PREFEASIBILITY STUDY ON DEVELOPMENT THE BYDGOSZCZ LOGISTICS HUB

by integrating the Solec Kujawski Multimodal Platform and the Bydgoszcz-Emilianowo combined transport terminal

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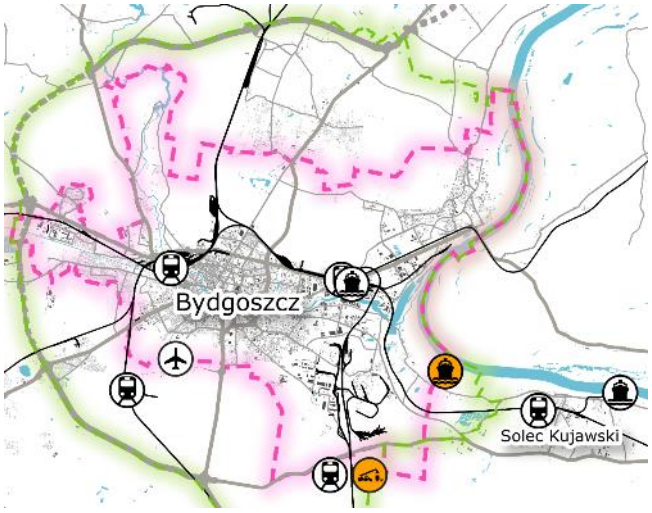

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CONTENT

1 ASSUMPTIONS FOR ANALYSIS

1.1 Purpose and scope of the Prefeasibility Study

1.1.1 Purpose of the study

The aim of the study is to identify and analyse the best investment scenario based on the selected selection criteria, in relation to the Bydgoszcz Emilianowo intermodal terminal, the Bydgoszcz-Solec Kujawski Multimodal Platform as well as the 'last mile' transport processes in the area of the City of Bydgoszcz. In line with the Contracting Party guidelines, this analysis is based on selected studies delivered as part of the COMBINE and EMMA projects. All analyses contained in the study refer only to cargo flows, i.e. they do not include passenger transport.

The aim of the study is directly in line with the goal of the COMBINE project, which is to increase the share of combined transport in the Baltic Sea Region, so that the transport of goods is more efficient and environmentally friendly. The subject of the study was included in package 4 ‘Building capacity for sustainable transport in the last mile’, action 4.4. ‘Development of the last mile concept for the Bydgoszcz-Solec Kujawski Multimodal Platform.

1.1.2 Basis and scope of the study

The basis for the study is the Contract for Specific Work No. WZR - V.271.2.8.2020 concluded on August 31, 2020 between the City of Bydgoszcz (Contracting Party, the COMBINE Project Partner) and the consortium of natural persons, including Bogusz Wiśnicki and Krzysztof Stępniewski. The consortium's offer was selected in the request for proposal - procedure number WZR-V.042.6.3.2020, announced on July 20, 2020.

In accordance with the above-mentioned contract and the description of the specific work, the subject of the contract is the Prefeasibility Study for the development of the Bydgoszcz logistics hub through the integration of the Bydgoszcz-Solec Kujawski Multimodal Platform and the Bydgoszcz-Emilianowo combined transport terminal. The substantive scope of the Prefeasibility Study covers five tasks:

1) Review and recommendations of the most effective transshipment technologies based on 'Analysis of combined transport terminal operations' carried out under the COMBINE project as well as other thematic studies and examples of other similar logistics platforms in the Baltic Sea Region.

2) Review and recommendations of the most effective last mile solutions for the Bydgoszcz logistics hub based on 'Analysis of combined transport terminal operations' carried out under the COMBINE project, as well as other thematic studies and examples of similar logistics platforms in the Baltic Sea Region. Particular emphasis should be placed on solutions from Western European cities, which will allow the limitation or elimination of heavy vehicle traffic in the area of the Bydgoszcz agglomeration.

3) The minimum functional program enabling the launch of the Bydgoszcz-Solec Kujawski Multimodal Platform's investment related to the assumed cargo volumes, accompanied with the recommended infrastructure elements and necessary technical installations indicated on overview maps.

4) Plan for the integration of logistics processes within the planned Bydgoszcz-Solec Kujawski Multimodal Platform and the concept of intermodal terminal technology and handling processes.

5) Overview of existing last mile solutions in Europe. Recommending optimal solutions from for combined transport within the Bydgoszcz-Solec Kujawski Multimodal Platform. In the study, the main emphasis should be placed on clean transport solutions, which reduce negative impacts on the environment, transport network and living conditions of the inhabitants.

1.2 Data and information sources

1.2.1 Related documents

The Prefeasibility Study is based on numerous strategic, planning and project documents relating to the scope of the study. The most important of them are enlisted in Table 1. They can be divided into four groups: strategic documents relating to Poland, strategic and planning documents of the Kujawsko-Pomorskie Voivodeship, strategic and planning documents of the City of Bydgoszcz and neighbouring communes, and project reports relating to the Bydgoszcz logistics hub. Among the latter, the deliverables of the EMMA and COMBINE international projects are the most significant. The vast majority of source documents are very up-to-date and come from the last two years. An important limitation is that some source documents were not finished, so as a result, their draft or in-consultation versions were used.

Table 1 The most important source documents for the Prefeasibility Study

No	Source documents
	Polish Government strategic documents
1.	Strategy for Responsible Development until 2020 (with a perspective until 2030). Warszawa, 2017.
	Strategic and planning documents of the Kujawsko-Pomorskie Voivodeship
1.	Development strategy of the Kujawsko-Pomorskie Voivodeship until 2030- Acceleration Strategy 2030+, Project for public consultation. 2020.
2.	Spatial development plan of the Kujawsko-Pomorskie Voivodeship. Project. 2018.
	Strategic and planning documents of the City of Bydgoszcz and neighbouring communes
1.	Bydgoszcz 2030. Development strategy. Bydgoszcz, 2020.

No	Source documents
2.	Study of land use conditions and directions of the City of Bydgoszcz. Bydgoszcz, 2009.
3.	Study of land use conditions and directions of the City of Bydgoszcz. Project. Bydgoszcz, 2019.
4.	Electromobility development strategy of the City of Bydgoszcz by 2030. Bydgoszcz 2020.
5.	Study of land use conditions and directions of the Nowa Wieś Wielka Commune. Nowa Wieś Wielka, 2020.
6.	Study of land use conditions and directions of the Solec Kujawski Commune. Solec Kujawski, 2006-2008 (as amended).
	Project reports related to Bydgoszcz logistics hub
1.	Business plan for a new potential shipping service in Poland on the Lower Vistula, from Tricity to Warsaw. Projekt EMMA. Bydgoszcz, 2019
2.	Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR. Project COMBINE (WP 3.1). 2020.
3.	Innovative last mile solutions to strengthen combined transport. Project COMBINE (WP 4.1). 2020.
4.	Concept of the last mile freight traffic on the city's road network for the Bydgoszcz logistics hub. Project COMBINE (WP 4). 2020.
5.	The last mile concept for the Bydgoszcz logistics hub COMBINE. Project (WP4). 2020.
6.	Location Study for the project entitled: “Multimodal Platform Based on Water, Rail, Road and Air Transport with a Logistics-Storage Centre and a River Port Located in the Indicated Area of the Left Bank of the Vistula River (km 766-771), Considering the Area of the City of Bydgoszcz and Commune of Solec Kujawski”. EMMA Project. Warszawa, 2018.

Source: own elaboration

1.2.2 Stakeholders

The project stakeholders were identified on the grounds of an expert analysis and consultation. In September 2020, the following consultation meetings took place:

1) workshops with stakeholders as part of the COMBINE Project - Bydgoszcz, 03/09/2020;
2) meeting with the key project stakeholder, Port of Gdynia Authority S.A. - Gdynia, 04/09/2020;
3) teleconference with stakeholders related to railway investments (railway infrastructure manager, railway designer) - on-line, 24/09/2020.

The list of parties participating in the meetings, together with their organisational forms and purpose, is presented in Table 2. The largest number of stakeholders was attended by workshops on 03/09/2020 at the Bydgoszcz City Hall. It was the initial meeting for the work on the Prefeasibility Study and was devoted to the verification of assumptions and methodology. The meetings on 04/09/2020 and 24/09/2020 were attended by representatives of institutions and companies involved in the Bydgoszcz-Emilianowo intermodal terminal project

implementation. In the first of these two meetings, the topics of intermodal cargo volumes from/to the seaport in Gdynia and the functional and spatial assumptions of the terminal's railway infrastructure were analysed.

Table 2 Organizational form, purpose and parties participating in the consultation meetings

	Meeting No 1 03.09.2020	**Meeting No 2 04.09.2020**	**Meeting No 3 24.09.2020**
Organizational form	Workshops	On-site meeting	Teleconference
Purpose	Presentation of the study methodology Verification of the study assumptions Defining expectations for the Bydgoszcz logistics hub development projects	Verification of assumptions regarding the role of the Bydgoszcz logistics hub in handling intermodal cargoes from/to the seaport in Gdynia	Verification of functional and spatial assumptions regarding Bydgoszcz-Emilianowo intermodal terminal railway infrastructure
Participants	Bydgoszcz City Hall Marshal's Office of the Kujawsko-Pomorskie Voivodeship Intermodal Terminal I Bydgoszcz-Emilianowo Ltd. Municipal and Communal Office of Solec Kujawski Municipal and Communal Office of Nowa Wieś Wielka PKP S.A. Bydgoszcz Industrial and Technological Park Ltd.	Port of Gdynia Authority SA.	PKP S.A. PKP PLK S.A. Intermodal Terminal Bydgoszcz-Emilianowo Ltd. Bydgoszcz City Hall Voessing Polska Ltd. - designer of the Emilianowo station railway infrastructure

Source: own elaboration

The conducted interviews and expert analysis served to identify relationships between individual entities and the two projects carried out in the area of the Bydgoszcz logistics hub, i.e. the Bydgoszcz-Emilianowo intermodal terminal project and the Bydgoszcz-Solec Kujawski Multimodal Platform project. As a result of the analysis, a map of stakeholders for both projects was developed (Figure 1).

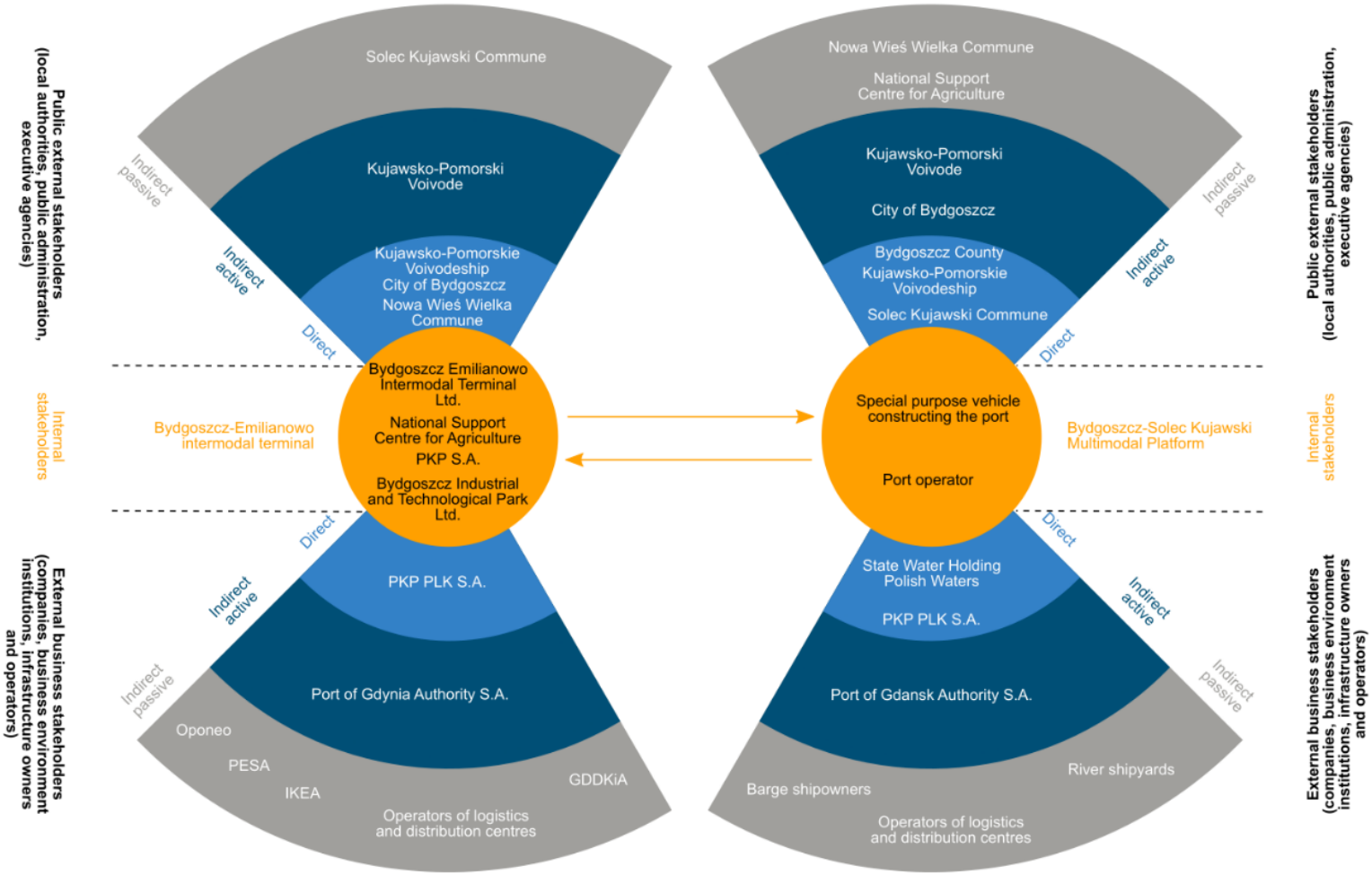

Figure 1 Project stakeholders' map – Bydgoszcz-Emilianowo intermodal terminal and Bydgoszcz-Solec Kujawski Multimodal Platform

Source: own elaboration

The map shows the assignment of stakeholders to different groups and determines their level of involvement in the implementation of the project. The division into internal and external stakeholders, including public institutions (local authorities, public administration, executive agencies) and business entities (companies, business environment institutions, infrastructure owners and operators), was adopted. External stakeholders were grouped using three levels of project involvement:

1) direct stakeholders - entities/institutions involved in the project as landowner or access infrastructure manager,

2) indirect active stakeholders - entities/institutions influencing the course of the project and/or directly involved in its implementation,

3) indirect passive stakeholders - entities/institutions that are project beneficiaries or project related but not directly involved in it.

It is important when creating a stakeholder map that both projects are at different stages of their development. In the case of the Bydgoszcz-Emilianowo intermodal terminal, we have the founding company (Bydgoszcz-Emilianowo Intermodal Terminal Ltd) and a preliminary concept of this terminal. In the case of the Bydgoszcz-Solec Kujawski Multimodal Platform, there is only the location study for this project. These differences are reflected in the precision of indicating stakeholders of the Bydgoszcz-Solec Kujawski Multimodal Platform and uncertainty about the role they will play in this project.

1.3 Bydgoszcz logistics hub

The Prefeasibility Study relates to two infrastructure projects: the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform, which are implemented in the area of the Bydgoszcz logistics hub. As both facilities are located partly outside the administrative area of the City of Bydgoszcz, there is a need to define the boundaries of a logistics hub in its new shape. For the purposes of the Prefeasibility Study, the boundaries of the Bydgoszcz logistics hub are set as follows (see Figure 2):

1) from the east, by the Vistula River (section Otorowo - Strzelce Dolne);
2) from the south, by expressway 10/S10 (from the intersection with ul. Nowotoruńska to the Białe Błota junction) with an additional area limited by railway lines No. 201 and No. 131 to their connection at the Nowa Wieś Wielka station;
3) from the west and north, by the city bypass which is formed by expressways 10/S10 and S5 which are under construction or modernization (from the Białe Błota junction to the Bydgoszcz Północ junction).

In this study, we define the area of the Bydgoszcz logistics hub, which is larger than the administrative area of the City of Bydgoszcz, merging the areas to the north and south of the existing borders. To the north, these are the residential and industrial areas of the Osielsko Commune, while to the south, there are the areas of the Nowa Wieś Wielka Commune, which include the Emilianowo village and PERN Fuel Depot in the Nowa Wieś Wielka Village.

The City of Bydgoszcz has road and railway orbital bypasses. It is important that the ring road formed by the 10/S10 and S5 expressways is incomplete and does not cover the eastern part of the Bydgoszcz agglomeration. Undoubtedly, a major infrastructural limitation is the insufficient capacity of the existing road and rail bridge over the Vistula (Bydgoszcz Fordon) and the lack of a river bridge at the height of Otorowo. Hence, cargo that flows along the north-south axis in the eastern part of the city utilizes downtown roads (Cardinal Stefan Wyszyński Avenue, Łęczycka Street, Sporna Street).

Figures 2 and 3 show the most important nodal infrastructure of the Bydgoszcz logistics hub, to which further analysis in the framework of the Prefeasibility Study will refer. The planned new facilities include the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform. The existing nodal infrastructure facilities include:

1) freight railway stations - Bydgoszcz East, Bydgoszcz West, Trzciniec, Bydgoszcz-Emilianowo and Solec Kujawski;
2) airport - Bydgoszcz Ignacy Jan Paderewski Airport;
3) river ports - port of Żegluga Bydgoska Ltd. (Bydgoszcz, Przemysłowa Street) and port Solbet Ltd. (Solec Kujawski, Toruńska Street).

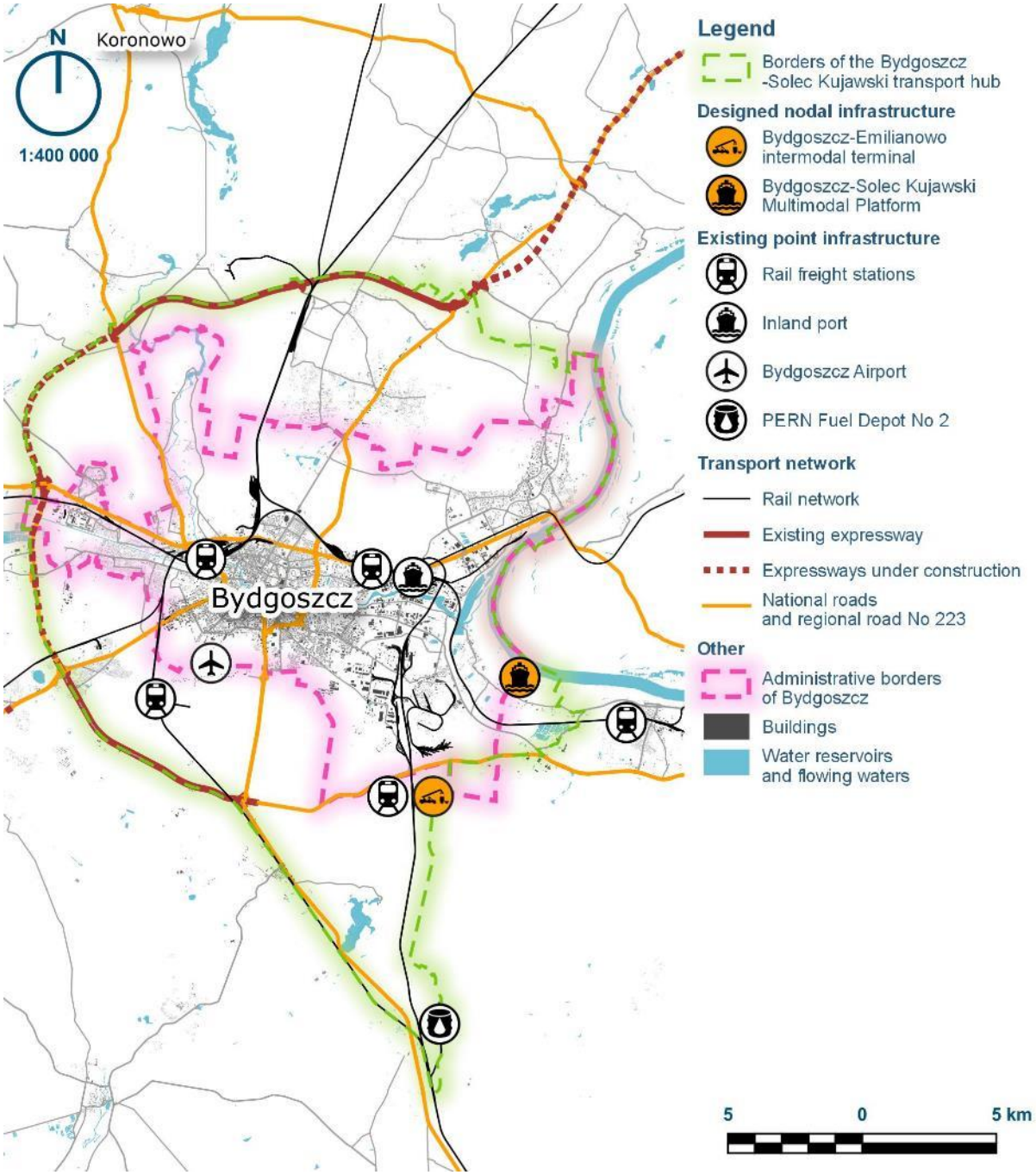

Figure 2 Borders of the Bydgoszcz logistics hub

Source: own elaboration

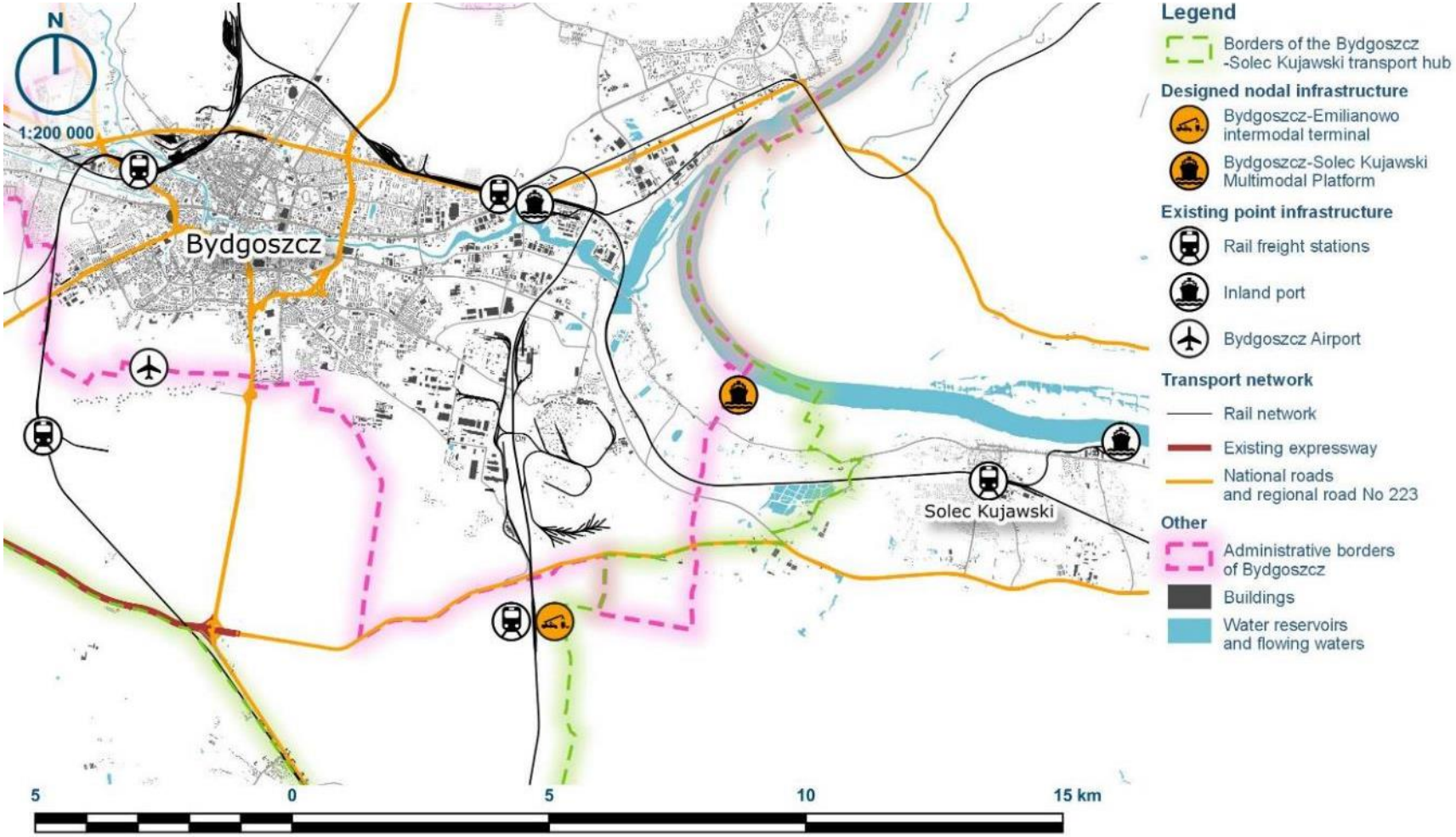

Figure 3 Nodal infrastructure of the Bydgoszcz logistics hub

Source: own elaboration

The Bydgoszcz logistics hub is a node in the European TEN-T transport network. Figure 4 shows the location of this node in relation to two TEN-T corridors crossing Poland, i.e. the Baltic-Adriatic Corridor and the North Sea-Baltic Sea Corridor. Within the corridors, a distinction is made between the core network and comprehensive network. Currently, only one core network railway line (No. 131) of the Baltic-Adriatic Corridor passes through the Bydgoszcz-Solec Kujawski hub. The hub itself is seen as a node of the comprehensive network on the same corridor. As part of the comprehensive network, Bydgoszcz is crossed by two expressways (S10 and S5) and the railway line No. 201, and the Bydgoszcz international airport.

It is significant that the waterways E40 and E70 are not included in the core network. This situation is identical to that of the Oder Waterway (E30), which, despite the fact that it is located on the route of the TEN-T corridor, is not included in it due to insufficient navigation parameters. Poland undertook measures to adapt its main waterways to international navigation standards by signing the AGN Convention. In order to unlock the possibility of using EU funds dedicated to TEN-T, the main waterways must have the parameters of navigability class IV, i.e. the transit depth on the route of min. 2.5 m. It should be remembered that an important condition for proposing corrections to the TEN-T core network is the need to complete infrastructure investments by 2030, which is a significant limitation in the context of the waterway development program in Poland. Hence, recommendations can be formulated to include the Bydgoszcz logistics hub and the railway line No. 201 in the core network in the nearest revision of the TEN-T network (2023). After including the modernized Vistula Waterway in the TEN-T network, it is necessary to extend the logistics hub with the river port in Solec Kujawski (Bydgoszcz-Solec Kujawski Multimodal Platform).

The role of the Bydgoszcz logistics hub in the Polish intermodal transport network is shown in Figure 5. The node is 150-170 km (as the crow flies) from the Tri-City seaports, 100 km from the Poznań agglomeration and 170 km from the Łódź agglomeration. Toruń with 201,447 inhabitants is located approx. 40 km away (GUS, 2019). Two spatial conditions are important from the point of view of the intermodal transport network. First, the Bydgoszcz logistics hub is located at the direct hinterland of large seaport terminals (container, ro-ro and ferry terminals), which handled a total of 2.68 million TEU in 2019. Second, north of the North Sea-Baltic Corridor, there are no land-based intermodal terminals (apart from seaport terminals) within Poland. Thus, there is the northern part of the country, measured with an area of approx. 200 km wide and approx. 600 km long, with no access to distribution rail-road terminals. In the middle of this strip, there is the Bydgoszcz logistics hub. The first condition indicates the chance for this hub to act as a dry port for seaport terminals. The second condition indicates the chance of carrying out intermodal transport distribution operations within the hub's service area, i.e. at a maximum delivery distance of 150 km.

