Interreg
CENTRAL EUROPE
European Union
European Regional Development Fund
TRANS TRITIA

D.T3.2.2 Report 12.2019

Zero scenario of TRITIA traffic model

Responsible Partner:
PP4 Transport Research Institute, JSC.

Contribution partners:
PP1 Upper Silesian Agency for Entrepreneurship and Development LTD.
PP3 The Union for the Development of the Moravian Silesian Region
PP5 Dopravní projektování
PP6 University of Žilina

Contents

List of Tables

List of Figures

1. The basics of the model of TRITIA multimodal potential

The process of traffic modelling plays an important role in the process of strategic planning of transport infrastructure development and investment allocation in the transport sector. The methodological approach in developing a traffic model largely depends on the purpose and aims, for which it is developed. At present, most traffic models are focused on demand analysis of passenger transportation. The main reason for this approach is the excessive volume of vehicles in agglomerations that needs to be addressed in order to improve traffic flow and population mobility.

Freight transport contributes significantly to these transport problems through increased load on transport infrastructure and the resulting negative impacts such as congestions, deterioration of environmental standards and lower quality of life of the affected population. The transportation of goods on a macroeconomic scale is a necessary precondition to ensure economic growth on national level and the satisfaction of population in terms of product demand. This function implies a continuous optimization of transport process of the carriers.

It is particularly necessary to tackle this problem at the European macro-region level, which achieves above-average economic growth and is defined by the unfinished infrastructure of higher transport relevance for individual transport modes. The territory of TRITIA consists of 4 regions from 3 neighbouring EU member states.

The TRITIA region is formed by Moravian-Silesian region (CZ), Silesian and Opole Voivodeship (PL) and Žilina region (SK). The total area of the considered region is 34 069 km2 with roughly 7,8 million residents. The biggest agglomerations of the TRITIA area are the cities of Katowice and Ostrava, which form important metropolitan areas.

Given the rather complex relationships within the transport process, which are based on the mobility behaviour of the population (passenger transport) and the ensuring of goods supply (freight transport), it is necessary to use transport engineering tools and procedures, which allow the verification and justification of infrastructure modification and other interventions. This way the modelling of the traffic flow allows the identification of the infrastructure bottlenecks and the testing of the impact of proposed alternative measures. In general, the basic purpose of the TRITIA traffic model can be defined as the quantification of transport relations in the considered area and the review of the changes in transport relations due to the infrastructure development in the region by 2030. The role of the traffic model was also to identify the potential for transferring a part of freight transport to more environmental friendly modes of transportation (railway and inland waterways).

The project is focusing on the cross-border, transnational and interregional cooperation with the aim of strengthening of economic and social cohesion in order to achieve the objectives defined by the Europe 2020 Strategy as well as the EU White Paper on Transport. The main task of the project is to improve coordination at the level of strategic planning aimed at the development of infrastructure in the regions, which will result in the elimination of bottlenecks on the main transit routes. One of the most important parts of the project is the elaboration of a strategy (implementation action plan) of multimodal freight transport implemented in the monitored regions. The main tool for the verification of proposed measures will be the development of a cross-border multimodal model describing mainly the state and trend in the freight transport development.

The aim of the project is to strengthen interregional cooperation by reinforcing the economic and social cohesion. In general, the project has been focusing on the identification of the possibility of meeting the objectives defined in the strategic documents Europe 2020 and White Paper - Roadmap to a Single European Transport Area. The project was principally divided into two main parts:

A. TRANS TRITIA Multimodal freight transport strategy and action plans

B. Model of the TRANS TRITIA multimodal potential.

The need for development of the traffic model has arisen from the current situation in the regions. The role of the model is to find and test the solutions for cross-border problems of transport modes. The aim of the solutions is to increase transport efficiency and development of the concerned regions. The increasing demand for transport shows the infrastructure bottlenecks in individual regions and also in cross-border interconnections. The main goal of the traffic model is to point out the need for the development of transport infrastructure in regions and in cross-border interconnections and to promote the unification of procedures in the concerned countries. For this reason, two main objectives have been defined in the traffic model development:

1) Quantification of the potential for modal shift of traffic from road freight transport to alternative transport modes (railway and inland waterway) in relation to the aims defined in the White Paper (shift of road freight over 300 km to other modes of transportation within the range of more than 30%).
2) Identification of bottlenecks on the transport infrastructure and proposal of typological measures to increase its capacity in order to increase the potential for modal shift to more environmentally friendly modes of transportation.

The aim and purpose of the project is reflected in the TRITIA traffic model solution and is divided into two sub models.

- Sub model that describes intra-zonal and inter-zonal transport relations.
- Sub model that describes the surrounding territory, including international roads and international transport.

The traffic model takes into account the infrastructure of road, rail, inland waterway and intermodal transport (intermodal terminals). Air transport is not considered as the TRITIA region is not large enough for efficient use of aircrafts.

In view of its purpose, the traffic model is designed separately for the freight and passenger transport, while passenger transport is calibrated solely in terms of reaching the maximum of infrastructure capacity.

The model was developed in the VISUM® program, which is a part of the PTV-VISION® traffic planning software package of PTV Karlsruhe.

1.1. Analysis of outputs provided by existing traffic models

When processing the TRITIA traffic model, the possibilities of using the outputs of already processed traffic models were analysed. The calibrated version of the processed traffic model represents a data base that can serve as a basis for the refining of parameters of the TRITIA traffic model. Available models were divided into two groups:

- Cross-border traffic models developed within the Interreg financing scheme (AT-CZ-SK-HU, SONORA, BATCO)
- National traffic models developed in individual TRITIA countries (national model SK, CZ).

The AT-CZ-SK-HU traffic model was implemented gradually in 2009-2014 and was financed bilaterally by AT-CZ, AT-HU and SK-AT via three separate financial programmes:

- Slovakia - Austria Cross-border Cooperation Programme 2007-2013,
- Austria - Hungary Cross-border Cooperation Programme 2007-2013,
- Austria - Czech Republic Cross-border Cooperation Programme 2007-2013.

The objective of the project was to create a cross-border traffic model of the CENTROPE region and to facilitate planning processes of infrastructure development in this area. The model was to be intermodal, meaning that it would fully cover both individual car transport (ICT) and public transport (buses, rail, suburban, according to specific graphic timetable). The data from this traffic model are not applicable for the needs of the TRANS TRITIA project, because they consider another area of interest, i.e. border regions between Hungary, Slovakia, Austria and the Czech Republic. The purpose of the project was to cover passenger transport in the monitored area (individual car transport and public transport). The project TRANS TRITIA is aimed on the freight transport.

SONORA project was implemented in 2008-2013 through the CENTRAL EUROPE 2007-2013 financial scheme. The goal of the SONORA project (South-North Axis) was to improve transport infrastructure and services across Europe. SONORA was a multi-national project oriented on the improvement of transport accessibility between Northern and Southern Europe, between Adriatic Sea and Baltic Sea in terms of:

- Creation of a genuine SONORA network through the support of transport infrastructure completion,
- Running and improving multimodal freight logistics services,
- Preparing a multi-national action plan for the future state of affairs,
- Supporting new regional development opportunities, caused by network improvement.

The aims of the SONORA project are very similar to the intention of TRANS TRITIA project. In the course of the project implementation, an application was sent, which was subsequently urged several times, to provide relevant documents from the SONORA traffic model for the needs of the TRANS TRITIA project. There was no response from the project partners and the lead partner of the project during the project. It was therefore not possible to use the SONORA traffic model for the needs of the TRANS TRITIA project. In addition, the 2008-2013 data base is already relatively outdated.

The BATCO project was implemented in 2010-2013 through the CENTRAL EUROPE 2007-2013 financial scheme. The project was focusing on improving economic development along the Baltic-Adriatic axis via the creation of conditions for the best possible integration of the affected markets and their balanced development. The project has included the development of a traffic model of the Baltic-Adriatic axis too as a means of decision-making support. Project partners PP3 - SPR MSK and PP4 - VUD participated in the project, but the data from the BATCO traffic model were not available.

For this reason, we approached both the project's lead partner and the traffic model developer to provide source data, but without feedback. For this reason it was not possible to use these data to refine the TRITIA traffic model.

Another source of data was represented by separate traffic models processed in individual categories at the national level. The Czech Republic and the Slovak Republic have processed national traffic models, which are available in an electronic form. After fulfilling some conditions, they could be used in the processing of the TRITIA traffic model. The feasibility study of the Danube-Oder-Elbe was also prepared in the Czech Republic during the project. In the framework of that study, a traffic model was also developed with planned inland waterways in the Czech Republic (interconnection through the Danube, Oder and Elbe canals), which means that the Danube-Oder-Elbe model is thematically closest to the TRANS TRITIA project. There are available partial output reports from the feasibility study, but the calibrated traffic model cannot be used for project purposes yet. It has not been completed yet. That is the reason, why the Ministry of Transport of the Czech Republic cannot provide it.

2. Model of TRITIA multimodal potential

2.1. Zoning of the modelled area

The primary step in the creation of most traffic studies, including modelling of traffic potential, is the definition of traffic zones of the given area - zoning, which represents the division of analysed area into discrete areas. Generally, there are no clear and universal formulated rules, they are mostly created and based on the existing traffic-engineering practice, which is based on the principle of obtaining a zonal division with homogeneous attributes and respecting the administrative boundaries of the area, for which socio-economic data are available for the quantification of the transport demand - attractiveness, and transport generation- supply.

System of zoning of the territory is applied for the purpose of aggregation of individual households and economic operations into units that can be elaborated by common tools of traffic modelling. The main parameters of the zoning system include the number of traffic zones and their range, there is interdependence between them. The higher the number of zones defined in the traffic model, the smaller their area to cover the area in question. One of the first tasks in development of the TRITIA traffic model was the clear identification of the area of interest and its delimitation to its surroundings.

This was the primarily aspect considered when defining the zones of the TRITIA cross-border freight traffic model. It is clear that for the freight traffic modelling via multimodal traffic model, it is necessary to base the model on the economic development forecast as there is a very strong correlation. Aiming to quantify the economic development in the given territory, it is necessary to have a set of socio-economic parameters that are statistically expressed for a given structure of territorial units corresponding to the administrative division of concerned territory.

The development of the traffic model was based on the outputs of traffic models processed at the national level, which, given their purpose, the range of the statistical survey and the nature of the processing, represent also a relevant basis for the TRITIA cross-border region. The application of the zonal segmentation based on national traffic models is also justified due to the potential use of the outputs of this project in the framework of updating national models.

2.1.1. Identification of the territory of interest

The territory of interest is usually an area with a non-homogeneous segmentation of land use and socio-economic characteristics. These disproportions have a negative impact on the relevance of traffic modelling outputs used for determining traffic demand. In order to eliminate these disproportions, the territory after its definition will be divided into smaller areas - zones that show relatively homogeneous characteristics of the analysed traffic relations.

Within the zoning of the modelled area, it was necessary to proceed in accordance with the requirements for securing outputs with high information value, thanks to which it is possible to develop and to calibrate the traffic model. The primary zoning of the survey area should be identical to the existing zoning that was created for the transport planning tools of higher importance. Subsequently, it is possible to proceed in more detailed area zoning in accordance with the requirements and purpose of the traffic model. Maintaining the primary zoning of the territory is related to the possibility of using the results not only for the assessment of planned measures, but also for updating the data of transport planning tools of higher importance (e.g. national traffic models) through data aggregation.

The concerned territory of the TRITIA project, for the purpose of the traffic model development, was defined as the territory, which is bounded by the administrative boundary of the territory of the Žilina Self-Governing Region /SK/, Moravian-Silesian Region /CZ/, Silesian Voivodeship /PL/ and Opole Voivodeship /PL/. The territory of these territorial self-governing units of the highest level also constitutes the basis of the transport area of interest. As there is a territorial overlap on the border between the individual cross-border regions of the territory thus defined, it was necessary to extend this basic area of interest. Specifically, it was the north area of the Olomouc Region (CZ), which has common border with the Opole Voivodeship (PL) - a member of TRITIA. This area was included in the area of interest mainly due to the existence of roads of higher transport importance between the Czech Republic (I/44 and I/60) and Poland (DK40 and DW382), where there is a potential for their use by road freight transport. There is also an overlap in the Žilina Self-Governing Region (SK), whose northern border extends to a part of the Lesser Poland Voivodeship (PL), and through this area, there is a major road connection passing through Slovakia via I/59 and DK7 in Poland. By incorporating these overlapping areas into the TRITIA partner self-governing territories, a compact area of interest has been obtained for the traffic model, in which the transport relations are examined in a more detailed way.

