RAPORT

Analysis of combined transport terminal operations

Identification of measures to improve terminals in BSR

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CONTENTS

Introduction

Because of the broad meaning of terms in the field of combined transport, certain assumptions have been made in order to show the topic fully and to systematize it. This analysis focuses on issues related to the operation of bimodal (rail-road, rail-rail) and trimodal (river-rail-road) combined terminals. In accordance with the recommendations of the commissioning party the City of Bydgoszcz, the analysis does not take into account the air and sea transport. The results of the analysis are to be used in the process of creating Bydgoszcz - Solec Kujawski multimodal platform accompanied with the necessary technical and organizational facilities.

From a spatial point of view, this analysis focuses on the European transport market with particular emphasis on the Baltic Sea Region. The analysis covers technological and process issues of combined transport and it discusses technologies currently used or, which according to the authors, have a chance for future development. Model examples of intermodal terminals are presented, taking into account infrastructure elements, transhipment (handling) equipment as well as terminal processes. This scope of the analysis is aimed at identifying various types of measures to improve the operation of terminals in BSR. As the result, the indicators for monitoring and improvement the quantitative and qualitative nature of terminal processes are presented.

The report consists of five chapters, the first of which focuses on creating a full classification of combined transport terminals. The next two chapters identify infrastructure elements and equipment necessary for the functioning of combine transport terminals. The fourth chapter focuses on terminal processes, distinguishing the process of handling loading units and the process of handling means of transport. The last, fifth chapter presents measures of transhipment and organisational efficiency of combined transport terminals.

As part of the analysis, the following definition of combined transport was adopted[1]: "*Intermodal transport, in which the majority of travel is made by rail, inland or sea waterways, and all initial and / or final road sections are as short as possible*." At the same time, this definition requires clarification of the concept of intermodal transport, which is a form of transport using at least two transport modes for the carriage of cargo in the form of an intermodal transport unit (ITU), also known as an intermodal cargo unit. This intermodal transport unit can be a standard container, a swap body, a semi-trailer or an articulated vehicle, provided that the transhipment of the cargo themselves when changing means of transport is not performed. Often the articulated vehicle is also treated as a type of ITU. Intermodal transport assumes full organizational and technical cooperation, among others in the field of documentation, technology or organization of the movement of an intermodal transport unit in the logistics chain.

[1] Combined Transport Directive 92/106/EEC, European Commission, SWD(2016) 141 final

1. Classification of combined transport terminals

1.1. Types and categories of terminals

In the narrowest sense, the combined transport terminal is an infrastructure point where the intermodal load unit is moved from one mode of transport to another. In a broader scope, the combined transport terminal can be described as a hub in the transport or logistics network, in which it performs many additional functions besides the basic transhipment function (e.g. consolidation, storage, forwarding). Due to the fact that combined transport terminals may differ significantly from each other, their multi-criteria classification is necessary. The following classification was created based on literature sources[2] and the expert knowledge of the authors of the analysis. The classification was created according to predefined assumptions, while enabling the matching of any combined transport terminal to each of the indicated categories of classification. In the further part of the analysis this possibility was shown on the basis of selected sample terminals. The developed classification of combined transport terminals will take into account nine categories of classification:

1. Classification by type of transhipped units:
    - 1.1. container terminals,
    - 1.2. terminals handling containers and swap bodies,
    - 1.3. terminals handling containers, swap bodies and semi-trailers,
    - 1.4. terminals handling semi-trailers,
    - 1.5. terminals handling articulated vehicles (tractor and semi-trailer).
2. Classification by terminal transhipment capacity:
    - 2.1. small terminals (less than 25000 ITU),
    - 2.2. mid-size terminals (25000 ÷ 50000 ITU),
    - 2.3. large terminals (50000 ÷ 100000 ITU),
    - 2.4. very large terminals (above 100000 ITU).
3. Classification by transhipment technology:
    - 3.1. Ro-Ro terminals,
    - 3.2. Lo-Lo terminals,
    - 3.3. Ro-Ro +Lo-Lo terminals,
    - 3.4. specialized terminals (Modalohr, Cargobeamer).
4. Classification by the size of service area:
    - 4.1. local and factory terminals
    - 4.2. regional and agglomeration terminals,
    - 4.3. national and international terminals.

[2] M. Jacyna, D. Pyza, R. Jachimowski, Transport Intermodalny - Projektowanie Terminali Przeładunkowych, PWN, Warszawa, 2018; R.Marek, Rola Terminali Kontenerowych W Kształtowaniu Bezpieczeństwa Przepływu Ładunków Skonteneryzowanych; J. Stokłosa, T. Cisowsk, A. Erd, Terminale przeładunkowe jako elementy infrastruktury sprzyjające rozwojowi łańcuchów transportu intermodalnego, Logistyka, 3/2014, 5991-5999; transportgeography.org.

5. Classification by operated transport modes:
    5.1. unimodal (rail) terminals,
    5.2. bimodal terminals (rail-road or river-road),
    5.3. trimodal terminals (river-rail-road).
6. Classification by relationship with a logistic centre (special economic zone, economic zone):
    6.1. terminal not related to logistics centre,
    6.2. terminal related to one logistics centre,
    6.3. terminal related to several logistics centres.
7. Classification by type of ownership:
    7.1. public terminal (publicly accessible),
    7.2. private terminal.
8. Classification by relationship with logistics operator:
    8.1. terminal in a network of one operator,
    8.2. terminal in networks of several operators,
    8.3. independent terminal.
9. Classification by place and role in the transport network:
    9.1. global distribution hub,
    9.2. regional distribution hub,
    9.3. transit hub (gate terminal),
    9.4. dry port terminal,
    9.5. border terminal
    9.6. departure/final terminal

Ad. 1) Classification by type of transhipped units

First of all, combined transport terminals can be divided according to the type of transhipped (handled) intermodal transport units. Most of the terminals currently use handling (or are ready for handling) three types of intermodal loading units, i.e. containers, swap bodies and semi-trailers. There are also specialized terminals using horizontal transhipment technology, i.e. Rollande Landstrasse (Ro-La), Modalohr or Cargobeamer, which support semi-trailers or articulated vehicles (tractor and semi-trailer).

Ad. 2) Classification by terminal transhipment capacity

The most common classification of combine transport terminals by their transhipment capacity. This is the theoretical amount of cargo that can be handled by the terminal at a given time, usually for one year. Depending on the studies, this value is given in tonnes, in ITUs or broken down into different types of intermodal units to be handled. The authors stated that for the above classification, the best solution is to determine the size of the terminal based on the declared transhipment capacity counted in ITUs. The adopted division is in line with the assumptions adopted by the COMBINE project consortium (Tab. 1).

Table 1. Division of combined terminals

Standard	Small	Mid	Large
Terminal transhipment capacity	< 25 000 ITU or 50 000 TEU	25 000 – 50 000 ITU or 50 000 – 100 000 TEU	> 50 000 ITU or 100 000 TEU
Terminal area	0 – 40 000 m^2	40 000 – 70 000 m^2	> 70 000 m^2
Equipment	Reachstackers, SCH, single gantry crane	3-4 gantries	More than 4 gantries

Source: Project COMBINE, 2020

Ad. 3) Classification by transhipment technology

Division is possible due to the transhipment technology used in the terminal. The classification allows to distinguish whether in a given terminal handling is carried out by means of vertical (Lo-Lo), horizontal (Ro-Ro) transport technologies, or maybe these technologies are combined (Ro-Lo + Lo-Ro). There are separate terminals offering special combined transhipment technologies, which include Modalohr (now renamed Lohr) and Cargobeamer. The possibility of using specific transhipment technology in a transport terminal decides which intermodal loading units can be accepted in it.

Ad. 4) Classification by the size of service area

The next division is according to the service area of the terminal. In this case, service area means a specific territory for which the selected terminal provides its services. The authors distinguished three types of terminals. Local and factory terminals, i.e. those that treat the immediate vicinity of the terminal or one specific enterprise as a service area. Regional and agglomeration terminals, i.e. those whose service area is the size of a large urban agglomeration or region of a given country. Finally, national and international terminals that support nationwide or inter-state transport.

Ad. 5) Classification by operated transport modes

The next division found in the literature and various studies is a division according to the transport modes operated by the terminal. The authors distinguish three types of terminals and three types of supported transport modes. Unimodal terminals are prepared to handle only one transport mode, in practice this means railway terminals. Bimodal terminals, in which transhipment is carried out between two branches of transport modes, in practice they are rail-road or river-road terminals. And as trimodal terminals that serve three modes of transport, i.e. river-rail-road terminals.

Ad. 6) Classification by relationship with a logistic centre (special economic zone, economic zone)

In the case of classification by relationship with the logistics centre (special economic zone, economic zone), various forms of spatial and operational relation of the terminal with the logistics centre are considered (Fig. 1). The terminal may not have such a relation, i.e. there is no developed logistics activity in the immediate vicinity of the terminal. In other cases, such a relationship can exist with one or several logistics centres. Transport and logistics connections may relate to separate administrative areas (country district or region) or terminals may support many spatially distributed logistics centres (several centres in different European countries).

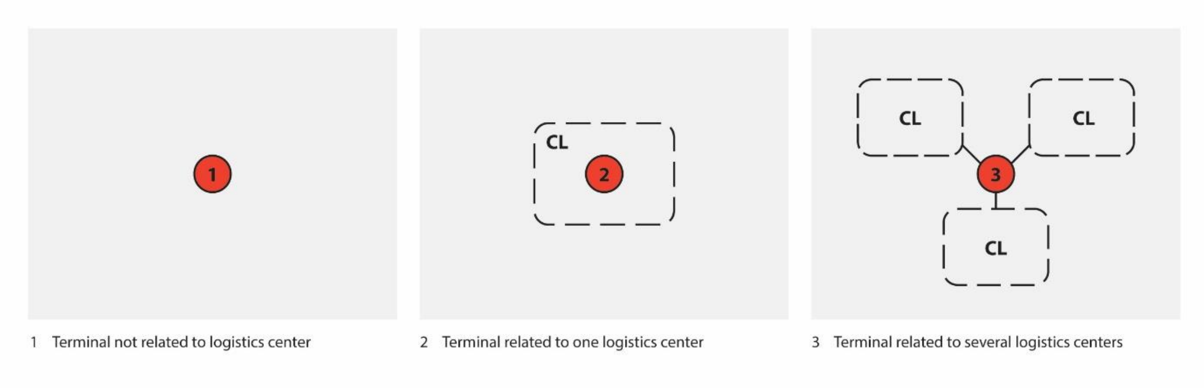

Figure 1. Classification of combine transport terminals by relationship with a logistic centre

Ad. 7) Classification by type of ownership

The division according to type of ownership is simple, because it distinguishes only two types of terminals. Publicly accessible terminals where cargoes from many customers can be handled, as well as private, closed terminals, usually created for the needs of one company or a specific transport chain, which are not made available to other operators than those cooperating with this company or within this chain.

Ad. 8) Classification by relationship with logistics operator

The division according to the relationship with the transport and logistics operator defines the business relationship with the transport and logistics operators, expressed by the place of the terminal in the connection network of a given logistics operator. The terminal may be business related to one or more logistic operators operating on the intermodal transport market. In this case, the terminal is in the network of connections of one large logistics operator or in the network of two-three operators (alliances and cooperation of logistics operators to achieve mutual benefits). In practice, this means preferential treatment of the loading units of these logistics operators. Currently, completely independent terminals are rare, i.e. they serve loading units from any recipients according to the principles of equal access.