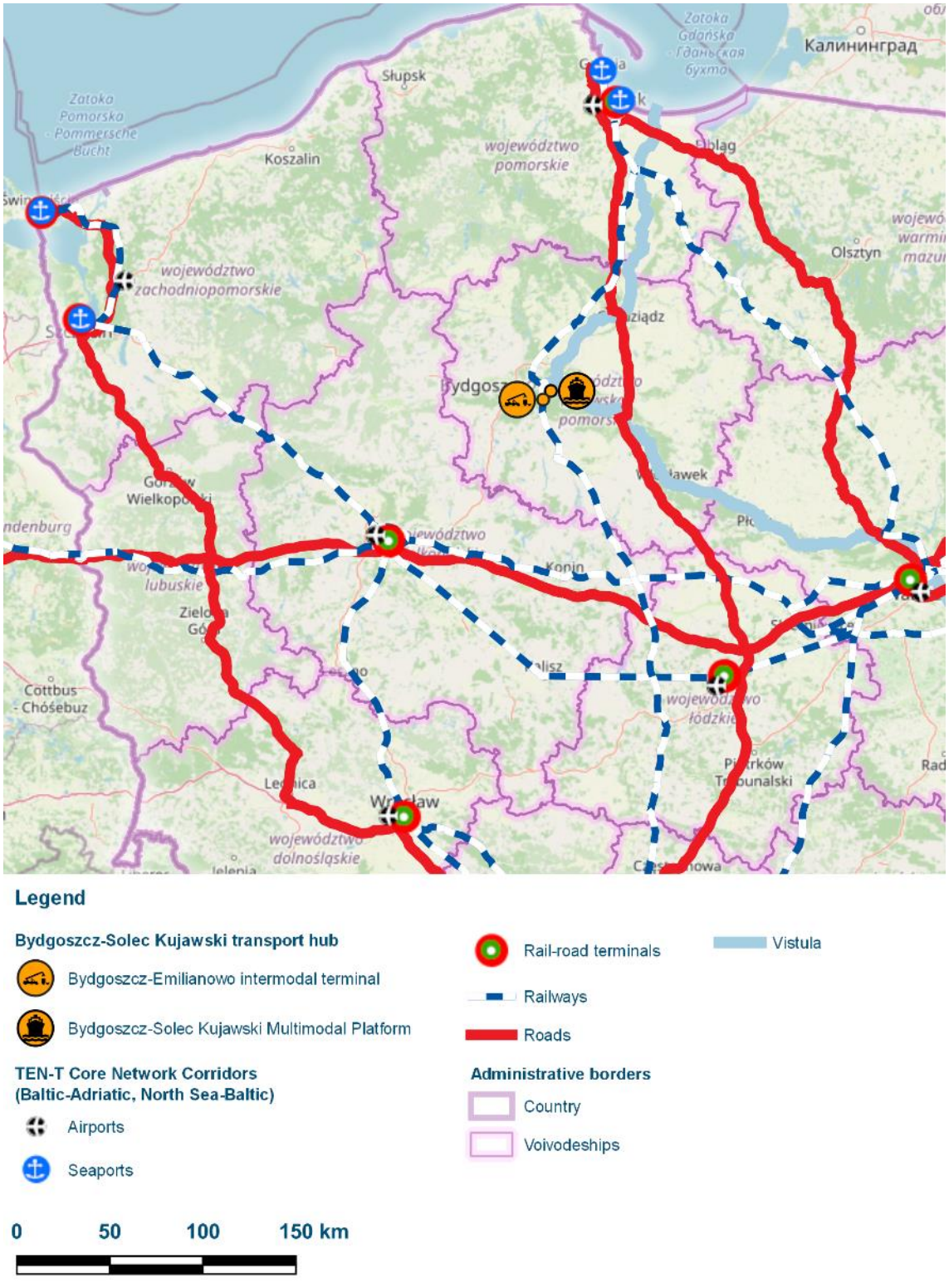

Figure 4 Bydgoszcz logistics hub in the TEN-T core network

Source: TENtec Interactive Map, https://ec.europa.eu/

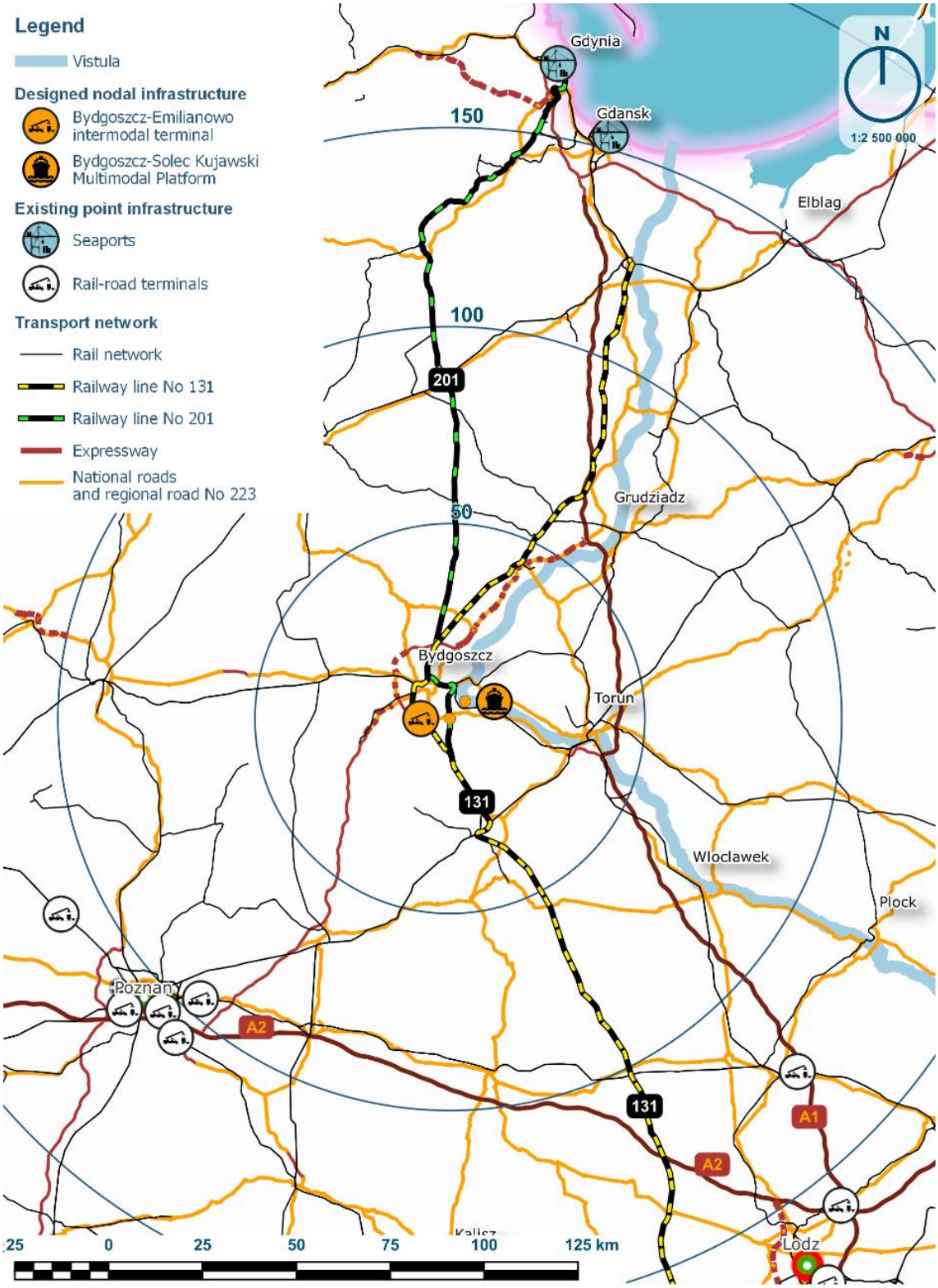

Figure 5 Location of the Bydgoszcz logistics hub in the intermodal transport network

Source: own elaboration

The work schedule for the construction projects of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform translates into the prospects for the development of the Bydgoszcz logistics hub. Both projects are currently at different stages of preparatory work and their completion dates should be assumed far from each other. In both cases, we can talk about untypical investment process, which is characterized by high uncertainty. The specifics of the Bydgoszcz-Emilianowo intermodal terminal construction process is discussed below, while the specificity of the construction project of the Bydgoszcz-Solec Kujawski Multimodal Platform results from its close connection with the waterway modernization project in Poland. It is a satellite project in relation to this big governmental infrastructure project, which will be implemented for a minimum of 20 years and carries a high risk of delays.

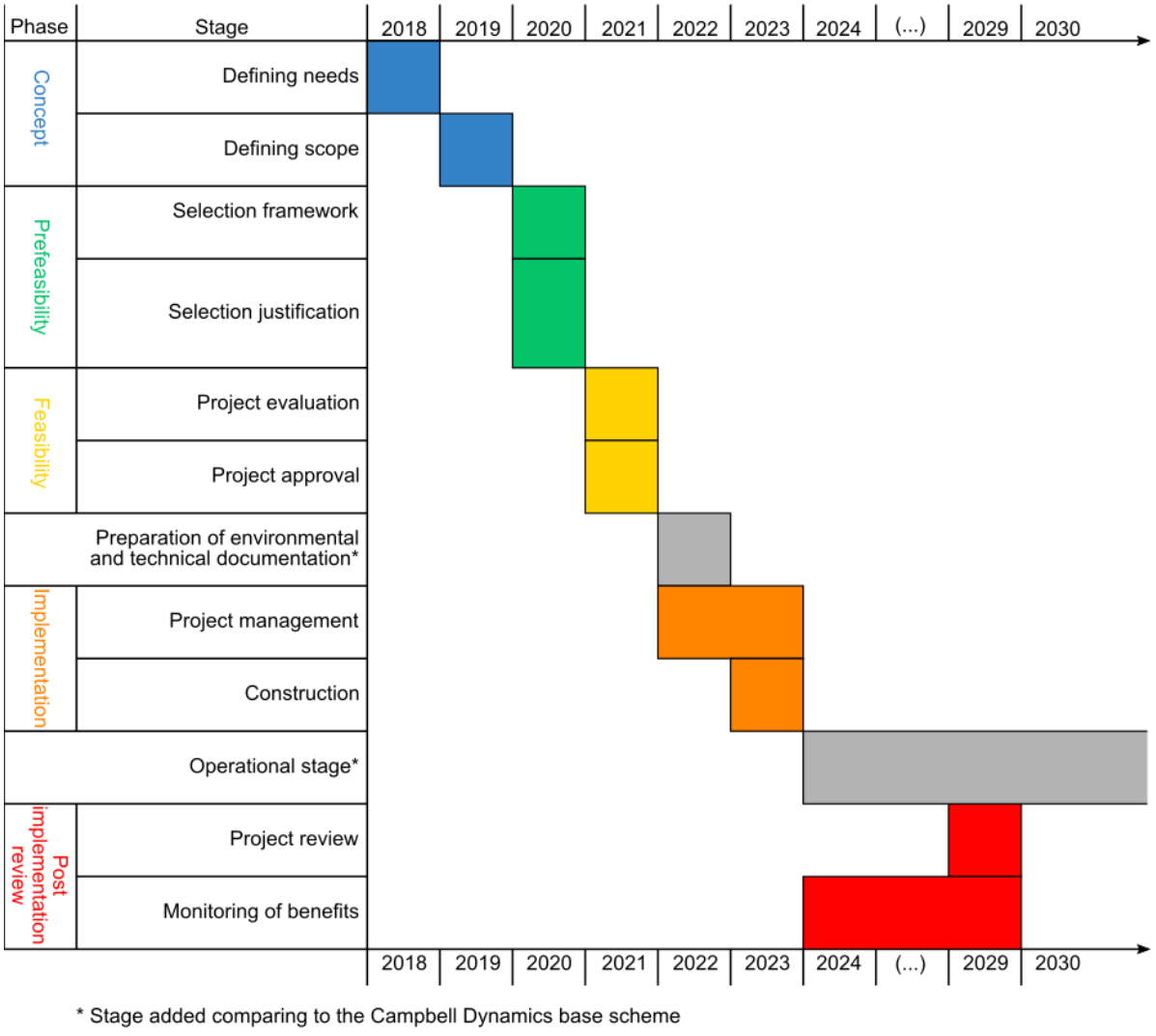

Figure 6 Project implementation schedule of the Bydgoszcz Emilianowo intermodal terminal

Source: Pre-Feasibility and Definitive Feasibility Studies, http://www.campbelldynamics.com/

The schedule of the investment process (Figure 6) has been prepared for the needs of the study and may be changed during further works under the terminal construction. This study fits into this process as the Stage 2 Prefeasibility study, followed by subsequent stages, starting with the Feasibility Study in 2021 and ending with the Post implementation review in 2029. In fact, the Prefeasibility Study for this project is carried out in parallel with works on technical documentation for railway infrastructure, commissioned by PKP PLK SA in 2020. The scope of the Prefeasibility Study is extended to the documentation of PKP S.A., as the current project concerns the construction of one loading front operated by one mobile transhipment unit (reachstacker). In addition, the Prefeasibility study includes references to a wider functional analysis covering the existing and future transport node infrastructure (road, rail, water, aviation).

In summary, this Prefeasibility Study carried out as part of the COMBINE project, is part of the standard procedure of implementing investment projects, which should lead to the construction of a long-term path to full functionality of the Bydgoszcz logistics hub. The activity carried out by PKP PLK SA in the scope of reconstruction of the existing infrastructure enabling to start transshipment operations at the Bydgoszcz-Emilianowo intermodal terminal can be treated as an action within a parallel, shortened investor procedure. The Prefeasibility Study is aimed at coordinating this action within the concept of an extended intermodal terminal and an integrated logistics hub. Other analytical assumptions relating to the two key projects within the integrated Bydgoszcz-Solec Kujawski logistics hub are given in the next section of the study.

1.4 Assumptions for the Bydgoszcz-Emilianowo intermodal terminal

For the Bydgoszcz-Emilianowo intermodal terminal project, the following assumptions are made for further analysis within this Prefeasibility Study:

1) The Bydgoszcz-Emilianowo intermodal terminal is the central point of the Bydgoszcz logistics hub infrastructure.
2) Due to its location at a distance of about 167 km from Gdynia and direct rail connection by the railway line No. 201, the Bydgoszcz-Emilianowo intermodal terminal will be able to operate as a dry port for the Port of Gdynia.
3) The Bydgoszcz-Emilianowo intermodal terminal will perform a last mile distribution function for the Bydgoszcz agglomeration and the Kuyavian-Pomeranian Voivodeship.
4) The last mile distribution concept will be differentiated with regard to the distance and the number of intermodal units transported in the relation terminal-consignee. In the case of single units/shipments, road transport will be preferred, while for larger volumes for one consignee, rail transport, e.g. in groups of wagons, will be preferable.
5) The Bydgoszcz-Emilianowo intermodal terminal will be linked to the port terminal in Solec Kujawski (Bydgoszcz-Solec Kujawski Multimodal Platform) and with other satellite terminals or transhipment points within the Bydgoszcz logistics hub.
6) Next to the terminal, a logistics centre closely related to it (including internal transport) will be built. It is planned to locate new production and storage facilities in the areas south of the S10 expressway and east of the terminal area.

1.5 Assumptions for the Bydgoszcz-Solec Kujawski Multimodal Platform

For the Multimodal Platform in Solec Kujawski project, the following assumptions are made for further analysis within this Prefeasibility Study:

1) The Multimodal Platform in Solec Kujawski is a much broader concept than the river port and cargo terminals in this port. As part of the Bydgoszcz logistics hub, the narrower scope of the platform will be analysed, i.e. a container terminal in the newly built river port. In the subsequent part of the Prefeasibility Study, the name 'Bydgoszcz-Solec Kujawski Multimodal Platform' will be used to refer to the container terminal, which will be understood as a trimodal (rail-road-river) terminal.
2) The Bydgoszcz-Solec Kujawski Multimodal Platform will be a satellite terminal in relation to the Bydgoszcz-Emilianowo terminal, linked by road and rail infrastructure. It is advisable to adjust the parameters of connecting roads for the passage of non-standard vehicles (heavier and oversized).
3) The condition for the construction of the port in Solec Kujawski is the completion of works related to restoration of navigability of the lower Vistula River. An important element of these works will be the construction of barrages, one of which will be built in Solec Kujawski. Current plans assume that it will take place around 2040.
4) Due to its location on the Lower Vistula waterway, the Solec Kujawski terminal will be dedicated to handling containerized cargo in logistic chains passing through the Port of Gdansk.

1.6 Demand analysis

Table 3 presents a summary of all available demand forecasts for the transhipment services of the analysed terminals, i.e. the Bydgoszcz-Solec Kujawski Multimodal Platform and the Bydgoszcz Emilianowo intermodal terminal.

Table 3 Demand forecasts for the transhipment services of the analysed terminals

Forecast source	Terminal covered by the forecast	Forecast summary	Forecasted quantities
Szaciłło L., Zielaskiewicz H. (2019). The development of intermodal transport in the Kujawsko-Pomorskie Voivodeship on the example of the project of intermodal terminal in Emilianów, Transportation Overview, 12/2019 and Logistics Office of PKP S.A., Construction of an intermodal terminal in Emilianowo, internal report	Bydgoszcz Emilianowo intermodal terminal	This is not a classic demand forecast, but an estimation of terminal handling capacity, which should not be treated as final one. The concept of the Bydgoszcz Emilianowo intermodal terminal development is based on the analysis of public statistical data. Three stages of development were assumed for which no time frame was given: Stage I - construction of a manoeuvring and storage yard of 1.56 ha area with drainage and construction of the basic accompanying infrastructure necessary to perform handling operations with the use of one transhipment track. Stage II - expansion of the manoeuvring and storage yard by 0.42 ha, expansion of the administrative and service facilities, drainage of the area and construction of accompanying infrastructure, embed one track into the manoeuvring surface to enable handling operations from with the use of two transhipment track. Stage III - expansion of the manoeuvring and storage yard by approx. 0.51 ha along with the construction of accompanying infrastructure, towards the east.	Annual handling capacity by stages: Stage / TEU / ITU I / 19 900 / 11 700 II / 38 300 / 22 500 III / 88 000 / 51 700

WYG International (2018). Location Study for the project entitled: "Multimodal Platform Based on Water, Rail, Road and Air Transport with a Logistics-Storage Centre and a River Port Located in the Indicated Area of the Left Bank of the Vistula River (km 766-771), Considering the Area of the City of Bydgoszcz and Commune of Solec Kujawski". EMMA Project report. WYG International Ltd. Warszawa.	Bydgoszcz-Solec Kujawski Multimodal Platform	The three stages of development of the Bydgoszcz-Solec Kujawski Multimodal Platform, understood as subsequent periods of port terminal operation, include: Stage I - commissioning of the terminal under the existing shipping conditions and a short navigable season (2nd class of the international waterway). Stage II - gradual development of the terminal and extension of the navigation season up to 240 days (2nd class of the international waterway). Stage III - full terminal operability and the proper navigability of the Vistula (4th class of the international waterway). The forecast assumes that the Bydgoszcz-Solec Kujawski Multimodal Platform will service seaports in Gdańsk and Gdynia.	Annual container turnover by stages: Stage (year) / tonnes/year I (2028) 591 574 II (2035) 996 190 II (2040) 1 098 325 III (2045) 1 428 362 III (2055) 1 648 514
Foundation „Rozwój UTP" (2020). The concept of the last mile freight traffic on the city's road network for the Bydgoszcz logistics hub. COMBINE Project Report (WP 4.4).	Bydgoszcz Emilianowo intermodal terminal and Bydgoszcz-Solec Kujawski Multimodal Platform	The subject of the study was to determine the impact of the construction and commissioning of the Bydgoszcz-Emilianowo intermodal terminal and the Solec Kujawski Multimodal Platform on the traffic of heavy vehicles in the City of Bydgoszcz. In terms of demand for the services of both terminals, the study is based on forecasts prepared by other entities. Those are: • development assumptions of PKP S.A. for the Bydgoszcz Emilianowo intermodal terminal, • a forecast prepared as part the Location Study for the Solec Kujawski Multimodal Platform. Operational commencement dates have been set for both terminals, taking into account the estimated time of preparatory works and the schedule of Vistula waterway modernization. The following dates have been specified: • 2025 for the Bydgoszcz-Emilianowo intermodal terminal, • 2040 for the Multimodal Platform Solec Kujawski.	Internal agglomeration traffic to/from terminals [ton] Bydgoszcz Emilianowo intermodal terminal Year / vans / trucks 2025 5 250 360 000 2030 7 875 450 000 2035 10 125 562 500 2040 7 627 394 962 2045 8 581 441 429 2050 11 625 607 500 Bydgoszcz-Solec Kujawski Multimodal Platform

For such a defined time horizon, in five-year intervals, prognostic transport models were developed in two variants:

- non-investment option - without building multimodal terminals,
- investment variant - with the construction of the Bydgoszcz Emilianowo intermodal terminal in 2025 and the Bydgoszcz-Solec Kujawski Multimodal Platform in 2040.

The forecast concerns the number of annual transports made by city delivery vehicles (vans up to 3.5 tons) and heavy goods vehicles (trucks up to 44 tons) between potential loading/unloading places within agglomeration and the terminals in Emilianowo and Solec Kujawski. In addition, the external agglomeration traffic to/from terminals were predicted. The forecast assumed an average load weight for a delivery 1 ton per van and 25 tons per truck.

Year	vans	trucks
2040	1 907	116 165
2045	3 814	174 248
2050	5 625	277 500

External agglomeration traffic to/from terminals [ton]

Bydgoszcz Emilianowo intermodal terminal

Year	vans	trucks
2025	3 750	675 000
2030	10 875	1 252 500
2035	13 125	1 462 500
2040	15 340	1 743 750
2045	15 873	1 809 375
2050	16 406	1 875 000

Bydgoszcz-Solec Kujawski Multimodal Platform

Year	vans	trucks
2040	10 738	1 220 625
2045	11 111	1 266 563
2050	11 484	1 312 500

Consultation meeting with the Port of Gdynia Authority S.A. on 04/09/2020	Bydgoszcz Emilianowo intermodal terminal	The forecast is based on cargo flows in containers that will be served by the Port of Gdynia. As a result of the implementation of key port investments, i.e. the new deep-water container terminal in the Outer Port and the modernization of the railway line No. 201, an increased share of intermodal transport is assumed. Some of these cargoes will be handled at the Bydgoszcz Emilianowo intermodal terminal (temporary storage of full containers, depot for empty containers, shuttle trains service in the dry port-sea terminal relation and service of long-distance trains in the dry-port-hinterland relation). The following forecast is an estimate based on the declared volumes of transhipments of the current (BCT and GCT) and planned port terminals (million TEU).	Annual container turnover

	Deepwater container terminal	BCT+GCT	Port Gdynia
2030	0,50	1,80	2,30
2035	2,00	2,00	4,00
2040	2,50	2,20	4,70

Year	mln TEU
2030	0,148
2035	0,450
2040	0,639

Infra - Centrum Doradztwa (2020). The last mile concept for the Bydgoszcz logistics hub (Multimodal Platform Bydgoszcz-Solec Kujawski and the Intermodal terminal Bydgoszcz Emilianowo). Concept analysis. Infra - Centrum Doradztwa Ltd. COMBINE. Project (WP4.4)	Bydgoszcz Emilianowo intermodal terminal and Bydgoszcz-Solec Kujawski Multimodal Platform	The study presents a transport demand forecast and it modal structure including the most important transport directions, i.e.: • TriCity seaports (Gdańsk and Gdynia) • Poznań • Łódź, • Warszawa. From the extensive forecast, only collective data on the transport of cargo in containers are presented. The conversion was made assuming the cargo weight of 12 tonnes per 1 TEU.	Container transport [1000 TEU]

Direction	2019	2028	2034
Gdajnsk/Gdynia	254	277	301
Poznań	99	111	121
Łódź/Warszawa	238	259	282

Source: own elaboration

Figure 7 presents forecasts of the demand for transhipment services of the analysed terminals. The following cargo transhipment functionalities of the Bydgoszcz logistics hub are defined:

- last mile cargo flows – handled by Bydgoszcz-Emilianowo intermodal terminal (since 2024) and Bydgoszcz-Solec Kujawski Multimodal Platform (since 2035);
- gate cargo flows - handled by Bydgoszcz-Emilianowo intermodal terminal (since 2030).

It was assumed 12 tons of transported cargo per 1 TEU to ensure consistency with the forecast made by Foundation „Rozwój UTP" (2020).

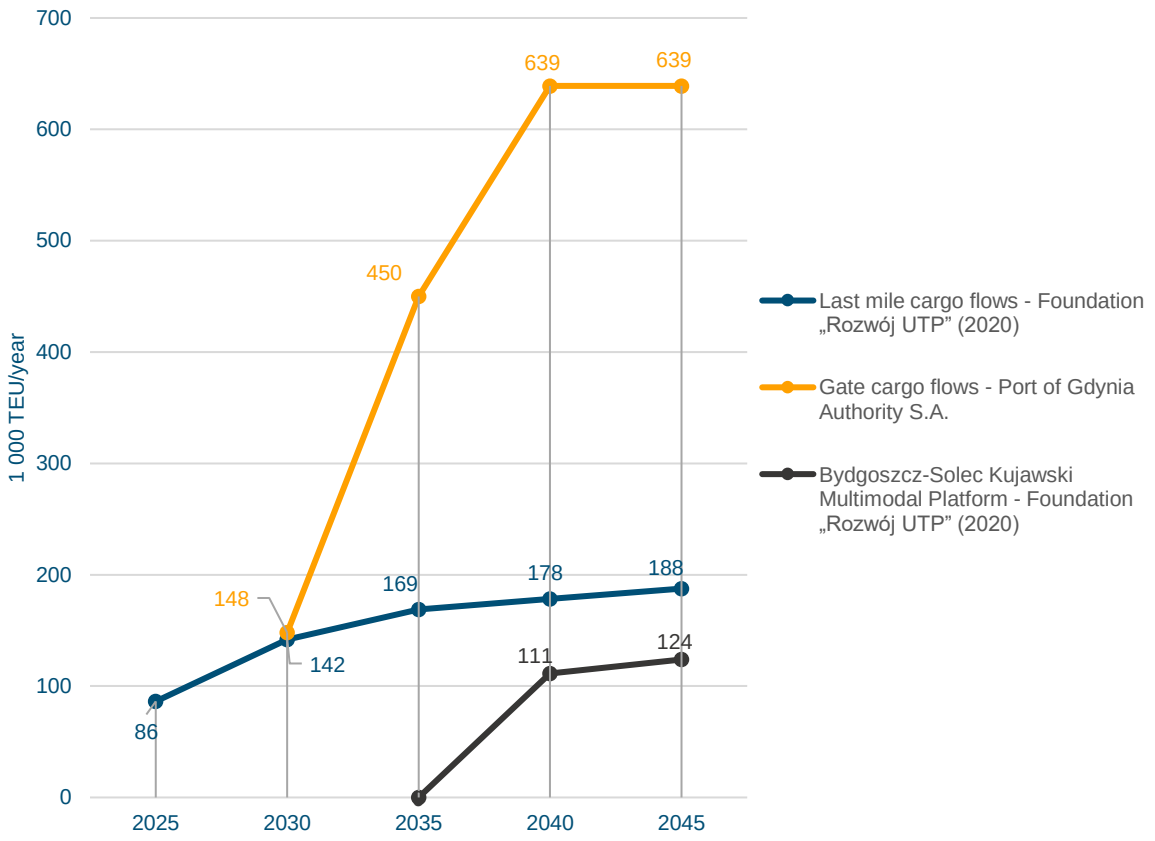

Figure 7 Last mile traffic and gate cargo flows of the Bydgoszcz logistics hub [1000 TEU]

Source: own elaboration

2 REVIEW AND RECOMMENDATIONS OF THE MOST EFFICIENT TRANSHIPMENT TECHNOLOGIES

2.1 Review and selection of transhipment technologies

The review of transhipment technologies and the selection of technologies to be implemented in the Bydgoszcz-Emilianowo intermodal terminal and Bydgoszcz-Solec Kujawski Multimodal Platform is based on the COMBINE project report, 'Analysis of combined transport terminal operations', and other thematic studies, which contain expert knowledge on the topic and also highlight examples of existing and newly-built terminals. The review takes into account the categories of combined terminals identified in the above-mentioned report. The term ‘terminal’ in the study is understood as the basic nodal infrastructure of the combined transport system, which is a commonly-used organizational form of intermodal transport[1]. This is a very broad approach in the adopted classification of terminals. It allows all types of terminals and the transhipment technologies used in terminals present on the European market to be considered.

