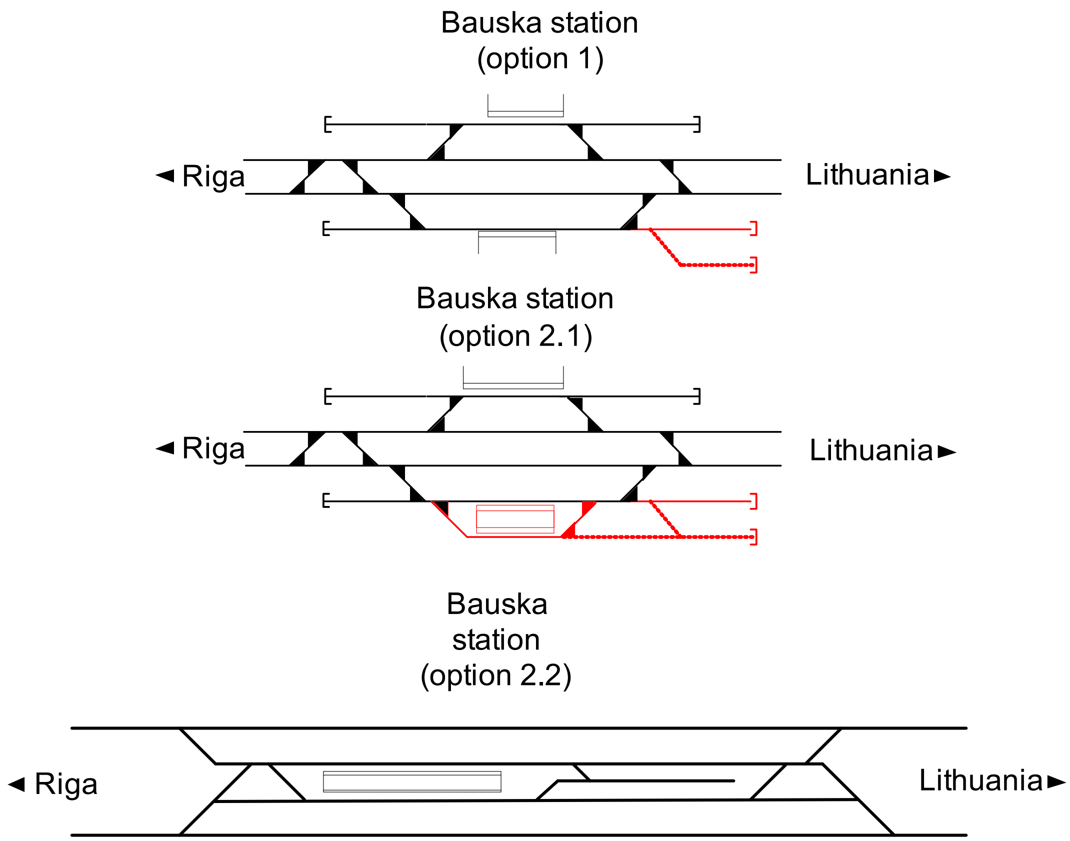

Figure 88: Layout development for terminating regional trains (example Bauska)

4.7.5. Panevėžys station

Since Panevėžys is proposed to be international passenger station. In addition to that it will be a major destination for regional train service in Lithuania with direct connections to Kaunas and Vilnius. To gain full demand potential the station should provide connectivity with 1520 mm network; at least if no direct 1435 mm connection to Panevėžys is planned. Pros and Cons of various variants are discussed in chapter 1.4 of this report. This interlink could be either provided on the south side of the station or as a tower station. The latter solution is indicated in the track maps as shown in annex 1 and in Figure 89. This means the platforms needs to be placed closed or on the overpass over 1520 mm railway line. Therefore the station could either be located such that the platform will be located closed to existing 1520 mm railway. If this is not possible an alternative would be to realign existing 1520 mm so that the tower station can be implemented at a more suitable location further north.

In case a direct 1435 mm or 1520 mm link shall be provided from the station the layout would be nearly the same as shown in Figure 89 and Figure 90, but the station is to be located further north.

In order to to serve long distance and regional trains at least four platforms shall be provided (200 m with extension option to 400 m). This would allow for operational flexibility and stability in the timetable. In addition to that stabling facilities for terminating regional trains need to be provided (3 tracks with length of 220 m). These should be preferably placed east of the mainline so that arriving trains do not need to cross the running line in opposite direction. However, it should be ensured that all platforms can be flexibly used by all trains.

For Panevėžys station an option to provide a freight terminal shall be also considered. Proposals developed for preliminary design and spatial plannung indicate a location of the terminal facilities on the west side of the station. This proposal can be confirmed by the operational plan. Further layout considerations shall be based on a detailed study identifiying the regional needs and interlink potential with 1520 mm.

Furthermore the layout shall include a local infrastructure maintenance facility as outlined in chapter 6.4. Proposal of the operational is to place this facility on the East side of the station to leave space for terminal development on the west side of the line.

The resulting recommended layout is depicted below.

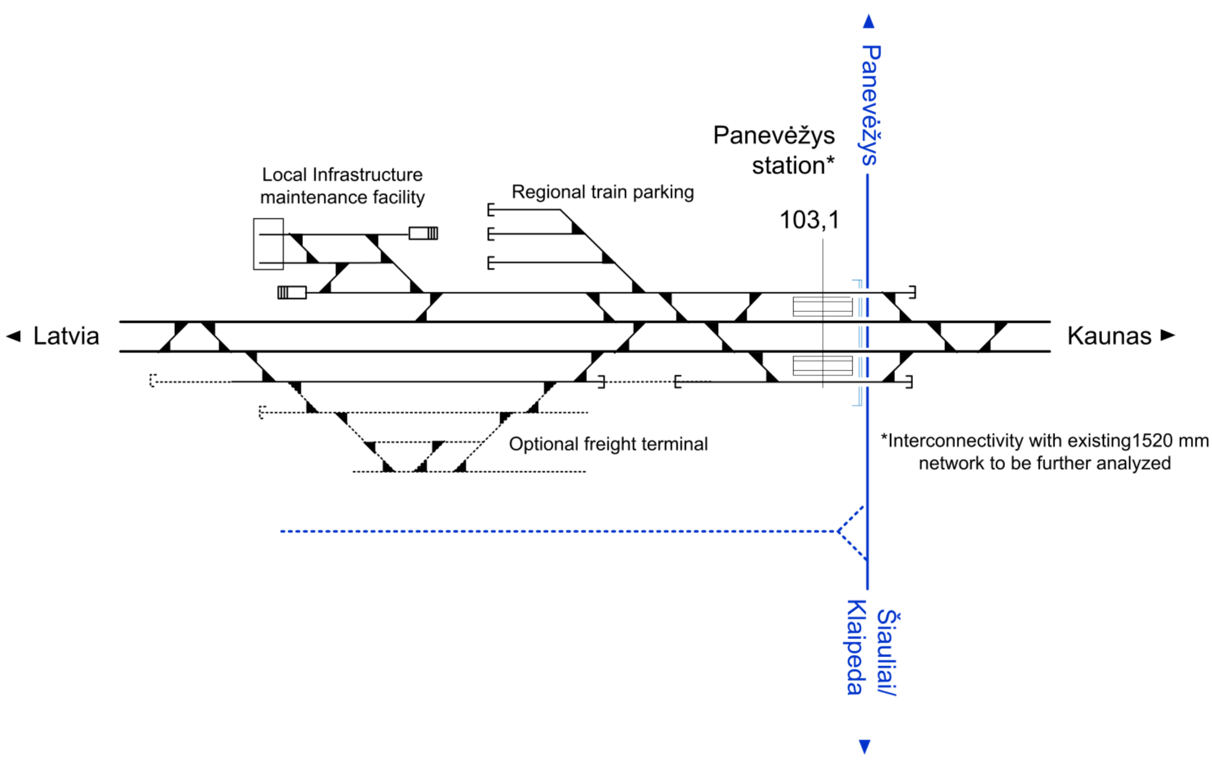

Figure 89: Recommended track layout Panevėžys station – Option A

Another option (option B) would be to place the regional train platforms and the stabling sidings for regional trains between the running lines. This would allow for simultaneous arrival and departure of regional trains without the need to shunt terminating trains to another platform. Furthermore regional trains going to the stabling sidings would not interfere with traffic on the main line.

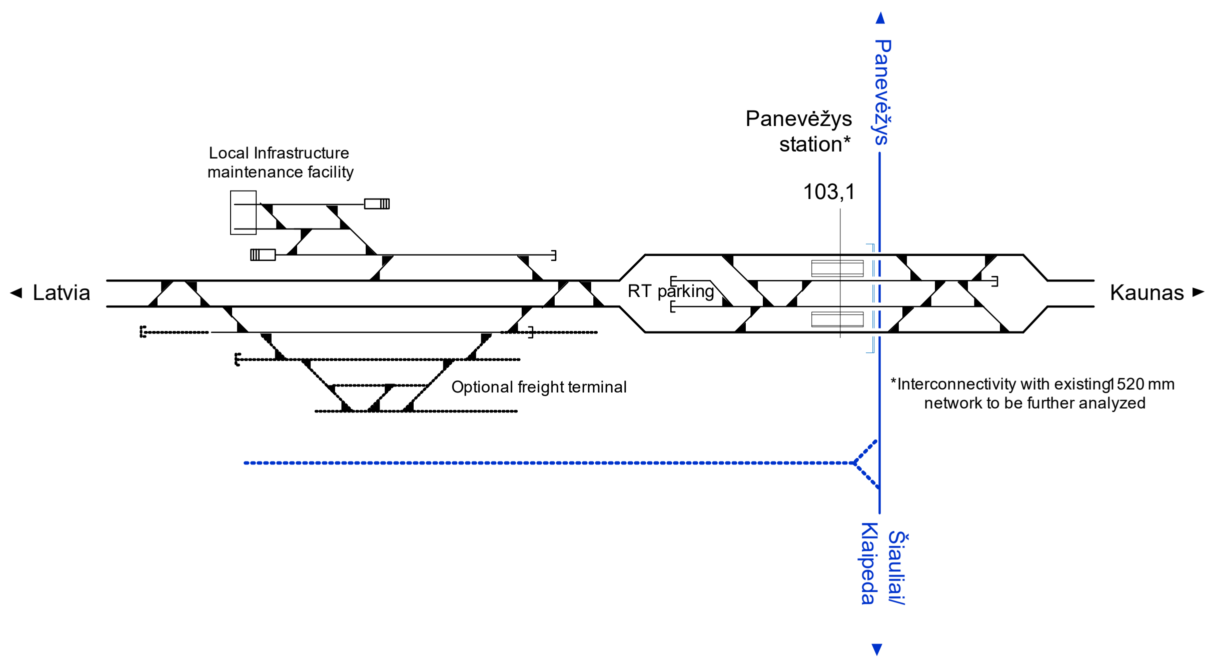

Figure 90: Recommended track layout Panevėžys station – Option B

4.7.6. Kaunas node

Kaunas node can be seen as the main hub of Rail Baltica, which will function as gateway to the Lithuanian railway network both on 1435 mm gauge and on 1520 mm gauge. For passengers it will provide interconnectivity to Kaunas – Vilnius section. Kaunas node is also vital for freight train service. According to consolidated freight forecast 1/3 of the trains from and to Poland are expected to start or terminate in Kaunas area, which corresponds to 8 (time horizon 2026) up to 11 (time horizon 2056) daily freight train departures from Kaunas area.

Starting from north to south the node consists of the following facilities:

- Kaunas triangle, which interconnects the Rail Baltica north-south-axis with the Kaunas – Vilnius section
- Proposed Kaunas airport station which will be located west of the Rail Baltica mainline adjacent to Kaunas triangle.
- Palemonas freight station, originally a 1520 mm shunting yard. Rail Baltica freight facilities will be located west of the yard, main functionality is to interconnect Kaunas intermodal terminal to Rail Baltica.
- Palemonas passenger station. Rail Baltica main tracks and passenger station will be located east of the existing 1520 mm yard. The passenger station is intended to be used for regional trains only and as emergen-

cy stop for HST in case access to Kaunas Central station is blocked. Therefore a 400 m platform is needed. In this emergency case also interchange to 1520 mm trains could be provided.

- Kaunas Central station. Today this station is served by 1520 mm. Since October 2015 the station is also connected to 1435 mm network by a single track track line running parallel to existing 1520 mm line to the Polish border. Therefore a dedicated 1435 mm platform with two platform tracks was implemented.
- Zemutinis track yard is located west of Kaunas station and is used as stabling facility for rolling stock as well as for rolling stock and infrastructure maintenance.
- Kaunas tunnel. This 1,285 m long tunnel is part of the existing 1520 mm railway line Palemonas – Kaunas Central - Jiesia. It will be also used by the proposed 1435 mm passenger services. Therefore a gauntled single track section is under construction and will be continued by a 1435 mm single track to Palemonas intermodal terminal, as part of the projects implemented by Lithuanian Railways.
- Kaunas bypass. To avoid Kaunas Central station and Kaunas tunnel a separate railway connection between between Jiesia junction and Palemenas shall be provided. This solution is already in place as part of the 1520 mm network. For Rail Baltica a separate bypass will be constructed parallel to the existing 1520 mm Kaunas bypass. As part of the projects implemented by Lithuanian Railways, a single track 1435 mm line between Jiesia junction and Palemonas is already under construction and partly implemented. Major target of this solution is to interconnect Kaunas intermodal terminal at Palemonas to 1435 mm network.
- Jiesia junction. Jiesia junction is the southern end of Kaunas bypass. At this location tracks from Kaunas bypass join the tracks from Kaunas Central station.

Location of thesese facilities and corresponding distribution of traffic are depicted in Figure 91 (time horizon 2026), Figure 92 (time horizon 2036/46) and Figure 93 (time horizon 2056). Generally, infrastructure needs to be designed to cater at least for requirements for time period 2036/46.

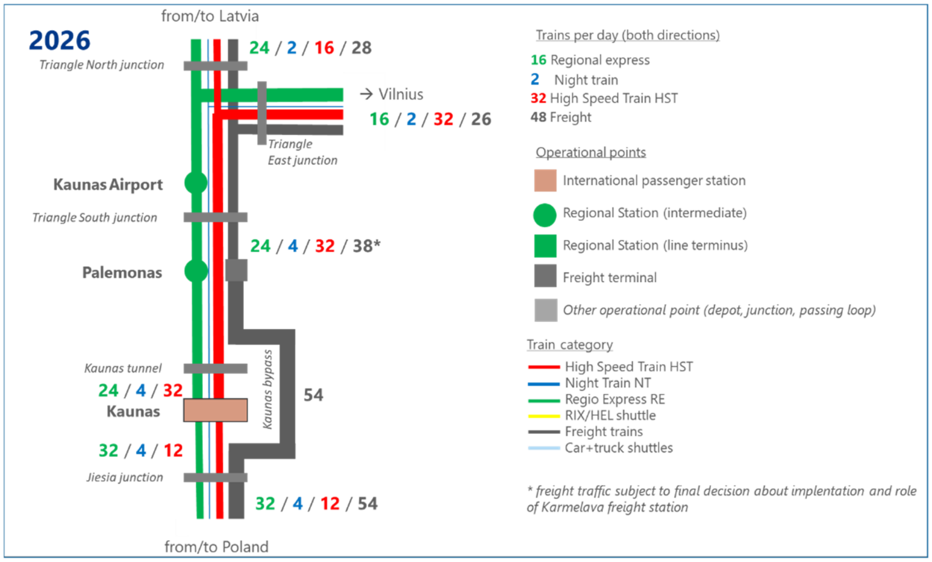

Figure 91: Kaunas node – traffic flows 2026 (trains per day)

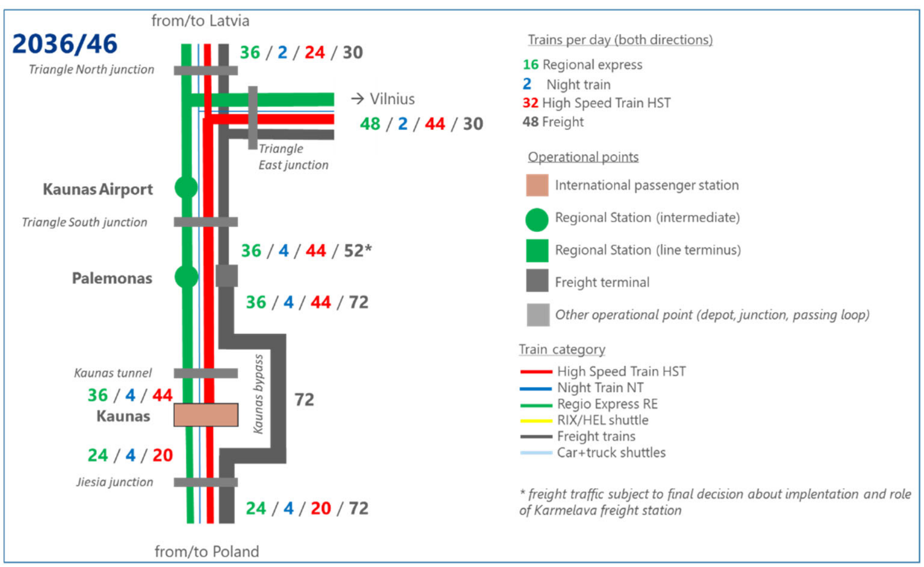

Figure 92: Kaunas node – traffic flows 2026 (trains per day)

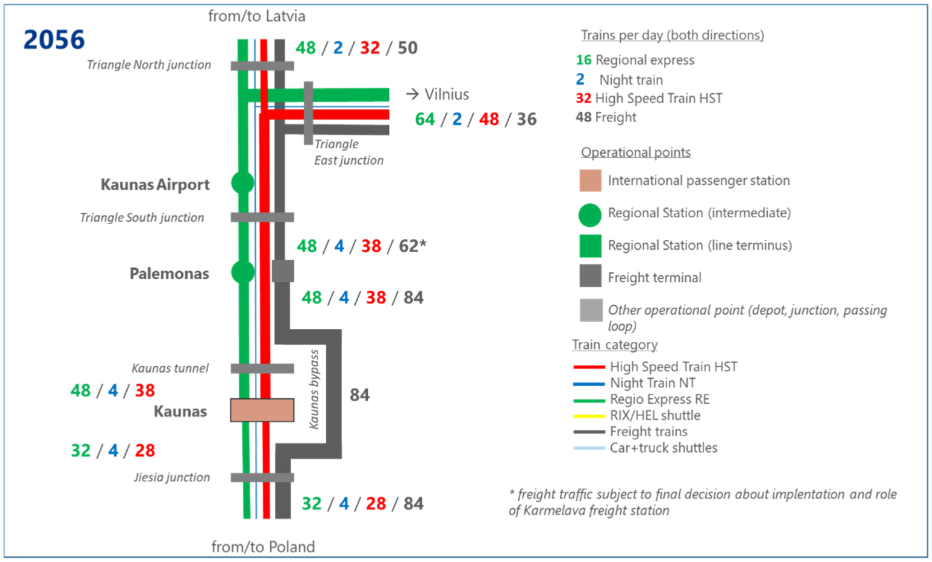

Figure 93: Kaunas node – traffic flows 2056 (trains per day)

4.7.6.1. Track layout Kaunas triangle and Kaunas airport station

Kaunas triangle will connect the Kaunas – Vilnius section to the Rail Baltica main line. Therefore, a triangle is foreseen to provide direct connections to Riga/Tallinn and Kaunas/Poland. The triangle is proposed as double track solution with grade separation on the north and west side. The developed timetable confirms that such a solution will be beneficial to accommodate the required passenger and freight paths. As far as local geographic conditions will allow the triangle shall be designed such that the proposed HST trains can pass all legs of the triangle at maximum speed.

The currently proposed track layout for Kaunas triangle and surrounding railway facilities is depicted in figure below. Since preliminary technical design and preparation of spatial planning documents for Kaunas – Vilnius section is not yet completed the shown layout is a reflection of the current discussion stage at the time of report writing.

Kaunas airport station will be located west of Kaunas triangle. This station shall be served by regional trains. Main functionality of the station is to provide a fast and convenient connection from Vilnius to Kaunas airport and to the other locations served by regional trains (Kaunas, Marijampolė, and Panevėžys). The station shall be located west of the mainline closed to the future airport terminal which is to be relocated to the west side of the airport.

To achieve that, the station needs to be located west of Rail Baltica main line. Therefore it is proposed that Kaunas - Vilnius line branches off to the west at Kaunas triangle south junction and crosses the north-south mainline again north of Kaunas airport station.

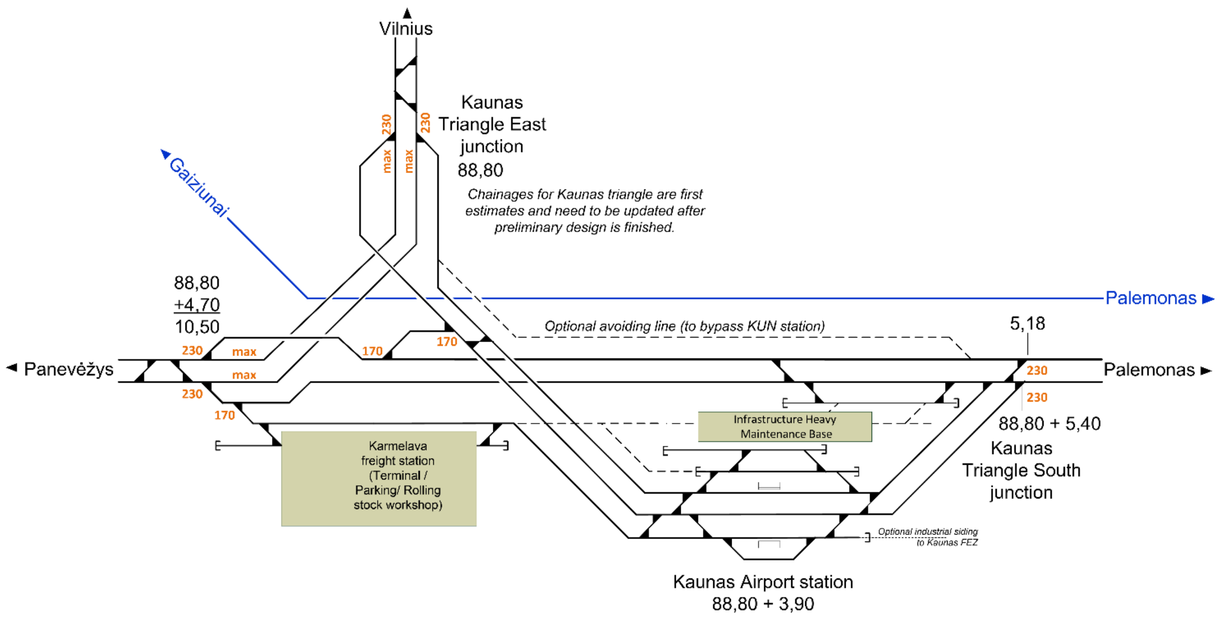

Figure 94: Track layout Kaunas triangle and Kaunas airport station

For **Kaunas triangle south junction,** a non-grade separated solution is proposed due to space constraints in the area. Trains towards Kaunas airport station/Vilnius will cross the up main line from Riga/Tallin to Kaunas. Since regional trains shall stop at Kaunas airport this line section will be used by HST services Riga – Warszawa (one train every two hours) and freight trains (3 train paths within two hours in 2046/56). With the proposed track layout freight trains from the north could also be diverted via Kaunas airport station. Thus, non-grade separated design of Kaunas triangle south junction will be no capacity issue.

To allow trains waiting for their respective slots and to regulate the traffic continuing further south through Kaunas node **passing loop facilities** shall be provided on the main line and at Kaunas airport station. Loop tracks at Kaunas airport station will also provide for passenger safety in case of passing HST services.

An **optional avoiding line** for Kaunas – Vilnius trains is shall be foreseen in case freight trains with dangerous goods are not allowed to pass Kaunas Airport station due to safety regulations. Depending on alignment constraints (curve radius) this track would also be beneficial for Vilnius – Warszawa and Vilnius – Kaunas HST train services which are not planned to stop at Kaunas Airport station.

4.7.6.2. Karmelava freight station

According to current planning stage there should be an option to develop an additional freight facility in Kaunas area in order to provide:

- additional capacity for parking of freight wagons

- freight rolling stock maintenance facilities, if needed
- additional terminal capacity to handle the forecasted amount of intermodal freight to be transshipped at Kaunas area[84].
- needed facilities to remarshalling of freight trains, e.g. to adapt train length from 750 m (Poland/Western Europe) to 1,050 m train length (Rail Baltica), depending on further development of facilities closed to the Polish/Lithuanian border
- provide additional loading capacity for handling of wagonload services

Role and track layout of the proposed station are not finalised at the time of report writing. An initial track layout study provided by LG is depicted in the figure below. According to this study the station is designed for remarshaling and stabling of freight trains and for rolling stock maintenance. Suggested location is on the western leg of Kaunas triangle adjacent to the north-south main line.

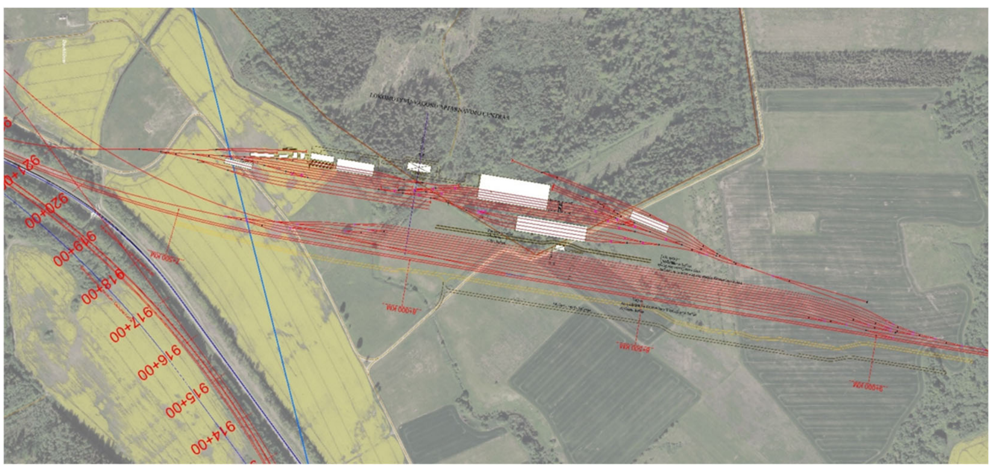

Figure 95: Layout study Karmelava freight station85

In order to allow easy road access and to provide for future area extentions it is suggested to keep this location outside the triangle and parallel to the main line, if still feasible subject to final alignment of Kaunas triangle. One downside of the chosen location is that a direct access from the main line to Vilnius cannot be provided. For finalizing the currently proposed track layout for Kaunas triangle as depicted on the track map in annex 1 and in Figure 94 it was assumed that freight trains from and to Vilnius need to change direction using dedicated loop tracks at Kaunas airport station. If this cannot be implemented, e.g. because of trains with dangerous goods are not allowed at

[85] Source: Presentation LG from TWG meeting 02.05.2018 (design parameters workshop)

Kaunas airport station an alternative track connection to Kaunas – Vilnius line or moving location of tracks for reversing (e.g. adjacent to Kaunas – Riga line) shall be foreseen.

Conclusion from operational plan is that the station should be placed at the proposed location outside of the triangle to ensure easy access by road and to allow enough spece for area extensions.

Given that from current perspective the space for development of additional terminal capacity at the vicinity of existing Kaunas intermodal terminal is limited and taking into account the number of trains to be loaded and unloaded at Kaunas according to the proposed train service pattern it is strongly recommended to provide an intermodal terminal at Karmelava as well. Terminal tracks shall be designed for handling of complete trains. The layout shall be developed such that intermodal trains can enter and leave the terminal tracks directly without additional need for shunting.

If the freight station cannot be provided at the proposed location, an alternative should be sought. To provide rail access to complete Rail Baltica network direct access to Vilnius without the need to change trains direction shall then also be possible. Potential candidate locations from operational viewpoint would be Jonava freight station or Ruciunai station. In the latter case also a connection to 1520 mm network could be considered or a location south of Jiesia (e.g. adjacent to proposed passing loop km 78.0), if sufficient road access can be ensured.

In order to determine optimum location and layout of a future freight station incl. intermodal terminal facility in Kaunas area, a separate study should be conducted. This should include the railway side and the demand side to shift volumes from from road to rail for Kaunas area and a wider catchment area including needs of local businesses (Kaunas FEZ and other industries, industries at Jonava area, interconnectivity with 1520 mm lines).

4.7.6.3. Track layout Palemonas Station

Palemonas Station

Traditionally, Palemonas station does serve as a shunting yard for 1520 mm and as a gateway for freight transport (including provision of connections to various industrial sidings on the west side of the station). In addition to that local 1520 mm passenger trains stop at Palemonas station.

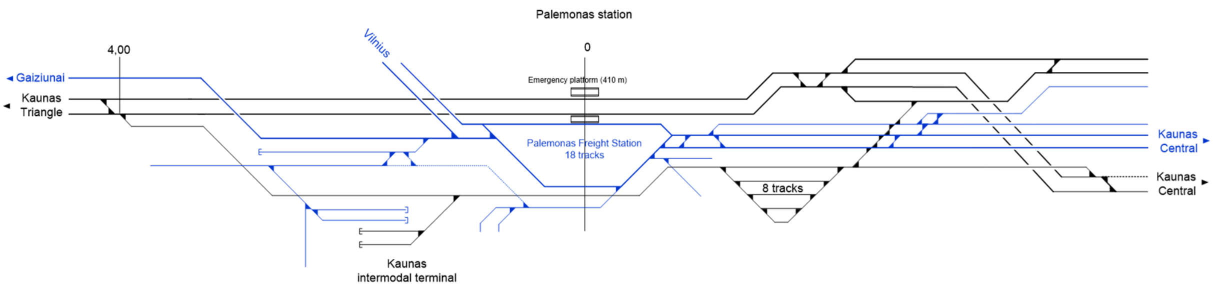

Figure 96: Track layout Palemonas station (1520 mm simplified)

The Rail Baltica main tracks will be situated on the East side of the station crossing the Kaunas – Vilnius line. In order to reach freight facilities and Kaunas Central station trains have to cross 1520 mm tracks. According to Rail Baltica Design Guidelines no gauge crossings on main tracks are allowed. According to the current planning stage the following solution developed by RB Rail will be implemented:

- The crossing with the existing 1520 mm Kaunas – Vilnius railway line will be implemented grade separated with Kaunas – Vilnius line overpassing Rail Baltica running lines.
- The connection from the 1435 mm main line to Kaunas Central station will be implemented by a cut and cover tunnel on the south side of Palemonas station. Due to restrictions in the area that would mean implementing gradients of up to 25 ‰. This is feasible, since the connection will be exclusively used by passenger trains. Freight trains to Kaunas main station could still use the provided track on the west side of the station.
- Adherence to Design Guidelines also means that the crossing with existing Palemonas – line to Gaižiūnai shall be a grade separated solution.

The resulting situation is depicted in Figure 96. A detailed layout of Palemonas station to scale is provided in annex 1 (initial solution with gauge crossings and RB Rail solution). The proposed development of the freight reception sidings is also depicted in annex 1.

With a total of 90 to 178 trains per day the line section is one of the most occupied sections of the Rail Baltica network. Implementing full grade separation as proposed will contribute to operational quality on the complete line and ensure that the necessary paths can be provided. This applies to the grade separated crossing of the Kaunas – Vilnius line on the north side as well as to the grade separated cut-and-cover solution for the line to Kaunas Central Station. If the latter solution was not implemented this would mean:

- Potential conflict between passenger trains to Riga and 1435 mm freight trains to the bypass
- Potential conflict between passenger trains from/to Kaunas Central station and 1520 mm freight trains from/to single track 1520 mm Kaunas bypass.

- Additional speed restriction on gauge crossings depending on final technical design[86] of this non-standard crossings to be tailor-made for purpose of Rail Baltica.

Taking into account the expected amount of passenger trains between Kaunas Central station and Kaunas triangle (60 trains time horizon 2026; 90 trains time horizon 2056 corresponding to 4 to 6 hourly passenger trains) and the already existing bottlenecks on the line Kaunas Central station - Palemonas (single track, gauntlet track Kaunas tunnel) implementation of cut-and-cover solution is highly beneficial, not only because it increases the capacity but also to reduce complexity of dispatching and signalling.

Kaunas intermodal terminal

The station will also serve as major freight transport hub for Rail Baltica by means of the Kaunas intermodal terminal, which is part of the Kaunas Public Logistics Centre (PLC). The terminal is designed to handle an annual freight volume of approx. 100.000 TEU. For loading and unloading of trains 2 loading tracks for 1435 mm gauge with a usable length of 440 m are foreseen. This will require splitting of train for loading and unloading in most cases. Possibilities to extend the terminal facilities on the current site are limited due to usage of surrounding areas. Subject to the feasibility to adapt the storage and road area two more loading tracks might be realized if needed. This is strongly recommended in the light of the expected freight traffic (1/3 of train services from Poland might have Kaunas area as their destination). For loading and unloading of 1520 mm two additional loading tracks already exist.

The related reception sidings for 1435 mm will be situated on the southwest side of the station. According to the current planning stage a track group with up to 8 tracks and usable track lengths up to 1050 m for the longest tracks can be implemented here. To ensure interconnectivity with the terminal and other freight facilities on the West side of Palemonas yard an additional 1435 mm main track will be provided at the West side of the station. This track will require several gauge crossings with 1520 mm yard tracks and sidings. These gauge crossings have been assessed regarding occupation rate to be expected during the conceptual design phase by LG. The result was that occupation is acceptable.[87]

The functionality of the reception sidings will require entrance and exit routes towards the Polish border. According to current planning stage of LG Kaunas intermodal terminal will be at first connected to the existing 1435 mm track at Kaunas main station using the track at the West side of Palemonas station. With growing traffic on Rail Baltica and in accordance with EU white book requirement to bypass city centres with freight services the terminal will be connected to the Kaunas bypass.

Therefore, a direct track connection to the Kaunas bypass line will be needed. Without compromising the usable track length in the reception yard on its currently planned location, this track connection could only be implemented by means of 1435/1520 mm gauge crossings passing all 1520 mm main tracks. This could only be avoided if

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[86] Example: currently implemented gauge crossing only allows for 40 km/h.

[87] (UAB "Nacionalinių projektų rengimas" / UAB "Kelprojektas" 2013)

trains from and to the reception yard will run via Kaunas Central station thus occupying the Kaunas tunnel bottleneck. Therefore this option is not included in the timetable examples developed for operational plan.

As part of predesign activities a more suitable location of reception sidings North of Palemonas station was assessed. According to current status such a solution cannot be implemented due to spatial planning constraints. If capacity boundaries of Kaunas Intermodal terminal will be reached, which is likely according to the freight traffic forecast provided in chapter 2.4.2, implementing intermodal terminal at Karmelava freight station would provide the necessary relief.

4.7.6.4. Track layout Kaunas Central Station

Current status

Today Kaunas Central station is an important passenger service hub of 1520 mm Lithuanian railway system with train services to Vilnius, Sestokai/Marijampole, Kybartai. Since 2015 the station is also connected to the 1435 mm network from the south. Therefore two dead end platform tracks (platform length: 204 m) exist. According to current planning stage, with introduction of Rail Baltica only two platform tracks for 1435 mm are foreseen. The currently implemented track layout is depicted in Figure 97. 1435 mm tracks are marked by in blue color. 1520 mm tracks are depicted in black.

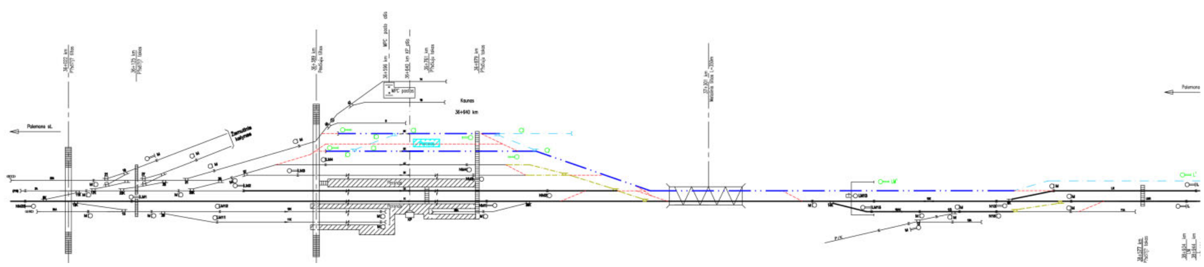

Figure 97: Track layout Kaunas Central station[88]

Since 1435 mm trains have to share the Kaunas tunnel with 1520 mm trains on one gauntleted track and 1435 mm platforms are to be placed on the east side of the station there is the need to implement a track layout with gauge crossings at the north side of the station.

On the east side of the station infrastructure and rolling stock maintenance facilities are provided (Zemutinis track yard). 1520 mm movements from/to these facilities will have to cross 1435 mm tracks.

Rail Baltica Timetabling Requirements

[88] Source: drawing provided by LG

The current operational plan requires that the high-speed trains in up and down direction will meet in Kaunas Central station. In order to provide fast and convenient interchange regional trains shall wait at the station at the same time. Depending on the route of the high-speed trains, interconnecting trains shall provide the missing link from/to Vilnius or towards Riga (see 4.5.5.1).

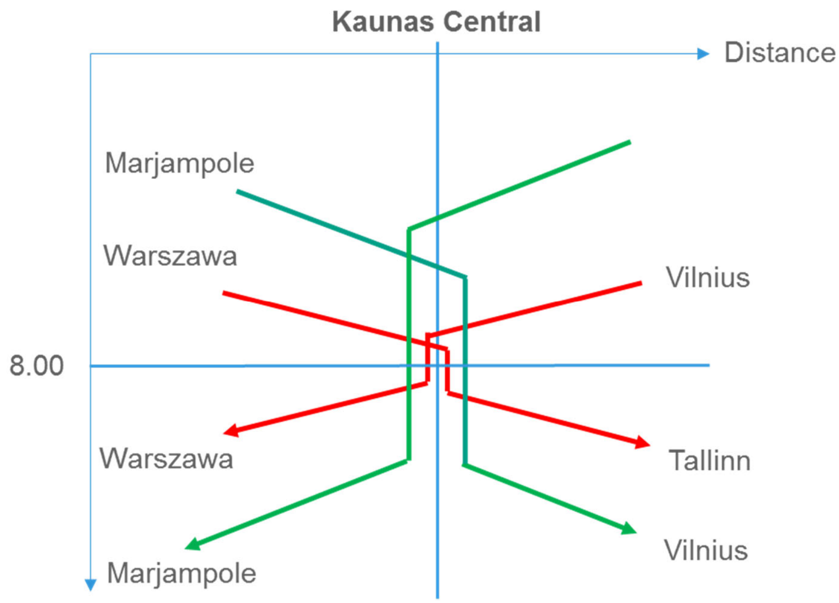

Figure 98: Timetabling principle: Meeting of trains at Kaunas Central station

The resulting track occupation diagram for Kaunas Central station is depicted in the following figure.

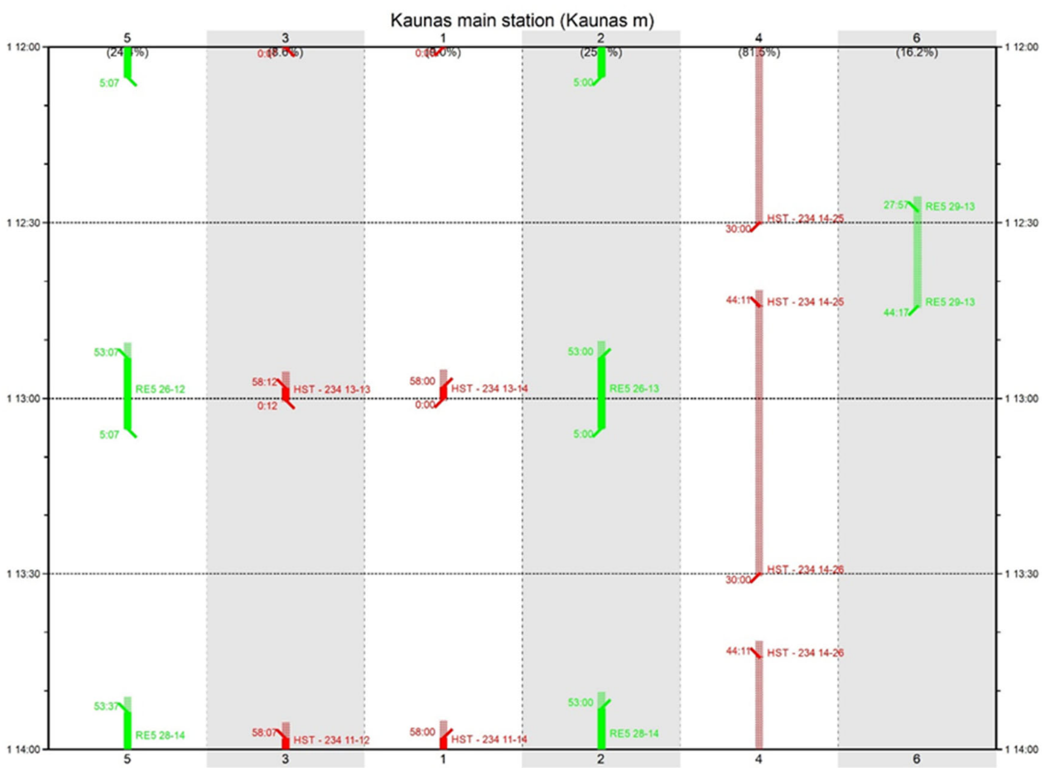

Figure 99: Kaunas Central station - Track occupation diagram

To realise the outlined target timetable at least 6 platform tracks (1435 mm gauge) at Kaunas Central station will be required, if the trains have to turn around at the platforms:

- Min. 2 platforms for HST service (200 m with extension option to 410 m). To accommodate for trains coupling and sharing, if needed in the future maximum possible platform length shall be at least 410 m.
- 2 platforms regional trains (200 m, extension option to 410 m beneficial to provide long term flexibility)
- 2 additional platforms for terminating trains from Vilnius (at least 200 m platform length). In principle these platforms could be designed as dead end tracks.