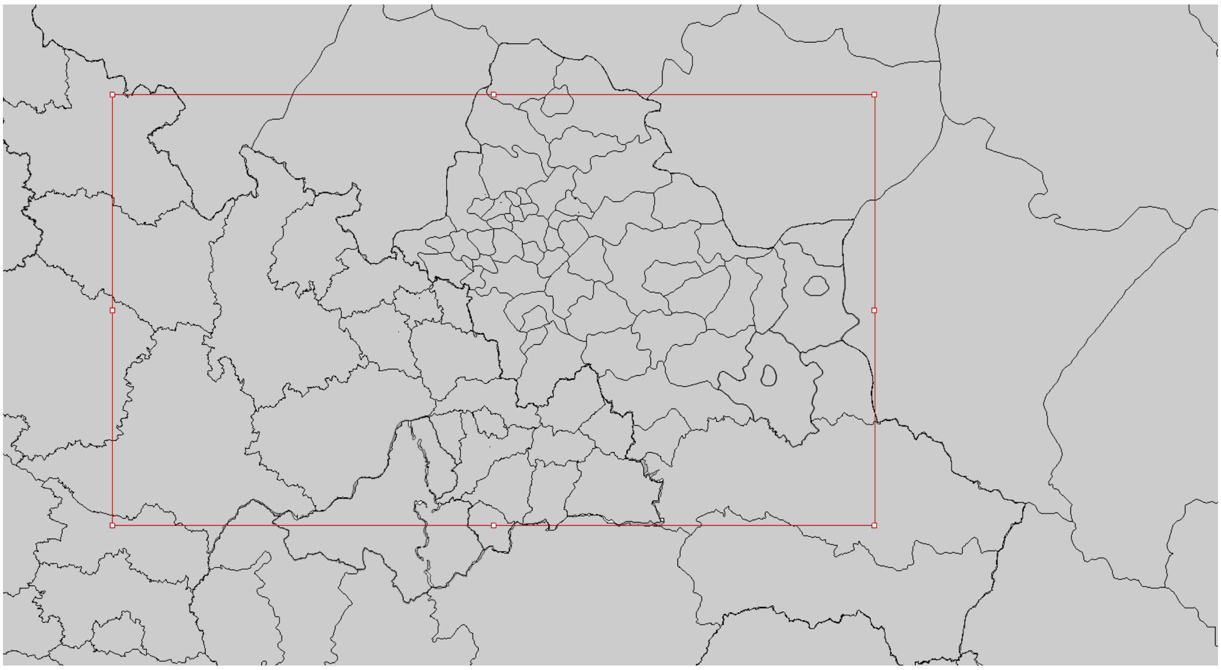

Figure 1 Detailed zonal division of the territory covered by TRITIA traffic model

Considering the fact that the traffic modelling not only monitors the traffic relations between the individual traffic zones within the surveyed area, but also the relationships between the external area relations and the surveyed area (origin, destination and transit traffic with respect to the modelled area) to define the division of the territory into traffic zones also outside the surveyed territory (wider territory).

The detail of the division of this territory depends on the required accuracy of the results and can be done on the basis of the administrative classification according to the nomenclature of territorial statistical units NUTS. In this case, some countries could be merged into one territorial unit based on historical or geographical context. As long as this is consistent with the nature and purpose of the traffic model, the primary zoning should respect the boundaries of the existing transport planning tools. Due to the fact that the TRITIA traffic model is macroscopic with significant transport relations of a cross-border nature, the surrounding territory is practically extended to the territory of the whole European continent. The wider modelled territory is divided into a total of 139 transport zones, of which 33 are located in the countries of the project consortium.

Figure 2 Zonal division of wider territory of the TRITIA traffic model

2.1.2. Structure of the zonal division

The extent of zoning of the TRITIA multimodal freight traffic model amounts to a total of 229 traffic zones, and covers the territory of virtually the whole European continent. The area of interest consists of 90 traffic zones, of which 64 are located in Poland, and 13 traffic zones are in Slovakia and the Czech Republic.

The level of traffic zones in the area of interest corresponds to the LAU statistical territorial unit, which represents the administrative segmentation of the area in question based on the district competence. An exception is represented by some traffic zones within the Polish part of the territory of interest, which are at the NUTS 3 level, which corresponds to the administrative division into regions or voivodships.

The wider territory of the traffic model consists of a total of 139 traffic zones, of which 33 of these zones additionally divide the remaining territory of the project consortium countries at NUTS 3 level (Slovakia, Czech Republic) or NUTS 2 in case of Poland. Foreign transport zones of the wider territory are broken down at NUTS 2 level for countries close to the area of interest up to NUTS 1 level, which according to the nomenclature of statistical territorial units represents macro-regions and states as a whole.

Table 1 Zonal structure of the TRITIA traffic model

Model territory	Country	Number of zones	NUTS
concerned	SK	13	LAU 1
	PL	64	LAU 1/NUTS 3
	CZ	13	LAU 1
wider	SK	7	NUTS 3
	PL	13	NUTS 2
	CZ	13	NUTS 3
	outside SK/PL/CZ	106	NUTS 2/NUTS 1
Total		**229**	**-**

2.2. Network model of the TRITIA territory – Infrastructure

The boundaries of traffic zones can generally be considered imaginary without the existence of natural barriers that functionally divide the territory. The traffic zone itself is represented by a point in this zone - a centroid, which aggregates all roads associated with one zone with its origin or end in that zone gravity centre. The traffic centre of gravity is integrated into the transport network and its primary task is to connect the traffic zone with the surrounding infrastructure. The connection of the traffic centre with the road network is provided by connectors. In the traffic model, connectors were defined separately for passenger and freight transport.

The design of the transport network of the TRITIA model was based on the principle that its scope should capture all significant changes in the traffic flows of the transport modes in question, which are potentially caused by the implementation of the analysed measures. As a multimodal macroscopic model of freight transport, significant existing infrastructure connections and junctions for road, rail and inland waterway transport have been included in the transport network. The network model was based on the rule that each transport mode within the traffic model is represented by a given infrastructure network.

The transport offer itself is represented by a transport network consisting of nodes and links. The nodes represent intersections - intersections of line transport constructions, or connection points of traffic zones. Intersections have following parameters:

- type of intersection (light controlled, non-controlled with / without priority, grade-separated);

- prohibited movements at intersections;

- time loss when crossing an intersection.

The transport network is defined in the traffic model by a set of basic parameters that directly affect the choice of use of the route. Mathematical operations thus simulate the decision-making of drivers, which route will they choose. The following parameters were entered when creating the transport network of the model:

Type of road - in the traffic model, it represents the category of road, for which the standardized parameters of the building structure are further developed in accordance with existing technical standards.

Capacity - expresses the maximum number of vehicles that will use the road for a given time unit. Communication capacity depends on weather conditions, technical solution, but also on transport conditions.

Transport system - in the traffic model, it represents vehicles by selected categories for the given transport mode.

Theoretical driving speed - the speed is defined for zero intensity and gradually decreasing as maximum capacity is reached, which has a direct impact on travel/transit time and the attractiveness of the route itself. This speed can be defined for individual transport systems based on different assumptions (e.g. maximum permitted speeds).

Length of section - is the distance between two nodes (intersections), or the place where the parameters of the road network change, e.g. speed reduction when entering the city.

Road resistance - represents the impact of the road capacity rate. The lower the capacity, the higher the resistance and the drivers simultaneously select a lower resistance route.

Number of lanes - is the number of lanes in one direction of the road. For each lane, the parameters are the same for the selected road type.

Permitted driving directions - for some sections, the route runs in one direction only and the transport system is then excluded in the opposite direction.

Table 2 Basic statistic data on the TRITIA transport network

Network statistics

Base network | PuT network

Number: 19	Filter	Total	Filtered	Selected	Active	Passive
Nodes	Not specified	27055	27055	27055	27055	0
Links	Not specified	62444	62444	62444	62444	0
Turns	Not specified	157026	157026	157026	157026	0
Zones	Not specified	229	229	229	229	0
Connectors	Not specified	1400	1400	1400	1400	0
Main nodes	Not specified	0	0	0	0	0
Main turns	Not specified	0	0	0	0	0
Main zones	Not specified	79	79	79	79	0
Territories	Not specified	2927	2927	2927	2927	0
OD pairs	Not specified	52441	52441	52441	52441	0
Main OD pairs	Not specified	6241	6241	6241	6241	0
Paths	Not specified	0	0	0	0	0
Sharing Stations	Not specified	0	0	0	0	0
Points of interest	Not specified	19106	19106	19106	19106	0
GIS objects	Not specified	0	0	0	0	0
Screenlines	Not specified	0	0	0	0	0
Count locations	Not specified	84	84	84	84	0
Detectors	Not specified	0	0	0	0	0
Toll systems	Not specified	0	0	0	0	0

Close

The complete transport infrastructure of the TRITIA model represents unification of traffic systems of individual transport modes in the following segmentation:

- road network;
- railway lines;
- inland waterway routes;
- intermodal transport terminals.

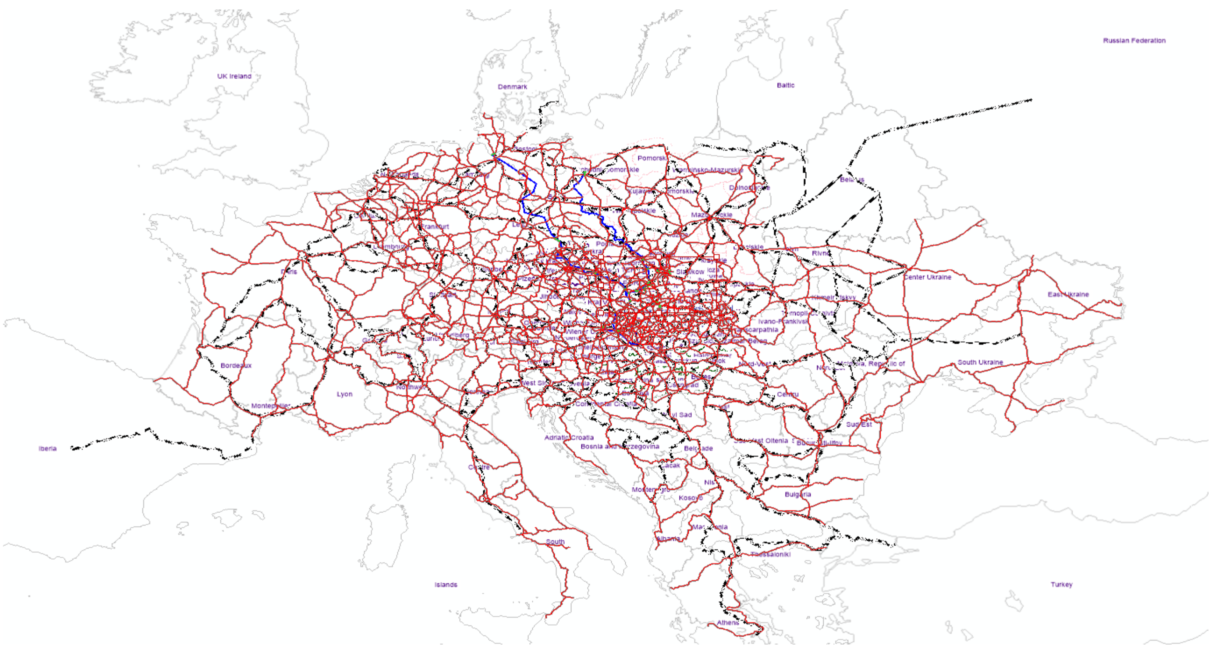

Figure 3 Transport infrastructure of the TRITIA traffic model

2.2.1. Transport infrastructure - zero scenario

Road transport infrastructure

The transport network of the TRITIA model consists of roads of higher traffic importance (motorways, expressways and I. class roads), on which the transit freight usually runs. The TRITIA territory of interest contains, besides these roads, also some road sections of II. and III. class (or local roads), which are relevant for the distribution and routing of the traffic load. Road infrastructure within the remote areas of the wider territory is limited to roads of international and national importance compared to the area of interest. The basis for the creation of the foreign road network was the OpenStreetMap map data.