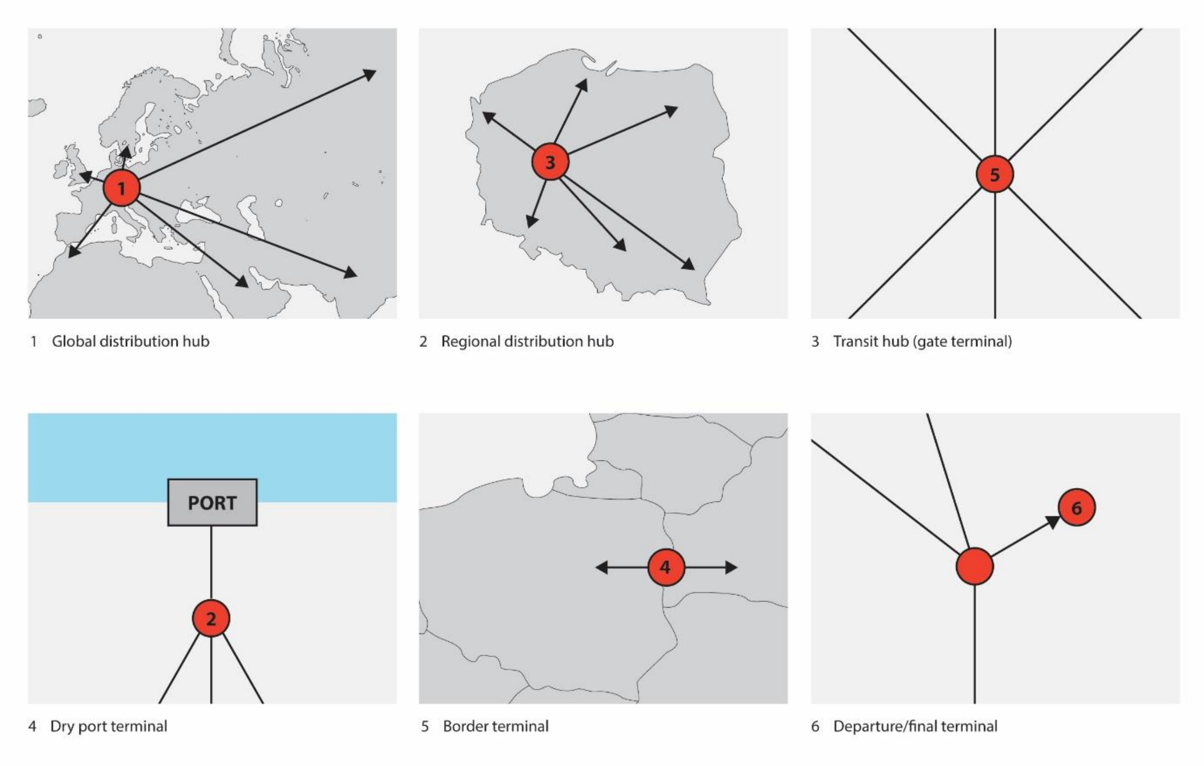

Figure 2. Classification of combined transport terminals by place and role of the terminal in the transport and logistics network

Ad. 9) Classification by place and role in the transport network

This classification refers to the place and role of the terminal in the transport and logistics network. It also includes the functions of the combined terminal it performs in the logistics system and distinguishes six types of terminals (Fig. 2). The first type is the terminal referred to as the global distribution hub, which means that in this terminal, loading units are transhipped within global supply chains. These types of terminals are few, but due to the development of intermodal transport and globalization, the authors predict that they will play an increasingly important role in the world's transport systems. Currently, such terminals support Asia-Europe intermodal trains, e.g. the terminal in Duisburg. The next type of terminal is the regional distribution hub, i.e. a terminal that performs as a transhipment node for a defined region. The next type is the terminal referred to as the transit hub or gate terminal, where the loading units are transhipped in a wagon-wagon relationship between different intermodal trains. These trains have different origin and/or destination stations and meet at the transit hub (often in a specific time window) to exchange loading units with each other. Another type of terminal is the dry port terminal, i.e. a combined transport terminal located at the hinterland of a large seaport. An example would be the Belgian terminal in Liege. There is also a type of terminal known as the border terminal. These types of terminals have a specific role and are specialized for transhipment of loading units between means of transport adapted to different infrastructure standards occurring in countries bordering each other. An example of this type of terminal may be the terminal in Małaszewicze in Poland located on the border of countries with different rail track gauge. In this classification, the last type of terminal is a departure/final terminal, i.e. the terminal of departure or destination for an intermodal train, which may be a siding of a large final recipient.

1.2. Representative terminal models

The authors of the analysis selected specific models of combined transport terminals representative for all terminals meeting the assumptions of the analysis, which, from the point of view of the Contracting authority, may be of significant importance in the process of preparing a multimodal infrastructure investment in Solec Kujawski and Bydgoszcz itself. In their example, elements of terminal infrastructure and equipment, as well as transport and logistics processes occurring in terminals are discussed. Selected models of combined terminals are, in order (Tab. 2):

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 2. Classification of combined transport terminals

	Model of the combined transport terminal						
	1	2	3	4	5	6	7
	Large rail-road terminal	Small rail-road terminal	Trimodal river terminal	Border terminal	Ro-La Terminal	Cargobeamer terminal	Modalohr terminal
	1. Classification by type of transhipped units						
container terminals							
terminals handling containers and swap bodies							
terminals handling containers, swap bodies and semi-trailers							
terminals handling semi-trailers							
terminals handling articulated vehicles (tractor and semi-trailer)							
	2. Classification by terminal capacity						
small terminals (< 25000 ITU)							
mid-size terminals (25000 ÷ 50000 ITU)							
large terminals (50000 ÷ 100000 ITU)							
very large terminals (> 100000 ITU)							

	Model of the combined transport terminal						
	1	2	3	4	5	6	7
	Large rail-road terminal	Small rail-road terminal	Trimodal river terminal	Border terminal	Ro-La Terminal	Cargobeamer terminal	Modalohr terminal
	3. Classification by transhipment technology						
Ro-Ro terminals		■		■	■	■	■
Lo-Lo terminals	■	■	■	■			
Ro-Ro +Lo-Lo terminals	■			■			
specialized terminals (Modalohr, Cargobeamer)						■	■
	4. Classification by the size of service area						
local and factory terminals		■					
regional and agglomeration terminals	■	■	■		■	■	■
national and international terminals	■		■	■	■	■	■
	5. Classification by operated transport modes						
unimodal (rail) terminals				■			
bimodal terminals (rail-road or river-road)	■	■		■	■	■	■
trimodal terminals (river-rail-road)			■				
	6. Classification by relationship with a logistic centre						
terminal not related to logistics centre		■	■	■	■	■	■
terminal related to one logistics centre	■	■	■	■	■	■	■
terminal related to several logistics centres	■		■	■			
	7. Classification by type of ownership						
public terminal	■	■	■	■	■	■	■
private terminal (not open terminal)		■	■				
	8. Classification by relationship with logistics operator						
terminal in a network of one operator		■	■		■	■	■
terminal in networks of several operators	■	■	■	■			
independent terminal			■	■			
	9. Classification by place and role in the transport network						
global distribution hub	■		■				
regional distribution hub	■	■	■				
transit hub (gate terminal)	■	■	■				
dry port terminal,	■	■	■				
border terminal	■	■		■	■		
departure/final terminal		■			■	■	■

It should be specified that, according to the authors, a specialized terminal is a terminal that uses specific modern combined transhipment technology. This type of terminal will be discussed based on two examples of transhipment technologies, i.e. Cargobeamer and Modalohr, according to the authors of the analysis having the greatest development prospects. In the case of the Modalohr technology, the name Lohr is used interchangeably, this is due to the name change of the company that developed the technology, i.e. from Modalohr to the consortium of Lohr Group. Due to the alternate use of both names, the authors of this analysis will remain with the old name Modalohr.

2. Infrastructure of combined transport terminals

2.1. Elements of infrastructure of combined transport terminals

The combined transport terminal is a node connecting the infrastructure of various modes of transport, i.e. road, rail or inland waterway, to enable efficient loading and handling of intermodal loading units and means of transport of the above-mentioned modes. The terminal can perform many transport and logistics functions on which the demand for access to specific elements of transport infrastructure depends. The infrastructure of a combined transport terminal means all elements needed or used to perform the process of moving, transhipping, storing and forwarding of intermodal loading units in the terminal and outside. The combined transport infrastructure can be divided into[3]:

1) linear infrastructure,
2) nodal infrastructure,
3) IT infrastructure,
4) superstructure.

Some sources combine the concepts of infrastructure and transport superstructure, while others distinguish them and the criterion of distinction is permanent location in space and permanent connection with the ground, in other words, the immobility of the object. For the purposes of this analysis, the superstructure of the combined terminal, i.e. mobile terminal objects, will fall within the broad sense of the term infrastructure. Each type of infrastructure is necessary for the proper and comprehensive service of loading units in the terminal, as part of the entire transport process from the sender to the recipient of the cargo. Linear infrastructure is defined as all transport links or transport routes necessary to carry out the process of cargo movement in a given transport mode (e.g. railroad tracks for rail transport). Nodal infrastructure is spatially separated objects or groups of objects supporting the transport process. For the scope of the transport and logistics network, such a nodal infrastructure can be the combined transport terminal. IT infrastructure is a relatively new element of the transport system, which in older studies appears as an element of linear infrastructure. IT infrastructure includes telematics infrastructure, used for data and information flow (e.g. telephone lines, optical fibres), as well as media, standards for data exchange and protection. The last type of infrastructure is superstructure, i.e. all devices enabling the movement of cargo in terms of transport (tractors and terminal trailers) and transhipment (cranes, reachstackers). Due to the wide scope of the superstructure of combined transport terminals, it will be discussed in the Chapter *Transhipment equipment of combined transport terminals.*

[3] According to: M. Jacyna, D. Pyza, R. Jachimowski, Transport Intermodalny - Projektowanie Terminali Przeładunkowych, PWN, Warszawa, 2018

Due to the adopted scope of analysis, the authors focus on selected variants of combined transport terminals serving river, rail and road transport modes. The nodal infrastructure of the terminal includes three separated operational zones:

1) transhipment fronts, include transhipment fronts dedicated to selected means of transport (rail wagons, road trucks or river barges) or combined fronts, together with the adjacent temporary (buffer) area of the ITUs storage,
2) storage yards, i.e. a separate area for storing ITUs and cargoes transported in ITUs and adapted to specific storage requirements, i.e. places for 45-foot containers, places for refrigerated containers, indoor warehouse for cargoes to be stuffed into ITUs,
3) complementary facilities along with the communication infrastructure of the terminal, e.g. car parks and administrative or office buildings of the terminal.

Indoor storage is usually available on large combined terminals and performs a similar consolidation role as CFS (Container Freight Station) on maritime container terminals. In open storage yards, intermodal loading units are stored forming compact blocks separated by internal communication routes. Containers are stacked up to 3-4 layers for full containers and 5-6 layers for empty containers. Swap bodies can be stacked only if they have a suitably reinforced structure (stackable swap bodies), when they lack such functionality swap bodies are stored similarly to semi-trailers in adapted storage yards and parking spaces. The place and order of stacking loading units depends on the waiting time for further transport and whether they are empty or full. Loading units with hazardous materials and refrigerated cargoes are stacked in separated sectors of storage yards, e.g. enabling access to energy supply points.

For the purposes of the analysis, the authors described the most common types of combined transport terminals based on seven previously identified models. The authors described the most important infrastructure elements necessary for the functioning of the analysed terminals.

2.2. Large rail-road terminal

The large rail-road terminal is the most common type of combined transport terminal. An example is the **PCC Intermodal terminal in Kutno**[4] (Poland), which is currently the biggest combined terminal in Poland and covers an area of 80,000 m^2 (Fig. 3). According to the classification presented in the Chapter 1 (1.1. Types and categories of terminals) of the analysis, this terminal belongs to the following categories:

1.2. terminal operating containers and swap bodies,
2.3. large terminal (60000 ITU),
3.2. Lo-Lo terminal,
4.3. international terminal,

[4] www.pccintermodal.pl

5.2. bimodal terminal (rail-road),

6.2. terminal related to one logistics centre,

7.1. public terminal,

8.1. terminal in the network of one operator,

9.2. regional distribution hub.

Figure 3. PCC Intermodal Terminal in Kutno
Source: www.pccintermodal.pl/terminal-kutno/

The large rail-road terminal has a developed road system, including terminal access and exit roads, as well as internal and manoeuvring roads (Fig. 3). An important element of the terminal's infrastructure is the track system, i.e. the network of access and internal railroads, including: transfer (take-over) tracks, siding tracks and transhipment (loading) tracks. In addition, there are tracks for gantry cranes along the transhipment tracks. This type of terminal has at least two separate transhipment fronts, with a minimum of one for each of the transport modes served. Within the fronts there is a separate buffer storage area for temporary storage of intermodal loading units waiting for further internal transport. As a rule, it has one large storage yard or several smaller storage areas with separate sections for empty lauding units, as well as refrigerated and with hazardous materials. Optionally, an indoor warehouse may be available on the terminal. A large rail-road terminal usually has several administration and office buildings (or one of a larger size) as well as external and internal parking for road vehicles arriving at the terminal. The terminal is connected to the ICT infrastructure enabling the terminal to offer present-day telematics solutions. In the indicated terminal, in addition to overhead gantry cranes, the small-size internal handling equipment and vertical reloading equipment is used, described in more detail in the next chapter of the analysis.