The categories of combination terminals according to the nine classification criteria are presented below. These categories were assigned to the two analysed terminals at the Bydgoszcz logistics hub (Table 1). The basis for assigning to a given category are the conditions related to the location and access to transport and logistics infrastructure as well as technological and organizational standards of intermodal transport on the European market. The strength of the relationship with the individual categories of terminals is indicated using the following colour symbols:

1) very strong relationship – green colour,
2) strong relationship – yellow colour,
3) weak relationship – brown colour,
4) no relationship – red colour.

Table 4 Relationship between the categories of combined terminals and terminals at the Bydgoszcz logistics hub

	Bydgoszcz-Emilianowo intermodal terminal	Bydgoszcz-Solec Kujawski Multimodal Platform
C1. Classification by type of transhipped units		
a) container terminals		
b) terminals handling containers and swap bodies		
c) terminals handling containers, swap bodies and semi-trailers		

1 combined transport - intermodal transport, in which most of the carriage is made by rail, inland waterways or sea, and all initial and/or final road sections are as short as possible (Combined Transport Directive 92/106 / EEC, European Commission, SWD (2016) 141 final)

	Bydgoszcz-Emilianowo intermodal terminal	Bydgoszcz-Solec Kujawski Multimodal Platform
d) terminals handling semi-trailers		
e) terminals handling articulated vehicles (tractor and semi-trailer)		
C2. Classification by terminal capacity		
a) small terminals (< 25000 ITU)		
b) mid-size terminals (25000 ÷ 50000 ITU)		
c) large terminals (50000 ÷ 100000 ITU)		
d) very large terminals (> 100000 ITU)		
C3. Classification by transhipment technology		
a) Ro-Ro terminals		
b) Lo-Lo terminals		
c) Ro-Ro +Lo-Lo terminals		
d) specialized terminals (Modalohr, Cargobeamer)		
C4. Classification by the size of service area		
a) local and factory terminals		
b) regional and agglomeration terminals		
c) national and international terminals		
C5. Classification by operated transport modes		
a) unimodal (rail) terminals		
b) bimodal terminals (rail-road or river-road)		
c) trimodal terminals (river-rail-road)		
C6. Classification by relationship with a logistic centre		
a) terminal not related to logistics centre		
b) terminal related to one logistics centre		
c) terminal related to several logistics centres		
C7. Classification by type of ownership		
a) public terminal		
d) private terminal (not open terminal)		
C8. Classification by relationship with logistics operator		
a) terminal in a network of one operator		

	Bydgoszcz-Emilianowo intermodal terminal	Bydgoszcz-Solec Kujawski Multimodal Platform
b) terminal in networks of several operators		
c) independent terminal		
C9. Classification by place and role in the transport network		
a) global distribution hub		
b) regional distribution hub		
c) transit hub (gate terminal)		
d) dry port terminal		
e) border terminal		
f) departure/final terminal		

Source: based on 'Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR'. Project COMBINE report (WP 3.1). (Wiśnicki, 2020).

Interpretation of the above table is as follows:

1) The Bydgoszcz-Emilianowo intermodal terminal will achieve a transhipment volume of 50,000 ITU[2] and will continue to grow steadily. Handling equipment must offer lo-lo transhipment technology with the possibility of additionally using ro-ro technologies, with preference for European specialized ro-ro systems. The terminal will be of regional importance (Kujawsko-Pomorskie Voivodeship) with a special distribution role in the service area of the Bydgoszcz agglomeration. By operational connections with the Port of Gdynia, the terminal will gain an important position in the European TEN-T network, playing the role of a node in the international corridor. The terminal will have strong links with at least one logistics centre or industrial zone[3]. The terminal must be open to all customers and have an ownership model in which the terminal will be preferably in the network of several intermodal transport operators. The most important functions of the terminal in the transport network include the function of a dry port for the Port of Gdynia and the function of a transit hub (gate terminal) for intermodal cargo flows.

2) The Bydgoszcz-Solec Kujawski Multimodal Platform, as a river terminal, will only handle standard sea containers. In the first phase of development, it should reach a handling volume of up to 25,000 ITU (50,000 TEU)[4]. The handling equipment will only offer lo-lo transhipment technology.

[2] The given handling volume refers to the moment of full implementation of the terminal processes, i.e. approximately five years from the opening of the terminal
[3] Strong link with a logistics centre or industrial zone means the direct neighbourhood and connection via internal roads without the need to use public roads
[4] The given handling volume refers to the moment of full implementation of the terminal processes, i.e. approximately five years from the opening of the terminal

The terminal will be of regional importance (Kujawsko-Pomorskie Voivodeship) with a special distribution role in the service area of the Bydgoszcz agglomeration. By operational connections with the Port of Gdansk, the terminal will gain an important position in the European TEN-T network, playing the role of a node in the international corridor. The terminal may eventually be linked to a single port logistics centre. The terminal must be open to all customers and the ownership model is preferred, in which the terminal will be operationally independent. The most important function of the terminal in the transport network is the dry port function for the Port of Gdansk.

In the COMBINE Project report 'Analysis of combined transport terminal operations' seven models of combined transport terminals representative of the European market were identified. On their example, the terminal infrastructure and transhipment equipment as well as the terminal transport and logistics processes are discussed. The selected models of combined terminals include:

Model 1. Large rail-road terminal

Model 2. Small rail-road terminal

Model 3. Trimodal river terminal

Model 4. Border terminal

Model 5. Ro-La Terminal

Model 6. Cargobeamer specialized terminal

Model 7. Modalohr specialized terminal

Table 5 presents the results of the analysis of the relationship between the above-reference models of combined terminals with the analysed terminals in the Bydgoszcz logistics hub. The letter 'E' for the Bydgoszcz-Emilianowo intermodal terminal and 'SK' for the Bydgoszcz-Solec Kujawski Multimodal Platform indicate models that are fully compatible with these two terminals. The analysis considers the above-defined terminal classification criteria (Table 4) and the condition for determining compliance in a given criterion as having a very strong relationship to the same terminal category, both for the analysed terminal and the terminal reference model. For example, the Bydgoszcz-Emilianowo intermodal terminal has a strong relationship with the category 'Lo-Lo terminals' under the C3 criterion as well as with four models of combined terminals (large rail-road terminal, small rail-road terminal, trimodal river terminal and border terminal)[5].

[5] The relationship between the seven models of combined terminals and categories of terminals is shown in the COMBINE project report (Wiśnicki, 2020).

Table 5 Relationship between the terminal reference models and terminals at the Bydgoszcz logistics hub

Models of combined terminals	Combined terminals classification criteria								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
1. Large rail-road terminal	E&SK	E	E&SK	E&SK	E	E	E&SK	E&SK	E&SK
2. Small rail-road terminal	SK	SK	E&SK	E&SK	E	E&SK	E&SK	E&SK	E&SK
3. Trimodal river terminal	SK	E	E&SK	E&SK	SK	E&SK	E&SK	E&SK	E&SK
4. Border terminal	E&SK	E&SK	E&SK		E	E&SK	E&SK	E&SK	
5. Ro-La Terminal		E&SK		E&SK	E	E&SK	E		
6. Cargobeamer specialized terminal		E&SK		E&SK	E	E&SK	E&SK		
7. Modalohr specialized terminal		E&SK		E&SK	E	E&SK	E&SK		

Source: based on 'Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR'. Project COMBINE report (WP 3.1). (Wiśnicki, 2020).

The interpretation of the analysis results presented in Table 5 is unambiguous: the Bydgoszcz-Emilianowo intermodal terminal fully corresponds to the large rail-road terminal model, and the Bydgoszcz-Solec Kujawski Multimodal Platform is consistent with the trimodal river terminal model and the small rail-road terminal model. In practice, this means that the Bydgoszcz-Solec Kujawski Multimodal Platform will be a trimodal terminal, and its handling volume in the first phase of operation will correspond to a small rail-road terminal.

2.2 Reference terminals

The next part of the Pre-execution Study analyses the functionality and spatial analysis of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform. The methodology applies analogous methods using reference terminals. Hence, it is necessary at this stage to designate reference terminals that will be a model for determining technical and operational parameters for the analysed terminals. The selection was made from a group of over 400 terminals in Europe, which are classified and characterized by the AGORA portal operated by KombiConsult GmbH (http://www.intermodal-terminals.eu/) and the SGKV portal (http: //www.intermodal-map.com/). The following selection criteria were used:

1) for the Bydgoszcz-Emilianowo intermodal terminal:
   - terminals performing a dry port function for seaports,
   - terminals performing gate function in the network of European intermodal operators,
   - large rail-road terminals;

2) for the Bydgoszcz-Solec Kujawski Multimodal Platform:
   - terminals performing dry port function for seaports,

- mid-sized trimodal terminals, including extended terminal concept (rail-road terminal + river terminal).

Additional selection indications were adopted, such as transport link with a nearby agglomeration (distance less than 25 km) and technical parameters of the infrastructure corresponding to the highest standards of intermodal transport in Europe (minimum standards are included in the AGTC agreement). The search was limited to terminals operating in the network of large European intermodal operators.

In the first step, all terminals referred as dry ports in scientific publications published between 2010 and 2019 were identified (Table 6).

Table 6 European dry port terminals and related seaports

Literature source	Dry port	Seaport
Rodrigue et al., 2010	Venlo (NL)	Rotterdam (NL)
	Lyon (FR)	Marseille (FR)
	Zaragoza (ES)	Barcelona (ES)
Korovyakovsky&Panova, 2011	Shushary Distriport (RU)	Saint Petersburg (RU)
Flämig&Hesse, 2011	Maschen (DE)	Hamburg (DE)
Wilmsmeier et al., 2011	Eskilstuna (SE)	Gothenburg (SE)
	Coatbridge/Glasgow (ENG)	Grangemouth (ENG)
Monios, 2011	Azuqueca de Henares (ES) Madrid Abronigal (ES)	Barcelona+Valencia+Bilbao (ES)
Eliza, 2013	Yana/Sofia (BG) Skopje (North Macedonia)	Thessaloniki (GR)
Bask et al., 2014	Kouvola (FI)	HaminaKotka (FI)
	Hallsberg (SE)	Gothenburg (SE)
Gonzalez-Aregall&Bergqvist, 2019	Skaraborg/Falköping (SE)	Gothenburg (SE)
Rodrigue&Notteboom, 2012	Lille (FR)	Dunkirk (FR)+Antwerp (BE)
	Vilvoorde (BE) Meerhout (BE) Liege (BE) Muizen (BE)	Antwerp (BE)
	Emmerich (DE) Duisburg (DE)	Rotterdam (NL)

Source: based on a literature review

In the second step, three subgroups were separated from the terminals listed in Table 6:

1) trimodal terminals
    - Lille Dourges Container Terminal (Novatrans)
    - Emmerich Rhein-Waal Terminal (Contargo)

2) trimodal terminals extended
    - Lyon terminal (Novatrans + Port de Lyon terminal, distanced 7 km)
    - terminal Lyege (Liege Container Terminal + Liège Logistics Intermodal, distanced 9 km)

3) gate terminals
    - terminal Zaragoza Plaza (Renfe)
    - Coatbridge terminal (John G Russell)
    - Muizen terminal (Ambrogio)
    - terminal Duisburg logport III (Samskip)

In the third step, the above subgroups were analysed in terms of terminal-agglomeration transport link and the level of technical development of terminals. On this basis, reference terminals were identified.

1) for the Bydgoszcz-Emilianowo intermodal terminal
    - terminal Duisburg logport III (Samskip)
    - Zaragoza Plaza terminal (Renfe)

2) for the Bydgoszcz-Solec Kujawski Multimodal Platform
    - Lille Dourges Container Terminal (Novatrans)

Figure 8 Terminal Duisburg logport III (Samskip)

Source: https://www.wms.nrw.de/geobasis/wms_nw_dop

Figure 9 Terminal Zaragoza Plaza (Renfe)

Source: Yandex

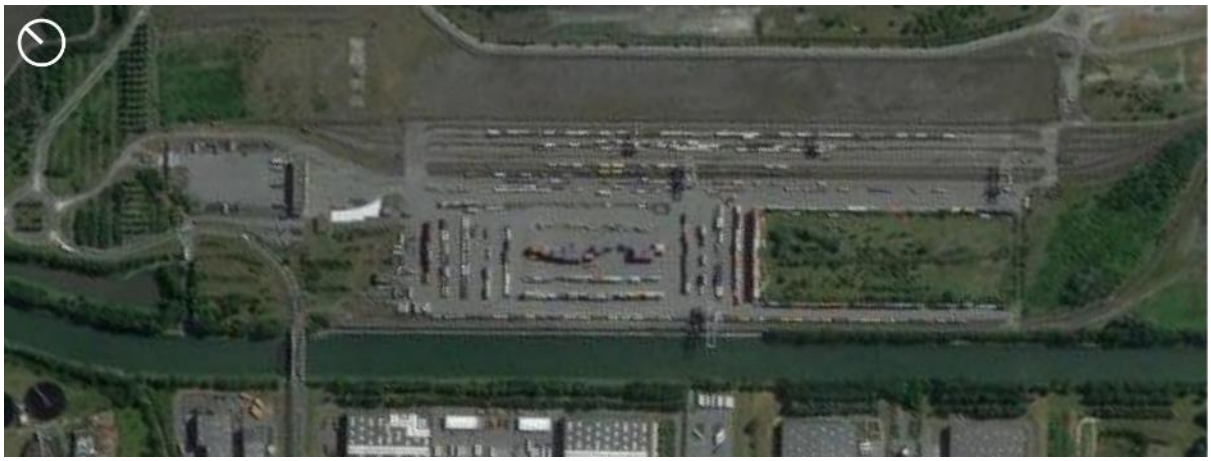

Figure 10 Lille Dourges Container Terminal (Novatrans)

Source: GoogleMaps

3 REVIEW AND RECOMMENDATIONS OF THE MOST EFFECTIVE THE LAST MILE SOLUTIONS FOR THE BYDGOSZCZ - SOLEC KUJAWSKI NODE

3.1 Review of last mile reference solutions in Europe

The review of the last mile solutions was based on the study 'Innovative last mile solutions to strengthen combined transport' prepared as the COMBINE Project report (Jankiewicz et al., 2020) as well as the authors' expert knowledge supported by relevant literature. Table 7 presents eight solutions that may be used as reference solutions for the Bydgoszcz logistics hub. The proposed solutions include:

1) the use of longer road vehicles, i.e. European Modular System (EMS),
2) the use of fully or semi-autonomous road vehicles,
3) the use of road vehicles powered by alternative fuel (LNG/CNG/H_2),
4) the use of electric road vehicles,
5) the use of hybrid road vehicles (diesel-electric),
6) 'truck platooning' system of road transport,
7) the use of regular railway connections within the logistics hub,
8) the use of regular inland shipping connections within the logistics hub.

Each of the proposed solutions will bring benefits in relation to standard road transport in the relation terminal-consignee. The first six solutions involve the use of appropriately modified road vehicles, i.e. non-standard tractors or tractor-trailer combinations, for last mile deliveries. The last two solutions involve the use of non-road modes of transport for service area deliveries, i.e. short intermodal trains or container barges. The main benefits of using each of the solutions are environmental (reduction or elimination of exhaust emissions, reducing congestion) or economic (reduction of unit transport costs).

Table 7 Characteristics of last mile solutions

Last mile solution	Description	Benefits	Limitations
Longer road vehicles, i.e. European Modular System (EMS)	Standard vehicle modules (tractor, semi-trailer, additional trailer) are compiled into a longer road train of 25.25 m. Longer EMS vehicles are used on minimum two-lane roads are coupled/decoupled in designated places (parking lots or satellite terminals).	• EMS technology is widely used in Scandinavian countries. • No investment in the fleet vehicles. • Fewer tractor units and drivers are involved. • Less exhaust emissions.	• EMS requires obtaining permits for oversized transport. • It can only be used on two- and three-lane roads. • Necessary investments in the adaptation of parking infrastructure and/or construction of satellite terminals. • The solution is effective only for long routes and large volumes transported to one destination. • Limited social acceptance.
Fully or semi-autonomous road vehicles	The tractor unit is operated semi-automatically (driver assistance) or automatically (without driver). Technology already proven in internal transport. Test runs on public roads have been carried out since 2019 (Sweden).	• Involving fewer drivers or eliminating drivers' work. • Increased loading capacity and system reliability.	• Costly investments in new fleet vehicles. • Technology under testing and currently not available on the market. • Lack of applicable legal regulations • The need to eliminate a high risk to traffic safety. • Unknown additional implementation cost. • Limited social acceptance.

Last mile solution	Description	Benefits	Limitations
Vehicles powered by alternative fuel (LNG/CNG/H_2)	The tractor unit runs on gas fuel and is powered by suitably modified internal combustion engines (LNG/CNG) or uses electricity from fuel cells (H_2). LNG/CNG powered vehicles are offered by numerous manufacturers and H_2 powered vehicles are not yet available on the market.	• The LNG/CNG engines technology is rapidly implemented in European countries. • Reduced (LNG/CNG) or no exhaust emissions (H2).	• Costly investments in new fleet vehicles. • Fuel cell technology (H_2) is being tested and is currently not commercially available. • Lack of sufficient number of fuel stations offering LNG/CNG and H_2. • Very small difference in exhaust emissions comparing to the newest Diesel engines. • The range of the truck after fuelling is only 1000 km for LNG and 500 km for CNG.
Electric road vehicles	The tractor unit is powered by an electric motor and the energy is stored in large batteries. Electric tractor units are offered by numerous manufacturers in the European market.	• Electric truck technology is already widely implemented spread in Germany. • No exhaust emissions.	• Costly investments in new fleet vehicles. • Increased empty weight of tractor units by approx. 15%. • Not enough charging points. • The range of the truck after loading is max. 500 km.
Hybrid road vehicles (diesel-electric)	The tractor unit is powered alternatively by a diesel combustion engine and an electric motor. As a rule, the electric motor has only a supporting role. The solution is offered by manufacturers, but so far not widely used in Europe.	• The technology gives a choice in terms of the type of drive, e.g. electric in built-up areas and diesel out of agglomerations. • No emissions from electric drive.	• Costly investments in new fleet vehicles. • A slightly higher tare weight of the tractor unit. • Not enough charging points. • Very short range of the electric drive.

Last mile solution	Description	Benefits	Limitations
Truck platooning system	The vehicles move in a convoy keeping short distances from each other. The driver may be partially exempted from driving the vehicle. Additional equipment for vehicles is necessary. Technology being tested in Europe.	• The technology saves fuel. • Ultimately, it is possible to drive without drivers in some convoy vehicles.	• Investments in additional vehicle equipment. • Technology under testing and all options are currently unavailable. • The solution is effective only for long routes and large volumes transported to one destination. • It can only be used on two- and three-lane roads. • Small fuel savings (6%).
Regular railway connections within the logistics hub	The deliveries are carried out by regular rail connections with the use of short intermodal trains or specialized freight railbuses (e.g. TruckTrain). Containers and swap bodies are handled at satellite terminals within the area of the logistics hub.	• The solution gives economies of scale resulting from transport in large capacity means of transport. • Elimination of the road congestion effects. • High reliability and flexibility of the delivery system while maintaining alternative terminal-consignee road deliveries. • Reduction of exhaust emissions.	• Necessary investments in satellite terminals. • Possible investments in specialized rolling stock. • Possible extension of the delivery time. • The road section of the last mile transport remains.
Regular inland shipping connections within the logistics hub	Shipments are carried out by regular inland shipping connections with the use of small container barges. Containers are handled at terminals with access to waterways within the area of the logistics hub.	• The solution gives economies of scale resulting from transport in large capacity means of transport. • Elimination of the road congestion effects. • High reliability and flexibility of the delivery system while maintaining alternative terminal-consignee road deliveries. • Reduction of exhaust emissions.	• Necessary investments in satellite terminals. • Possible investments in specialized rolling stock. • Possible extension of the delivery time. • The road section of the last mile transport remains. .

Source: based on ‘Innovative last mile solutions to strengthen combined transport’. Raport projektu COMBINE (Jankiewicz et al., 2020)

3.2 Selection of solutions and recommendations for the Bydgoszcz logistics hub

After the intermodal terminal Bydgoszcz-Emilianowo is launched as the central point in the Bydgoszcz logistics hub, it will be necessary to implement technical and organizational solutions for last mile deliveries in the service area of the terminal. The investment schedule presented for the purposes of this study provides for the terminal's commissioning in 2024 and a gradual increase in its turnover as part of its distribution function. The forecast presented in COMBINE Project report 'Concept of the last mile freight traffic on the city's road network for the Bydgoszcz logistics hub' (Foundation „Rozwój UTP" (2020) predicts that that last mile transport should reach approx. 140,000 TEU in 2030 (Figure 7). The year 2030 is a rational time horizon for choosing a 'last mile' transport solution for the Bydgoszcz-Solec Kujawski hub. Recommendations for a longer development perspective will be burdened with the lack of proper knowledge about the state of technology and external market conditions. Hence, the methodically correct choice of the last mile solution for the Multimodal Platform Bydgoszcz-Solec Kujawski cannot be made. Regardless of the future possibilities, it seems logical for this project to exploit the potential of the waterways inside the Bydgoszcz logistics hub and to set up regular inland shipping connections using small container barges.

Taking into account the priorities of the transport policy and local conditions, the following criteria were adopted, necessary to be met by the last mile transport solutions for the Bydgoszcz-Emilianowo intermodal terminal:

Criterion 1. The solution must be commercially available in Europe, i.e. fully implemented and tested in at least one of the European countries,

Criterion 2. The solution must provide effective transport services for customers in the area of the Bydgoszcz logistics hub (Figure 2),

Criterion 3. The solution must allow for the transport of intermodal units (containers, swap bodies) in a terminal-consignee relation,

Criterion 4. The solution must bring environmental benefits,

Criterion 5. The solution must be scalable (the possibility of a gradual increase in the number of shipments) and must provide a transport capacity of 140,000 TEU in 2030.

When analysing all the previously proposed solutions in terms of meeting the criteria indicated, four of them can be considered for the recommendations (Table 7). Acceptable solutions include: the use of alternative propulsion vehicles (LNG/CNG, electric, diesel-electric engine) and the use of regular rail connections within the logistics hub. The indicated alternative propulsion technologies are characterized by a similar level of implementation on the European market. By far the greatest environmental benefits are brought using fully electric vehicles, which are emission-free. Therefore, this solution in the field of vehicle engine modification should be considered the best. The use of short intermodal trains or specialized freight trains (e.g. TruckTrain) can be a complementary solution to the use of electric vehicles.

Table 8 Matrix for selecting the last mile solution for the Bydgoszcz-Emilianowo intermodal terminal

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
EMS					
autonomous vehicles					
LNG/CNG/H_2	LNG/CNG H_2				
electric vehicles					
hybrid vehicles					
truck platooning					
railway connections					
barge connections					

Source: own elaboration

In conclusion, it is recommended to use road vehicles powered by an electric motor for last mile deliveries from the Bydgoszcz-Emilianowo intermodal terminal. In the case of larger volumes of cargo carried to one destination, it is advisable to launch rail connections within the logistics hub using short intermodal trains or specialized freight trains. An example of such a train is the modular TruckTrain, which can have a capacity of 2 to 21 TEU (Figure 11).

Figure 11 Visualisation of the TruckTrain freight railcar

Source: http://trucktrain.co.uk/

The recommended circular route of an intermodal train connecting several satellite terminals in the area of the Bydgoszcz agglomeration is shown in Figure 12. The figure additionally shows the recommended circular barge route, which could serve the Solec Kujawski Multimodal Platform in the future.

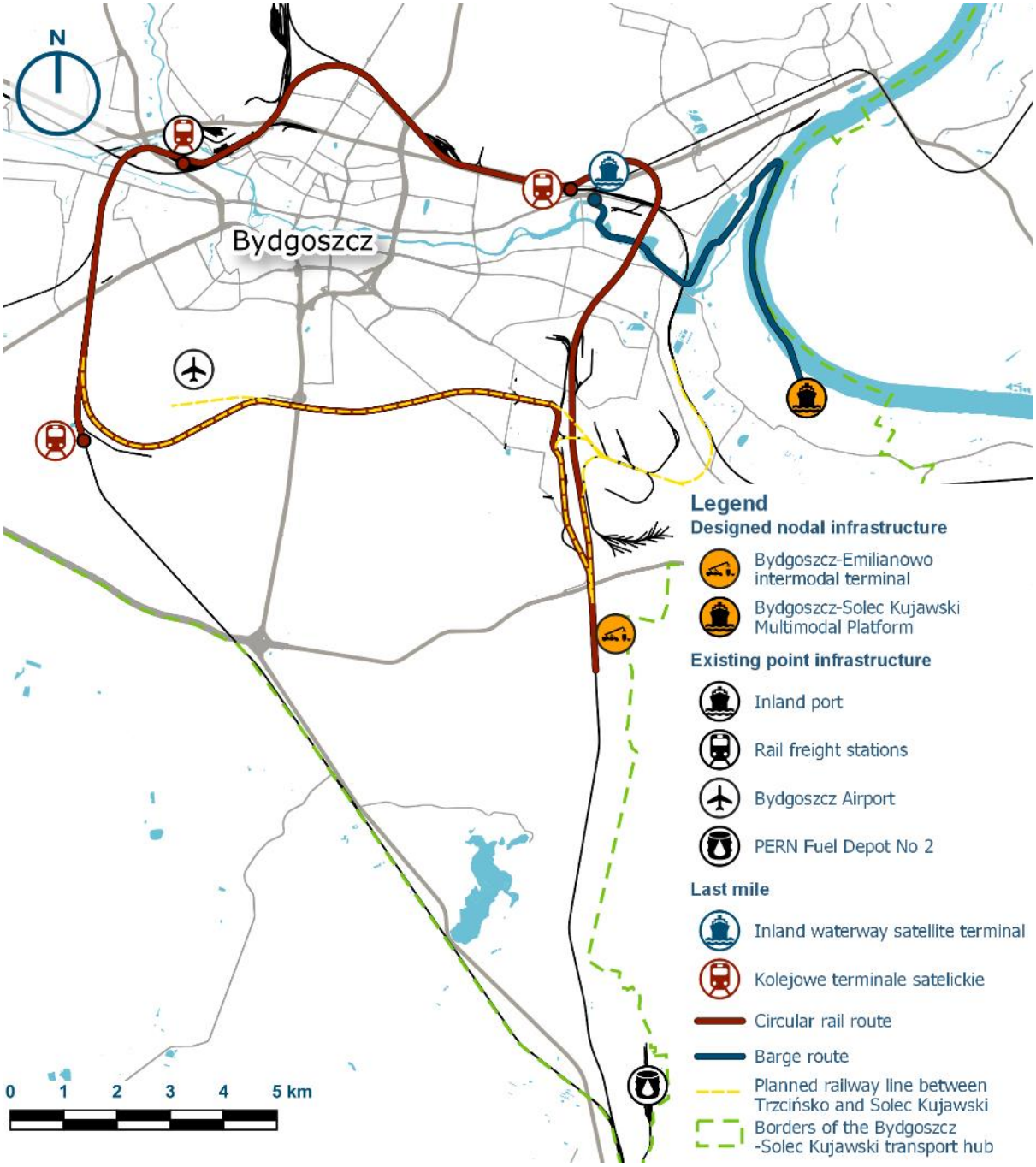

Figure 12 Rail and water transport routes inside the Bydgoszcz logistics hub

Source: own elaboration

4 MINIMUM FUNCTIONAL PROGRAM

4.1 Methodical introduction

Chapter 2.2 identifies 3 reference terminals, selected among 21 European dry port terminals linked with seaports of north-western, northern, and southern Europe. The identification and selection were made in 3 steps detailed in chapter 2.2. In the first step, the selection criterion was the function performed by the terminal in the intermodal transport network, complemented by criteria of capacity and modes of transport served. In the next step, for 8 terminals undergoing further analysis, 3 sub-groups were separated - 2 spatial sub-groups for trimodal terminals and 1 sub-group, which includes rail-road terminals. In the third and final step, based on the terminal-agglomeration relation analysis and the analysis of the level of technical development of the terminal, 3 reference terminals were identified.

With a similar function, they are characterized by a variety of features in the range:

- handling capacity - expressed in annual turnover of transport units;
- type of intermodal transport units handled;
- modes of transport served.

Thanks to this, the group of reference terminals is cross-sectional, necessary for its usefulness in the subsequent stages of the analysis using the analogy to the reference objects to determine the basic functional and spatial parameters of the intermodal terminal Bydgoszcz-Emilianowo and the Multimodal Platform Bydgoszcz-Solec Kujawski.