For each type of connector, a set of technical parameters has been defined in terms of basic capacity, number of lanes/tracks and maximum speed. These parameters were determined in the area of interest on the basis of data from national road databases and other data sources, while the values of driving speeds were reduced on sections limited by road signs (municipalities, limited maximum speed) and on sections with increased ratio of length and air line length (bee-line). Road intersections were broken down by type into:

- intersections with right of way,
- intersections with traffic lights,
- connecting and turning at interchanges,
- roundabouts, and
- intersections with right of way from right.

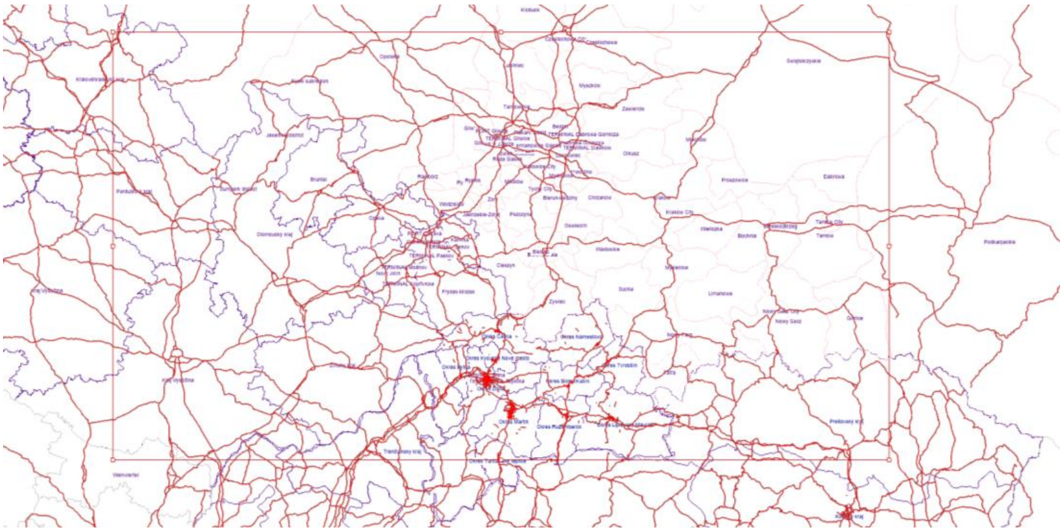

Figure 4 Road transport infrastructure in the TRITIA area of interest

Railway transport infrastructure

The model network of the railway transport includes the complete railway network in the territory of TRITIA, including operable lines currently not used for passenger transport. The railway network was divided according to the number of tracks and power supply system. In addition, a maximum line speed was specified for each section. The network also contained all stops, including the name and track number. The input to the creation of the railway network was a list of national points including coordinates and a list of railway sections.

The railway network outside the TRITIA concerned area of interest covers main routes and its density, as in the case of the road network, corresponds to the detail of zoning of the wider area, including all network lines crossing the boundary of the area of interest.

Each train line is determined by a list of stops and travelling times. Timetables were entered into the model using an interval based on an average working day. Delay in transfers was based on average line intervals. The railway lines connecting the TRITIA macro-region with the rest of Europe were entered into the model in a similar structure, i.e. by list of stops and travelling times. Other rail connections within external territory were entered by fictitious lines. The network was complemented by pedestrian links, which are running within the interconnections between individual modes of public traffic.

Each train line is determined by a list of stops and travelling times. Timetables were entered into the model using an interval based on an average working day. Delay in transfers was based on average train intervals. The railway lines connecting the TRITIA macro-region with the rest of Europe were entered into the model in a similar structure; i.e. through a list of stops and travelling times. Other railway connections within the external territory were entered by fictitious lines. The network was complemented by pedestrian links, which operate within the change relations between individual modes of public transport.

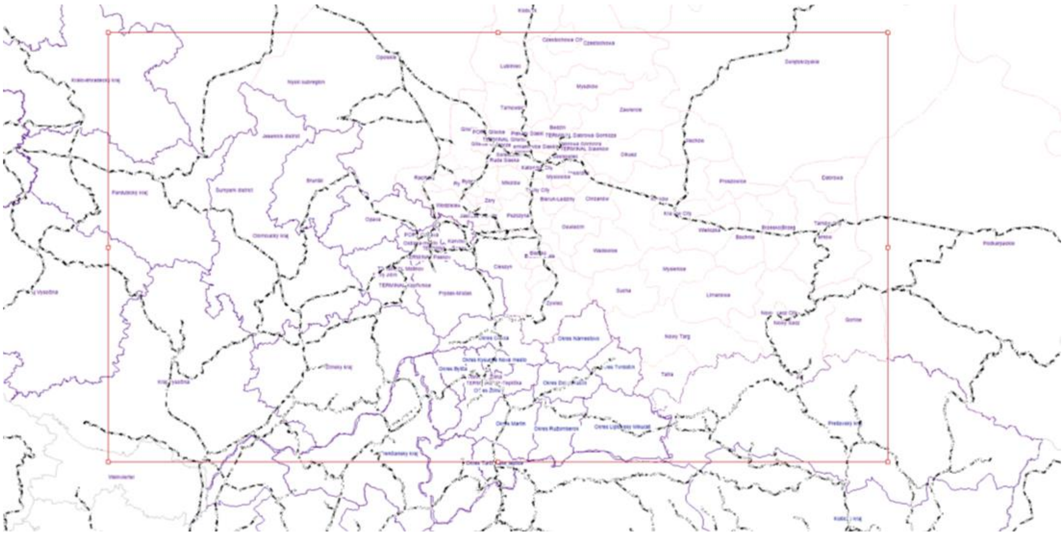

Figure 5 Railway transport infrastructure in the TRITIA area of interest

Inland waterway infrastructure

The inland waterway infrastructure of the TRITIA model is based on the latest revision of major European waterways and their parameters in the 3rd revision of the "Blue Book" issued by the UN - Economic Commission for Europe in 2017 as ECE/TRANS/SC.3/144/Rev.3. This updated document presents the technical characteristics of the European Inland Waterways and Ports of International Importance as defined by the AGN and provides a comparison of the minimum standards and parameters foreseen by the AGN.

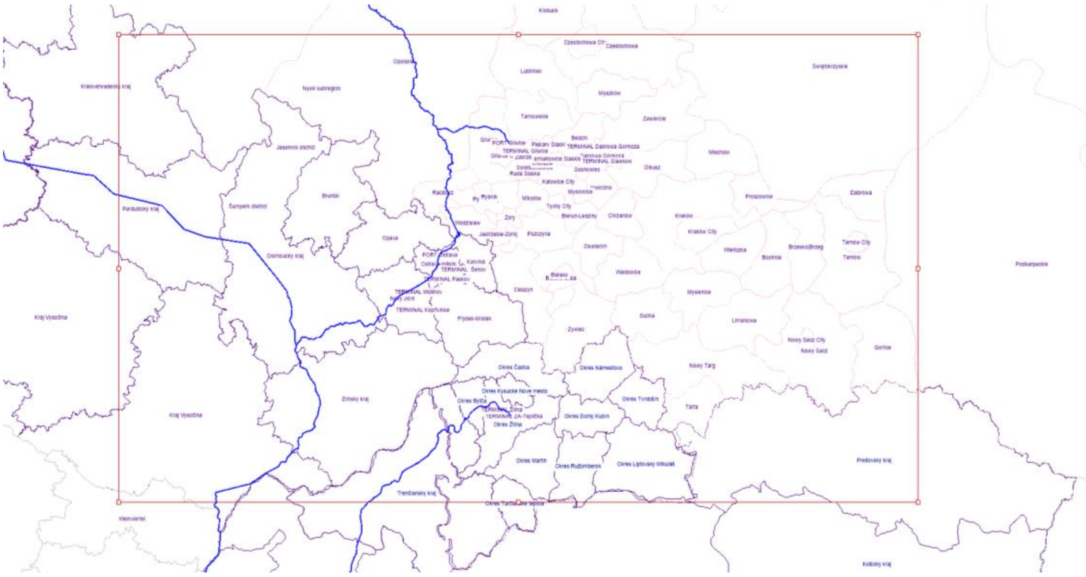

Figure 6 Inland waterway infrastructure in TRITIA area of interest

2.2.2. Development of transport infrastructure by 2030

Road infrastructure projects

The bypasses and new I. class roads in this part of Czech Republic are supposed to take transit traffic from Opava and other larger cities and thus relieve mainly the congested city centres. New bypasses will also make better connections to Opava, Krnov and Osoblažsko regions, which represent the western part of the Moravian-Silesian Region, one of the worst accessible areas in the country.

The I/11 road forms an important part of the long-distance road system of the Moravian-Silesian Region, also called the Silesian Cross, and connects the eastern and western parts of our region. It is the only link between the northern parts of Moravia and Silesia and Bohemia. The I/11 road is currently passing through villages and is arranged as a two-lane road - outside the section at the beginning of the treatment, which is arranged as a directionally divided four-lane road. The current solution does not meet the needs and importance of this road. The prospective traffic makes it impossible to ensure the required level of transport quality on a dual-lane road - traffic flows correspond to the required design category of the four-lane road. In the long term, the proposed I/11 route will be an important link between the completed D1 (D47) and D48 motorway in the Ostrava-Hrušov (D1) –Havířov (planned I/68), Havířov – Třanovice (I/11) and Třanovice (D48) – Bystřice – Hrádek – Jablunkov – Slovakia. A connection of the Karviná agglomeration to the superior traffic network will be implemented here.

The D48 motorway is a part of further development of the VI. Trans-European Corridor within the TEN-T (Trans-European Transport Network). In the future, it will replace the existing road I/48, which is an important connection especially for long-distance transport to Poland via the Cottbus border crossing. However, in addition to the international aspects of building of transport networks as part of the Trans-European Network, there is also a national reason to develop the transport network. The existing road I/48 Bělotín – Frýdek-Místek – Český Těšín –state border with Poland is included in selected road network, along which the European road E462 is running. At the same time it forms an important capacity link of industrial areas in the foothills of Beskydy Mountains, especially the towns of Nový Jičín, Příbor, Kopřivnice, Frýdek-Místek, Český Těšín and Třinec area. However, the technical condition and width parameters of the existing I/48 are no longer suitable for these traffic requirements.

The expressway S1 is located in the 4th corridor of the Trans-European Transport Network connecting the countries of the Baltic Sea basin with the countries of Southern Europe and running in priority axis TEN-T No. 25 "road axis Gdansk-Brno / Bratislava-Vienna". The extension of the S1 expressway to the south, outside of Poland, is the Slovak motorway D3 between Žilina and Skalité. The completion of investments along this motorway will make the S1 route a safe and comfortable road and express connection from the state border in Zwardoń to the airport in Pyrzowice and the A1 motorway.

The construction of the A1 motorway is an investment of European significance. The need to build it results from the need to create a transit road system in the territory of the country. The newly built motorway will be a significant factor relevant for the economic recovery due to the possibilities of increasing demand for domestic services and goods, and in the field of construction investments, it will contribute to the development of contractors as well as other economic entities providing services within the construction. This will improve the acoustic climate, road safety and reduce air, soil and water pollution in areas near roads that will be relieved by the highway. The use of modern materials and technologies, including high-quality pavements, drainage systems, road safety systems and effective environmental protection equipment (noise protection, rainwater pretreatment devices, animal crossings, planting of greenery, etc.) will contribute to reducing the motorway nuisance environment and will improve safety conditions for both pedestrians and car traffic.

The main purposes of the investment on expressway S1, motorway A1 and other I. class roads are:

- adaptation of road infrastructure to European standards,
- removal of transit traffic outside the urban development area,
- creating a safe section of the express road ensuring a high level of safety and comfort for transit traffic as well as local traffic (source and destination),
- shortening travel time,
- fuel savings,
- this will contribute to the improvement of car traffic safety conditions (collision-free intersections, full road equipment related to its functioning and environmental protection), improvement of road connections and removal of transit traffic from towns and cities,
- the implementation of the expressway will be a significant factor conducive to economic recovery due to the possibilities of increasing demand for domestic services and goods, and in the field of construction investments, it will contribute to the development of contractors as well as other economic entities servicing construction,
- shortening the travel time of emergency services to places of road accidents, which will automatically translate into a reduction in the number of fatalities, thus improving safety on polish express roads in general.