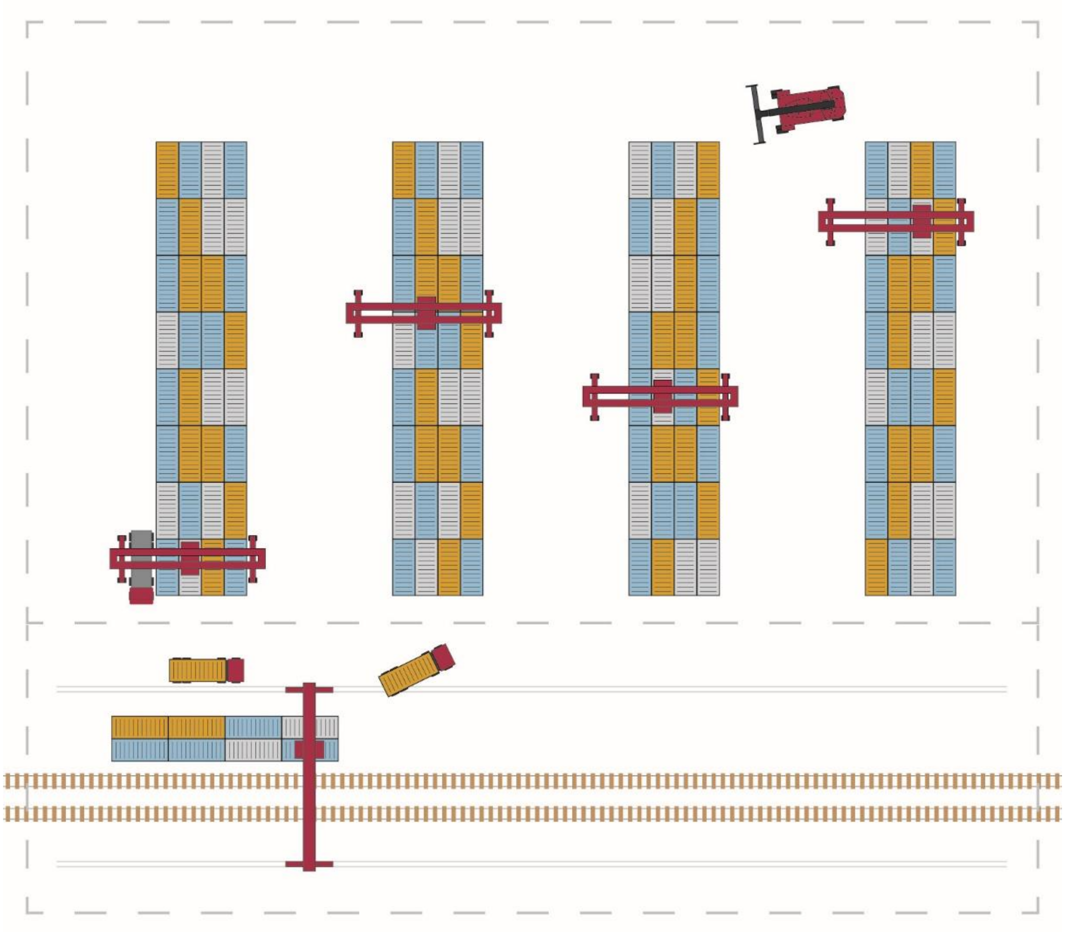

Figure 4. Large rail-road terminal

2.3. Small rail-road terminal

The small rail-road terminal is a terminal of limited area handling a smaller number of loading units, and often treated as a satellite terminal in relation to large combined transport terminals. An example is **METRANS Terminal in Pruszków**[5] (Poland), which is located in Warsaw agglomeration and covers an area of 33,000 m^2 (Fig. 5). According to the classification presented in the Chapter 1 (1.1. Types and categories of terminals) of the analysis, this terminal belongs to the following categories:

1.3. terminal operating containers, swap bodies and semi-trailers,
2.1. small terminal (less than 25000 ITU),
3.2. Lo-Lo terminal,
4.2. regional and agglomeration terminal,
5.2. bimodal terminal (rail-road),
6.1. terminal not related to logistics centre,
7.1. public terminal,
8.1. terminal in a network of one operator,

[5] www.metrans.eu

9.2. regional distribution hub.

Figure 5. METRANS Terminal in Pruszków
Source: www.metrans.eu/terminal-operations/terminal-pruszkow-warszawa---pl

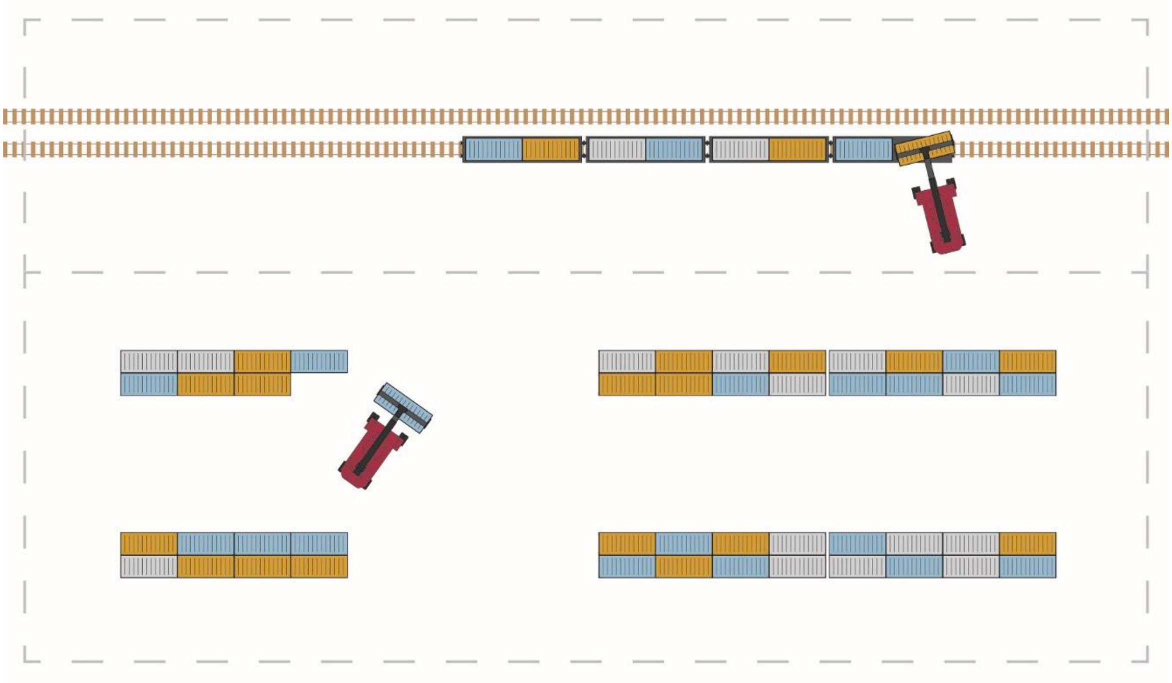

Figure 6. Small rail-road terminal

The small rail-road terminal has access to the linear infrastructure of road and rail transport (Fig. 6). The track system includes at least sidings and transhipment tracks. In terms of road system, the terminal has access and manoeuvring roads and at least one internal parking area, an open storage yard and, optionally, a small buffer storage area for loading units ready for transhipment are separated at the terminal.

In most cases, this type of terminal does not have high-capacity transhipment equipment (gantry cranes), but only small-size internal handling equipment (reachstackers, mobile stacking cranes). Due to the market requirements, even the smallest terminal must currently have access to modern ICT infrastructure. This terminal has an administration and office building on an appropriate scale depending on the number of terminal employees.

2.4. Trimodal river terminal

The river terminal is a terminal found mainly in countries with a well-developed network of inland waterways. An example is **DeCeTe Duisburg Terminal**[6] (Germany) which is one of several large terminals in the largest river port in Europe and covers an area of 170,000 m^2 (Fig. 7). The port of Duisburg is recognized as a global node in the European transport network[7]. However, DeCeTe Duisburg Terminal itself according to the classification presented in the Chapter 1 (1.1. Types and categories of terminals) of the analysis, belongs to the following categories:

1.1. container terminal,
2.3. large terminal (100000 ITU),
3.2. Lo-Lo terminal,
4.3. international terminal,
5.4. trimodal terminals (river-rail-road),
6.3. terminal related to several logistics centres,
7.1. public terminal,
8.2. terminal in networks of several operators,
9.2. regional distribution hub.

[6] www.ect.nl/en/terminals/hutchison-ports-duisburg
[7] Part of the European Gateway Services network

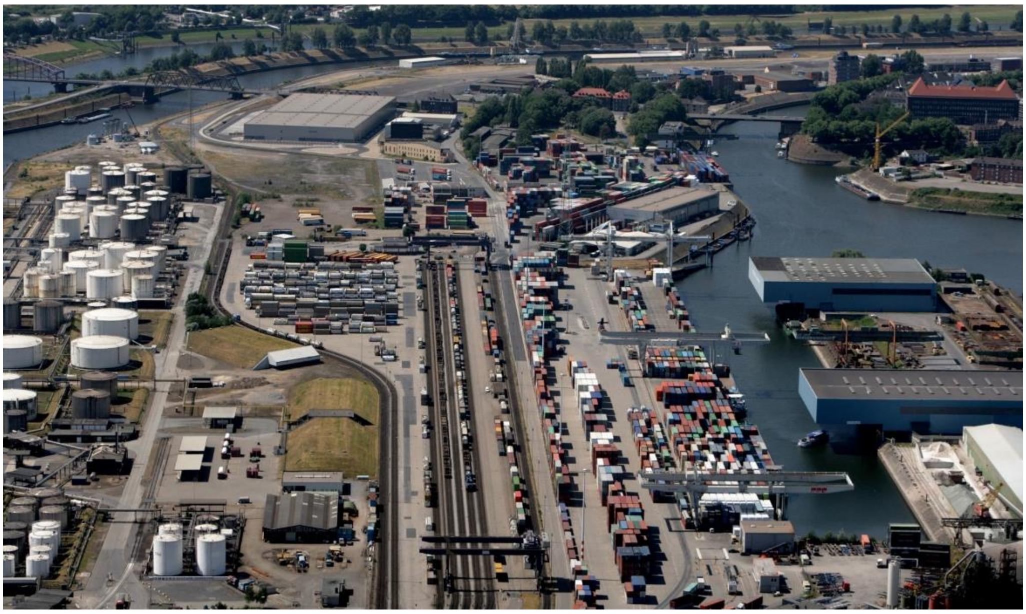

Figure 7. DeCeTe Duisburg Terminal

Source: www.verhoex.com/about-verhoex-companies/verhoex-zollagentur-gmbh

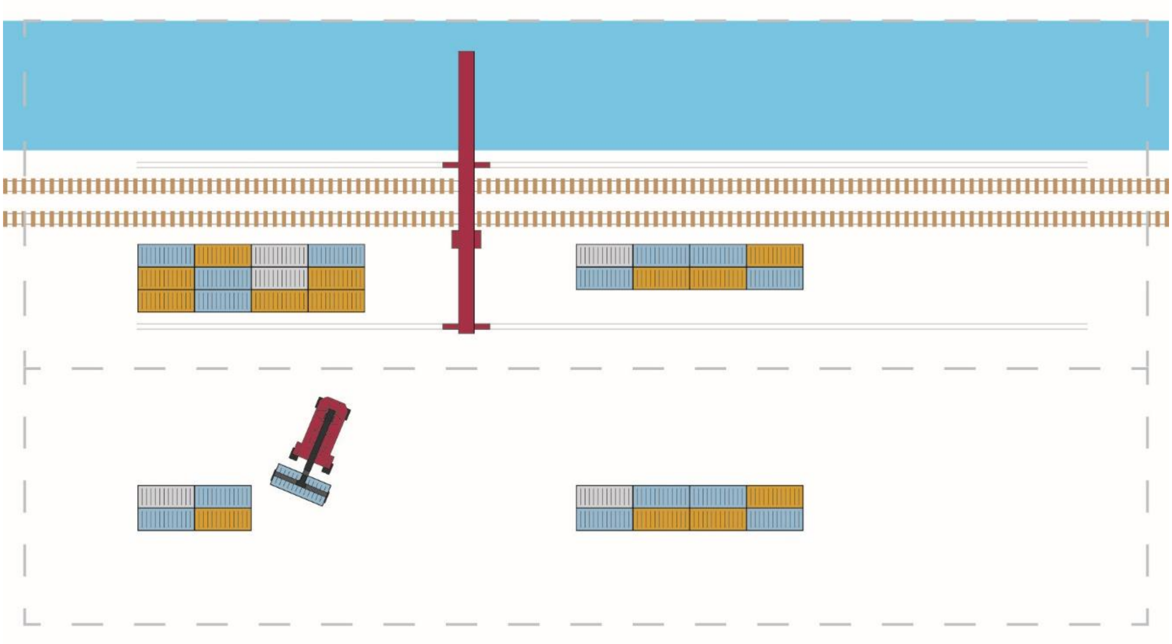

Figure 8. Trimodal river terminal

In the case of the tri-modal terminal, access to the waterway is necessary, i.e. directly to the navigable river or water canal (Fig. 8). Regardless, access to rail and road infrastructure is necessary. Rail-road infrastructure is similar to the small rail-road terminal, with the difference that the terminal is equipped with a Ship-To-Shore (STS) gantry crane, having a water outreach and constituting the basic transhipment device. Transhipment railway tracks are usually routed along the shoreline so that the crane can handle both barges and railway wagons. The terminal has storage yards adapted for high container storage. Due to the high cost of land with access to the waterway, large parking lots are rarely offered at terminals and the organization of processes enforces high rotation of supported means of transport with preferences for barges. The terminal uses vertical and internal handling facilities described in more detail in the next chapter of the analysis.

2.5. Border terminal

A border terminal is a special type of terminal operating in special cases at the borders of countries where other technical standards of infrastructure apply. An example is the **PKP CARGO Logistics Center Małaszewicze**[8] (Poland), which is located on the Polish-Belarus border and covers an area of 40,000 m^2 (Fig. 9). Transhipment of loading units at the terminal is necessary due to the difference in rail track gauge, i.e. in Poland it is 1435 mm and in Belarus 1520 mm. According to the classification presented in the Chapter 1 (1.1. Types and categories of terminals) of the analysis, this terminal belongs to the following categories:

1.1. container terminal,
2.1. small terminal (less than 25000 ITU),
3.2. Lo-Lo terminal,
4.3. international terminal,
5.2. bimodal terminals (rail-road or river-road),
6.2. terminal related to one logistics centre,
7.1. public terminal,
8.1. terminal in a network of one operator,
9.5. border terminal.