The following section presents the location of the intermodal reference terminals with the seaports they serve. The following steps were taken:

- analysis of the functions performed by the reference terminals;
- analysis of transport links for trimodal terminals dispersed on the selected example;
- multi-criteria analysis, which resulted in the selection of functions of the reference terminals to be the subject of spatial analysis;
- determination of the minimum functional program.

The conducted research was based on data made available by operators and infrastructure owners, supplemented by information obtained in the course of documentary and spatial analyses.

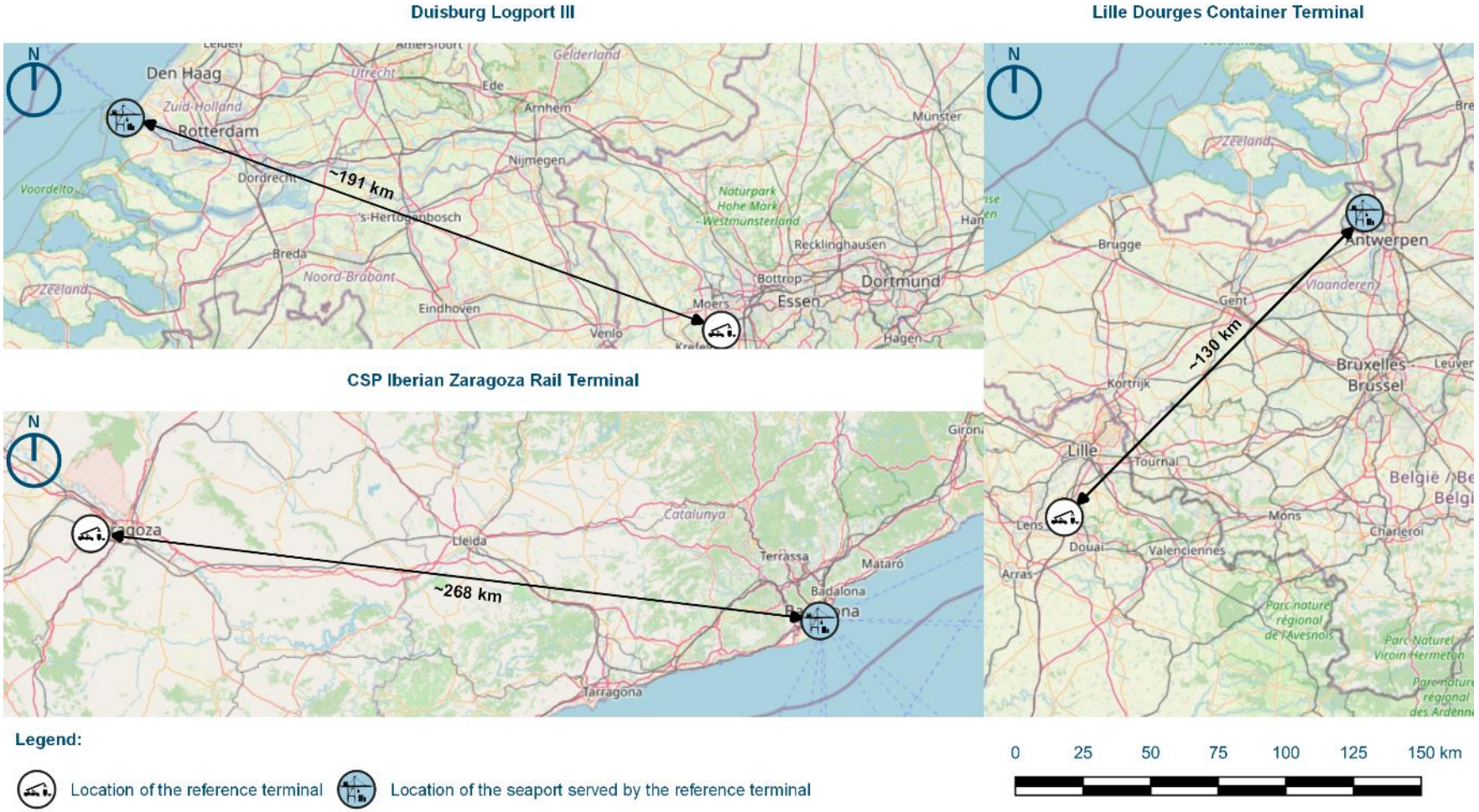

Figure 13 Location of reference terminals against the background of the seaports they serve

Source: OpenStreetMap

4.2 Characteristics and analysis of reference terminals

4.2.1 Analysis of functions performed by intermodal terminals

Characteristics and analysis of the functions performed by intermodal terminals were conducted according to their characteristics:

- handling function;
- the storing function for transport units;
- the forwarding and inspection services (e.g. customs and border clearance);
- providing additional services (e.g. washing and repairing of loading units, repairing of means of transport).

Its summary is presented in tabular and graphic form on the following pages of the study (Tables 9-11, Figures 14-17).

Table 9 Duisburg Logport III terminal characteristics

Terminal: Duisburg logport III (Samskip)

Functions performed at the terminal		***Performance of the function / Scope of performance***	***Key infrastructure parameters***
Transhipment	*Transhipment of containers*	Yes	• 3 rail-road loading fronts • Transhipment tracks: ○ 6 x 720 m ○ 2 x 700 m
	Transhipment of swap bodies	Yes	
	Transhipment of semi-trailers	Yes	
Storage		• Full units storage • Container depot	• 254 semi-trailers slots • 576 45ft container slots
Transport chain support		• Cross-docking • Customs services	• Storage facilities • Office facilities • Designated customs clearance points for transport units
Serving of transport units		• Container repair • Weighting	Workshop facilities Truck weight
Logistics potential of the location		A terminal located within an agglomeration	
The area for expansion		The lack of area for expansion	

Source: own elaboration

Table 10 Zaragoza Plaza (Renfe) / CSP Iberian Zaragoza Rail Terminal characteristics

Terminal: Zaragoza Plaza (Renfe) / CSP Iberian Zaragoza Rail Terminal

Functions performed at the terminal		***Performance of the function / Scope of performance***	***Key infrastructure parameters***
Transhipment	*Transhipment of containers*	Yes	• 1 rail-road loading front • Transhipment tracks: ○ 5 x 750 m ○ 1 x 665 m
	Transhipment of swap bodies	Yes	
	Transhipment of semi-trailers	No	
Storage		• Full units storage • Container depot	Capacity 3 300 TEU
Transport chain support		Customs services	• Storage facilities • Designated customs clearance points for transport units
Serving of transport units		• Container repair • Weighting	Workshop facilities Truck weight
Logistics potential of the location		• Direct neighbourhood of the industrial park • Close proximity of the airport	
The area for expansion		The space to double the capacity and size of storage yards.	

Source: own elaboration

Table 11 Lille Dourges Container Terminal characteristics

Terminal: Lille Dourges Container Terminal (Novatrans)

Functions performed at the terminal		**Performance of the function / Scope of performance**	**Key infrastructure parameters**
Transhipment (rail-road fronts)	*Transhipment of containers*	Yes	• 2 rail-road loading fronts • Transhipment tracks: ○ 3 x 750 m ○ 2 x 750 m
	Transhipment of swap bodies	Yes	
	Transhipment of semi-trailers	No	

Terminal: **Lille Dourges Container Terminal (Novatrans)**

Functions performed at the terminal		**Performance of the function / Scope of performance**	**Key infrastructure parameters**

Transhipment (rail-road-water front)	*Transhipment of containers*	Yes	• 2 loading fronts:
			  ○ rail-road
			  ○ rail-road-water
			• Transhipment tracks: 2 x 750m

	Transhipment of swap bodies	Yes	
	Transhipment of semi-trailers	No	
Storage		• Full units storage • Container depot	Capacity 2 500 TEU

Transport chain support		• Logistics centre
		• Fuel station
		• Office facilities for external logistics companies
		• Customs services
			• 3 existing warehouse complexes:
			  ○ complex 1: 280 000 m2
			  ○ complex 2: 130 000 m2
			  ○ complex 3: 2 x 35 000 m2
			• 2 warehouse complexes under construction:
			  ○ complex 4 – planned: 2 x 11 000 m2
			  ○ complex 5: 350 000 m2
			• Office facilities
			• Wyznaczone miejsca odprawy celnej jednostek ładunkowych

Serving of transport units		• Vehicle service and trailer rental • Weighting	Workshop facilities - external partner Truck weight
Logistics potential of the location		Logistics city directly connected with the terminal	
The area for expansion		• Possibility of doubling the area of storage yards • Space for the extension of the rail-road front • Space for more than doubling the length of the rail-road-water front	

Source: own elaboration

Maps with the marking of functional zones of the reference terminals are presented on the following pages.

Figure 14 Main functional zones of the Dusiburg Logport III terminal

Source: https://www.wms.nrw.de/geobasis/wms_nw_dop

Figure 15 Main functional zones of the CSP Iberian Zaragoza Rail Terminal

Source: Yandex

Figure 16 Main functional zones of the Lille Dourges Container Terminal – including terminal services zones

Source: Google Maps

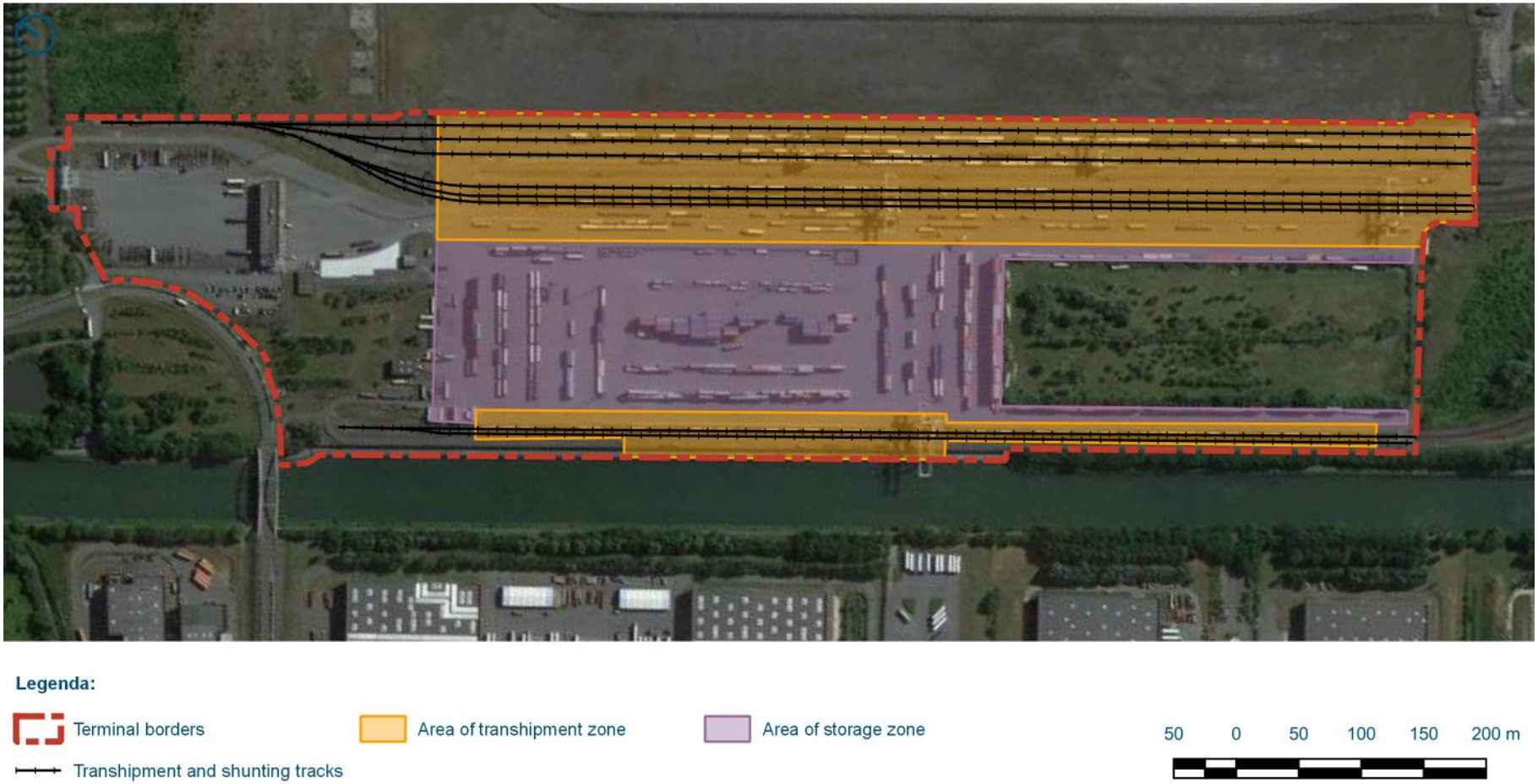

Figure 17 Main functional zones of the Lille Dourges Container Terminal - within the terminal borders

Source: own elaboration

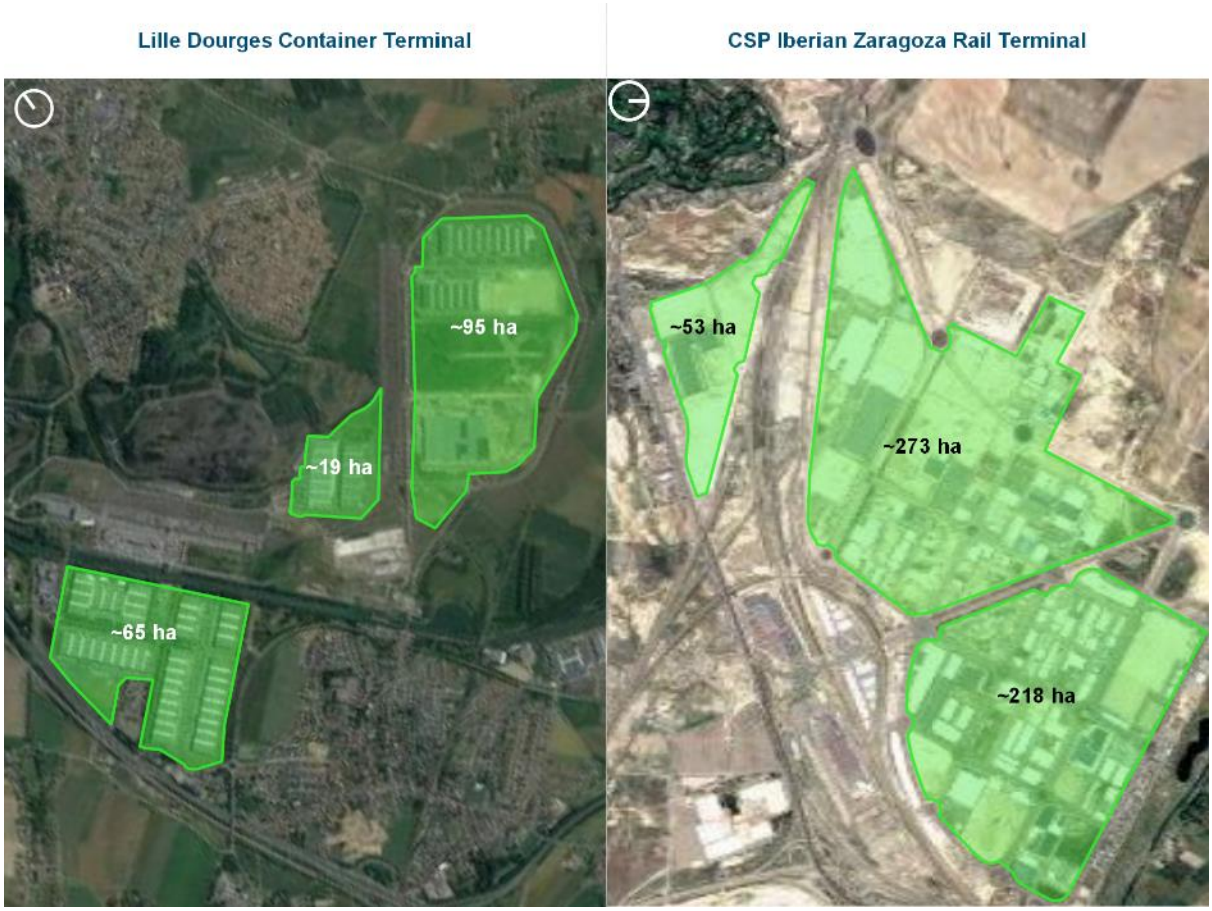

Figure 18 Examples of concentration of associated activity development around reference intermodal terminals

Source: Google Maps

The above-described characteristics of the functions performed within the reference terminals allow to formulate the following conclusions:

- As a standard, the length of tracks forming the rail transhipment front should be assumed to be 750 m.
- In all cases, the reloading function is carried out using gantry cranes (Gantry Crane). This type of handling equipment is typical for large intermodal terminals (capacity over 50,000 TEU/year).
- The location of the terminal determines its development potential and business profile. If the terminal is adjacent to industrial areas or located within the city limits, the development of terminal services will be minimised, and they will be offered in the form of outsourcing outside the terminal area. This is visible on the example of the Duisburg Logport III terminal, which is an agglomeration terminal. A characteristic feature of such terminals is the lack of space for their development. Terminal services are limited to a minimum, as they are met by entities dispersed within the agglomeration. In the case of terminals adjacent to an industrial zone such

as the Zaragoza terminal, terminal services are dispersed outside the terminal within that industrial zone.

- The example of Lille Dourges Container Terminal illustrates the concentration of a "logistics city" around the terminal.
- In all analysed cases, the concentration on the basic functions - transhipment and storage - is visible. The other functions are implemented in the form of handing over land or infrastructure to third parties specialised in a specific activity. The standard is that the terminal offers only weighing and the possibility to carry out customs clearance - carried out under a separate order.

4.2.2 Analysis of transport links between distributed trimodal terminals

The following pages present graphically the communication links (road and rail) between the dispersed intermodal terminals. The selection of examples has been made in such a way that one terminal is trimodal and the other one rail-road. Therefore, the situation reflects the plans for independent development of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform.

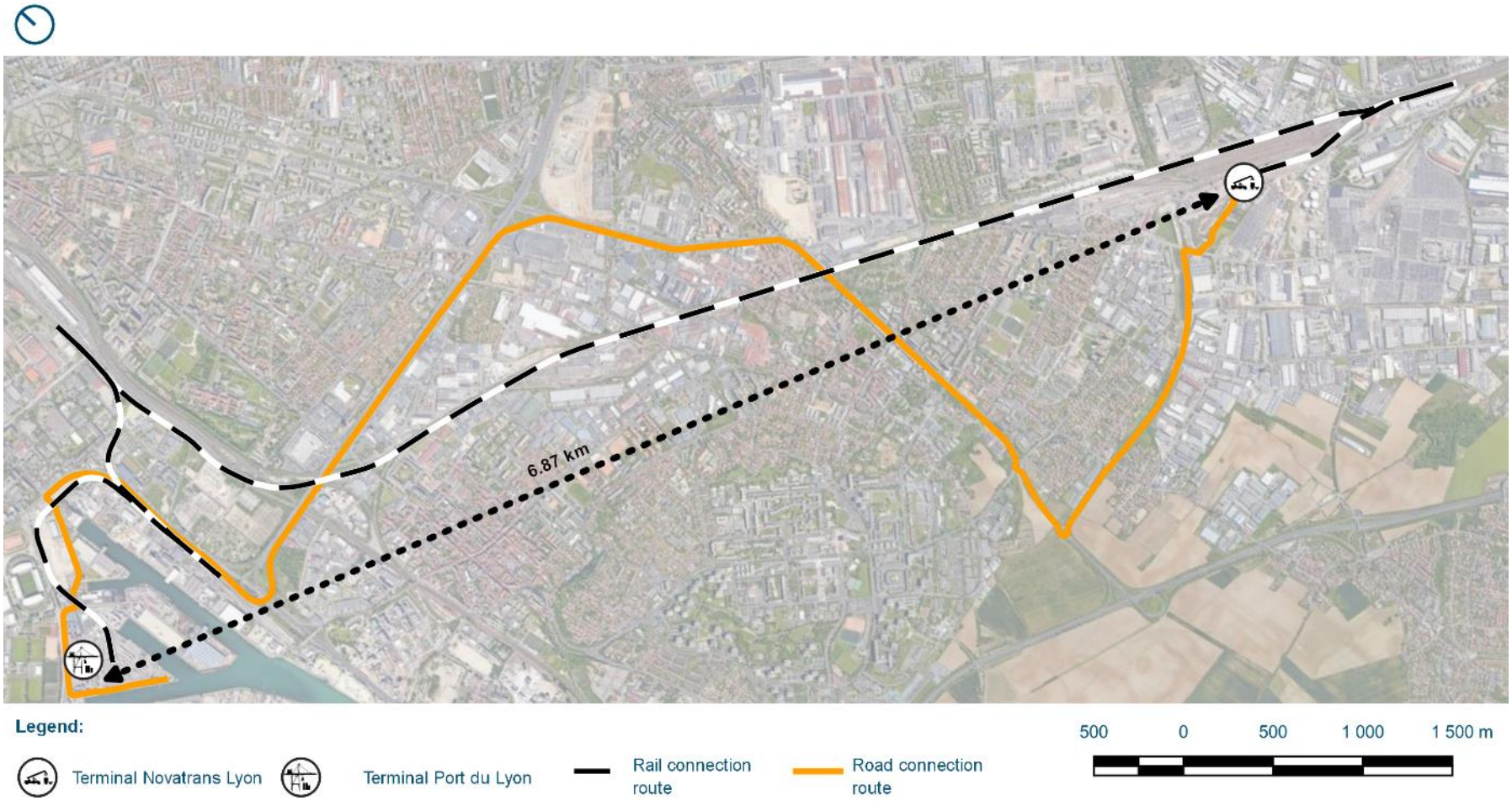

Figure 19 Connections within the trimodal dispersed terminal - Lyon du Port terminal and Novatrans Lyon terminal

Source: Google Maps

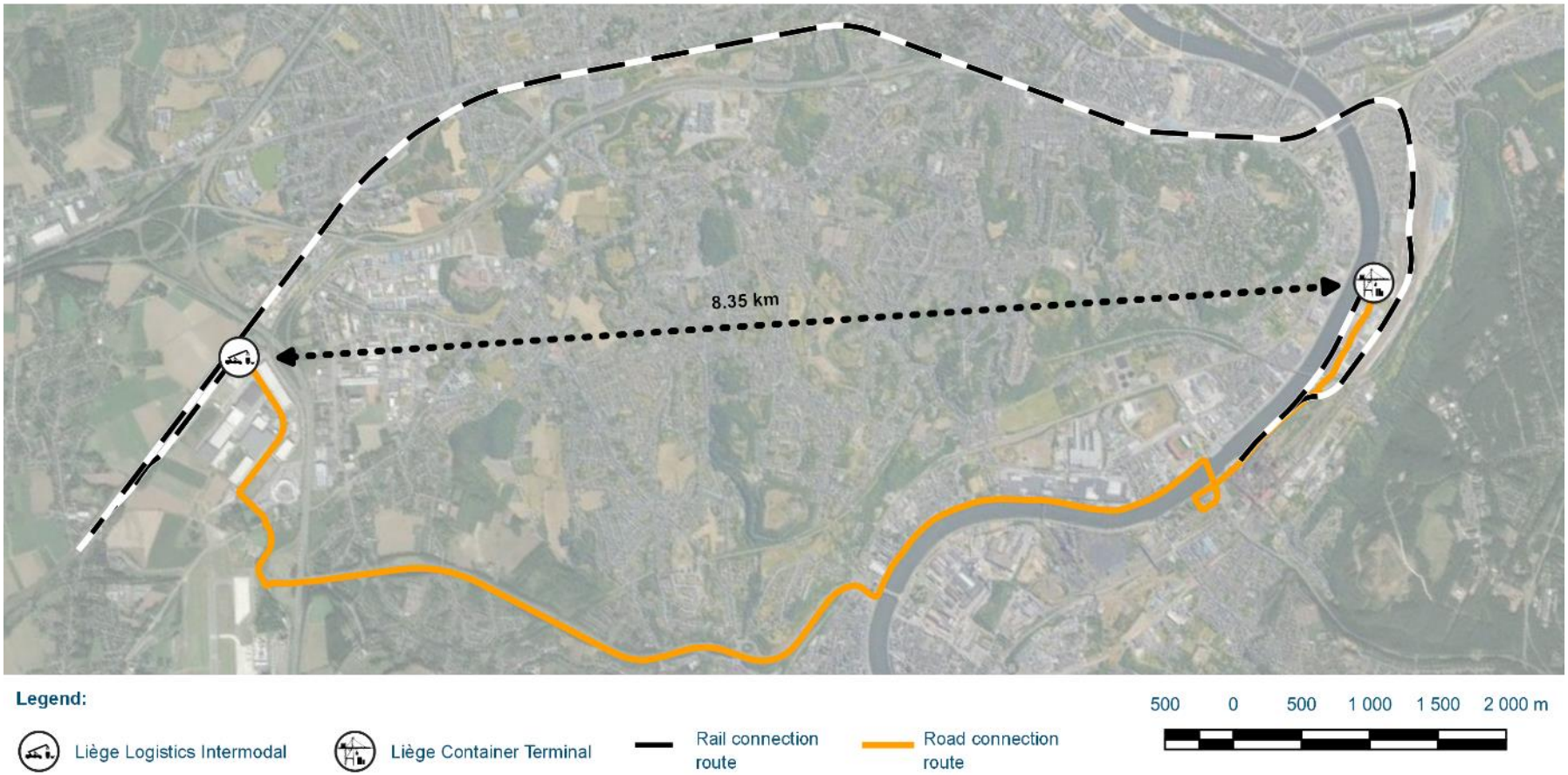

Figure 20 Connections within the trimodal dispersed terminal - Liege Container Terminal and Liege Logistics Intermodal

Source: Google Maps

The analysis of both examples enables the following conclusions to be drawn:

- In terms of space, the location of terminals in Liege corresponds to the planned location of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform. Liège Logistics Intermodal is located in the immediate vicinity of the motorway junction. It is not surrounded by urban development. There are industrial and warehousing buildings in the back of it.
- The railway link between the dispersed terminals, i.e. the inland waterway terminal and the rail-road terminal, may involve great difficulties resulting in additional shunting work and longer journey times. Take the links between the Novatrans Lyon and Port du Lyon terminals, where the straight-line distance is 6.87 km, and the rail distance is about 14 km and requires a triple change of direction. Without large investments in the new railway system, a similar situation may occur in the case of the railway link between the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform.
- Both dispersed terminals are located such that the road link is convenient in the case of Liege (generally accessible two-lane roads with collision-free intersections) and acceptable in the case of Lyon (generally accessible roads, on a significant section of a two-lane road).

The perspective in which the link between the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform will be launched is so distant that it is impossible to clearly define its business and technological model. The current state of technology and market conditions make it possible to formulate a thesis that due to a different business model, the expected traffic between the terminals will be dispersed hourly and quantitatively. For this reason, it will be unattractive to railway carriers. A rational solution is to base communication links on road transport. As it is not possible to create a separate connection, closed for external traffic, due to the costs and spatial conditions, it is recommended to use a model that utilises public and publicly-accessible road infrastructure for this purpose. In such a case, it is necessary to provide the necessary area buffer for, among others, future extension of the S10 expressway with additional driving lanes.

4.3 Multi-criteria analysis of reference terminals

The analysis was conducted under the scheme of fulfils/doesn't fulfil for particular functional attributes and parameters of the reference terminal (Tables 12 and 13). The criteria were determined based on assumptions resulting from previous studies on the subject of the investment, the results of consultations and workshops carried out as part of the Prefeasibility Study, and the analysis of functional models of intermodal terminals. The defined criteria are related to the perspective after 2030, i.e. the period when Bydgoszcz-Emilianowo intermodal terminal will be the transit hub.