The priority interest of the Slovak Republic is the construction of those sections of motorways and expressways, the absence of which is negatively reflected in the areas of economy, environment and which hinder the mobility of the population. New sections of motorways and expressways will be built in accordance with the applicable environmental and technical requirements in order to reduce the negative impacts of transport, with an emphasis on improving air quality.

Main objective is to remove key bottlenecks on the TEN-T network, especially in the section Žilina - Liptovský Mikuláš and Žilina - border SK/CZ and SK/PL, and completion of expressways R1 and R3.

Table 3 List of planned road infrastructure projects in Poland, Czech Republic and Slovakia by 2030

Country	Road No.	Name	Project type	1st year of the operation
CZ	I/11	Opava - north bypass, west part	new I. class road bypass	2023
CZ	I/11	Opava - north bypass, east part	new I. class road bypass	2019
CZ	I/11	Ostrava – extended Rudná, bypass	new motorway	2020
CZ	I/11	Havířov - Třanovice	new motorway	2032
CZ	I/45	Bruntál - east bypass, 1st phase	new I. class road bypass	2026
CZ	I/45	Nové Heřminovy-Zátor - bypass, 1st phase	new I. class road bypass	2026
CZ	D48	Bělotín – Rybí, highway	upgrade of existing motorway	2023
CZ	D48	Rybí - Rychaltice, highway	upgrade of existing motorway	2020
CZ	D48	Frýdek - Místek, highway bypass	new highway bypass	2022
CZ	D56	Frýdek - Místek, connecting to D48	new highway bypass	2022
CZ	I/57	Krnov – north east bypass	new I. class road bypass	2021
CZ	I/58	Příbor - Skotnice	new I. class road	2020
CZ	I/58	Mošnov - bypass	new I. class road bypass	2024
CZ	I/58	Frenštát pod Radhoštěm - Vlčovice	new I. class road bypass	2031
CZ	I/67	Karviná bypass	new I. class road bypass	2022
CZ	I/68	Třanovice - Nebory	new motorway	2022
PL	GP40	Bypass Kędzierzyna Koźla nr 40 (2 stages)	new I. class road bypass	2022
PL	S11	Expressway S11 Kępno - A1 (excluding the Olesno bypass)	new expressway	n/a
PL	GP46	Bypass Niemodlina within DK 46	new I. class road	2021
PL	S1	Expressway S1 "Kosztowy II" from Mysłowice to "Suchy Potok" in Bielsko-Biała	new expressway	2023
PL	A1	Motorway A1 Częstochowy – Tuszyn	new motorway	2022
PL	S1	Expressway S1 (former S69) Przybędza – Milówka (bypass Węgierska Górka)	new expressway	2023
PL	S1	Reconstruction of national road No. 1 to the parameters of the express road on the section Podwarpie – Dąbrowa Górnicza	new expressway	n/a
PL	S11	Bypass Kępno within S11, stage II	new expressway	2021
PL	GP78	Bypass Poręba and Zawiercie DK 78	new I. class road	2023
PL	GP78	Bypass Poręba and Zawiercie DK 78	new I. class road	2021
PL	S11	Expressway S11 Kępno-A1, section bypass Tarnowska Góra	new expressway	n/a
PL	GP45	Bypass Praszka	new I. class road	2022
PL	S11	Bypass Olesna within DK 11	new expressway	2022
PL	GP1	Section DK1 from DW 933 and local communal road in Pszczynia	new I. class road	n/a
PL	S11	Expressway S11 Kępno-A1, (without bypass Tarnowska Góra)	new expressway	n/a
PL	S1	Expressway S1 Pyrzowice-Podwarpie (III. stage without section "Pyrzowice" - "Lotnisko")	new expressway	n/a
PL	GP39	Bypass Brzeg in road section nr. 39	new I. class road	n/a

Country	Road No.	Name	Project type	1st year of the operation
PL	A1	A1 Tuszyn - Pyrzowice, section. Pyrzowice – end of bypass Częstochowa	new motorway	2019
PL	S1	I. class road S1 from "Kosztowy II" in Mysłowice to "Suchy Potok" in Bielsko-Biała	new expressway	2023
PL	S1	I. class road S1 from "Kosztowy II" in Mysłowice to "Suchy Potok" in Bielsko-Biała	new expressway	2023
PL	GP44	I. class road S1 from "Kosztowy II" in Mysłowice to "Suchy Potok" in Bielsko-Biała	new I. class road	n/a
SK	R1	Banská Bystrica – Sl. Ľupča	New expressway	2023
SK	R1	Sl. Ľupča – Korytnica	New expressway	2027
SK	R1	Korytnica – Liptovská Osada -Ružomberok, south	New expressway	2028
SK	R1	Ružomberok section, I/18 – D1	New expressway	2026
SK	R3	Tvrdošín – Nižná nad Oravou	New expressway	2021
SK	R3	Nižná nad Oravou – Dlhá nad Oravou	New expressway	2026
SK	R3	Dlhá nad Oravou – Sedliacka Dubová	New expressway	2026
SK	D1	Hubová – Ivachnová	New motorway	2022
SK	D1	Ružomberok, juh – Križovatka I/18	New motorway	2025
SK	D1	Hričovské Podhradie – Lietavská Lúčka	New motorway	2020
SK	D1	Lietavská Lúčka – Dubná Skala	New motorway	2023
SK	D1	Feeder Lietavská Lúčka – Žilina II. Stage	New motorway	2020
SK	D1	Turany – Hubová	New motorway	2030
SK	D3	Žilina, Brodno – Kysucké Nové Mesto	New motorway	2030
SK	D3	Kysucké Nové Mesto – Oščadnica	New motorway	2030
SK	D3	Oščadnica – Čadca, _Bukov – II. Profile	New motorway	2030

Railway infrastructure projects

The purpose of the reconstruction of railway tracks and stations is to eliminate track speed drops, increase traffic safety, ensure reliable operation, ensure the necessary parameters for freight transport, ensure barrier-free access for persons with reduced mobility, improve the technical condition of the track, ensure interoperability parameters and ensure compliance with applicable legislation.

Projects in the Czech Republic include the redevelopment of the railway substructure, electrification of tracks, the restoration of the railway superstructure, the construction of platforms, including island platforms with non-level barrier-free access. Selected existing bridge structures and culverts will be reconstructed to the required parameters, railway technological ground structures, and roofing of platforms will be modernized or newly built. Modernization of security, communication and heavy-current equipment is proposed. New cabling in the stations will be placed in the ducts as a priority. The construction part also includes reconstruction of traction lines and rails, electric heating of switches, relaying, modifications and connections of cable lines, lighting. Relocation and protection of the utilities concerned are proposed to the extent necessary.

A very important project in this area is the planned construction of a high-speed railway line. The objective is to divert long-distance passenger traffic to a new line and thus create new capacity for freight trains on an existing network.

Projects in Poland vary from construction of a completely new railway to the reconstruction of an operated railway, where the aim of the component is to stop degradation of the railway infrastructure, including transport corridors, also in areas along railway lines, for which a decision has already been issued to eliminate them. The government's Railway Plus program is to be implemented in 21 places in the country. These are big towns, where trains do not go today. The project involves the implementation of railway connections to towns with more than 10,000 inhabitants, where passenger trains used to stop or where they have never been before.

Projects include replacing the track superstructure, and replacing and reinforcing of the substructure, along with modernisation and construction of engineering structures such as bridges and viaducts. Stations and passenger stops along the route will be adapted to the needs of people with reduced mobility.

The scheme includes construction of new signalling controls and work on traction networks – including construction and modernisation of the traction network subsystems. The upgrade paves the way for future implementation of the European Rail Traffic Management System (ERTMS).

Overall, the project aims to reduce transit times for cargo transport. In addition, transit times for interregional and regional railway transport should be reduced as well. It should therefore improve the competitiveness of railway transport compared to other modes of transport.

The project also serves to improve railway connections in the EU's Trans-European Transport Network (TEN-T). A total of 178.8 km of lines covered by this project is in the TEN-T network, including railway line No. 131, which forms a part of the TEN-T core network. Investments in the

TEN-T aim to improve transport infrastructure across Europe, so that people and goods can move more easily into and between Member States.

In Slovakia, there is a planned reconstruction of the railway node in Žilina and transition to 25 kV system in section Varín – Poprad and Krásno nad Kysucou - Čadca. The project of the modernization of the Žilina railway node and the adjacent section of the Žilina - Varín - Strečno railway line is currently being implemented. The Žilina railway node is the junction of two branches of international railway corridors, where the project will include reconstruction of rails and switches, railway bridges, platforms, traction lines with change of power supply from direct to alternating current, railway signalling and safety equipment. The removal of level crossings and their replacement with grade-separated crossings is being done as well.

The project addresses the deployment of GSM-R on the 329,374 km Varín - Košice - Čierna nad Tisou (section Varín - Poprad) railway line, which is located on the corridor of the Rhine - Danube main network (CNC). It involves the preparation of detailed design and construction work related to

GSM-R deployment. It includes 4 activities - preparatory tasks, supervision of construction work, construction work and project management. GSM-R will be used for voice and data communication and will allow future operation of a section with ETCS level 2 and above. Part of the modernization of corridor lines is also the change of traction system from direct current traction system 3 kV to AC 25 kV, 50 Hz according to government decision from previous years, which should gradually unify the traction system used for ŽSR railways. Advantages of AC line system: simpler traction line design, greater distances between supply points, elimination of reverse traction currents, electricity savings - reduced operating costs.

Table 4 List of planned railway infrastructure projects in Poland, Czech Republic and Slovakia by 2030

Country	Name of project	Location	Project type	1st year of the operation
CZ	Modernization of Ostrava railway junction	Town Ostrava with surrounding area	Modernisation and capacity utilisation of the railway junction Ostrava hl.n. and adjacent track sections, triple track of section Ostrava-Svinov-Ostrava hl.n. (Frýdlantské nádraží), fourth track of section -Ostrava Mar. Hory stop station – Ostrava hl.n., construction of rearrangement,	2034

Country	Name of project	Location	Project type	1st year of the operation
			track section Ostrava (Frýdlantské nádraží) – Ostrava střed stop station	
CZ	Polom – Suchdol n. O., BC	Section Polom – Suchdol n. O., km 221,028 – 233,553; odbočka Vrážné, (km 228,988 – 229,188)	Reconstruction of 12,525 km of track, new railway turning Vražné (0,200 km)	2024
CZ	Dětmarovice – Petrovice u K., crossing border PR, BC	Section Dětmarovice – Petrovice u K	Reconstruction of 9,8 km of track and railway station Petrovice u. Karviné and Dětmarovice, increase in track speed to 100 km/h	2023
CZ	Rekonstrukce žst. Petrovice u Karviné	Border station Petrovice u Karviné	track electrification, new safety device, displacement of Dětmarovice head by 0,176 km, extension of track for freight trains 740 m, new platform	2023
CZ	HSL Moravská brána (new Hight speed railway line)	Section Přerov – Ostrava	diverting long-distance passenger traffic to a new line and thus creating new capacity for freight trains on an existing network	2026, 2029
CZ	Optimalization section line Český Těšín (outside) - Albrechtice u Českého Těšína (including)	Section Český Těšín (outside) - Albrechtice u Českého Těšína (including)	increase speed from 80 km/h to 100 -145 km/h	2023
CZ	Optimalizace traťového úseku Ostrava-Kunčice (mimo) - Ostrava-Svinov/Polanka nad Odrou	Section Ostrava-Kunčice - Ostrava-Svinov/Polanka n.O.	track reconstruction in the section and station Ostrava-Vítkovice, increase speed to 120 km/h	n/a
CZ	Optimalization and electrification of railway line Ostrava-Kunčice - Frýdek-Místek	Section Ostrava-Kunčice - Frýdek-Místek	double-track (13,797 km) and electrification of existing tracks in the Vratimov - Frýdek-Místek section, extension of rails at freight train stations 740 m long, increase speed to 120 km/h	2024
CZ	Rekonstruction of head of station Bohumín-Vrbice (for direction Chałupki) and line track in the section Bohumín Vrbice (outside) - Chałupki	Station Bohumín-Vrbice, Section Bohumín Vrbice - Chałupki	track reconstruction in the section Bohumín-Vrbice (outside) – border crossing PR, new railway turning Bohumín-Pudlov	2023
CZ	track line interconnection - 305C Bohumín-Vrbice - Chałupki and 305A Bohumín - Chałupki (railway turning Bohumín - Pudlov)	Section Bohumín-Vrbice - Chałupki and Bohumín - Chałupki	track line interconnection (305C and 305A) by switches, renewal of the Bohumín - Pudlov railway turning	n/a
CZ	new connecting line (clutch) between, line 305B and 306A in direction Přerov - Mošnov, and	line 305B (near Studénka station), line 306A (near Sedlnice-	new connecting line (clutch) between line 305B (near Studénka station) and 306A (Sedlnice - Bartošovice station), Sedlnice-Bartošovice station - new track, Sedlnice - station - new track	n/a