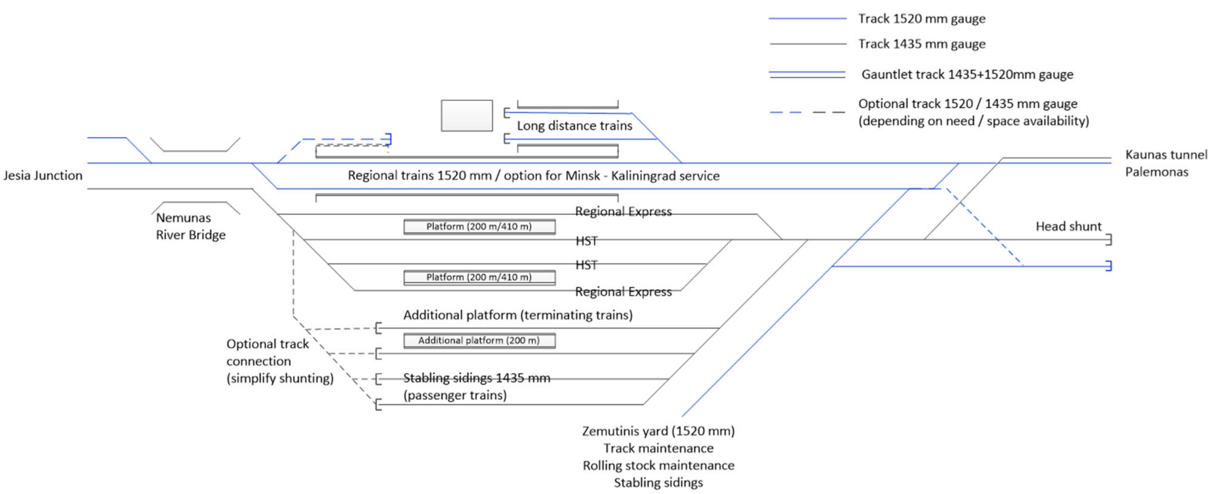

Figure 100: Track layout Kaunas main station – minimum requirements for operational plan

A more advanced layout would provide:

- Double track 1435 mm over Nemunas river
- At least two additional turning sidings south of Nemunas bridge

This would allow additional flexibility and a more customer friendly solution without the need for passengers interchanging from/to Vilnius to change platforms. Connecting service from Vilnius would arrive shortly before HST Tallinn – Warszawa (on the same platform as Tallinn – Warszawa service), turn at the turning siding south of the river and depart after train Warszawa – Tallinn service (on the same platform as the Warszawa – Tallinn service).

The corresponding layout is depicted in Figure 101. Since the trains from Vilnius would use the turning siding, only four platforms (through tracks) would be required.

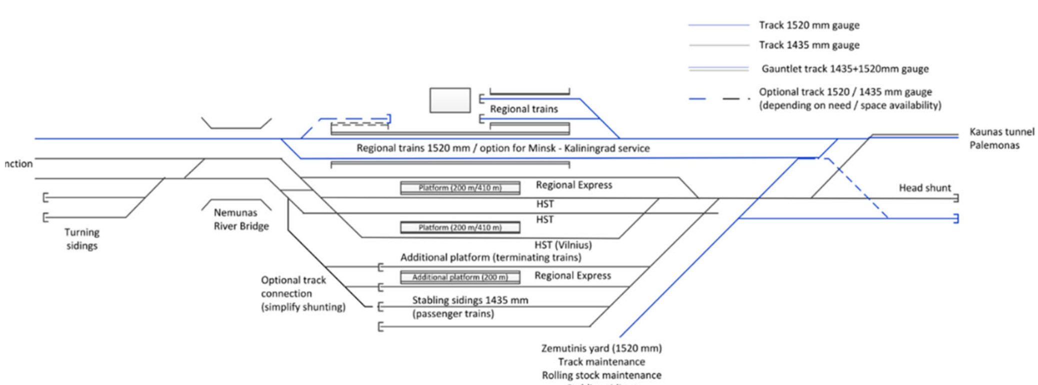

Figure 101: Track layout Kaunas main station –advanced layout

Conclusion

In order to serve the 1435 mm Kaunas – Vilnius connection in the best way, there is the need to provide connecting trains at Kaunas Central station. To provide optimum connection with short transfer times the HST trains meet in Kaunas Central station while connecting services are waiting at other platforms. Thus more than the proposed two platform tracks will be needed depending on the final decisions regarding regional traffic on 1435 mm.

Results of the timetabling study carried out as part of the operational plan indicate also that provision of a turning facility for 1435 mm south of Nemunas river would be required in order to provide the most attractive timetable and to minimize number of required platform tracks in Kaunas Central station.

Given the space constraints in the area a detailed layout study needs to be carried out reflecting the requirements outlined in the operational plan out taking into account:

- required train service pattern 1435 mm as defined in the operational plan and stated requirements on track layout,
- available area for development of track layout,
- future requirements for 1520 mm operation,
- future requirements on functionality of Zemutinis track yard.

4.7.6.5. Single track section Palemonas – Kaunas Central station – Jiesia

According to preliminary design the line section Palemonas – Kaunas Central station – Jiesia is planned to be designed as single track line. The situation is depicted in the following figure. In Kaunas tunnel a gauntleted track section will be implemented, which means 1435 mm trains for Rail Baltica and 1520 mm on the conventional 1520 mm network. Results from capacity analysis indicate that single track will provide for required capacity.

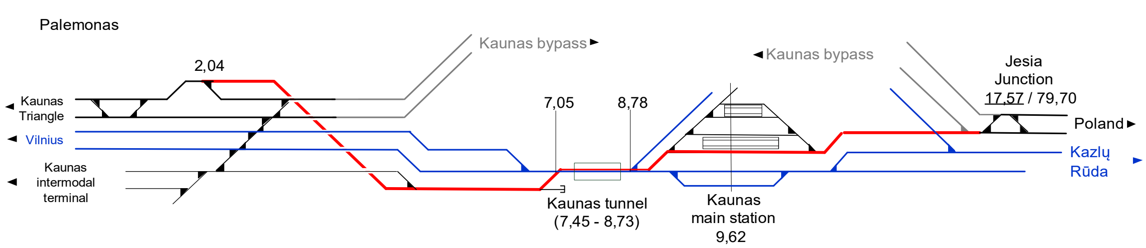

Figure 102: Initially proposed track layout single track Palemonas – Kaunas Central – Jiesia

Results from capacity analysis undertaken based on the implemented RailSys timetable show that there will be sufficient capacity. This is illustrated by capacity analysis according to UIC 406 method for section Kaunas Central station – Jiesia. Calculated concatenated occupation time rates:

- 22.7 % for 24 hour period,
- 31.1 % for peak hour (14.00-18.00)

These rates are below recommended upper line utilisation boundaries. This calculation is based on the assumption that sufficient platform capacity at Kaunas Central station can be provided.

To occupy the track for 75% of the time during peak hours (recommended upper boundary for max. capacity); there is room for 42.9% more, equivalent to 18 trains in 4 hours.

Same applies to Kaunas tunnel (see section).

Nevertheless the following restrictions apply:

- Train timings on this section will be ruling passenger timetable planning on the whole Rail Baltica network (e. g. meeting of trains in up and down direction in Kaunas Central)
- If up and down line passenger trains meet in Kaunas main station minor delays of trains in up direction (up to approx. 8-10 min) will have an impact on trains in down direction. To compensate these delays additional run time supplements will be needed slowing down passenger services.
- If the planned meeting of HST services in Kaunas is implemented, punctuality of meeting trains is critical for overall punctuality along the whole Rail Baltica corridor. Slight delay of inbound train from North or south will cause a delay for the outbound train, which needs to wait until the single track section is cleared by the meeting train to Kaunas Central.
- Flexibility to set up a customer friendly timetable is limited due to occupation of the single track section.
- Ease of operation in the remaining bottleneck Kaunas tunnel (trains to Kaunas can wait at the junction for trains in opposite direction).

Above stated arguments showing the need to provide timetabling flexibility and to restrict propagation of delays in daily operation are supported by overall analysis of line capacity for longer sections Panevėžys – Kaunas Central, Vievis - Kaunas Central and Marijampole – Kaunas Central indicating exceed of recommended upper boundaries of line capacity utilisation (see Table 138 in section 4.5.9).

In Figure 103 the principle of meeting of high speed trains in Kaunas is shown as graphical time-distance-diagram. In this example train 1 (direction Tallinn – Warszawa) is delayed. Thus train 2 has to wait at Kaunas until the single track section to Palemonas is cleared by train 1. This results in a following delay for train 2, which arrived on time in Kaunas Central. This following delay can be avoided or minimised by additional run time supplements, but this will result in longer travel times of the high speed trains. Double tracking of sections Palemonas – Kaunas tunnel (excl.)

and Jiesia – Kaunas Central would ease operation and will minimise interdependencies between trains of both directions.

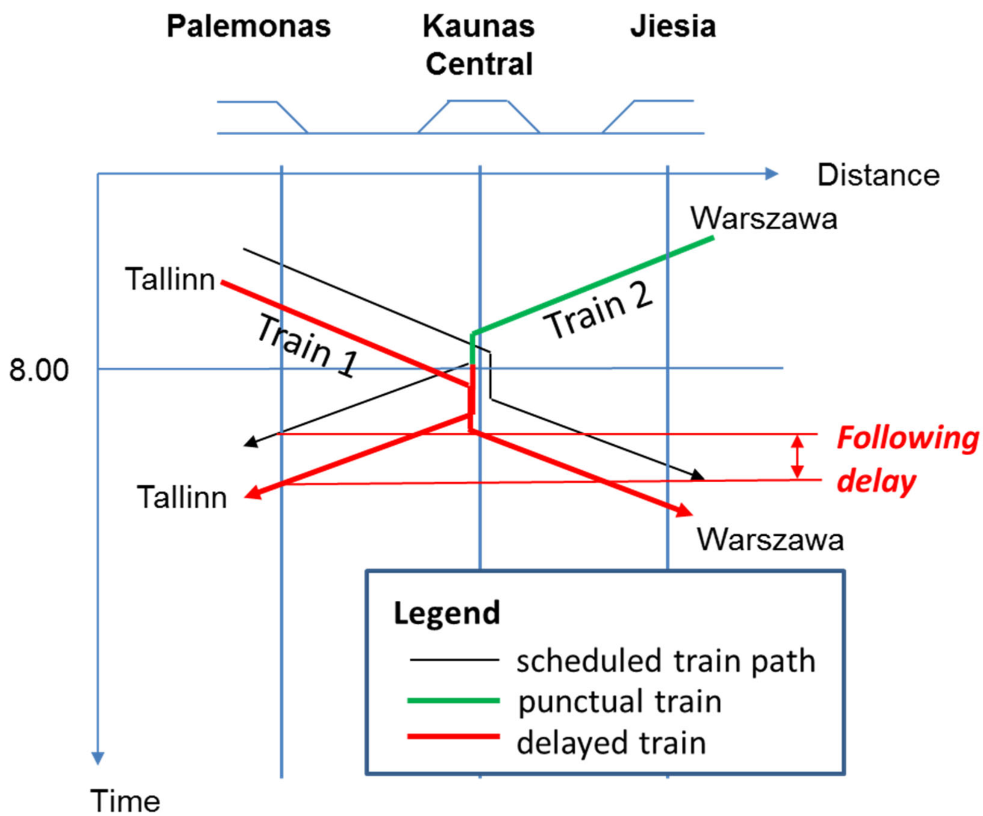

Figure 103: Meeting of HST in Kaunas – example of following delay due to single track sections

Given these restrictions and the high importance of punctual operation for attractiveness of Rail Baltica at least double-tracking of this line section, Palemonas – Kaunas tunnel should be considered to increase punctuality of operation. If this solution is implemented as a second step at a later stage, the cut and cover solution proposed at Palemonas shall be prepared such, that double tracking can be easily implemented at a later stage.

Since the delay propagation issue described above (also applies to lower occupied section Kaunas Central – Jiesia, provision for double tracking of this section at later stage shall be made in layout of Jiesia junction to avoid costly rework of layout and to minimise traffic disruption during related engineering works. Double tracking of this section might be also considered if it is decided to implement turning facility south of Nemunas River. To avoid costly construction of an additional bridge over Nemunas River, provision of one gauntlet track could be considered as workaround.

Resulting development of track layout for Palemonas – Kaunas Central – Jiesia section is depicted in the figure below. The depicted time horizons are based on development of train service as outlined in this operational plan.

Implementation timeline will depend on final decision regarding regional traffic on 1435 mm and on future development of passenger traffic on 1520 mm in Lithuania.

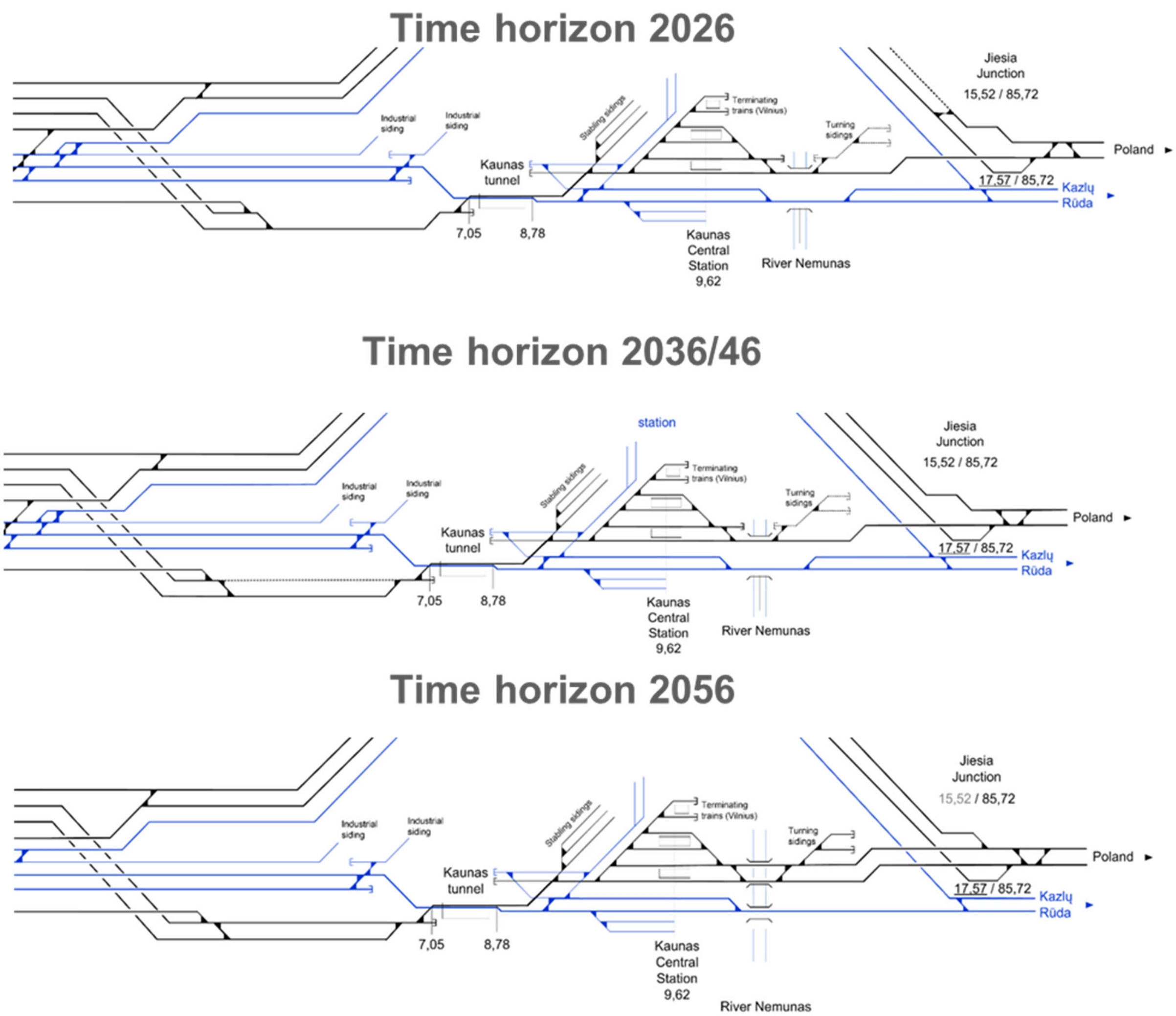

Figure 104: Recommended development stages fortrack layout Palemonas – Kaunas Central - Jiesia

4.7.6.6. Kaunas tunnel

Utilisation of single track lines Palemonas – Kaunas – Jiesia has already been addressed in the previous chapter. Overall, line capacity will be sufficient to handle expected amount of traffic up to the end of the forecasting period (2056). Remaining question is how many additional 1520 mm traffic can be handled on the tunnel section.

To answer this question, UIC 406 capacity utilisation was calculated for the line section from Kaunas Central station to Kaunas tunnel. According to calculation results for the peak hour (14.00 – 18.00) the trains occupy the track section 31, 4% of the time, equivalent to 24 trains passing the tunnel during this four hour period. To occupy the track to maximum line capacity approx. 33 more trains could be operated before maximum capacity would be reached. This indicates that there will be still a lot of spare capacity to be utilised.

The results indicate that there will be at least three to four slots per hour still available which could be used for 1520 mm trains. This would mean the tunnel will be passed by 9 to 10 trains per hour passing the tunnel. However, the whole timetable system will then be even more prone to propagation of delays within 1435 mm system as well as between the systems (1435 mm and 1520 mm). Such a high level of utilisation can only be reached if there are not too many additional operational constraints in the surrounding area.

4.7.6.7. Jiesia junction and Kaunas Bypass

The 15.5 km long Kaunas bypass will allow freight trains to bypass Kaunas Central station and to avoid Kaunas city area by providing a separate connection between Jiesia junction and Palemonas station. In this section the alignment of Rail Baltica will be parallel to the existing single track freight bypass for 1520 mm, which is mainly used for transit services from and to Kalinigrad. The track layout of Kaunas bypass currently proposed by RB for Kaunas bypass and Jiesia junction is depicted in Figure 105 below. Tracks of Rail Baltica Kaunas bypass are marked red. Initial proposal of RB Rail is to provide Kaunas bypass as double track solution except the 1 km km long single track section where the railway track will cross the dam of Kaunas hydroelectric power station using the existing structure of the dam. Provision of double track on this section will be costly. As a result of former planning activities for previous phase of Rail Baltica implemented by Lithuanian railways, a 1435 mm single track solution to connect Palemonas station with 1435 mm network was planned. This solution is currently partly implemented from Jiesia junction as far as Rokai station. At the time of report writing construction of the remaining section was not started. This solution does also include a gauge crossing with 1520 mm at Jiesia junction to provide connection to Kaunas Central station, which is already in service.

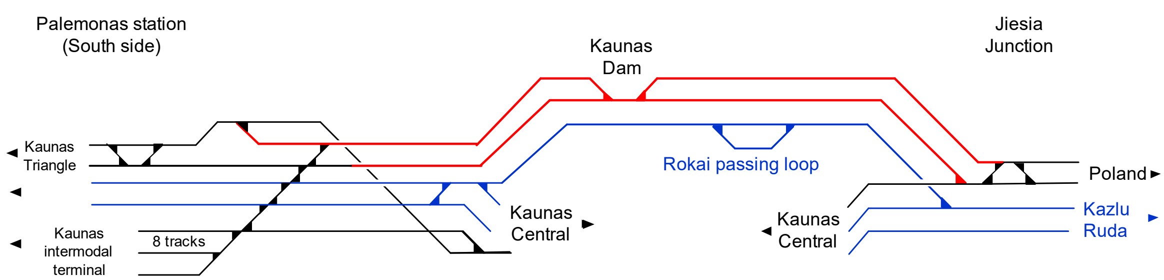

Figure 105: Kaunas bypass – track layout proposed by RB Rail

To be compliant with the RB Design Guidelines Jiesia junction shall be designed without grade separation for 1435 mm. According to the RB Design Guidelines Jiesia junction shall have no gauge crossings with 1520 mm. To comply with this requirements Jiesia junction would be needed to be grade separated as depicted in Figure 108.

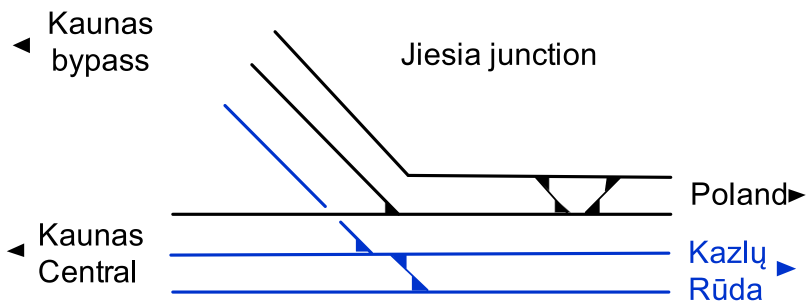

Figure 106: Proposed design of Jiesia junction without gauge crossing according to Rail Baltica Design Guidelines

Given the already existing planning for Kaunas bypass and the currently implemented stage at Jiesia (gauge crossing with 1520 mm) the question remains, whether the initially planned layout will be sufficient. Therefore the following options for development of track layout will be analysed separately:

- Jiesia Junction: Crossing with 1520 mm at grade
- Jiesia Junction: At grade junction 1435 mm
- Kaunas bypass: Single track instead of double track

These options are depicted in the figure below.

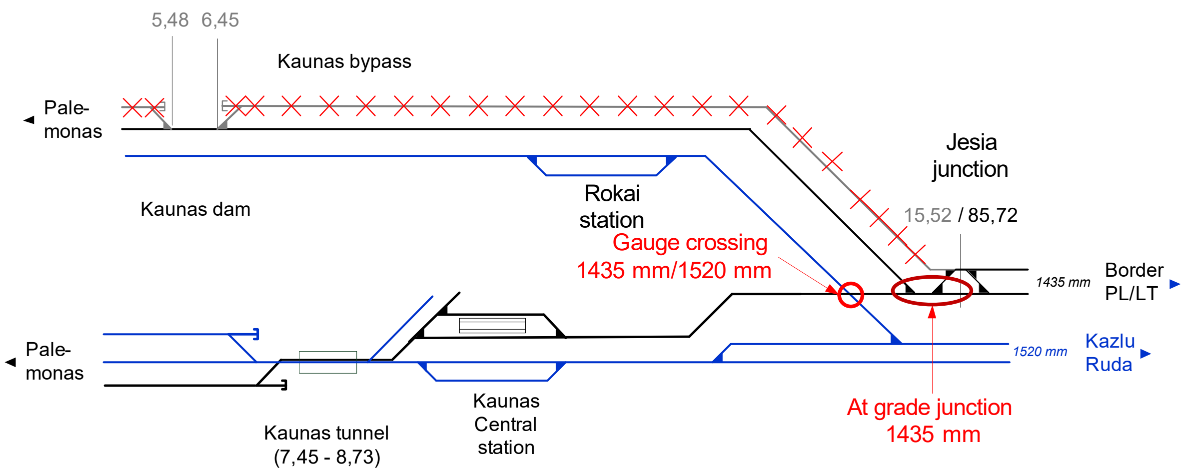

Figure 107: Investigated Layout options for Jiesia junction and Kaunas bypass

Jiesia junction: Gauge crossing 1435 mm / 1520 mm

In the currently implemented track layout for Jiesia junction the existing 1520 mm track to Kaunas bypass will cross the 1435 mm line to Kaunas main station at the same level. Maximum speed on the crossing is 40 km/h for 1435 and 1520 mm trains. Keeping this solution will have negative impact on travel time and energy consumption.

To support evaluation of impact of keeping this or a similar solution the remaining slots for crossing 1520 mm have been analysed. For this purpose UIC 406 method was applied to the timetable for section Kaunas Central – Jiesia. As already outlined in chapter 4.5.9 line utilisation will be 32 % in peak (concatenated time occupation rate). To occupy the track on the complete section for 75% of the time (upper boundary for stable operation according to UIC leaflet 406) there is room for 18 additional trains within 4 hours in the peak time. That means approx. up to 4 additional 1520 mm trains hourly could pass the non-grade separated junction. According to the current working timetable not more than 2 to 3 hourly trains are operated on the single track section Jiesia – Rokai.

This indicates that the gauge crossing is not a big capacity issue as long as Rail Baltica services will be prioritised accordingly, which means:

- During timetabling phase: Fixed interval timetable for long distance trains and regional services are not compromised during timetabling phase
- During daily operation: High speed trains have priority over 1520 mm fast trains and regional trains must not be delayed by freight trains on 1520 mm.

Nevertheless additional complexity will be added to a system already prone to small delays due to single track operation Kaunas – Jiesia. In addition the speed over the junction will be lower than speed on adjacent track sections.

Jiesia junction: At grade junction 1435 mm

As pointed out above Jiesia junction shall be implemented grade separated to avoid gauge crossing with 1520 mm. In this case it is recommended to provide a junction layout which also includes grade separated junction to Kaunas bypass avoiding at grade junction on 1435 mm depicted in Figure 107. Advantage of this is the flexibility to operate 1435 mm freight trains on the Kaunas bypass during times with passenger traffic. After end of ramp up period (time horizon 2036/46/56) the route node depicted in Figure 107 will be passed by up to approx. 7 trains per hour (3 freight trains to Poland, 2 HST trains from/to Poland and 2 Regional Express trains) in peak time. Slots for passenger trains are more or less fixed due to single track situation on the line to Kaunas main station and cannot be moved. Given the line utilisation on the mixed traffic lines as indicated in section 4.5.9 it is advisable to provide complete grade separation also on 1435 mm. Junction layout shall be designed such that double tracking on line section Kaunas Central – Jiesia can be implemented at a later stage.The recommended junction layout for final stage is shown in.the following figure.

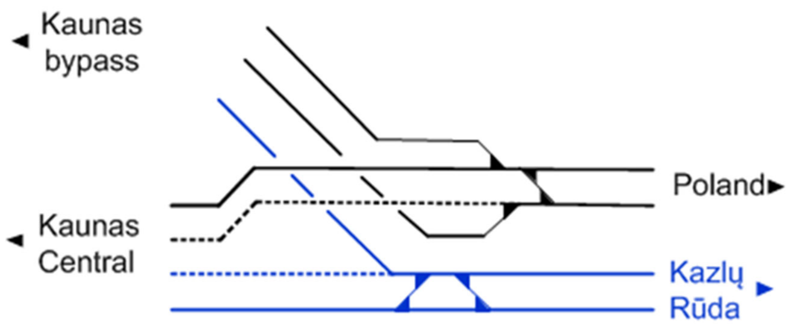

Figure 108: Jiesia Junction – layout with complete grade separation (1435 mm and 1520 mm)

Single track Kaunas bypass

In the present timetable example, the bypass is assumed with double track except for the Kaunas Dam.

Kaunas Bypass is the freight train connection from the Baltic countries to Poland. The bypass leads the freight trains around Kaunas without passing the passenger station.

To operate the train service pattern 2056 6 freight trains per direction per two hours will be required (3 freight trains per direction per hour) in a conflict free timetable with mixed traffic (see annex 6). In the Railsys timetable 144 conflict free paths have been implemented for 24 hour period. Taking into accoung a nightly maintenance time window of four hours this would correlate to at least 120 train paths. For this timetable double track between Kaunas Dam and Jiesia Junction as shown on the track map in annex 1 and in Figure 107 is assumed. Thus it can be concluded that capacity of a double track Kaunas bypass will be sufficient, also in the long term (time period 2056).

To evaluate single-track capacity on Kaunas bypass two sample timetables were constructed:

- Option 1: Complete single track Palemonas – Jiesia
- Option 2: Complete single track Palemonas – Jiesia with additional passing loop at Rokai meant to improve capacity

To ensure that the pathing regime is not too optimistic the sample timetables were constructed for section Kaunas triangle south to the passing loop at section km (section Jiesia – border PL/LT) south of Jiesia. Furthermore, the train paths were evenly distributed over 20 hours thus allowing for a maintenance time window of 4 hours and not over-estimating amount of freight trains to be operated at night time. With approx. 3 to 4 hourly required trains (sum for both directions) throughout the complete day this assumption seems also to be realistic for operation during nighttime.

Capacity of Option 1 (complete single track without additional passing loop at Rokai):

An extract of the constructed example timetable is provided in Figure 109 below. To maximise possible capacity utitilisation on the single track line it is assumed that two freight trains in the same direction are following each other. Therefore the freight trains need to wait for their slot at the passing loops south of Jiesia and at Kaunas triangle (or Palemonas).

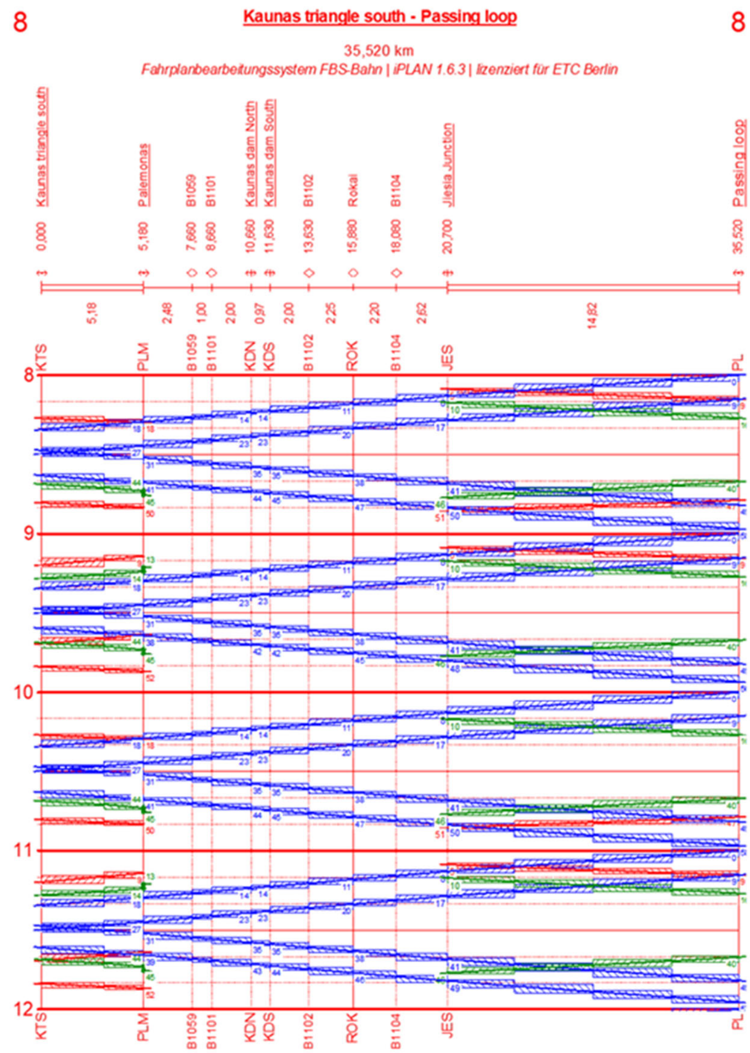

Figure 109: Sample timetable for capacity evaluation Kaunas bypass (Option 1, without passing loop at Rokai)

Based on the constructed timetable the nominal capacity of the single-track Kaunas bypass can be estimated at 80 freight trains per day (total for both directions) taking into account still sufficient operational quality (concatenated occupation time rate below 60% for 20 hour period).

In Figure 109 the estimated nominal capacity of 80 freight trains per day on single track Kaunas bypass is compared to the required number of freight trains according to consolidated traffic forecast.

Based on these figures it can be concluded that the capacity limit of Kaunas bypass will be exceeded within the forecasting period. Looking at the utilisation of timetabled capacity for time horizon 2036/46, the capacity limit will be reached within first 15 to 20 years of operation according to consolidated freight train forecast. It must be noted that the number of required freight trains does not include reserves for maintenance trains and empty runs (e. g.

light engines). Comparison with estimated required number of freight train paths incl. light runnings, maintenance trains and a reserve for timetabling flexibility illustrates, that a single track Kaunas bypass will be a limiting factor for attractiveness of freight services on the complete Rail Baltica line.

It can be argued that with introduction of long freight trains (1,050 m maximum length) the number of required paths will be lower than forecasted. However, currently it is not clear where longer freight trains will be formed and how the market will adopt to this offer.

Capacity utilisation Kaunas bypass	Time horizon			
Year	2026	2036	2046	2056
required capacity (freight trains per day)	54	62	72	84
nominal capacity single track bypass[89]	80	80	80	80
utilisation of nominal capacity	68%	78%	90%	105%

Table 139: Capacity utilisation Kaunas bypass for option 1 (complete single track bypass)

<u>Capacity of Option 2 (complete single track with additional passing loop at Rokai):</u>

The evaluated sample timetable for single track Kaunas bypasss with passing loop at Rokai is depicted in Figure 110 below.

[89] Total number of trains for both directions, sufficient operational quality (UIC 406 concatenated occupation time rate below 60% for 20 hours)

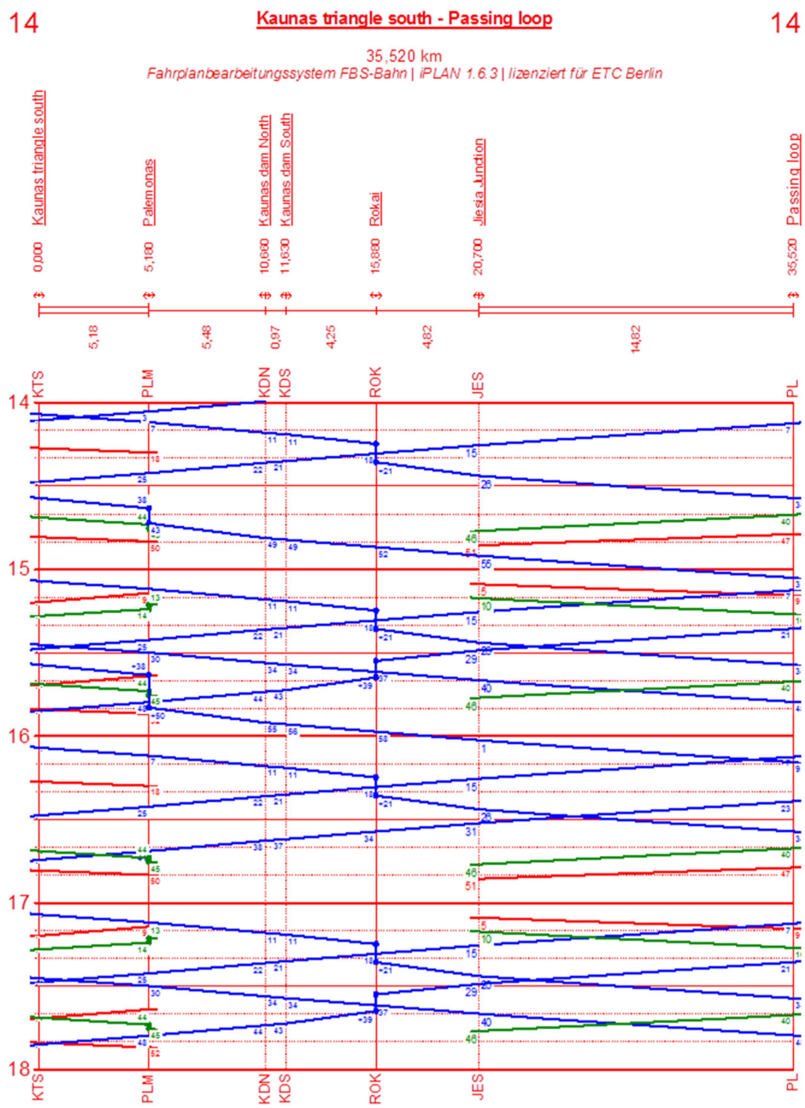

Figure 110: Sample timetable for capacity evaluation Kaunas bypass (Option 2, with passing loop at Rokai)

Implementation of the sample timetable will provide for 88 freight trains per day at still sufficient operational quality (concatenated occupation time rate 57%). The related evaluation of capacity utilisation of single track Kaunas bypass Palemonas – Jiesia with passing loop at Rokai is shown in the table below.

Capacity utilisation Kaunas bypass	Time horizon			
Year	2026	2036	2046	2056
required capacity (freight trains per day)	54	62	72	84
nominal capacity single track bypass[90]	88	88	88	88
utilisation of nominal capacity	61%	70%	82%	95%

Table 140: Capacity utilisation Kaunas bypass

Conclusion

From these results it can be concluded that capacity on the bypass will only be sufficient for first 10 to 15 years of operation. Main advantage of implementation of passing loop at Rokai is that the occupation of passing loops south of Jiesia and at Kaunas triangle or Palemonas will be lower.

Looking at the timetabling examples and taking also structure of long distance and regional passenger train service pattern into account it must be stated that the indicated maximum capacity could only be provided with single track Kaunas bypass if the following conditions are met:

- Jiesia junction will be grade separated as depicted in Figure 108 in minimise interference with passenger traffic on 1435 mm)
- Junction to Kaunas Central Station at Palemonas is implemented grade separated as currently planned (no interference with passenger traffic and traffic on 1520 mm)
- Additional passing loops are provided adjacent to Palemonas, Kaunas triangle or at Palemonas station and south of Jiesia. Otherwise the freight timetable will be more restricted by passenger services, which will lead to reduction of usable capacity on the bypass during daytime
- HST service is limited to two-hourly service interval south of Kaunas

Thus, implementing Kaunas bypass as single track will require additional investments and alteration of existing design in order to provide the necessary pre-conditions to ensure stable operation, namely investment in additional passing loops at Rokai, Palemonas or adjacent to Kaunas triangle south junction. For direction to Kaunas bypass at least two tracks shall be provided at Jiesia and Kaunas triangle. At Rokai provision of one additional loop track might be sufficient.

If single track operation is to be applied during first years of operation when capacity demand will be lower additional investments would be needed to provide such facilities, e. g. additional passing loop at Palemonas, passing

[90] Total number of trains for both directions, sufficient operational quality (UIC 406 concatenated occupation time rate below 60% for 20 hours)

loop south of Jiesia junction. To provide for a modular track layout which can be adapted step by step in line with traffic growth to future needs the following path could be a solution:

- Implement junction to Kaunas bypass at Palemonas as planned
- Implement second track between Palemonas – Kaunas dam.
- Provide for waiting track near Jiesia junction taking into account potential grade separation at Jiesia

Advantage of double track to Kaunas dam is that the single track section is shortened. Thus chances are higher that trains could pass each other without stop. If a stop is required coming from Palemonas this will be possible without impacting the passenger service. Disadvantage is that the incline from Kaunas dam to Rokai is approached with low speed if the train from Palemonas is forced to stop.

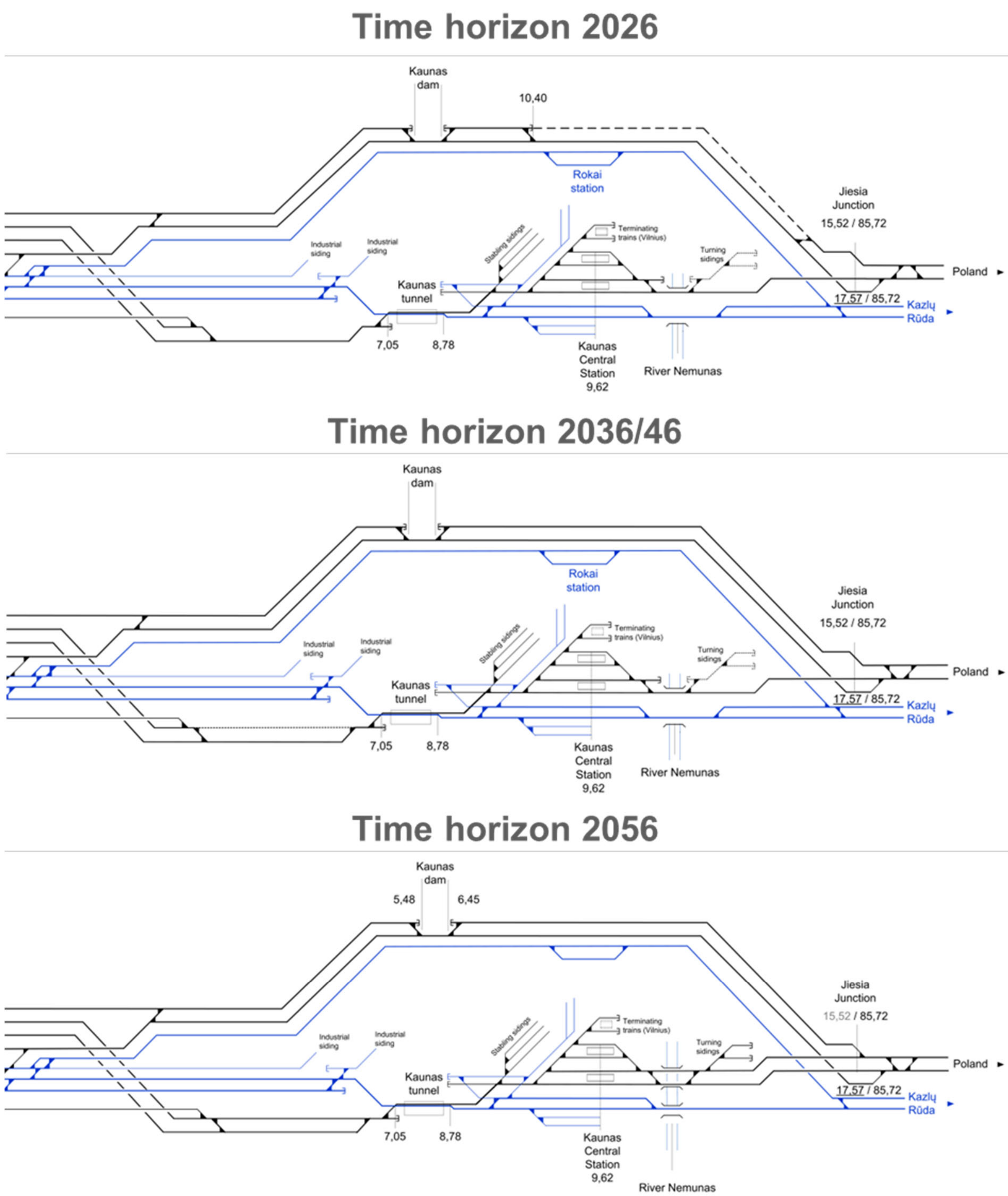

Figure 111: Kaunas bypass – recommended development stages of track layout

The passenger line via Kaunas Central will be of limited use for freight services for the following reasons:

- Diversion of freight trains via Kaunas would put additional pressure on the potential bottleneck Kaunas tunnel
- Proposed gradients at the south side of Palemonas station to provide grade-separated solution will limit trailing load for freight services
- Limited station track capacity at Kaunas Central station.