Table 12 Criteria used for the multi-criteria analysis of the reference terminals

No.	Criterion	Necessary parameter/condition	Reference
1	Type of transhipped units	• Containers • Swap bodies • Semitrailers	The criterion according to the classification of terminals (table 4, chapter 2.1) based on the COMBINE project report 'Analysis of combined transport terminal operations' (Wiśnicki, 2020).
2	Number and parameters of rail-road loading fronts (planned at the Bydgoszcz-Solec Kujawski Multimodal Platform)	• ≥ 2 rail-road loading fronts • ≥ 5 transhipment tracks • ≥ 750 m in length of each transhipment track	The criterion determined by the categorization of terminals presented in '2020 Report on Combined Transport in Europe' (UIC, 2020). The condition relates to parameters of a large rail-road terminal. The length of transhipment tracks determined by the requirements of the project stakeholders provided during consultations.
3	Number and parameters of rail-road-water loading fronts (planned at the Bydgoszcz-Emilianowo intermodal terminal)	• 1 x rail-road loading front • 1 x rail-road-water loading front • ≥ 2 transhipment tracks • ≥ 750 m in length of each transhipment track • min. 2 mooring berths	The criterion determined by the categorization of terminals presented in '2020 Report on Combined Transport in Europe' (UIC, 2020). The condition relates to parameters of a medium rail-road terminal. The length of transhipment tracks determined by the requirements of the project stakeholders provided during consultations.
4	Terminal primary services (internal)	• Customs clearance area • Weighing area	The criterion based on the standard offer of intermodal terminal operators.
5	Terminal services zone (external) - logistics, servicing of means of transport and loading units	Terminal services zone (internal and external) equal to or greater than the terminal area*	Condition determined on the basis of the authors' expertise.
6	Area of storage yards and internal parking areas for trailers (planned at the Bydgoszcz-Solec Kujawski Multimodal Platform)	≥ 5 ha	The area of storage yards and parking areas at a large rail-road terminal estimated on the basis of '2020 Report on Combined Transport in Europe' (UIC, 2020).
7	Terminal development area	Backup area equal to or greater than the area of storage yards	The criterion determined by: • the categorization of terminals presented in '2020 Report on Combined Transport in Europe' (UIC, 2020); • maximum possible cargo flows indicated in Table 3, Chapter 1.6.
8	Terminal external parking area	Minimum 50 parking places for trailers	The criterion determined by the estimated number of vehicles necessary for the last mile distribution flows specified in the COMBINE project report 'The concept of the last mile freight traffic on the city's road network for the Bydgoszcz logistics hub'

* Area for service companies at a road distance of up to 1 km from terminal borders.

Source: own elaboration

Table 13 Multi-criteria analysis of reference terminals

No	Criterion	Parameter	Duisburg Logport III	CSP Iberian Zaragoza Rail Terminal	Lille Dourges Container Terminal
1	Type of transhipped units	• Shipping containers • Swap bodies • Semi-trailers	• Shipping containers • Swap bodies • Semi-trailers	• Shipping containers • Swap bodies	• Shipping containers ITU • Swap bodies

2	Number and parameters of rail-road loading fronts (planned at the Bydgoszcz-Solec Kujawski Multimodal Platform)	• ≥ 2 rail-road fronts
		• ≥ 5 transhipment tracks
		• ≥ 750 m each track length
			• 3 rail-road loading fronts
			• Number and length of transhipment tracks:
			  ○ 6 x 720 m
			  ○ 2 x 700 m
				• 2 rail-road loading fronts
				• Number and length of transhipment tracks:
				  ○ 5 x 750 m
				  ○ 1 x 665 m
					• 3 rail-road loading fronts
					• Number and length of transhipment tracks:
					  ○ 3 x 750 m
					  ○ 2 x 750 m

3	Number and parameters of rail-road-water loading fronts (planned at the Bydgoszcz-Emilianowo intermodal terminal)	• 1 x rail-road loading front • 1 x rail-road-water loading front • ≥ 2 transhipment tracks • ≥ 750 m each track length • min. 2 barge berths			• 1 x rail-road loading front • 1 x rail-road-water loading fornt • Number and length of transhipment tracks: 2 x 750 m • 2 barge berths
4	Terminal services zone (external) - logistics, servicing of means of transport and loading units	Site area for external activities equal to or larger than the terminal area*	No	Yes	Yes
5	Area of storage yards and internal parking areas for trailers (planned at the Bydgoszcz-Solec Kujawski Multimodal Platform)	≥ 5 ha	~3.2 ha	~2.1 ha	~5.3 ha

No	Criterion	Parameter	Duisburg Logport III	CSP Iberian Zaragoza Rail Terminal	Lille Dourges Container Terminal
6	Terminal primary services (internal)	• Customs clearance area • Weighing area	• Customs clearance area • Weighing area	• Customs clearance area • Weighing area	• Customs clearance area • Weighing area
7	Terminal development area	Spare space at least equal to the current area of the storage yards	No	Yes	Yes
8	Terminal external parking area	At least 50 parking spaces for heavy goods vehicles	No	No	Yes

* Area for service companies at a road distance of up to 1 km from terminal borders.

Source: own elaboration

The features of the reference terminal that fully meet the defined criterion are marked green, while those of the assessed features that partially meet the criterion or are important for determining the minimum functional programme of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform are marked orange (Table 13).

The Lille Dourges Container Terminal (Novatrans) meets the highest number of criteria relating to the Bydgoszcz-Emilianowo intermodal terminal. The results of the assessment confirm that the Bydgoszcz-Emilianowo intermodal terminal, despite its agglomeration location, will be functionally closer to dry ports located on the border of the agglomeration or outside its borders. They are characterized by a greater capacity of storage yards than agglomeration and transit terminals. They are also surrounded by industrial and storage facilities, which benefit from the direct vicinity of the terminal, often without the need for transporting the transport unit using public roads.

The Lille Dourges Container Terminal (Novatrans) is the only trimodal reference terminal. For this reason, the characteristics related to trimodality have been assessed under separate criteria. The results of the analysis in the part relating to the expected functionalities and parameters of the trimodal terminal confirm the accuracy of the selection of the reference terminal.

The infrastructure of intermodal reference terminals, which is responsible for meeting the criteria indicated in Table 13, will be subject to further spatial analysis, which will determine the dimensioning of key infrastructure elements (area, length, width) and their location towards functional zones.

4.4 Spatial analysis of reference terminals

According to the results of the multi-criteria analysis presented in Table 13, the following pages present, in graphical form, the results of the spatial analysis of the three reference terminals, i.e. Lille Dourges Container Terminal, Duisburg Logport III and CSP Iberian Zaragoza Rail Terminal, in order to determine the minimum functional requirements of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform. Spatial analysis by practice allows the determination of characteristic spatial parameters of the functional zones of the terminals, with particular attention to their loading fronts. According to the multi-criteria analysis of the reference terminals, the most observations and measurements were made for the Lille Dourges Container Terminal, whereas for the Duisburg Logport III and CSP Iberian Zaragoza Rail Terminal the analysis included a narrower range of characteristic parameters.

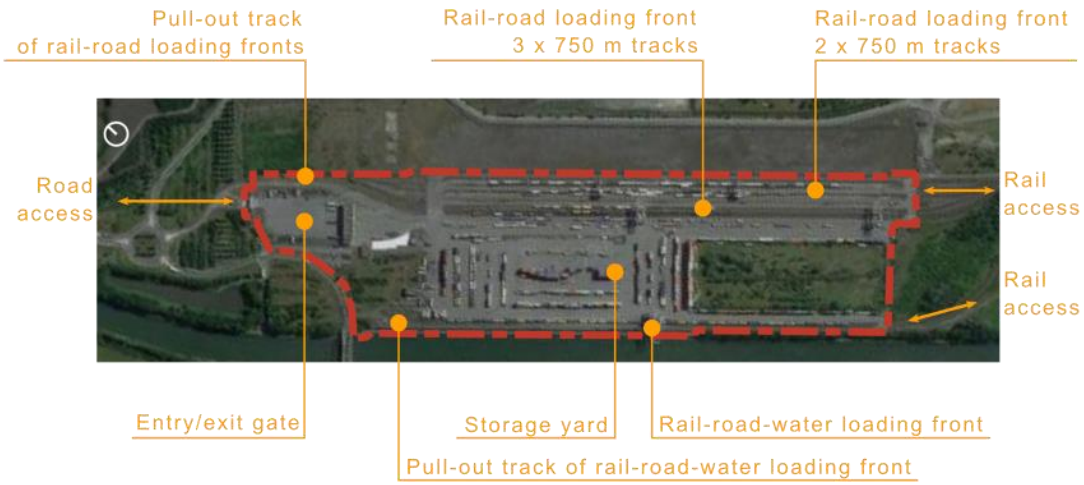

Figure 21 Location of the loading fronts of Lille Dourges Container Terminal in relation to functional areas

Source: Google Maps

Figure 22 Spatial analysis of the Lille Dourges Container Terminal loading fronts - sheet 1

Source: Google Maps

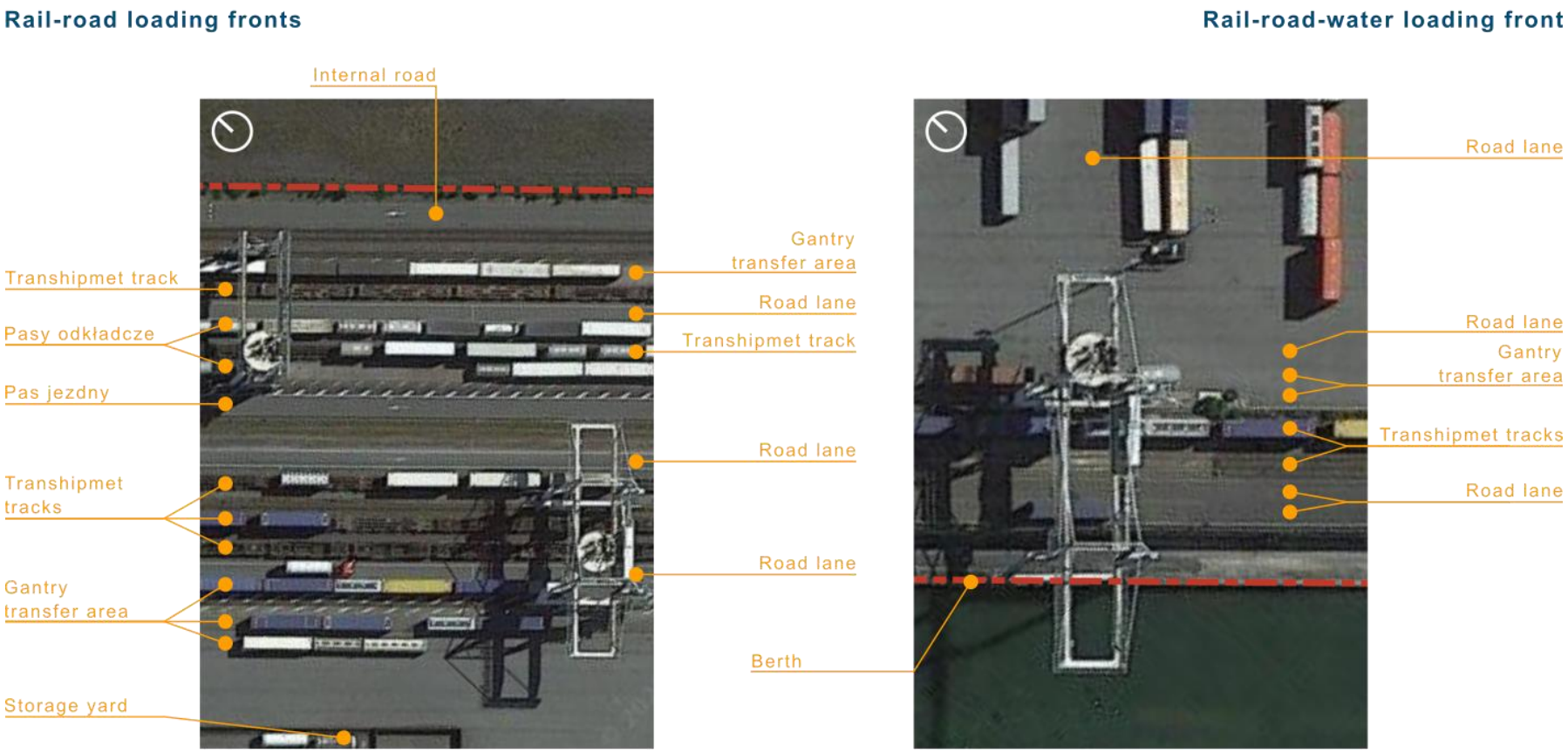

Figure 23 Spatial analysis of the Lille Dourges Container Terminal loading fronts - sheet 2

Source: Google Maps

Storage yard

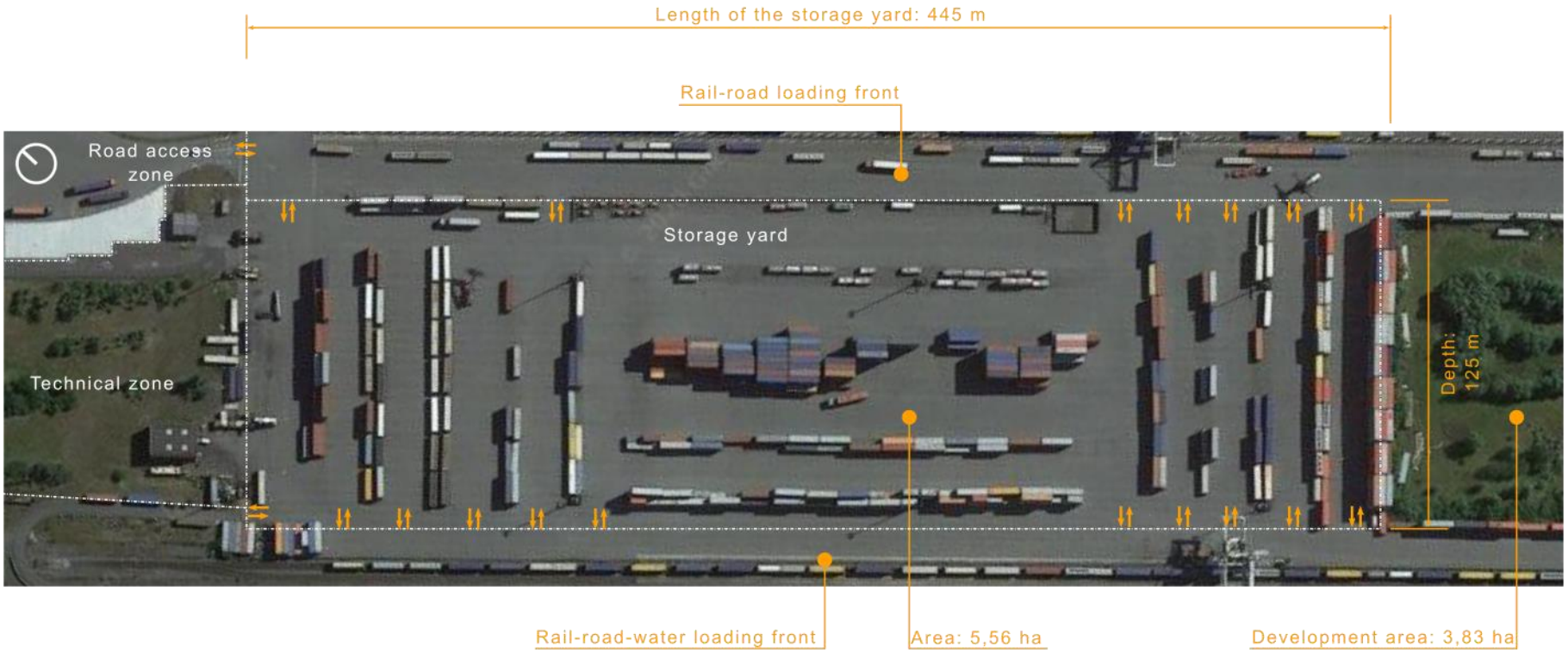

Figure 24 Spatial analysis of the Lille Dourges Container Terminal storage yard

Source: Google Maps

Figure 25 Spatial analysis of the CSP Iberian Zaragoza Rail Terminal

Source: Yandex

Figure 26 Spatial analysis of the Duisburg Logport III terminal - sheet 1

Source: https://www.wms.nrw.de/geobasis/wms_nw_dop

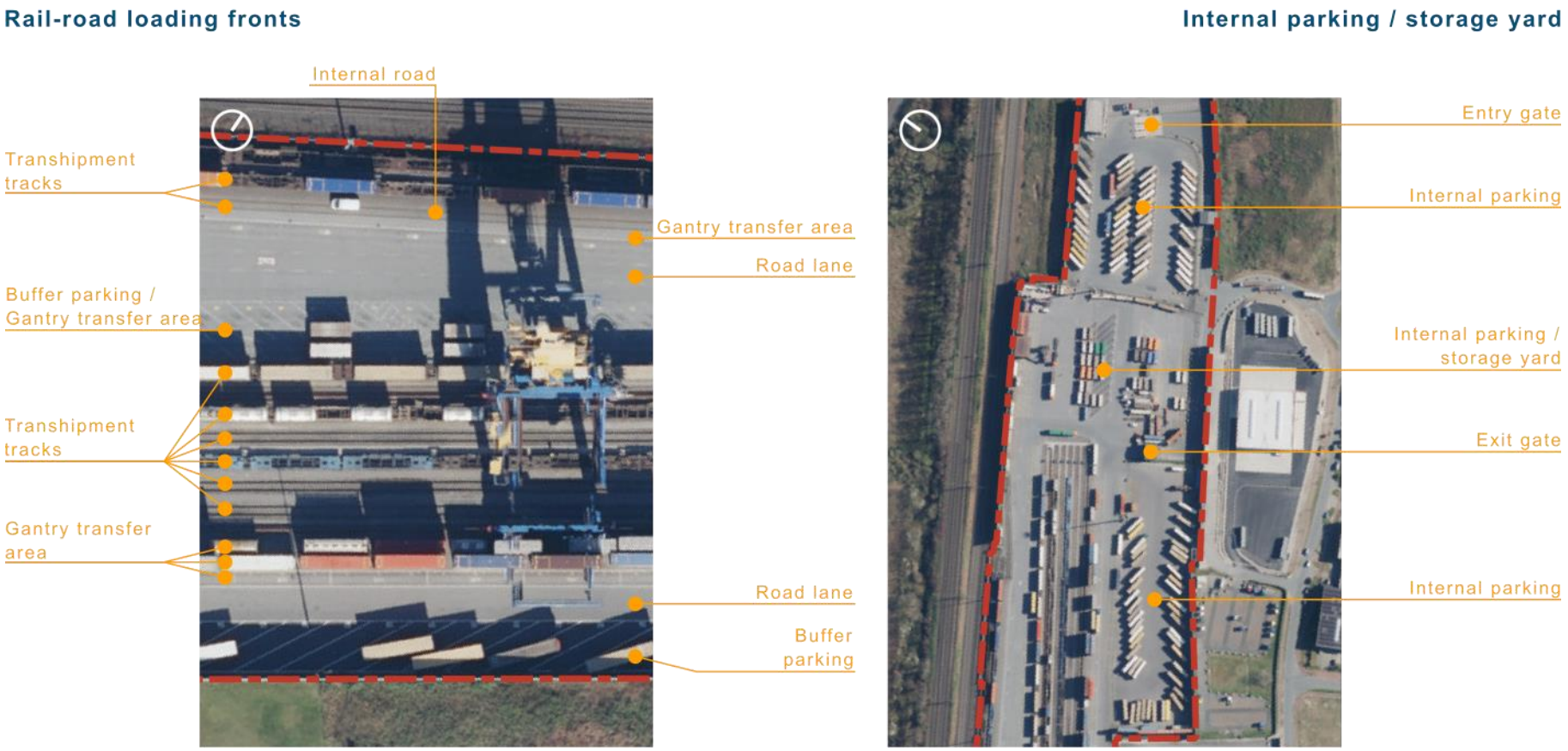

Figure 27 Spatial analysis of the Duisburg Logport III terminal - sheet 2

Source: https://www.wms.nrw.de/geobasis/wms_nw_dop

Below there is a summary of the spatial analysis carried out, distinguishing three reference terminals.

1) Lille Dourges Container Terminal (Novatrans)
   - Figure 21 marks the position of loading fronts in relation to zones and infrastructure elements. The trimodal character of the terminal with a clear spatial separation of the rail-road fronts from the rail-road-water front determined the location of the storage function and the road entry/exit in the central axis. It should be noted that the transhipment tracks are blind. There is a railway siding to the east of the terminal, which allows a maximum limitation of shunting work.
   - In Figure 22, it is worth noting that the real length of the loading front is longer than the length of the transhipment track on which the main loading device operates. It is enlarged by additional access roads linked to front use and access for means of transport. This solution can be found everywhere where there are laneways for trucks and/or terminal equipment between the bundles of transhipment tracks. The length of the berths, with 2 berths, indicated in Figure 22, is, in the authors' opinion, the minimum necessary length. At the same time, the quay itself can be easily extended to 3 berths by extending the gantry crane tracks.
   - According to the markings in Figure 23, the sections of all fronts have been selected to provide the necessary gantry transfer areas. This is a necessary solution for the role of a transit hub, which will result in combining within a single train, units transhipped to other trains and units intended for road distribution.

2) CSP Iberian Zaragoza Rail Terminal
   - Figure 25 illustrates what the spatial layout of the infrastructure is like when a single-track bundle serves only one loading front. In this case, there is no crossing of road and rail traffic.
   - The terminal has 2 loading fronts, of which the north-eastern one with a single sorting track is not used for transhipment purposes. This solution has significantly increased the useful capacity of the storage yard.
   - The main bundle of transhipment tracks is pass-through, and the electric traction is located a few dozen metres from the border of the loading fronts. This allows the necessary shunting work to be drastically reduced.

3) Duisburg Logport III terminal
   - Figure 26 presents a terminal with an extended central bundle of 6 transhipment tracks. The surrounding loading fronts have a significant buffer area for intermodal transport units and semi-trailers.
   - The terminal's intra-agglomeration location results in lack of possibility to expand internal car parks and storage yards along the loading fronts (Figures 26 and 27). For this reason, the necessary buffer and storage area is located largely axially - at the rear of the blind transhipment tracks. Only one of the designated internal car parks is situated along the loading front.
   - Figure 27 shows in detail the cross-sectional layout of the loading fronts. It differs from the layouts shown in Figure 23 by the clear separation of the front served by the crane from the front served by the reachstackers and by the absence of any storage and traffic areas between the gantry crane tracks. The area used for buffering of the transport units is delimited on the outer sides of the transhipment tracks.

4.5 Determining the minimum functional program of the Bydgoszcz-Emilianowo intermodal terminal

4.5.1 Functional-spatial zones with their characteristics

Work on the functional and spatial structure of the Bydgoszcz-Emilianowo intermodal terminal focused on the essential elements of infrastructure:

- loading fronts,
- handling and storage facilities,
- track layout,
- road layout,
- administrative, technical and gateway facilities.

According to the adopted methodology, the parameters of these infrastructure elements were determined based on functional and spatial solutions of the reference terminals, including the following specific location conditions:

- assumption of the pass-through character of the terminal;
- elimination of the risk of restrictions on the operational activities of the northern loading front related to the construction of the southern front;
- the possibility of staging the construction of the southern front.

The above assumptions were formulated based on workshops and consultations with the participation of the Project Stakeholders, as indicated in chapter 1.2.

The developed layout of the functional zones is shown in Figure 28, followed by a table with the characteristics of the functional-spatial zones.

Figure 28 Functional zones of the Bydgoszcz-Emilianowo intermodal terminal - southern loading front

Source: own elaboration

Table 14 Functional zones of the Bydgoszcz-Emilianowo intermodal terminal with a brief description

Functional zone	Area in ha	Characteristics

Transhipment	24,2	• 3 ail-road loading fronts, including:
		  ○ 2 handled by a gantry cranes, with the possibility of vertical handling of containers, swap bodies and semi-trailers;
		  ○ 1 Modalohr system loading front;
		• 7 loading tracks, 750 m each, including 6 within the reach of gantry cranes, 1 track on the Modalohr system loading front.

Storage	18,24	• Storage yard with an area of 4.6 ha, developed in two stages; • Storage yard located centrally between two main loading fronts equipped with gantry cranes; • Internal car parks - for trucks and semi-trailers.
Terminal services zone (internal)	14,05	• Area for administration and office facilities; • Technical facilities - modelled on those of Lille Dourges Container Terminal and Zaragoza Plaza terminals.
Terminal services zone (external)	6,77	• Buffer parking for the terminal; • Transport units service facilities; • Means of transport service facilities; • Logistics and warehousing facilities and facilities for production activities.

Source: own elaboration

Despite the location of the southern cargo front in the direct vicinity of the northern front, its construction should be treated as a greenfield investment. Due to the necessity to ensure uninterrupted operation of the northern loading front and the assumption of no interference with its spatial layout, the investment will require separate communication with the public road network and separate incorporation into the railway line No. 201 on the south end (towards Nowa Wieś Wielka). Therefore, it will be necessary to build an access road connecting the entry/exit gate with the voivodeship road No. 274. It is also necessary to extend the rail siding by a track parallel to the railway line No. 201, which will be incorporated into the track system of Emilianowo station, from which the shunting and transhipment tracks of the southern front will depart.

The required basic infrastructure parameters are given in Table 15. The access infrastructure is shown in Figures 41 and 42.

4.5.2 Basic infrastructure elements with minimum technical, spatial and other characteristic information

The main elements of the Bydgoszcz-Emilianowo intermodal terminal infrastructure are presented in Table 15, together with basic technical, spatial, and functional requirements.

Similar to the requirements for terminal infrastructure, Table 16 presents the requirements for access infrastructure.