Country	Name of project	Location	Project type	1st year of the operation
	capacity increase of the Sedlnice-Bartošovice and Sedlnice station	Bartošovice station)		
PL	Reconstruction of the railway connection to Jastrzębie Zdrój - Wodzisław Śl.	Silesia Voivodeship	Modernization of infrastructure	2024
PL	Reconstruction of the Gogolin - Krapkowice - Prudnik connection	Opole Voivodeship	Modernization of infrastructure	2024
PL	Reconstruction of the railway line 171	Silesia Voivodeship (Dąbrowa Górnicza Towarowa z posterunkiem Panewnik (between Katowice Muchowiec and Ruda Kochłowice))	Works on the south-eastern GOP beltway along with adjacent sections	2022
PL	Works on the C-E 65 railway line on section Chorzów Batory - Tarnowskie Góry - Karsznice - Inowrocław - Bydgoszcz - Maksymilianowo	Silesia Voivodeship	Program Operacyjny Infrastruktura i Środowisko 2014-2020 (POIiŚ)	2023
PL	Revitalization of railway lines No. 694/157/190/191 Bronów - Bieniowiec - Skoczów - Goleszów - Cieszyn / Wisła, Głębce	Cieszyn district	Modernization of infrastructure	2021
SK	Žilina node	Town Žilina with surrounding area	Infrastructural, modernization with new line signalling and safety (ETCS 2 with GSMR)) and transition to 25kV traction system	2022
SK	Krásno nad Kysucou - Čadca (border), section Čadca - Krásno nad Kysucou	Čadca region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2026
SK	Poprad - Východná	Poprad and Liptov region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2029
SK	Východná - Liptovský Hrádok	Liptov region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2027
SK	Liptovský Hrádok - Liptovský Mikuláš	Liptov region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2024
SK	Liptovský Mikuláš - Ružomberok	Liptov region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2026
SK	Ružomberok - Turany	Liptov and Turiec region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2030

Country	Name of project	Location	Project type	1st year of the operation
SK	Turany – Vrútky	Turiec region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2026
SK	Vrútky – Varín	Turiec and Žilina region	Modernization of infrastructure, line signalling and safety and transition to 25kV traction system	2029

Inland waterway infrastructure projects

The Gliwicki Channel, an important inland waterway with a transport function, undergoes comprehensive modernization works. Under the implemented project, ports will be renovated, including new bridges and water and electricity intake points will be built for units using the Gliwice Canal. Control room buildings, both in the underground and above-ground part, as well as mechanical and electrical devices driving the gate will undergo renovation. Comprehensive works will be carried out in the engine room buildings. After the modernization is completed, the objects lighting will be replaced with new energy-saving LED lighting. During the modernization a new circulation channel will be created, economical sluicing will be possible. The project also includes new social buildings already used by the lock service, roads and pavements on the premises.

The investment being implemented is the second stage of the project "Modernization of the Odra locks on the section managed by the Regional Water Management Board in Gliwice - adaptation to class III of the waterway". In the first stage, the Kłodnica and Rudziniec locks were renovated, and the renovation of the lock in Łabędy and Dzierżno is coming to an end. The comprehensive modernization of the six locks of the Gliwice Canal will be completed in the first quarter of 2021, closing the next stage of the project. Thanks to, among others, adjustment of banks, improvement of the fairway condition and supplementation of infrastructure related to water transport, the navigation conditions on the Canal will improve.

Table 5 List of planned inland waterway infrastructure projects in Poland, and Czech Republic by 2030

Country	Name of project	Location	Project type	1st year of the operation
CZ	Water corridor Dunaj-Odra-Labe	Czech Republic	Study	Study in verification process, no confirmed schedule for next project steps and construction
PL	Support for the inland waterway development policy in the light of the new Water Law	Oder Waterway	The project is financed from the European Commission's Structural Reform Support Programme.	2018-2021
PL	The research and technical concept for the modernization of the canal section of the Oder Waterway to the navigability class Va	Oder Waterway	Technical elaboration prepared by the Szczecin and Świnoujście Seaports Authority.	2018-2019
PL	Research guidelines for the design of water degrees on the Odra flowing freely, planned in order to obtain a navigable waterway of Va	Oder Waterway	Technical elaboration prepared by the Szczecin and Świnoujście Seaports Authority.	2018-2019
PL	Opole – Kedzierzyn Kozle	Poland	Modernisation Va	2020-2025
PL	Kedzierzyn-Kozle - Waterway Node (ODW-DOL)	Poland	Construction Va (km 117,000 – km 159,800) 42,8 km	2025-2030

Country	Name of project	Location	Project type	1st year of the operation
PL	Waterway Node – Lock Bukow (incl. reservoir Raciborz Dolny)	Poland	Construction Va (km 103,000 – km 117,000) 14 km	2025-2030
PL	Lock Bukow – cross border PL/CZ	Poland	Construction Va (km 103,000 – km 98,300) 4,7 km	2025-2030
PL	Kedzierzyn Kozle - Gliwice	Poland	Modernization, Va	2020-2030

Intermodal terminals

The Moravian-Silesian Region, Statutory City of Ostrava, the Railway Administration Authority (SŽDC), Concens Investments and Antwerp Port Authority will cooperate in developing a new container terminal in the strategic Mošnov industrial zone. On September 18, 2019 they have signed a Memorandum of Understanding to start this new project, called the Mošnov Multimodal Transport Terminal.

Amongst others, the new terminal will link the Moravian-Silesian Region with one of Europe’s largest ports Antwerp. As a result, a substantial share of cargo is expected to make the modal shift from road to rail.

Table 6 List of planned intermodal terminals in Poland, Czech Republic and Slovakia by 2030

Country	ID	Transport modes	Location	Operator	Public/Private	Manipulation capacity (TEU) per day	Stacking capacity (TEU)
CZ	TIP 4	Road/rail	Mošnov	DB Schenker	Public	1 600	20 000 m^2 (empty containers)

3. Model of TRITIA multimodal potential

The originally proposed process of developing a four-stage model with a given structure of commodity groups for freight transport was modified to a model quantifying the potential for shifting part of the traffic load from road freight transport to other modes due to the absence of relevant data inputs characterizing transport demand. The lack of input data is mainly due to the minimum response from shippers and carriers in the statistical survey of goods flows, as well as incomplete documents characterizing the routing and volume of freight transported by the railway. As a result, it was not possible to quantify the volume and routing of transport flows for railway and inland waterway transport in the TRITIA traffic model. The developers thus proceeded to modify the methodological procedure while maintaining the original purpose and objectives of the traffic model in accordance with the available data inputs.

3.1. Traffic model of current state /2020/

The determination of the modal shift potential was based on the general assumption that long-distance sessions are particularly suitable for railway and inland waterway transport. From the point of view of the TRITIA territory, it is therefore a long-distance transit traffic, which passes through that territory as well as a destination / origin transport whose beginning or end is located in that area. In this context, the role of traffic modelling was to obtain an output in the form of a calibrated unimodal road traffic model, from which it would be possible to derive precisely these types of roads for the subsequent redistribution of traffic loads to other modes of transport. The relevance of this approach is also proved by the fact that it was also used in other freight traffic models that corresponded to the TRITIA region in terms of their area of interest. The simplified approach to modelling transport relations within road freight transport through the allocation of traffic to the network was based on the basic assumptions of the modelled relations in the territory of interest, which allow the application of this procedure. These are mainly the following common characteristics:

- suitability for projects, where no significant change in traffic flow on the transport network is expected, but only a shift of a part of the traffic from one mode (mode) to a parallel mode (mode);
- a basis in analogous approaches, where actual data on traffic and directions are obtained by traffic engineering surveys and by taking outputs from other models.

The direct demand model method aggregates the first three stages of traffic modelling in the form of quantifying the volume of production / attractiveness of a given zone, the distribution of trips between these zones, and the actual allocation of traffic to road infrastructure. For the creation of the basic demand matrix data from the results of the questionnaire traffic survey on the direction of road freight vehicles at the following border crossings were used.

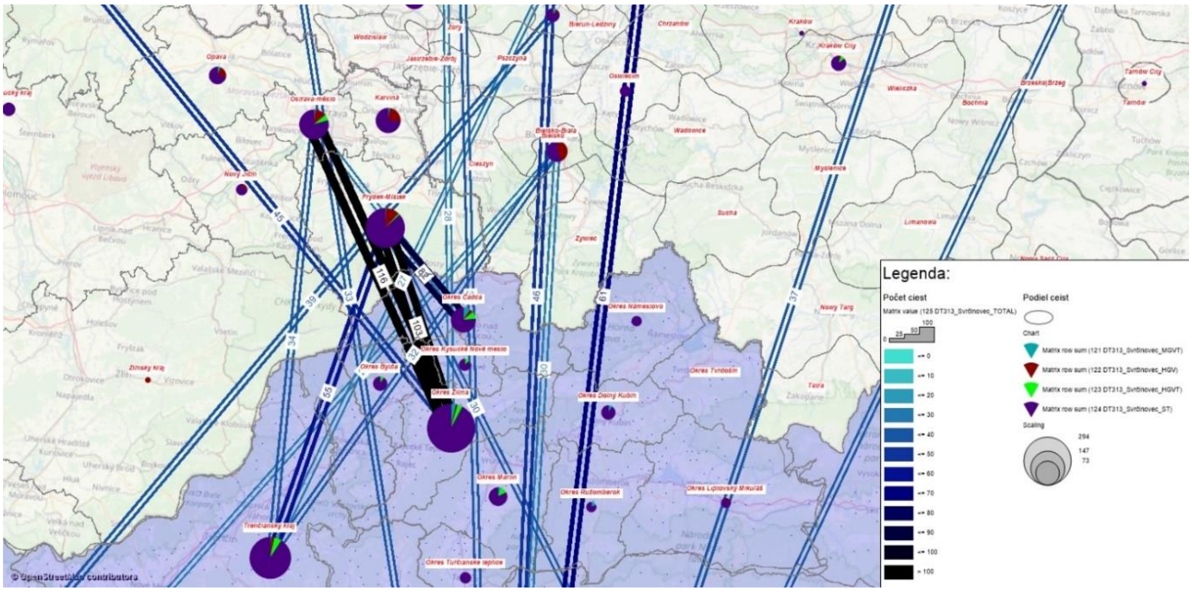

Figure 7 Example of transport relations passing through the Svrčinovec - Mosty u Jablunkova border crossing

Since the values of the primary demand matrix are based on the recorded road traffic frequency of freight vehicles between the zones of the traffic model, the conversion of the volume of goods into means of transport on individual sessions was not necessary as part of the network assignment.

Several standardized algorithms are available for the assignment of traffic on the road network that can be applied on the road transport mode. The most frequently used approaches include:

- "all or nothing",
- gradual (incremental) assignment,
- equilibrium assignment.

The "all or nothing" assignment allocates the entire generated traffic between two zones on one route. The incremental assignment allocates the total load in a given segment of traffic in several steps, looking for the route with the lowest impedance (resistance) for each. Equilibrium assignment allocates routes by multiple iterations so that the impedance on all alternative routes is balanced. This will result in a more credible allocation to all alternative routes, but at the cost of a more demanding and longer-lasting process.

The basis of all algorithms is to find one or more alternative most beneficial routes between the origin and destination of allocated roads. The advantage is assessed on the basis of the calculation of the total impedance (resistance) of the route. Impedance is usually understood as the real time of transit through individual infrastructure sections, including delays due to their capacity.

$$T_{real}=t_0\times f_{(Sat)} \qquad [1]$$

, where:

T_{real} real transit time in a given section (turn) with assigned traffic

t_0 basic transit time in a given section (turn) without traffic

$f_{(Sat)}$ resistance function of the so-called limited capacity, which extends transit time depending on the achieved degree of saturation of traffic capacity in a given section (turn)

For practical reasons (a more realistic assignment than the 'all or nothing' method and a shorter calculation time), the incremental allocation method for freight was used in the traffic model, divided into individual iterative steps.