The border terminal has the same infrastructure elements as the small rail-road terminal, with the difference that a rail track system of the border terminal is designed to include tracks with two different track gauges corresponding to different standards of railway infrastructure in neighbouring countries (Fig. 10). Another difference specific to the border terminal is the increased number of primary transhipment devices, which are gantry cranes, that allows to minimize the time of transloading loading units between trains. Due to the border location, apart from the standard infrastructure elements, the terminal usually has a separate building for customs clearance.

[8] www.clmalaszewicze.pl

Figure 9. PKP CARGO Centrum Logistyczne Małaszewicze
Source: wig.waw.pl/centrum-swiata-w-malaszewiczach/

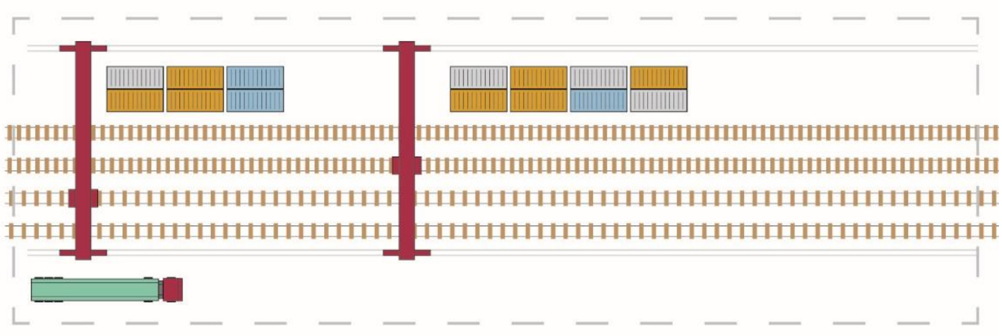

Figure 10. *Border terminal with railway tracks with two different track gauge*

2.6. Ro-La terminal

Ro-La terminals are adapted to one transhipment technology, so-called Rollande Landstrasse (rolling highway system). An example is the **Rail Freight Centre Wörgl** (Austria)[9] operating transalpine transport from Austria to Italy and covering an area of 40,000 m^2 (Fig. 11). We can classify this terminal according to the division presented in section 1.1:

1.5. terminal operating articulated vehicles (tractor and semi-trailer),
2.1. small terminal (less than 25000 ITU),
3.1. Ro-Ro terminal,
4.3. international terminal,
5.2. bimodal terminal (rail-road),
6.1. terminal not related to logistics centre,

[9] www.infrastruktur.oebb.at

7.1. public terminal,
8.3. independent terminal,
9.3. regional distribution hub.

Figure 11. Rail Freight Centre Wörgl
Source: chriszenz.com/portfolio/oebb-terminal-woergl/

The Ro-La terminal is based on the key technological solutions such as low-floor wagons and loading ramps attached at the end or beginning of the intermodal train. These ramps are used by articulated vehicles to drive-in the first or drive-out the last wagon (Fig. 12). Unloading and loading operations are carried out according to the FIFO (First In First Out) principle, i.e. the first vehicle which is loaded on the train takes place directly behind the locomotive and the first is unloaded at the destination terminal. The Ro-La terminal has access to transhipment tracks and road network enabling vehicle access to the terminal. In addition to the above, the Ro-La terminal has a parking area for vehicles awaiting loading operations. Access to the ICT infrastructure enables better organization of the terminal's work, including gate appointment service necessary to ensure the efficiency of the train loading process.

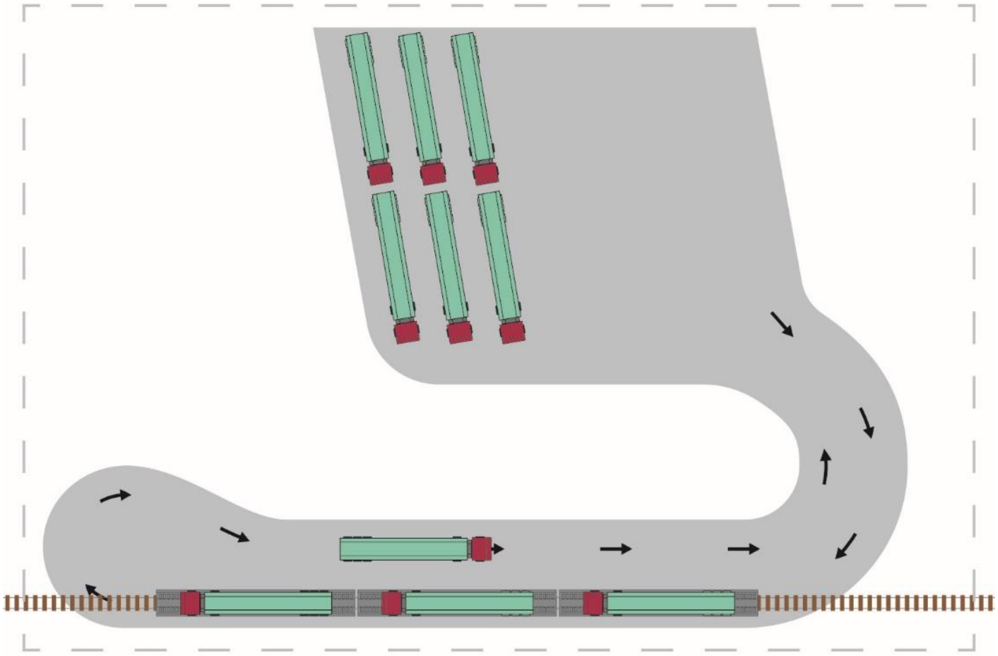

Figure 12. Ro-La terminal

2.7. Modalohr technology specialized terminal

Another type of combined transport terminal is a specialized Modalohr technology terminal. An example is the **Aiton Terminal**[10] located near the City of Chambéry (France) (Fig. 13). For this specialist terminal, its classification, according to the categories presented in section 1.1. are as follows:

1.4. terminal operating semi-trailers,
2.2. mid-size terminal (25000 ÷ 50000 ITU),
3.4. specialized terminal (Modalohr),
4.3. international terminal,
5.2. bimodal terminal (rail-road),
6.1. not related to logistics centre,
7.1. public terminal,
8.3. independent terminal,
9.3. regional distribution hub.

[10] www.lohr.fr/lohr-railway-system/the-lohr-system-terminals

Figure 13. Aiton Terminal
Source: lohr.fr/lohr-railway-system/the-lohr-system-terminals/

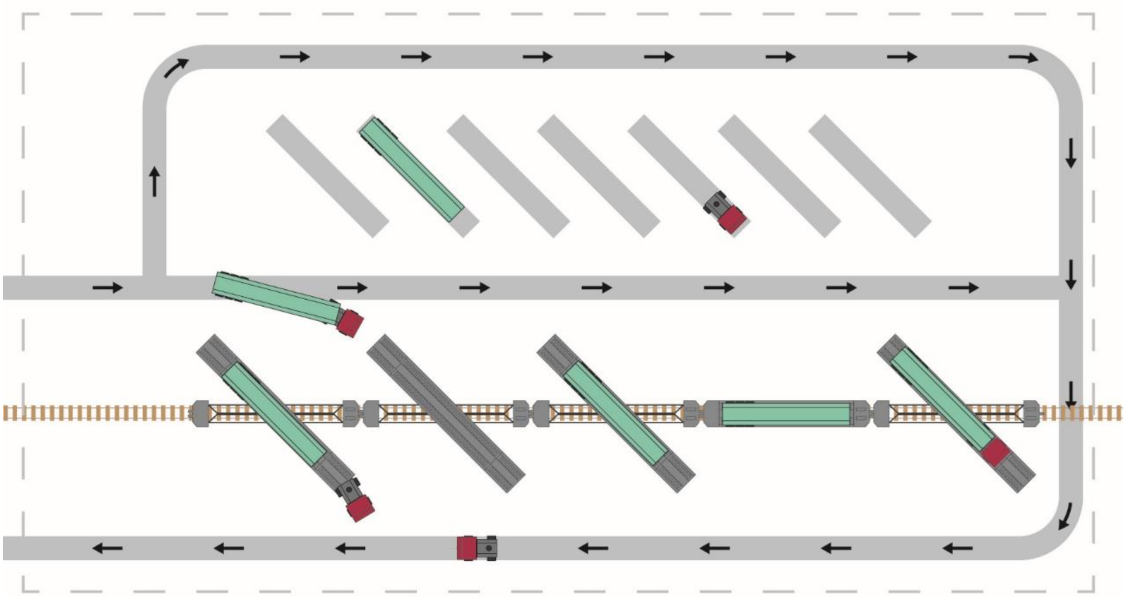

Figure 14. Combined transport terminal in Modalohr technology

Due to infrastructural demand, the Modalohr specialized terminal has access to road and rail infrastructure in the form of access roads and transhipment track (Fig. 14). In the terminal area there is a developed system of roads for internal transport connecting loading stations located along the transhipment track with parking area. The terminal has a need for a small administrative office building and for connecting it to the ICT infrastructure. The specificity of the Modalohr specialist terminal is mainly based on the use of unique transhipment devices, which are described in more detail in the next chapter of the analysis.

2.8. Cargobeamer technology specialized terminal

The last distinguished type of combined transport terminal is a specialized terminal in Cargobeamer technology. An example is the terminal currently under construction in Calais, which is part of the **Transmarck-Turquerie Logistics Hub**[11] (France) (Fig. 15). Investment works began in 2018 and the opening of the terminal is planned for 2023. Construction is carried out with the support of European Union funds[12]. For this specialist terminal, its classification according to the categories presented in section 1.1. is as follows:

1.4. terminal operating semi-trailers,
2.1. small terminal (less than 25000 ITU),
3.4. specialized terminal (Cargobeamer),
4.3. international terminal,
5.2. bimodal terminals (rail-road),
6.1. terminal not related to logistics centre,
7.2. public terminal,
8.3. independent terminal,
9.3. regional distribution hub.

The Cargobeamer specialized terminal has an infrastructure similar to the Modalohr terminal (Fig. 16). It includes access roads, internal roads manoeuvring areas and transhipment track. The terminal area has a separate parking space for semi-trailers waiting for transhipment. The terminal usually has a small administrative office building and appropriate connection to the ICT infrastructure. The technologically unique transhipment devices that are used in the Cargobeamer terminal are described in the next chapter.

[11] www.cargobeamer.eu/7m-from-the-EU-for-the-CargoBeamer-rail-motorway-terminal-in-Calais-852891
[12] www.ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/2018-eu-tm-0148-m

Figure 15. Project of combined terminal of Transmarck-Turquerie Logistics Hub
Source: Cargo Beamer baut Terminal in Calais, www.eurotransport.de/

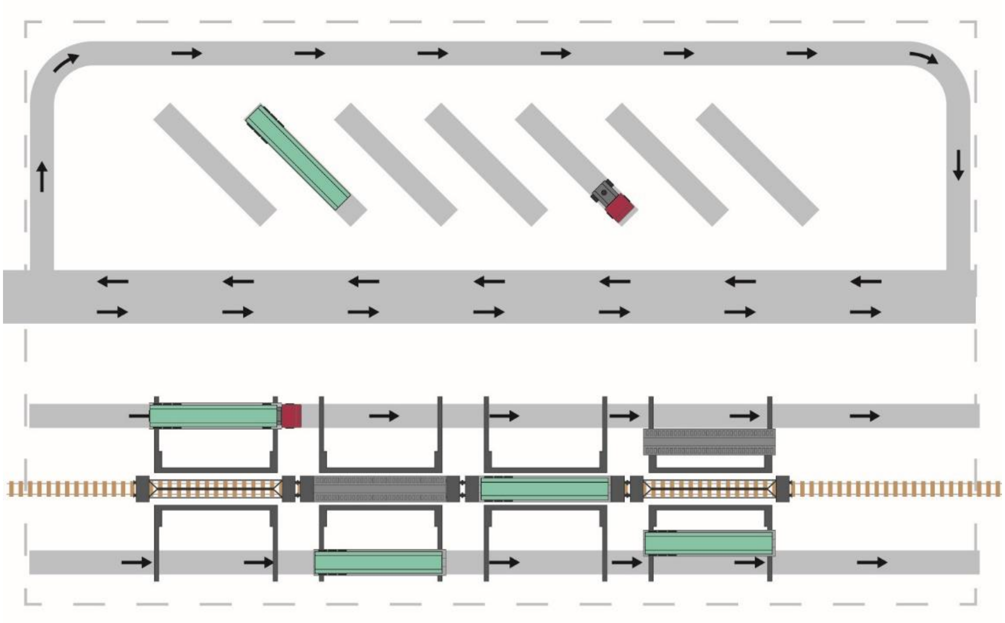

Figure 16. Combined transport terminal in Cargobeamer technology

3. Transhipment equipment of combined transport terminals

3.1. Types of transhipment equipment of combined transport terminals

Terminal equipment used for transhipment processes have various technical and operational parameters adapted to the specific requirements of a given terminal. The transhipment equipment of the combined transport terminal can be divided into three groups considering their most important functional features.