Table 15 Technical and spatial requirements for the infrastructure of the Bydgoszcz-Emilianowo intermodal terminal

No	Infrastructure element	Functional zone	Characteristic parameters	Equipment in installations
1.	Transhipment tracks	Transhipment zone	• 6 x 750 m tracks within the gantry cranes range • 1 x 750 Modahlohr loading front • axle load 221 kN • rail track embedded in the surface only at crossings with the terminal's road system	• Installation of rainwater collection and drainage from embedded tracks • Traffic control equipment
2.	Storage yard	Storage zone	• Depth: 71.5 m • Length: 828 m • Area: ○ stage I: 2,32 ha ○ stage II: 2,28 ha • Load capacity: 260 kN/wheel • Surface: concrete	• Installation of rainwater collection and drainage from embedded tracks • Electrical connectors for reefers on the storage yard • Power supply system for lighting and CCTV system and Wi-Fi access points located on lighting poles
3.	Surfaces of internal roads and maneuvering areas	Transhipment zone Terminal services zone	• Surface: concrete • Load capacity: 260 kN/wheel • Single road lane width: 4 m • Single roadway, one- and two-way sections	• Telecommunication installation with connectors enabling connection of the CCTV system and Wi-Fi access points to the network
4.	Surfaces of gantry crane lanes	Transhipment zone	• 4 lanes (2 for each 2 loading fronts) • Length: 770 m / each • Width: 3.30 m / each • Gantry crane tracks embedded in the surface	• Installation of rainwater collection and drainage from embedded tracks • Power grid and power supply connections for gantry cranes
5.	Gate	Terminal services zone	• 4 gateway lanes: ○ 3 entry lanes ○ 1 exit lane • additional 1 internal traffic lane	• Power connector enabling power supply of barriers, terminals (in the form of kiosks) and possibly other systems installed within TOS • Connection to the internal telecommunication network enabling connection of terminals (kiosks) and other systems installed within TOS • 2 embedded truck scales - 1 at the entrance and 1 at the exit
6.	Car parks for heavy goods vehicles	Terminal services zone (external)	• Surface: concrete • Load capacity: 11,5 kN/axle • Hygienic and sanitary facilities for drivers	• Equipped with installations such as those in points 4 and 5, plus power and electrical installation for the driver's hygienic and sanitary facilities
7.	Terminal administration	Terminal services zone	• Two-storey • Modular	The building should be equipped with the following installations: • water and sewage systems

No	Infrastructure element	Functional zone	Characteristic parameters	Equipment in installations
	and office facilities			• central heating • air conditioning • electrical • lightning protection • structural network
8.	Technical and workshop facilities	Terminal services zone	• Single-storey workshop, two-storey administrative part; • Modular	The building should be equipped with the following installations: • water and sewage systems • central heating • Mechanical ventilation and workplace exhaust ventilation • electrical • lightning protection • stairwell smoke ventilation • burglary and robbery alarm system • structural network • CO (NOx) level detection in the workshop hall
9.	RTG or RGM gantry crane		• Gantry crane at the rail-road front constructed as part of stage I - working span: 29 m • Gantry crane at the rail-road front constructed as part of stage II - working span: 45 m • Drive: electric • Load capacity 40t	
10.	Reachstackers		• Drive: combustion engine or alternative • Load capacity 40t	

Source: own elaboration

Table 16 Technical and spatial requirements for an access infrastructure

No	Infrastructure element	Characteristic parameters	Equipment in installations
1.	Siding track on the access section from Nowa Wieś Wielka, the section parallel to the terminal, and on the entry sections from the northern loading front	• Axle load 221 kN • GPL-1 gauge	• Traffic control devices • Automatic Video Gate (entry / exit gates)
2.	Access roads	• Class of public roads: „Z” • Cross-section of internal and public roads: single road - 2 x 3.00 m • The road structure corresponding to traffic category KR6	• Storm water collection and drainage system • Power supply system for street lighting

Source: own elaboration

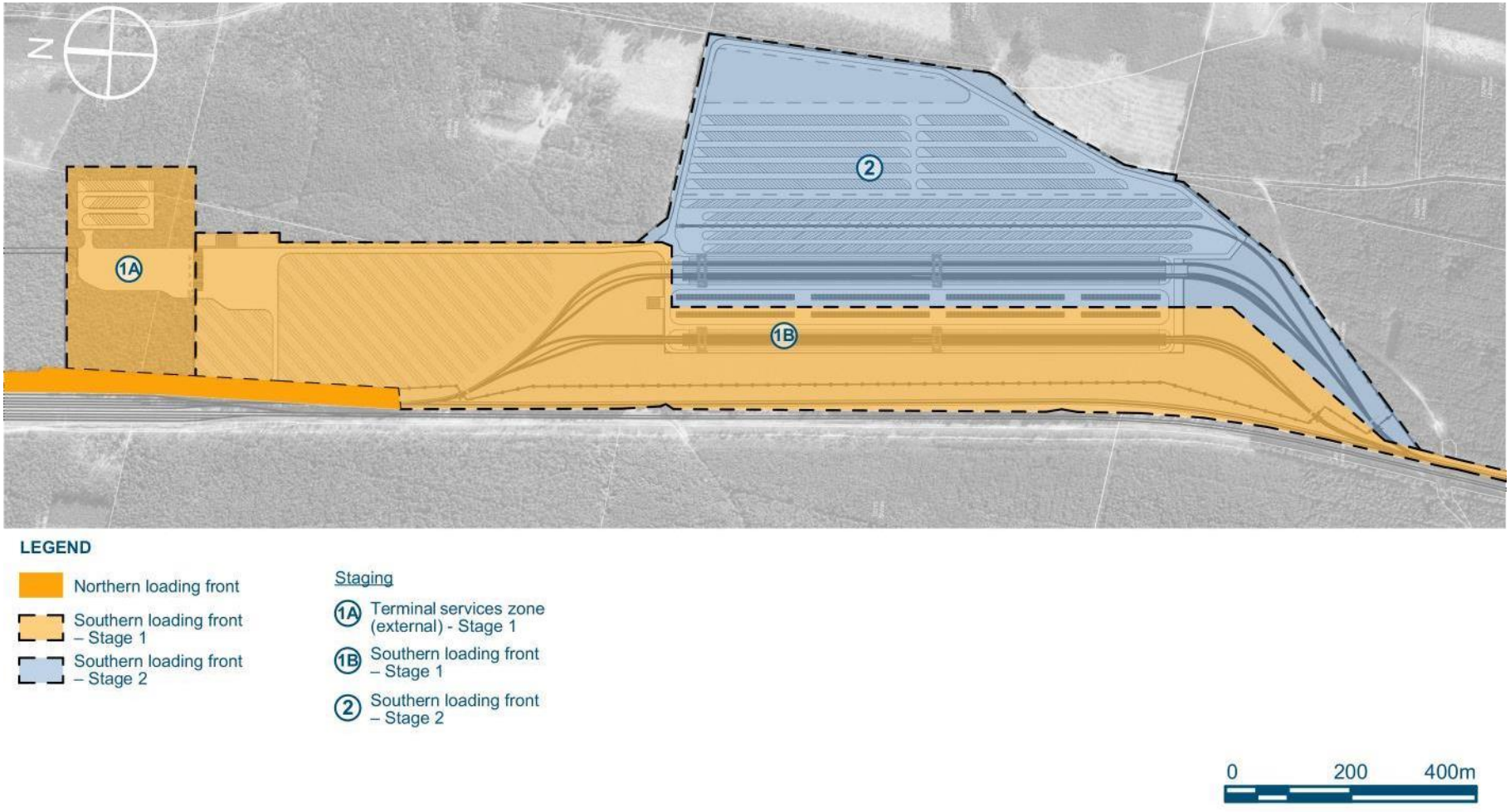

Figure 29 Terminal construction staging

Source: own elaboration

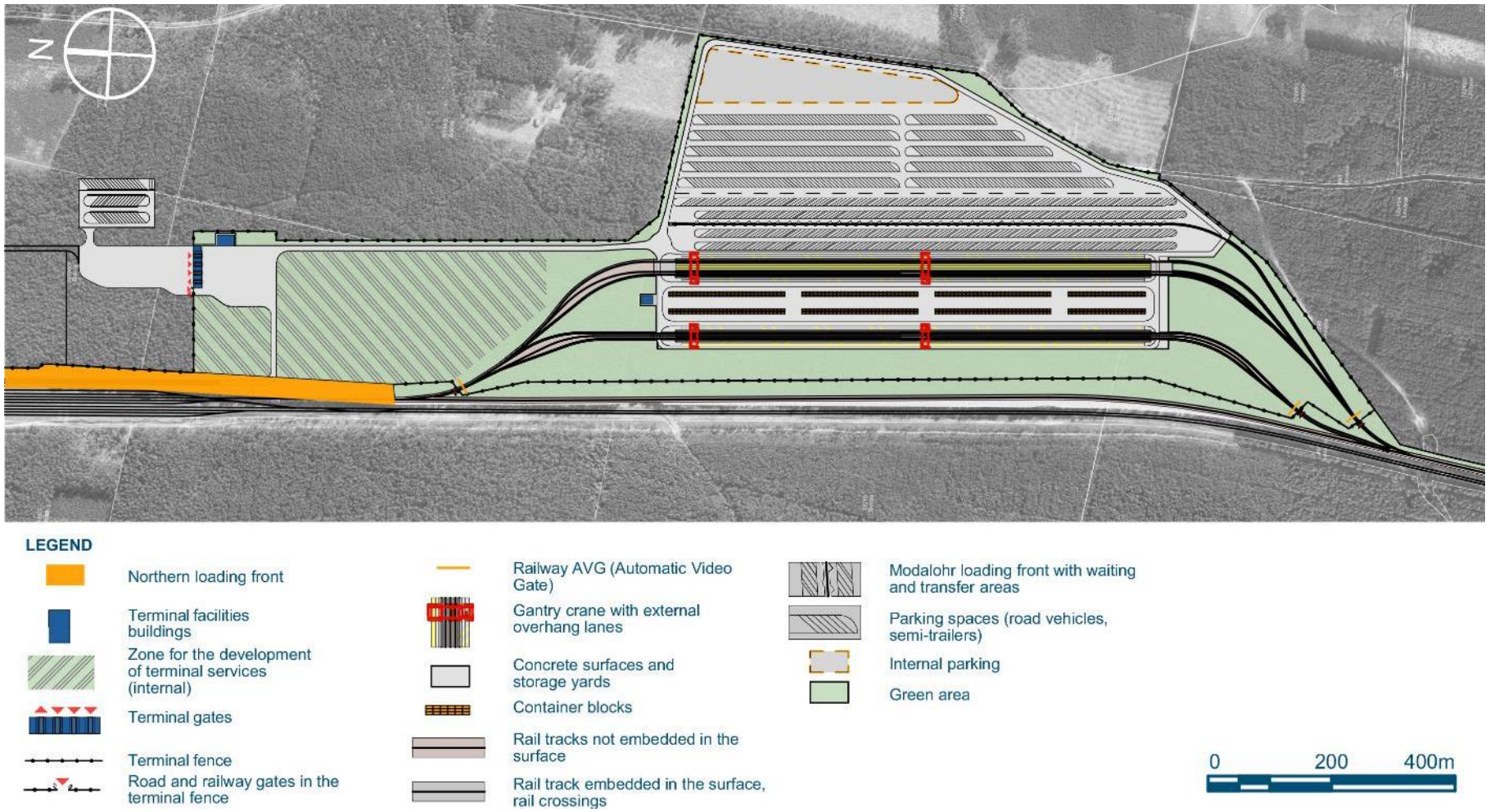

Figure 30 Land use concept for the southern loading front of the Bydgoszcz-Emilianowo intermodal terminal

Source: own elaboration

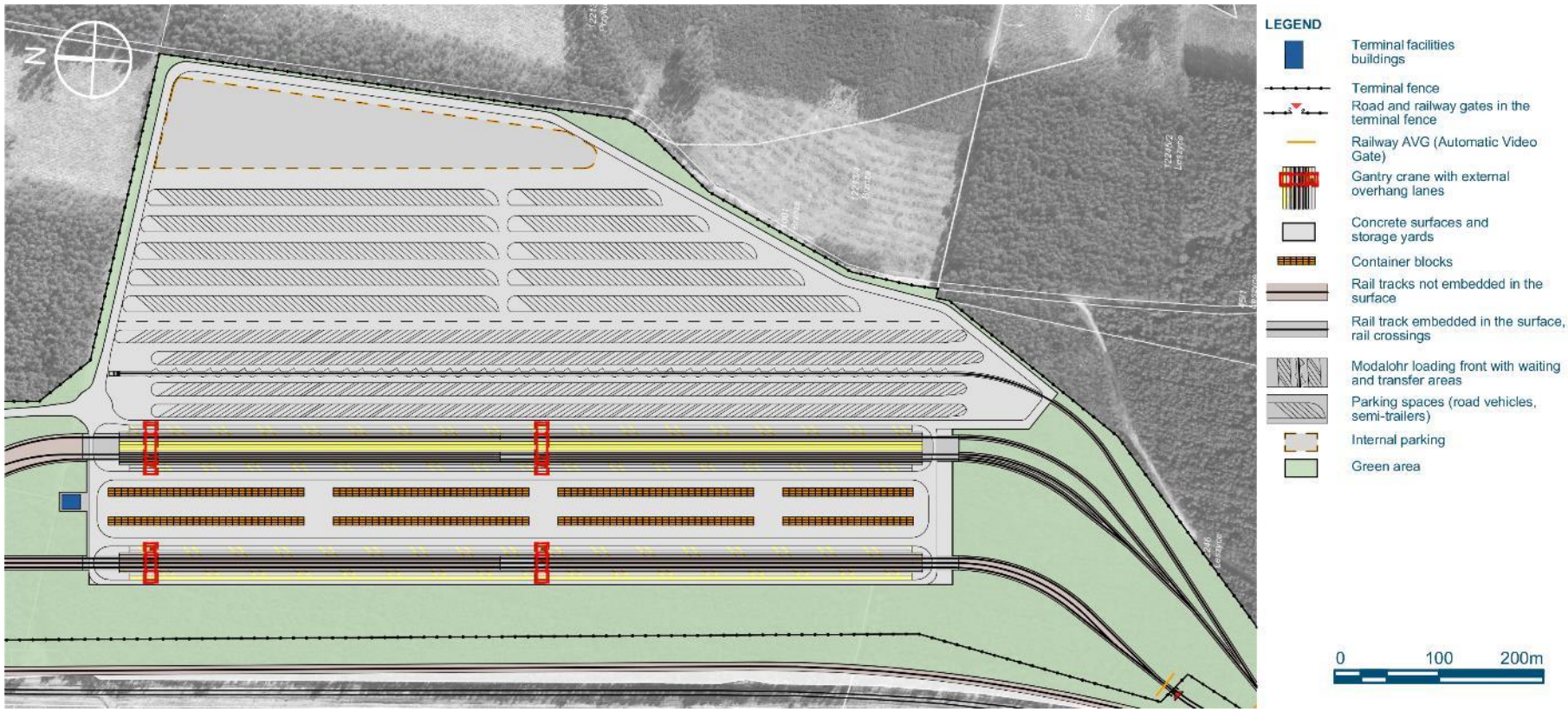

Figure 31 Land use concept for the southern loading front of the Bydgoszcz-Emilianowo intermodal terminal - close-up

Source: own elaboration

4.5.3 Terminal logistics processes

The logistic process at the Bydgoszcz-Emilianowo intermodal terminal has been illustrated based on service process diagrams of the intermodal train and road vehicles at the large rail-road terminal, described in COMBINE project report 'Analysis of combined transport terminal operations' (Wiśnicki, 2020). On the diagram, the stages of processes performed within the framework of granted slots, i.e. reloading windows, are marked green. On the following page, a map of the described processes is presented on the plan of the Bydgoszcz-Emilianowo intermodal terminal.

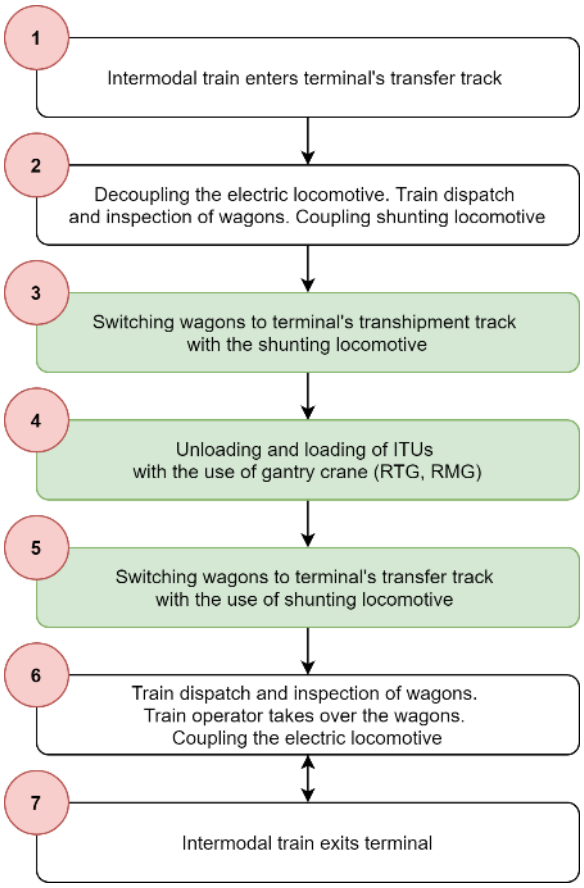

Figure 32 Scheme of the process of an intermodal train handling at the Bydgoszcz-Emilianowo intermodal terminal (large rail-road terminal)

Source: based on 'Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR'. Project COMBINE report (WP 3.1). (Wiśnicki, 2020).

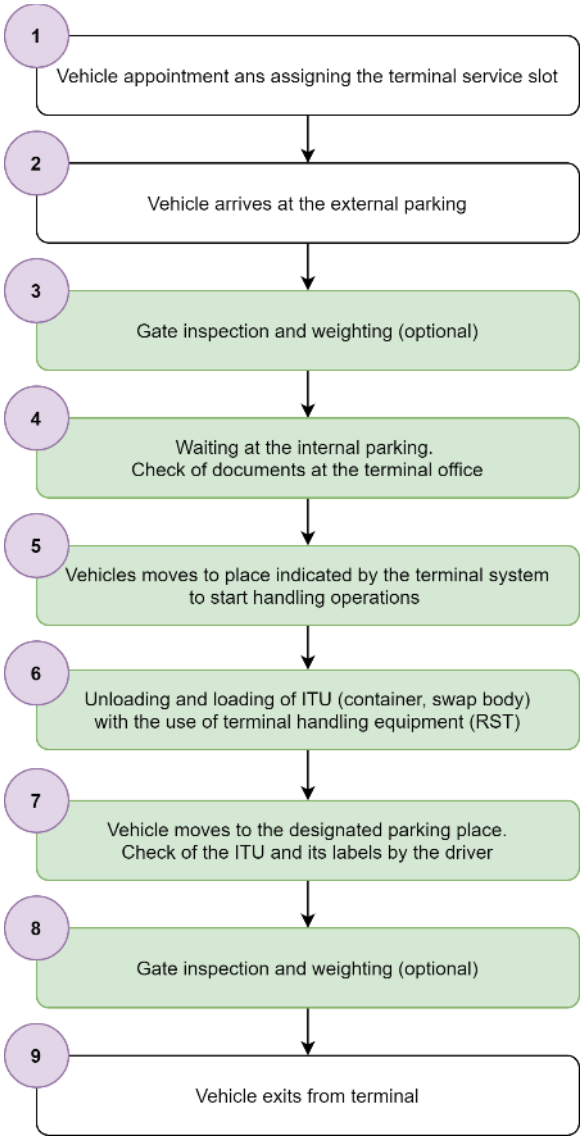

Figure 33 Scheme of the process of a road vehicle handling at the Bydgoszcz-Emilianowo intermodal terminal (large rail-road terminal)

Source: based on 'Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR'. Project COMBINE report (WP 3.1). (Wiśnicki, 2020).

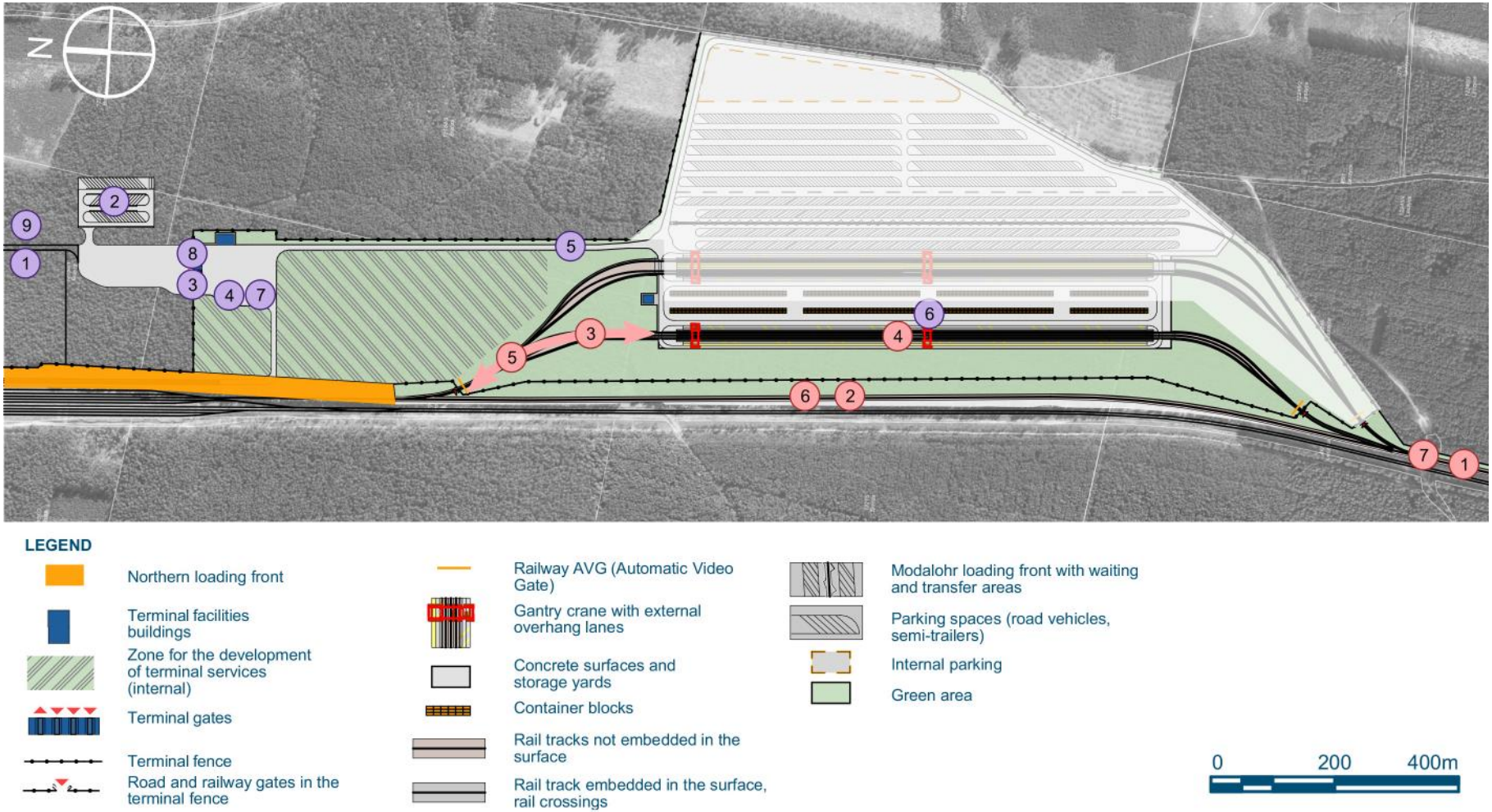

Figure 34 Logistic process scheme for the Bydgoszcz-Emilianowo intermodal terminal

Source: own elaboration

4.6 Description of the minimum functional program for the Bydgoszcz-Solec Kujawski Multimodal Platform

The minimum functional programme for the Bydgoszcz-Solec Kujawski Multimodal Platform has been defined as part of the 'Location Study for the investment project entitled Multimodal Platform based on water, rail, road and air transport with a logistics and storage centre and a river port located on the indicated area of the left bank of the Vistula (km 766-771), including the area of the City of Bydgoszcz and Solec Kujawski Commune' (WYG International, 2018). Its detailed justification (selected calculations and information from infrastructure operators) is contained in the "Stage III Land Development Concept" section and a summary form in the "Stage III Functional Programme" section. In the authors' opinion, the subject matter and the level of detail with which the project assumptions are discussed in the above-mentioned document are more than what is required at the stage of the Pre-feasibility Study. Therefore, the following sections only present the information which refers to the infrastructure necessary for the functioning of the trimodal terminal within the Bydgoszcz-Solec Kujawski Multimodal Platform and those necessary to define and justify the minimum functional programme for this terminal.

Due to the comprehensive and coherent scope of the Location Study exceeding the requirements of the pre-feasibility study, no changes to this document were made. It is recommended to verify the land development concept and the functional programme in the subsequent stages of the project due to organisational and technical progress, which affect the expected parameters of the port and terminal infrastructure.

The information on the minimum functional programme is presented below under the order and classification given in the sections 'Stage III Land Development Concept' and 'Stage III Functional programme' of the Location Study.

4.6.1 Basic data of the river port

The infrastructure parameters have been adopted for:

- Daily lock availability during 23 of 24 hours and a single locking time of 0.5 hours. 11 incoming and 11 outgoing barges per day were adopted;
- The sailing season is 204 days in stage I, 240 days in stage II and 292 days in stage III;
- Annual services:
  - 2,244 barges and 1,122 thousand tonnes of handled cargo in stage I;
  - 2,640 barges and 1,848 thousand tonnes of handled cargo in stage II;
  - 3,212 barges and 4,818 thousand tonnes of handled cargo in stage III;
- Vessels:
  - At stage I, barges with draught <1.6 m, length <57 m, width <7.5 to 9 m and payload 500 t;
  - In stage II, barges with draught <1.6-2.0 m, length <67-70 m, width <8.2-9.0 m and payload 700 t;

- In stage III, barges with draught <2.5 m, length 80-85 m, width <9.5 m and other vessels with the same draught and larger dimensions reaching <110 m length and <11 m width.

The parameters recommended by authors of the Location Study are presented below.

Table 17 Parameters of the basic elements of port facilities within the Bydgoszcz-Solec Kujawski Multimodal Platform

Infrastructure element	Parameters / investment scope
Entrance channel with external outport	The parameters are defined as for the final stage: • channel width 50 m • transit depth 2.8 m
Navigation lock with floodgates	The parameters are defined as for the final stage: • lock width 12 m • lock length 120 m • depth at the lower lock threshold 4 m
Port area with manoeuvering basin	The parameters are defined as for the final stage: • diameter 200 m • technical depth 4.4 m
Port channel	Defined parameters of the port channel are: • width 50 m • technical depth 4.4 m • length 355 m

Container quay	Defined parameters of the quay are:
	• length 280 m - 2 barge berths, final length in stage I
	• minimum width of quayside strip 15 m
	• technical depth along the quays 4.4 m
	• permissible loads for quays for the container transhipment of not less than 50 kPa
	• equipped with:
	  ○ a pair of crane rails
	  ○ drainage of the surface of the quay
	  ○ 2 channels for the electrical network and the water pipes in the quayside;
	  ○ bumper devices, wall ladders and mooring bollards.

Main handling equipment	STS (ship to shore) gantry crane - target 2 pcs.
Container yards	Located directly at the back of the quay. A reinforcement of the whole area for storage of containers and a 50 kPa load capacity was adopted.
Hydrotechnical structures and equipment related to the protection of the port area against flooding and the reconstruction of the polder system in the areas around the port	The range of hydrotechnical structures and equipment includes: • embankments of port areas with elevated ground levels • modification and reconstruction of the system of drainage ditches draining polders in the areas around the port • drainage passes under roads outside the strict harbour area

Source: based on Location Study (WYG International, 2018)

The area of the trimodal terminal assumed in the Location Study is 1.62 ha - the initial stage, with the assumption of expansion as handled cargo increases. The land reserve resulting from the land development concept is about 2.3 ha.

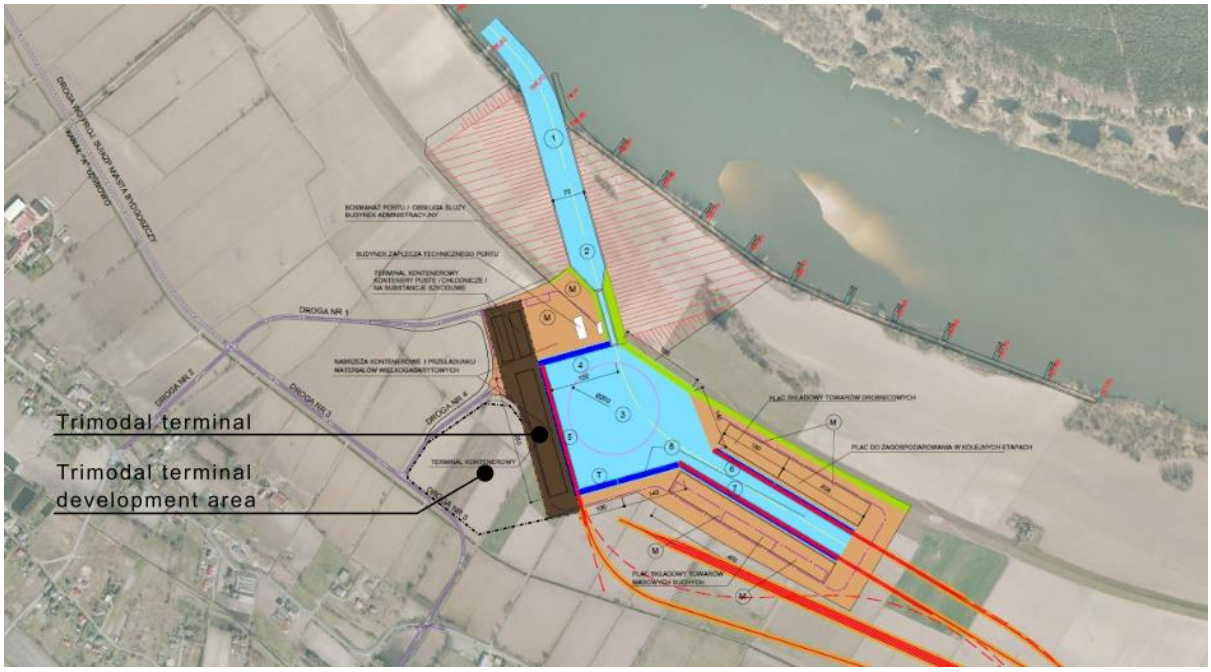

Figure 35 Spatial development plan for the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: based on Location Study (WYG International, 2018)

As part of the construction of the Bydgoszcz-Solec Kujawski Multimodal Platform, the following media will be provided to the constructed river port and distributed within its borders:

- rainwater sewage system,
- sanitary sewage,
- water supply network,
- gas network,
- the power grid.

4.6.2 Road and rail access infrastructure to the Bydgoszcz-Solec Kujawski Multimodal Platform

The Bydgoszcz-Solec Kujawski Multimodal Platform will be a greenfield investment, located in a place without access to public roads and the railway network. Therefore, apart from the construction of the river port and cargo terminals, the construction of access roads and a railway siding will be necessary.