The actual assignment of trucks to the road network of the traffic model was based on the primary demand matrix, while the calculation apparatus took into account the resistance of the route on individual transport relations. This procedure resulted in the resulting load matrix exhibiting some degree of difference from the original demand matrix.

In order to take into account the capacity constraints of the modelled road network, a model of transport relations for individual car transport (passenger vehicles) was developed through conventional traffic modelling procedures. By loading the network with this component of the transport stream, the operational conditions for it were streamlined and the simulation of the reallocation of transport reached a higher level of reality.

3.1.1. Calibration and validation

The calibration is the process of refining data and constants based on measured or accurately obtained inputs relevant to modelling. In a first step, the infrastructure load was calibrated based on the latest national censuses in Poland (2015), the Czech Republic (2016) and the Slovak Republic (2015). In the second calibration, data was selected on selected profiles where profile traffic surveys were performed. After recalculating the recorded road traffic data to AADT, it was necessary to identify a subset of trucks on long-haul sessions that fall within the set of multimodal transfer potential. In this respect, the categories of trucks, which allow the transport of a 40 foot ISO container (road haulage vehicles with a maximum permissible gross weight exceeding 3 500 kg) were considered relevant. The identification of this subset of vehicles on the overall captured traffic flow within the ASD census opinion was carried out in the form of an expert estimate based on an analysis of the tracing of the recorded movement of trucks in questionnaire traffic surveys at border crossings.

In the traffic model, the T-FlowFuzzy calculation module PTV Visum was used to calibrate the measured data. It is directly intended for calibration. This calculation module uses multiple iterative calculations to calibrate, thus approaching the desired real values. Individual transport modes were calibrated separately.

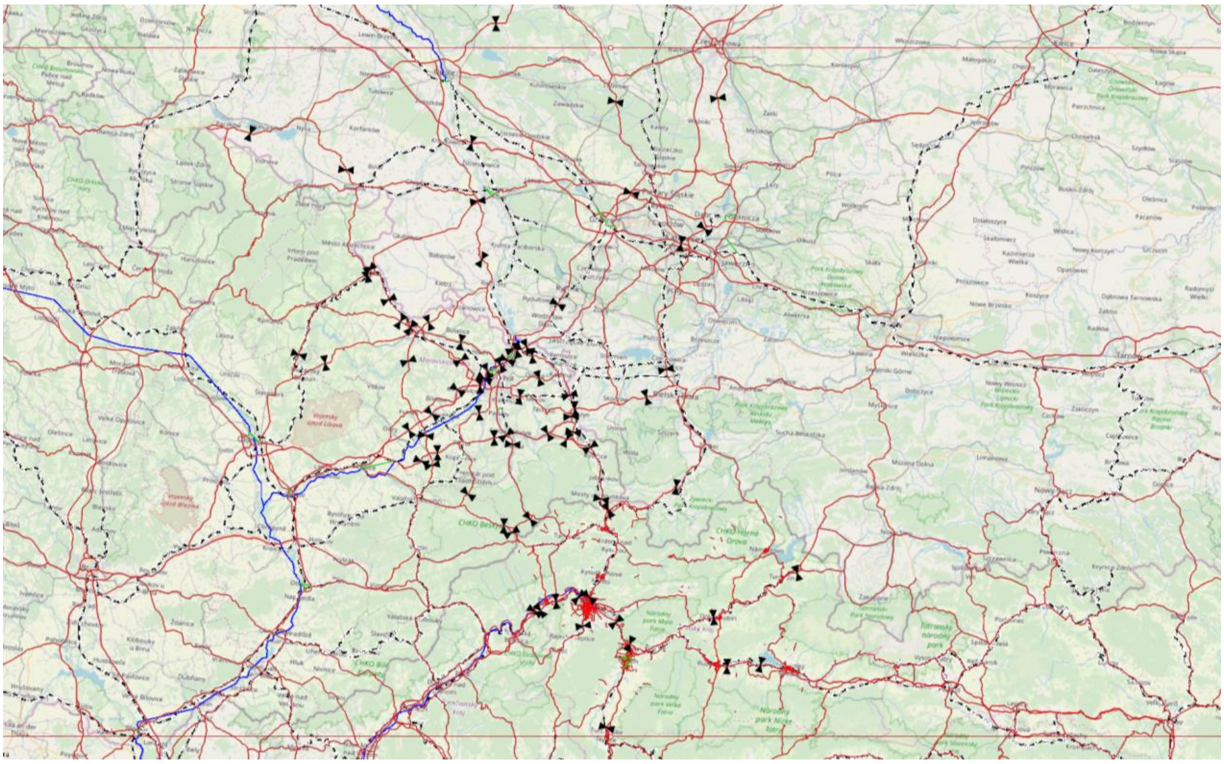

Figure 8 Localization of calibration and validation profiles of TRITIA model

The data obtained by traffic surveys and modelled values in the traffic model or data from national traffic censuses can be compared with each other to obtain the deviation values for individual sections of the transport infrastructure. Statistical tools are used to define the match of modelled and real measured values. The most commonly used statistical tool is the GEH parameter. This parameter is used to verify the distribution of random variables and is also used for the good conformity test. The statistics include absolute and relative error, so it is used when comparing the match of real measured values with the modelled values in the traffic model. The following mathematical formula was used to calculate the GEH parameter:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}} \qquad [2]$$

, where:

M traffic volume in the traffic model

C traffic volume obtained by real measurement (traffic survey)

Table 7 Values of the GEH parameter within the calibration of the current state /2020/ of TRITIA model

No.	ATC	NTC	Model	GEH	Census site localization /GPS/
1	21 916	8 992	1 458	**2,786389**	50.248882,18.90812
2	13 486	8 674	278	**0,694102**	50.480599,18.122100
3	8 892	0	1 048	**7,202016**	50.125656,19.023316
4	7 390	10 752	1 016	**5,908744**	50.624815,19.143506
5	6 506	0	22	**9,294382**	50.411035,19.220954
6	6 474	5 450	3 270	**0,820294**	49.80201, 18.19089

No.	ATC	NTC	Model	GEH	Census site localization /GPS/
7	6 232	3 850	913	**0,995604**	49.22158, 18.58498
8	6 216	4 650	4 491	**9,747676**	49.88259, 18.30492
9	5 580	4 452	3 270	**1,915509**	49.77791, 18.09794
10	5 552	5 300	1 161	**2,116038**	49.887809,18.996841
11	5 536	4 782	3 270	**1,269008**	49.7031947, 17.9866489
12	5 512	4 534	2 390	**5,476934**	49.68274, 17.94014
13	5 266	4 658	3 839	**3,518055**	49.82449, 18.21405
14	4 680	0	3 296	**0,482032**	49.954204,18.468105
15	4 432	2 812	1 087	**0,880308**	49.67417, 18.33001
16	3 828	3 660	845	**3,974194**	49.76305, 18.61222
17	3 688	2 552	264	**7,522268**	49.09163, 19.51139
18	3 648	3 682	2 595	**11,75489**	49.241624, 18.737950
19	2 984	2 750	2 455	**6,338304**	49.51616, 18.75635
20	2 894	2 032	255	**2,941618**	49.1212, 18.93206
21	2 776	1 844	1 539	**5,56446**	50.371692,18.780032
22	2 428	2 048	255	**1,100693**	49.110849, 19.226195
23	2 302	2 626	99	**2,182316**	49.66355, 18.27981
24	2 294	3 306	1 116	**1,28959**	49.6955058, 18.6128053
25	1 492	1 014	426	**1,45961**	49.230996, 19.322699
26	1 354	3 332	133	**0,299315**	49.60759, 18.02741
27	1 352	1 578	301	**2,58141**	49.240804, 18.693728
28	1 296	1 270	108	**2,765044**	49.66027, 18.35666
29	1 182	1 534	188	**1,160207**	49.341342, 19.567565
30	1 042	1 108	24	**6,315389**	49.85193, 17.88183
31	1 040	816	19	**7,810541**	50.12237, 17.63902
32	1 028	650	188	**1,733729**	49.35684, 19.62195
33	1 028	1 256	449	**2,586828**	49.78811, 18.59425
34	976	1 036	23	**1,647195**	49.99515, 17.81138
35	974	854	301	**0,703996**	49.40224, 18.38608
36	964	1 010	375	**6,693273**	49.192854, 19.304452
37	944	1 028	375	**7,191256**	49.109765, 19.298816
38	940	1 090	339	**4,566545**	48.9774904, 19.2747483
39	890	714	432	**0,855604**	50.08474, 17.66827
40	874	890	15	**0,755748**	49.187928, 19.190402
41	870	888	449	**0,950937**	49.89993, 18.40986
42	806	892	339	**1,282799**	48.876023, 19.2376463
43	798	1 904	7	**3,684853**	49.95117, 17.87286

No.	ATC	NTC	Model	GEH	Census site localization /GPS/
44	494	698	42	**1,48157**	49.49671, 18.18161
45	466	700	236	**0,2979**	49.92194, 18.09611
46	310	576	108	**2,15363**	49.44696, 18.46248

The aggregate average value of GEH reached 3.364191.

Validation is a process of verifying calibrated values that is separate from the process of calibrating the traffic model. Several validation criteria can be used for validation, such as transit time, speed, traffic flow and others. Calibration and validation data are very similar because they reflect the performance, spatial distribution of transport relations and their structure. When validating the current state for 2020, data from a set of profiles was applied, on which a traffic survey by means of ATCs (so-called validation ATCs) was performed.

After performing several calibration calculations, the validation ATC values were compared with the values obtained by the traffic model. If the GEH parameter was less than five, it can be argued that the traffic model is calibrated correctly. If this parameter is higher, it is necessary to refine the data modelled in the traffic model by further calibration and iterative calculations. The inputs for assessing the correctness of the modelled and subsequently scaled values within the model validation process were obtained from the processed outputs of the profile traffic survey at the road infrastructure points shown in the following figure.

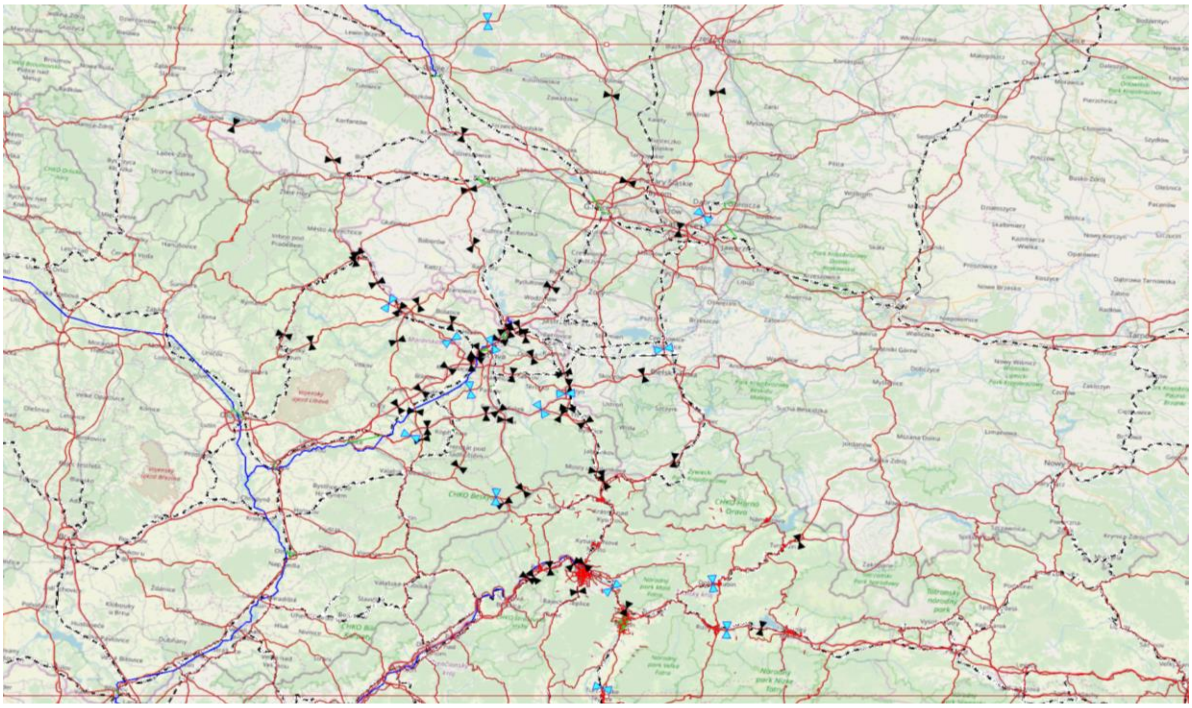

Figure 9 Localization of validation profiles of TRITIA model (highlighted in blue)

For the above mentioned validation road profiles, the values of the GEH parameter were then calculated by comparison with the modelled traffic volumes. The results of this calculation are shown in the following table.