1) Primary Lo-Lo handling equipment:
   - Ship-to-Shore Quay Cranes (STS),
   - Mobile Quay Cranes,
   - Rail Mounted Gantry Cranes (RMG),
   - Rubber Tired Gantry Cranes (RTG),
   - Reachstackers (RST).
2) Primary Ro-Ro handling equipment:
   - Terminal Tractors (TT),
   - specialized loading mechanisms built into the transhipment track,
   - loading ramps built-in/mobile.
3) Secondary handling and internal transport equipment:
   - storage yard cranes (RTG/RMG),
   - Terminal Tractors (TT),
   - Roll-trailers (RT),
   - terminal trailers,
   - Reachstackers (RST),
   - Empty Container Handlers (ECH).

According to the above division, the most common types of combined transport transhipment equipment are described later in the analysis. Technical and operational parameters of specific handling units used on typical combined transport terminals indicated in previous chapters are given. It should be remembered that the parameters of transhipment equipment may differ significantly depending on the manufacturer, model or version of the handling unit. There is also a tendency to adapt handling equipment to the needs of a specific combined terminal. Certainly, a common feature of all transhipment facilities is their technical adaptation to handle intermodal loading units, i.e. by applying spreader for containers and grappler arms for swap bodies and semi-trailers.

Three common market trends can be distinguished in the scope of construction and equipment of transhipment equipment of combined transport terminals. The first of these is the wider use of low-emission or zero-emission drives. These include, first of all, electric engines, which are commonly used in STS and RMG gantry cranes, used as a primary and secondary handling unit. In RTG gantry cranes and reachstackers RST, due to the need for high-capacity batteries, conventional or hybrid engines are more often used. In addition, LNG, CNG and hydrogen engines are increasingly used in secondary transport equipment used for internal terminal processes.

The second strong market trend associated with new engines, is to reduce the energy consumption of all handling equipment at combined transport terminals. Modern work control systems on board of mobile facilities and integrated with a Terminal Operating System (TOS) are applied. This allows better work and maintenance planning and ongoing monitoring of critical operating parameters of every handling unit. Advanced control systems allow the reduced time of separate handling processes and thus energy saving.

Table 3. Assignment of transhipment equipment to combined transport terminal types

	Model of the combined transport terminal						
	1	2	3	4	5	6	7
	Large rail-road terminal	Small rail-road terminal	Trimodal river terminal	Border terminal	Ro-La terminal	Cargobeamer terminal	Modalohr terminal
	Primary handling equipment Lo-Lo						
Ship-To-Shore Quay Cranes (STS)			X				
Mobile Quay Cranes			X				
Rail Mounted Gantry Crane RMG	X			X			
Rubber Tired Gantry Crane RTG	X			X			
Reachstackers RST		X					
	Primary handling equipment Ro-Ro						
Terminal Tractors TT						X	X
Specialized loading mechanisms built into the transhipment track						X	X
Loading Ramps (built-in)							X
Loading Ramps (mobile)					X		
	Secondary handling and internal transport equipment						
Stacking Gantry Cranes (RMG/RTG)	X			X			
Terminal Tractors TT	X	X	X	X	X	X	X
Roll-trailers RT	X	X	X	X			
Terminal Trailers	X	X	X	X		X	X
Reachstackers RST	X		X	X		X	X
Empty Container Handlers ECH	X	X	X	X			

A third important market trend is the automation of the terminal operations with the use of semi-automatic and fully automatic equipment. Such solutions are introduced only at large rail-road terminals and trimodal river terminals. In practice, this means, to control of transhipment and storage processes using semi-automatic handling equipment, i.e. Automated RTG (ARTG), Automated RMG (ARMG) and Automated TT (ATT). The transformation from a conventional terminal to a fully automatic terminal is not applicable due to large differences in infrastructure and organizational requirements, as well as requirements for terminal customers. Hence, similar to big seaports, coexistence of conventional terminals with new high-performance automated terminals is preferred.

In table 3 transhipment equipment has been assigned to analyse combined terminal types. In the further analysis tables describing selected handling units are an attempt of synthesis and unification of technical data according to different models and different manufacturers of these facilities (table. 4 and 5).

3.2. Primary Lo-Lo handling equipment

The primary handling equipment in Lo-Lo (Lift On - Lift Off) technology are realizing the most important process of transhipment of intermodal loading units at the terminal. In the Lo-Lo handling process intermodal loading unit is lifted in the vertical axis, next shifted along the horizontal axis at a certain height, to finally to be placed on the means of transport or storage area. Primary Lo-Lo handling equipment are ordered and adjusted to the previously defined requirements of the terminal. Currently, the most commonly used Lo-Lo handling units include:

1) Ship-to-Shore Quay Cranes (STS),
2) Mobile Quay Cranes,
3) Rail Mounted Gantry Cranes (RMG),
4) Rubber Tired Gantry Cranes (RTG),
5) Reachstackers (RST).

The gantry cranes due to its size and high performance are always the primary handling equipment used at combined transport terminals. The STS quay cranes used at the trimodal river terminals do not differ in construction from gantry cranes used at seaport container terminals (Fig. 17). Characteristic is the extended working arm of the gantry in the form of a horizontal boom having a water outreach beyond the shoreline of the terminal. The water outreach depends on the breadth of barges accepted at the terminal and is up to 20m. From quayside of the STS quay crane the outreach enables access to at least one transhipment track and a container storage yard. STS quay cranes most often move on transport rails, similar to those used by RMG gantry cranes and running along the shoreline of the terminal. Besides STS quay cranes, mobile quay cranes that move on wheels or caterpillars can be used in trimodal river terminals as well (Fig. 18). They are universal handling units used in small trimodal terminals that, due to its mobility can handle all transhipment fronts of the terminal. The disadvantage of mobile quay cranes is the limited water outreach and lower cargo handling performance comparing to STS gantry cranes.

Gantry cranes are the primary transhipment equipment on the large rail-road terminals. They carry out transhipments operations at the railway front and optionally support stacking operations at storage yard as well as loading of vehicles. Gantry cranes can move on wheels (RTG crane) and on rails (RMG crane) (Fig. 19 and 20). Table 4 presents the comparison of operational parameters for both types of cranes.

Figure 17. STS quay cranes in trimodal river terminal
Source: ect.nl/en/terminals/hutchison-ports-duisburg

Figure 18. Mobile quay crane
Source: mantsinen.com

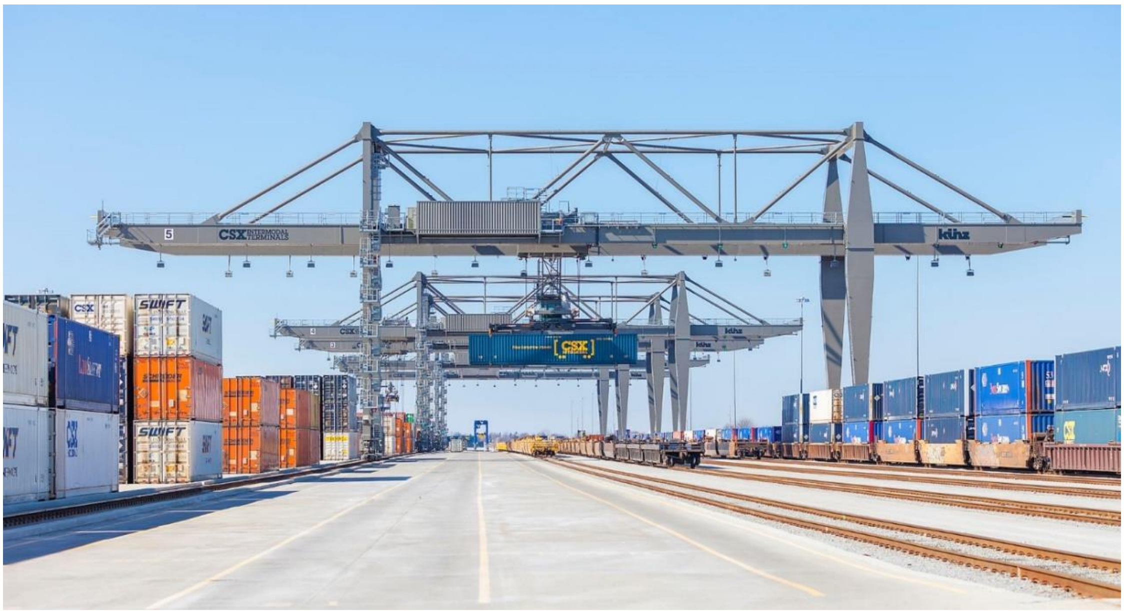

Figure 19. Rail Mounted Gantry Crane (RMG)
Source: mi-jack.com/rail-mounted-gantry-cranes/

Figure 20. Rubber Tired Gantry Crane (RTG)
Source: forkliftaction.com

In the small combined transport terminals as a main handling equipment reachstackers RST are used (Fig. 21). The reachstacker is a heavy self-propelled vehicle on wheels with telescopic boom ended with spreader/grappler arm. Table 5 presents the reachstacker operational parameters in comparison with the Empty Container Handler (ECH), which are used next to each other for handling containers at storage yards.

Figure 21. Reachstacker (RST)

Source: uniktruck.com

Table 4. Comparison of operational parameters of Rubber Tired Gantry Crane (RTG) and Rail Mounted Gantry Crane (RMG)

Parameters	 RTG	 RMG	Differences	
			RTG	RMG
Rated Lifting Weight (t)	40.5	40.5		
Span (m)	23.47	47	The span is small and single, no extend cantilever	
Rated Lifting Height (m)	18.2	18.2		
Base Distance (m)	6.4	16	Smaller	Bigger
Full Load Lifting Speed (m/min)	20	30		
No Load Lifting Speed (m/min)	40	50		
Trolley Speed (m/min)	70	120	Slower	Faster
Trolley Speed (m/min)	90-135	80	Faster	Slower
Driving Mode	Diesel Engine Electric Motor	AC Electric Motor		
Running Bridge	Vacuum Tire	Steel Tyre	It can turn direction, but tires are easy to wear.	Walk on the track, unable to change direction.

Source: gantrycranedesign.com/

Table 5. Comparison of operational parameters of Reachstacker (RST) and Empty Container Handler (ECH)

Parameters	 RST	 ECH
Axle base	approx. 6200 mm	approx. 4320-4830 mm
Wheelbase	approx. 3060-3703 mm	approx. 2108-3365 mm
Length	Without boom approx. 8360-8650 mm Including boom around 11873-12073 mm	approx. 9185-10050 mm
Height	approx. 4700-4800 mm	With the mast folded in approx. 5800-10795 mm With mast spread around 8850-19020 mm
Width	approx. 4200-12200 mm	Basically approx. 3380-4110 mm With gripping mechanism approx. 6084-12218 mm
Load Capacity	It depends on the distance of the load from the centre of gravity of the vehicle and is about 14000-46000 kg	approx. 36280-48070 kg
Raising height	approx. 13375-15355 mm	approx. 9750-12650 mm
Load movement mechanism	Vertically and horizontally	Vertically
Cargo displacement distance	More	Less
Optional accessories	Different types of front attachments (spreader), automatic scale	Different types of gripping devices mounted on the lifting mechanism depending on the purpose and model of the lift truck

Source: based on commercial offer of manufacturers

3.3. Primary Ro-Ro handling equipment

The primary Ro-Ro (Roll-on Roll-off) handling equipment allows the horizontal transhipment of selected intermodal loading units, i.e. semi-trailers and articulated vehicles (tractor and semi-trailer). These loading units are transhipped horizontally on rail wagons without lifting or lowering. Vehicles drive onto the rail wagon by means of their own propulsion or external loading mechanism provided by the terminal. In Ro-Ro technology terminals, i.e., the Ro-La terminal, the Modalohr terminal and Cargobeamer, standard and dedicated handling equipment supporting reloading processes are used. Standard equipment is a terminal tractor (TT), which is used to move semi-trailers between the parking area and the transhipment track (Fig. 25, left). For dedicated handling equipment should be considered mobile loading ramps designed for a particular terminal and enabling vehicles to drive-in or drive-out the rail wagon with the help of their own engine or terminal tractor available at the terminal. In the case of Modalohr and Cargobeamer terminals there are specialized loading mechanisms built into the transhipment track. They cause the rotation of the loading platform of the wagon (Modalohr) or the perpendicular movement of the loading cradle (Cargobeamer), resulting in loading a vehicle onto a rail wagon. Figure 22 shows elements of the loading mechanism of the Modalohr terminal comprising: centring system, lifting system, turning bodies and ramps (Fig. 22).