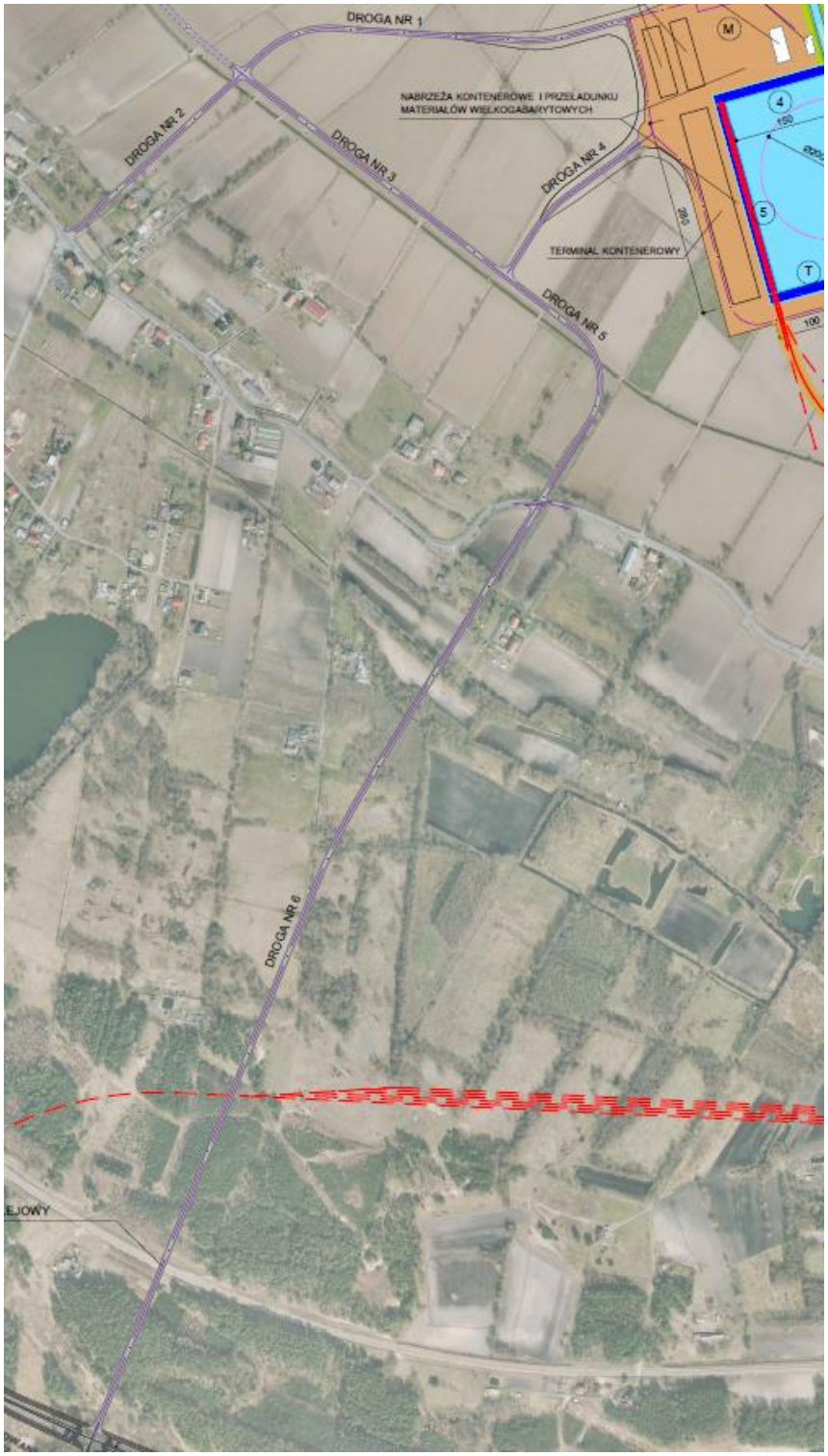

Figure 36 Planned access roads to the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: based on Location Study (WYG International, 2018).

The information presented below is a summary of the parameters adopted at the Location Study (WYG International, 2018) stage. More details are specified in "Part III Land Development Concept", of the above-mentioned study.

The transport links with the Bydgoszcz-Solec Kujawski Multimodal Platform will be provided by a network of newly-built public roads, a network of existing public roads, and internal roads located within the port area. For the roads planned for construction within the investment, the Location Study defines the following key parameters:

- class of public roads: ”Z”;
- section of internal and public roads: single carriageway - 2 x 3.00 m;
- roadway structure corresponding to traffic category KR6.

Due to the variant location of the multimodal platform itself, the integration into the road system was also prepared as a variant. Three variants were analysed - each adapted for a different location of the Bydgoszcz-Solec Kujawski Multimodal Platform. 6 sections of public roads with a total length of about 3.5 km are planned. Construction and extension of intersections is planned within the planned layout of public roads as well as the construction of a railway crossing at the intersection with railway line No. 18.

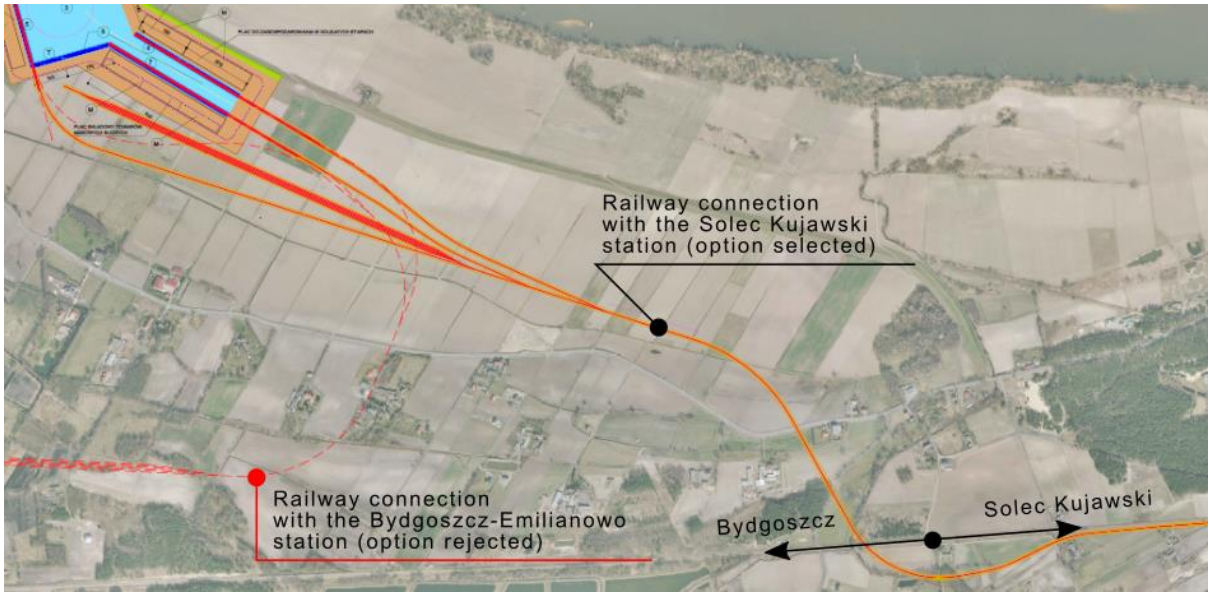

Figure 37 Planned access railways to the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: based on Location Study (WYG International, 2018).

According to the Location Study, it has been assumed that the terminal will have the character of a station siding connected with the Solec Kujawski station by a new railway viaduct over the railway line No. 18. For all three analysed location variants of the multimodal platform, 3 stages of development of the track system have been defined:

- Stage I includes the connection with the Solec Kujawski station tracks with the construction of a viaduct over railway line No. 18 and the construction of individual transhipment tracks at quays;
- Stage II includes the construction of the sorting tracks with a useful length of 750 m, an extension of the transhipment tracks at quays;
- Stage III includes the further extension of the sorting tracks and additional transhipment tracks.

For the siding planned for construction within the project, the Location Study defines the following key parameters:

- permitted axle load: 221 kN (line section class: D3),
- gauge: GPL-1,
- maximum track gradient not exceeding 10‰, which will eliminate the need for auxiliary locomotives.

4.6.3 Recommendations

Due to the distant time horizon of the investment's implementation, it is recommended to verify the validity of the adopted design assumptions in the case that the launch date of the design works moves beyond 2030. This is due to a noticeable organisational and technical progress, which manifests itself in the formation of increasingly longer intermodal trains and the expectation of a maximally short stopover time for means of transport at the terminal.

The possible verification should concern particularly:

- The available length of the loading tracks (currently <300 m), which force the splitting of the train before entering the trimodal terminal – this requires additional shunting work and extends the service time and cost. The length of tracks expected by carriers is at least 600 m.
- The available length of the quay and the number of berths along the quay of the trimodal terminal – 2 berths is the minimum solution, not the optimal one.
- Location of technical and office facilities generating a collision in road access in the case of increasing the length of the transhipment tracks at the quay of the trimodal terminal and leaving the length of the quay of the trimodal terminal unchanged, to enable the handling of intermodal trains without the need to split them.

5 PLAN FOR INTEGRATION OF LOGISTICS PROCESSES

5.1 Identification of operation models of intermodal terminals sharing a service area

After defining the minimum functional programmes for the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform, it is necessary to indicate models of their parallel functioning within the Bydgoszcz logistics hub. These models depend on the following factors:

- terminal management model – a common operator of both terminals, an operator-independent from intermodal operators on one or both terminals, operators of both terminals being logistic operators;
- geographical diversification of destinations – terminals focused on serving different destinations, terminals competing for cargo on the same destinations;
- infrastructure and organisational potential – time to service a single train, hourly and daily capacity.

Table 18 Main attributes of competition strategies and logistical competition strategies

Competition strategies	Cost leadership	Differentiation	Focusing
Strategy features	• Low costs as a factor of competition • Polityka niskich cen	• Products and services differentiation • Customization	Focusing on specific services or customers
Relationship between competition and logistics strategies	• Searching for opportunities to reduce logistic costs • Low level of logistic customer service	• Differentiation of logistics services • Developing a high level of logistics customer service by various attributes (time, delivery flexibility, etc.)	The orientation of specific logistics services on certain groups of clients
Priority	Aiming to minimise logistics costs	Focusing on the quality of services provided, competing by time, by the flexibility of deliveries, by reliability, by accuracy (timeliness)	Paying particular attention to the needs of certain groups of clients, often in the form of "tailor-made services" - i.e. according to the needs of customers

Source: Jezierski et al., 2019

According to the publication "Competition on the market of logistics services in Poland" by Andrzej Jezierski, PhD, it can be concluded that the prevailing formula on the market is to combine selected elements of the above-mentioned strategies in the form of a mix. A. Jezierski based the above statement on the results of research conducted by Capgemini and quoted by Rafał Matwiejczuk in the publication "Logistics in the enterprise management system" edited by Blaik P., Bruska A., Kauf S., Matwiejczuk R. (2013), PWE, Warsaw.

The most probable variant is the capital connection of the Bydgoszcz-Emilianowo intermodal terminal operator with an intermodal operator from the PKP group. If it obtains a dominant position in the company managing the terminal, the terminal in Bydgoszcz-Emilianowo should be treated as managed by an intermodal operator. If, on the other hand, it will be a minority shareholder, the model in which the Bydgoszcz-Emilianowo intermodal terminal operator is independent will apply. A similar distinction will apply to the future operator of the Bydgoszcz-Solec Kujawski Multimodal Platform.

Table 19 presents models of functioning of the intermodal terminal Bydgoszcz-Emilianowo and Multimodal Platform Bydgoszcz-Solec Kujawski on a single geographical market identified by the authors.

Due to the limited potential of the distributive function and the proximity of Tri-City seaports, maximisation of benefits related to the functioning of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform on a single geographical market can be achieved in the models of:

- single operator;
- independent operators and geographical diversification of destinations and concentration on different services and customers.

Both options will allow achieving a synergy effect related to a wider network of destinations than in the case of competition based on cost leadership, and a complementary, diversified range of services within the hub. The optimal solution, increasingly used on developed markets, is a single operator managing both terminals. This is the so-called operator integration, which is a trend already functioning on the market. Preference should be given to an operator who is active or firmly embedded in maritime transport chains.

Table 19 Identified models of functioning of the intermodal terminal Bydgoszcz-Emilianowo and Multimodal Platform Bydgoszcz-Solec Kujawski on a single geographical market

No	Terminal	Category and potential of the terminal	Type of the operator	Geographical diversification of the destinations	Available model for functioning on the single market			
					Services and clients profiles diversification		Lack of diversification of services and clients profiles	
1	Bydgoszcz-Emilianowo	Gate terminal	Independent	Terminals competing for cargo on the same directions	Natural competition		Strong competition	
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
2	Bydgoszcz-Emilianowo	Gate terminal	Independent	Terminals focused on serving different destinations	Reduced competition	Cooperation	Natural competition	Cooperation
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
3	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals competing for cargo on the same directions	Natural competition		Strong competition	
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
4	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals focused on serving different destinations	Reduced competition	Cooperation	Natural competition	Cooperation
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
5	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals competing for cargo on the same directions	Natural competition		Strong competition	
	Multimodal Platform	Trimodal terminal (small => large)	Intermodal operator					

No	Terminal	Category and potential of the terminal	Type of the operator	Geographical diversification of the destinations	Available model for functioning on the single market			
					Services and clients profiles diversification		Lack of diversification of services and clients profiles	
6	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals focused on serving different destinations	Reduced competition	Cooperation	Natural competition	Cooperation
	Multimodal Platform	Trimodal terminal (small => large)	Intermodal operator					
7	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals competing for cargo on the same directions	Natural competition		Strong competition	
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
8	Bydgoszcz-Emilianowo	Gate terminal	Intermodal operator	Terminals focused on serving different destinations	Reduced competition	Cooperation	Natural competition	Cooperation
	Multimodal Platform	Trimodal terminal (small => large)	Independent					
9	Bydgoszcz-Emilianowo	Gate terminal	Single operator	Terminals focused on serving different destinations	Cooperation		Cooperation	
	Multimodal Platform	Trimodal terminal (small => large)						

Source: own elaboration

5.2 Roadmap for the development of the Bydgoszcz logistics hub

Below, a road map of the development of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform is presented in graphical form with the decision points (Figure 38). The decision points indicated in the timeline refer to key infrastructural conditions related to the terminal:

- transport accessibility of the Bydgoszcz-Emilianowo intermodal terminal;
- improvement of rail accessibility of the Gdynia seaport;
- the occurrence of demand for transit hub services by the Port of Gdynia Authority;
- providing stable navigation conditions on the Vistula waterway and, subsequently, the parameters of the IV class of the international waterway.

Further phases of the development of the Bydgoszcz-Emilianowo intermodal terminal, and later also the Bydgoszcz-Solec Kujawski Multimodal Platform, are scheduled to take place with a delay to the completion of the investments that determine them.

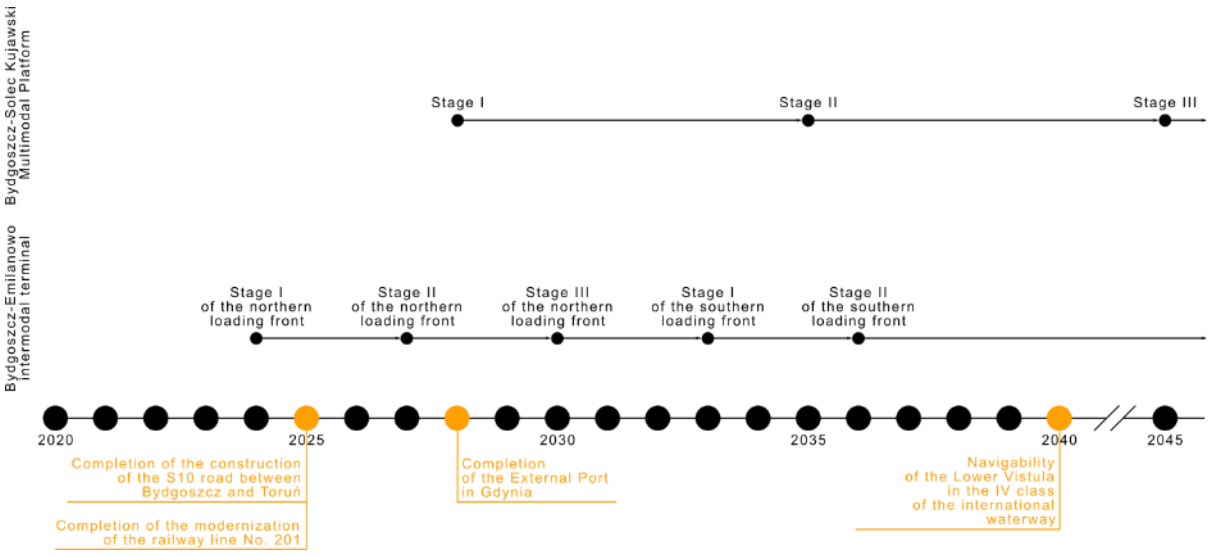

Figure 38 Roadmap for the development of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: own elaboration

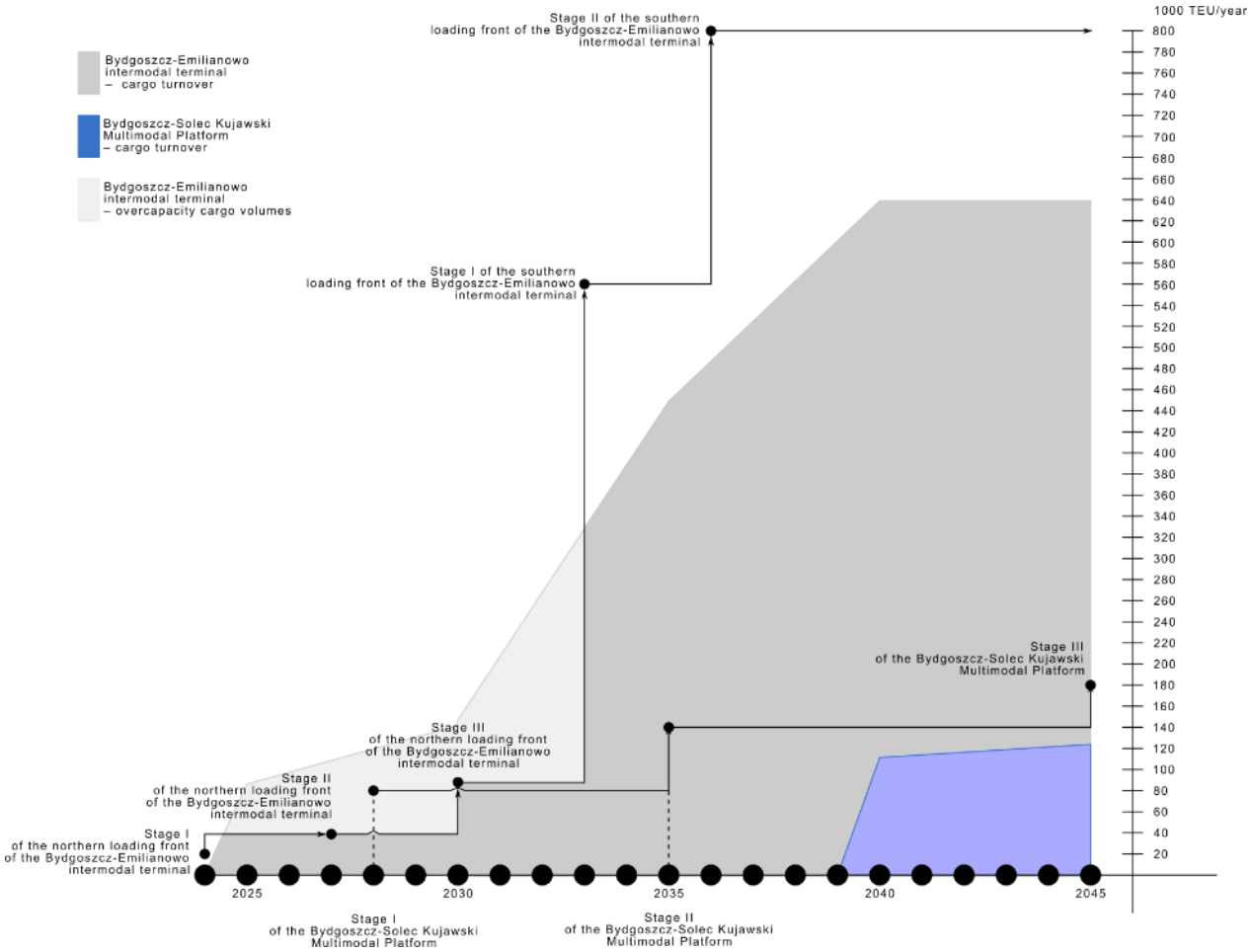

Figure 39 Development stages of the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform in relation to projected cargo volumes

Source: own elaboration

5.3 Logistics process integration plan

The stages of integration of logistic processes proposed in the following section were formulated taking into account:

- lack of a convenient railway link until the completion of the Trzciniec-Solec Kujawski railway line (see Figure 3);
- changes in the road network resulting from the completion of the S10 expressway in the Bydgoszcz-Toruń section;
- the schedule planned in the Location Study for the commissioning of particular stages of the Bydgoszcz-Solec Kujawski Multimodal Platform.

The integration plan is focused on ensuring the efficient connection of the Bydgoszcz-Emilianowo intermodal terminal with the Bydgoszcz-Solec Kujawski Multimodal Platform, as a basis for deeper integration at the process level.

As part of the integration plan, a road map for the integration of logistic processes has been formulated, assuming staging and two action paths. These are:

- integration of logistic processes based on road transport (path A);
- integration of logistic processes based on rail transport (track B).

The presented activities can be divided into two periods:

- Until 2030 - the mid-term perspective - by 2030 the basis for integration will be road transport, using standard road sets, dedicated for container transport.
- After 2030 - the long-term horizon - at the time of this study, the choice of transport modes as a basis for the integration of logistics processes after 2030 is an open question and two options are possible. Basing the integration of logistic processes on rail transport requires the completion of the Trzciniec-Solec Kujawski railway line. On the other hand, long-term basing of the integration on road transport will involve the use of oversized road sets. Ultimately, it will also require the completion of dedicated infrastructure to minimise the mixing of shuttle traffic between terminals and daily traffic.

The conditions necessary to start implementing the next stage have been defined within the periods. These are in order:

- Completion of the Bydgoszcz-Solec Kujawski Multimodal Platform in 2028.
- Navigability of the Lower Vistula in the IV class of the international waterway.

The above-mentioned is supplemented by maps of the possible road connections between the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform - in the perspective until 2030.

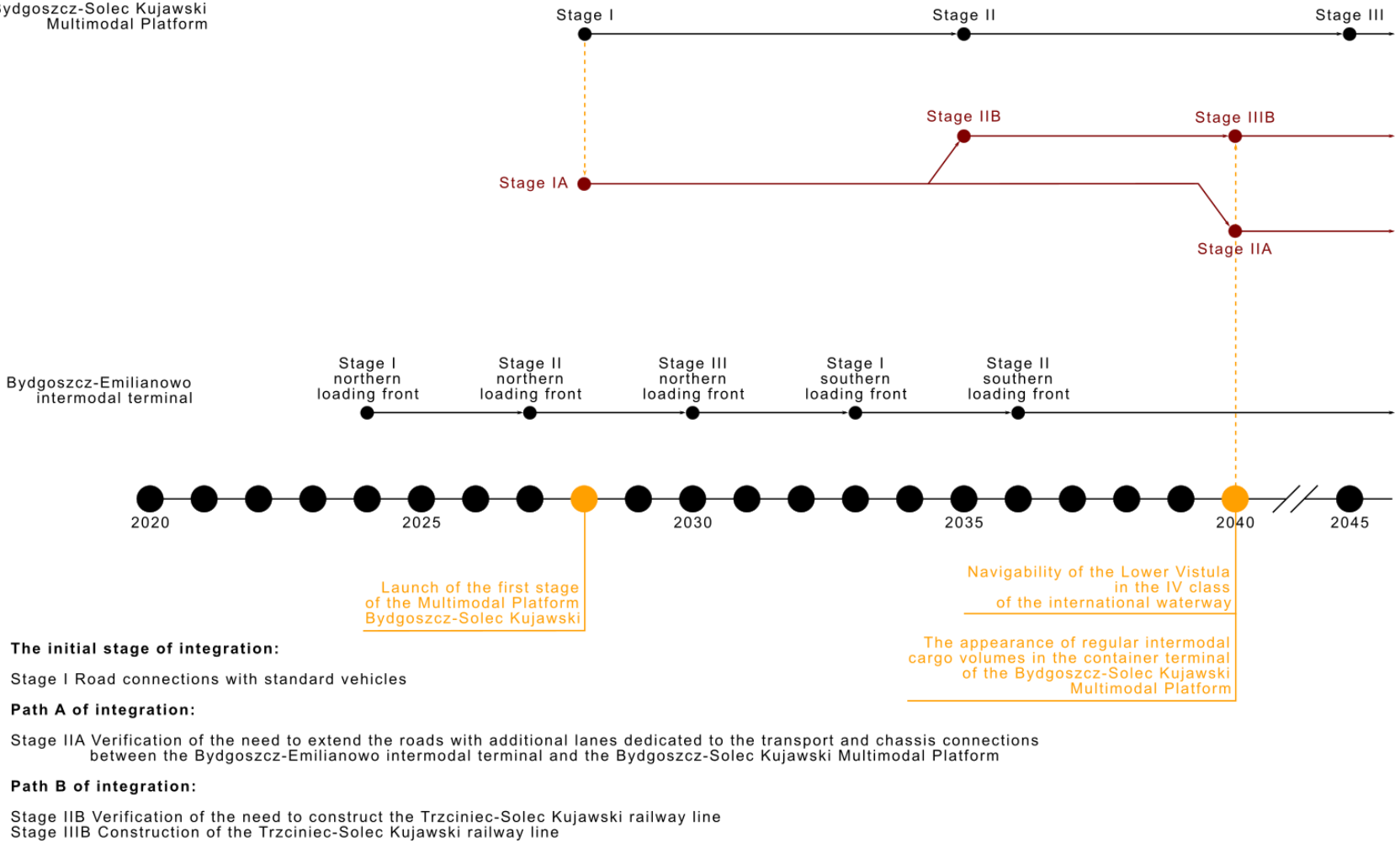

Figure 40 Roadmap for the integration of logistics processes in the area of the Bydgoszcz logistics hub