Table 8 Values of the GEH parameter within validation of current state /2020/ of TRITIA model

No.	ATC	NTC	Model	GEH	Census site localization /GPS/
1	10 076	9 554	1 010	**0,121255**	50.294322,19.115953

No.	ATC	NTC	Model	GEH	Census site localization /GPS/
2	6 676	4 516	4 075	**1,544434**	49.86805, 18.28075
3	6 232	3 872	745	**0,151249**	49.1871, 18.50844
4	4 520	5 028	1 635	**1,867304**	49.177777, 18.863064
5	4 322	4 128	1 487	**0,929154**	49.73922, 18.60196
6	2 822	2 984	264	**1,553315**	49.078807, 19.340638
7	2 352	2 358	663	**2,294318**	49.68468, 18.51076
8	1 910	2 116	845	**0,685129**	49.908460,18.735794
9	1 644	2 366	84	**0,266423**	49.58073, 17.97458
10	1 232	1 186	63	**0,29196**	49.211672, 19.271706
11	1 014	1 644	238	**3,36416**	50.816709,18.134453
12	950	1 084	326	**3,32907**	49.873436, 18.104289
13	852	722	437	**0,753801**	49.82082, 17.39468
14	682	1 208	30	**1,102633**	48.891858, 18.863704
15	614	630	192	**0,854723**	49.41928, 18.34997
16	536	826	49	**0,90191**	49.7332444, 18.2271467
17	482	564	54	**1,092588**	49.96607, 17.82705

The average value of the GEH parameter on defined road profiles within the model validation reaches the value of 1.24178, which means that the calibration criteria and thus the correctness of the traffic model calibration are fulfilled.

The above-mentioned traffic modelling procedure has led to the quantification of the TRITIA model transport/traffic relations and the result is the traffic load of the road infrastructure by goods vehicles for the current state.

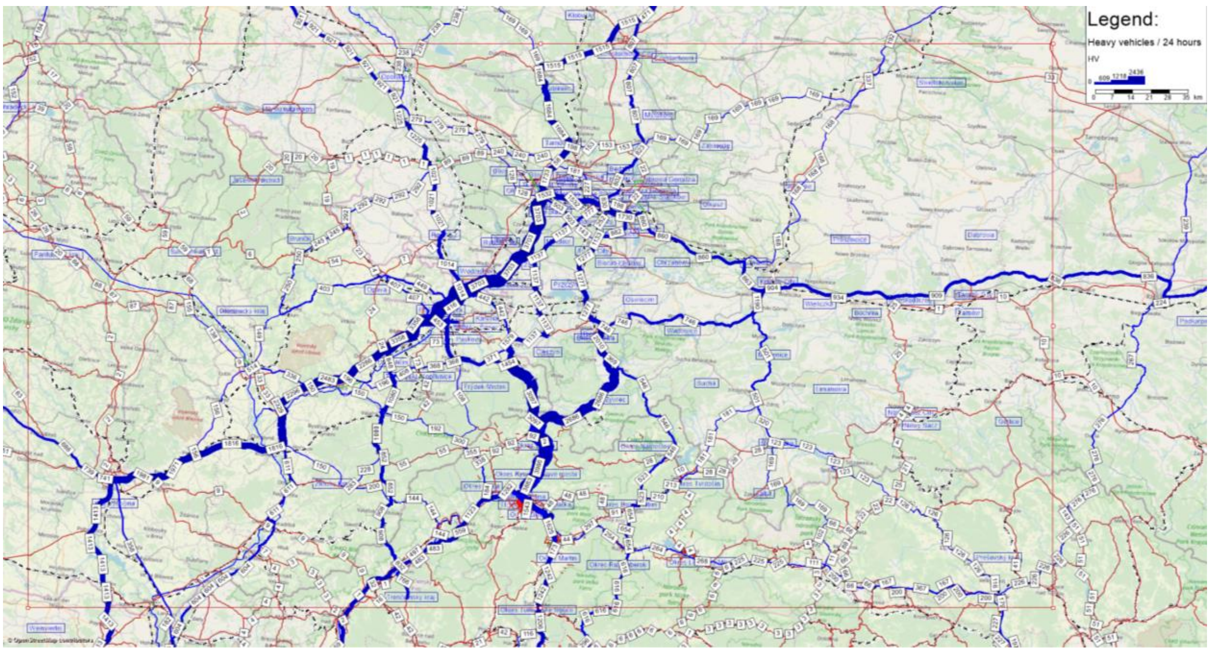

Figure 10 Road network load by freight traffic in TRITIA model, current state /2020/

3.2. Traffic model of zero scenario /2030/

Following the validation of the model for the current state of 2020, it was possible to forecast traffic relations by 2030, which represents the zero state of the TRITIA model. With regard to the development of transport infrastructure, planned measures have been incorporated into the model network, which are set out in Chapter 2.2.1 of this report. Demand for the freight transport has been forecasted on the basis of the expected long-term GDP growth, as the existing studies in this area have shown a strong correlation of this macroeconomic indicator with the evolution of freight transport performance. This was based on the reference values of forecasted GDP growth, which were applied in the creation of the national traffic model of the Czech Republic. Related differences resulting from different GDP growth in individual countries participating directly in the project (SK and PL) were eliminated in the modelling of alternative scenarios, where the effects of variable GDP development on the development of transport relations in the TRITIA model are analysed.

Table 9 Prognosis of GDP applied in road freight traffic model

	2010	2020	2035	2050
GDP growth	1,00	1,27	1,74	1,88

Although the level of GDP development for the Czech Republic appears to be slightly optimistic in the context of current developments, this estimate can be considered realistic, as the dynamics of growth in international and long-distance road transport are higher than in the case of transport on shorter-distance transport relations. The higher dynamics of transit traffic is linked to the ever-increasing effect of globalization and its associated trade links within the EU. To quantify the forecasted trend in road freight transport for 2030, the calculation applied a linear interpolation method between the relativized values in the reference years 2020 and 2050.

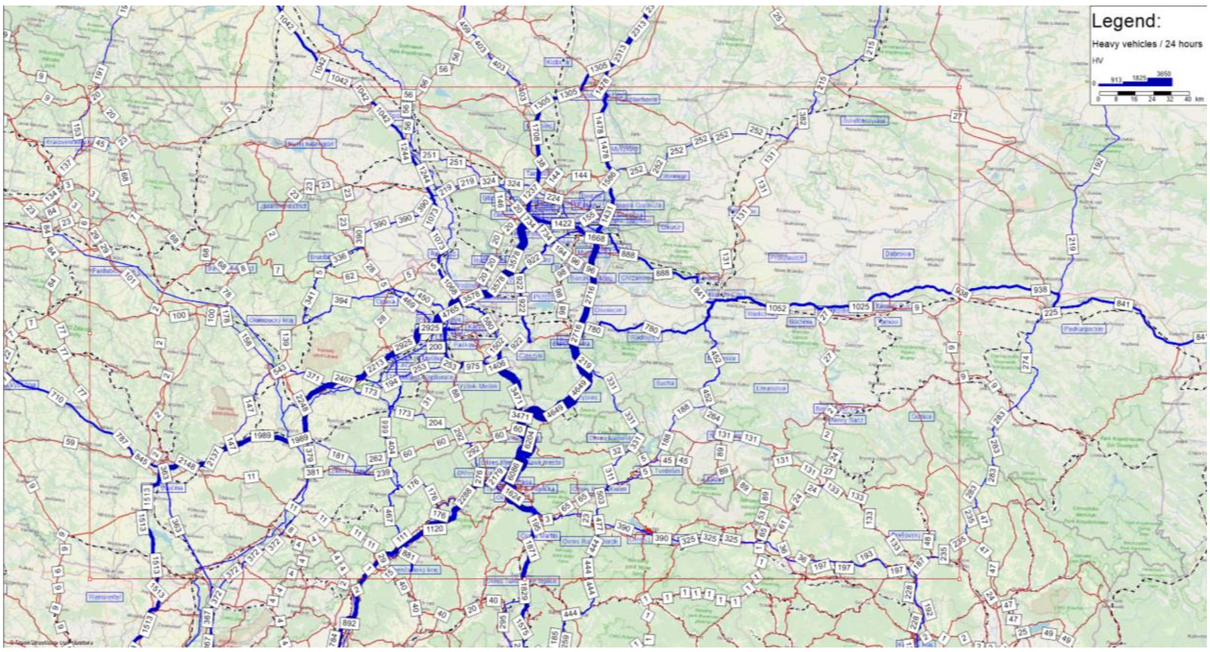

Figure 11 Road network load by freight traffic in the TRITIA model, zero scenario /2030/

3.2.1. The quantification of the useable potential for the transfer to rail and inland waterway transport

The application of the forecasted development to the calibrated model of the current state resulted in an output in the form of a heavy-duty road network load for zero scenario in the reference year 2030. This output represents the value of the maximum transfer potential from road freight transport to more environmentally friendly modes of transport (railway and inland waterway transport).

In order to model the transfer of traffic load to other transport modes, the layer of the infrastructure network of railway and inland waterway transport (multimodal transport network) was activated in the PTV VISUM programming environment. In this context, it was necessary to convert the original outputs in the form of road transport frequencies (heavy goods vehicles) into intermodal transport units (containers), which can be assigned to the entire multimodal network of the TRITIA model. The conversion of road transport vehicles to containers was carried out in a 1:1 ratio, as the modelling of road freight transport was developed for heavy vehicles, whose carrying capacity corresponds to the parameters of a 40 foot ISO container.

The subsequent assignment of the traffic load to the multimodal network was carried out by means of a calculation algorithm of the resistance (impedance) function, which was based on the national traffic model of the Czech Republic with updated values of parameters for the TRITIA region. It is a composite function ($f_{imp} = f_{(t, c, d)}$), which takes into account the resistance of the multimodal network sections in the following structure:

- $f_{(t)}$ as a function of transit time
- $f_{(c)}$ as a cost function (infrastructure usage fee and handling costs)
- $f_{(d)}$ as a function of the impact of the saturation of the transport network due to its capacity constraints

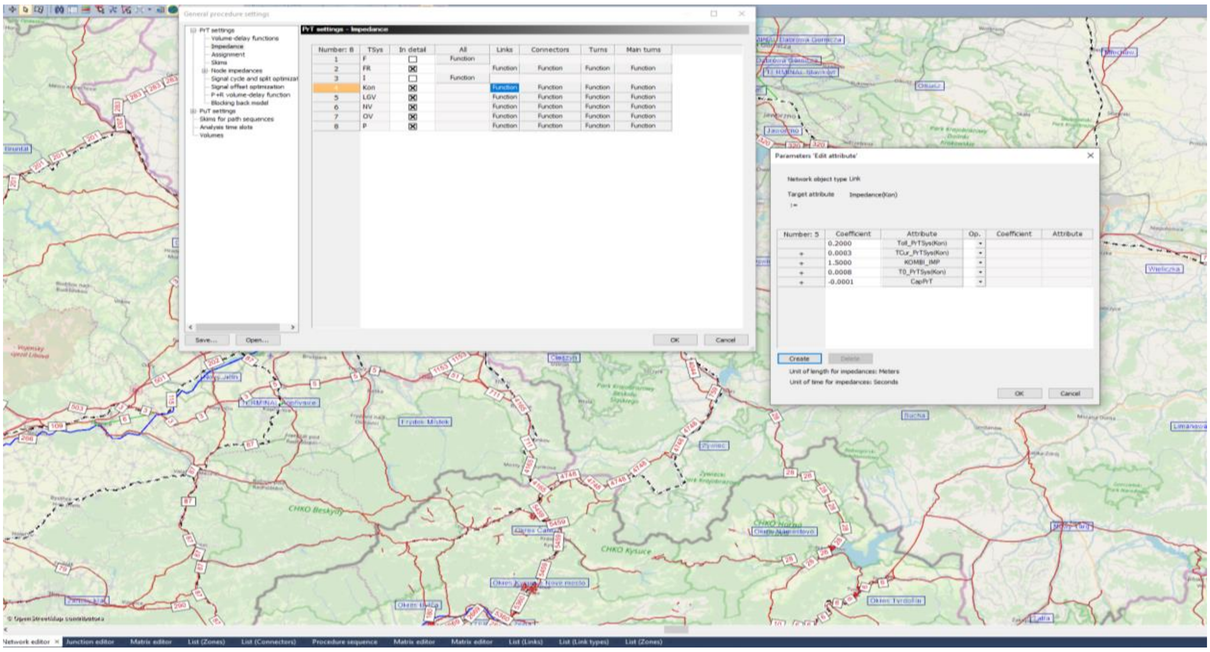

Figure 12 Parameterization of the impedance function of the TRITIA model, zero scenario /2030/

In the TRITIA model, its impedance is defined for each section of the transport network based on different variables, for which the BPR (Bureau of Public Roads) resistance function is defined. These resistance functions simulate different route conditions, such as congestion and intersection delays. The BPR resistance function is calculated using the formula:

$$t_{cur} = t_0 * \left(1 + a * \left(\frac{q}{q_{max} * c}\right)^b\right) \qquad [3]$$

,where:

t_{cur} current transit time with network load

t_0 transit time without network load

q traffic volume

q_{max} infrastructure capacity [vehicle / time]

a, b, c parameters

The total resistance of a given route consists of individual resistances for road, connectors, turns and more. Resistances are largely dependent on road traffic and are expressed in terms of "Volume-delay functions".