Because of these obstacles it cannot be considered as significant relief for a single track Kaunas bypass.

Improvement of gradients on Kaunas bypass

The currently planned alignment does foresee vertical gradients of up to 12.5 ‰ in direction North – South. The critcal section is 300 m long and located between Kaunas dam and Jiesia. This value is the maximum permitted value according to Rail Baltica Design Guidelines. In addition to that curve radii have to be taken into account since curves in the section concerned are in a range having a significant impact on train resistance. For example, in the critical section curve radius is 512 m. Since the section concerned is rather short train length does have a significant impact.

Taking into account the critical section with highest gradient and there are different ruling gradients depending on train length. In the table below the maximum trailing load is depicted for a typical intermodal train consist with 80% utilisation depending on the length of the train and Bo’-Bo’ locomotive with axle load of 22.5 t (since adhesion weight will determine tractive force). It is assumed that the train does not come to a standstill in the critical section and on the neighbouring sections with slightly lower gradients.

Given the specific local situation on line section Kaunas dam – Jiesia, restart with complete train in the slope from standstill is only necessary in case of an incident. Passing of trains can be ensured by proper desing of block sections. Thus it can be assumed that the train will not stop until normal operating conditions. In addition to that it is acceptable if the speed of the train will drop when the train is approaching the gradient since the section concerned is not used by passenger trains under normal operating conditions. Given above stated conditions

Train length	500 m	790 m	950 m
Ruling gradient	12.6 ‰	10.3 ‰	8.3 ‰
Maximum trailing load	**1340 t**	**1.660 t**	**2.200 t**
Minimum speed (speed drop due to gradient)	52 km/h	56 km/h	35 km/h

Table 141: Maximum trailing load for Bo’-Bo’ locomotive (12.5 ‰ max. gradient)

Train length	790 m
Ruling gradient	9 ‰
Corresponding maximum trailing load	**1.991 t**
Corresponding minimum speed (speed drop due to gradi-ent)	35 km/h

Table 142: Maximum trailing load for Bo'-Bo' locomotive (improved situation with 8‰ max. gradient)[91]

If six axle Co'-Co' locomotives with higher adhesion weight and resulting higher transmissible tractive force are used, no specific additional restrictions will apply to trailing load from currently planned vertical alignment of Kaunas bypass with max. gradient of 12.5‰.

From above stated figures it can be concluded that the main benefit is utilisation of train length and traction power for intermodal trains within TEN-T parameters (22.5 t axle load, train length 500 – 740 m depending on route and destination terminal) and single traction. Comparing results of Table 141 and Table 142, trailing load gain for single traction and Bo'-Bo' locomotive is approx. 20%. Even if provisions for longer trains (1,050 m train length) are made and utilised in line with growing freight demand on Rail Baltica from the infrastructure side, these trains will have in any case a significant share of the total traffic volume. This especially applies to trains from/to destinations in Lithuania, where applying higher train length and remarshaling of the trains en route will have less benefits compared to trains to Latvia and Estonia.

Analysis has shown that due to favourable topographic conditions in the Baltic States gradients on the Rail Baltica mainline (Kaunas – Tallinn) are smaller in all places. As result of ongoing CPTD process they will be further reduced. Overall the nominal gradient limit of 8‰ will not be exceeded. By reaching the upper limit of the Design Guidelines, this section will become the limiting section for train configuration on the entire line, which is especially relevant for single traction and heavy trains with double traction. Therefore it is recommended to reduce the gradient to approx. 9 ‰, subject to technical feasibility. According to that such a reduction would be most benefitial for freight trains to be operated with single traction and an interoperable train length of 500 to 740 m compatible to to TEN-T standards and infrastructure limits in Poland and Central Europe. For usage of longer freight trains with length of up to 1,050 m using double traction will be required anyway, thus additional benefits in this market segment are limited.

[91] Source: Compilation of consultant based on detailed simulation study carried out by Alain Gaudry

4.7.6.8. Conclusions

Evaluation of the individual potential bottlenecks Kaunas tunnel, Jiesia junction (without grade separation), single track line Palemonas – Kaunas Central - Jiesia, gauge crossing at Jiesia junction shows that each individual bottleneck alone will be no issue regarding required line capacity in short and long term.

Nevertheless, the question remains how stable the operation will be at the end. When interpreting this result is must be also highlighted that timetabling restrictions due to mixed traffic with a rather large speed gap put additional stress on the system. Therefore, a simulation study is suggested to test the impact of delays on the system and to decide which of the described improvement measures shall be implemented to allow stable operation on all line sections in and around Kaunas node. This simulation shall be based on the optimised timetable and also include 1520 mm traffic in Kaunas tunnel. From current viewpoint, partial double tracking of single track line section Palemonas – Kaunas Central – Jiesia is benefitial and therefore shall be considered at later stages of development (beginning time horizon 2036/46). It is recommended to design the junctions at Jiesia and Palemonas for double track from the beginning.

To avoid gauge crossings with 1520 mm, to ensure necessary capacity and operational flexibility and to simplify technical solutions (e.g. interlocking at Palemonas) the crossings at Palemonas station shall be designed grade-separated from the beginning. According to current planning stage one gauge crossing will remain in order to provide access from Kaunas bypass to 1435 mm freight reception sidings at the south west side of Palemonas station and to Kaunas intermodal terminal.

If Kaunas bypass would be implemented as single track, the capacity boundaries will be reached soon (time horizon 2036/46) given the number of expected freight trains and the number of required train paths to provide necessary flexibility for timetabling of different services by different operators. This also applies, if a passing loop is provided in Rokai or the single track section is reduced to Kaunas dam – Jiesia. Furthermore, implementation as single track would require additional infrastructure investments to ensure that freight trains can wait closed to the bottleneck without negative impact on the passenger train operation (at least additional passing loops at Palemonas and Jiesia junction). Therefore it is recommended from operational viewpoint to implement Kaunas bypass as double track from the beginning. From capacity viewpoint it could be considered to implement Kaunas bypass as partial single-track as depicted for time horizon 2026 in Figure 111 above but to prepare the line for later upgrade, which according to traffic forecast will be necessary after first 10-15 years of operation. That includes spatial planning, land acquisition, and preparation of embankment as well as implementation of junctions at Palemonas and Jiesia for double track Kaunas bypass from the beginning.

Regarding alignment of Kaunas bypass it shall be also highlighted that this sections contains one of the ruling gradients for determining freight train trailing load for the complete route. Flattening of the proposed gradient by at least 1 or 2‰ would ease the situation and contribute to the vision to operate longer freight trains in the future.

According to Rail Baltica Design Guidelines Jiesia junction shall be without gauge crossing 1520 mm/1435 mm. If this solution is implemented as per Design Guidelines, the junction shall be completely grade separated with layout as depicted in Figure 108 above.

Design of Kaunas Central station shall provide sufficient infrastructure to allow for meeting of high speed trains and short connection times between long distance and regional trains in all directions. To operate the proposed service pattern, the following minimum requirement on 1435 mm track layout of Kaunas Central station do apply:

- provision of six platforms (four through tracks, two dead-end tracks) or alternatively
- Provision of four platform tracks (through tracks) plus at least two additional turning sidings south of Nemunas river bridge.

Regarding layover of trains during night time requirements outlined in section 5.1.1 shall be taken into account as basis for infrastructure design.

The layout for Kaunas triangle provided in this report mirrors the current state of discussion and might be further improved with ongoing technical design. Besides providing maximum speed for HST trains on all three legs of the triangle the different required operational funtions

- Serving Kaunas airport by regional trains
- Implementation of Karmelava freight station, including intermodal terminal, with access to all directions
- Provision of infrastructure maintenance facility

need to be combined within a consistent solution. Therefore the requirements need to be further studied (potential for freight station) and fixed (e.g. decision on Kaunas airport development).

4.7.7. Station facilities at Marijampolė

Town of Marijampolė with approx. 36.000 inhabitants (city area only) is the largest settlement along the line with no stop of international trains. In order to provide a fast and convenient service an hourly non-stop train service on 1435 mm between Marijampolė and Kaunas shall be introduced. To provide an attractive service and to gain full passenger a branch to existing Marijampolė station is recommended (hereinafter referred to as Marijampolė loop). This branch shall be connected to the main line north and south of Marijampolė. This will allow for cross-border regional traffic complementing HST service and also provide attractive connections from Marijampolė towards Poland.

This branch is not part of the current planning stage and spatial planning, but shall be considered regarding decisions about future regional traffic. For the purpose of the timetabling study it is assumed that Marijampolė loop does exist. At Marijampolė station a passing loop and stabling facilities for up to two 1435 mm regional trains (2x100 m) shall be provided.

Another option to serve Marijampolė would be erection of a separate station on the main line. Therefore the location of the recommended Marijampolė passing loop shall consider this option (space, attractive access by road). Provision of platforms and stabling facilities shall be considered as option, as long as no final decision how to serve Marijampolė is made. Further option to be considered is provision of a freight station to cater for needs of local industry. Provision of this station is subject to further studies analysing demand and needed facilities. To provide the option of a freight station and for terminating regional trains from Kaunas, the freight passing loops shall be separated from the passenger platform tracks.

Resulting situation as assumed for the analysis in the operational plan is depicted in below.

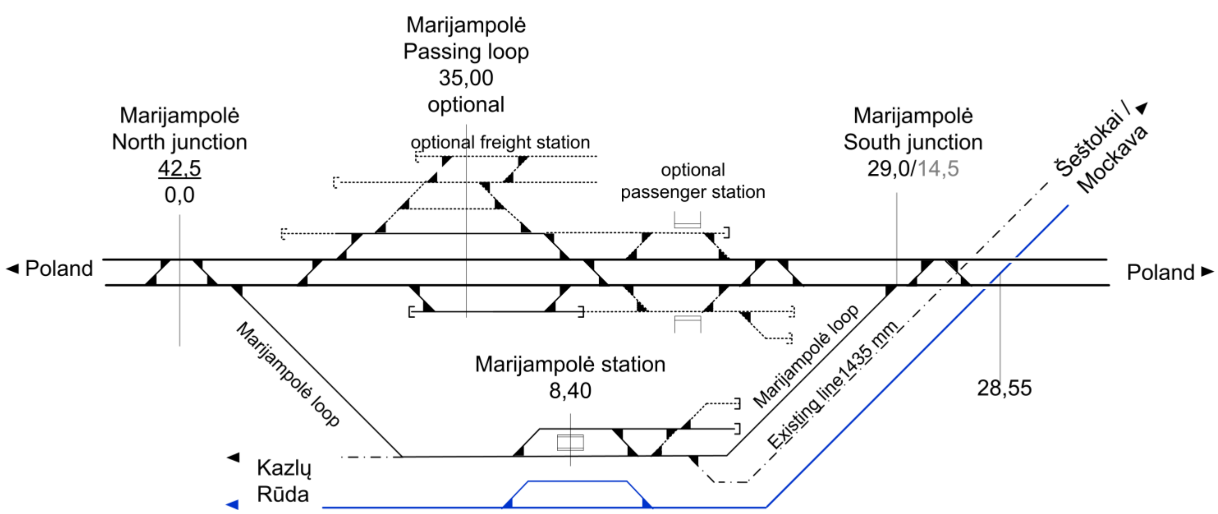

Figure 112: Track layout of station facilities at Marijampolė

4.7.8. Interconnecting existing 1435 mm infrastructure south of Kaunas

Currently, a 1435 mm non-electrified single track line is operational from the border PL/LT until Kaunas Central station parallel to existing 1520 mm railway Kaunas – Kazlu Ruda – Marijampolė - Mockava. Section Mockava – Šeštokai is implemented as gauntlet track section. Currently the line is served by 1520 mm regional passenger trains Kaunas – Marijampolė – Šeštokai stopping at all intermediate stations (7 to 8 daily train pairs, 1 hour and 5 minutes of travel time).

In Mockava and Šeštokai freight service facilities for 1435 mm are provided:

- gauge changing facility at Mockava station

- oil terminal at Mockava station
- intermodal terminal at Šeštokai station.

These facilities are connected to 1435 mm and 1520 mm network.

Options how to connect existing 1435 mm lines to Rail Baltica have not been part of alignment feasibility study for line section Palemonas – border PL/LT.

On 1435 mm these facilities are currently served from Poland, since there are no 1435 mm freight destinations further north. Maximum length of 1435 mm reception sidings in Mockava and Šeštokai is approx. 700 m. Thus, the existing layout does not provide for formation of longer freight trains (1050 m usable length).

From current point of view there are two options how to serve existing freight facilities:

- **Option A: Keeping southern connection of existing line to serve Mockava and Šeštokai from Poland.** Depending on final alignment of Rail Baltica this could be implemented by interconnection in Trakiszki station or by a separate junction (approx. 5 km north of border PL/LT). This would allow the existing operators to keep their service concept, at least during first years of Rail Baltica operation when other terminal facilities are not completely developed and market has not fully adapted to Rail Baltica. If there is a need to reach destinations further north (e. g. Kaunas, Vilnius) implementation of a triangle shall be considered. A triangle would also allow provision of border station services at Mockava. Viability and demand of such services will also depend on technical framework conditions (electrification, ERTMS implementation on both sides of the border). For formation of long freight trains a consolidation point closed to a large terminal / freight destination might be more suitable from market perspective.
- **Option B: Keeping complete existing line operational.** This means the existing line shall be interconnected to Rail Baltica near Kazlų Rūda or Jiesia and south of Mockava. This would allow replacing existing 1520 mm service by 1435 mm service and serving additional freight facilities as needed from both sides, e.g. a military freight facility at Kazlų Rūda. This option will result in high operational costs since the existing 1435 mm line shall be kept in operating condition on complete length despite having a high capacity double track line in parallel.
- **Option C: Providing interlink at Marijampolė.** According to operational plan, existing Marijampolė station shall be served by regional passenger trains using a separate interconnection to Rail Baltica to provide a fast regional passenger train sercvice. If this option is chosen existing line could be kept between Marijampolė and Mockava station and interconnect to newly constructed Rail Baltica "bypass" at Marijampole station. This could also mean that an option for connection to Kazlų Rūda is provided, if needed for freight.
- **Option D: provide separate connection to Kazlų Rūda** (either from north or south) This option includes a separate junction at the main line near Kazlų Rūda to serve freight facilities at Kazlų Rūda. Location of the

junction will depend on distribution of transport demand (direction and relations with most traffic). This option could be combined with option A for low overall infrastructure operational cost.

From technical viewpoint additional investments would be needed if the line is to be electrified so that trains can reach the freight facilities without need for locomotive change or application of bimodal traction.

From operational and economic viewpoint (needed investments) option A seems more promising than other options. If needed to serve Kazlų Rūda it could be combined with option D. Which option is chosen to interconnect Rail Baltica with already existing 1435 mm facilities south of Kaunas shall be be subject to further studies in following versions of the operational plan. In such decision the current terminal operators, local authorities and the current infrastructure provider (LG) need to be closely involved.

Necessity of a triangle north of the Polish/Lithuanian border and decision how to serve Kazlų Rūda is also subject to final decision if and how to serve existing Marijampolė station by 1435 mm trains and which infrastructure will be therefore implemented in the future.

4.7.9. Dedicated service facilities at the PL/LT-border

From operational viewpoint a dedicated freight station closed to the border would provide the following functionalities:

1. Allowing for locomotive change. Thus train operators could use locomotives not equipped for operation on Rail Baltica (3 KV DC, no ETCS, no homologation) depending on train route and ERTMS implementation on line sections in Poland).
2. Allowing for driver change or change of railway undertaking. Railway undertakings can than use staff not trained to operate on Rail Baltica (operating language, dedicated operational rules) as far as closed to the border.
3. Possibility to consolidate volumes for Rail Baltica (by shunting or usage of intermodal terminal facilities)
4. Allowing for additional checks if needed (brake test, gauge check). Under modern operating conditions this is not needed as part of normal operation.

To provide for functionalities 1 and 2 a potential station for locomotive or crew change should be located south of the point along the route from where operational rules for Rail Baltica shall apply and south of the electrification border. For option 2 it is beneficial if the handover takes place closed to existing larger settlements where sufficient facilities for rest of train crew are available and staff can also access the site by public transport. Furthermore the changeover point will depend on crew rostering decisions of the railway undertakings, if multiple systems locomotives are used to cross the border.

To provide for option 3 a location closed to an existing node (e.g. Ełk or Kaunas) is beneficial, since there likely will be volumes to be consolidated from market perspective and needed facilities can be better utilised which contributes to reduction of additional operational costs costs for consolidation (shunting, loading, storage, usage of reception sidings).

Option 4 could be partly automated by trackside detection systems, which will be implemented in any case along the route. If trackside fault-detection systems detect a failure train will be stopped. Therefore a passing loop closed to the border will be sufficient.

Assuming that

- multiple systems locomotives will be used, for the majority of trains from the starting point or larger terminals or freight stations in Poland
- crew change will be performed also at other stations

only a fraction (20 to 40% of the forecasted trains would use a dedicated station near the border.

Assuming an average track occupation time of 4 hours (to cover for typical delays and allow more flexible crew and engine scheduling) at least 6 reception sidings would be required to operate freight services as required (total of 60 trains per day in both direction for time horizon 2026 - 2036.

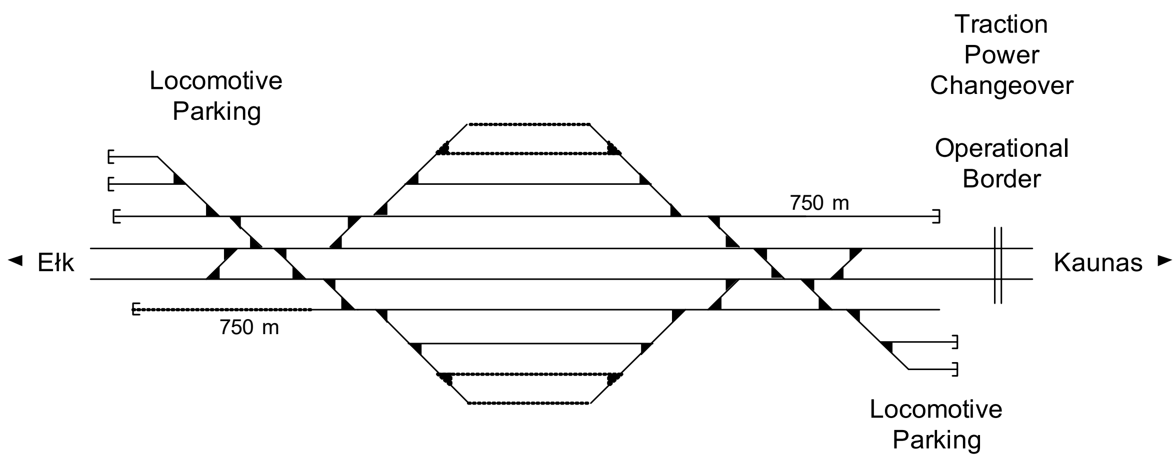

Figure 113: Example layout of a potential border station for crew and locomotive change

Since need for such station will heavily depend on service and cooperation models of future train operators and logistics service providers and availability of track capacity on adjacent railway nodes (e.g. Kaunas node, Ełk, Białystok) it is recommended to analyse this topic also as part of the regular transport market study activities for North Sea - Baltic Rail Freight Corridor.

Case study Use of existing facilities at the border Germany – Czech Republic

The border Germany – Czech Republic south of Dresden is crossed by approx. 75 freight trains per day. Freight services are provided by various train operators. Traction power changeover section is provided on the open line between Schöna (last station in Germany with no freight facilities) and Dolní Žleb (also no freight facilities). Most of the trains cross the border by means of electric multiple systems locomotives. Handover between railway undertakings takes place at a variety of operational points, e.g. Dresden Friedrichstadt, Pirna, Bad Schandau, Bad Schandau Ost, Děčín-Prostřední Žleb, Děčín východ. Some trains are running through without locomotive change to final destination, e.g. to Praha-Uhříněves intermodal terminal, Nymburk (single wagonload shunting yard) or – on the German side – for example to Falkenberg/Elster (newly introduced consolidation point for automobile industry logistics) or even as far as Hamburg. Changeover is also used to park trains in order to synchronise timetables on the different sections en route. While the variety of stations used closer to the border is partly due to geographical restrictions and for historical reasons the example illustrates the need for parking as buffer in the transport chain and to allow for cooperative service models to operate on long distances.

Railway undertakings rejected plans of DB Netz AG to close down the service facility at Bad Schandau Ost due to needed track capacity for parking and handover of freight trains.

4.7.10. Vilnius node

4.7.10.1. Vilnius Central station

According to current planning stage track layout for Vilnius Central station is not fixed yet in detail. According to LG four platform tracks are planned to be provided. To test out the need initially a station layout with five platforms has been assumed in order to develop the RailSys timetable as basis for the assessment (see Figure 114 below).

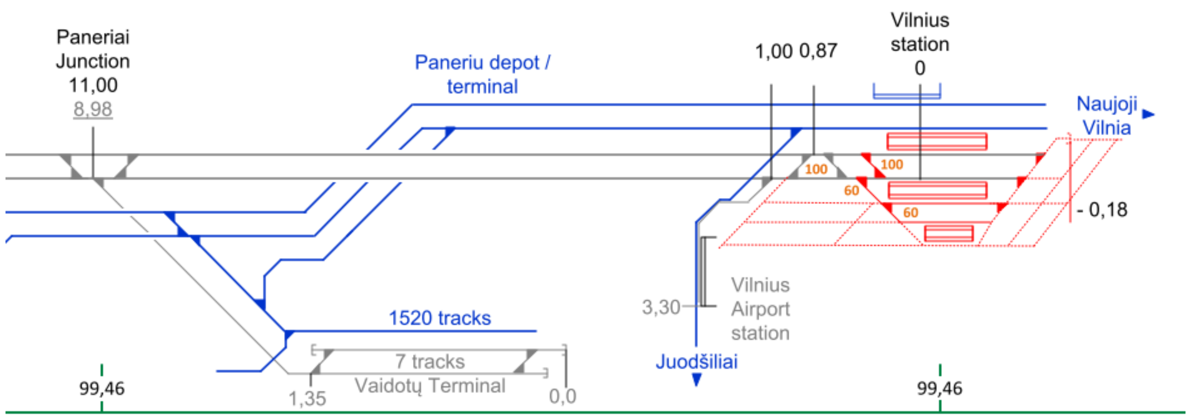

Figure 114: Assumed track layout for Vilnius node

According to proposed train service pattern in 2056 the station shall handle termination of:

- three high-speed lines (red on the track occupation diagram)
- three regional train lines (green on the track occupation diagram) and
- one night train pair to Warszawa continuing to further destination, e. g. Vienna (not shown on the track occupation diagram).

The track occupation diagram from 14:00 to 18:00 shows the traffic in 2056. Regarding track occupation the following assumptions are made:

- The high speed line 12 is (Vilnius – Tallinn Ülemiste – Helsinki) will is handled from arrival, turnaround in 50 minutes to departure.
- The high speed line 13 (Warszawa - Vilnius) appears on the track occupation diagram approx. 30 minutes before departure, and is assumed to make a turnaround at stabling tracks in Vilnius.
- The high speed line 14 (is handled from arrival, turnaround in 7 minutes (or 1 hour and 7 minutes, in off peak hours) to departure.
- Regional express line 27 will stay at the platform tracks for approx. 46 min and continue as line 28
- Regional express line 28 will be turned around at the platform tracks, will stay for approx.43 min and return as line 27
- Regional express line 29 will stay at the platform and continue as line 27

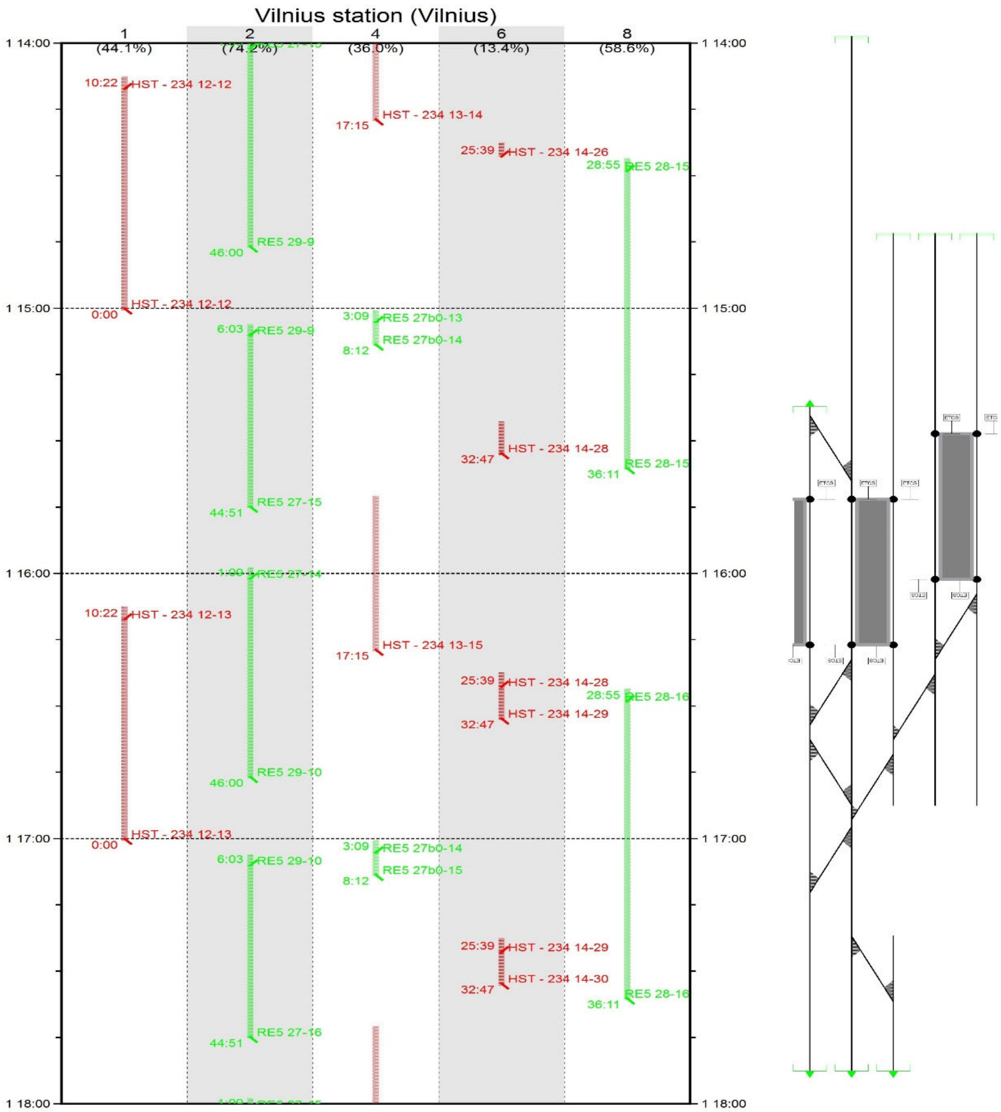

Figure 115: Track occupation diagram Vilnius Central station 2056

The result of this timetabling exercise based on the proposed train service pattern 2056 shows that at least five platform tracks will be needed to provide a stable timetable with sufficient turnaround times and without the need for shunting trains to stabling sidings. Regarding required sidings for stabling of trains, please refer to chapter 5.1.1.

Currently provision of a 1435 mm link to Vilnius airport is under discussion. This would mean that Rail Baltica trains would continue to Vilnius airport station after a short stop incl. change of direction.

If the airport link is to be served by 1520 mm trains either for regular or diversionary traffic gauge crossing in the entrance area of Vilnius station area will be needed, thus adding additional technical and operational complexity to the station layout. From that perspective serving Vilnius airport station by 1435 mm trains would be an advantage.

Regarding layover of trains during night time requirements outlined in section 5.1.1 shall be taken into account as basis for infrastructure design.

Due to the overall amount of stabling trains an additional yard for stabling and servicing HST and regional trains is needed. Taking into account the current planning stage this facility will be most likely located at the west side of the station.

4.7.10.2. Freight line Paneriai junction - Vaidotai

Vilnius intermodal terminal located adjacent to existing 1520 mm Vaidotai freight yard is planned to be served by a single track line. According to proposed train service pattern up to 13 departures per working day are expected for time horizon 2026 increasing to 18 departures in 2056 incl. volumes for FinEst link. This single track line is planned to be connected to the Vilnius – Kaunas line at Paneriai junction. Therefore an at-grade junction is foreseen as depicted in Figure 116 below.

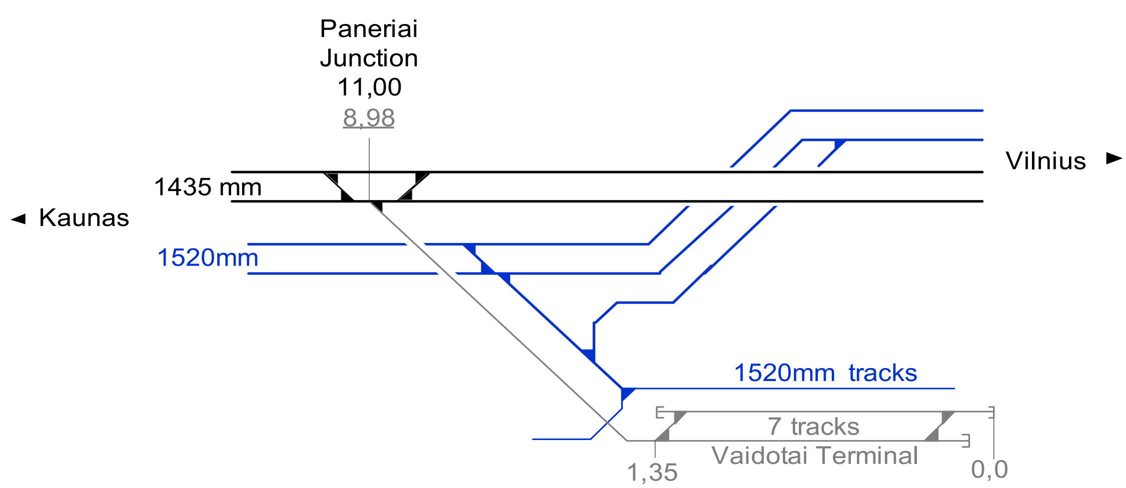

Figure 116: Currently proposed track layout for Paneriai junction and single track line to Vaidotai

Timetabling study shows that this constellation will limit flexibility to provide required freight train paths since availability of the routes at the junction needs to be synchronised with slots on the single track line.

Therefore it is recommended to improve the solution as part of further planning and design work. Possible solutions include:

- Double track to Paneriai junction – Vaidotai,

- Provision of additional passing loops adjacent to the junction to ensure freight trains can leave/enter single track section as quickly as possible and wait in front of the bottleneck without impacting following passenger trains on the main line,
- Grade separation of the junction (1435 mm).
- In the track layout suggested by the operational plan for Kaunas - Vilnius section a dedicated loop line is foreseen in Lentvaris station as initial proposal, so that freight trains can wait to enter single track line there without obstructing passenger traffic.

4.8. Operation Resources Assessment (WP 4.4)

4.8.1. Scope

According to the ToR the operational plan shall include an assessment of operational resources (staff and material) needed for safe and reliable operation of the railway. To achieve this, a staffing plan has been developed taking into account the required staff for railway operation. The staffing plan is based on the following assumptions

- Resources Assessment will be provided for posts directly related to safe and reliable railway operation. Overhead staff is only included for safety critical tasks. This does include all tasks which are to be provided as part of the minimum access package as required by 2012/34/EU. According to annex II of this directive the minum access package shall comprise:
    - handling of requests for railway infrastructure capacity;
    - the right to utilise capacity which is granted;
    - use of the railway infrastructure
    - train control including signalling, regulation, dispatching and the communication and provision of information on train movement;
    - use of electrical supply equipment for traction current, where available
    - all other information required to implement or operate the service for which capacity has been granted.
- Provision of ancillary services to train operators, e.g. ticket sales or enqueries at stations, is subject to further infrastructure management studies and will not be covered in this assignment.
- The organisational structure of Rail Baltica infrastructure management is not yet finally decided and will be based on the outcome of a separate study. For the compilation of the operational plan it shall be assumed that Rail Baltica in the Baltic states will be operated by a single infrastructure manager for all three countries.
- Only the staffing for 1435 mm line sections will be incorporated in the study. On several fields there might be synergies with operation of existing 1520 mm network, e.g. regarding functionality of common station, emergency management, which will not be considered in detail.
- Maintenance of technical facilities and related incident management on site will not be considered in this assessment as this is part of the maintenance plan. Initiation of incident management on site will be considered, as far as the Operations Control Centre (OCC) is concerned.

4.8.2. General Operating Principles

In this section the general operating principles which are the basis for the operation resources assessment will be established.

Centralised Traffic Control

As described above, operation of Rail Baltica by a single infrastructure manager for all three countries shall be assumed for the purpose of operational plan. In modern railways traffic management and coordination of related activities on site is performed as highly centralised function by means Operational Control Centres (OCC). This is also required by Rail Baltica Design Guidelines[92]. The following functions should be provided as part of the OCC:

- Control and supervision of the line
- Emergency and crisis management
- Offline timetable management activities
- Security supervision

Such supervision of networks of more than 1,000 km length from a single OCC is widely used and in from technical viewpoint the whole railway line can be controlled from one centralised Operations Control Centre.

Common operating Rules

For all three Baltic States the same operational rules shall be applied. Special regulations might be necessary to deal with local specialties, e. g. situation in Kaunas tunnel. These regulations are part of required location and route knowledge.

Common operating language and local language

The core section of Rail Baltica crosses three Baltic States with three different local languages. In addition to that trains cross the border to Poland on their way to Warszawa. If FinEst link is to be implemented a fifth national language has to be considered. For smooth and fast operation additional stops at the borders shall be avoided. In traditional railway operation the crew of a train crossing a national border is required to speak the two languages defined as operating languages of the infrastructure providers involved. For safety relevant communication between staff of the infrastructure providers (e. g. signallers) on both sides of the border a common language is defined as part of operational rules for the cross border line section.

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[92] RBDG-MAN-022-0101:Railway Control-Command Signalling System, chapter 12.4 OCC organisation

To ease centralised supervision of traffic and efficient communication between members of the train crew as well as between train crew and local or centralised staff a common operating language will be benefitial. In air traffic English is used as operating language allowing efficient communication between plane crews and to other operational staff (e.g. air traffic controllers, ground staff at airports). Given the relatively low share of staff involved in international cross-border traffic in most European countries, this principle is currently not applied for European railway operation. For the special case of Rail Baltica crossing four countries a common operation language will be an advantage for train operation. Most of the train crew members will have to cross at least one border during their shift (exception: local passenger trains in Lithuania or drivers of shunting engines at the terminals). This would support flexible utilisation of train crew for the complete route by the railway undertakings and simplify operational training as well as traffic management.

National emergency management

To warrant short reaction times, to ensure that impacted persons get the best level of medical and other assistance and to avoid unnecessary doubling of resources between national emergency services and railways, emergencies are handled by local and national emergency services of each country. National staff involved is to be trained by the railway to ensure safety on site and efficient handling of railway equipment if needed. For national emergency services it cannot be expected that staff can be trained to a common language as described above. Therefore, it is assumed that emergency management must be performed separately for each country. However, incident managers from the railway infrastructure provider working on site and in centralised incident management need to be familiar with the common operating language in order to communicate with members of the train crew.

4.8.3. Organisational Structure of Traffic and Safety Management

Based on aforementioned operational principles, the need to coordinate traffic and safety related task in a clear structure with short decision times and clear communication is proposed to provide traffic management in two-tier architecture as depicted in Figure 117 below. The related elements are described in the following paragraphs.

Centralised Operations Control Centre (COCC)

All tasks which can be centralised shall be integrated in a Centralised Operations Control Centre (COCC). This control centre is responsible for smooth and safe operation on the complete line from the Polish border to Tallinn. If needed, operations control for FinEst link could be also integrated at a later stage. In addition to that the COCC will be also responsible for local traffic management and incident management in one country.

Subject to further study and decisionmaking this could be placed in the country where the headquarter of a common infrastructure manager for all three Baltic countries would be located. Advantage of this is a closed communication with administrative management. **Satellite Operational Control Centres (SOCC)**

The COCC will be supported by Satellite Operational Control Centres (SOCC) dealing with regional traffic and incident management in the two other countries. By this approach short communication ways in case of incidents, failures and emergencies can be ensured. As outlined above there it will be required to deal with third parties, especially national emergency services using respective national languages. One further advantage of such approach is that local route knowledge can be easier gained and applied and a closer contact to involved third parties on national level can be obtained. This will ease local traffic management as well as handling of incidents and all safety related tasks.

Another advantage of that structure is that in daily operation certain tasks might be delegated to the COCC. For safety critical tasks, e.g. signalling, this will work, if a common operation language and common operational rules are applied. It would be also possible to delegate incident management and hotline functionalities to the COCC if staff there is properly trained in national language.

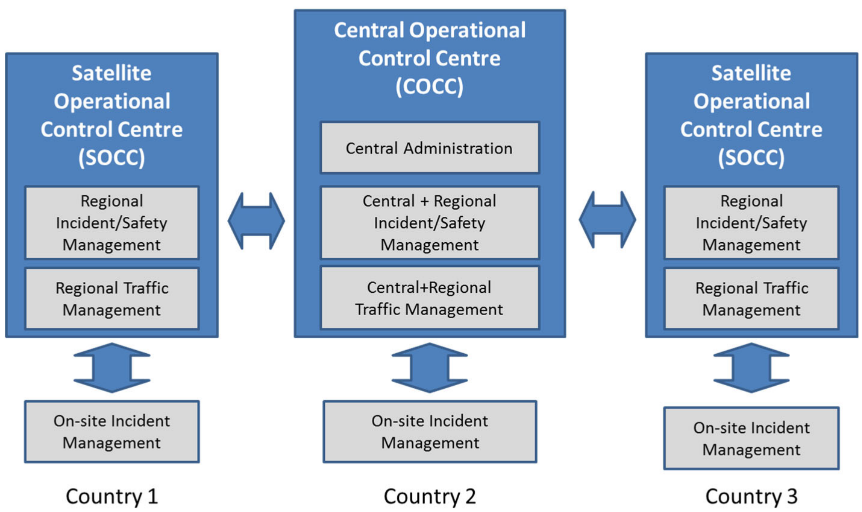

Figure 117: Suggested Organisational structure of Traffic, Incident and Safety Management for Rail Baltica

4.8.4. Operations Control Centre (OCC)

Centralised train dispatching and traffic management

Train dispatching is to be carried out as centralised function. This comprised the following tasks:

- Monitoring of train movements and train punctuality
- Adjustment of train sequence in case of delays
- Ensuring proper data for automatic route setting at central level (e. g. timetables, planned track usage)

Given the relatively simple structure of the network a lean structure is chosen for decision making and reporting with three levels:

- Higher management, preparatory and support functions
- Traffic coordination level: high level decisions about train running considering a larger area
- Traffic control level comprising of the traffic controllers responsible for a dedicated signalling area

Centralised traffic control

Route setting and signalling is done by dedicated Traffic Controllers. Under normal operating conditions route setting will be highly automated. Manual interactions are required in case of degraded mode operation and emergencies and for shunting operation.

The Traffic controllers will also be the first point of contact to the crews of the trains operating in the respective signalling area. The Operation Controllers will coordinate closely with national incident managers to ensure direct communication, if needed fast. It is assumed that the signalling control areas will relate to the individual countries along the route. Communication will be done in the operating language.

Shunting in larger depots and terminals will be performed locally. Signalling and coordination of shunting movements within depots and terminals will be done by means of a local OCC situated on site of the terminal or depot.

The maximum feasible size of a signalling control area is determined by the workload of the signaller, which depends on the following factors:

- Number of trains simultaneously operating in the area
- Amount of manual interactions with the signalling system in regular and degraded mode operation
- Amount of communication with local station staff, dispatcher, train crew in regular and degraded mode operation

Given the relatively simple track layout and operating conditions outside the node and a high level of automation (automated route setting, support of train supervision), line sections of at least approx. 150…200 km can be handled by one signaller. Boundaries of signalling control areas shall be defined such, that the amount of additional communication and entities involved in dispatching of movements crossing the boundary can be minimised. Based on these assumptions a rough estimate of involved signalling staff is provided below. The signalling control areas are outlined as nationally to be compliant with the two-tier structure outlined above. From operational viewpoint this structure is also supported by the fact that according to the train service pattern proposed in the operational plan the overall amount of movements crossing the national borders will be lower compared to neighbouring line sections within each country (additional regional traffic in surroundings of Tallinn, Riga, Vilnius, Kaunas). As long as a common operating language is applied and staff is trained properly, the signalling control area boundaries can be allocated more flexible and do not need to be constrained by the national borders.

For final definition of signalling control areas and definition of required staff a separate detailed study needs to be carried out taking into account workload for regular and degraded mode operation as well as necessary interaction with train crew, loacal signallers, traffic management, and incident management.

Depending on user interface design of signalling and control systems, boundaries of signalling control areas can vary to allow operation with less staff outside of peak hours (2 areas controlled by one signaller, 3 areas controlled by 2 signallers). For which areas such approach is applicable will be subject to further studies. Therefore for a first staff estimate of OCC a continuous staffing of all workplaces for 24 h is assumed.

Country	No of signalling control areas	Description
Estonia	2	1: Tallinn node[93] 2: lines south of Tallinn
Latvia	2	1: Border EE/LV - Riga passenger loop 2: Riga bypass – border LV/LT
Lithuania	4	1: Border LV/LT – Kaunas triangle 2: Kaunas triangle – Palemonas – Jiesia (including operation in Kaunas Central and Palemonas)[94] 3: Kaunas node: Kaunas bypass / Jiesia – border PL/LT 4: Section Vilnius / Vaidotai – Kaunas triangle[95]
Relief crew	3[96]	Taking over to allow for short breaks / peak workload
Total	**10**	

Table 143: Centralised signalling control areas

Centralised Management of incidents, emergencies and technical failures

Most related activities in coordination with third parties have to be performed in national language. In addition to that there might be differences regarding emergency handling procedures, related communication channels to be

[93] Shunting operation at Muuga freight station and Ülemiste depot shall be controlled locally.
[94] Shunting operation at Palemonas and Kaunas Central station (shall be coordinated by local operator.
[95] Shunting operation at Vaidotai and Vilnius shall be coordinated by local operators
[96] One relief in COCC, one relief each in SOCC

used. To provide a single point of contact to national emergency services and other third parties involved in incident management a centralised unit for each of the three Baltic States is proposed by the consultant.