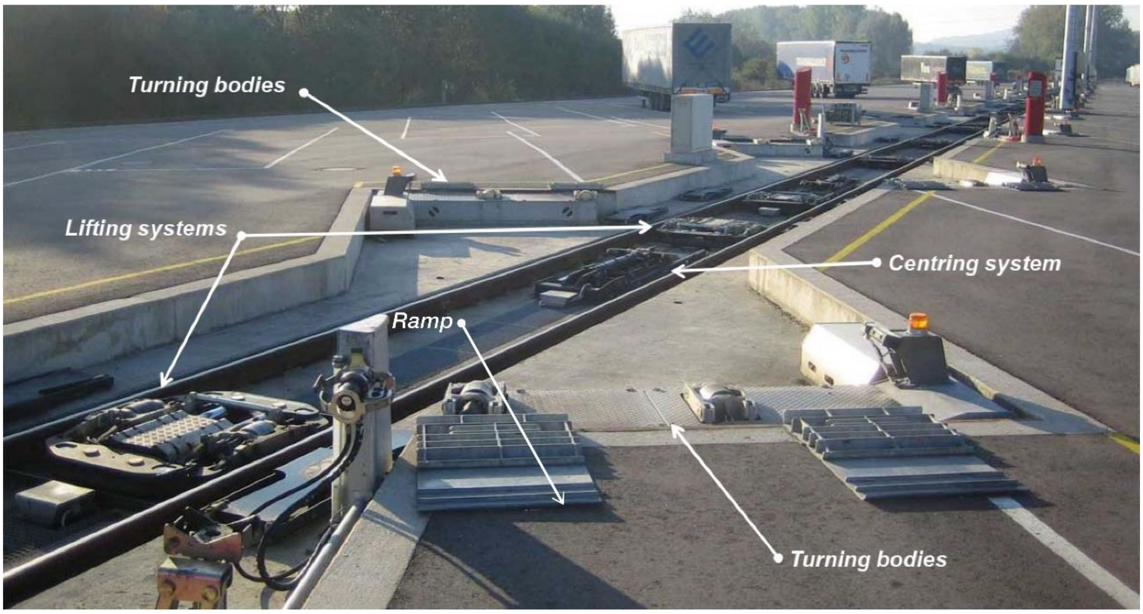

Figure 22. Specialized loading mechanism built into the transhipment track of Modalohr terminal
Source: lohr.fr

3.4. Secondary handling and internal transport equipment

Secondary handling and internal transport equipment are a group of transport facilities used to move and tranship the loading units and supporting the operation of the primary handling equipment. Internal transportation at the terminal is carried out mainly between the transhipment fronts and storage yards or parking areas. It is correlated with the primary transhipment operations. Secondary handling and internal transport equipment include (table. 3):

1) Terminal Tractors (TT), which are used at the Ro-La terminals;
2) Terminal Tractors (TT) coupled with Roll-trailers (RT) or terminal trailers, which are used at rail-road terminals, trimodal and border terminals;
3) Terminal Tractors (TT) coupled with terminal trailers, which are used at all terminals except Ro-La terminals;
4) storage yard gantry cranes (RTG/RMG), which are used at large rail-road terminals and optionally at border terminals;

5) Reachstackery (RST), which are used at large rail-road terminals, trimodal and border terminals and optionally at Modalohr and Cargobeamer terminals;
6) Empty Container Handlers (ECH), which are used which are used at rail-road terminals, trimodal and border terminals.

The type and number of handling units are closely related to the cargo turnover and the structure of cargo units transhipped by the terminal. In the case of a large number of transhipped containers empty container handlers ECH are in use. These handling units are equipped with the front mast, allowing stacking of empty containers up to 5-6 layers (Tab. 5, Fig. 23). Storage yard gantry cranes (RMG or RTG) and/or reachstackery RST are used as secondary handling equipment for large rail-road terminals, mainly for stacking intermodal loading units and loading of vehicles. The important role in the internal terminal transport perform terminal tractors TT coupled with terminal trailers (5th wheel coupling) or roll-trailers ('goose neck' coupling) (Fig. 24 and 25). Additionally, the terminal tractors can move client’s semi-trailers at the Ro-La terminal.

Figure 23. Empty Container Handler (ECH)
Source: pesahyster.com.br/product-detail/movimentacao-de-conteineres-h40-50xm-16ch/

Figure 24. Roll trailer loaded with two swap bodies
Source: photography by author of the analysis

Figure 25. Terminal tractor (TT) to be coupled with terminal trailer (left) and roll-trailer (right)
Source: tradus.com

Table 6 presents concisely the advantages and disadvantages of the selected terminal handling equipment, that are key handling facilities of the rail-road terminals. That comparison evaluates technical, operational and economical parameters facilitating the proper investment decision answering to the specific needs of each terminal.

Table 6. Advantages and disadvantages of selected terminal handling equipment

	 RTG	 RMG	 RST	 ECH
Advantages	• Mobility • Load lifting height • High reloading speed • Large load weight possible • Possibility of stacking several rows of loads	• Load lifting height • High reloading speed • Large load weight possible • Options of full automatization • Possibility of stacking several rows of loads	• Can be used for both reloading and moving loading units on the terminal premises • Possibility of stacking several rows of loads • Relatively low investment costs	• Can be used for both reloading and moving loading units on the terminal premises • Relatively low investment costs
Disadvantages	• Tire wear • Low movement speed • Traffic restrictions related to the surface • Shorter load travel distance than RMG • High investment costs • The need to have a qualified crew to service	• The need to move on transport rails • Very high investment costs • The need to have a qualified crew to service	• Low reloading speed • Low transport speed	• Vertical load movement with a small horizontal range • Low reloading speed • Low transport speed • Mainly used for reloading empty loading units

Below are discussed in more detail the primary and secondary handling equipment of selected types of combined terminals and exemplary configuration of handling equipment of currently operating terminals in Europe is given.

3.5. Equipment of model terminals

3.5.1. Large rail-road terminal

The large rail-road terminal is equipped with several high-capacity gantry cranes (RTG or RMG), which are the primary handling equipment, and several smaller storage yard gantries (RTG or RMG). Primary gantry cranes move along the transhipment tracks with the reach to a buffer area and optionally to a selected storage yard. Storage yard gantry cranes as secondary handling equipment are stacking loading units and loading vehicles. The gantry cranes are supported by reachstackers that have more universal application. In case of stacking empty containers, ECH units are used. For internal transport between the buffer area of rail transhipment front and storage yards/parking area terminal tractors TT with roll-trailers RT or terminal trailers are used. In the largest rail-road terminals multi-trailer system is introduced for the high-capacity internal transport.

The example of a transhipment equipment configuration of the large rail-road terminal based on **PCC Intermodal Terminal in Kutno**[13]**:**

- 2 Rail Mounted Gantry Cranes (RMG),
- 5 Reachstackers (RST),
- 1 Empty Container Handler (ECH),
- 1 Terminal Tractor (TT).

3.5.2. Small rail-road terminal

The small rail-road terminal is rarely equipped with gantry crane, and when this the case, it is used as a multipurpose handling unit operating all transhipment fronts and storage areas. Most often in such terminals reachstacker plays the role of primary handling equipment. It can be supplemented by empty container handler ECH and terminal tractor for internal transport. Roller trailers or terminal trailers are very rarely used in the small rail-road terminals.

The example of a transhipment equipment configuration of the large rail-road terminal based on **METRANS Terminal in Pruszków**[14]**:**

- 3 reachstackers (RST).

3.5.3. Trimodal river terminal

Trimodal river terminal offers STS quay cranes or mobile quay cranes as primary handling equipment for transhipment of barges. Gantry or mobile quay crane is operating both water and rail transhipment front of the trimodal terminal. Other handling equipment is similar to the small rail-road terminal, with the difference that the trimodal terminal almost exclusively handles containers and reachstackers are complementary devices to quay gantry cranes/mobile cranes.

The example of a transhipment equipment configuration of the large rail-road terminal based on **DeCeTe Duisburg Terminal**[15]**:**

- 4 Ship-to-Shore Quay Cranes (STS),
- 4 Reachstackers (RST),
- 4 Empty Container Handlers (ECH),
- 4 Terminal Tractors (TT),
- 8 terminal trailers.

[13] Data according to: utk.gov.pl
[14] Data according to: utk.gov.pl
[15] myservices.ect.nl/Terminals/InlandTerminals/DeCeTeDuisburg

3.5.4. Border terminal

The primary handling equipment of the border terminal represent gantry cranes (RTG or RMG) in the amount of several units along the transhipment track. The handling capacity of the terminal aims to reduce the time of wagon-wagon transhipment operation. The secondary handling equipment is similar to the small rail-road terminal. The border terminal rarely offers large storage yards, hence the number of stacking and transport units is very limited.

The example of a transhipment equipment configuration of the large rail-road terminal based on **PKP CARGO Centrum Logistyczne Małaszewicze**[16]**:**

- 3 Rail Mounted Gantry Cranes (RMG),
- 1 Rubber Tired Gantry Crane (RTG),
- 2 Reachstackers (RST).

3.5.5. Ro-La Terminal

Rollande Landstrasse (Ro-La) terminal provide service for low-floor wagons used in Ro-La technology. In terms of handling equipment, this means usage of appropriate mobile ramps with the option of placing them at the end and beginning of the intermodal train. The example of the **Rail Freight Center Wörgl terminal** in Austria has no transhipment equipment other than mobile ramps.

3.5.6. Terminal of Modalohr and Cargobeamer technologies

A common feature of specialized terminals of Modalohr and Cargobeamer technologies, is the fact that these terminals offer service only to intermodal trains formed from non-standard rail wagons meeting the requirements of these technologies. In the case of both terminals the necessary equipment is the specialized loading mechanisms built into the transhipment track. The Modalohr terminal offers about 30 transhipment stations evenly distributed along the train according to wagons positions (Fig. 22 and 26). Transhipment stations include ramps built-in in the surface of the terminal at an angle of c.a. 40 degrees to the transhipment track. Specialized loading mechanism integrated with the station lift and turn the wagon platform docking it to the loading ramp. After loading the semi-trailer, the platform returns to its original position on the rail wagon.

Transhipment stations (CargoGate) adjusted to load semi-trailers on Cargobeamer wagons (CargoJet) are the most important equipment of the Cargobeamer terminal (Fig. 27). During loading operation, the specialized hydraulic mechanism move perpendicularly to the transhipment tracks the cradle with a semi-trailer using embedded transport rails. Then the cradle is automatically placed on the rail wagon, which is ready for departure. The number of transhipment stations is determined by the intermodal train length and the size of the terminal.

[16] Data according to: utk.gov.pl

Figure 26. Loading station at the Modalohr terminal

Source: Poliński J., Podsystemy transportu intermodalnego. Część I, Prace Instytutu Kolejnictwa – Zeszyt 154 (2017)

Figure 27. Loading station at the Cargobeamer terminal

Source: cargobeamer.com

The example of Modalohr that is **Aiton Terminal** in France offers 30 transhipment stations. In the case of the example Cargobeamer terminal of **Transmarck-Turquerie Logistics Hub** in Calais according to current assumptions 18 automated transhipment stations will be installed.

4. Handling processes of combined transport

4.1. Organization of work of combined transport terminal

The organization of a combined terminal's work must correspond to its size and function in the transport and logistics network. Large terminals typically offer longer working hours and a greater level of digitalisation and automation of the services offered. Standard terms of service for terminal customers include:

1. the terminal is open to customers 24/7 (24 hours a day/7 days a week);
2. service of rail wagons and vehicles are offered on a continuous basis according to previously agreed schedule;
3. warehouse services are offered during warehouse opening hours;
4. additional and non-standard services are each time agreed between the parties, i.e. the terminal operator and the client;
5. services rendered on Sundays and holidays are charged extra and require prior agreement.

In the case of small, private and related to one distribution centre terminals, opening hours and scope of services are limited and adapted to local needs.

4.2. Combined terminal services

Combined terminal processes are closely related to the implementation of services offered to terminal customers, that can be classified in two categories (Tab. 7).

1. Services to intermodal transport units (ITU),
2. Services to means of transport:
    - road transport (trucks, semi-trailers)
    - rail transport (wagons, locomotives),
    - inland shipping (barges).

Standard intermodal transport units (ITU) that terminal provides services to, includes:

- 20', 30', 40 'and 45' containers according to ISO standard,
- swap bodies long (Class A) and short (Class C) according to CEN standard,
- semi-trailers and articulated vehicles allowed to move on public roads.

Other load units may be considered non-standard and the terminal may refuse to accept them or require an additional fee.

The specificity of combined terminals is the fact that articulated vehicles (tractor+semi-trailer) can be both means of transport and intermodal transport units. The second situation occurs at Ro-La terminals.

The catalogue of services is described in terminal tariffs, which also give their price and method of settlement. Services not included in the tariff are not paid or are not offered directly by the terminal. For example, an external parking is usually free-of-charge and major repairs of loading units and vehicles are usually outsourced to external companies.