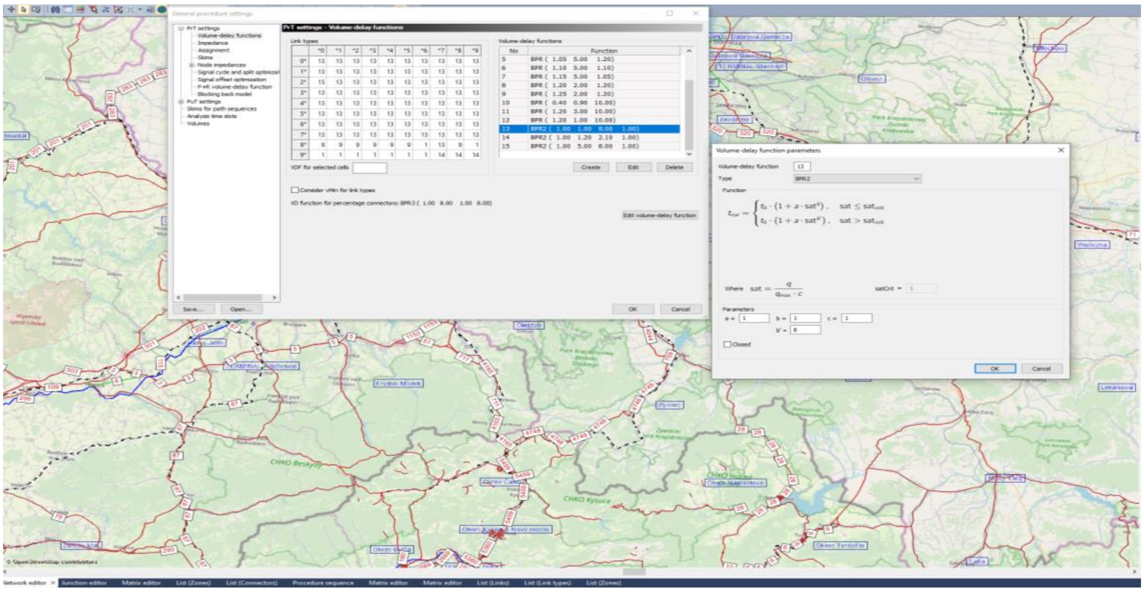

Figure 13 Resistance functions of TRITIA model in PTV VISUM, zero scenario /2030/

Inputs for the cost component of the resistance function were unit rates of charges for the use of transport infrastructure, which amounted to € 0.1905 / km for road transport (toll) and € 0.1084 / km for rail transport. In the case of railway infrastructure charges, the quantification of costs was based on the so-called "reference train" of 20 wagons. The infrastructure of the inland waterway network is not subject to a charge, as the amount of transhipment at terminals, which also affects the use of the rail network, has a fundamental impact on its amount. In some cases, the prices did not differ between the loaded container and the empty container because the fees were charged for handling, regardless of whether the container is empty or loaded. The unit price of transhipment was set at 40 € / container.

Based on the aforementioned procedures for the assignment of traffic to the TRITIA multimodal network, the output is a redistribution model for zero scenario (2030), which is shown in the following figure.

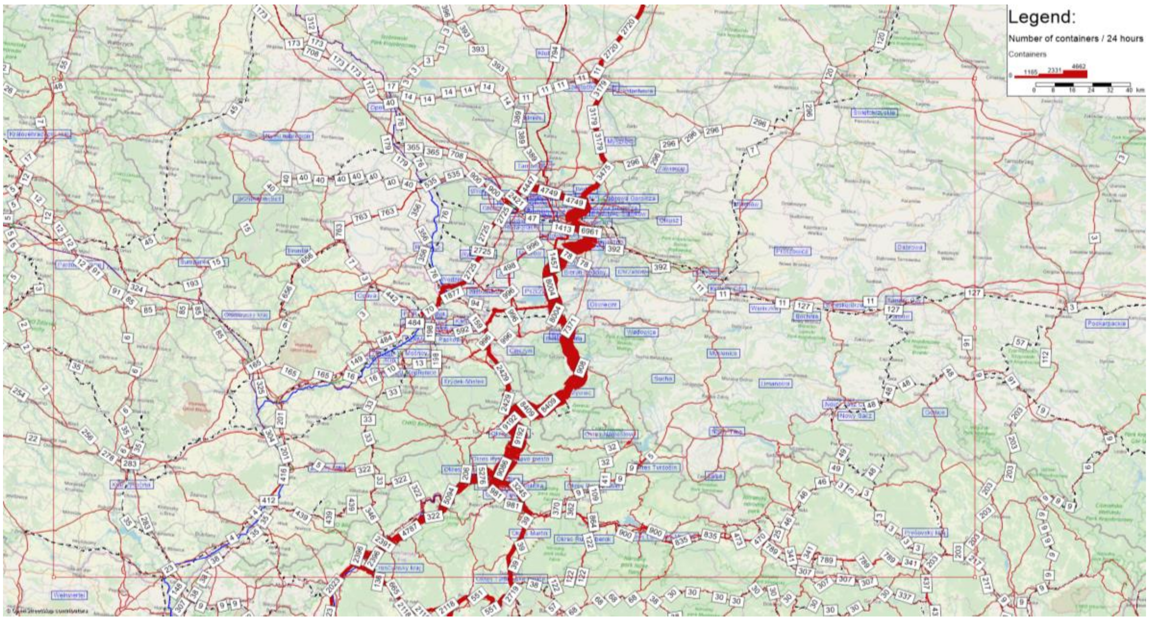

Figure 14 Model of redistribution of traffic load to multimodal transport network of TRITIA territory, zero scenario /2030/

The outputs of the TRITIA multimodal potential model, following the redistribution of traffic load, show that from the total volume of road freight transport of 12,546,256 container-kilometres per year (total potential) almost half of this load shifts towards the railway and around 4% to the inland waterway. In the modelling of the transport load shift, capacity constraints have not been taken into account in the case of railway and inland waterway infrastructure. The remaining part of the modelled transport load (46.7%) remains on the road infrastructure, where it is transported by heavy goods vehicles.

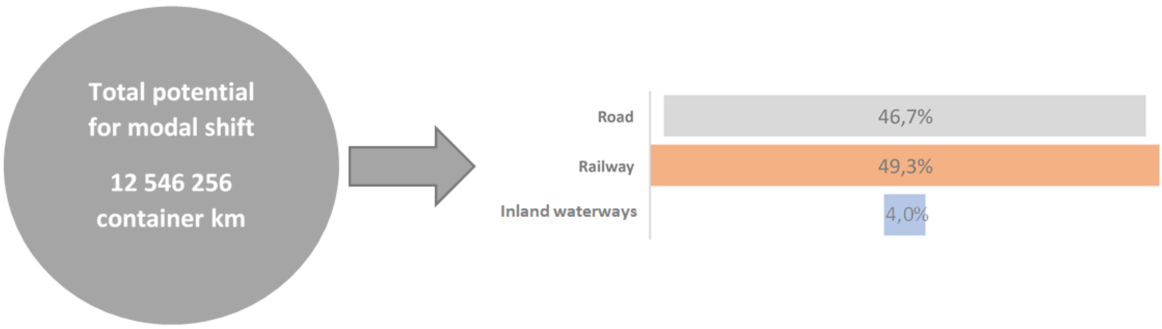

Figure 15 Shift of total transport load potential to individual transport modes, zero scenario /2030/

3.2.2. Identification of railway infrastructure bottlenecks

After the redistribution of the overall transport load potential to the infrastructure of other transport modes, its capacity parameters were analysed to identify bottlenecks. No overcapacity has been identified for inland waterway infrastructure. For the railway transport, the assessment was carried out by comparing the technical capacity of individual sections with the level of the modelled load, with the railway passenger transport also contributing to this load.

Railway sections with an occupancy rate of at least 70% were considered as bottlenecks. Despite the fact that the sections with 70% to 80% utilization rate of the railway line do not exceed the capacity, in practice it is usually considered to implement necessary measures in the medium or long term at this stage. For bottlenecks, where more than 80% of the line utilization has been identified, measures should be sought and implemented in a short term.

However, railway line sections, where the capacity in the zero scenario for 2030 would be exceeded in the event of a potential shift of traffic from road, can be considered as the most important ones. In such cases, the necessary infrastructure measures need to be implemented as soon as possible in order to increase the potential for shifting freight from road transport, in line with the common direction of the transport policy.

Table 10 Bottlenecks on the railway infrastructure after redistribution of transport load in zero scenario /2030/

Priority	ID	Section name	Tracks (number)	Capacity (Number of trains/week) (2030)	Number of passenger trains/week (2030)	Number of freight trains/week (2030)	Number of containers/ day (2030)	Number of container trains/day (2030)	Number of container trains/week (2030)	Number of total trains/week (2030)	Occupancy rate (%) (2030)
1	PL131-5	Herby Nowe - Kłobuck	2	511	0	419	794	40	280	699	136,8%
2	SK05-C	Diviaky - Vrútky	2	1106	312	218	2759	138	966	1496	135,3%
3	PL139-2	Tychy - Pszczyna	2	1015	588	250	1457	73	511	1349	132,9%
4	PL139-1	Katowice Ligota - Mąkołowiec	2	1484	1141	218	1457	73	511	1870	126,0%
5	CZ301A-5	Třinec – Český Těšín nákl. nádr.	2	1687	568	611	2429	122	854	2033	120,5%
6	PL131-4	Strzebiń - Kalina	2	735	98	419	794	40	280	797	108,4%
7	PL131-2	Radzionków - Tarnowskie Góry	2	1029	238	516	794	40	280	1034	100,5%
8	CZ301A-1	(SK) st. border - Mosty u Jabl.st. border	2	1554	294	381	2429	122	854	1529	98,4%
9	PL131-1	Chorzów Stary - Bytom Północny	2	791	238	210	794	40	280	728	92,0%
10	PL131-3	Tarnowskie Góry - Zwierzyniec	2	966	322	451	257	13	91	864	89,4%
11	CZ301A-4	Bystřice n. Olší – Třinec	2	1967	550	327	2429	122	854	1731	88,0%
12	CZ301D-2	Odb. Chotěbuz – Albrechtice u Č.Těšína	2	1421	478	390	839	42	294	1162	81,8%
13	CZ305B-9	Jistebník - Studénka	2	2373	1090	786	149	8	56	1932	81,4%
14	CZ301A-2	Mosty u Jabl.st.hr. – Návsí	2	2135	450	380	2429	122	854	1684	78,9%
15	CZ301A-3	Návsí – Bystřice n. Olší	2	2338	540	380	2429	122	854	1774	75,9%
16	PL136	Opole Groszowice - Kędzierzyn-Koźle	2	637	112	339	76	4	28	479	75,2%

ANNEXES

Annex 1	Zero scenario of TRITIA traffic model (electronic annex)

ANNEX 1

ZERO SCENARIO OF TRITIA TRAFFIC MODEL (ELECTRONIC ANNEX)