For the purpose of this report unit is called National incident and emergency centre. NIEC shall provide the following functionalities:

- handling of emergencies as single point of contact to national emergency services, local authorities and technical service providers
- handling of minor incidents, technical failures and security related issues supported by SCADA systems for traction power supply, signalling, telecommunication systems supporting local staff allocated to the maintenance bases along the line by triggering and monitoring related maintenance activities
- handling of security related issues including hotline function for passengers seeking assistance at stations
- centralised management and coordination of related local staff

The suggested roles to be considered for staffing of the NIEC are provided in Table 146 below together with a short description of the main tasks.

Staffing of COCC

Overall a staff of approx. 75 persons (FTE) is required to provide the operative functionalities of the OCC as described. The related job descriptions are presented in Table 144. It must be noted that only functions directly involved in railway operation are shown. Staff for maintenance of technical system and equipment (IT administration, signalling and telecommunication systems, cleaning and facility management is also not included.

Job title	Work regime	Main Tasks
Head/Deputy Head of OCC	Normal	Leading of OCC staff Involved in staff administration Guidance regarding operational issues Preparation of operation related reports Management of major emergencies and incidents (on-call activity)
Operations Secretary	Normal	Preparation and circulation of operation related documents on behalf of Head of OCC, Timetable Manager and traffic supervisors
Timetable Manager	Normal (2 shifts)	Handling of short term path requests Preparation of timetable amendments Issue and distribution of timetable documents Coordination of timetable with IMs of adjacent railway lines Ensuring circulation of timetables
Operation Supervisor	24 h	High-level coordination of train movements (train sequence decisions, incl. coordination with dispatching staff of adjacent infrastructure managers) Documentation of operation (punctuality and status of trains) Central management emergencies and major incidents (in case of major events until handover to separate on-call duty staff)
Traffic Controller	24 h	Safety relevant route setting operations for all shunting[97] and train routes, supervision of movements, incl. all related communication to local and train staff Authorisation of works in the railway danger zone and management of related track closures
Power Controller[98]	24 h	Initiation of actions in case of technical failures and emergencies of traction power supply Isolation of power line, transformer and substation equipment in case of emergencies and planned works Authorisation of planned and emergency work Guidance of staff on-site (works and emergency procedures)
Information Controller	24	Management of passenger information and public announcement systems
Incident Coordinator	24 h	Centralised Coordination of activities in case of emergencies and incidents Working closely together with SOCC

[97] For terminals and depots shunting operation is managed locally, however certain shunting movements will remain to be centrally controlled or at least the local operation must be authorized, e.g. shunting of maintenance vehicles or damaged train at a passing loop.
[98] Other SCADA based controlling functions could be implemented here as well. These functions are on purpose part of NIEC as described in chapter 4.8.5

Job title	Work regime	Main Tasks
Safety Manager	Nor-mal/On call	Responsible for railway safety related issues Independent investigation of major accidents and incidents Preparation of staff training Preparation of safety related reports and regulations
Emergency Coordinator	On-Call	Central Relief in case of major accidents (taking over case or handling hotline instead)
Service and Technical Incident Hotline	24 h	Centralised assistance to passengers and third parties regarding any issues on railway property, where no local staff is available Supervision of SCADA system, initiation of handling of technical faults, e.g. on passenger information systems, signalling and telecommunication systems, security systems, low voltage power supply, CCTV, buildings etc. Authorisation of minor repair works in closed coordination with local maintenance staff

Table 144: Staffing of OCC – Staff roles and main tasks

Function		Head/Deputy Head of COCC			Operations Secretary			Safety Manager			Timetable Manager			Incident Coordinator			Information Controller			Operation Supervisor			Emergency Coordinator			Service and Technical Incident Hotline			Power Controller			Traffic Controller			Total workplaces	Total Staff
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total		
OCC		2	1		2	1		2	2		1	2		1	3		1	2		2	3		1	2		1	3		1	3		3	3			
Total Staff				4			4			8			4			6			4			11			4			6			6			17	**16**	**74**
Qualifikation Level	1	x		4				x		8																										**12**
	2										x		4	x		6				x		11	x		4											**25**
	3				x		4										x		4							x		6	x		6	x		17		**37**

Table 145: Staffing of COCC – Estimation of required operational staff

4.8.5. Satellite Operations Control Centre (SOCC)

In principle, in the satellite operations control centre the same task are to be performed as in COCC to cover all necessary support functions for railway operation. Central administrative functions, central hotline functions and for instance central traffic management shall not be duplicated and assumed to be provided only in COCC.

Job title	Work regime	Main Tasks
Head of SOCC	Normal	Leading of SOCC staff Involved in staff administration Guidance regarding operational issues Preparation of operation related reports Management of major emergencies and incidents (on-call activity)
Operations Secretary	Normal	Preparation and circulation of operation related documents on behalf of Head of OCC, Timetable Manager and traffic supervisors
Traffic Controller	24 h	Safety relevant route setting operations for all shunting[99] and train routes, supervision of movements, incl. all related communication to local and train staff Authorisation of works in the railway danger zone and management of related track closures
Power Controller[100]	24 h	Initiation of actions in case of technical failures and emergencies of traction power supply Isolation of power line, transformer and substation equipment in case of emergencies and planned works Authorisation of planned and emergency work Guidance of staff on-site (works and emergency procedures)
Safety Manager	Normal/On call	Responsible for railway safety related issues Independent investigation of major accidents and incidents Preparation of staff training Preparation of safety related reports and regulations
Incident Coordinator/ Assistant Traffic Supervisor	24 h	First point of contact in case of any emergencies Coordination of activities in case of accidents with national emergency services and local authorities Assistant of Central Traffic Control
Assistant Incident Coordinator	On-Call	Relief for handling major incidents and emergencies, e.g. in case of major accidents (taking over case or handling hotline instead)
Service and Technical Incident Hotline	24 h	Centralised assistance to passengers and third parties regarding any issues on railway property, where no local staff is available

[99] For terminals and depots shunting operation is managed locally, however certain shunting movements will remain to be centrally controlled or at least the local operation must be authorized, e.g. shunting of maintenance vehicles or damaged train at a passing loop.
[100] Other SCADA based controlling functions could be implemented here as well. These functions are on purpose part of NIEC as described in chapter 4.8.5

Job title	Work regime	Main Tasks
		Supervision of SCADA system, initiation of handling of technical faults, e.g. on passenger information systems, signalling and telecommunication systems, security systems, low voltage power supply, CCTV, buildings etc. Authorisation of minor repair works in closed coordination with local maintenance staff

Table 146: Staffing of SOCC – Staff roles and main tasks

For each of the two SOCCs proposed approx. 54 staff (FTE) will be needed. During day time 10 … 12 work places will be required in each SOCC plus necessary rooms for other administrative functions as well as training and conference rooms (at least 3). Regarding requirements for signalling workplaces please also refer to chapter 7.

Function		Head of SOCC			Operations Secretary			Safety Manager			Incident Manager/Assistant Traffic Supervisor			Operation Supervisor			Incident Coordinator			Power Controller			Traffic Controller			Total workplaces	Total Staff
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total		
SOCC		1	1		1	1		1	2		1	1		2	3		1	3		1	3		4	3			
Total Staff				2			1			4			2			11			6			6			22	12	54
Qualifikation Level	1	x		2				x		4																	6
	2										x		2	x		11	x		6								19
	3				x		1													x		6	x		22		29

Table 147: Staffing of SOCC – Estimation of required operational staff

4.8.6. Staffing of freight terminals

Provision of local staff of freight terminals is done by the freight terminal operators. Staffing for local signalling in terminals is described in section 4.8.9.

4.8.7. On-site incident managers

Task of on-site incident managers is to assist public emergency services, train crew and local staff in case of emergency. They need special training for that purpose. On-Site incident managers must be able to act within a certain timeframe set by legislative or other institutions to reach the scene of the accident at the specified time. For a rough estimation of the personnel requirements for accident management, the time limit of 30 minutes valid for Germany is assumed here. Another assumption is the achievable average "travel speed" by car. This is 60 km/h. From the point of view of a preparatory period of 5 minutes and the fact that not every scene of the accident is to be reached on roads parallel to the railway route, it is assumed that an emergency district is to be set up for each 50 km of the main line. The resulting required human resources are outlined in Table 148. Overall approx. 55 to 60 staff (FTE) would be required to provide on-site emergency management for 24 hours/7 days a week.

Function		Local Incident Manager (Estonia)			Local Incident Manager (Latvia)			Local Incident Manager (Lithuania)			Total Staff
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	
On-site incident managers		4	2		5	2		7	2		
Total Staff				15			18			26	**59**
Qualifikation Level	1										**0**
	2	x		15	x		18	x		26	**59**
	3										**0**

Table 148: On-site incident management – required staff (FTE)

On-site incident managers work on on-call duty during day and night hours. They might also perform other tasks as part of a more complex rotation regime. For example, local safety managers or maintenance staff located in the local maintenance bases could be included in the rotation regime. However, it must be ensured that they can react quickly once they are on duty. Hence their costs are calculated separately. To reach the scene they need a dedicated road vehicle equipped for the purpose (4WD, space for small tools, earthing and bonding equipment, emergency signal, radio equipment for communication with public emergency services, GSM-R radio, documentation material). Operational costs are estimated at 750 EUR per month.[101]

4.8.8. Emergency trains

For technical assistance at accident sites emergency trains will be needed. These trains will carry heavier machinery and re-railing equipment. Firefighting equipment and evacuation facilities to support handling of tunnel emergencies could be integrated into the emergency train, but are not considered here since utilisation of local fire brigades

[101] Source: Cost database of General German Automobile Club for Toyota Cruiser 4 WD. https://www.adac.de/infotestrat/autodatenbank/autokosten/autokosten-rechner/default.aspx

and provision of evacuation facilities in the tunnel is to be preferred. Otherwise a very high availability of the train as well as very short reaction times would be required.

Minimum 3 emergency trains will be required, which are to be based in Tallinn Rae depot, Acone depot and Kaunas area (either Palemonas or Zemutinis yard). With such an allocation of emergency trains each train would cover 300 km of railway from its base. That means a train would be able to reach accident sites as far as approx. 150 km from the base within 90 ... 120 min subject to train speed the reaction and preparation time until departure. To ensure short time periods until departure the emergency train shall be equipped with a dedicated engine (diesel traction, 120 km/h) or be designed as diesel multiple units. Subject to a risk analysis the dedicated engine could be replaced by engines from other railway undertakings. However, possibilities will be limited to get diesel engine in time from railway undertakings. The only diesel engines available would be shunting locomotives from the freight terminals.

To provide the necessary functionality the following equipment will be installed in the wagons of the emergency train:

- Workshop and tool storage
- Staff room/kitchen
- Power generator
- Emergency lighting
- Light cranes (e. g. 200 kg) and lifting equipment
- Re-railing equipment

One current design trend is to provide the specialised functionality in dedicated containers and to put it on standard container wagons. This allows availability in case of needed wagon revision or repair. The container is than swapped to another wagon.

Vehicle	No of vehicles	CAPEX Million EUR	Annual Maintenance million EUR
Workshop- / material wagons Staff wagon	3	3,0 EUR	0,2
Heavy Rail Crane	1	1,5	0,3
Buffer wagon (for crane)	1	0,1	0,01
Diesel locomotive (120 km/h)	1	3,2	0,48
Total unit costs per train		7,8	0,99
Total Rail Baltica (3 trains)		23,4	2,97

Table 149: Emergency train – vehicles and related costs

The required staff for emergency train services is depicted in Table 152 based on the requirement of 3 emergency trains as stated above and availability of 24 hours / 7 days per week.

Function		Emergency Train Chief			Engine Driver			Emergency Train crew			Total Staff/train	No. of emergency trains	Total Staff (all trains)
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total			
NIEC		1	2		1	2		4	2				
Total Staff				4			4			15	23	3	69
Qualification Level	Management										0		0
	University degree	x		4							4		12
	Operational staff				x		4	x		15	19	3	57

Table 150: Emergency train crews – estimation of required staff

4.8.9. Local signalling

According to the Rail Baltica infrastructure Design Guidelines shunting in depots shall be performed locally by means of a local signalling system (depot OCC). Typical for intensive shunting operation is a high level of radio communication, which is more difficult to integrate in a centralised OCC environment. Based on that local signallers are foreseen at the following locations:

- Muuga freight terminals
- Salaspils terminal
- Vaidotai terminal
- Palemonas freight station
- Other facilities (e. g. Riga, Vilnius and Tallinn passenger rolling stock depot)

Depending on operational model of terminals and depots the local signallers may also perform other coordination support functions in the depot and terminal areas but are included here.

Initially it is assumed that all posts need to be staffed on a 7 days/week 24 hours basis.

Function		Local Signaller Muuga			Local Signaller Salaspils			Local Signaller Vaidotai			Local Signaller Palemonas			Local signallers (other facilities)			Total Staff
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	
Local signalling		1	3		1	3		1	3		1	3		3	3		
Total Staff				6			6			6			6			17	41
Qualification Level	Management																
	University degree																
	Operational staff	x		6	x		6	x		6	x		6	x		17	41

Table 151: Local signalling – estimation of required staff

Local signalling as fall-back mode operation shall be subject to further technical study since the need depend on the final specification of the signalling system. Staffing emergency operators work place of an interlocking or RBC could also be a task for Local Incident Managers, if properly trained.

4.8.10. Management of passenger stations

In an open access environment typical operational functions to be provided at stations are tasks of the passenger train operating companies (e.g. ticket sales, provision of information, platform assistance, goods handling, and terminal management).

The following functions are to be performed by station staff of the infrastructure provider:

- Platform assistance
- Dedicated local security staff
- Dedicated Management of station facilities, mainly as management of sub-contractors.

Further functionalities could be provided as services of service facilities in accordance with annex II of the Directive 2012/34. This could include Ticket sales and passenger enqueries on behalf of the Train Operators

In every case the infrastructure manager must ensure that space and needed facilities are provided to the train operators to provide such functionalities, which not always are managed by the infrastructure manager himself (such situation is foreseen for some multimodal facilities – subject of infrastructure management studies). Ticket sales on behalf of TOC is not the only existing practice, it could also be ticket sales by TOC themselves, while the station manager is providing facilities for this function in the non-discriminatory way. However local control mentioned in comment to p. 2.7.7 falls under minimum access package, provided by the infrastructure manager.

Provision of platform assistance in international passenger stations will ensure smooth train operation by supervising boarding and alighting process including assistance to passengers and train crew. Including this staff to It is assumed, that only the international passenger stations and Kaunas airport station will have dedicated staff provided by the infrastructure manager. Management of facilities of other stations will be performed by management of large stations. Therefore, facility managers, head of station and security staff will need to have access to a car to reach the facilities independently of railway passenger timetable. Security staff is only provided for passenger assistance and incident management on site. It is assumed that no additional security checks need to be performed by the infrastructure manager. The functionality “Facility manager” does only include management of sub-contractors and dedicated railway maintenance staff.

Estimation of required staff to provide the functionalities as described above is outlined in Table 152 below.

Station		Function	Station Master			Technical Facility Manager			Platform Assistance			Station Security Staff			Total Staff
Number	Name	Type	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	
1	Tallin Ülemiste	International/New	1	1	1	2	1	2	1	2	4	2	2	8	12
2	Pärnu	International/New	1	1	1	1	1	1	1	2	4	2	2	8	11
3	Riga Main Station	International/Existing	1	1	1	1	1	1	1	2	4	0	2	0	3
4	Riga Airport Station	International/New	1	1	1	1	1	1	1	2	4	2	2	8	11
5	Panevezys	International/New	1	1	1	1	1	1	1	2	4	2	2	8	11
6	Kaunas Airport	Regional/New				1	1	1	1	2	4	2	2	8	10
7	Kaunas Main station	International/Existing	1	1	1	1	1	1	1	2	4	0	2	0	3
8	Vilnius station	International/Existing	1	1	1	1	1	1	1	2	4	1	2	4	7
		Total Staff			**7**			**9**			**32**			**44**	**60**
Qualification Level		1	x		7										7
		2				x		9							9
		3							x		32				32
		4										x		44	44

Table 152: Staffing of passenger stations – estimation of required staff

4.8.11. Sales and Marketing

One of the core functionalities of an infrastructure manager is to provide capacity to train operating companied by selling and coordinating the required capacity (train paths, service facilities) and to manage related customer relations on operative and strategic level. Staffing of the sales and marketing unit is outlined in below.

Function		Headof Sales Unit			Secretary / Team assistance			Timetabling/Operational Planning			Strategic affairs/corridor management			Controlling			Local Representatives (EE,LV,LT,PL)			Central Customer Management			Total workplaces	Total Staff
		staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total	staff/shift	shifts/day	staff total		
OCC		1	1		2	1		2	1		3	1		2	1		4	1		2	1			
Total Staff				1			2			2			3			3			4			2	14	17
Qualifikation Level	1	x		1																				1
	2							x		2	x		3	x		3	x		4	x		2		14
	3				x		2																	2

Table 153: Sales and marketing unit – estimation of required staff

4.8.12. Estimation of operational costs (staff and materials)

Based on the estimated staff and material requirements a first estimate of total operational costs is provided below. According to the figures outlined in Table 154 total operational costs are approx. 18.5 million Euros per year, thereof 12.4 million Euro need to be spent for labour costs. The indicated operational costs relate to the year 2036.

This estimate is based on the following assumptions:

- Difference between wage levels of railway staff as in Central Europe
- Annual growth of income 4% until 2036
- Calculation based on average wage for Latvia, Estonia and Lithuania
- Allowance for other personal material costs 10% of staff costs (training, training material, clothing, tools)
- Costs for rail vehicles as indicated
- Costs for company cars to reach incident and local working sites 750 EUR per month (4WD) / 600 EUR per month (standard car or transporter) are accounted as material costs
- Infrastructure maintenance is not included
- Costs for administrative overhead are not included in this first estimate, if not otherwise indicated in the staffing tables.

Functionality	Staff (FTE)	Annual Operational Costs 2036		
		Staffing	Material	Total
Operations Control Centre (COCC)	74	1,630,000 €	180,000 €	1,810,000 €
Satellite Operations Control Centres (SOCC)	108	2,300,000 €	280,000 €	2,580,000 €
Local Traffic Control (depots, terminal)	54	1,390,000 €	140,000 €	1,530,000 €
On-site Incident Managers	59	1,510,000 €	682,000 €	2,192,000 €
Emergency trains	69	1,230,000 €	4,050,000 €	5,280,000 €
Passenger Station Operation	60	1,460,000 €	320,000 €	1,780,000 €
Sales and Marketing	17	420,000 €	70,000 €	490,000 €
Total	**424**	**9,940,000 €**	**5,722.000 €**	**15,662,000 €**

Table 154: First estimate of operational costs

Operational costs are independent of the different time periods (2026, 2036, 2046, 2056) since they are related to growing traffic in only very few occasions. Considering the traffic forecasts all functionalities need to be provided from the start, since all stations and terminals are assumed to be served from the beginning and the railway shall be kept open 24 hours 7 days per week from the beginning.

5. Rolling Stock Maintenance (WP 5)

The Results of this chapter is based on the traffic patterns developed in WP 1 (see Figure 2, Figure 3 and Figure 4), the fleet proposals outlined in WP 2 and the distances between the stations according to WP 3. The required performances for the proposed passenger train operations were identified and it has been assumed that the trains are in service at a constant level for 365 days per year. In real operations, daytime, weekday and seasonal variations will occur, but would lead to similar average production volumes.

Train Category	Line	Route From	Route To	Vehicle type	Fleet perfomance, million vehicle-km per 2026	2036	2046	2056	Required Vehicles 2026	2036	2046	2056	Unit performance, million vehicle-km p. a. 2026	2036	2046	2056
HST	11	Warszawa	Tallinn (Helsiki)	High-Speed trainset 200 m	3.2	4.8	4.8	7.0	4	6	6	8	0.797	0.797	0.797	0.876
HST	12	Vilnius	Tallinn (Helsiki)		2.1	3.1	3.1	4.8	3	5	5	7	0.687	0.619	0.619	0.679
HST	13	Warszawa	Vilnius		2.5	1.7	1.7	2.5	5	3	3	5	0.500	0.556	0.556	0.500
HST	14	Kaunas	Vilnius		0.4	0.8	0.8	0.7	3	6	6	5	0.135	0.135	0.135	0.135
Spares									3	3	3	4	Averages including spares:			
		Subfleet total			**8.2**	**10.4**	**10.4**	**14.9**	**18**	**23**	**23**	**29**	**0.453**	**0.450**	**0.450**	**0.515**
NT	41	Warszawa	Tallinn (Helsiki)	Electric Locomotive	0.8	0.8	0.8	0.9	2	2	2	2	0.399	0.399	0.399	0.438
NT	42	Berlin/Vienna	Vilnius		0.4	0.4	0.4	0.5	2	2	2	2	0.208	0.208	0.208	0.248
Spares									1	1	1	1	Averages including spares:			
		Subfleet total			**1.2**	**1.2**	**1.2**	**1.4**	**5**	**5**	**5**	**5**	**0.243**	**0.243**	**0.243**	**0.274**
NT	41	Warszawa	Tallinn (Helsiki)	Coach, Sleeper, Dining car	5.6	5.6	5.6	6.1	14	14	14	14	0.399	0.399	0.399	0.438
NT	42	Berlin/Vienna	Vilnius		2.9	2.9	2.9	3.5	14	14	14	14	0.208	0.208	0.208	0.248
Spares									1	1	1	1	Averages including spares:			
		Subfleet total			**8.5**	**8.5**	**8.5**	**9.6**	**29**	**29**	**29**	**29**	**0.293**	**0.293**	**0.293**	**0.331**
NT	41	Warszawa	Tallinn (Helsiki)	DDm auto transporter	2.4	2.4	2.4	2.6	6	6	6	6	0.399	0.399	0.399	0.438
NT	42	Berlin/Vienna	Vilnius		1.3	1.3	1.3	1.5	6	6	6	6	0.208	0.208	0.208	0.248
Spares									3	3	3	3	Averages including spares:			
		Subfleet total			**3.6**	**3.6**	**3.6**	**4.1**	**15**	**15**	**15**	**15**	**0.243**	**0.243**	**0.243**	**0.274**
RE	21	Riga Airport	Tallinn Ülemiste	5-car articulated EMU 90 m	1.0	1.5	1.5	2.0	3	3	3	4	0.341	0.512	0.512	0.512
RE	22	Pärnu	Tallinn Ülemiste		0.4	0.6	0.6	0.8	1	2	2	2	0.403	0.302	0.302	0.403
RE	24	Bauska	Salacgrieva		0.6	0.9	0.9	1.2	1	2	2	2	0.615	0.461	0.461	0.615
RE	25	Bauska	Skulte		0.5	0.5	0.5	0.9	1	1	1	2	0.454	0.454	0.454	0.454
RE	26	Marjampole	Riga Central		1.0	1.5	1.5	2.0	3	3	3	4	0.328	0.491	0.491	0.491
RE	27	Vilnius	Panevezys		1.1	1.7	1.7	2.2	3	3	3	4	0.370	0.556	0.556	0.556
RE	28	Bialystok	Vilnius		0.9	1.4	1.4	1.9	3	3	3	4	0.314	0.471	0.471	0.471
RE	29	Kaunas	Vilnius		0.3	0.4	0.4	0.5	1	1	1	1	0.270	0.405	0.405	0.540
RIX	31	Riga Airport	Riga Central		0.1	0.1	0.1	0.1	1	1	1	2	0.073	0.091	0.091	0.073
HEL	51	Tallinn Ülemiste	Helsinki					1.9				4				0.470
Spares									3	3	3	5	Averages including spares:			
		Subfleet total			**5.9**	**8.6**	**8.6**	**13.6**	**20**	**22**	**22**	**34**	**0.294**	**0.389**	**0.389**	**0.401**
		Fleet total			**27.4**	**32.3**	**32.3**	**43.6**	**87**	**94**	**94**	**112**				

Table 155: Production volume required for passenger train operations

- The initial HST fleet size is well comparable to the fleet of 20 PKP ED250 trains which were delivered and are maintained for the first 17 years by Alstom. Depending on circumstances, it may even be possible to use this fleet for early operations.

- The proposed fleet for the regional passenger service is similar to the fleet of 18 STADLER FLIRT EMU + 20 STADLER FLIRT DMU = 38 vehicles purchased by railway undertaking "Elron" of Estonia in 2013/14, albeit these EMUs are designed for max. 160 km/h.

The average performance goals for HST and NT rolling stock are oriented to the DB and SNCF benchmark numbers[102]. For regional services they are usually lower, typically 144,000 to 191,000 km p. a., but include diesel lines too, services with top speeds of only 80, 120, or 160 km/h, frequent stops and high peakiness in commuter service. In the specific case of the Elron EMUs they could reach up to 102,000 km p. a.[103] Further Examples of EMU fleets in 160 km/h regional service in Germany exhibit values in the range of 235,000 km p. a. In the case of Rail Baltica, the RE service with a top speed of 200 km/h and large inter-station distances could be technically more like "Inter-Regio" or "Inter-City" service in existing commuter systems. As another orientation, typical British long distance operations are averaged at 266,000 to 292,000 vehicle-km p.a. under unfavorable circumstances (low line speed, frequent stops). And even 30 years ago, it was possible to accumulate 300,000 km p. a. with conventional loco-hauled DB Intercity trains.[104]

According to the fleet proposal, it has been assumed:

- Each HST service uses exactly one HST train set.

- Each NT service uses 1 locomotive, 7 coaches and 3 auto transporters.

- Each RE, RIX and HEL service uses exactly one RE train set.

Specific decisions which will have impact on the maintenance program have not been made yet, and resulting in open issues:

- viability of regional traffic in general – our concept thus avoids interdependencies,

- concepts for minimizing train operation costs by using true EMU operations of smaller units that the proposed 5-car EMU, such as 2- or 3- car EMU running single or in any combination,

- strategic options for allocation of lines to individual operators – this will be treated below,

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[102] Zschoche, Frank et al.: European Benchmarking of the costs, performance and revenues of GB TOCs. Civity Management Consultants, Hamburg 2012
[103] "Kilin, T.: VEEREMI VEOLIIGI VALIK AS-I EESTI LIINIRONGID STADLER FLIRT ELEKTRI- JA DIISELRONGIDE NÄITEL. LÕPUTÖÖ Logistikainstituut Raudteetehnika eriala, Tallinn 2018"
[104] Solf, W.: Instandhaltung und technische Behandlung der ICE-Triebzüge. ETR 36 (1987), H. 7/8, p. 475 ff.

- fine adjustment of timetables (e. g. optimization of turnaround times to save vehicles) – to be done in next planning phases, and
- detailed scheduling of train rotation in "working diagrams „that define in which sequence a given train set or EMU is to be used to cover advertised trains – this is necessary to prove whether a proposed depot location is the optimum choice; has to be done in next planning phases too.

5.1. Passenger rolling stock fleet maintenance facilities (WP 5.1)

For the workout of the Passenger rolling stock fleet maintenance facilities some considerations regarding the rolling stock are noteworthy at first:

- HST train sets and NT locomotives must be set suitable for 25 kV 50 Hz and 3 kV DC. While the maintenance, it must be possible to test propulsion systems under both systems (while the train is stationary).
- At initial operations, HST trains may be replaced by locomotive and coaches. Some shunting and run-around capabilities must be provided in the track layouts of the depots.
- Generally, for regional service as proposed in this operational plan, single system 25 kV 50 Hz EMU equipped with ETCS would be appropriate, but for the cross-border RE line Białystok – Vilnius, about 10 EMU must be of the AC/DC variant, suitable for 25 kV 50 Hz as well as 3 kV DC and equipped with ETCS too. At any depot concerned with the maintenance of the latter sub-type of EMU, it must be possible to test propulsion systems under both systems (while the train is stationary).
- Any rolling stock using the FinEst Link will have to adhere to higher standards regarding fire protection. These requirements are not relevant for the first investment period in passenger rolling stock and associated maintenance facilities, thus they are not discussed further. However, such requirements must be considered in the second investment period along with a new depot strategy. Otherwise, services on the lines 11 and 12 would need to be broken at Tallinn-Ülemiste, forcing passenger to transfer from conventional to "tunnel" rolling stock.
- Smaller EMUs for regional service will impact the maintenance operations in different ways:
  - Smaller units will be detached and stabled in off-peak periods and can be taken to maintenance, if the depot is close to the terminus with daytime layover, i.e. at the city terminals; thus reducing the required maintenance reserve;
  - More units need to be handled by fleet management and the administrations costs are slightly higher due to a higher amount of shunting and a more difficult shunting planning;
  - More work on couplers, control and ETCS equipment;

- More stub tracks or double-sided access is needed to avoid placing two short units with different scope of work on the same track, where one unit may block another from re-entry into service

- Regional traffic will most likely have to be subsidized by individual countries.

At least the services must be procured from the European market by tendering traffic franchises. Typically, such a contract runs about 12 to 14 years (equaling half-life of typical rolling stock). In Germany, typical long-term contracts range from 2 to 4 million train-km in the initial year, typically bundles of lines that can be served from a single depot location. Table 156 shows the distribution in the Rail Baltica planning area. Outgoing from this table, the following assumptions are necessary:

- HST and NT will be medium-sizes operations from the beginning. Their operators must be multi-national because those trains serve international traffic needs.

- In the initial 2026 traffic period, only Lithuania exceeds 2.0 million train-km p. a. in regional service

Train Category	Line No.	Route From	Route To	Train pairs per day				Poland Mio. train-km per year				Lithuania Mio. train-km per year				Latvia Mio. train-km per year				Estonia Mio. train-km per year				Finland Mio. train-km per year				TOTALS Mio. train-km per year			
				2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
HST	11	Warszawa	Tallinn (Helsiki)	4	6	6	8	1.1	1.7	1.7	2.2	0.8	1.2	1.2	1.6	0.7	1.0	1.0	1.4	0.6	0.9	0.9	1.5	0.0	0.0	0.0	0.3	3.2	4.8	4.8	7.0
HST	12	Vilnius	Tallinn (Helsiki)	4	6	6	8	0.0	0.0	0.0	0.0	0.8	1.2	1.2	1.6	0.7	1.0	1.0	1.4	0.6	0.9	0.9	1.5	0.0	0.0	0.0	0.3	2.1	3.1	3.1	4.7
HST	13	Warszawa	Vilnius	6	4	4	6	1.7	1.1	1.1	1.7	0.9	0.6	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.7	1.7	2.6
HST	14	Kaunas	Vilnius	6	12	12	10	0.0	0.0	0.0	0.0	0.4	0.8	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8	0.8	0.7
		Subtotal		**20**	**28**	**28**	**32**	**2.8**	**2.8**	**2.8**	**3.9**	**2.9**	**3.8**	**3.8**	**4.7**	**1.4**	**2.1**	**2.1**	**2.7**	**1.2**	**1.8**	**1.8**	**3.0**	0.0	0.0	0.0	**0.6**	**8.2**	**10.4**	**10.4**	**15.0**
		Regional share						*34%*	*27%*	*27%*	*26%*	*35%*	*36%*	*36%*	*32%*	*17%*	*20%*	*20%*	*18%*	*14%*	*17%*	*17%*	*20%*	*0%*	*0%*	*0%*	*4%*				
NT	41	Warszawa	Tallinn (Helsiki)	1	1	1	1	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.8	0.8	0.8	0.8
NT	42	Berlin/Vienna	Vilnius	1	1	1	1	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.8	0.8
		Subtotal		**22**	**30**	**30**	**34**	**0.9**	**0.9**	**0.9**	**0.9**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**	**0.2**	0.0	0.0	0.0	0.0	**1.6**	**1.6**	**1.6**	**1.6**
		Regional share						*58%*	*58%*	*58%*	*56%*	*22%*	*22%*	*22%*	*22%*	*11%*	*11%*	*11%*	*11%*	*9%*	*9%*	*9%*	*12%*	*0%*	*0%*	*0%*	*0%*				
RE	21	Riga Airport	Tallinn Ülemiste	4	6	6	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.7	0.7	0.9	0.6	0.9	0.9	1.2	0.0	0.0	0.0	0.0	1.0	1.5	1.5	2.0
RE	22	Pärnu	Tallinn Ülemiste	4	6	6	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.6	0.8	0.0	0.0	0.0	0.0	0.4	0.6	0.6	0.8
RE	24	Bauska	Salacgrieva	4	6	6	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.9	0.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.9	0.9	1.2
RE	25	Bauska	Skulte	4	4	4	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.9
RE	26	Marjampole	Riga Central	4	6	6	8	0.0	0.0	0.0	0.0	0.7	1.0	1.0	1.4	0.3	0.4	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.5	1.5	2.0
RE	27	Vilnius	Panevezys	8	12	12	16	0.0	0.0	0.0	0.0	1.1	1.6	1.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.6	1.6	2.2
RE	28	Bialystok	Vilnius	4	6	6	8	0.5	0.7	0.7	0.9	0.5	0.7	0.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.4	1.4	1.9
RE	29	Kaunas	Vilnius	4	6	6	8	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.5
RIX	31	Riga Airport	Riga Central	8	10	10	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
HEL	51	Tallinn Ülemiste	Helsinki	0	0	0	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.9	0.0	0.0	0.0	2.0
		Subtotal		**16**	**22**	**22**	**56**	**0.5**	**0.7**	**0.7**	**0.9**	**2.6**	**3.8**	**3.8**	**5.1**	**1.9**	**2.6**	**2.6**	**3.7**	**1.0**	**1.5**	**1.5**	**3.1**	0.0	0.0	0.0	**0.9**	**5.9**	**8.5**	**8.5**	**13.7**
		Regional share						*8%*	*8%*	*8%*	*7%*	*44%*	*45%*	*45%*	*37%*	*32%*	*30%*	*30%*	*27%*	*17%*	*17%*	*17%*	*23%*	*0%*	*0%*	*0%*	*6%*				
		Total						**4.2**	**4.4**	**4.4**	**5.8**	**5.8**	**8.0**	**8.0**	**10.2**	**3.4**	**4.8**	**4.8**	**6.6**	**2.3**	**3.4**	**3.4**	**6.3**	0.0	0.0	0.0	**1.5**	**15.7**	**20.5**	**20.5**	**30.4**

Table 156: National shares in passenger train production volume

Based on different experiences it is feasible to handle all the required regional EMU (34 units) at a single location. This can be illustrated by many examples such as the existing Tallinn-Pääsküla depot, currently serving 38 units. In Germany, it is very typical to serve lines not directly connected to an EMU depot. For the maintenance of the trains could “swap” through the lines and replace the requested trains for maintenance. Surely, this is only possible if a homogeneous rolling stock is used on several lines operated by the same operator.

In the context of RailBaltica, it is highly probable that individual lines, or only small packages, will be contracted at individual points in time. Even when technically interchangeable exists, the vehicles may belong to separate operators and will be typically equipped and branded in an individual manner. For any maintenance activity, they must run as Empty Coaching Stock (ECS) from one of the two ends of the timetabled line to the assigned depot, and a replacement train must be brought out to the terminal to protect the next scheduled service. For the estimation of transfer cost, it is assumed that such a manoeuver always takes place at the terminal closer to the depot. The cost for one ECS train-km is taken for German practice. The frequency of the transfers is governed by the basic maintenance interval of the EMUs which is assumed to be 10,000 km.

ECS transfers from line terminals to maintenance facilities		OPEX increase, million € p. a.				OPEX increase, million €, 40 years
Maintenance facilities	Lines served	2026	2036	2046	2056	
Acone	21, 22, 24, 25, 26, 27, 28, 29, 31	0.664	0.984	0.984	1.327	39.592
Acone / Vilnius	21, 22, 24, 25, 26, 31 / 27, 28, 29	0.140	0.198	0.198	0.280	8.171
Jaunmārupe / Vilnius	21, 22, 24, 25, 26, 31 / 27, 28, 29	0.107	0.148	0.148	0.215	6.172
Scheduled transfers per day		1.6	2.3	2.3	3.7	

Table 157: ECS transfer cost comparison

Table 157 clearly indicates that a full centralisation of the EMU maintenance is not optimal from an economic point of view. The CAPEX of the second facility (in the range 10 to 20 million €) clearly outweighs the potential savings (31 to 33 million €). The Jaunmārupe option yields even slightly better results.

It is assumed to use the same type of EMU for the Riga airport RIX shuttle service as well as for the general regional train services to avoid uneconomic small sub-fleets and to eliminate the need for a dedicated spare EMU that can be only used for the Riga airport RIX shuttle. Differences in branding etc. may be made, but this should not preclude technical and operational flexibility.

The fleet size appears large from the beginning, totals only growing from 38 trains in 2026, 50 trains in 2036/2046 and 68 trains in 2056. From the point of view of capacity, all maintenance activities (i.e. such that go beyond cleaning and servicing) could be performed by one central facility.

5.1.1. Required passenger and freight train stabling and servicing facilities

Given the large distances involved in Rail Baltica, trains will have to lay-over at several places. To identify the required number of layover tracks, solutions for the following tasks had to be found:

- estimation of the number of required trains to cover a given service as defined in the Service Pattern,

- even allocation of the obtained number of trains to both terminal points of the line; the obvious asymmetry according to peak load direction was assumed (e.g. morning trains starting from Marijampolė, Panevėžys, Bauska, Vangazi, Salacgriva, Pärnu and Rapla heading for the next larger city),
- if the trip time of the line is more than 2 hours, lay over at intermediate terminals is considered (e. g. HST at Kaunas and Riga Central),
- in some instances, two lines are assumed to be connected in a terminal to save layover time (e.g. assignment of trains from Tallinn Ülemiste alternates between lines to Riga Airport and Pärnu).

Spare trains are assumed to be located at points where a large number of services originate, allowing fast inclusion of spare trains in the service when needed:

- At larger stabling points of passenger rolling stock, 1 or 2 spare tracks (in excess of the scheduled layovers) are added for operational flexibility, e.g. disabled trains or, when swapping vehicles for maintenance.
- At small freight terminals, it may happen that terminating trains accumulate, e.g. during the weekend. For a first assessment, the required locomotive stabling capacity is assumed to be 1.5 times the average number of daily departures. The number is increased by 1 - 2 shunting locomotives. To explore the potential for synergy, the locomotive stabling requirements for freight traffic are included in Table 158.

Type of Service	Free standing length, meters	EXTERNAL	Warszawa	Bialystok	Elk	Suwalki	Marijampole	Kaunas main station	Palemonas	Karmelava	Vilnius	Vaidotu	Panevezys	Bauska	Jaunmārupe	Riga Airport	Acone	Salaspils	Skulte	Salacgrieva	Pärnu	Rapla	Tallinn Rae	Muuga	Helsinki	Total Number
Operations Plan 2026																										
Stabling, HST	210		4					3			7						5						5			24
Stabling, NT w/o DDm cars	210																									0
Stabling, spare coaches	30																									0
Stabling, DDm auto wagons	30																									0
Stabling, EMU	95			1	1		4				8		2	1			10		1	1	1	1	3			34
Stabling, Locomotive (pass+freight)	25	X			6				12			20				2	2	6						18		66
Stabling tracks, meters total	9.908		840	95	245	0	380	630	300	0	2230	488	190	95		50	2050	150	95	95	95	95	1335	450	0	
Shore power (1 kV train line pre-heating)			(HST and EMU trains are stabled power-on with raised pantograph)																							0
Shore power (230 V pedestal)			X		X				X			X				X	X	X						X		8
Interior Cleaning			X								X						X						X			4
Exterior Cleaning (train washer)											X						X									2
Closed Toilet Service & water filling			X								X						X						X			4
Refilling sand			X						X		X	X					X	X					X	X		8
Diesel fuel refilling			X									X						X						X		4
Provisons for dining cars (kitchen)			X								X						X						X			4
Provisons for sleeper cars (laundry)																										0

Table 158: Stabling and servicing facilities proposed for 2026

With regards to the option of using locomotive + 7 coaches as long-distance passenger trains, a free-standing length of 210 m is proposed. After arrival of a night train, the DDm auto wagons will be shunted to the auto terminal. The remaining car is the same size as a long-distance passenger train. When two stabling positions are needed in one track, 2 x 210 = 420 m free standing length shall be assumed.

For one 5-car EMU, 95 m will be sufficient. For holding 2 5-car EMU in one track, 190 m would be sufficient, but 210 m should be used for flexibility of track use between HST and EMUs. This will also ensure a safe walking path to cross the track between two EMUs parked without being coupled. Allowance for walking path or carriageway crossings at the end of tracks have to be considered separately.

Spare coaches and DDm car transport wagons may be stored in a stub track of appropriate length. No shore power is needed there.

With regards to 6 axle locomotives, 25 m has been assumed for one locomotive stabling position. Modern locomotives have a spring-actuated parking brake that is released by applying pressure to the main brake pipe. Thus, even locomotives of foreign operators can be shunted to give access to otherwise blocked locomotives. It is common practice to use a stub track for two or three locomotives or a through track for up to five locomotives.

Type of Service	Free standing length, meters	EXTERNAL	Warszawa	Bialystok	Elk	Suwalki	Marijampole	Kaunas main	Palemonas	Karmelava	Vilnius	Vaidotu	Panevezys	Bauska	Jaunmārupe	Riga Airport	Acone	Salaspils	Skulte	Salacgrieva	Pärnu	Rapla	Tallinn Rae	Muuga	Helsinki	Total Number
Operations Plan 2036/2046																										
Stabling, HST	**210**		4					3			8						5						5			**25**
Stabling, NT w/o DDm cars	**210**	1	1								1												1			**4**
Stabling, spare coaches	**30**	3	3								3												3			**12**
Stabling, DDm auto wagons	**30**		10								5												5			**20**
Stabling, EMU	**95**			1	1		4				8		2	1			10		1	1	1	1	4			**35**
Stabling, Locomotive (pass+freight)	**25**	X	3		8				15		2	24					2	6					2	24		**86**
Stabling tracks, meters total	**12.225**		**1515**	**95**	**295**	**0**	**380**	**630**	**375**	**0**	**2940**	**600**	**190**	**95**		**0**	**2050**	**150**	**95**	**95**	**95**	**95**	**1930**	**600**	**0**	
Shore power (1 kV train line pre-heating)			X								X						X						X			**4**
Shore power (230 V pedestal)			X		X				X		X	X				X	X	X					X	X		**10**
Interior Cleaning, partial			X				X				X						X						X			**5**
Exterior Cleaning (train washer)											X						X									**2**
Closed Toilet Service & water filling			X				X				X						X						X			**5**
Refilling sand			X				X		X		X	X					X	X					X	X		**9**
Diesel fuel refilling			X									X						X						X		**4**
Provisons for dining cars (kitchen)			X								X						X						X			**4**
Provisons for sleeper cars (laundry)		X	X								X												X			**4**

Table 159: Stabling and servicing facilities proposed for 2036/46

The locomotive stabling demand for freight traffic in Poland cannot be assessed at the moment.