Table 7. Combined transport terminal services

No.	Name of service	Calculation of service fee	Remarks
	Services to intermodal transport units (ITU)		
1	Lo-Lo unloading/loading (container, swap body)	rate per 1 move	Rates can differ per ITU type and size
2	Ro-Ro unloading/loading (semi-trailers, articulated vehicle)	rate per vehicle	Rates can differ per ITU type and size
3	Storage of full ITU Storage of empty ITU Storage of reefer ITU Storage of dangerous goods ITU	rate per day of storage after free-of-charge period	Rates can differ per ITU type and size type, per cargo type and manipulations ordered during storage time
4	Sweeping out ITU floor Removal of lashing materials (nails, hooks, etc.) from the ITU	rate per activity	Rates can differ per ITU type and size
5	High-pressure external washing of ITU (container, swap body, semi-trailer) High-pressure internal washing of ITU (container, swap body)	rate per activity	Rates can differ per ITU type and size
6	Repair of ITU (container, swap body)	rate per working hour + cost of materials	Non-standard service
7	Reefer ITU plug in/out (container, semi-trailer) Electricity supply Monitoring of a refrigeration unit	rate per activity + energy consumption based on time/meter	Rates can differ per refrigeration unit and manipulations ordered
8	ITU internal transport (storage yard–warehouse, storage yard-workshop, storage yard-wash area)	rate for transport relation	Rates can differ per ITU type and size
9	ITU inspection (container, semi-trailer)	rate per activity	Rates can differ per ITU type and size
10	ITU weighing according to the SOLAS Convention requirements (container)	rate per activity	Method I of the SOLAS Convention of is offered as standard
11	ITU stuffing/stripping	rate per working hour + cost of stowage materials	Rates can differ per ITU type and size type, per cargo type and manipulations ordered
12	Other services: - placing/removing ADR/RID labels, - sealing, - providing the emergency tub for damaged dangerous goods ITU - flexi-tank fitting/removal (container, swap body) - snow removal from ITU roof	rate per activity	
	Services to means of rail transport		
1	Track access: - transfer tracks - siding tracks - transhipment tracks	fixed rate + rate per wagon	Rates can differ per type of traction, type of wagons and manipulations ordered
2	Shunting operations: - shunting in/out track - shunting locomotive additional work	fixed rate + rate per wagon rate per locomotive + traction fee	Rates can differ per type of traction, type of

No.	Name of service	Calculation of service fee	Remarks
			wagons and manipulations ordered
3	Occupying siding track	rate per wagon and hour after free-of-charge period	
4	Repair of wagon	rate per working hour + cost of materials	Non-standard service
5	Other services: - provision of a shunting crew - service outside the terminal service slot	rate per shunting crew	
	Services to means of road transport		
1	Truck parking: - guarded - unguarded	rate per hour of parking	
2	Fuel supply	rate per litre of fuel	
3	Repair of vehicle	rate per working hour + cost of materials	Non-standard service
4	High-pressure external washing of tractor	rate per activity	
	Services to means of water transport		
1	Mooring at the quay	tonnage or harbour fees based on Gross Tonnage (GT) or Gross Registered Tonnage (BRT)	Tonnage or harbour fees are charged by large ports and port authorities
2	Electricity supply	energy consumption based on time/meter	
3	Water supply	rate per m^3 of water	
4	Fuel supply	rate per tonne or m^3 of fuel	
5	Collection of waste from the ship	rate for m^3 of waste	
6	Ship repairs (hull parts, ship equipment)	rate per working hour + cost of materials	Non-standard service

Source: based on terms of service and tariffs of PCC Intermodal and CLIP terminals

Additional services offered by the terminal include various types of office services, e.g. documents' printing and scanning.

4.3. Services to means of rail transport

The largest number of combined terminals in Europe are rail-road terminals. At these terminals, efficient service to means of rail transport, i.e. intermodal trains, is a priority. This train priority over road transport results from high fixed operating costs and low flexibility of rail transport. Intermodal train service is done in terms of committed terminal service slots, and the ordering and implementation procedures must meet the standards of international rail traffic regulations.

The intermodal train service process at the combined terminal must be adjusted to the terminal capacity in terms of railway infrastructure. It is important for the terminal to have in disposal separated groups of tracks used during standard shunting services and other terminal handling services. There are two basic layouts of combined terminal railways: frontal system and transit system (Fig. 28 and 29). In the framework of these two terminal layouts, track groups are identified including:

- transfer tracks,
- siding tracks,
- transhipment tracks.

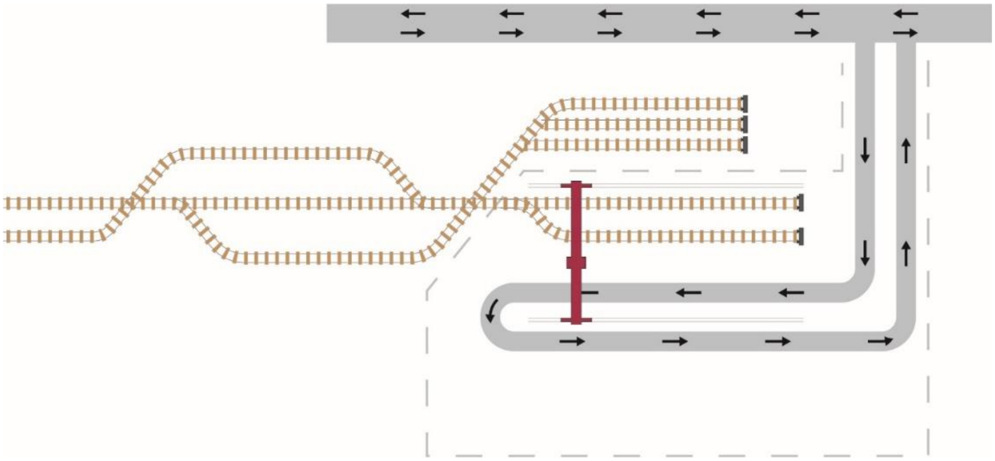

Figure 28. Rail-road terminal with frontal railway system
Source: based on Kostrzewski A., Nader M., Analiza zagadnienia projektowania lądowych terminali przeładunkowych dla transportu intermodalnego, Logistyka 2/2015, 397-407

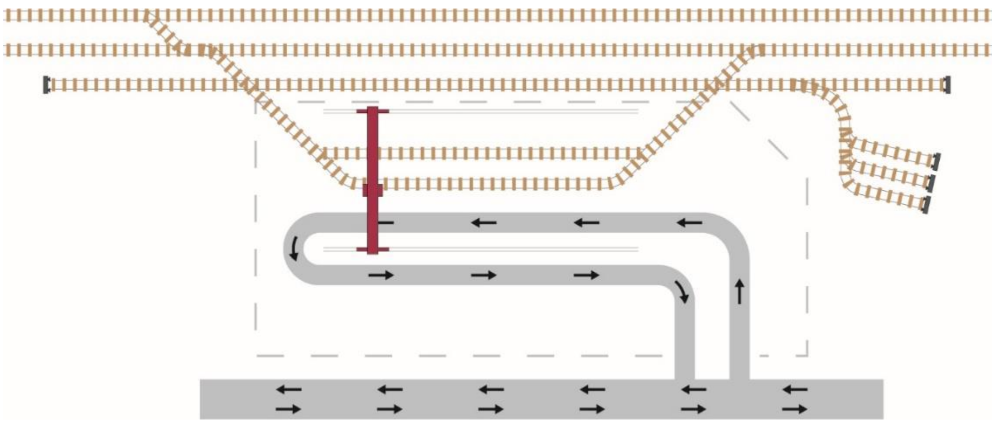

Figure 29. Rail-road terminal with transfer railway system
Source: based on Kostrzewski A., Nader M., Analiza zagadnienia projektowania lądowych terminali przeładunkowych dla transportu intermodalnego, Logistyka 2/2015, 397-407

The most important three phases of the intermodal train service process include ordering the terminal service, train monitoring and terminal operations[17].

[17] Based on terms of service of PCC Intermodal terminals (https://www.pccintermodal.pl/)

Ordering a terminal service is associated with the granting of terminal service slots. Slots are assigned by the terminal operator to the rail carrier or intermodal operator representing the rail carrier. The operator reserves the right to refuse to accept a train or to operate it in another service slot.

Train monitoring should be reported to the terminal operator starting 8 hours prior to train arrival time at the railway station from which the train will enter terminal's railway system. Every 2 hours the intermodal train operator is obliged to send, by e-mail, information regarding the performance of the train containing confirmation that transport is in accordance with the timetable or informing about potential delays. The train operator is obliged to provide the e-mail information at least 24 hours before the planned arrival of the train containing (Tab. 8):

- train arrival time,
- lists and specifications of ITUs on the train (cargo name, weight, etc.),
- documents specifying cargo properties (Material Safety Data Sheet),
- other instructions referring to each particular ITU.

Table 8. Data form for intermodal train service in a terminal slot

Order number:		Customer:			Train number:		Terminal:		Date of Service:	
	ITU Number	ITU type (size)	Name of cargo	RID/ UN Number	Seal number	Gross weight of ITU	Accompanying documents *	Consignee	Instructions	Remarks
1										
2										
3										
...										
I hereby declare that the cargo in the loading unit is not indicated on the list of prohibited cargoes. I hereby declare that I have the appropriate licenses and permits to transport the cargo in question.										

* T1, certificates, MSDS, SMGS
Source: based on terms of service of PCC Intermodal terminals

The intermodal train shall arrive at the railway station from which the train will enter terminal's railway system 1 hour before the planned terminal service slot. The train departure from the same station after the transhipment is complete is within 2 hours after the terminal service slot. The intermodal train reception is done at the terminal and is divided into a commercial part (receipt of intermodal units) and a technical part (train inspection) performed by the terminal operator and the railway train operator. The intermodal train operator's representative is obliged to stay in the terminal until the reception of the train is completed. Absence of the train operator's representative during reception is equivalent to accepting the assessment performed by the terminal operator. In the case of identified wagons or ITUs in technical condition that not allow for their further transport, the train operator is obliged to arrange and cover the costs of necessary repairs. Shunting operations between the railway station and the terminal (or vice versa) is performed by the terminal operator's shunting crew. The break test is being proceeded each time by the person assigned and approved by the intermodal train operator.

4.4. Handling processes of the large rail-road terminal

Below are presented flowcharts of intermodal train and vehicle handling processes at the large rail-road terminal (Fig. 30 and 31). The green colour indicates the processes stages within terminal service slots, i.e. time windows granted by terminal operator. In addition, the analysed processes map was shown on the terminal plan (Fig. 32).

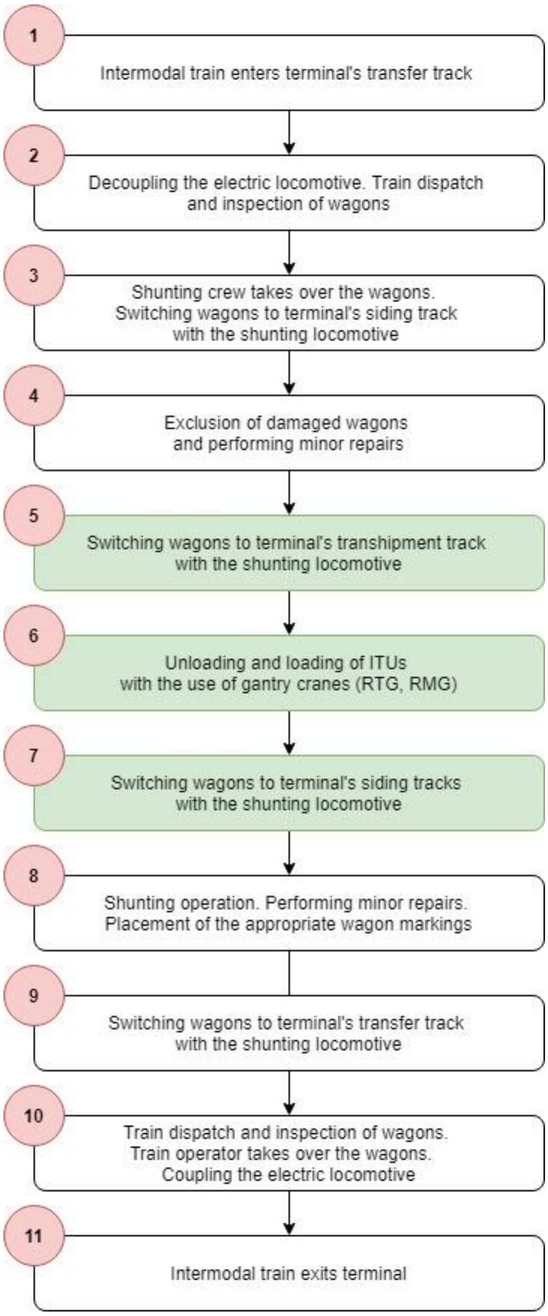

Figure 30. Flowchart of intermodal train handling process at the large rail-road terminal