Source: own elaboration

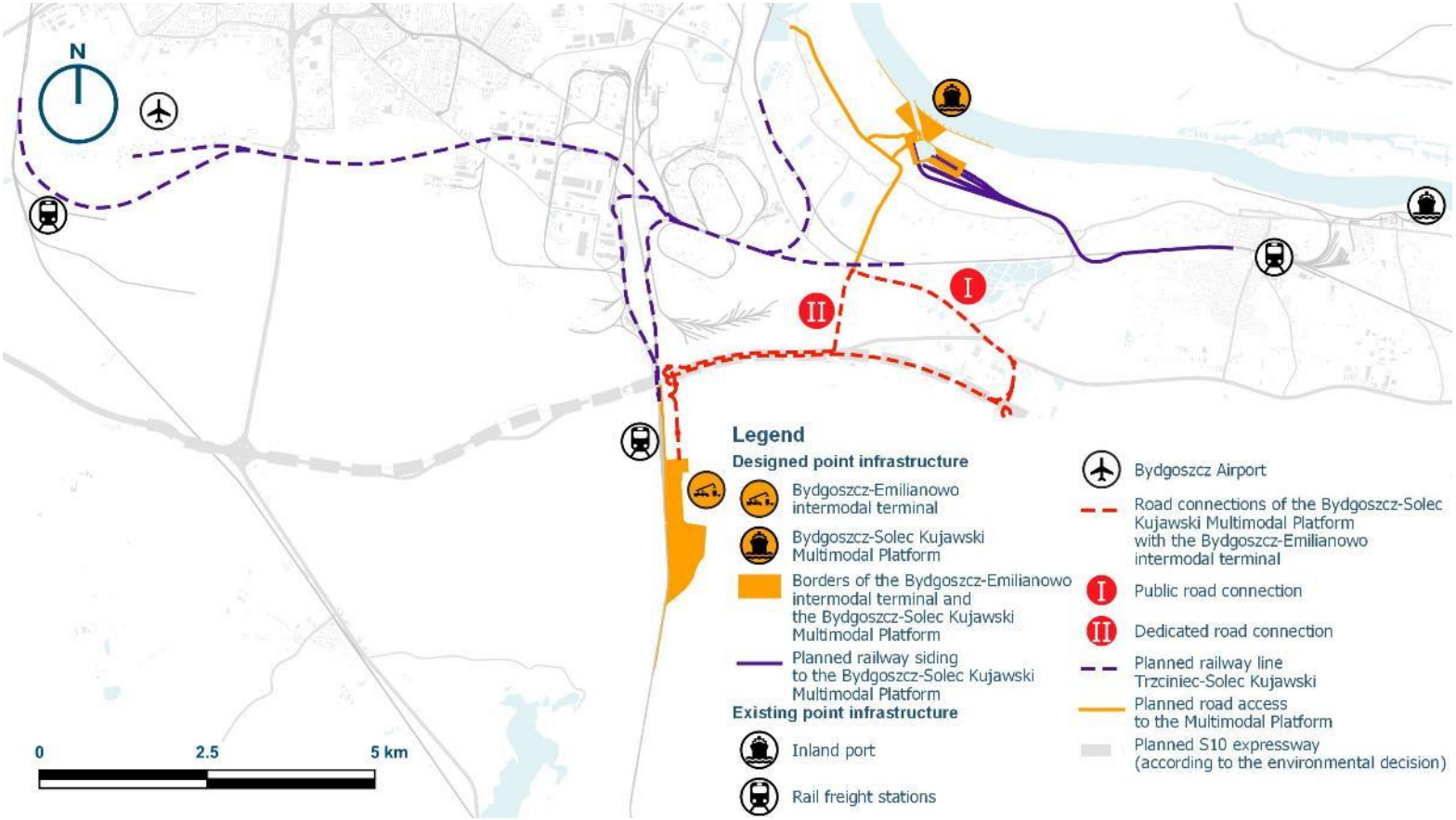

Figure 41 Transport links between the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: Municipal Studio for Urban Planning in Bydgoszcz, OpenStreetMap, Geoportal GUGiK, GDDKiA, the Location Study (WYG International, 2018)

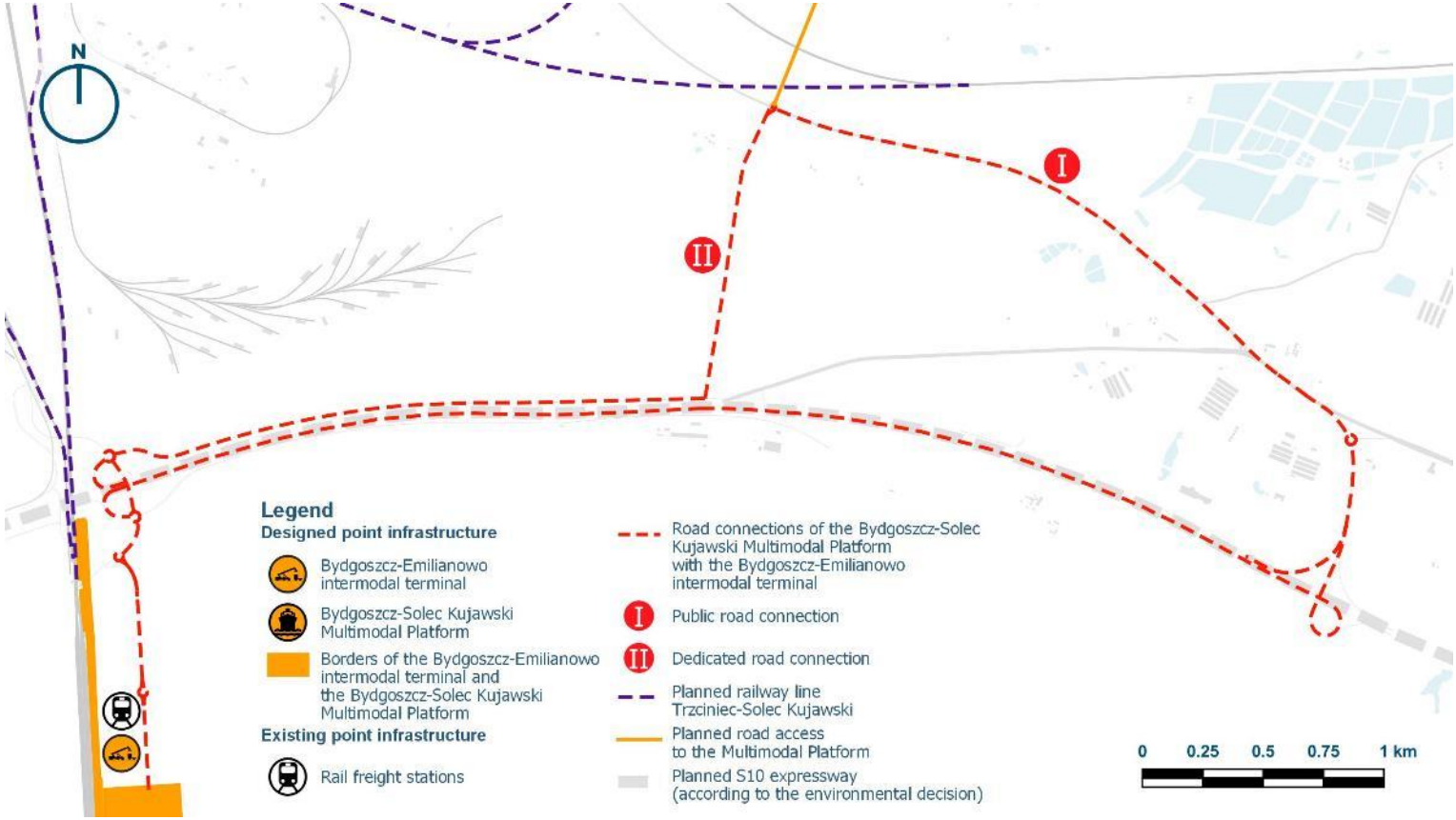

Figure 42 Road connections between the Bydgoszcz-Emilianowo intermodal terminal and the Bydgoszcz-Solec Kujawski Multimodal Platform

Source: Municipal Studio for Urban Planning in Bydgoszcz, OpenStreetMap, Geoportal GUGiK, GDDKiA, the Location Study (WYG International, 2018)

5.4 The concept of the technological scheme of cargo handling

The concept of the technological scheme for the transhipment of goods is based on the "Analysis of combined transport terminal operations. Identification of measures to improve terminals in BSR. COMBINE project report" (chapters 4.4. and 4.5.) diagrams of the intermodal train handling process and road vehicle handling process. Diagrams for terminals: large rail-road and river trimodal were used. During the development of the technological scheme, the focus was on the transhipment operations between the means of transport and between the means of transport and the storage yard. The diagram shows the subsequent stages on the path of the transport unit.

The diagrams were made for:

- rail-road front - scheme of an intermodal train unloading,
- the rail-road front - scheme of a road vehicle unloading,
- the rail-road-water front - scheme of a barge unloading,

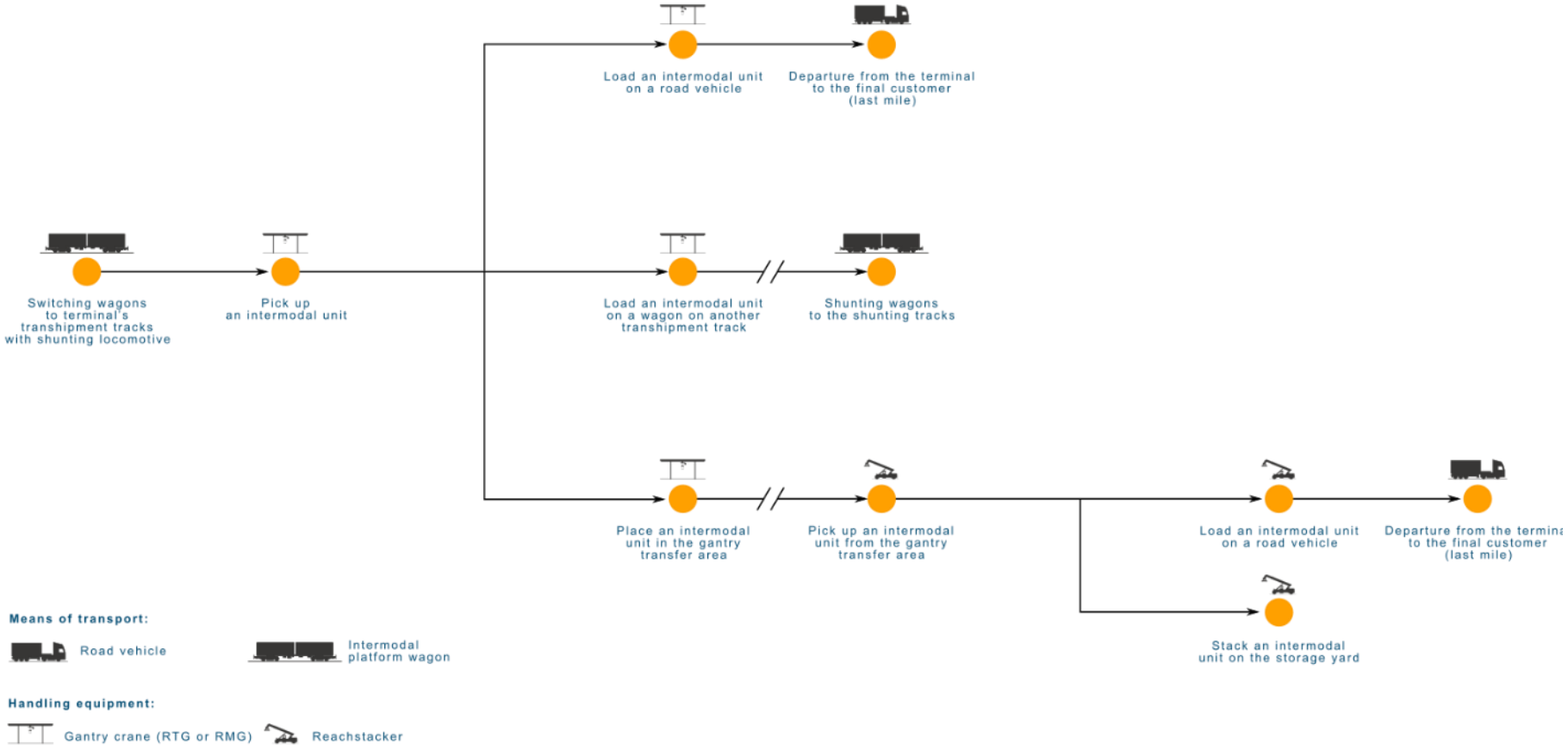

Figure 43 Handling process of rail-road loading front - unloading of an intermodal train

Source: own elaboration

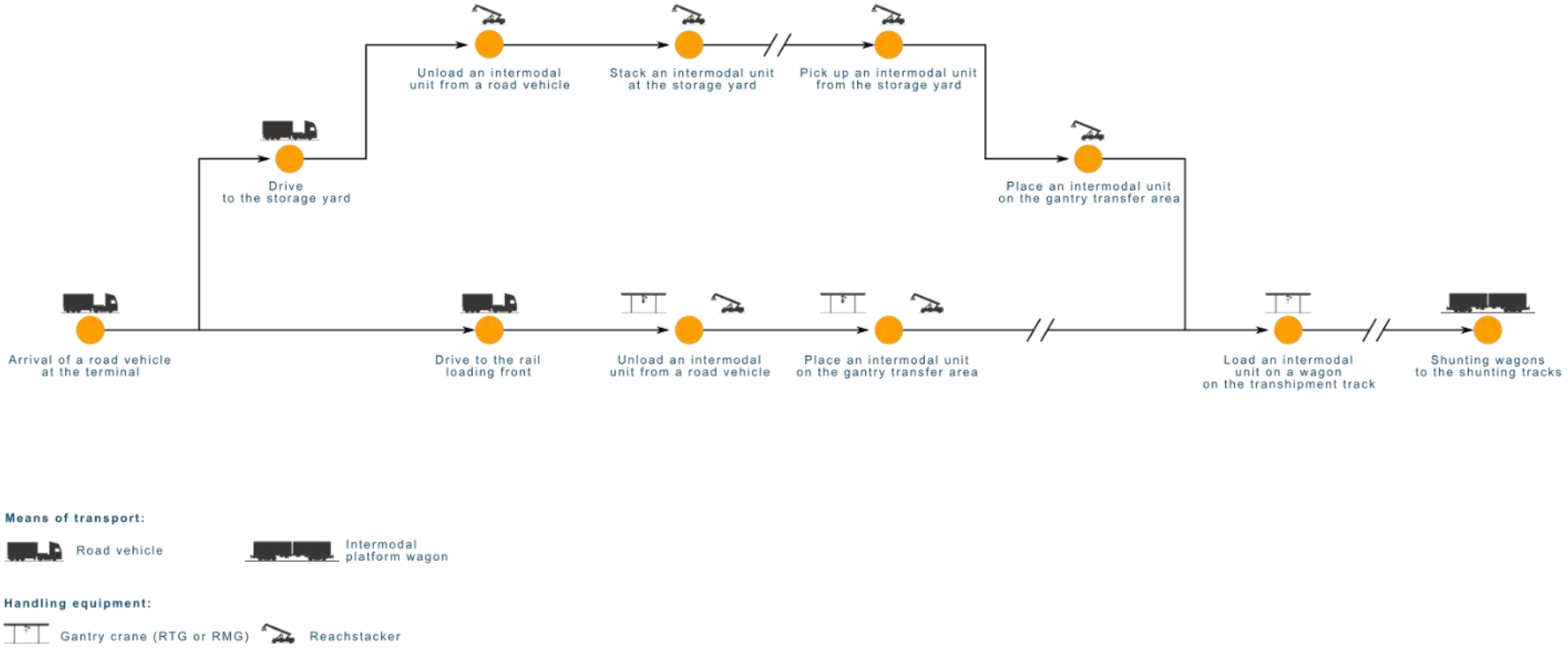

Figure 44 Handling process of rail-road loading front - - unloading of a road vehicle

Source: own elaboration

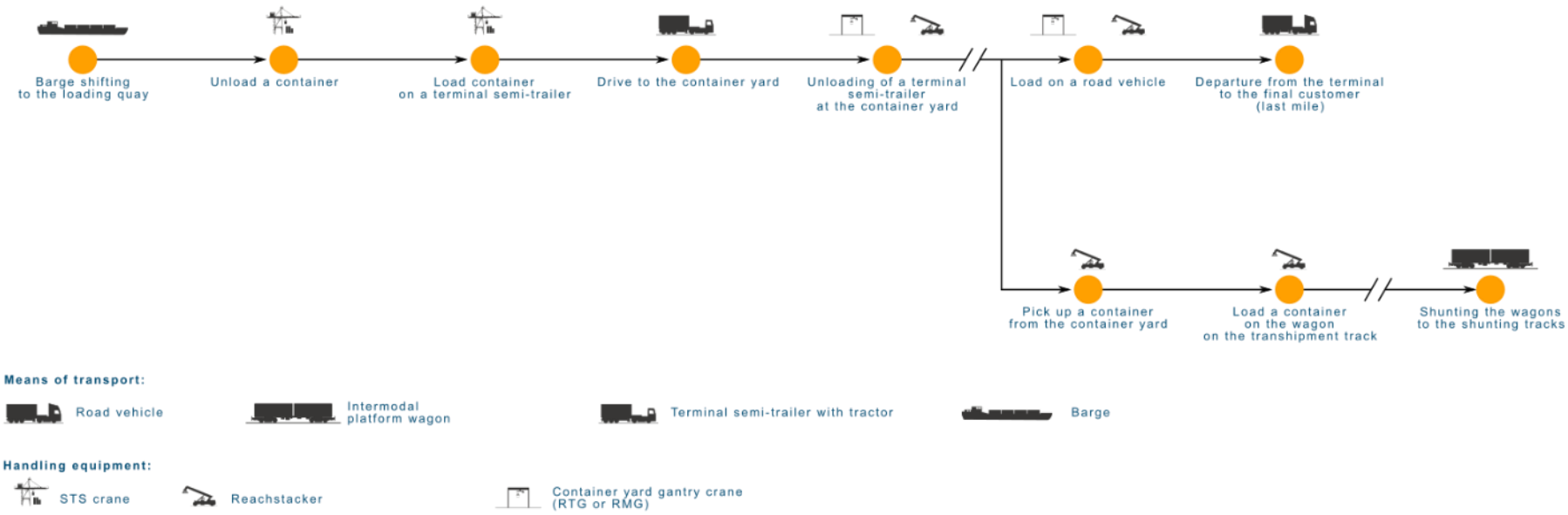

Figure 45 Handling process of rail-road-water loading front - unloading of a barge

Source: own elaboration

6 INVESTMENT COSTS AND ECONOMIC BENEFITS

6.1 Costs and economic benefits for the Bydgoszcz-Emilianowo intermodal terminal

The estimation of infrastructure investment costs at an early stage of preparatory works requires the acceptance of a large margin for error. In this context, it is worth quoting seven factors characterising infrastructure investments (based on the 1990 European Conference of Transport Ministers), which also apply to investments in intermodal terminals[6]:

- **The first factor**, a long economic life, which is over 20 years. This results in a payback time that is usually between 15 and 30 years, i.e. much later than the payback time expected in public benefit investments (5 to 10 years).
- **The second factor**, the realization of the investment requires access to large financial resources, which are needed at the construction stage without the possibility of offering services at the same time.
- **The third factor**, the time of investment preparation before construction takes many months and is associated with the risk of changes leading to an increase in project costs.
- **The fourth factor**, the inability to easily withdraw from the project to recover the expenditures made, which generates an increased investment risk.
- **The fifth factor**, long duration of the investment, counted in years - usually between 2 and 7 years.
- **The sixth factor**, uniqueness of each project, affecting negatively the accuracy of cost estimates and comparability of projects.
- **The seventh factor**, relatively small share of variable costs in operating costs, meaning that optimal pricing models are not capable of achieving a satisfactory return on investment.

In the case of the Bydgoszcz-Emilianowo intermodal terminal investment costs estimation, it is particularly important to take into account factors three, five and six as they directly affect the accuracy of the estimation of investment cost and economic benefits. The presented cost estimates should be read in conjunction with a provision for deviations related to specific location conditions and price increases during the preparatory works. The authors propose a 20% provision.

The uniqueness of the projects of construction and extension of intermodal terminals combined with the long duration of the construction results in the inability to directly relate their costs to the designed Bydgoszcz-Emilianowo intermodal terminal. Terminals with handling capacities over 100 thousand TEU/year are developed in many stages over a long period, which distorts the image of investment costs. For the same reasons, the issue of reference costs for the construction of intermodal terminals is also unique in foreign publications. An exception is the 2018 publication by Wiegmans B. and Behdani B. from the University of Technology in Delft, the Netherlands, entitled "A review and analysis

[6] Wiegmans B., Behdani B. (2018), A review and analysis of the investment in, and cost structure of, intermodal rail terminals, Delft University of Technology. Transport Reviews, Volume 38, 2018.

of the investment in, and cost structure of, intermodal rail terminals". The authors have distinguished five categories of terminals:

- XL - very large intermodal terminal,
- L - large intermodal terminal,
- M - medium-modal terminal,
- S2 - small intermodal terminal type 2,
- S1 - small intermodal terminal type 1.

For each category, the authors assigned the loading capacity, number of loading tracks and surface area as well as the cost of equipment and the total investment cost in millions of euros (Table 20).

Table 20 Intermodal terminal costs by category

No	Name	TEU Capacity	Infrastructure	Terminal area	Equipment in million EUR	Realisation cost (total infrastructure, ground breaking and equipment) in million EUR
1.	XL	500 000	12 transhipment tracks	40 ha	23	138,0
2.	L	100 000	6 transhipment tracks	10 ha	13	47,0
3.	M	30 000	3 transhipment tracks	6 ha	3	9,5
4.	S2	20 000	2 transhipment tracks	4 ha	1,5	5,5
5.	S1	10 000	1 transhipment tracks	4 ha	1	3,5

Source: Wiegmans B., Behdani B. (2018), A review and analysis of the investment in, and cost structure of, intermodal rail terminals, Delft University of Technology. Transport Reviews, Volume 38, 2018

The presented data refer to publications from 1999 and 2011, based on data from 2010. They refer also to prices in EUR, which are characterised by different year-on-year dynamics of change than construction works prices in Poland. For that reason, the authors decided to update them as follows:

- prices were updated with the index of prices of construction and assembly production (change between November and November of the previous year) from 2011-2020;
- since price indices are available until November 2020, the average PLN/EUR exchange rate used to convert costs to PLN was adopted as on November 2010, and prices were adopted as on November 2010;
- the value of a possible deviation related to the underestimation of the costs of works was calculated to be 20% of the basic cost for the given year.

The results for the southern loading front of the Bydgoszcz-Emilianowo intermodal terminal are shown in Figure 46. Due to the infrastructure parameters (6 loading tracks, area of over 40 ha, handling

capacity >500 thousand TEU/year), the Bydgoszcz-Emilianowo intermodal terminal should be classified as XL - i.e. very large. The estimated value of the investment to build the southern front of the terminal is 626-752 million PLN net.

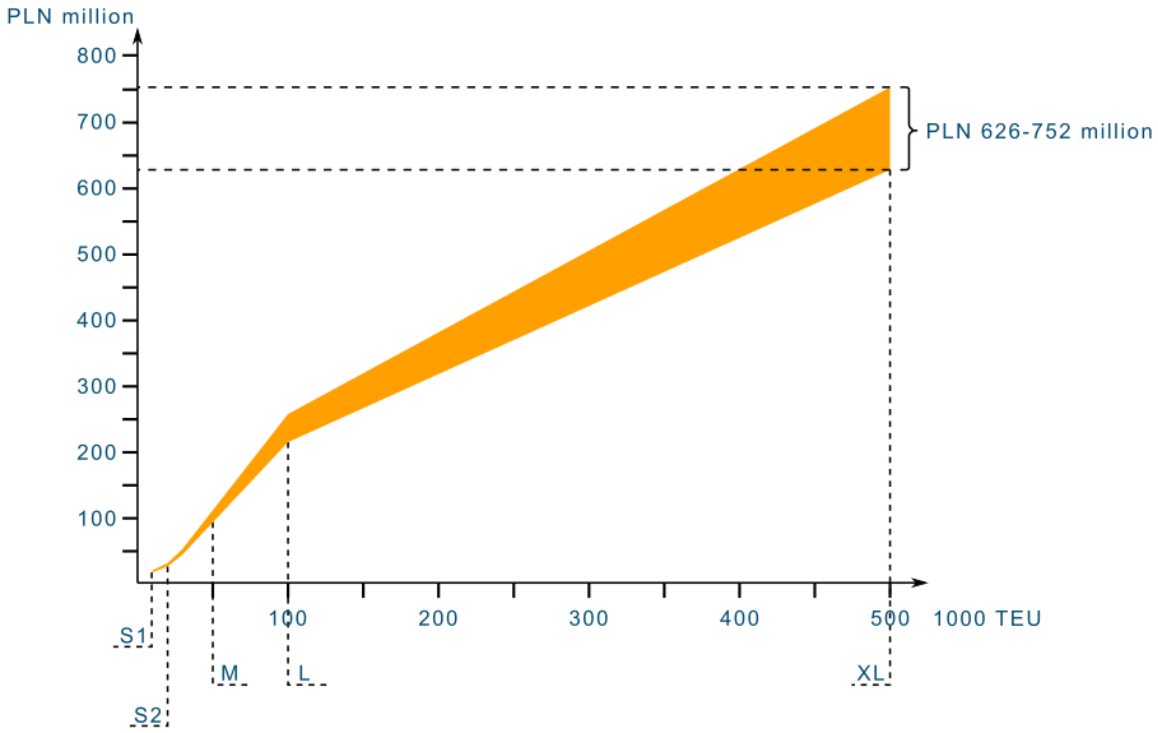

Figure 46 Construction costs of the southern loading front of the Bydgoszcz-Emilianowo intermodal terminal depending on its handling capacity

Source: based on 'A review and analysis of the investment in, and cost structure of, intermodal rail terminals' (Wiegmans and Behdani, 2018).

The justification for incurring such high investment expenditures are the economic benefits they generate. The structure of such benefits for each zloty of capital expenditures on an intermodal transport project calculated by the EU Transport Projects Centre (CUPT) is shown in Figure 47.

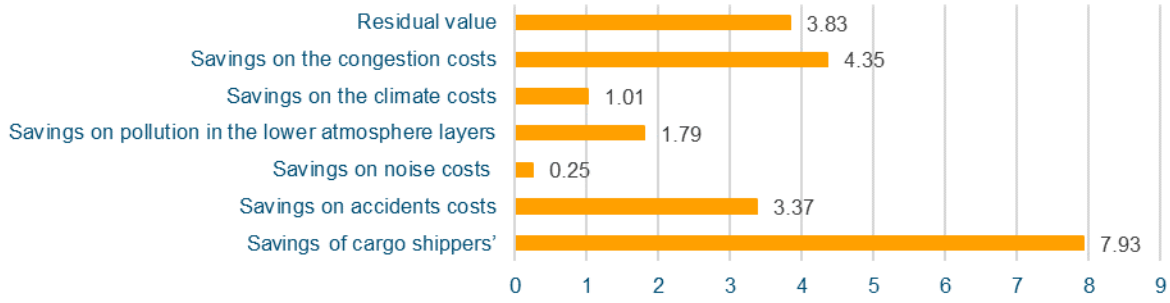

Figure 47 Benefits from 1 PLN capital expenditure on an intermodal transport project

Source: based on 'Opracowanie własne na podstawie' (Kapczyńska , 2020).

The total economic benefit per 1 PLN of capital expenditure on an intermodal transport project is 22.53 PLN. This means that the potential economic benefits related to the construction of the southern loading front of the Bydgoszcz-Emilianowo intermodal terminal should be estimated at 14.10 to 16.94 billion PLN in the period of economic analysis, i.e. 30 years.

6.2 Costs and economic benefits for the Bydgoszcz-Solec Kujawski Multimodal Platform

Information on the estimated construction costs and economic benefits for the Bydgoszcz-Solec Kujawski Multimodal Platform is given according to the 'Location study for the investment project entitled Multimodal Platform based on water, rail, road and air transport with a logistics and storage centre and a river port located on the indicated area of the left bank of the Vistula (km 766-771), including the area of the City of Bydgoszcz and Solec Kujawski Municipality' (WYG International, 2018). Information on estimated costs of all 3 stages of the recommended variant can be found in the "Stage III Functional Programme".

The total net value of investment costs specified in the above-mentioned study, excluding the costs of handling equipment, is PLN 1,028,241,340.80 net, including:

- Stage I: 953.58 million PLN,
- Stage II: 43.09 million PLN,
- Stage III: 31.57 million PLN.

Within the costs of the first, crucial stage for the investment and the most expensive stage, three main components should be indicated:

- hydro-technical works: 713.25 million PLN net,
- storage yards (excluding other road works): 105 million PLN net,
- railway tracks network: 78.7 million PLN net.

All the above figures refer to the Bydgoszcz-Solec Kujawski Multimodal Platform, i.e. an inland port consisting of terminals for containers, bulk and general cargo and specialized quay for oversize cargo. The cost estimation and the functional connection of the container terminal with the entire investment do not allow for the separation of costs concerning intermodal transport.

The authors of the Location Study in the section "Stage III Financial-economic, legal and institutional feasibility study" indicated the following economic benefits (discounted for 2018):

- savings the congestion costs: 1,045.91 million PLN,
- savings on accidents costs: 112.39 million PLN,
- savings on pollution in the lower atmosphere layers: 50.47 million PLN,
- savings on the climate costs: 15.44 million PLN,
- savings on noise costs: 32.64 million PLN,
- savings on the congestion costs: 116.58 million PLN,

- residual value: 448.69 million PLN.

The total value of benefits over the analysis period is 1,771.65 million PLN over 30 years. The ratio achieved should be considered very good, although it is significantly lower than the value estimated for the Bydgoszcz-Emilianowo intermodal terminal. Since CUPT has made available the information quoted in chapter 6.1, it is recommended to update the assessment of economic benefits at the next stages of work, at least in the part concerning the economic benefits generated by the container terminal designed within the framework of the Bydgoszcz-Solec Kujawski Multimodal Platform.

LIST OF TABLES AND FIGURES

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