Jaunmārupe is listed as an option if passenger stabling capacity south of the Daugava river crossing is requested. Karmelava is listed as an option for a freight handling facility and consolidation point if there is not enough room at Palemonas.

Type of Service	Free standing lLength, meters	EXTERNAL	Warszawa	Bialystok	Elk	Suwalki	Marijampole	Kaunas main	Palemonas	Karmelava	Vilnius	Vaidotu	Panevezys	Bauska	Jaunmārupe	Riga Airport	Acone	Salaspils	Skulte	Salacgrieva	Pärnu	Rapla	Tallinn Rae	Muuga	Helsinki	Total Number
Operations Plan 2056																										
Stabling, HST	**210**		4					3			8						5						5			**25**
Stabling, NT w/o DDm cars	**210**		2								1												1			**4**
Stabling, spare coaches	**30**		5								3												3			**11**
Stabling, DDm auto wagons	**30**		10								5												5			**20**
Stabling, EMU	**95**			1	1		4				6		2	1			8		1	1	1	1	2			**29**
Stabling, Locomotive (pass+freight)	**25**	X	3		10				17		2	27				2	2	8					2	36	2	**110**
Stabling tracks, meters total	**12.525**		**1785**	**95**	**345**	**0**	**380**	**630**	**413**	**0**	**2750**	**675**	**190**	**95**		**50**	**1860**	**188**	**95**	**95**	**95**	**95**	**1740**	**900**	**50**	
Shore power (1 kV train line pre-heating)			X								X						X						X		X	**5**
Shore power (230 V pedestal)			X		X				X		X	X				X	X	X					X	X	X	**11**
Interior Cleaning, partial			X				X				X						X						X			**5**
Exterior Cleaning (train washer)											X						X						X			**3**
Closed Toilet Service & water filling			X				X				X						X						X			**5**
Refilling sand			X				X		X		X	X					X	X					X	X		**9**
Diesel fuel refilling			X									X						X						X		**4**
Provisons for dining cars (kitchen)			X								X						X						X	X	X	**6**
Provisons for sleeper cars (laundry)		X	X								X														X	**4**

Table 160: Stabling and servicing facilities proposed for 2056

5.1.2. Required maintenance facilities

Location

Generally, a rolling stock maintenance facility should be located close to a terminal where a sufficient number of trains originates and terminates. Deadheading is a cost factor in many respects (energy, crew cost, access charges, wear, increase of fleet size, reduction of natural maintenance windows in the train working diagram), and should thus be avoided wherever possible.

However, some distances between terminal and maintenance facility will be incurred, because land next to the terminal is not available or too valuable for such kind of use. On the other hand, given the large basic inspection intervals of modern Regional Train EMU, which are typically 30.000-40.000 km or 30 days, all vehicles operating in a large system may be routed to a central maintenance point by skilfully planning rolling stock assignment.

From the operational point of view, the suitability of a location for a Passenger Rolling Stock Maintenance Facility may be assessed as follows:

- Vilnius has the largest number of trains to be parked (7 HST, 1 NT and 6 RE in the 2056 scenario) and is therefore the first candidate for a Passenger Rolling Stock Maintenance Facility. Disadvantages are the connection to the RB mainline via the Kaunas-Vilnius line, which is a single point of failure, and probably difficulty finding a suitable location not too far from Vilnius main station. There is still some planning latitude with this regard at this area.
- Riga (Acone Depot) has fewer trains (4 HST and 9 RE in the 2056 scenario) for stabling. Due to lack of stabling capacity at Riga Airport, no RE trains can be held out at Riga Airport to allow for an efficient start-up. Not all trains lying over in the Riga area would need to be at the maintenance facility every day. An advantage of the Acone Depot is its location along the Riga loop of Rail Baltica, which allows redundant access in any case of track or Daugava bridge outage. If there is an outage at any single point on the Rail Baltica mainline, at least half of the system would still be connected to Acone or any other facility along the Riga loop. At Acone, there is restricted planning latitude due to the current EIA process and a road overpass. Development of potential sites for stabling sidings near Riga Airport Jaunmarupe or a newly to developed site at Riga Airport Cargo Park enjoy the same benefits and could be developed into a Rolling Stock Maintenance Facility alternatively to Acone.
- The Tallinn Ülemiste station has at most 4 HST per night (2036/2046) and 3 RE trains (2056) at night, plus one NT during daytime. Servicing of those trains can only be done at the Tallinn Rae depot. At the proposed location of the Tallinn Rae depot, space is restricted to a width of about 5 tracks. This is probably sufficient when the last resp. first trains are held in Tallinn Ülemiste platform tracks for some hours before respectively after pulling in or out of the Tallinn Rae depot.
- At Kaunas main station, only 3 HST need to park; facilities for stabling should be sufficient and can be located close to the platform area by modification of existing track layout of the Kaunas Down Yard.
- In the Warszawa area, various facilities already exist which technically could serve the up to 4 HST and 1 NT to be stabled there, but it is a question of free access to Rolling Stock Maintenance Facilities provided by incumbent or independent operators if this is feasible. At least, stabling on rented PLK trackage should always be possible.
- At Białystok, Ełk, Marijampolė, Panevėžys, Bauska, Riga Airport, Skulte, Salacgriva, Pärnu and Rapla facilities for stabling are needed. It remains to be evaluated whether servicing and interior cleaning should also be provided, probably at Marijampolė and Riga Airport.
- The NT entering from Berlin or Vienna may also be maintained at Berlin respectively Vienna, depending on operatorship.

From the rolling stock point of view, Running Gear Check (RGC), required for HST train sets, will dictate where at least a pit track enclosed in a hall with provisions for thawing off frozen rolling stock has to be provided.

From the strategic point of view, the decision on location will be heavily influenced by the fact, which approach Rail Baltica chooses regarding operatorship. In Europe, various models exist:

- A single operator (e. g. incumbent operators such as DB, SNCF, PKP Intercity) will seek economies of scale by concentrating maintenance tasks at sites with more efficient technology. Larger CAPEX; investment decisions are based on long term planning horizons. If traffic reduces or is lost to competitors, facilities become under-utilised. Then, the incumbent operator can find benefits in offering maintenance service to competitors to recover its sunk cost (i.e. DB Regio maintains National Express trains after losing a franchise to them).

- Where multiple operators compete for franchises, the individual operators may build and operate rolling stock maintenance facilities to support their operations only. Usually, such facilities are erected on leased land, preferably industrial brown lands, inheriting the connection by private railway sidings. In passenger service, due to the limited term of franchise contracts, designs to minimise CAPEX were adopted and are very specific to the rolling stock used at the start of the franchise term. Some design decisions may later turn out as not effective.

- Vehicles may be procured by a state-owned Rolling Stock Leasing Company (ROSCO), maintained by the ROSCO (or a service provider contracted therewith) and leased to operators (wet lease). Several recent contracts in German regional service may serve as examples for this approach. A variation to this is the privatisation scheme of Norway.

- Rolling Stock Maintenance is contracted to the manufacturer of the trains. Typically, a local company is created for the purpose of providing such service, and it will lease the land and erect the necessary installations. This scheme is very dominant in Great Britain, but is also adopted in Germany, Poland, Russia and many other countries.

- Services requiring large CAPEX and OPEX as well as a large number of vehicles to make good utilisation (such are Heavy Maintenance Facilities, Wheel lathes, Bogie drops, spare parts pools) may be shared in any way possible.

The implications on assessment of the required Rolling Stock Maintenance Facilities are:

- Capacity assessment independent of tactical location decisions (which are made later).

- Provision of at least one option for centralizing.

- Provision of at least two options for any area to be operated under a separate franchise.

- Analysis of potentials for sharing cost-intensive installations.

Maintenance Capacity for High-Speed Train Sets

The consultant has reviewed maintenance programs and strategies used by DB, SNCF and PKP as well as proposals for High Speed Rail California and other projects.

For its High-Speed TGV trains, SNCF uses a system of five levels of maintenance activities. At the outer ends of their star-shaped network, only stabling and Level One light maintenance is performed. Associated to the various terminals in the Paris railway node, there are maintenance facilities providing the levels 1 to 3 light maintenance. Heavy maintenance (levels 4 and 5) is provided by two dedicated facilities, Bischheim and Hellemes, which are somewhat remote in the network and have been adapted from existing heavy maintenance facilities. This strategy is also proposed in the Design Guidelines[105].

DB started their ICE service using a large maintenance facility at Hamburg-Eidelstedt which is capable of proving all levels of maintenance activities and even the minor revisions to be carried out after 1.6 million running kilometres. Bogies can be exchanged through a specialised system without moving the train. However, the facility has no bogie regeneration shop of its own; bogies are shipped to dedicated facilities at Krefeld-Oppum and Nuremberg. With the expansion of the network, several other dedicated ICE maintenance facilities were added, Köln-Nippes being the most recent one. Several outer ends of the system are only served by trains turning at the platform or spending the night at stabling tracks.

PKP uses a centralised maintenance facility for their 20 Alstom ED250 trains at Warszawa-Grochów. This facility was built and is operated for the first 17 years by Alstom. Heavy maintenance of the ED250 trains is performed at another Alstom site in Poland.

Running Gear Check (RGC) required for HST train sets will dictate where at least a pit track enclosed in a hall with provisions for thawing off frozen rolling stock is to be provided. For example, DB initially required RGC for its ICE trains every 3.000 km. For the ICE-T[106] this was increased to 4.000 – 4.400 km. SIEMENS Velaro RUS requires RGE every 4.000 km[107]. SNCF allows for 5,000 km[108]. Recently, DB increased the values to 8.000 km. The value for Alstom ED 250 is unknown. The RGC (along with other examinations and servicing) takes 30 to 90 min.

Based on the German ICE maintenance schedule, the required number of maintenance stations is projected. A station is to be understood as a spot where a single vehicle is placed for a given maintenance task. There can be more than one station per line. Also, several stations can be combined in one line, where line utilisation permits.

[105] RBDG-RPT-005-B1 List of operational values, Chapter 15.4 Depot
[106] Zöll, D.: Weiterentwickeltes Bereitstellungs- und Instandhaltungskonzept im Personenverkehr. ETR 52 (2003) 6, p. 323 ff.
[107] Müller, C.: Zustandsgetriebene Instandhaltung ohne feste Intervalle. ETR 1+2/2011, p. 57 ff.
[108] CHSRA (Hrsg.): TERMINAL AND HEAVY MAINTENANCE FACILITY GUIDELINES AUGUST 2009. California High Speed Rail Authority, 2009

Operations Plan 2026											
Maintenance Schedule, HST train set							km/train/year		Fleet Size		
							352.782		20		
Level	**Average mileage, km**	**Maintenance Task**	**Occupation time per oocurrence, hours**	**Modules**	**Shunting allowance, hours**	**Track occupation time per ocurrence, hours**	**Occurences per year**	**Track occupation time per train, hours**	**Track time, total fleet, hours**	**Maintenance operating hours per stations and year**	**Equivalent number of stations**
RGC	4.000	Running Gear Check	1,5	none	0,5	2	88,2	176,4	3.528	1.500	2,35
EX	24.000	Examination	2,5	none	0,5	3	14,7	44,1	882	1.500	0,59
I1	144.000	Inspection Level 1	8	none	0,5	8,5	2,4	20,8	416	4.000	0,10
I2	280.000	Inspection Level 2	16	2 x 8 h	1	17	1,3	21,4	428	4.000	0,11
I3	576.000	Inspection Level 3	24	3 x 8 h	0,3	24,3	0,6	14,9	298	4.000	0,07
R1	1.200.000	Revision Level 1 (minor)	240	2 x 5 days	2	242	0,3	71,1	1.423	4.000	0,36
R2	2.400.000	Revision Level 2 (major)	240	2 x 5 days	Performed at heavy maintenance facility outside RailBaltica						
		Totals, scheduled maintenance					**107,5**	**348,8**	**6.975**		
		Contingency for corrective maintenance			20%			69,8	1.395	4.000	0,35
		Total						**419**	**8.370**		

Table 161: Required maintenance stations for HST train sets in 2026

Operations Plan 2036/46											
Maintenance Schedule, HST train set							km/train/year		Fleet Size		
							502.802		21		
Level	**Average mileage, km**	**Maintenance Task**	**Occupation time per oocurrence, hours**	**Modules**	**Shunting allowance, hours**	**Track occupation time per ocurrence, hours**	**Occurences per year**	**Track occupation time per train, hours**	**Track time, total fleet, hours**	**Maintenance operating hours per stations and year**	**Equivalent number of stations**
RGC	4.000	Running Gear Check	1,5	none	0,5	2	125,7	251,4	5.279	1.500	3,52
EX	24.000	Examination	2,5	none	0,5	3	21,0	62,9	1.320	1.500	0,88
I1	144.000	Inspection Level 1	8	none	0,5	8,5	3,5	29,7	623	4.000	0,16
I2	280.000	Inspection Level 2	16	2 x 8 h	1	17	1,8	30,5	641	4.000	0,16
I3	576.000	Inspection Level 3	24	3 x 8 h	0,3	24,3	0,9	21,2	445	4.000	0,11
R1	1.200.000	Revision Level 1 (minor)	240	2 x 5 days	2	242	0,4	101,4	2.129	4.000	0,53
R2	2.400.000	Revision Level 2 (major)	240	2 x 5 days	Performed at heavy maintenance facility outside RailBaltica						
		Totals, scheduled maintenance					**153,2**	**497,1**	**10.438**		
		Contingency for corrective maintenance			20%			99,4	2.088	4.000	0,52
		Total						**596**	**12.526**		

Table 162: Required maintenance stations for HST train sets in 2036/46

Operations Plan 2056											
Maintenance Schedule, HST train set							km/train/year 589.095		Fleet Size 26		
Level	Average mileage, km	Maintenance Task	Occupation time per oocurrence, hours	Modules	Shunting allowance, hours	Track occupation time per ocurrence, hours	Occurences per year	Track occupation time per train, hours	Track time, total fleet, hours	Maintenance operating hours per stations and year	Equivalent number of stations
RGC	4.000	Running Gear Check	1,5	none	0,5	2	147,3	294,5	7.658	1.500	5,11
EX	24.000	Examination	2,5	none	0,5	3	24,5	73,6	1.915	1.500	1,28
I1	144.000	Inspection Level 1	8	none	0,5	8,5	4,1	34,8	904	4.000	0,23
I2	280.000	Inspection Level 2	16	2 x 8 h	1	17	2,1	35,8	930	4.000	0,23
I3	576.000	Inspection Level 3	24	3 x 8 h	0,3	24,3	1,0	24,9	646	4.000	0,16
R1	1.200.000	Revision Level 1 (minor)	240	2 x 5 days	2	242	0,5	118,8	3.089	4.000	0,77
R2	2.400.000	Revision Level 2 (major)	240	2 x 5 days	Performed at heavy maintenance facility outside RailBaltica						
		Totals, scheduled maintenance					**179,5**	**582,4**	**15.142**		
		Contingency for corrective maintenance			20%			116,5	3.028	4.000	0,76
		Total						**699**	**18.170**		

Table 163: Required maintenance stations for HST train sets in 2056

For all Time Periods, it was assumed that RGC and EX will take place at night (6 hour time window 23-5 h) at 250 working days per year, 6 x 250 = 1.500 hours. In the result, 4, 5 and 7 tracks are needed around the system each night for this type of work in 2026, 2036/2046 and 2056, respectively. The precise spatial distribution of the RGC tracks can only be assessed on basis of a train working diagram. Possible locations are Warszawa, Vilnius, Acone, Tallinn Rae and Helsinki (only from 2056 on).

According to the modern practice implemented by DB[109], the inspection tasks (I1, I2 and I3) can be split into work packages of 8 hours each. Such work packages can be performed during an extended night layover or during a day layover. For a revision (R1 and R2), a train set is taken out of service for 5 consecutive days, blocking one station. In total, 2 or 3 spots (210 m tracks) will be sufficient for inspections and revisions.

Performing the Revision Level 1 at facility oriented towards light maintenance is a somewhat special feature used by DB at selected locations, see Figure 118. In high-speed service, trains accumulate mileage very quickly, so that all bogies need to be exchanged after about 4-5 years, which is about half of the interval of major revisions. The bogies are then sent to the bogie workshop for refurbishment. This bogie workshop may be located either next to the light maintenance facility (typical stand-alone high-speed lines overseas) or within a dedicated heavy maintenance facility (typical for high-speed lines integrated into existing systems such as DB and SNCF). In the latter case, frequent shipping of the bogies is necessary.

[109] Zöll, D.: Weiterentwickeltes Bereitstellungs- und Instandhaltungskonzept im Personenverkehr. ETR 52 (2003) 6, p. 323 ff.

Revision Level 2 (major revisions), half-lifetime overhauls (2nd major revision typically after 16 years) and accident repairs may be contracted outside Rail Baltica infrastructure.

Assuming 16 hours at 250 working days, no more than 3 spots (or 210 m tracks) are sufficient for inspections, revisions and all associated corrective maintenance (extended duration of repair). Attached to this track capacity is personnel with specialised training, lifting or bogie exchange equipment specific to the HST train sets and a large inventory (worth approx. 10 Mio €) of spare parts specific to the HST train sets. It is evident that it is not economic to duplicate this high fixed-cost maintenance resource over more than one location.

The fleet size of at most 26 train sets is at the lower end of typical HST fleets assigned to one maintenance facility at DB, SNCF or Japan Railways. For example, in Germany, about 280 train sets are assigned to 9 maintenance facilities and 2 heavy repair and component refurbishment facilities.

Provision of a Heavy Maintenance Facility for the HST train set within RailBaltica infrastructure is not foreseen.

It is recommended to contract this work to existing facilities outside the Baltic countries. The precise location of such a facility will depend on design and manufacturer of the HST train sets to be procured. For example, major revisions (level 4 maintenance) for the 20 PKP ED 250 pendolinos are performed at an Alstom site in Poland.

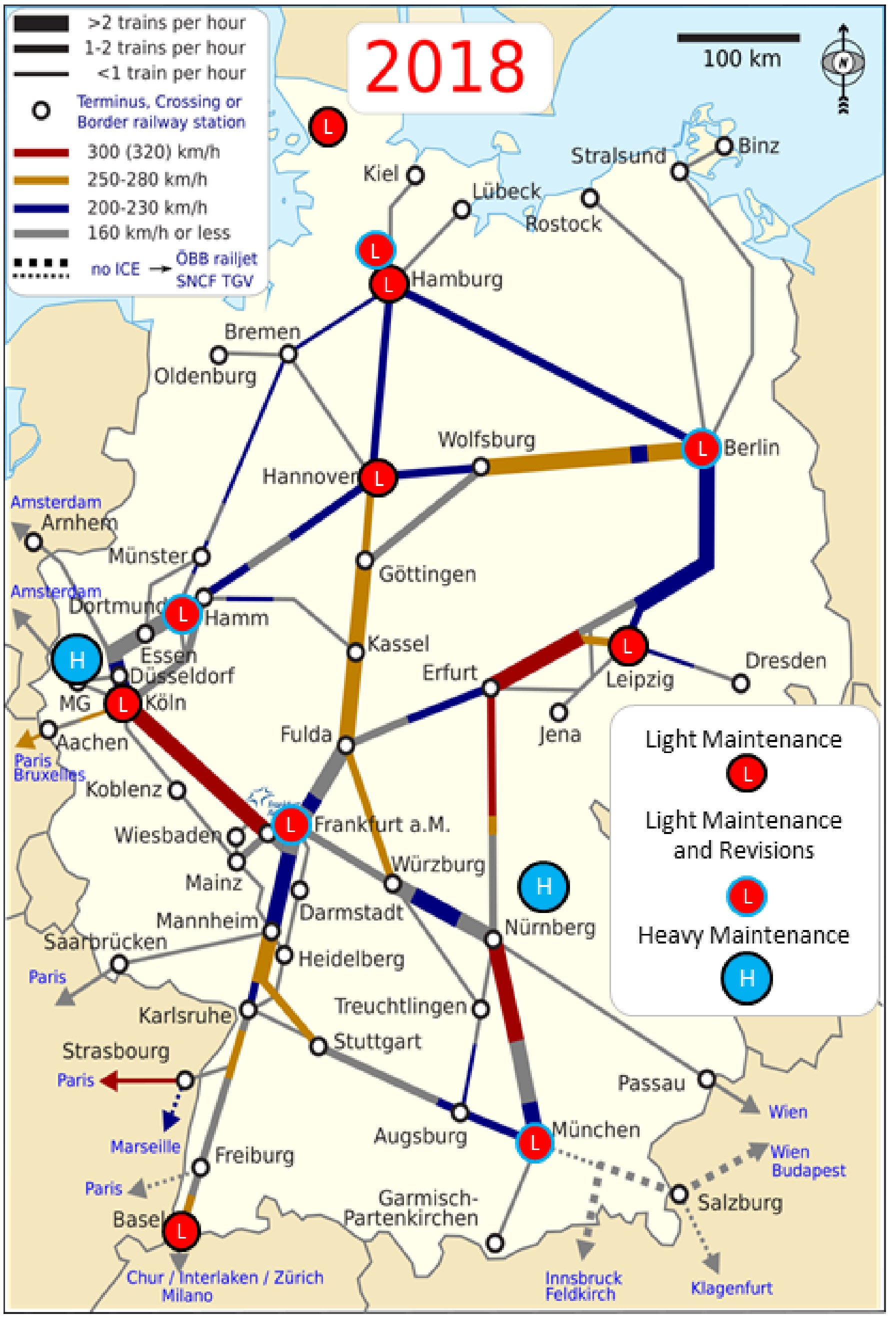

Figure 118: Rolling Stock Maintenance facilities for ICE trains in Germany, serving approx. 280 train sets

The only existing HST maintenance facility along the Rail Baltica corridor is the Alstom maintenance facility at Warszawa-Grochów. It has not enough excess capacity to handle 20 to 26 extra trains for RB purpose. However, being in use for 20 trains today, it is a well suited reverence design for such a facility. It even could maintain all HST train sets needed for RailBaltica if the lines presently served by ED 250 would use other rolling stock.

In conclusion, independent of the result of HST train set procurement, a one full HST inspection facility is needed within Rail Baltica territory. As outlined in the layover analysis, Vilnius is the prime location and Acone would still be an acceptable location. Other HST terminals, such as Warszawa and Tallinn, should be provided with the capability for servicing, Running Gear Check and Examination.

Revision level 1 (minor revision, exchange of all bogies) may also be performed at the proposed site. Sufficient area either for bogie storage or a fully equipped bogie workshop needs to be considered.

An underfloor wheel lathe, capable of handling trains up to 205 m and 22.5 t axle load, has to be provided near the HST maintenance facility.

Train washing facilities for HST train sets up to 205 m may use fixed portals and a shunting or travelling wash portals where train is kept stationery (an example is to be found at Köln Betriebsbahnhof).

At the underfloor wheel lathe and at a fixed-portal washing facility, the train will need to be moved by shunting tractors capable of handling up to 500 t train mass. Rope winches are not suitable for this task. Enough free track length on both sides of the facilities has to be provided.

Maintenance Capacity for Night Trains

Maintenance of Night trains would occasionally need 8-16 hours of track time at Vilnius and Tallinn. This can easily be done by the HST facilities.

A unit-train approach for handling night trains is recommended. Locomotive and coaches will not be separated in the stabling yard. Maintenance of locomotive and coaches is done on the same track essentially by the same personnel, which needs to be trained accordingly. This activity will occur during daytime, when little servicing and inspection activity is done at high-speed trains. Hence, no extra track is needed (difference between 1,500 resp. 4,000 operating hours for HST maintenance assumed in Table 161 to Table 163 vs. 8,760 total hours per year). Separation of the night train is only needed to place the DDm auto-transport wagons at the loading dock and occasionally to switch in spare cars.

Maintenance Capacity for Regional Passenger Trains

Concluding form many existing operations in Germany and new installations, a fleet size of up to 36 EMUs can be efficiently handled by just one rolling stock maintenance facility equipped with 2 or 3 stub tracks of 95 m.

5.1.3. Planned or existing maintenance facilities for passenger rolling stock

Present recommendations[110] to the Rail Baltica project are of a very general nature. No Design Guidelines for Rolling Stock Maintenance Facilities (RSMF) have been worked out. Only a very general hint as how to connect or RSMF to the mainline has been given[111]. The proposed centre passing loop as a holding point before crossing the adjacent main tracks is a sophisticated solution, only needed in an environment with high traffic density, which is not the case with Rail Baltica.

Figure 11 shows the location of existing and planned maintenance facilities, and also locations worth to be considered.

For none of the locations, satisfactory documentation was provided. The only pieces of information supplied were:

- Estonia – Tallinn: Plans and text (Estonian only) regarding a passenger rolling stock maintenance facility near the village of Rae, called “Tallinn-Rae” in this work; the material contained almost no railway-specific information;
- Estonia – Muuga: Sketches of 2 track layout variants showing 1435 mm tracks leading into existing 1520 mm locomotive service facility operated by EVR Cargo with no further explanations;
- Latvia – Acone: 1:1000 track layout, no textual explanation;
- Lithuania – Karmėlava: Very large scale sketch, no textual explanation;
- Lithuania – Kaunas Down Yard: Very large scale sketch, no textual explanation;
- From Poland, no information was received at all.

The consultant reviewed Network Statements in Estonia, Latvia, Lithuania and Poland to gather information on existing facilities. Also, more desktop research was done to collect information on independent light and heavy maintenance providers. All 1435 mm facilities within about 250 km of the Rail Baltica Corridor, existing 1520 mm facilities right next to the Rail Baltica 1435 mm trackage and heavy maintenance providers capable of component refurbishment are taken into consideration.

110 RBDG-RPT-005-B1 List of operational values, Chapter 15.3.2 Maintenance of rolling stock, only 3 pages
111 RBDG-MAN-025-0101 Infrastructure Facilities, Chapter 6, only ½ page

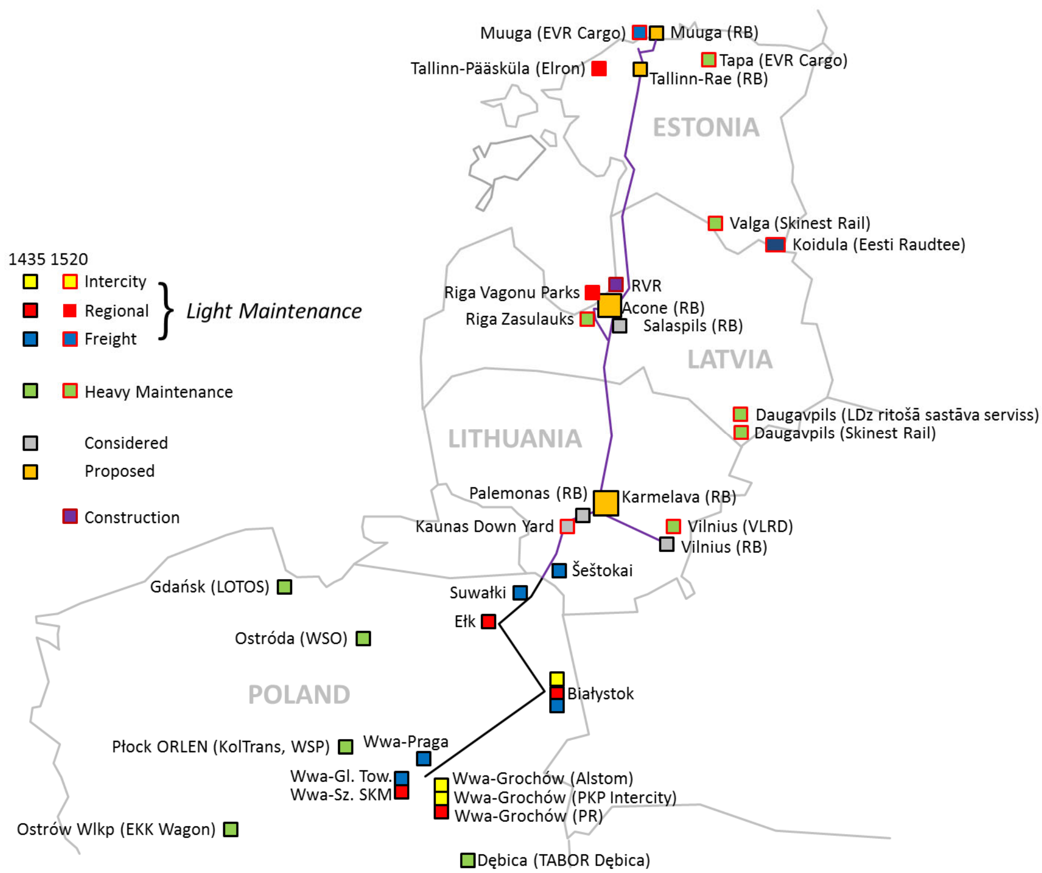

Figure 119: Existing, planned and proposed Rolling Stock Maintenance Facilities in the Rail Baltica planning area

5.2. Cost estimate of passenger rolling stock fleet maintenance (WP 5.2)

5.2.1. Investment cost

As already outlined the allocation of maintenance activities to specific sites cannot be determined finally. To estimate required CAPEX for maintenance facilities a generic approach was chosen. Based on the conclusions regarding allocation of maintenance activities to the sites along Rail Baltica there are two two main options:

- Allocation of activities to three locations (e. g. Tallinn Rae, Acone, Vilnius).
- Concentration of vehicle maintenance activities to two locations. This would correspond to the overall fleet size. In this case a mixed approach will be desirable.

Calculation of CAPEX is based on total amount of facilities required for HST and regional train fleet. For a first estimate it is assumed that CAPEX is proportional to size and number of stations where the work is performed. Based on consultant's experience, the average cost per station for maintenance of regional trains can be estimated at 35.000 Euro per track meter. To reach each station, access tracks are needed, which are calculated separately. It is assumed that the length of access tracks is proportional to length of stations. Facilities which are only used once per workshop are also calculated separately (wheel lathe, exterior cleaning facility).

Calculation results are provided in Table 164 below. Based on the assumption that specific investment costs per station will decrease, if maintenance activities are centralized in two workshops a deduction of 15% was made from the specific investment costs per station to highlight potential synergies. Furthermore, it is assumed that in the two-depot-scenario tracks can be better utilized, thus one station less is calculated for regional trains in this scenario.

3 Workshops	Quantity	Length	Cost/Unit	Total Cost
Stations HST Train Fleet	8	210	40.000 €	67.200.000 €
Stations Regional Train Fleeet	8	100	35.000 €	28.000.000 €
Exterior Cleaning	3		3.000.000 €	9.000.000 €
Wheel Lathe	3		1.800.000 €	5.400.000 €
Access Tracks HST	8	250	1.500 €/m	3.000.000 €
Access Tracks RT	8	150	1.500 €/m	1.800.000 €
Total Investment				**114.400.000 €**
2 Workshops	Amount	Length [m]	Cost/Unit	Total Cost
Stations HST	8	210	34.000,00 €	57.120.000 €
Station Regional Train	7	100	29.750,00 €	20.830.000 €
Exterior Cleaning	2		3.000.000,00 €	6.000.000 €
Wheel lathe	2		1.800.000,00 €	3.600.000 €
2 Workshops (cont.)	Amount	Length [m]	Cost/Unit	Total Cost

Access Tracks HST	8	250	1.350,00 €	2.700.000 €
Access Tracks RT	7	150	1.350,00 €	1.420.000 €
Total Investment				**91.670.000 €**

Table 164: CAPEX estimation (basis timetable 2046)

Based on the table above the needed total investment amounts at 92 million Euros (two depots) and 114 million Euros (three depots) for time horizon 2036/46. As can be deducted from the table, implementation of the two-depot-strategy would safe investments of approx. 20 million Euro.

5.2.2. Operating cost

Typical maintenance programme

A typical maintenance program encompasses

- Light maintenance activities (Inspections), which can be further broken down to
    - Preventive Maintenance activities, performed at regular intervals,
    - Corrective Maintenance activities, performed whenever needed;
- Heavy maintenance (Revisions), which e. g. in Germany is legally required in effect every 8 years for passenger rolling stock; this is to be considered in CAPEX as an repeated re-investment in the assets – it adds a betterment to the assets; should a railway undertaking or vehicle keeper be liquidated, a vehicles with a fresh revision has a larger market value than a vehicle which is due for revision or is expired;
- Accident repair, which should be covered by insurance or causing party;
- Modifications (half-life overhauls), which also add a betterment to the assets and should be viewed as re-investment on the CAPEX side.

In HST train service, at Western European wage levels, approximately 40% of total rolling stock cost is attributed to materials cost and 60% to personnel cost. Converting wages to Latvian levels and keeping materials unchanged, the total cost would be reduced to 56% off the base value.

Based on experiences with 3-car and 4-car 15 kV 16,7 Hz EMUs used by several operators in regional service in Germany, a typical light maintenance schedule was developed for the projected Rail Baltica 5-car 25 kV 50 Hz EMU. The cost increment for adding the 5^{th} car was determined by the benchmarked ratio between 3 and 4 car EMU. The different AC voltage has no significant impact as many parts would be unaltered in a modern power supply system using inverters.

Maintenance Effort, 5-car EMU	running	294,000	km per year			
			per occurrence		per year, average	
Maintenance Level	Interval	per year	man-hours	Materials	man-hours	Materials
Running Gear Check	1 Month	12	10	- €	119	- €
Inspection Level 1	3 Month	4	17	71.59 €	70	270.00 €
Inspection Level 2	6 Month	2	36	130.35 €	71	330.00 €
Inspection Level 3	1 Year	1	160	4,088.22 €	160	4,088.22 €
Inspection Level 4	2 Years	0.5	176	4,589.36 €	88	2,100.00 €
Inspection Level 5	4 Years	0.25	361	61,868.35 €	90	15,467.09 €
Corrective Maintenance	per 1000 km	294	1	201.47 €	430	59,232.35 €
Moveable Step Service	1 Month	12	20	127.53 €	240	1,530.36 €
Moveable Step end pieces	4 Months	3	1	1,962.22 €	3	5,886.66 €
Gear Oil Change	1 Year	1	3	61.36 €	3	61.36 €
Winter Ready Preparation	1 Year	1	2	- €	2	- €
Minor Brake Revision	3 Months	4	9	- €	37	- €
Major Brake Revision	12 Months	1	12	- €	12	- €
GSM-R Train Radio Level 1	3 Months	4	1	- €	2	- €
GSM-R Train Radio Level 2	1 Year	1	2	- €	2	- €
GSM-R Train Radio Level 3	2 Year	0.5	3	- €	1	- €
ATC Minor Inspection	6 Months	2	4	- €	7	- €
Totals, Light Maintenance				**per vehicle**	**1,340**	**88,966.04 €**
				per 1000 km	**4.56**	**302.61 €**

				man-hours	**materials**
Fleet size	20		**Fleet Total, per average year**	**26,795**	**1,779,320.81 €**
Maintenance direct FTE productive hours per year		1300	FTE/vehicle	1.03	
Required FTE workers (direct maintenance workers, without overhead)				**20.6**	

Table 165: Typical maintenance effort for a 5-car EMU

In the context of rolling stock procurement, the bidder will make proposals for maintenance schedules, work effort and materials cost. In the above case, the experience of the rolling stock operator the numbers proposed by the rolling stock supplier were exceeded by 10% to 40%. This adjustment is already considered in the given data.

Corrective Maintenance depends on mileage. In the given example, about 35% of man-hours and 70% of materials are caused by corrective actions. All condition-based maintenance tasks, such as replacement of brake pads or wheel re-profiling (also called wheel trueing), fall within this category despite their need is identified by checks prescribed by preventive maintenance activities.

As the given example is based on a maintenance program with fixed time intervals, there is an incremental cost decrease with higher productivity.

RE trains			OPEX per 1,000 km		OPEX per year	
Year	Fleet	Avg km	man-hours	Materials	man-hours	Materials
2026	20	294,000	4.56	302.61	26,795	1,779,321
2036	22	389,000	3.80	277.91	32,535	2,378,326
2046	22	389,000	3.80	277.91	32,535	2,378,326
2056	34	401,000	3.73	275.62	50,878	3,757,795

Table 166: Regional Train Maintenance OPEX

Another data set[112] was published on the STADLER FLIRT EMU und DMU sets operated by railway undertaking "Elron" of Estonia since 2013/2014. Based on actual maintenance costs and performance in 2017, a maintenance rate of 145 € per 1000 vehicle-km for the average Elron EMU, with no separation between 3- and 4-car EMUs can be estimated.

From the data, further conclusions can be drawn:

- The hourly wage rate in the 4th quarter of 2017, when calculated from Labour Cost / Maintenance Time cumulated, would be 8.50 € per hour, which is unrealistically low; for a CBA, the labour cost must be properly determined and factored in.
- The Elron fleet consists of 6 four-car and 12 three-car EMUs, a theoretical average of 3.333 cars per EMU. The 5-car RB EMU will still have the same number of end-car components and propulsion units and simpler middle sections added, but that advantage will be offset by the more complex ETCS and brake systems required to run 200 km/h instead of 160 km/h. Scaling can be used to forecast on the 5-car RB EMU.
- 3.5 man-hours per 1,000 vehicle-km were spent in the 4th quarter of 2017 on the 3.333 car EMU; scaling to 5 cars yields 5.2 man-hours per 1,000 vehicle-km.
- Materials (scheduled and non-scheduled maintenance, lubricants) amounts to a rate of 118 € per 1,000 vehicle-km of the average 3.333-car EMU, scaling to 5 cars yields 217 € per 1000 vehicle-km.
- Materials appear to contribute to 81% of total maintenance cost.
- The time frame used does not necessarily give a precise cost base; a more thorough rolling average calculation would be desirable.
- P5 and P6 revisions are excluded.

[112] Kilin, T.: VEEREMI VEOLIIGI VALIK AS-I EESTI LIINIRONGID STADLER FLIRT ELEKTRI- JA DIISELRONGIDE NÄITEL. LÕPUTÖÖ Logistikainstituut Raudteetehnika eriala, Tallinn 2018

Both data source lead to results that fall in the same range.

Light maintenance of High Speed Trains causes significantly more expenses due to closer maintenance intervals and additional safety requirements. Comfort requirements are increased also.

The length of HST vehicles is substantially larger than Regional EMU (approx. 200 m vs. approx. 90 m), so that at least 2.2 times more components are involved.

Night trains use less sophisticated technology and have a rather low mileage.

5.2.2.1. Human resources

Calculation of required human resources is based on specific maintenance effort per train km. This allows for scaling human resources to the operational programme in each time horizon. The required man-hours per fleet km were estimated on typical example maintenance schedule as provided above, taking into account differences between HST and regional trains.

Based on the required work hours the number of required staff was calculated. For this study, 1,300 man-hours/FTE is assumed. This value is confirmed by benchmarking experience[113]. According to benchmarking of several European Train Operating Companies average productivity ranges from 1,272 to 1,679 man-hours per FTE. An example in Germany used 1,350 man-hours per FTE. Trainings and audits must also be taken into account.

To maintain the fleet according to operational program for time horizon 2026 a total of 80 workers would be required for maintenance in the workshops. With growing fleet milage this number would raise to approx. 150 FTE for time horizon 2056. This figure does not include overhead for administration and management.

It can be assumed that at least 15 more staff would be required for that purpose.

113 Zschoche, Frank et al.: European Benchmarking of the costs, performance and revenues of GB TOCs. Civity Management Consultants, Hamburg 2012

Frontline FTE worker productivity man-hours/FTE p. a.	1300

Train Category	Line	Route From	Route To	Vehicle type	Unit MDBM, km	Maintenance spottings per day 2026	2036	2046	2056	work-hours per 1,000 km 2026	2036	2046	2056	Fleet man-hours p. a. 2026	2036	2046	2056	FTE maintenance workers 2026	2036	2046	2056
HST	11	Warszawa	Tallinn (Helsiki)	High-Speed trainset 200 m	4,000	2.2	3.3	3.3	4.8	8.9	8.9	8.9	8.9	28,528	42,791	42,791	62,665	21.9	32.9	32.9	48.2
HST	12	Vilnius	Tallinn (Helsiki)		4,000	1.4	2.1	2.1	3.3	8.9	8.9	8.9	8.9	18,443	27,665	27,665	42,497	14.2	21.3	21.3	32.7
HST	13	Warszawa	Vilnius		4,000	1.7	1.1	1.1	1.7	8.9	8.9	8.9	8.9	22,371	14,914	14,914	22,371	17.2	11.5	11.5	17.2
HST	14	Kaunas	Vilnius		4,000	0.3	0.6	0.6	0.5	8.9	8.9	8.9	8.9	3,622	7,245	7,245	6,037	2.8	5.6	5.6	4.6
Spares					Averages including spares:													(3.12)	(3.10)	(3.10)	(3.54)
		Subfleet total			**4,000**	**5.6**	**7.1**	**7.1**	**10.2**									**56.1**	**71.2**	**71.2**	**102.7**
NT	41	Warszawa	Tallinn (Helsiki)	Electric Locomotive	10,000	0.2	0.2	0.2	0.2	2.5	2.5	2.5	2.5	1,993	1,993	1,993	2,189	1.5	1.5	1.5	1.7
NT	42	Berlin/Vienna	Vilnius		10,000	0.1	0.1	0.1	0.1	2.5	2.5	2.5	2.5	1,042	1,042	1,042	1,238	0.8	0.8	0.8	1.0
Spares					Averages including spares:													(0.47)	(0.47)	(0.47)	(0.53)
		Subfleet total			**10,000**	**0.3**	**0.3**	**0.3**	**0.4**									**2.3**	**2.3**	**2.3**	**2.6**
NT	41	Warszawa	Tallinn (Helsiki)	Coach, Sleeper, Dining car	30,000	0.5	0.5	0.5	0.6	0.9	0.9	0.9	0.9	5,023	5,023	5,023	5,517	3.9	3.9	3.9	4.2
NT	42	Berlin/Vienna	Vilnius		30,000	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	2,626	2,626	2,626	3,120	2.0	2.0	2.0	2.4
Spares					Averages including spares:													(0.20)	(0.20)	(0.20)	(0.23)
		Subfleet total			**30,000**	**0.8**	**0.8**	**0.8**	**0.9**									**5.9**	**5.9**	**5.9**	**6.6**
NT	41	Warszawa	Tallinn (Helsiki)	DDm auto transporter	30,000	0.2	0.2	0.2	0.2	0.5	0.5	0.5	0.5	1,196	1,196	1,196	1,314	0.9	0.9	0.9	1.0
NT	42	Berlin/Vienna	Vilnius		30,000	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	625	625	625	743	0.5	0.5	0.5	0.6
Spares					Averages including spares:													(0.09)	(0.09)	(0.09)	(0.11)
		Subfleet total			**30,000**	**0.3**	**0.3**	**0.3**	**0.4**									**1.4**	**1.4**	**1.4**	**1.6**
RE	21	Riga Airport	Tallinn Ülemiste	5-car articulated EMU 90 m	10,000	0.3	0.4	0.4	0.6	4.6	4.1	4.1	4.1	4,706	6,291	6,291	8,389	3.6	4.8	4.8	6.5
RE	22	Pärnu	Tallinn Ülemiste		10,000	0.1	0.2	0.2	0.2	4.6	4.1	4.1	4.1	1,854	2,478	2,478	3,305	1.4	1.9	1.9	2.5
RE	24	Bauska	Salacgrieva		10,000	0.2	0.3	0.3	0.3	4.6	4.1	4.1	4.1	2,827	3,779	3,779	5,039	2.2	2.9	2.9	3.9
RE	25	Bauska	Skulte		10,000	0.1	0.1	0.1	0.2	4.6	4.1	4.1	4.1	2,087	1,860	1,860	3,720	1.6	1.4	1.4	2.9
RE	26	Marjampole	Riga Central		10,000	0.3	0.4	0.4	0.5	4.6	4.1	4.1	4.1	4,520	6,043	6,043	8,058	3.5	4.6	4.6	6.2
RE	27	Vilnius	Panevezys		10,000	0.3	0.5	0.5	0.6	4.6	4.1	4.1	4.1	5,112	6,835	6,835	9,113	3.9	5.3	5.3	7.0
RE	28	Bialystok	Vilnius		10,000	0.3	0.4	0.4	0.5	4.6	4.1	4.1	4.1	4,332	5,791	5,791	7,722	3.3	4.5	4.5	5.9
RE	29	Kaunas	Vilnius		10,000	0.1	0.1	0.1	0.1	4.6	4.1	4.1	4.1	1,242	1,661	1,661	2,215	1.0	1.3	1.3	1.7
RIX	31	Riga Airport	Riga Central		10,000	0.0	0.0	0.0	0.0	4.6	4.1	4.1	4.1	336	374	374	599	0.3	0.3	0.3	0.5
HEL	51	Tallinn Ülemiste	Helsinki		10,000				0.5				4.5				8,467	0.0	0.0	0.0	6.5
Spares					Averages including spares:													(1.04)	(1.23)	(1.23)	(1.28)
		Subfleet total			**10,000**	**1.6**	**2.3**	**2.3**	**3.7**									**20.8**	**27.0**	**27.0**	**43.6**
		Fleet total																**80.6**	**102.0**	**102.0**	**150.5**

Table 167: Maintenance frequency and human resources required in passenger train maintenance (numbers in brackets: FTE maintenance workers per vehicle in the fleet)

5.2.2.2. Heavy maintenance

Performing revisions at fixed intervals is a legal requirement in many countries. For example, German norm "Eisenbahn-Bau- und Betriebsordnung" (EBO) requires a revision after 6 years, and in case of good condition of the vehicle, this can be postponed two times by one year. This is possible virtually every time, so that revisions are conducted every 8 years at a heavy maintenance facility. The downtime is typically 2 to 3 weeks for modern HST train sets and regional EMU.

During this time, many large components such as bogies, transformers, inverters and air conditioning units are removed from the car body. The car body is checked, repaired and repainted when necessary.

Often, revisions are out-sourced and procured as a service including labour and materials. For a 5-car EMU, price estimates are about 250,000 to 300,000 €. Revision of one HST train set may cost 600.000 to 1,000,000 €. Offers for such services may be submitted by service divisions of rolling stock manufacturers or independent maintenance providers. Their heavy maintenance facilities are connected to the existing European 1435 mm network.

Recently, a trend can be observed with private Railway Undertakings in Germany to perform the revisions at or close to the light maintenance area which the fleet is assigned to. One or more tracks in the depot must be equipped and available for such activity. In the given case of initial fleet sizes of 18 to 34 EMU fo regional trains, it is possible to conduct the revision program in less than one year using only one dedicated track in the workshop. Components such as bogies, transformers, power packs etc. may be shipped to remanufacturing sites, which do not need to be centralised at one location. Just-in-time logistics is needed in this case, often using road transport for sake of speed and flexibility. Hence, workshop sited must be provided with internal roadways and a good connection to the national road system.

Another trend observed with SBB in Switzerland and DB Fernverkehr is breaking up the revision schedule in many small work packages that can be handled during natural layover of the vehicles. A rolling stock design supporting this approach is desirable.

5.2.2.3. Maintenance cost estimate based on specific costs

Several benchmarking reports state maintenance cost rates per train-km.
According to the experience of three operators it was concluded that

- High-Speed Train maintenance costs are 7.52 €/train-km including cleaning and restocking[114].

From several franchise operators in passenger service, average maintenance cost rate, including cleaning and provisions, have been determined[115] for

- Regional service, 5.14 €/train-km,
- Long-Distance service, 3.79 €/train-km.

For night trains, a rate increased by 1/3 is assumed due to low train-km of such rolling stock, technical complexity and re-stocking of supplies, hence

- Night Train Service costs, 5.04 €/train-km.

The prices are based on the higher local labour cost of the operators investigated (Japan, UIC, GB, Germany). As labour cost is lower in Baltic countries, the estimates are on the safe side.
Using the train-km estimates from chapter 5.2, the total passenger rolling stock maintenance budget can be projected.
According to press reports, along with the purchase of 20 Alstom Pendolino ED250 trains, Alstom was contracted to maintain these 20 train sets over a period of 17 years for a contract value of 665 million €. This includes provision of a dedicated maintenance facility at Warszawa-Grochów, wages of light maintenance personnel (at Warszawa levels), materials and two revisions of each train set to be conducted at another Alstom facility. The annual average per train-set is 1.5 million €. The annual total for 20 train sets would be 30 million €.
In 2011, SNCF reported[116] purchase cost of one 350 seat high-speed train set of 30 to 60 million USD with yearly maintenance cost of 1.4 million USD or 2 to 5 USD per mile. This roughly matches with the Alstom figures.

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[114] CHSRA (Ed.): Revised 2012 Business Plan. California High Speed Rail Authority, 2012
[115] Zschoche, Frank et al.: European Benchmarking of the costs, performance and revenues of GB TOCs. Civity Management Consultants, Hamburg 2012

5.3. Freight rolling stock maintenance facilities (WP 5.3)

5.3.1. Required maintenance facilities

The required maintenance capacity and its location are heavily dependent on the chosen operator model:

- Multiple freight train operators using AC/DC locomotives crossing the Border PL/LT will lead to scattered maintenance requirements along the terminals based on their individual business approach.
- A single operator approach with a uniform fleet of locomotives allows a centralizing locomotive maintenance at a border station (to be discussed) or a consolidation punt (Karmėlava yards).

However, it shall be noted that the single operator approach contradicts EU policy, therefore there is a scant probability that the second case will be implemented on Rail Baltica corridor.

Furthermore, the small terminal operations at Salaspils will not warrant locomotive or maintenance facilities at this terminal. Empty runs (light running) to Vaidotai or Acone can be incurred and bad-ordered wagons have to be moved unloaded too. In the following figure the impact of the operator model to the locations of the freight rolling stock maintenance facilities is shown.

[116] Gautier, Pierre-Etienne: Maintenance and Operation of High Speed Rolling Stock. 2011 International Practicum on Implementing High-Speed Rail in the United States

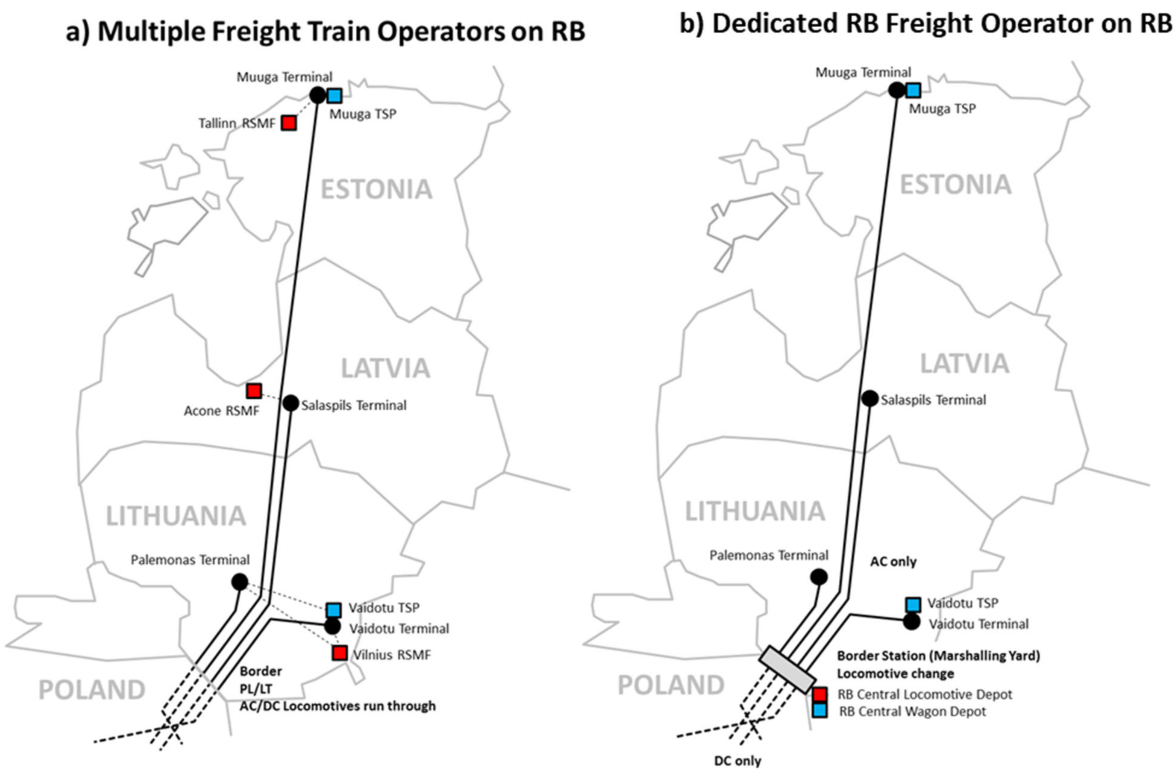

Figure 120: Impact of operator model on location of freight rolling stock maintenance facilities

Based on these boundary conditions the following 6 possible proposals for maintenance facilities are presented:

- PROPOSAL 1 - LOCAL Muuga, Acone, Vilnius, Kaunas
- PROPOSAL 2 - CENTRALIZED at Triangle
- PROPOSAL 3 - CENTRALIZED at Acone
- PROPOSAL 4 - Muuga, Vilnius, Kaunas
- PROPOSAL 5 - Muuga and Vilnius
- PROPOSAL 6 - Muuga and Triangle

It has to be known, that the exact position of a maintenance facility in the triangle is to be done later and until then it is defined as a triangle. In the following figures the so called running “dead km” are compared to the several possible facilities.

Allocation of terminals to maintenance facilities			Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Muuga	1	1.620	1.767	2.209	3.240	3.240	3.534	4.418	6.479	2	2	3	4
Salaspils	Acone	17	7.510	7.510	7.510	7.510	15.020	15.020	15.020	15.020	9	9	9	9
Vílnius	Vilnius	5	9.571	11.044	11.780	13.253	19.143	22.088	23.560	26.505	11	13	14	16
Kaunas	Kaunas	5	5.890	6.626	7.363	8.099	11.780	13.253	14.725	16.198	7	8	9	10
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	34	39	47	58
Extended	existing													
Total dead km (terminal to workshop)			54.041	60.814	68.619	79.221	108.082	121.629	137.237	158.441	63	71	81	97
Total dead km (terminal to workshop and back to terminal for reuse)			108.082	121.629	137.237	158.441	216.163	243.257	274.474	316.882	126	142	163	194
dead/productive wagon km			0,03%	0,03%	0,03%	0,03%	0,07%	0,07%	0,07%	0,06%	0,00%	0,00%	0,00%	0,00%

Table 168: PROPOSAL 1 - LOCAL Muuga, Acone, Vilnius, Kaunas

Allocation of terminals to maintenance facilities			Wagon maintenance scenario "average" 2,5%				Wagon maintenance scenario "high" 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Triangle	560	907.060	989.520	1.236.900	1.814.120	1.814.120	1.979.040	2.473.800	3.628.240	327.239	356.902	454.318	687.456
Salaspils	Triangle	229	101.161	101.161	101.161	101.161	202.322	202.322	202.322	202.322	36.496	36.487	37.157	38.335
Vílnius	Triangle	92	176.111	203.205	216.752	243.846	352.222	406.410	433.504	487.692	63.535	73.292	79.614	92.405
Kaunas	Triangle	10	11.780	13.253	14.725	16.198	23.560	26.505	29.450	32.395	4.250	4.780	5.409	6.138
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	10.625	12.215	14.603	17.856
Extended	existing													
Total empty wagon-km (terminal to workshop)			1.225.562	1.341.006	1.609.295	2.222.444	2.451.124	2.682.012	3.218.591	4.444.889	442.144	483.677	591.100	842.189
Total empty wagon-km (terminal to workshop and back to terminal for loading)			2.451.124	2.682.012	3.218.591	4.444.889	4.902.247	5.364.023	6.437.181	8.889.777	884.288	967.353	1.182.199	1.684.379
dead/productive wagon km			0,77%	0,75%	0,77%	0,85%	1,54%	1,50%	1,55%	1,69%	5,28%	5,13%	5,40%	6,10%

Table 169: PROPOSAL 2 - CENTRALIZED at Triangle

Allocation of terminals to maintenance facilities			Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Acone	330	534.518	583.110	728.888	1.069.035	1.069.035	1.166.220	1.457.775	2.138.070	192.837	210.317	267.723	405.108
Salaspils	Acone	17	7.510	7.510	7.510	7.510	15.020	15.020	15.020	15.020	2.709	2.709	2.758	2.846
Vilnius	Acone	338	647.017	746.558	796.328	895.869	1.294.033	1.493.115	1.592.656	1.791.738	233.423	269.270	292.494	339.487
Kaunas	Acone	346	407.588	458.537	509.485	560.434	815.176	917.073	1.018.970	1.120.867	147.045	165.386	187.136	212.375
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	10.625	12.215	14.603	17.856
Extended	existing													
Total empty wagon-km (terminal to workshop)			1.626.082	1.829.581	2.081.968	2.579.967	3.252.164	3.659.163	4.163.936	5.159.935	586.639	659.897	764.714	977.672
Total empty wagon-km (terminal to workshop and back to terminal for loading)			3.252.164	3.659.163	4.163.936	5.159.935	6.504.327	7.318.325	8.327.871	10.319.869	1.173.278	1.319.794	1.529.428	1.955.344
Empty/total wagon km			1,02%	1,02%	1,00%	0,98%	2,05%	2,04%	2,00%	1,97%	7,01%	7,00%	6,98%	7,08%

Table 170: PROPOSAL 3 - CENTRALIZED at Acone

Allocation of terminals to maintenance facilities			Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Muuga	1	1.620	1.767	2.209	3.240	3.240	3.534	4.418	6.479	584	637	811	1.228
Salaspils	Muuga	331	146.219	146.219	146.219	146.219	292.439	292.439	292.439	292.439	52.751	52.739	53.707	55.409
Vilnius	Vilnius	5	9.571	11.044	11.780	13.253	19.143	22.088	23.560	26.505	3.453	3.983	4.327	5.022
Kaunas	Kaunas	5	5.890	6.626	7.363	8.099	11.780	13.253	14.725	16.198	2.125	2.390	2.704	3.069
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	10.625	12.215	14.603	17.856
Extended	existing		0	0	0	0	0	0	0	0	0	0	0	0
Total empty wagon-km (terminal to workshop)			192.750	199.524	207.328	217.930	385.501	399.048	414.656	435.860	69.538	71.965	76.152	82.584
Total empty wagon-km (terminal to workshop and			385.501	399.048	414.656	435.860	771.001	798.095	829.312	871.720	139.076	143.929	152.305	165.168
Empty/total wagon km			0,12%	0,11%	0,10%	0,08%	0,24%	0,22%	0,20%	0,17%	0,83%	0,76%	0,70%	0,60%

Table 171: PROPOSAL 4 - Muuga, Vilnius, Kaunas

Allocation of terminals to maintenance facilities			Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Muuga	1	1.620	1.767	2.209	3.240	3.240	3.534	4.418	6.479	584	637	811	1.228
Salaspils	Vilnius	321	141.802	141.802	141.802	141.802	283.604	283.604	283.604	283.604	51.158	51.145	52.084	53.735
Vilnius	Vilnius	5	9.571	11.044	11.780	13.253	19.143	22.088	23.560	26.505	3.453	3.983	4.327	5.022
Kaunas	Vilnius	102	120.156	135.176	150.195	165.215	240.312	270.351	300.390	330.429	43.349	48.755	55.167	62.608
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	10.625	12.215	14.603	17.856
Extended	existing													
Total empty wagon-km (terminal to workshop)			302.599	323.656	345.743	370.628	605.198	647.311	691.486	741.257	109.168	116.737	126.993	140.449
Total empty wagon-km (terminal to workshop and back to terminal for loading)			605.198	647.311	691.486	741.257	1.210.395	1.294.622	1.382.972	1.482.513	218.336	233.473	253.985	280.897
Empty/total wagon km			0,19%	0,18%	0,17%	0,14%	0,38%	0,36%	0,33%	0,28%	1,30%	1,24%	1,16%	1,02%

Table 172: PROPOSAL 5 - Muuga and Vilnius

Allocation of terminals to maintenance facilities			Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
			empty wagon-km per year				empty wagon-km per year				dead locomotive-km per year			
Terminal ... to ...	Workshop	Distance km	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Muuga	1	1.620	1.767	2.209	3.240	3.240	3.534	4.418	6.479	584	637	811	1.228
Salaspils	Triangle	229	101.161	101.161	101.161	101.161	202.322	202.322	202.322	202.322	36.496	36.487	37.157	38.335
Vilnius	Triangle	92	176.111	203.205	216.752	243.846	352.222	406.410	433.504	487.692	63.535	73.292	79.614	92.405
Kaunas	Triangle	10	11.780	13.253	14.725	16.198	23.560	26.505	29.450	32.395	4.250	4.780	5.409	6.138
Warszawa	Warzsawa	10	29.450	33.868	39.758	47.120	58.900	67.735	79.515	94.240	10.625	12.215	14.603	17.856
Extended	existing													
Total empty wagon-km (terminal to workshop)			320.122	353.253	374.604	411.564	640.243	706.506	749.208	823.128	115.490	127.412	137.593	155.961
Total empty wagon-km (terminal to workshop and back to terminal for loading)			640.243	706.506	749.208	823.128	1.280.486	1.413.011	1.498.416	1.646.255	230.980	254.824	275.187	311.922
Empty/total wagon km			0,20%	0,20%	0,18%	0,16%	0,40%	0,39%	0,36%	0,31%	1,38%	1,35%	1,26%	1,13%

Table 173: PROPOSAL 6 - Muuga and Triangle

For a significant decision the CAPEX numbers are calculated and include the running “dead km” too:

Ratio dead/productive km = leveraging factor for rolling stock CAPEX increase	Wagon maintenance average defect rate				Wagon maintenance high defect rate				Locomotives			
	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
PROPOSAL 1 - LOCAL Muuga, Acone, Vilnius, Kaunas	0,03%	0,03%	0,03%	0,03%	0,07%	0,07%	0,07%	0,06%	0,00%	0,00%	0,00%	0,00%
PROPOSAL 2 - CENTRALIZED at Triangle	0,77%	0,75%	0,77%	0,85%	1,54%	1,50%	1,55%	1,69%	5,28%	5,13%	5,40%	6,10%
PROPOSAL 3 - CENTRALIZED at Acone	1,02%	1,02%	1,00%	0,98%	2,05%	2,04%	2,00%	1,97%	7,01%	7,00%	6,98%	7,08%
PROPOSAL 4 - Muuga, Vilnius, Kaunas	0,12%	0,11%	0,10%	0,08%	0,24%	0,22%	0,20%	0,17%	0,83%	0,76%	0,70%	0,60%
PROPOSAL 5 - Muuga and Vilnius	0,19%	0,18%	0,17%	0,14%	0,38%	0,36%	0,33%	0,28%	1,30%	1,24%	1,16%	1,02%
PROPOSAL 6 - Muuga and Triangle	0,20%	0,20%	0,18%	0,16%	0,40%	0,39%	0,36%	0,31%	1,38%	1,35%	1,26%	1,13%
Base fleet size, units	2185	2470	2793	3401	2185	2470	2793	3401	95	107	124	159
Typical base CAPEX, Mio €/unit	0,081	0,081	0,081	0,081	0,081	0,081	0,081	0,081	3,000	3,000	3,000	3,000
Typical base fleet CAPEX, Mio €	176,0	198,9	224,9	273,9	176,0	198,9	224,9	273,9	285,0	321,0	372,0	477,0

Table 174: CAPEX for each proposal

Freight Wagon Rolling Stock typical CAPEX increase	Facilty CAPEX,				Total CAPEX increase, average defects scenario,				Total CAPEX increase, high defetcts scenario,			
	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
PROPOSAL 1	16,0	16,0	16,0	16,0	16,1	16,1	16,1	16,1	16,1	16,1	16,1	16,2
PROPOSAL 2	8,0	8,0	8,0	8,0	9,4	9,5	9,7	10,3	10,7	11,0	11,5	12,6
PROPOSAL 3	8,0	8,0	8,0	8,0	9,8	10,0	10,3	10,7	11,6	12,1	12,5	13,4
PROPOSAL 4	14,0	14,0	14,0	14,0	14,2	14,2	14,2	14,2	14,4	14,4	14,4	14,5
PROPOSAL 5	10,0	10,0	10,0	10,0	10,3	10,4	10,4	10,4	10,7	10,7	10,7	10,8
PROPOSAL 6	10,0	10,0	10,0	10,0	10,4	10,4	10,4	10,4	10,7	10,8	10,8	10,9

Table 175: CAPEX increase per proposal and facility for wagons

Freight Electric Locmotives Rolling Stock typical CAPEX increase	Locomotives				Facilty CAPEX				Total CAPEX increase, average defects			
	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
PROPOSAL 1 - LOCAL Muuga, Acone, Vilnius, Kaunas	0,0	0,0	0,0	0,0		16,000	16,000	16,000	0,0	16,0	16,0	16,0
PROPOSAL 2 - CENTRALIZED at Triangle	15,1	16,5	20,1	29,1		8,000	8,000	8,000	15,1	24,5	28,1	37,1
PROPOSAL 3 - CENTRALIZED at Acone	20,0	22,5	26,0	33,8		8,000	8,000	8,000	20,0	30,5	34,0	41,8
PROPOSAL 4 - Muuga, Vilnius, Kaunas	2,4	2,5	2,6	2,9		8,000	8,000	8,000	2,4	10,5	10,6	10,9
PROPOSAL 5 - Muuga and Vilnius	3,7	4,0	4,3	4,9		10,000	10,000	10,000	3,7	14,0	14,3	14,9
PROPOSAL 6 - Muuga and Triangle	3,9	4,3	4,7	5,4		10,000	10,000	10,000	3,9	14,3	14,7	15,4

Table 176: CAPEX increase per proposal and facility for locos

Based on the 3 figures above, the following conclusion (in operating period 2056) is presented:

- According to the CAPEX numbers, the freight wagon maintenance should be placed in either Muuga and Vilnius (proposal 5) or Muuga and Kaunas Triangle (proposal 6).
- The freight locomotive maintenance in single observation would be best placed at 3 Terminals (proposal 4). At a first view, this decisions seems not to be reasonable, but the results includes the effect of the running “dead km” and in this case, it seems that PROPOSAL 4 have the best CAPEX numbers.

5.3.1.1. Number of wagons and locomotive waiting for maintenance

To estimate the amount of wagons and locomotives waiting for maintenance, the following presumptions for freight traffic transport are done:

The average amount for freight trains is calculated in table Table 177 and the number of operating days is estimated to 310.

	per wagon		Maint. Cost	in train			
Type of wagon	**Length [m]**	**Axles**	**€/km**	**Number**	**Length [m]**	**Axles**	**€/km**
2 part container wagon	33,9	6	0,025	2	67,9	12	0,050
High-Cube-container wagon	19,1	4	0,015	2	38,3	8	0,030
2 part container wagon	26,7	6	0,025	2	53,4	12	0,050
2 part pocket wagon	34,2	6	0,030	5	171,0	30	0,150
80' container wagon	25,9	4	0,015	8	207,5	32	0,120
	Averages			**Totals**			
	28,3	4,9	0,021	19	538,1	94	0,4

Table 177: Average freight train

According to the updated number of trains, based on 1,600 t-trains with 19 wagons in 2026, 63 train sets per day are expected with 1197 wagons, for the other operating periods Table 178 is presented.

Terminal	Wagons handled per day				Locom. handled per day			
	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	209	228	285	418	11	12	15	22
Salaspils	57	57	57	57	3	3	3	3
Vilnius	247	285	304	342	13	15	16	18
Kaunas	152	171	190	209	8	9	10	11
Warszawa	380	437	513	608	20	23	27	32
Extended	152	171	190	247	8	9	10	13
Totals	1.197	1.349	1.539	1.881	63	71	81	99

Table 178: Overall fleet size calculation of freight wagon and locomotive fleet for different operating periods

Aside from the scheduled maintenance (predictive maintenance, condition-based maintenance and interval-based maintenance) bad-ordered wagons should be expected every day and have to be respected and shunted additionally. To calculate the amount of vehicles waiting for maintenance or which have to go into maintenance, an approach is done by a comparison with respect to 3 points:

- Comparing storage sidings and workshop capacities of existing freight rolling stock maintenance facilities like e.g. shunting yard Munich north, a ratio of bad-ordered wagons is calculated between 2.5% and 5%.
- Based on MDBM (Main Distance between Maintenance) for freight wagons with 30,000 km.
- For locomotives it is more difficult to estimate spontaneous failures because of a broad variety of different technology used for supplying traction power or traction and brake control. Therefore aside from scheduled maintenance a MDBM (Main Distance between Maintenance) of 5000 km for locomotives is expected.

Defective wagons	Wagon maintenance average defect rate 2,5%				Wagon maintenance high defect rate 5,0%				Locomotive maintenance			
	Defective Wagons per day				Defective Wagons per day				Locomotives due for maintenance per day			
Terminal	2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	5	6	7	10	10	11	14	21	1,9	2,1	2,6	4,0
Salaspils	1	1	1	1	3	3	3	3	0,5	0,5	0,5	0,5
Vílnius	6	7	8	9	12	14	15	17	2,2	2,6	2,8	3,2
Kaunas	4	4	5	5	8	9	10	10	1,4	1,5	1,7	2,0
Warszawa	10	11	13	15	19	22	26	30	3,4	3,9	4,7	5,8
Extended	4	4	5	6	8	9	10	12	1,4	1,5	1,7	2,3
Totals	30	34	38	47	60	67	77	94	10,8	12,2	14,1	17,8

Table 179: Numbers of defect wagons and locos

		MDBM, km	Maintenace spottings per day, wagons				MDBM, km	Maintenace spottings per day, locos			
			2026	2036	2046	2056		2026	2036	2046	2056
Muuga	Warszawa	30.000	10,5	11,9	15,8	22,4	5.000	3,3	3,7	5,0	7,1
Salaspils	Warszawa	30.000	1,8	1,8	1,8	1,8	5.000	0,6	0,6	0,6	0,6
Vilnius	Warszawa	30.000	6,6	8,1	8,8	8,8	5.000	2,1	2,6	2,8	2,8
Muuga	Vilnius	30.000	2,5	2,5	2,5	4,1	5.000	0,8	0,8	0,8	1,3
Salaspils	Vilnius	30.000	0,4	0,4	0,4	0,4	5.000	0,1	0,1	0,1	0,1
Kaunas	Warszawa	30.000	4,8	5,4	6,0	6,5	5.000	1,5	1,7	1,9	2,1
Extended service to othe		30.000	7,6	8,6	9,5	12,4	5.000	2,4	2,7	3,0	3,9
		30.000	**34,2**	**38,5**	**44,8**	**56,4**	**5.000**	**10,8**	**12,2**	**14,1**	**17,8**

Table 180: Numbers of maintenance spotting per day based on MDBM for wagons and locos

On the basis of the Table 179 and Table 180 it can be seen exemplary, that in 2056, 47 wagons with spontaneous defects (average defect rate 2.5 %) and 57 wagons with maintenance spottings can be expected per day.

5.3.1.2. Layout of maintenance facilities

Depending on the service concept for the maintenance facilities (two or three shifts) and the given numbers (from tables Table 179 and Table 180) of locomotives and wagons with failures, a minimum (small) maintenance facility for freight rolling stock is needed at every terminal except at Riga (Salaspils). At Riga the predicted numbers of wagons and locomotives with failures are too low to justify a maintenance facility.

The following three general assumptions for the workshop layout are done:

1. Maintenance for wagons and locomotives (not heavy maintenance) can be performed in 4 hours.
2. A typical maintenance facility consists of 2 tracks with 3 workstations.
3. Alternatively capacity is calculated for 2 tracks with 2 workstations.

In the table Table 181 the maintenance capacity for different working shifts and different workshop layouts are done. With the best workshop layout 12 respective 24 vehicles could be maintained.

	No. of work cycles	Capacity for maint. [2 tracks, 3 stations each]	Capacity for maint. [2 tracks, 2 stations each]
One shift [8h]	2	12	8
Two shifts [16h]	4	24	16

Table 181: Capacity of maintenance facilities subject to number of shifts and workstations

The typical maintenance work for freight rolling stock and their share in the total amount is displayed in Table 182. It is based on studies of incoming or routine work at typical maintenance facilities throughout one year. It could be seen that the highest amount of works is inducted by the brake blocks

Module	No. of works	Ratio
brake blocks	7,331	45.93%
Lubricate the push-pull mechanism	2,902	18.18%
Flat car (bodies)	1,274	7.98%
Brake (revision)	858	5.38%
screw coupling	844	5.29%
loading facilities	780	4.89%
Car carrier wagons	693	4.34%
wheelset	334	2.09%
Car body, painting	242	1.52%
Brake, mechanical part	156	0.98%
Suspension Y-25 bogie	131	0.82%
Brake, pneumatic part	117	0.73%
Tank cars	71	0.44%
Supplementary work	51	0.32%
Trolley undercarriage and bogie frame	41	0.26%
Handbrake / parking brake	38	0.24%
drawbar	33	0.21%
Hitch	23	0.14%
Radio fender	17	0,11%
Connection spring / axle box bearing	12	0,08%
Suspension Y-25 bogie	10	0,06%
buffer	2	0,01%

Table 182: Maintenance work on freight rolling stock

Aside from the light maintenance in the existing facilities along the planned corridor, the heavy maintenance of freight rolling stock for 1435 mm cannot be performed. All existing workshops for heavy maintenance are located in Poland (see Figure 11 in chapter 1.2.2.) and it is the author's opinion to do heavy maintenance at the workshops in Poland.

5.3.1.3. Excursion: Freight wheel wear

To estimate the freight wagons waiting for maintenance due to (worn) wheel sets, a short literature research have been done. This research provides the following results, based on wheel wear data from LKAB experiences (a heavy haul operator with 30 t max. axle load) [117]:

- A natural wear of 3 mm for every 100 000 km is found to be the rate of degradation. By approximating this wheel wear and re-profiling, a total lifetime of 1 200 000 km can be achieved.
- About 200,000 to 400,000 km between re-profiling. At least 0.8 million km is the goal before installing new wheels.
- Wagons run 120,000 to 140,000 km per year.
- Inspection each 80,000 km in a workshop.

[117] Palo, Mikael: Condition-Based Maintenance for Effective and Efficient Rolling Stock Capacity Assurance. PhD Thesis, Luleå 2014

Depending on the wheel wear, the following number of wagons can be expected for workshop:

Rail Baltica freight wagon fleet			wagon inspection interval, km 80.000	wheelsets per wagon (average) 4,95		Re-profiling interval, km 200.000	Re-wheeling interval, km 800.000		wheelset line production days per year 250
Period	Wagons	million wagon-km per year		wheelsets installed	million wheelset-km per year	Re-profiling of wheelsets per year	Re-wheeling of wheelsets per year	Wheelsets handled per year	Wheelsets handeld per day
2026	2.185	317,9	3.974	10.816	1.573,8	5.902	1.967	7.869	31
2036	2.470	358,2	4.478	12.227	1.773,2	6.650	2.217	8.866	35
2046	2.793	416,2	5.202	13.825	2.060,1	7.725	2.575	10.301	41
2056	3.401	524,8	6.560	16.835	2.597,8	9.742	3.247	12.989	52

Table 183: Numbers of wagons ready for re-profiling

The conclusions for the wheel wear are:

- Wheelset drop is warranted at main wagon shop (Lithuania).
- Specialized wheelset shop is warranted in later years (private activity, area needed).
- Lithuanian price levels will attract all wheelset work in fleet concerned.

5.4. Cost estimate of freight rolling stock fleet maintenance (WP 5.4)

The following benchmarking of the freight rolling stock maintenance costs is usually done as cost per wagon-km. A literature review[118] revealed for container wagons with good utilisation (running about 120,000 km per year) shows the following costs:

- 0.015 €/wagon-km for 40' container wagon type Sgns,
- 0.025-0.030 €/wagon-km for articulated 2x40' container wagon type Sdggmrss,
- 0.60 €/km for typical freight locomotives.

These costs contain labour and materials (Prices 2011 in Sweden) and include any failures and breakdowns.

A second approach in order to present benchmarks is a Swiss study[119] to RoLA trains (roll-on roll-off trains) which present a range of cost for freight wagons from:

[118] Report within project "Strategic Modeling of combined transport between road and rail in Sweden"; Department of Business Administration, School of Business, Economics and Law, University of Gothenburg, Göteborg 2011, p. 9-11
[119] Schlussbericht: Betriebs- und Investitionskostenvergleich der RoLa, Stand 2007, Ecoplan, Bern 2007

- 0,103 – 0,133 €/wagon-km for typical low-floor freight wagons
- 0,273 €/km for typical freight locomotive

For the first estimate, a weighted average cost rate according to the mix of wagon types for an intermodal train as defined in WP 2 can be assumed (Table 184). The maintenance cost rate for tank and bulk wagons differs slightly, but due to the low number of such trains the deviation will be negligible.

Type of wagon	Number	€/Wg-km	€/Wg-km
High-Cube Container Wagon	2	0,015	0,030
Articulated (2-part) Container Wagon	4	0,025	0,100
Articulated (2-part) Pocket Wagon	5	0,030	0,150
Non-Articulated Container Wagon 80'	8	0,015	0,120
Average	**19**	**0,021**	**0,400**

Table 184: Average freight wagon maintenance cost

Based on the train configurations defined and used in the RailSys model too, the wagon-km totals have been calculated. It was assumed that train sets have an average length of 19 wagons (1,600 t train set) and the freight trains will operate at an equivalent of 310 days per year.

Based on train numbers and travelled distances the separate train kilometres p.a. in the different operation periods are calculated (Table 185).

Freight train relation		Consist	Train pairs/day				Mio. train-km p. a.				Fleet Mio. vehicle-km per year			
			2026	2036	2046	2056	2026	2036	2046	2056	2026	2036	2046	2056
Muuga	Warszawa	Freight Train Wagons	8,0	9,0	12,0	17,0	5,2	5,8	7,7	11,0	98,0	110,3	147,0	208,3
Salaspils	Warszawa		2,0	2,0	2,0	2,0	0,9	0,9	0,9	0,9	16,7	16,7	16,7	16,7
Vilnius	Warszawa		9,0	11,0	12,0	12,0	3,2	4,0	4,3	4,3	61,5	75,2	82,0	82,0
Muuga	Vilnius		3,0	3,0	3,0	5,0	1,2	1,2	1,2	2,0	23,0	23,0	23,0	38,3
Salaspils	Vilnius		1,0	1,0	1,0	1,0	0,2	0,2	0,2	0,2	3,8	3,8	3,8	3,8
Kaunas	Warszawa		8,0	9,0	10,0	11,0	2,3	2,6	2,9	3,2	44,3	49,8	55,4	60,9
Extended service to other EU countries			8,0	9,0	10,0	13,0	3,7	4,2	4,7	6,0	70,7	79,5	88,4	114,9
Spares														
Fleet totals							**16,7**	**18,9**	**21,9**	**27,6**	**317,9**	**358,2**	**416,2**	**524,8**

Table 185: Train km p.a. in different operation periods

For comparison of different maintenance benchmarks the typical train km per time period from Table 185 is combined with the average maintenance cost per km for freight wagons and locomotives from Sweden and Switzerland. The cost of maintenance of freight vehicles in different operation periods is shown in Table 186.

	Mio. train-km p. a.				Fleet Mio. vehicle-km per year (19 wagons/train)			
	2026	2036	2046	2056	2026	2036	2046	2056
	16,7	18,9	21,9	27,6	317,9	358,2	416,2	524,8
Average cost [EUR] benchmark Sweden (0,021 EUR/km), wagon	351.410	395.938	459.997	580.041	6.676.786	7.522.826	8.739.935	11.020.779
Average cost [EUR] benchmark Swiss (0,113 EUR/km), wagon	1.890.919	2.130.525	2.475.220	3.121.173	35.927.469	40.479.967	47.029.176	59.302.287
Average cost [EUR] benchmark Sweden (0,60 EUR/km), locos	10.040.280	11.312.520	13.142.760	16.572.600				
Average cost [EUR] benchmark Swiss (0,273 EUR/km), locos	4.568.327	5.147.197	5.979.956	7.540.533				

Table 186: Freight maintenance costs in different time periods

5.4.1. Investment cost

Depending on interior and exterior technical equipment a literature review of build and planned maintenance facilities for rolling stock was done. Like for the layout, described in 5.3.1.2, the real investment costs are in a range from 4 to 6 million Euro.

Terminal	Light maintenance facility	Heavy maintenance facility
Muuga	existing	Nearby facilities in 1520 mm planned or available
Salaspils	Not-existing	Planned for 1520 mm
Vilnius	Proposed (purpose TBD)	Existing for 1520 mm
Palemonas	Planned (purpose TBD)	

Table 187: Maintenance facilities at the terminals north of border Pl/LT

In the first time period (2026) light maintenance facilities are needed at every terminal except Salaspils. The existing facility at Muuga (Table 187) has already freight maintenance capacity but is mostly designed for locomotives. Therefore, the construction of maintenance facilities for freight wagons is necessary at the terminals Muuga, Vilnius and Palemonas.

The number of wagons and locomotives waiting for maintenance from chapter 5.3.1.1combined with the layout in Table 181 suggest a similar layout for every location: 2 tracks with 3 workstations each (one shift model). This proposal has the advantage, that an increase of waiting vehicles for maintenance can be matched by increasing the workforce with a second shift.

Furthermore table Table 180 reveals that only in Muuga a significant rise of units up to 2056 will occur. So, only the workshop in Muuga might be updated with a second shift.

At least it is mentioned, that experiences from other sites and location of maintenance facilities throughout Europe indicates that spare area for more tracks and / or more workstations should be considered (if possible) while designing the maintenance facilities.

5.4.2. Human Resources

In a literature review, the preferred layout of a maintenance facility from 5.4.1 has in average 45 staff members in a 3 shift design. As pointed out in 5.4.1 only 1 shift is needed in the maintenance facilities at the beginning. Therefore a workforce of 19 staff members is considered (13 for workstations and 6 administration, planning, etc.). If a second shift is necessary only workstations staff members have to be doubled, the administration is sufficient for both shifts.

In Table 188 the typical hourly wages in the Rail Baltica area[120]are shown. The Increase in wages at this particular area of the EU was significant higher in the recent years than the average increase in the EU. Forecasts on wages for the time periods 2036, 2046 and 2056 are calculated with a lower increase of wages (2% per year).

Country	Hourly wage 2017[EUR]	Hourly wage 2026[EUR	Hourly wage 2036[EUR	Hourly wage 2046[EUR	Hourly wage 2056[EUR
Estonia	11.70	13.71	16.71	20.37	24.83
Latvia	8.10	9.49	11.57	14.10	17.19
Lithuania	8.00	9.37	11.43	13.93	16.98

Table 188: Hourly wages in Rail Baltica area

5.4.3. Operating Cost

For estimating the ratio of personal and material costs in a lifecycle, a comparison in a presentation of Siemens is used. It was shown that the personal cost contributes only 22% of the sum of overall lifetime maintenance cost. It has to be understood, that these information are based on Unites Stated wage levels and will be used in comparison and for pre-calculations which are sufficient at this stage in the operational plan. That leads to the following calculations.

[120] eurostat_hourly_wages_EU_2017.pdf

The per-capita income was about 3,444 €/year in the U.S. and 895 €/year in Lithuania. The gross wage ratio is expected to be 895/3,444 = 0.026. Assuming identical prices for materials, the adjusted total maintenance cost is

$$78\% + \frac{895€}{3{,}444\,€} \cdot 22\% = 84\%$$

of the absolute U.S. value, of which 6% of the U.S. value are personal costs at Lithuanian wage levels.

5.4.4. Total costs

Overall costs per time period are calculated as a combination of investment cost and current costs. Current costs are working cost (without spare parts) on the base of 1 shift from 2026 including 2056. In 2056 it is calculated with 2 shifts in Muuga. Working days per year are calculated with 250 days.

Due to the capital consumption allowance and renewal of technical equipment, reinvestments of 20% of the start investment are calculated in every time period combined with an increase of prices of 2% per year from 2036 onwards. In Table 189 the expected total costs for the four time periods are shown. As shown in 5.3.1 and Table 175 best options for freight maintenance are proposal 5 or 6. In Table 189 Palemonas is used to describe proposal 6 (Muuga and triangle) for maintenance facilities.

	2026 [EUR]		2036 [EUR]		2046 [EUR]		2056 [EUR]	
Workshop	**Invest**	**current**	**Invest**	**current**	**Invest**	**current**	**Invest**	**current**
Muuga	5.000.000	520.920	1.000.000	520.920	1.218.994	774.059	1.485.947	1.589.177
Salaspils	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Vilnius	5.000.000	356.184	1.000.000	434.187	1.000.000	529.271	1.000.000	645.179
Palemonas	5.000.000	356.184	1.000.000	434.187	1.218.994	529.271	1.485.947	645.179

Table 189: Investment and current costs in different time periods

5.5. Summary

5.5.1. Early operations

To support early operations of the Riga airport RIX 31 shuttle services between Riga Airport station and Riga Central station and to avoid sunk cost of a provisional facility, it is recommended to locate the regional train depot for the Riga node at Jaunmārupe station. All freight trains, which will enter the RailBaltica route from Polan, will be maintained in Poland or elsewhere at the route at the early beginning of the RailBaltica service period.

5.5.2. Year 2026

The High-Speed Ppassenger rolling stock maintenance will be centred at the Tallinn-Rae depot.

The Jaunmārupe depot will be used as a base for local EMU services in Latvia and Estonia too, taking benefit of the wage gradient and good connection via lines 21 and 22. It is also possible to operate line 26 to Marijampole from this depot.

With opening of the line to Vilnius, a depot in the Vilnius area is needed for local EMU service in Lithuania, which included cross-border service to Riga Central and Białystok. This depot will host dual system EMU for 25 kV 50 Hz and 3 kV DC.

At Warszawa, only servicing (interior cleaning, toilet service, restocking dining cars) is necessary during day and night layovers of HST lines 11 and 13.

Maintenance of night trains can be done one a unit-train approach at Tallinn-Rae and by single-wagon approach at the Vilnius EMU depot, when necessary.

Passenger rolling stock heavy maintenance (major revisions, half-life overhauls, rebuilding after accidents) will be contracted to existing facilities in the European 1435 mm railway system (EXTERNAL), because the fleet size does not warrant operation of a dedicated facility. However, minor revisions are carried out locally.

Freight wagon repairs may be done at Muuga and at central location in Lithuania (either Karmėlava or Vaidotai). Defective wagons or wagons due for maintenance from Salaspils (only few) and any other terminal in Lithuania (only approx. 100 km) are dead-hauled to the Lithuanian facility. A repair facility at Muuga is considered indispensable to avoid long dead hauls (distance 545 km Muuga to Karmėlava).

Freight locomotives are centrally maintained in Lithuania. The depot layout can be optimised for the maintenance of locomotives only (shorter tracks, traverser possible). Locomotives schedules for maintenance on trains terminating at other terminals than in the Kaunas area are taken from their trains and replaced with a fresh locomotive as they pass through Kaunas node or dead-hauled from those terminals. This is a standard practice with many freight RUs operating at open-access infrastructure throughout Europe. However, at Muuga one spot to conduct running gear checks on electric locomotives is needed.

Freight rolling stock heavy maintenance will be contracted to existing facilities in the European 1435 mm railway system (EXTERNAL), because the fleet size does not warrant operation of a dedicated facility. This expressly includes private enterprises operating in the Baltic countries. It is technically feasible to transport 1435 mm rolling stock on 1520 mm lines by transport bogies or a technology branded "Loco Buggy". At least for locomotives, this may be economically feasible for performing a major revision.

Generally, due to breakdowns en route, defective rolling stock must be set out from trains. To avoid blocking valuable passing loops, dedicated set-out tracks should be available at regular intervals. They must be equipped to allow safe working of a mobile maintenance team. Eventually it would be necessary to use a mobile crane to lift a wagon body for exchanging defective bogies or wheel sets.

5.5.3. Year 2036

By the year 2036, the volume of passenger and freight rolling stock is slightly increased.

With the increased HST service (filling gaps up to the 2 h basic intervals); turnaround times at Tallinn will be shortended. Maintenance during day layovers at Tallinn is no more feasible. A second HST depot capable of doing at least Running Gear Inspections in the Warszawa area is added. Up to 10 light maintenance (e.g. Running Gear Inspections) could be done each night, but only 6 trains would lay over at Tallinn.

The other facilities will largely stay unaltered.

5.5.4. Year 2046

By the year 2046, the volume of freight rolling stock is further increased. A second shift may be introduced at the freight rolling stock depots. No additional facilities would be needed.

5.5.5. Year 2056

As the passenger traffic pattern is extended by 2056, the passenger rolling stock maintenance capacity needs to be enlarged. Minor extensions to all depots will be executed to implement full build-out.

The impact of FinEst link is not assessed in this work. Probably a new maintenance centre will be needed on the Finnish side to cater for the extended HST services terminating in the Helsinki area.

6. Infrastructure Maintenance (WP 6)

6.1. Overview Infrastructure Maintenance

It is expected that the Infrastructure of Rail Baltica will consist of the following sections, with the related administration separated:

- Railway section in Poland – existing infrastructure manager,
- Rail Baltica through the Baltic states – one single infrastructure manager,
- Tunnel from Estonia to Finland and 1435 mm line in Finland - One single infrastructure manager (either the same as for Rail Baltica or a separate entity).

The maintenance will be based on maintaining a new railroad, and there are no expectations of major rebuilds for the next 20 years.

In the following table there is an overview of the Rail Baltica sections in the individual countries including the branch lines:

Section	Length
FI – EE: FinEst Tunnel Helsinki – Tallinn	107.40 km
EE: Rae Junction - Muuga	*16.70 km*
EE: Tallinn (Ülemiste) – Pärnu – Border EE/LV	200.76 km
LV: Border EE/LV – Riga – RIX – Border LV/LT	234.87 km
LV: Riga Bypass	*28.55 km*
LT: Border LT/LV – Kaunas – Border LT/PL[121]	249.00 km
LT: Kaunas Triangle East Junction – Vilnius	93.43 km[122]
LT: Kaunas Bypass (Palemonas – Jiesia)	*15,52 km*
LT: Vaidotai branch (Junction – Vaidotai freight station)	*8,98 km*

[121] Length according to alignment option 3 of Kaunas – border PL/LT feasibility study
[122] Length according to option 3B of Kaunas – border PL/LT feasibility study (status 05/2018)

PL: Lithuanian-Polish-border – Suwałki – Ełk – Białystok – Warszawa	~379 km
Total distance (Helsinki – Warszawa)	~1,265 km
Total length of alignment sections (Baltic states)[123]	847,81

Table 190: Length of the alignment sections

In total Rail Baltica corridor has a length of approx. 1,265 km whereof approx. 847,81 km are located within the three Baltic countries.

The Baltic part of the line is crossing 3 independent countries, all with their own current railway infrastructure administration. But none of the countries have any 1435 mm standard gauge tracks (with the exception of Lithuania and the current single track line under construction to Kaunas). This means, that even though there is experienced railway knowledge in the countries, there is little or no equipment available for use on a 1435 mm railway.

As the Rail Baltica line is considered a common railway line, it is planned to have a common infrastructure manager for the part of the railroad that is located in the three Baltic States. The new infrastructure manager should be able to draw on the experience existing in the area with regard to staffing, training and synergy with exiting railroads.

The infrastructure manager will take care of all overall issues in a central administration, while the local day-to-day maintenance is carried out by the teams in the individual countries, with location based on the geography of the line.

As the line is the first standard gauge double track electrified railway line in the Baltic countries, it is not expected that they have equipment suited for that track gauge at hand. Investment must be expected in track maintenance equipment, trolleys for local maintenance and other larger equipment for maintenance of the whole line.

Maintenance requiring heavy machines will most likely be done by external contractors in the future.

6.2. Maintenance strategy

As a new railway organisation it is important that there from the start is a clear maintenance strategy, that covers all maintenance from daily maintenance to rebuilds of the railway.

The maintenance strategy should focus on what's possible to do internally and what requires work by external contractors.

As the railway is completely new, it is expected that the amount of maintenance will be limited for the first year, and any repairs will be the responsibility of the contractor. This will give the maintenance organisation a short time to

[123] Including all line sections, excluding FinEst link

ramp up while the railway is starting operation, as repairs still is the responsibility of the contractor. The maintenance organisation will be responsible for inspection from day one.

It is expected that the railway will be equipped with a number of modern surveillance systems, like pantograph inspection, wheel flat detection and wheel inspection.

While these systems often are more directed towards the rolling stock, elimination of faults in these areas on the rolling stock will help reducing maintenance of the tracks.

It will be expected that the railway is build using 3D modelling. This will give Rail Baltica a full digital model of the railway, and allow RB to be much more efficient when it comes to future changes and rebuilds.

Overall it is expected that a new railway is equipped with state of the art monitoring systems that helps to supervise and maintain the railway.

Overall the maintenance strategy should be based on an organisation with two layers:

- Central maintenance administration
- Operation units
  - Central maintenance unit
  - Local maintenance units

The central administration will take care of all issues regarding the overall operation and maintenance of the railway.

The maintenance strategy should be based on three layers of maintenance:

- Light maintenance
- Heavy maintenance
- Scheduled maintenance/rebuilds

The local operation units will take care of inspection and light maintenance in the field. The local units will primarily operate within a local area.

The central maintenance unit will take care of planned heavy maintenance and will operate along the whole line.

Apart from the planned and scheduled maintenance there is the unplanned maintenance or emergency repairs. This can to a certain degree be avoided, if maintenance is done to plan, but are never completely unavoidable due to climate and operation of trains.

Light maintenance

It is expected that the RB local units will be able to take care of all light maintenance.

Light maintenance is all inspections of the tracks, turnouts, catenary system, bridges, tunnels, drainage etc.

Included in light maintenance is maintenance of turnouts, small repairs of track, smaller adjustment of tracks, catenary system and other issues that can be repaired within short time.

Included in light maintenance is replacement of single turnout elements, and tracks elements, that are not part of a major rebuild or upgrade of the railway.

The light maintenance units should be located with a distance of approx. 100 km along the line and should be able to respond to incidents within their area immediately.

Heavy maintenance

It is expected that the RB central maintenance unit will be able to take care of most heavy maintenance. The heavy maintenance is the responsibility and planned by the central administration.

Heavy maintenance is primary maintenance of the tracks that require use of heavy machines like tamping machines, stabilisation machines, ballast ploughs and other equipment.

The heavy maintenance equipment will be operated by the central maintenance administration, and the machines should be located either centrally or at the local units depending on, where they are working.

Heavy maintenance should be planned in advance, and will require periods with track position and reduced operation.

Heavy maintenance is normally based on time and condition. Based on the inspections carried out under the light maintenance, all systems are monitored for wear, condition and age, and this monitoring will be part of the planning of the heavy maintenance or the scheduled maintenance.

Scheduled maintenance/rebuilds

Scheduled maintenance is all maintenance that is expected to be done during the lifetime of the railway. Scheduled maintenance is planned by the central administration or tendered out to external engineers. Scheduled maintenance or replacement is done by external contractors.

Scheduled maintenance is rebuilding of the tracks that require use of specialised track building machines that are not prat of the RB inventory, but typically owned by the contractors.

Included in scheduled maintenance are replacements of multiple turnouts, and tracks, in station areas that is not part of a major rebuild or upgrade of the railway.

Scheduled maintenance should be planned long time in advance, and resources should be allocated to the projects several years in advance. Planning should also be several years in advance and will require planning of periods with track possessions and reduced operation.

Scheduled maintenance should not be expected for the first 20 years, except for changes to the railway but after 20-30 years regularly scheduled maintenance should be expected and planned for.

Emergency repair

Emergency repair is an unplanned repair of any system on the railway that is not working properly, and witch is essential to operating the railway.

Emergency repairs is primary the responsibility of the local work teams, who will have at least one team on alert duty around the clock. They will be responsible for repairing cracks in the track, not functioning turnouts, faults on the catenary system etc. on the railroad in their area.

Repairs performed by local repair and maintenance teams are done in a track possession, but with traffic continuing on a limited scale.

If a larger emergency repair team is required, assistance from the central maintenance organisation will called on, and the traffic might be completely closed.

6.3. Maintenance and maintenance areas

Maintenance is for most parts done by the local maintenance teams who will take care of inspection and light maintenance in the field.

The local units will operate within a local area.

Line Inspection

One of the main activities for the local work teams is the line inspection, which is regularly done along the line in the local area.

The task is to inspect almost everything that has influence on the safety of the line, and consist of following overall activities. The listed activities are not covering everything, and activities have to follow a specific pattern set up for Rail Baltica by the maintenance organisation.

The overall requirements for different maintenance areas are described in the following table and text.

Subject	Line inspection
Track	Track location - primary task in train
Track	Rails (Broken rails)
Track	Fastening (missing or loose)
Track	Slippers (cracked, shelled, rotten)
Track	Ballast profile (ballast shoulder)
Track	Gauge
Track	Kilometre post
Catenary	Inspection of contact wire
Catenary	Inspection of foundations
Catenary	Inspection of switches
Forest	Gauge (Greenery)
Forest	Fences and doors along the track
Geotechnical	Excavation slopes (fractures, holes and water extraction)
Geotechnical	Dams (bride, cracks in the top of the dam, general damage)
Signalling	Inspection of trackside equipment.

Table 191: Line inspection activities

Bridges and tunnels

There is expected to be a number of bridges on the line, either as overpasses or underpasses as well as smaller tunnels. On the central level there will be a person with overall responsibility for the bridges and tunnels, leading a number of employees who are working for administration of bridge & tunnel maintenance, new bridges and renewal.

On local level there will be staff responsible for local bridges, with a number of employees taking care of inspection and minor repairs.

	Inspection	Evaluation	Renovation
Interval	Light: 1-2 times a year. Major: every 4-6 years.	Every 20 years.	Every 50 years.
Task	Manual inspection. Inspection and inspection report.	Status report on expected maintenance.	Midlife renovation of bridges.
Track Possession	No	No	Yes
Work force	Local workforce, part of internal organisation.	External contractor.	External contractor.

Table 192: Bridge & Tunnel Maintenance

Large Bridges and tunnels over 40 m

There is expected to be a smaller number of larger bridges on the line, either as overpasses or underpasses as well as larger tunnels.

On the central level there will be a single person with overall responsibility for the bridges and tunnels as with smaller bridges and tunnels.

With longer bridges there are further requirements to safety regarding evacuation from the bridge or tunnel when examination work is done, and track possession is needed when carrying out inspections.

	Inspection	Evaluation	Renovation
Interval	Light: 1-2 times a year. Major: every 4-6 years.	Every 20 years.	Every 50 years.
Task	Manual inspection. Inspection and inspection report.	Status report on expected maintenance.	Midlife renovation of bridges.
Track Possession	Yes	Yes	Yes
Work force	Local workforce, internal organisation.	External contractor.	External contractor.

Table 193: Large bridges & tunnel maintenance

High voltage power supply & Catenary system

The High voltage power supply & catenary system is an integral part of the rail system. On the central level there will be a person with overall responsibility for the high voltage power supply & catenary system, leading a number of employees who are working for administration of high voltage power supply & catenary system maintenance, changes and renewal.

On local there will be staff responsible for parts of the line with a number of employees taking care of inspection, service and minor repairs.

	Inspection	Measurement	Renovation
Interval	Minor: every year. Major: every 4-6 years.	Every second year by measuring car.	Every 30-50 years.
Task	Manual inspection of all wires, masts and founda-tions.	Dynamic testing and measuring of contact wire.	Renovation of catenary system.
Work force	Local workforce as part of internal organisation	Specialised measuring car. External contractor.	External contractor.

Table 194: High voltage power supply & Catenary systems' maintenance

Rebuilds due to layout changes and renovation are normally done by an external contractor.

Signalling

The Signalling system is going to be an ERTMS system, which is adopted for the Rail Baltica line. Normally, the supplier of the ERTMS system is responsible for the system's maintenance and system's upgrades for a number a year after the initial delivery, varying between 5-20 years. On the central level there will be a person, overall responsible for Signalling system, with a number of employees working as internal experts.

It is vital that Rail Baltica in their contract with the supplier of the ERTMS system ensures that the supplier has an adequate organisation for maintenance of the system and quick response to any incidents. In general all supervision of the ERTMS system is done on a central level, where the system is monitored.

Visual inspection of trackside equipment will be done during track inspection. Maintenance of equipment will be done by the supplier on a local basis.

The instalment of vehicle equipment and maintenance of it is in the responsibility of the train operating company.

Tracks and ballast

The tracks are expected to have a lifetime between 30 and 50 years, depending on track load, speed and maintenance.

If maintained properly, even with high traffic, there is an expectation of a life of at least 30 years without major rebuilds or reconstruction.

To achieve the expected lifetime, the tracks have to be inspected and measured regularly. There are two types of inspection; inspection from a train and inspection on foot. Apart from the inspection there will regularly be monitoring of the tracks and track bed by a measuring car.

1. Inspection from a train is typically from the driver's compartment of an ordinary train in service. There is no need for speed reduction or any restriction in track use.

2. Visual on-foot line inspection is where a team will walk through the whole railway network, both open lines and stations. Ballast has to be inspected once a year at the same time as visual on-foot line inspection also. A single team expected to cover app 10 km a day.

3. Measuring of the line by a measuring car. These measurements gives indications of track faults in different categories. It goes from faults that have to be taken care of immediately to faults that are acceptable but should be observed for further development. It will also give an indication the ballast and whether there is areas with soft ground under the ballast.

On open lines with train speed of over than 200 km/h on-foot line inspections cannot be done, but if there is made a local speed reduction (Normally to 180 km/h), on-foot inspection can be carried out without track possession.

Visual inspection and track repair with trolley/train or a team of workers can only be carried out during track closure or during the night-time non-operational period.

Combined the inspections and measuring will approximately give an inspection or monitoring every month, so there should always be a good knowledge of the state of the railway, regardless of the number of trains on the line.

	Inspection 1	Inspection 2	Measuring	Repair	Replacement

				/stamping	
Interval	4 times a year	4 times a year	4 times a year	Every 5 years	App 25 -30 years
Task	On board inspection. Inside train.	On foot inspection along the line.	Track measuring by measuring car.	Stamping of tracks	Replacement of tracks, sleepers or ballast
Track possession	No	No	No	Yes	Yes
Speed reduction	No	Yes	No	Yes (neighbour track)	Yes
Work force	Local workforce	Local workforce	External Contractor	Local workforce and/or central unit.	External contractor

Table 195: Track inspection

The inspections should be made to comply with local conditions, especially if there is climatic conditions that should be considered. That is, if harder winter conditions is expected in some areas, the inspection protocols should reflect that, and precaution should be taken to reduce any foreseeable incidents.

For example, during winter, if experience shows that certain turnouts is vulnerable to snow and ice clogging, this should be addressed in winter regulations.

Likewise if areas is expected to be extremely dry during summer, initiatives should be taken to reduce track wear in sharp curves.

Ballast

Visual inspection of ballast layer has to be done generally at the line inspections thoroughly every year. The ballast layer must at all times be controlled for weeds. The ballast layer must be maintained, so:

- The track is in such a state that the track alignment is not compromised.,
- Water can drain away,
- The track is in compliance with the geometric requirements for the ballast shoulder width and inclination.

Lifetime of ballast, sleepers and rails should be harmonised, so that they can be replaced during the same renewal period of the track.

The ballast layer has normally a lifetime of 22 years. This can be extended to 32-35 years if the ballast is cleaned at a regular interval.

Information from the measuring car will give an indication, if there is problems with the ballast and bellow. Usually if the same problems is repapering after repairs.

The maintenance units will be able to resupply the ballast and perform stamping on a regular basis, while ballast cleaning normally is done by an external contractor as it requires specialized machines.

Turnouts

The local maintenance units have to realise line inspection, inspection of turnouts, maintenance and greasing of turnouts, winter measures etc. Given the number of turnouts, it is possible to have some indication of the workload. In general it is expected that all turnouts on the main line is inspected and greased 26 times a year (Safety Inspection 1) and is measured once a year.

Safety Inspection 1 on turnouts should be performed minimum 26 times a year, but not less than every third week. It should be made by a local maintenance unit and contains:

- Observation of loose, defect and broken bolts, screws, fasteners;
- Rails condition, rail spots;
- Switch point gabs;
- Switch blade rollers;
- Frog conditions;
- Abnormal wear;
- Slippers packing;
- Ballast profile.

	Inspection	Measurement	Renovation	Replacement
Interval	Every 14 days, Type 1	Every year, Type 2	10 Years	App 25 -30 years
Task	Manual inspection of all parts and greasing of moving parts.	Type 1 + Total measurement of turnout.	Renovation of single turnout element. Normally done according to need and inspection.	Replacement of turnout.
Work force	Local workforce	Local workforce	Local workforce	External contractor

Table 196: Turnouts' inspections & maintenance

There should be a database containing all information regarding status of turnouts. This information should be used to monitor and diagnose the turnouts to reduce failures and optimize maintenance.

In the table below there is an estimation of the number of turnouts on the stations in the three Baltic States. The numbers in the table is based on the schematic layout of the line and Stations. If the design changes the number of turnouts might also change, but it's a good indication of the workload.

Country	Main tracks	Sidings
Total EE	185	46
Total LV	124	48
Total LT	254	55

Table 197: Indicative number of turnouts

The numbers above are based on the preliminary schematic layout of the Rail Baltica line. As the design is only preliminary the numbers might change.

This gives an indication of the workload in the different countries. A work group can inspect and maintain approx. 4 turnouts per nightshift and approximately one turnout per hour on the open line.

Turnouts on stations can be measured and inspected faster, because of a short distance between the turnouts and therefor, no traveling time incorporated.

Normally travel time is included as well as the fact that at least one person of a work team has to serve as security post in case the team is working near lines with traffic.

Station Facilities

A part of task for the local maintenance units might be maintenance of Station facilities.

If the maintenance unit is located at a station it could be possible for the unit to perform maintenance tasks like snow sweeping, maintenance of elevators etc.

Snow cleaning will often be performed by temporary employees.

6.4. Maintenance Organisation

Rail Baltica organisation

Below is shown an example for an overall organisation for Rail Baltica.

It demonstrates how a maintenance organisation could fit into the general company's organisation of a common infrastructure provider for Rail Baltica in all three Baltic States.

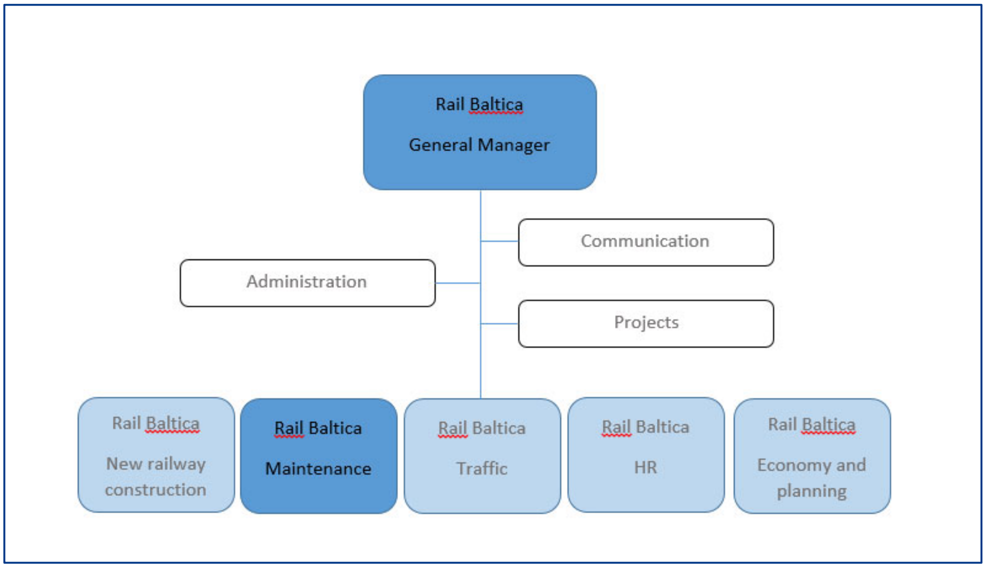

Figure 121: Example of Rail Baltica Organisation.

Maintenance organisation

As the focus is on maintenance organisation, the figure below gives a possible organisational structure with a centralised administration for all types of maintenance.

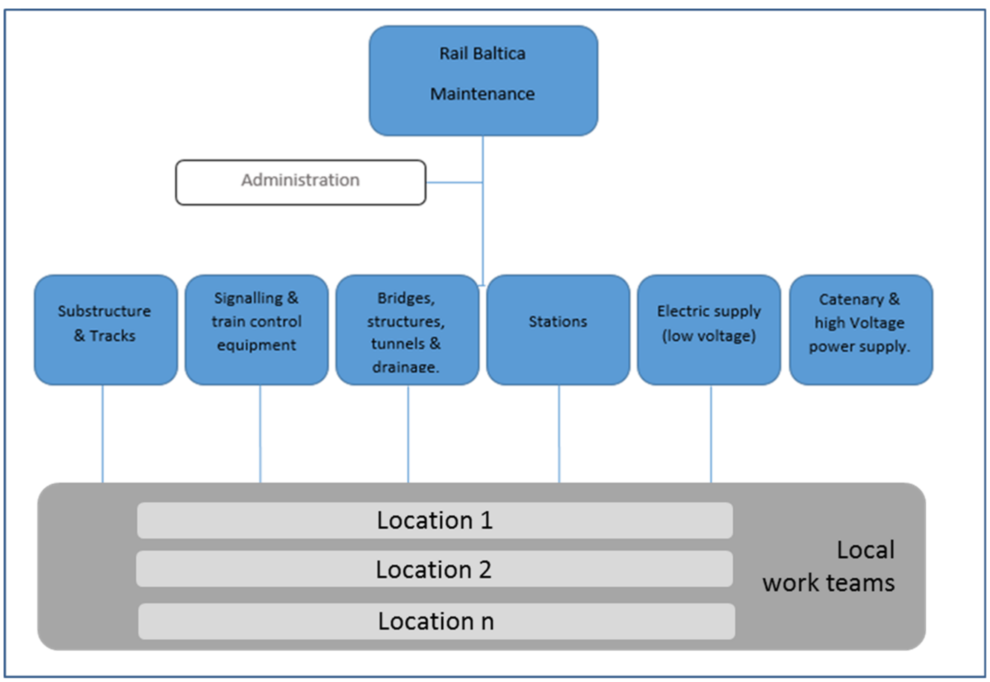

Figure 122: Maintenance organisation. Blue boxes are central administration; grey boxes - local based work teams

The purpose of this organisation is the definition and distribution of responsibilities for the maintenance at the entire stretch of the line. This organisation does not include the maintenance of the proposed FinEst Link tunnel.

Central organisation

The central administration assumes the overall responsibility for all issues concerning maintenance of the railway undertaking, changes to the railway system, new projects and inquiries from 3rd parties.

The followings tasks should be handled in-house within the maintenance organisation:

- Standards, rules and procedures for railway operation & maintenance,
- System's administration,
- Systems' responsibilities (tracks, signals etc.),
- BIM and AIM tasks
- Laboratory tasks
- GIS, geodesists and geotechnical tasks.
- Overall operation & maintenance planning,
- Project responsibilities,
- Project tendering,
- Definition of general maintenance requirements,
- Organisation & provision of day-to-day inspections,
- Organisation & provision of day-to-day maintenance.

The central administration will also have the responsibility for maintenance activities that require equipment being common for the whole line. For inspection and day-to-day maintenance, the line will be divided into local maintenance areas. Each maintenance area will have a small local administration, with employees being responsible for rails, catenary, bridges, high voltage and others within their area.

All inspection and day-to-day maintenance will be done by local teams, located along the line. They will have a local maintenance depot with common spare parts, and will be equipped with trolleys and rail-road vehicles, enabling them to have quick access to the railroad.

The distance between different local depots should be no more than 100 km.

As the comparable maintenance organisation in Banedanmark (see below) is having approx. 900 employees, a similar organisation in Rail Baltica would be expected to have about 450 - 500 employees. The number of employees will be lower in the initial phase, as little maintenance work is expected at the start, but will reach full capacity after 5 - 8 years.

With seven local work teams, each of 20 persons (track, signalling and bridges & tunnels), and some local administration, it is expected that approx. 220 workers will be employed locally.

In the heavy maintenance unit it is expected that there will be 70 staff, and about 195 will be employed central administration.

These numbers are an estimate, and it only expected that the full number of employees will be reached after a number of years.

It is expected that planning of major rebuilds is done by external contractors, and it is not expected there is internal capacity for that kind of tasks.

Estimated workforce in the central administration:

Type	Number of employees in the central administration	Comments
Management	10	Manager + staff.
Administration	20	Administration, HR etc.
Planning and economy	20	Long term planning and economy.
Tracks	25	Track rules, maintenance and administration of tracks.
Catenary	20	Catenary rules, maintenance and administration.
Bridges	20	Rules, supervision, projects.
Signalling	20	Rules, supervision, projects.
High Voltage	20	Power supply, supply of railway related equipment, projects and administration.
Laboratory	5	Material tests. Evaluation of measurements
Others	25	BIM, AIM, GIS Vegetation control, Drainage, Environment, Work heath.
Projects	10	Project managers for new projects working across the whole organisation.
Total	**195**	

Table 198: Central Maintenance administration - Estimation of number of necessary employees

Benchmark organisation

As a railway Rail Baltica is comparable with the main Danish rail network, administered by Rail Net Denmark (Banedanmark in Danish).

The Danish network has a length of approx. 2,100 km, with 3,476 km of track, while Rail Baltica will be having approx. 870 km line and approx. 1,700 km of track.

The climate in Denmark is comparable to the climate in the Baltic Countries, and the operating conditions are comparable.

As an organisation Banedanmark is responsible for all issues with regard to operation and maintenance of all major railroads in Denmark. The tasks include among other:

- Operation (traffic control and signalling),
- Track access (administration of operators),
- Maintenance of railroads,
- Renewal and upgrade of railroads,
- Special projects (new signalling system or electrification project),
- Economy (Budgets for renewal and track access fees).

New railway projects are typically tendered out in corporation with the ministry for transport, and the finished project is then transferred to Banedanmark. The total number of employees in Banedanmark is approx. 2,500 with approx. 900 employees allocated to the Maintenance Division.

The Maintenance Division is the organisation responsible for maintenance of railroads as well as projects regarding upgrades and rebuilds of railroads. In this context maintenance of railroads includes maintenance of substructure, tracks, electrification and catenary, bridges and structures, tunnels, signalling and train control command equipment, drainage, stations.

Banedanmark is only doing minor laboratory work themselves, most are outsourced to contractors, and is overseen by specialists.

Banedanmark is not doing the engineering part for new lines and major rebuilds of lines in-house. It normally is done by an external engineering company after a tender process.

Banedanmark only has its own smaller work teams. They are carrying out light maintenance and repairs, while major rebuilds and heavy maintenance is being carried out by external contractors.

6.5. Maintenance facilities

The maintenance strategy is based on an organisation with a Central maintenance administration (described in previous part) and operational units.

The organisation will consist of:

- Central Administration,

- Central (heavy)maintenance unit,
- Local maintenance units.

The general principles of the maintenance facilities are:

- 1 Depot per 100 Line km,
- Fast Access to (more complex) infrastructure at major nodes (Tallinn, Riga, Helsinki, Kaunas),
- Placement of facilities near proposed stations,
- Bundling of central maintenance tasks and local maintenance tasks.

In order to be able to maintain the lines properly and respond to incidents quickly, it is necessary that there is a number of maintenance locations along the line, with approx. 100 km distance between them. This will give an acceptable traveling distance for day-to-day inspection, and correspondingly a quick reaction time in case of the necessity to provide fast response to incidents.

Given the length and geography of the line, it would be appropriated to establish seven maintenance depots along Rail Baltica with two in Estonia and Latvia and three in Lithuania (normally four in Lithuania but one could be a bigger one at Kaunas and serve the line to Vilnius from there).

One in each country should be larger and accommodate the local administration. They should be located next to the major conurbation and main stations within the respective countries.

Location	Alternatives	Central	Local
Tallinn Rae Junction	Muuga	X	X
Pärnu freight station	Tootsi station		X
Vangaži	Salaspils, Acone	X	X
Bauska			X
Panevėžys			X
Kaunas Airport	Jonava station	X	X
Lentvaris	Vaidotai		X

Table 199: Maintenance Locations – possible location

In the table above are listed a number of possible and alternative locations for maintenance facilities. The facilities marked as central are where the heavy maintenance units will be located.

It is most important that track possession and sidings to park the machines are planned carefully. The average operation planned is very high. Track possession for inspection is also important, and at least once a month there should, on all parts of the railway, be a window of at least 6 hours to allow for track possession and maintenance.

Central administration facilities

The Central maintenance administration, will handle the general administration of issues regarding maintenance, be the location for all specialists and handle planning of overall maintenance operation.

The central maintenance administration need administration offices but location is not needed to be near tracks. The offices could be either near the other administration or could be near the maintenance facility.

The central administration will include general laboratories and plants. These laboratories will do minor work and they will oversee work done by contractors.

For employees in the central administration see Table 198.

Central (heavy) maintenance base

There will be a need for both offices for the administration part and facilities that handles heavy maintenance equipment.

The central maintenance facility is where major maintenance equipment and machines are based. It is expected to be next to, or part of, one of the major local facilities, most probable the one in Latvia, as it will be central on the line. As the major machines is located here, there have to be increased storage and workshop facilities,

The facilities that handle the heavy maintenance equipment have necessarily to be located near a major station with following facilities:

- Offices,
- Change facilities,
- Closed Storage facility,
- Open storage facilities,
- Maintenance facility for equipment,
- Workshops,
- Ramps and sidings for loading and unloading equipment,
- Maintenance facility for Heavy maintenance machines,
- Central maintenance facility for light maintenance machines,
- Track space for heavy maintenance machines,
- Track space for light maintenance machines.

The depots should be equipped as listed below (not detailed).

- Reception/ storage siding 750 m (Track 1 and 2),

- A shunting/run around track (Track3),
- Track for emergency train (Track 4),
- Head shunts (Track 1A and 1B),
- Loading sidings 200 m (Track 5),
- Trolley storage/loading siding (Track 6),
- Trolley storage 2 x 80 m (Track 7 and 8),
- Workshop area 500 m^2 with gantry cranes for maintenance of equipment. (H1 and H2),
- Closed Storage area - 500 m^2,
- Roofed storage area – 5000 m2 (R),
- Open storage area - 5000 m^2 (F),
- Office Space and other facilities (O).

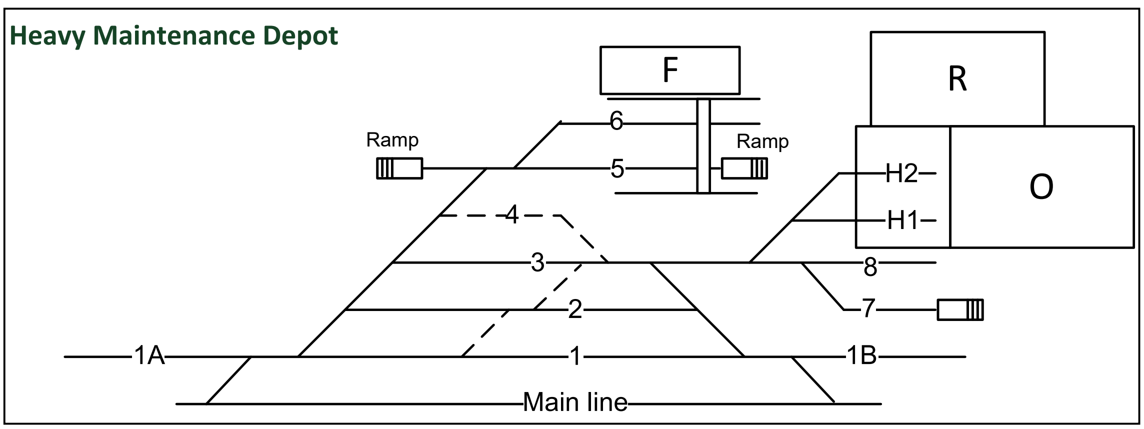

Figure 123: Heavy maintenance depot - Example of schematic layout

Following equipment should be kept at the Central maintenance facility (not complete or detailed)

- Replacement rails,
- Replacement sleepers,
- Spare parts for turnout,
- Ballast,
- Catenary masts of different types,
- Foundations for common catenary masts,
- Cantilevers for catenary,
- Contact wire,
- Messenger wire,
- Fasteners and equipment for catenary,
- cable for power supply,

- Insulators,
- Earthing equipment,
- Spare parts for electric heating of turnouts,
- other equipment.

Staff for the central maintenance bases is listed below,

Area	Number of employees in Central maintenance bases	Comments
Administration	10	Heads of areas Engineers Technicians
Tracks	30	Foreman. Track supervisors Track brigades Machine operators Mechanics
Catenary, power supply and electricity	20	Catenary inspection Minor repairs Substation maintenance teams Emergency repairs.
Bridges, tunnels, culverts and vegetation.	5	Inspection and evaluation. Trimming of vegetation.
Signalling and commu-nication	5	Inspection Minor repairs Emergency repairs.
Total	70	

Table 200: Central maintenance staff - Estimation of Staff

Local facilities

In order to handle the day to day maintenance and respond to incidents quickly, it is necessary that there is a number of maintenance locations along the line, with approx. 100 km distance between them. This will give an acceptable traveling time and distance for day-to-day inspection, and correspondingly a quick reaction time in case of the necessity to provide fast response to incidents.

The local facilities for the light maintenance of the railway have to be located near a station and equipped with following facilities:

- Offices,
- Change facilities,
- Storage facility,
- Maintenance facility for equipment,
- Workshops,
- Track space for light maintenance machines,
- Extra tracks for visiting heavy maintenance machines,

- Rail road vehicles.

There are expected to be seven local facilities along the line.

The depots should be equipped as listed below (not detailed):

- Reception/ storage siding 750 m (Track 1),
- Run around/ parking siding (Track2),
- Loading sidings 2 x 100 m (Track 3 and 4),
- Trolley storage (1B and 5),
- Head shunts (Track 1A),
- Light maintenance, parking 2 x 25 m. (H1 and H2),
- Roofed storage area – 500 m2 (R),
- Open storage area - 1000 m^2 (F),
- Office Space and other facilities – 1000 m^2 (O).

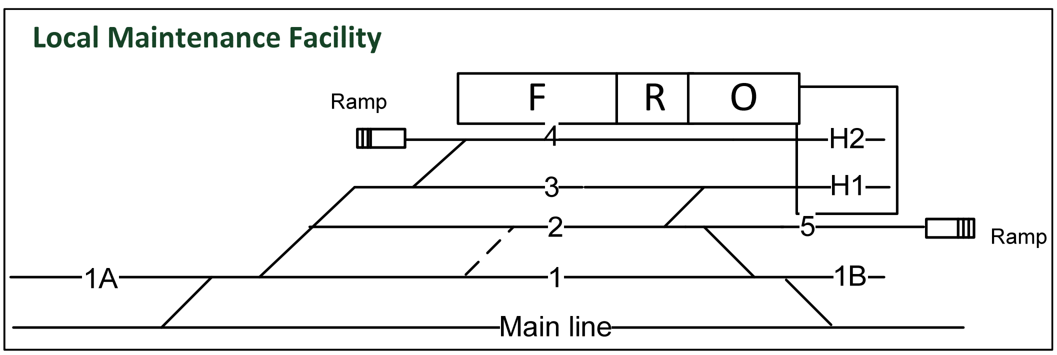

Figure 124: Local maintenance depot - Example of layout

Following equipment should be kept at the local maintenance facility (not complete or detailed):

- Replacement rails,
- Replacement sleepers,
- Spare parts for turnouts,
- Ballast,
- Cantilevers for catenary,
- Contact wire,
- Messenger wire,
- Fasteners and equipment for catenary,
- cable for power supply,
- Insulators,
- earthing equipment,
- Spare parts for electric heating of turnouts,
- Other.

Type	Number of employees in local depots	Comments
Local Admin	60	Local managers Local Line manager Local catenary manger Local tunnel manager Local administration
Work teams	7 x 20	Track, bridges, signalling, catenary, vegetation control etc.
Total	220	

Table 201: Maintenance organisation - Estimation of total local maintenance staff

The work teams it is expected that the staffing will be as indicated below. The numbers are not fixed and it is expected that the exact staffing will reflect the local needs.

Area	Number of employees in local depots	Comments
Tracks	13	Foreman and workers Inspection of tracks and turnouts Minor repairs Emergency repairs
Catenary and electricity	4	Catenary inspection Minor repairs Emergency repairs
Bridges, tunnels, culverts and vegetation.	3	Inspection and evaluation Trimming of vegetation
Signalling and communication	2	Inspection Minor repairs Emergency repairs
Total	20	

Table 202: Local work Teams - Estimation of Staff

There should be two trolleys at the depot one primarily for track work and one equipped for catenary work, as well as two trucks for other tasks not requiring access by track. The trolleys used, could also be two-way-vehicles to be used on Rail and Road.

In the design layout of the stations along the line, space for the allocation of a small work train or a trolley must be considered. This makes inspections easier, and will enable work teams to act locally without restricting rail traffic.

Spare parts

For maintenance of the line, there is expected to be a certain use of spare parts. Below are listed spare parts that are expected to be used during general maintenance on an annual basis. These figure are for maintenance only and do not cover renewals after end of design lifetime.

Most used and most costly item is ballast used for when stamping the railway. Volume and approx. prices is coming from Danish railroads:

Item	Volume	Cost /item	Cost/year
Ballast central (maint.)	25 m^3/km-year	100 €/m^3	2.5 mill €
Ballast local (repair)	5 m^3/km-year	100 €/m^3	0.5 mill €
Tracks local (repair)	100 m total	50 €/m	50.000 €
Turnout parts (repair)	2 sets	15.000 €	30.000 €
Catenary wire (repair)	2000 m	15 €/m	30.000 €
Cantilevers (repair)	15	2000 €	30.000 €
Masts (repair)	3	3000 €	9000 €
Other parts (e.g. signalling and telecommunication equipment)			1 mill €

Table 203: General spare parts - Estimation of annually required quantities and prices

Monitoring systems

For monitoring of bridges and structures, tracks there is several monitoring and diagnostics systems that could help optimize the maintenance of the line.

Many of them are indirect systems in the way that the monitor the trains on the line, and by reducing the faults on the trains they also reduce faults induced on the line.

For direct monitoring there is the use of the measuring car and a thorough use of the data from this monitoring will optimize the maintenance of the line.

Finally there is the use of databases, when filing results from inspection in the field. Good use of databases are essential to monitoring turnouts, bridges and structures.

Banedanmark is primary depending on input from the measuring car and turnout inspection for direct action on the railway. For structures they use a database with information on all the structures.

Below a list of recommended monitoring systems is provided together with related annual cost estimate. For databases only the cost of maintaining database is estimated, not the cost of the inspections on-site to get the necessary information:

Item	task		Cost/year
Measuring car, tracks	Measuring of track faults	Direct	1 mill €
Measuring car, catenary	Measuring of catenary	Direct	0.2 mill €
Turnout database	Status of turnouts	Direct	0.1 mill €

Item	task		Cost/year
Asset database	Status of assets	Direct	0,1 mill €
Pantograph inspection (primary for trains)	Inspection of panto-graphs	Indirect	0.1 mill €
Wheel monitoring	Inspection of wheels	Indirect	0.1 mill €
New systems	New systems to be in-trduced	Direct	1 mill €
Total			**2.6 mill €**

Table 204: Monitoring systems - Estimation of types and prices

6.6. Maintenance machines and heavy maintenance

It is recommended to concentrate the heavy maintenance, in a unit designated to carry out heavy maintenance on the line. This unit will have machines for track maintenance, stamping machines etc., suited for a railroad of this size.

The heavy maintenance unit will be stationed at the central maintenance facilities, and the staff will be allocated there. Cooperation with the local units is expected for tasks in the local area.

As Rail Baltica is a closed line within the region, it makes sense investing in the necessary machines, and thereby having the possibility to form an overall maintenance unit equipped with the right equipment.

This unit will be responsible for keeping the track in the right condition, adjusting the track, supplying new ballast and stabilizing the track after maintenance.

Below are listed the expected machines for a railway of this size, with an estimation of costs for the activities. The activities are based on night work that can be done with only minor disturbance of the rail traffic.

For local maintenance there is a need for universal machines for track work and catenary work. It is expected that the universal machines will be placed at the local depots.

The machines in Table 205 are the general machines:

Task	Type	Example	Number of Vehi-cles	Cost	Overall cost
Line work	Auxiliary ma-chine	P&T OBW 10	14	2 mill€	16 – 20 mill €
Catenary works	Auxiliary ma-chine	P&T Auxiliary vehicle DIS 40	7	2 mill €	16 – 20 mill €
Tamping ma-chine	Multi-purpose machines	P&T Unimat Combi 08-275	3	3-4 mill €	9-12 mill €

Track inspection	Rail road vehicle	Unimog 405	7	0.7 mill €	5 mill €
Ballast car	For resupplying ballast		7	0.15 mill €	1 mill €
Flatbed car	For track parts		7	0.15 mill €	1 mill €

Table 205: Maintenance equipment - General maintenance, located locally - Only examples

There are two types of auxiliary machines. Two at each location should be equipped for light track maintenance and other work around the tracks. They should be equipped with a crane, and able to carry equipment depending on the task, i.e. be equipped with snow blowers for snow clearance.

The other auxiliary machine should be equipped for catenary work, with a lift that enables work on the catenary system and under bridges.

There should be one multi-purpose tamping machine at each of the central facilities. These will ensure that there is a local machine available when repairs are made to tracks and turnouts.

For heavier maintenance there is a need for dedicated tamping machines. Typically three types of tamping machines are being used, one for straight track, and one for turnouts. Apart for these tamping machines there is a need for Dynamic Stabilizing machines and ballast ploughs.

All machines is in Table 206 are examples of machines needed for major maintenance work to be done by Rail Baltica. These machines will be administrated centrally, but will be located at the central facilities in each region, depending on the need for these machines.

Prices for these machines are estimates.

Task	Type	Example	Number of vehicles	Costs	Overall costs
Tamping machine	Track machines	P&T 09-3X	1	4-5 mill €	4-5 mill €
Tamping machine	Universal machines	P&T Unimat 08-475/4S	1	4-5 mill €	4-5 mill €
Stabilizing machine	Dynamic Stabilizing Machine	P&T DGS 90N	1	2-3 mill €	2-3 mill €
Plough	Ballast plough	P&T SSP 110 SW	2	2-3 mill €	4-6 mill €
Crane					
Ballast car			10	0.15 mill €	1.5 mill €

Table 206: Maintenance equipment - Specialised track maintenance

The Heavy Maintenance unit will be capable of track maintenance like stamping and ballast supply where the machines will be used regularly.

It must be expected that there is less work in the first years of operation, as the railway is still new, and investment in machines could be done gradually. It is not expected that these units will perform major rebuilds or building new lines.

It is not considered viable to invest in following cars or machines:

- Measuring car,
- Ultra-sonic inspection car,
- Grinding train.
- Heavy railway crane

These tasks should be performed by external contractors, as it is specialised equipment that only has to be used very seldom.

Work that requires rebuilding of the line will be done by external contractors with heavy equipment for maintenance.

6.7. Climate

The climate in the Baltic countries is characterized by the transition between north European costal climate and Russian continental climate.

The normal temperatures are 20-25 degrees Celsius in the summer and around and below zero degrees C in winter time. Variations are not unusual.

In order to specify the maintenance needs and available time for tasks, following climatic conditions are considered:

- Minimum temperature (-35^{0}C - -40^{0}C),
- Snowfall 40 cm,
- Ice on catenary.

All turnouts are to be electrically heated, due to expected temperature. Snow cleaning equipment should be available, to be mounted on trolleys.

Consideration should also be taken regarding falling leafs in the autumn.

6.8. External activities

With the proposed organisation, all day to day activities will be handled in house by either the administration, the heavy maintenance units or the local maintenance units.

The central administration is expected to be the governing body regarding rules for operation and use of the railway as well as having specialists employed that are responsible for specific fields.

Following tasks is expected to be handled by external engineering firms on behalf of Rail Baltica:

- Investigation for renewal or expansion.
- Planning and design of renewal of lines.
- Specialised task requiring external knowledge.
- Assessment of bridges, building and other structures.
- Planning of major track rebuilding.

6.8.1. Investment in Facilities

Infrastructure and equipment for proposed maintenance facilities are described in chapter 6.5. The related investment costs per facility are presented below. Overall investment necessary can be estimated at 38.3 million Euro. Further justification of this is provided below. Price estimates are based on German practise infrastructure investment costs and market experience of the consultant.

Heavy Maintenance Depot

Rough CAPEX estimate for heavy maintenance depot is provided in Table 207 below. Based on that necessary CAPEX per depot can be stated to be in the range 25 - 30 mill Euro. For all three depots together the total investment would be approx. 75 - 90 mill Euro.

Contents	Amount	Unit	Price/Unit	Invest
Reception/ storage siding 750 m (Track 1 and 2)	750	m	1,500 €	1,125,000 €
A shunting/run around track (Track 3)	750	m	1,500 €	1,125,000 €
Track for emergency train (Track 4)	400	m	1,500 €	600,000 €
Head shunts (Track 1A and 1B)	500	m	1,500 €	750,000 €
Catenary Track 2 + head shunt	1.000	m	400 €	400,000 €
Loading sidings 200 m (Track 5)	200	m	1,500 €	300,000 €
Trolley storage/loading siding (Track 6)	200	m	1,500 €	300,000 €
Trolley storage 2 x 80 m (Track 7 and 8)	160	m	1,500 €	240,000 €
Workshop area 500 m^2 (H1 and H2)	3.500	m^3	225 €	787,500 €
Workshop equipment	1	-	1,000,000 €	1,000,000 €
Gantry cranes, lifting	2	-	2,000,000 €	4,000,000 €
Closed Storage area - 500 m^2	3.500	m^3	225 €	787,500 €
Roofed storage area – 5000 m^2 (R)	5.000	m^2	120 €	600,000 €
Open storage area - 5000 m^2 (F)	5.000	m^2	30 €	150,000 €
Office Space and other facilities (O)	9.000	m^3	350 €	3,150,000 €
Cleated areas	40.000	m^2	25 €	1,000,000 €
Turnout	15	-	120,000 €	1,800,000 €
Local signalling, IT / interface to mainline				800,000 €
Subtotal				18,915,000 €
Unforeseen costs			25%	4,728,750 €
Planning, Management			20%	3,783,000 €
Total				27,500,000 €

Table 207: Estimated Investment Costs for Heavy Maintenance Depot[124]

Local maintenance facility

Rough CAPEX estimate for local maintenance facilty is provided below. Based on that necessary CAPEX per depot it can be stated to be in the range 10 - 12 million Euro. For all seven facilities together the total investment would be approx.70 - 84 million Euro. Seven local maintenance facilities will be placed at the same location as the Heavy Maintenace Depot. Due to synergies real investments will be lower than originally estimated.

[124] Consultants estimate

Contents	Amount	Unit	Price/Unit	Invest
Reception/ storage siding 750 m (Track 1)	750	m	1,500 €	1.125.000 €
Run around/ parking siding (Track2)	750	m	1,500 €	1,125,000 €
Loading sidings 2 x 100 m (Track 3 and 4)	200	m	1,500 €	300,000 €
Trolley storage (1B and 5)	160	m	1,500 €	240,000 €
Head shunts (Track 1A)	500	m	1,500 €	750,000 €
Catenary Track 2 + head shunt	600	m	400 €	240,000 €
Light maintenance, parking 2 x 25 m, (H1 and H2)	50	m	2,500 €	125,000 €
Roofed storage area – 500 m^2 (R)	500	m^2	120 €	60,000 €
Equipment	1	-	500,000 €	500,000 €
Open storage area - 1000 m^2 (F)	1,000	m^2	30 €	30,000 €
Office Space and other facilities – 1000 m^2 (O)	3,000	m^3	350 €	1,050,000 €
Cleated areas	10,000	m^2	25 €	250,000 €
Turnout	11		120,000 €	1,320,000 €
Local signalling, IT / interface to mainline				300,000 €
Subtotal				7,415,000 €
Unforeseen costs			25%	1,853,000 €
Planning, Management			20%	1,483,000 €
Total				10,800,000 €

Table 208: Estimated Investment Costs for Local Maintenance Facility[125]

6.8.2. Rolling Stock

Requirements on needed rolling stock for infrastructure maintenance are outlined in chapters 6.5 and 6.6. Based on estimates provided there for

- Specialised track maintenance machines (located at Heavy Maintenance Depots) and
- General maintenance machines (located at Local Maintenance Facilities)

total amount of investment costs for maintenance machines will be approx. 72 mill Euro. Annual maintenance costs for these machines can be estimated at approx. 10.75 mill Euros (assumption: 15% of total investment).

[125] Consultants estimate

Contents	Investment	Annual Maintenance
Specialised track maintenance machines	23 mill €	3.45 mill €
General Maintenance machines	48.5 mill €	7.3 mill €
Total	71.5 mill €	10.75 mill €

Table 209: Estimated Investment Costs for maintenance dedicated rolling stock[126]

The aboce estimate does not include rolling stock, typically provided by contractors as part of their assignments (e.g. material transport vehicles, measuring cars).

6.8.3. Human Ressources and related materials

Costs for human resources do include costs for staffing and provision of working material and equipment to dedicated staff.

As part of this assignment maintenance cost of the infrastructure provider is calculated based on the eleborated quantities for staffing, rolling stock and equipment in order to perform the tasks done by the infrastructure provider. This does not cover external activities to be tendered out.

To operate the maintenance organisation a total of approx. 620 staff is needed, including administration. The detailed staffing parameters for

- central administration (1x),
- heavy maintenance bases (3x), and
- local maintenance facilities (7x)

are described in the chapters above.

The related mapping of staffing to qualification levels and summing up of staffing costs is provided in Table 210. Assumptions about wage level and equipment costs are the same as in chapter 4.8. Also included in material costs is the need to provision motor vehicles to dedicated staff, teams or facilities so that the individual work sites can be reached quickly via the public road network and Rail Baltica access roads (first estimate 120 vehicles with monthly costs of 750 Euro per road vehicle).

[126] Consultants estimate

	Maintenance Organisation					Heavy Maintenance Bases					Local Maintenance Facilities					Total	
Function	Management	Management support	Foremen, Inspectors	Work teams	Adminstration	Management	Management support	Foremen, Inspectors	Work teams	Adminstration	Management	Management support	Foremen, Inspectors	Work teams	Adminstration	Staff [FTE]	Annual costs [EUR]
	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total	staff total		
Total Staff	10	20	140	0	20	15	15	40	120	20	25	25	60	90	20	620	13,700,000
Qualification Level 1	x					x					x					50	1.640,000
Qualification Level 2		x	x				x	x				x	x			300	7,700,000
Qualification Level 3				x	x				x	x				x	. x	270	4,360,000
																Material	2,450,000
																Total cost	16,150,000

Table 210: Staffing costs - Infrastructure maintenance

Based on this mapping an annual total staffing cost of 13.7 million Euro per year can be estimated. Adding material cost (10% + costs for provision of motorised road vehicles) total cost for human ressources can be estimated at 16.2 million Euros per year.

6.8.4. Estimate of total annual maintenance costs

The figures provided above give an overview about the operational costs for all maintenance activities carried out by Rail Baltica infrastructure internally. External maintenance activities are not included in the figures above.

To complete the picture the total maintenance costs to be expected were assessed based on benchmarking of Western and Central European annual maintance costs.[127] [128] Based on three sample values for Belgium, France and Germany, average annual maintenance costs can be estimated at 48.000 Euro per track km[129]. Taking into account a track length of approx. 1,700 km for Rail Baltica network, average annual maintenance costs for Rail Baltica infrastructure can be estimated at approx. 80 million Euro.

[127] Feigenbaum, B.; High Speed Rail in Europe and Asia: Lessons for the United States. May 2013
[128] Deutsche Bahn AG: Infrastrukturzustands- und -entwicklungsbericht 2017. 30.04.2018
[129] Consultants estimate

Following activities should be given to contractors, due to need for specialized equipment, that is not expected to be economical viable to buy by Rail Baltica:

- Track inspection with measuring car – 4 times a year.
- Track grinding - Every 5 years.
- Ultra-sonic inspection of tracks - Down to every two years.

Other activities that are expected to be done by external contractors are:

- New sections of the line.
- Major rebuilds or renewals.
- Major maintenance with replacement of tracks/sleepers/ballast.

The border between internal and external tasks is normally drawn with the capacity of the machines available to Rail Baltica. Internal capacity should be sufficient to handle accidents and repairs, but specialized task should be done by external companies.

External activities are normally based on tenders for projects or maintenance contracts, all handled by the central administration.

7. Control command systems (WP 9)

7.1. Signalling systems (WP 9.1)

According to EU legislation all lines on TEN-T lines must be equipped with a signalling system based on the common standard provided by the European Railway Agency – ERTMS. For a new line like the standard gauge line Rail Baltica is planning with mixed traffic only ERTMS Level 2 can be recommended. ERTMS Level 2 without signals gives on a newly built line significant advantages on capacity and maintenance since:

1. the movement authority is continuously transmitted to the train via radio block centres, so the train does not have to pass a signalling balise for update. Studies from Switzerland shows capacity improvement for this alone on 15-20%;
2. the sectioning (track vacancy proving) on both the line and in stations with points can be much more freely design since the placement of signals for visibility does not have to be taken into consideration. Simulations from the re-signalling of the entire Danish railway shows that this brings 20-50% more capacity on lines even with mixed traffic. This has partly been taken into consideration in the operational studies;
3. the amount of cabling and equipment – especially along the line are significantly less due to the absence of line side signals. ETCS L2 can rely on incab signalling (where all information necessary is displayed directly on the drivers screen.

The ERTMS system consist of the train protection system ETCS = European Train Control System and the radio system standard GSM-R, which is similar to the GSM network for cell phones, but operates on different frequencies only used for Railway communication.

ERTMS sets via the industrial consortium UNISIG the requirements for functionality and safe communication between

- train and track via a standard Euro-Balises placed between the rails that gives the exact position on regular basis and at critical points in the infrastructure – in between the train compiles it's position via various vendor-specific equipment like wheel sensors, radars, accelerometer, GNSS etc.;
- train and radio system – GSM-R;
- train and Radio Block Centre (via GSM-R);
- train and Key management system, that provides Train and RBC with encryption codes used to provide sufficient IT-Security on the radio borne safety communication between train and Radio Block Centre.

Having these main ingredients of a signalling system specified within the ERTMS standard these systems are not further described in this report.

However a complete ERTMS Level 2 signalling system consists furthermore of

1) Trackside equipment like all the field elements (points, train detection, level crossing, etc.), the interlocking and the ETCS trackside equipment, such as Radio Block Centre (RBC), Network transmission and key management;

2) Traffic Management System that supervises and controls the complete traffic on the railway.

The Traffic Management System is described in chapter 7.2 (WP9.2).

7.1.1. Trackside functionality

The key benefits of an ERTMS level 2 system is among others:

- European standard for signalling is achieved;
- Allowing interoperability and eases cross-border traffic without double equipped trains;
- Ensures a very high and uniform level of safety;
- The coherence of the system, where a trains on-board computer are communicating all the way to the top of the signalling system – the Traffic Management System – gives operational benefits and allows for better direct and safe communication between driver and signal operator.

The Trackside equipment shall mainly support normal ERTMS features desirable for smooth operations like

- applying emergency brakes for one or several trains directly from the TMS system in emergency situations;
- fast and cooperative route release (if the RBC hasn't issued a movement authority to any train over the route, the route can be released immediately and even if a movement authority has been issued it can be released immediately if the train reports that it is able to stop normally before the start of the route;
- setting and release of Temporary Shunting Areas (TSA), that is typically used in areas that occasionally is used for stabling or where shunting simply allows a smoother operation;
- possession/work areas (with or without cut of catenary), which is typically used to restrict an area in which track work is ongoing (or work on the catenary overhead wire);
- temporary speed restrictions – pieces of the line where track conditions temporarily requires a lower speed limit or where track work is ongoing in adjacent tracks.

Where the latter one is handled functionally by the RBC alone, the first two also requires functionality in the interlocking safety equations to prohibit train routes into the restricted area. It is recommendable that areas like possessions and TSA's are defined with fix borders. In that way the safety requirements for an area only needs to be assessed and proven once – otherwise a safety assessment would have to be executed every single time an area has to set or removed. Having fix areas allows the signaller to easily assess the safety implications and if larger areas can easily be obtained by setting several fix areas in combination (like combining track 2 east end of a station with track 2 west end of a station, or track 2 and track 3).

7.1.2. Interfaces from the signalling system

For the Rail Baltica line the interlocking may need several interfaces to both new and legacy systems, but three interfaces should be handled in dedicated studies:

1) The operational interface to Permanent Shunting Areas. For Rail Baltica local signalling systems for marshalling yards and depots are foreseen. These areas are handled as permanent shunting areas that may or may not be indicated to the traffic management centre. Technically an uncomplicated interface, since the points of interference all are located on borders of the ERTMS signalling system allowing automatic train routes to be set like from any other adjacent signalling system as long as the operational rules for the traffic are well defined.

2) In the three Baltic States the trains are not expected to run on non-ERTMS lines, since standard gauge lines don't exist within the current railway network and no correspondence is foreseen. However, one of the main objectives with the line is to connect to the European network and let trains run all the way to Warsaw. Since the current plan for reaching the border station Trakiszki with ERTMS is 2030. The Rail Baltica line in operation before requires a STM system to run the Rail Baltica trains on the Polish lines not yet equipped with ERTMS. Since the same Automatic Train Braking system SHP is installed in vast areas of the Polish railway network, it is assumed that the STM system can be considered as an off-the-shelf delivery and its interface is given within the ERTMS standards. The technical challenge lies in the installation of the STM equipment and the corresponding antennas for reading the 'balises'/trackside equipment in Poland (not being Eurobalises and located at the right side of the train and not in the middle as Eurobalises are). An important part is also here the operational rules for operating ERTMS equipped trains on not equipped lines through an STM device or running without automatic train protection at all. For train operators not willing to invest in an STM for a rather short time period until ERTMS implementation is finished in Poland, facilities for engine change closed to the Polish-Lithuanian border could be foreseen as temporary solution. In this case passenger traffic can only be performed by locomotive hauled trains. ERTMS shall be available on Rail Baltica north of the border station and border station tracks shall be included.

   Having the STM equipment on-board allows crossing the border without any technical stops, since the level transition from ERTMS Level 2 to ERTMS Level NTC/0 would be executed automatically and on the fly. Whether the complete Polish lines has level 2 or some parts level 1 is of no concern since the On-board equipment from all suppliers is capable of both level 2 and level 1 – also this level transition is executed seamless on the fly.

3) A special interface, special functionality in the interlocking equations as well as special operation rules must be developed for not only interfacing to the signalling systems on 1520 mm (this would not be more complicated than the interface to the depots), but also implementing functionality to handle crossings, turnouts and gauntlet tracks with 1520 mm. Although the technical interface can be overcome with relays exchanging signals resulting in a minimum of changes in the legacy system, the functional interface and especially their safety implications will require dedicated studies and probably specific safety assessments and approvals to be developed in each single case, both at generic and specific level. Depending on the safety level of the 1520 mm signalling system a recertification of the generic application level is to be expected. The requirements and implications on installation and test (regression testing of the 1520 mm signalling system as well) will be higher than by normal interfaces towards adjacent systems. In daily operation this will require increased communication between the signal operator of the Rail Baltica line and the signal operator of the 1520 mm network.

7.1.3. Signalling equipment

Signalling equipment (apart from on-board equipment) can be divided into four levels in regard to placement:

Level 1. OCC

Here are all servers for TMS, GSM-R central servers, ETCS interface equipment like key management system, workplaces placed together with building surveillance systems like fire detection, cooling, intrusion control. This must all be placed in a high security building with strict access control to each room and restricted access to the building as well to prevent possibilities for terror attacks. The systems on this level are of very high criticality and adequate precautions is to be made in design and operation of such building. Although servers should be equipped with no break power supply, be redundant and placed in separate rooms and cables in separate cable ducts, a fire, a terror attack or other disasters can occur setting the complete line out of service for a longer period. A disaster recovery centre placed in another building and another of the town/country is recommendable for establishment of emergency operation in less than 24 hours. The placement of this centre should only be known to very few people.

Technical rooms for servers, building equipment and no break will typically occupy 200-250 m^2 in the OCC and 70-100 m^2 in the disaster recovery centre (depending on requirements). In addition hereto the control room itself will require 15-25 m^2 per workplace and offices for both normal office work and back-office operations around 500 m^2. This does also include conference rooms for training and preparation of operation as well as back-office for data analysis and timetable data preparation. Normal building facilities like toilets, wardrobes, canteen, reception etc. not integrated in the above. Depending on the operational concept with train operators it is beneficial to have the train operators operational centres placed in OCC as well. This would give them the opportunity to follow the traffic situation live and make fast decisions together with the dispatchers or the network manager of Rail Baltica, that concerns drivers and train material. Depending on the number of expected train operating companies' space must be added in the OCC for these personnel groups as well. If provided, such facilities are part of open-access, so ther shall be always a reserve for added train operator workplaces.

Level 2. Central signalling equipment

The central signalling equipment consists of interlocking and radio block centre (RBC) along with necessary transmission and power supply. For a fully electronic signalling system as en ERTMS system the availability and robustness of the transmission system is the key to a successful system. This means that from a technical point of view it does not matter, where the central interlocking and RBC equipment is placed as long as it has sufficient access to the transmission network – it could all be placed in OCC.

For maintenance reasons and the fact that the line crosses several countries this approach is not recommendable. Most suppliers has standardize containers, that contains all cabling, transmission and hardware equipment for several interlockings and RBC's (2-4) including juridical recorders and frontend equipment for interfacing with traffic management centre and GSM-R. These containers are fully mounted and tested in the supplier's factory and brought to their destination as a whole, which minimises the work on site and the need for testing as well. The placement should be along the line with no access for the public.

Facing the size and especially the low complexity of the stations on the Rail Baltica line 8-10 interlockings and the same number of RBC's can be estimated. There is no 1:1 correlation between the number of interlocking and RBC's – they have different capacity triggers – the exact number is a supplier decision. Since each container contains several interlockings and RBC's it is recommended to aim for one container in each country – this would ease maintenance issues and keep trained people in each country's working groups mentioned in chapter 6.5 and would offer sufficient capacity for the line and also allow for successive commissioning of lines.

Level 3. Satellite technical object buildings

Although the signalling systems main communication lines are on optical fibres, objects in the field like counter heads for axle counter sectioning, point machines, derailers, is electrically hard wired with cables. For cost and maintenance as well as technical reasons direct cables are to be kept as short as possible. This is done by placing containers with object controllers in regular distances along the track – typically where points are located, since point machines require the shortest cables. Depending on the size of a station (number of points, axle counters to be controlled and the physical distance to the object more than on container may be needed pr. station. Each container requires power and transmission. Power supply can either be with battery backup or connectable for a moveable generator depending on the importance of the area the container controls.

The object controllers communicates with the interlocking via optical fibre and 'translates' commands (e.g. switch point from right to left) from the interlocking to the field objects into direct electrical signals and vice versa 'translates' the electrical signals received (e.g. point detected in left position) into indications that are transmitted to the central interlocking.

Level 4. Field objects

The field objects themselves (axle counter heads, point machines etc.) are the lowest level. These are connected to the object controllers in the satellite containers. There are no differences to traditional class B systems for this level.

7.2. Traffic control (WP 9.2)

Modern Traffic Management Systems can control very large areas with one system only due to the scalable computational power in blade servers, where the operating system automatically distributes workload on the blade servers – and reorganises on remaining servers by faults on one server (or planned maintenance). Additional computational power can always be reached by adding more servers without having to reprogram or reorganise the TMS Software.

A central Operations Control Centre is recommended – and placed e.g. in Riga – controlling the full line in all 3 countries. For operational issues it is recommended to seek to either embed views from the Polish part of the line or receive indications and train numbers from that part of the line as well. Technically the TMS System should be build redundant and placed in separate server-rooms separated with fireproof walls and communicating with the outside and all in-house workplaces on separate communication lines. The servers can in normal operation be in hot standby position in crossed operation (meaning both servers in server room A and server room B is operating leaving remaining servers in both rooms in hot stand by position ready to take over operation seamless within seconds). In case of emergency – e.g. fire, cable failure, transmission errors etc. – each server room should have the capacity to run the full line.

Workplaces are connected to the servers via the transmission network and can be placed wherever the transmission network can be reached – whether this is 50 m away or 500 km away makes no difference in availability and system response times. Due to the advantage of having local knowledge and language capabilities available in a traffic control centre it is recommended to take advantage of this possibility and build satellite Traffic Control Centres in Estonia (e.g. Tallinn) and Lithuania (e.g. Kaunas due to the Kaunas node – or even better if possible: Together with the traffic control centre, that controls the areas, where the 1520 mm railway crosses or passes the Rail Baltic Line). This would give a significant advantage when communicating with emergency authorities, drivers, maintenance personnel, personnel from adjacent traffic control centres etc., both due to the knowledge of the line and the local language spoken, in case needed. As outlined in chapter 6.8 this will be at least the case if external entities have to be involved, e.g. national public emergency services.

Any workplace in any of the three control centres shall technically be in position to take over control of any part of the line – meaning operational backup or movement of signalling authority and thereby flexibility in operation is ensured. What area a workplace is to control depends solely on the users privileges acquired at login. The login can also set the role (signal operator, dispatcher, maintenance coordinator, shift leader, network manager – i.e. all roles defined in the TMS system – along with the preferred language in menus, boxes and error messages and preferred setup of mimics on the screens.

Local operators as shunters and train guards that have the need of knowledge about the traffic situation in the adjacent areas to their possession or temporary shunting area, should have a Hand Held Terminal (HHT) connected to TMS, on which local operations like setting a shunting route or throwing a point, marking a point as trailed and in a certain position can be executed without having additional equipment on site. This is cost efficient alternative to local control buttons and keys and allows for a strict, controlled and safe communication with the signal operator in OCC. The TMS system will know that the area is under local control and therefore only allow commands from the authorised Hand Held Terminal (and reject any non-permitted commands from the signal operator or another HHT). This also makes it easy to place the safety responsibility, since only commands feasible in the interlocking can be executed.

7.2.1. Interfaces

It is the task of the TMS System to interface both signalling system and adjacent systems like

- Timetable system to receive new plans for operation;
- Catenary system to receive, show on mimics and eventually react on power cut (e.g. by rescheduling an electrical driven train to another track that is powered or set emergency markers to prevent all trains from entering a suddenly unpowered section, where the reason for the power drop could be drop of the overhead catenary line;
- Surveillance cameras on stations and other significant positions;
- Maintenance systems for automatically reporting on maintenance activities etc.;
- Passenger information systems for visual and audio information to passengers and personnel.

It is recommended to leave TMS have the direct interface with the signalling system as its main objective. All other interfaces not vital for TMS should not be connected directly to the TMS Servers, since jamming from other system then could jeopardize TMS operations. Bringing in a dedicated interface server that communicates on <u>one</u> channel with the TMS servers with <u>one</u> protocol has several advantages like e.g.:

- it shields the TMS Servers from jamming from the outer world;
- the interface server can automatically distribute the same type of information like e.g. delays to several system request this type of information without having the TMS servers duplicating the information;
- it is expandable for new protocols/systems without having to reprogram anything in the TMS Servers.

7.2.2. Testing and commissioning

The Table 154 in section 4.8.12 gives an overview of the Workplaces needed for operation of the line in normal and degraded mode.

The line will be built and commissioned successively over many years and afterwards continuously modified for maintenance and upgrading purposes. It is there for highly recommended that in the main control centre in Riga two workplaces are added for commissioning and training purposes and likewise to add a workplace in the local satellite control centres at Tallinn and Kaunas.

Upon test and commissioning dedicated workplaces can be connected to a virtual set of the TMS servers containing the new set of infrastructure data or even software, allowing full monitoring of the line and possible control of dedicated areas without possible interference on the operating TMS System. This independence towards the TMS System in charge of operations is vital for the availability of the system. New infrastructure data can very easily (regardless of thorough lab testing) introduce fatal errors in the TMS System. Without ability to test new releases in a controlled real-time environment under full load the chance of blackouts of the complete Rail Baltica line would be significant. The workplaces do not have to be dedicated for test purposes only – any workplace should be able to both act in normal operation, as training workplace and as test workplace hence all workplaces should be equally equipped. Having the test workplaces in the control room bring additionally the advantage of having the operational knowledge at hand while testing and will ease any needed communication between the signal operator at the test place and the remaining signal operators.

7.3. Conclusive recommendations

Although big parts of an ERTMS based signalling system is described in the Unisig standards, significant parts as the TMS System and the interlocking are not and the ETCS system itself has also a set of national values as e.g. max speed while shunting, that has to be defined. The major change is however the operational rules. The clarification of these rules should not be underestimated and hence have the top priority ahead of specifying and procuring the signalling system – the rules will also have impact on track layout and how depots are to be handled.

The operational rules together with the desired way of operating and maintaining the line is not only crucial regarding the TSI-OPE, but also politically to be clarified on an overall level (not on a detailed level, since this has to be aligned with the possibilities of the chosen system) before specification of the signalling system can commence, since this work will give the overall requirements to the signalling system. The right organization fit for technic used to operate and maintain the line is a key issue for its success.

Hint: Operational rules from current Class B systems can only be used in very limited areas. It is expected to describe the operational rules from scratch.

Another important issue is the key management system. Technically one system to distribute the keys to the trains and the radio block centres would be sufficient, that would however require, that the IT Security policies is aligned in all three Baltic States. Having dedicated RBC's in containers in each country would allow for different IT-Policies either from the start or later during operation.

8. Recommendations (WP 7)

As described in the introduction to this report the Operational Plan is an initial basis for improving infrastructure design and the integration of Rail Baltica in the overall spatial structure of the Baltic countries. Complementary analyses will be required in the following planning and design phases of Rail Baltica in order to improve the infrastructure layout and the overall eligibility of the project. Based on the results of the Operational Plan and its individual work packages the following recommendations can be given for the further planning and design process:

8.1. Traffic studies (WP 1)

- The future demand in passenger transportation will depend significantly on the integration of the planned stations in the urban structure and the accessibility, mainly by public transportation. To ensure a high demand and competiveness with car transportation a good integration of the stations should be envisaged on a local and regional level in close cooperation with the according authorities in the future planning and design phases for Rail Baltica. This relates to all long-distance stations but especially for Tallinn (possible extension of Rail Baltica to Balti Jaam and the ferry port would create additional demand) and Panevėžys where the planned Rail Baltica station is located far from the urban centre and not directly connected to the existing 1520 mm railway line.
- The passenger demand of the proposed regional stations was analysed on base of the existing structure, available data and a general assumption for the planned service pattern. To get more detailed information on the passenger potential, detailed studies on regional passenger transport should be initiated including the planned spatial structure (new settlements), the planned service pattern and the transport offer on feeding and competing lines.
- Especially in Riga node Rail Baltica will be integrated with numerous other public means of transportation, e.g. 1520mm suburban railway, regional and long-distance busses, trams and local (trolley-) busses. The actual demand on rail Baltica and the other modes will depend on the kind of integration including a unified ticketing system for all modes and an integrated time table system. This integration is task of the local and regional authorities and operators. However RBRail should give according input to these stakeholders in order to initiate the required analyses.
- To obtain more reliable information on the traffic demand a strategic passenger and freight transport model for the whole Rail Baltica line in connection with other modes should be established.
- With regard to the rising uncertainty with passenger and freight volume to be realised in the future with time horizons < 20 yrs. it is recommended to focus on shorter horizons and to consider a phased construction approach to reduce the risks involved.

- Additional detailed freight transport studies shall be carried out from the perspective of business development and to initiate further technical and organisational action to facilitate modal shift to rail. This does include the following topics: potential and technical needs for postal and express services, Potentials for usage of dual gauge wagons.

- Regarding development of freight facilities local studies shall be carried out to investigate freight potential and best way to serve the market by Rail Baltica, e.g. Panevėžys and Marijampolė. Marijampolė study could also be used to elaborate the future market potential along and to determine the future role of the existing terminals in serving the local transport market.

8.2. Rolling stock studies (WP 2)

- It is recommended to use EMU for all passenger service (HST as well as RE/RIX/HEL). For HST the main parameters are a maximum speed of 249 km/h and a capacity of 400 seats per vehicle. For all regional services (RE, RIX and HEL) a common EMU type should be used in order to unify the fleet and simplify maintenance. The main parameters of regional EMU are a maximum speed of 160/200 km/h (depending of requirements by the regional authorities) and a seating capacity of 300 seats per EMU including the possibility to couple trains (also refers to HST trains).

- The use of existing rolling stock for passenger services is not recommended as the availability and flexibility of use is rather limited with the current available rolling stock especially in Poland with regard to multi-voltage capability and ERTMS.
- For freight traffic all relevant types of multi-system locomotives and waggons are available as standard solutions on the market.
- Procurement of rolling stock for passenger traffic has to be coordinated centrally in coordination with regional authorities for regional passenger services depending on the final business model for operation on Rail Baltica. Information about the required vehicle specifications and fleet size should be given to potential suppliers as soon as possible in order to confirm availability and realistic delivery time lines including homologation and trail run.
- For procurement of rolling stock for freight traffic the operators will be responsible. However early information on the homologation, trail run process and operational rules will ease rolling stock procurement and initial usage.

8.3. Infrastructure studies (WP 3)

The recommendations for infrastructure development include all requirements to operate the proposed train service pattern (WP 2) as result of the 1st iteration of the operational plan (WP 4). This relates to:

- General design parameters:

  - The final number and localisation of regional passenger stations has to be decided.
  - Localisation and layout of passing loops and crossovers.
  - Block section length.
  - Platform height (in coordination with rolling stock); a platform height of 760 mm is recommended according to TSI and with respect to current and future situation in Poland, where 760 mm platform height is applied, to provide a single platform height along the whole corridor.
  - Maximum train length should be coordinated with future market needs and the plans in Poland. Even if PKP PLK S.A: will continue with the current planning of 750 m train length, Rail Baltica should at least include an option for 1,050 m trains in later stages.
  - Increasing maximum operational speed from proposes 234 km/h as per Rail Baltica Design Guidelines to 249 km/h subject to final considerations regarding trial runs and homologation conditions for Rail Baltica infrastructure.
  - Removal of remaining existing limitations on maximum line speed as part of CPTD process.
  - Application of turnout speeds at stations and junctions according to proposal in this report. Generally, junction design should allow for passing of high-speed trains at maximum speed.
- Individual infrastructure elements:
  - The final location of stations in Tallinn in addition to Ülemiste (Balti Jaam and ferry port) has to be decided. These both additional stations would significantly improve accessibility to Rail Baltica. However, at Tallinn Ülemiste four platform tracks should be realised.
  - The final localisation of Rapla station and integration with 1520 mm network has to be determined. At common regional station for both 1435mm and 1520 mm would increase the future demand on Rail Baltica.
  - In Riga node additional capacity is required to realise the proposed train service pattern. This relates mainly to additional tracks at Riga Central (4 platform track at least) as well as improved track layout at RIX and/or provision of turning facilities at Jaunmārupē.
  - The final localisation of Panevėžys passenger station and the integration with other transport modes including the 1520 mm network shall be decided in order to improve accessibility.
  - After determination of the regional passenger train service the layout of Kaunas node has to be further developed. This includes the layout of Palemonas, Kaunas Tunnel, Kaunas Central Station, Jiesia and Kaunas bypass).

- The final alternative of the section Kaunas – Vilnius including Kaunas triangle configuration has to be decided.
- The final alternative of the section Kaunas – LT/PL border has to be decided. A regional stop in Marijampolė should be realised in all alternatives.
- Depending on the traction voltage and operational rules in both countries the border-crossing procedures between Lithuania and Poland must be determined. This includes the potential requirement of a border station.

The on-going process of infrastructure optimisation has to be continued based on the results of this study and taking into accounts results from CPTD process initiated by RB Rail. This work is to be continued in the following planning and design phases.

8.4. Operation plan (WP 4+8)

- The service pattern of regional services has to be confirmed and further developed by the regional and national authorities as soon as possible in order to provide the required capacity and to size infrastructure according to the needs of first 20 years of operation. Reasonable future growth options shall be considered from the beginning.
- The transnational train services and operational rules between the Baltic States and Poland must be coordinated including the planning by PKP PLK, the national and regional authorities in Poland.
- The future operation on the 1520 mm network should be further developed in order to analyse the interdependencies with operation on Rail Baltica in more detail.
- Need and technical requirements for freight train service shall be further elaborated taking into account all relevant stakeholders. This process shall be embedded in ongoing market research activities for the North Sea – Baltic rail freight corridor. Topics include requirements on layout of terminals, stabling facilities for locomotives and freight wagons, required maintenance facilities, necessity of dedicated services near the Polish – Lithuanian border.
- The operational plan shall be updated at least annually to reflect the latest planning stages regarding proposed train offer and transportation demand and to serve as basis for further infrastructure design and spatial planning activities. Vice versa results from technical design shall be reflected in the operational plan.
- Station track layout and location of passing loops shall be further elaborated based on results of operational plan during further design stages (spatial planning, technical design).
- Future 1435 mm network south of Kaunas needs to be finally decided regarding interconnectivity between Rail Baltica main line and already existing single track line sections (Trakiszki -) Mockava – Šeštokai – Marijampolė -Kazlų Rūda– Jiesia and future location of the regional passenger station at Marijampolė.

- The capacity analysis done in this study shall be accompanied be more detailed investigations incl. timetable stability analysis to prove functionality of proposed infrastructure layout in Kaunas node and to choose the final infrastructure layout. This can be based on the Railsys model provided as result from this study.

8.5. Rolling stock maintenance (WP 5)

- Based on considerations outlined in the Operational Plan the options regarding potential rolling stock maintenance facilities shall be finalised.
- Utilisation of the defined options will depend on individual requirements and business relation of the passenger and freight train operating companies.
- In order to provide the right facilities for passenger rolling stock maintenance the final organisational model for provision and procurement of passenger train services and rolling stock shall be defined first.

8.6. Infrastructure maintenance (WP 6)

- Maintenance organisation and maintenance facilities shall ensure that overall availability of infrastructure is maximised.
- Regarding maintenance organisation a two-tier approach is recommended with central maintenance administration and local facilities to be located along the line.
- The maintenance facilities should be preferably located near larger stations, where shunting operation can be facilitated and easy access for staff and material transport can be provided.
- Local Maintenance bases shall be placed approx. every 100 line km. That means at least 7 maintenance depots are to be provided (3 heavy maintenance depots, 4 additional local maintenance facilities).
- Before setting up maintenance organisation it should be determined which activities are to be provided by the infrastructure manager and which activities shall be tendered out.
- With growing business intelligence ensurance of data availability about all infrastructure components on the line is crucial. This will be the basis for any condition-based maintenance activities and decisionmaking on reinvestments and management of maintenance activities. This should be reflected from the beginning in setup of maintenance organisation and structuring of business processes and definition of procurement requirements to external contractors.

8.7. Control Command Systems (WP 9)

- Before starting design and procurement of signalling system the operational rules shall be defined and clarified. The applicable national values shall be set based on further study. This task is directly related to operational rules will impact infrastructure layout and how depots and terminals are to be handled.

- Before specification of the signalling system can commence the necessary political decision on organisational structure and operational rules, and operational interfaces need to be defined (border stations, not only on operational and technical level but also on technical level. before specification of the signalling system can commence, since this work will give the overall requirements to the signalling system. The right organization fit for technic used to operate and maintain the line is a key issue for its success.

- Another important issue is the key management system. Technically one system to distribute the keys to the trains and the radio block centres would be sufficient, that would however require, that the IT Security policies is aligned in all three Baltic States. Having dedicated RBC's in containers in each country would allow for different IT-Policies either from the start or later during operation.