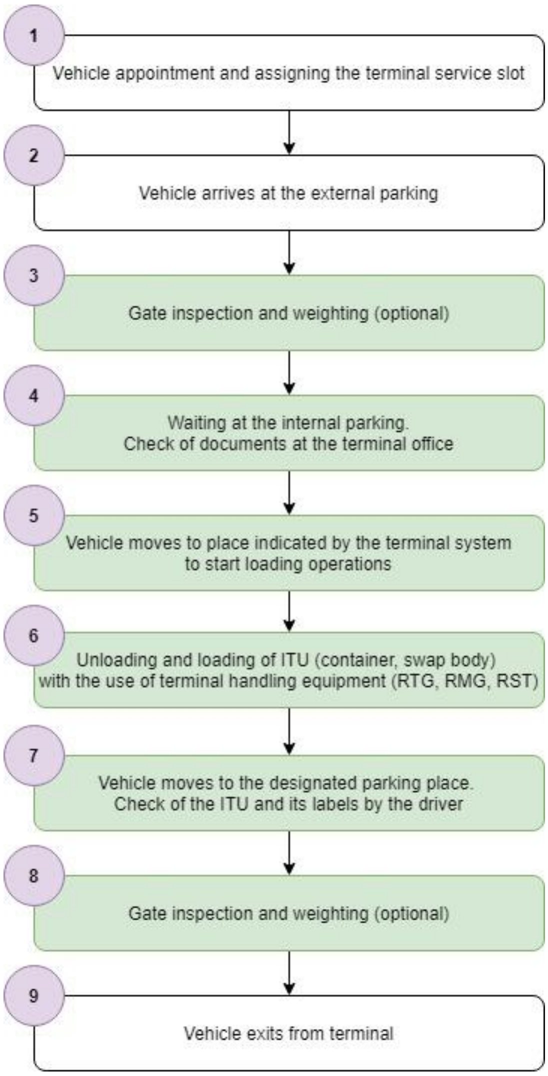

Figure 31. Flowchart of vehicle handling process at the large rail-road terminal

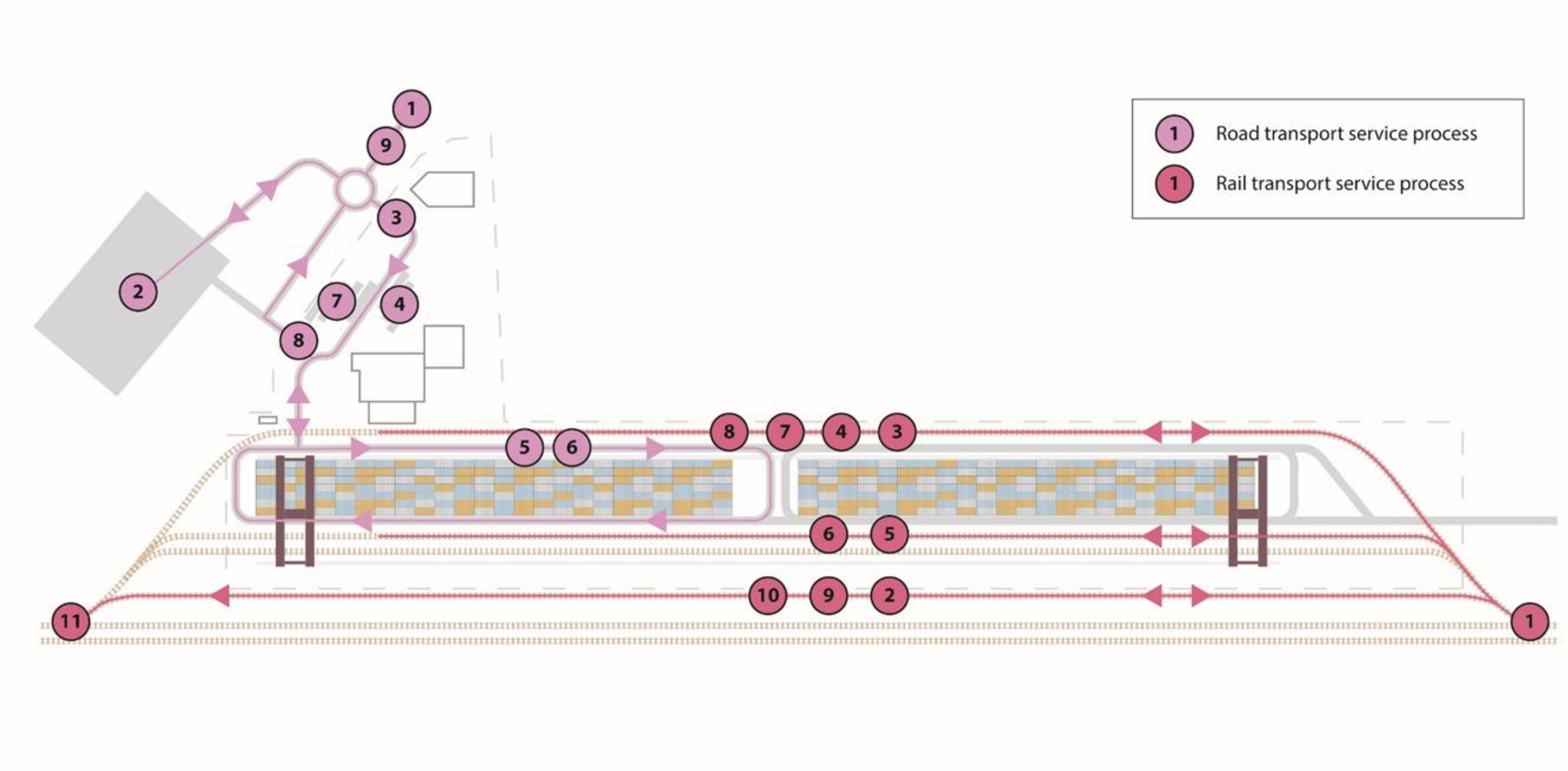

Figure 32. Terminal service process map of the large rail-road terminal

4.5. Handling processes of the trimodal river terminal

Below are presented flowcharts of container barge and intermodal train handling processes at the trimodal river terminal (Fig. 33 and 34). The vehicle handling process is the same as presented for the large rail-road terminal (Fig. 31). The green colour indicates the processes stages within terminal service slots. In addition, the analysed processes map was shown on the terminal plan (Fig. 35).

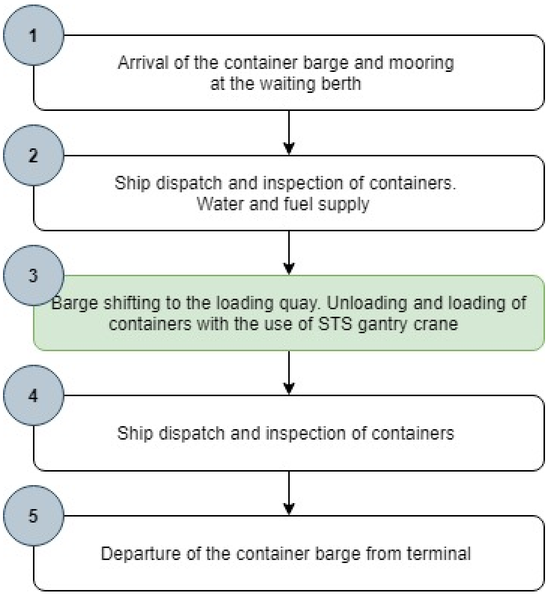

Figure 33. Flowchart of container barge handling process at the trimodal river terminal

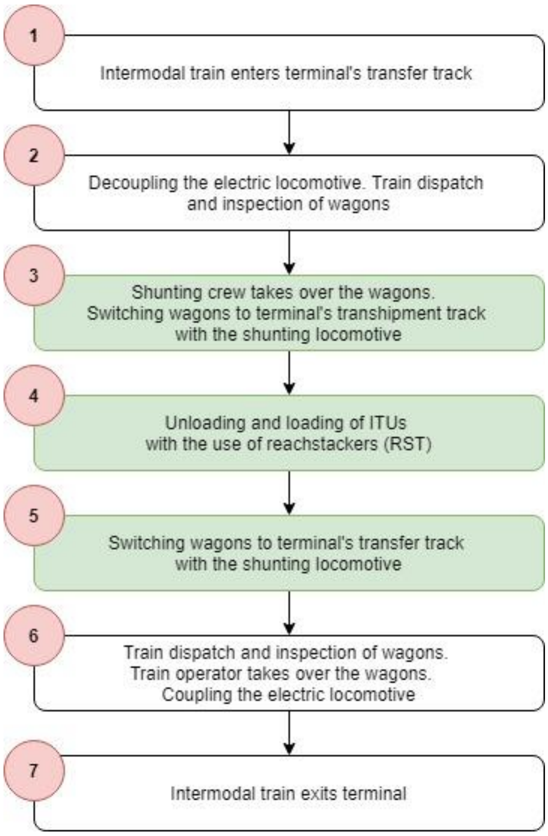

Figure 34. Flowchart of intermodal train handling process at the trimodal river terminal

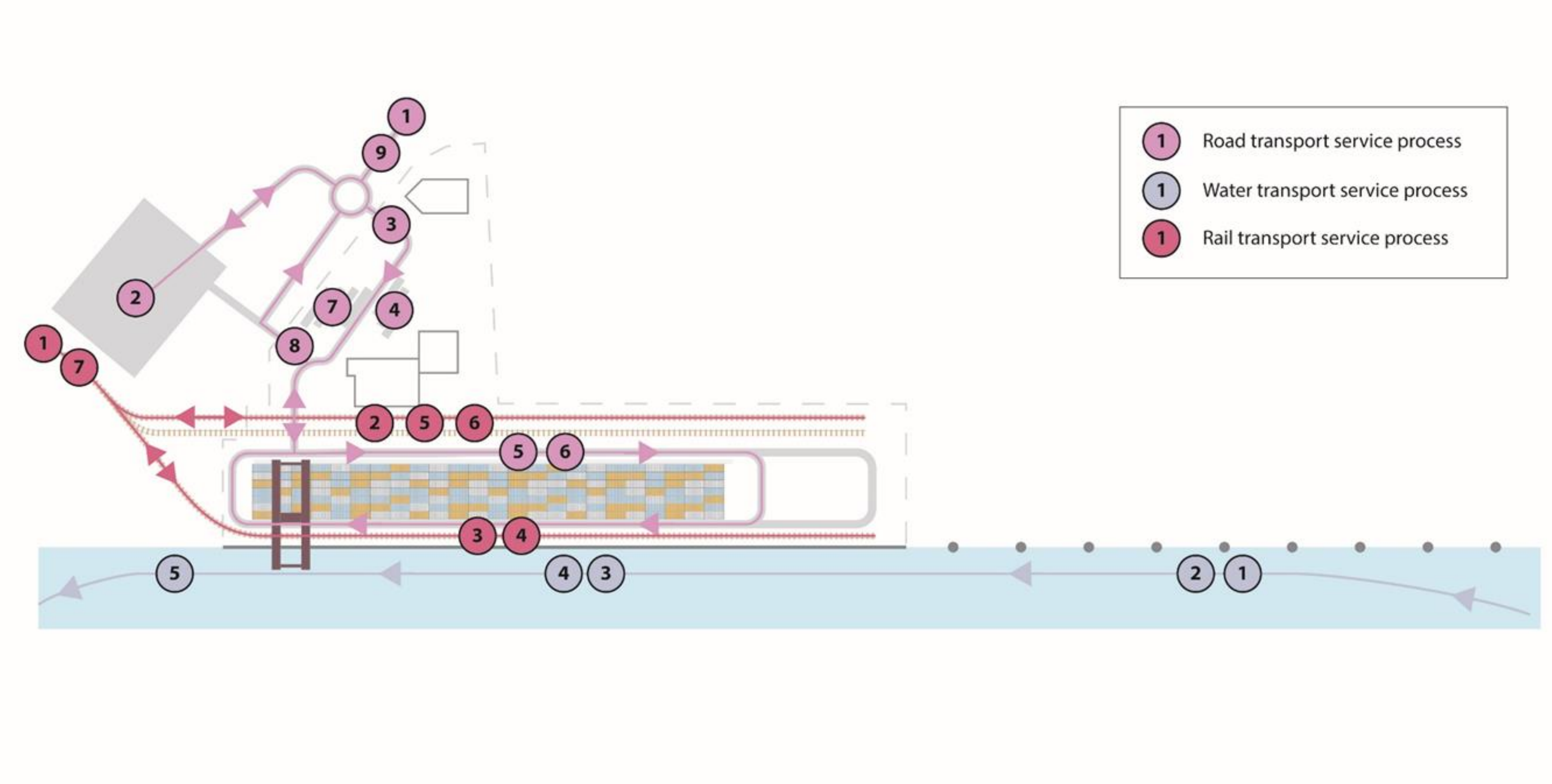

Figure 35. Terminal service process map of the trimodal river terminal

4.6. Handling processes of the Ro-La terminal

Below are presented flowcharts of intermodal train and vehicle handling processes at the Ro-La terminal (Fig. 36 and 37). The green colour indicates the processes stages within terminal service slots. In addition, the analysed processes map was shown on the terminal plan (Fig. 38).

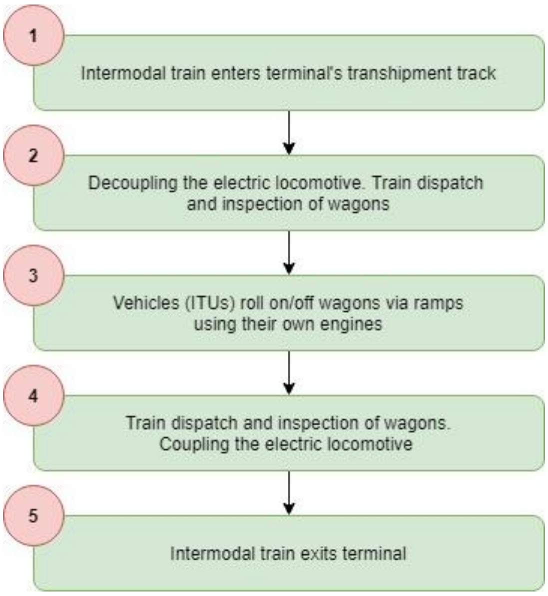

Figure 36. Flowchart of intermodal train handling process at the Ro-La terminal

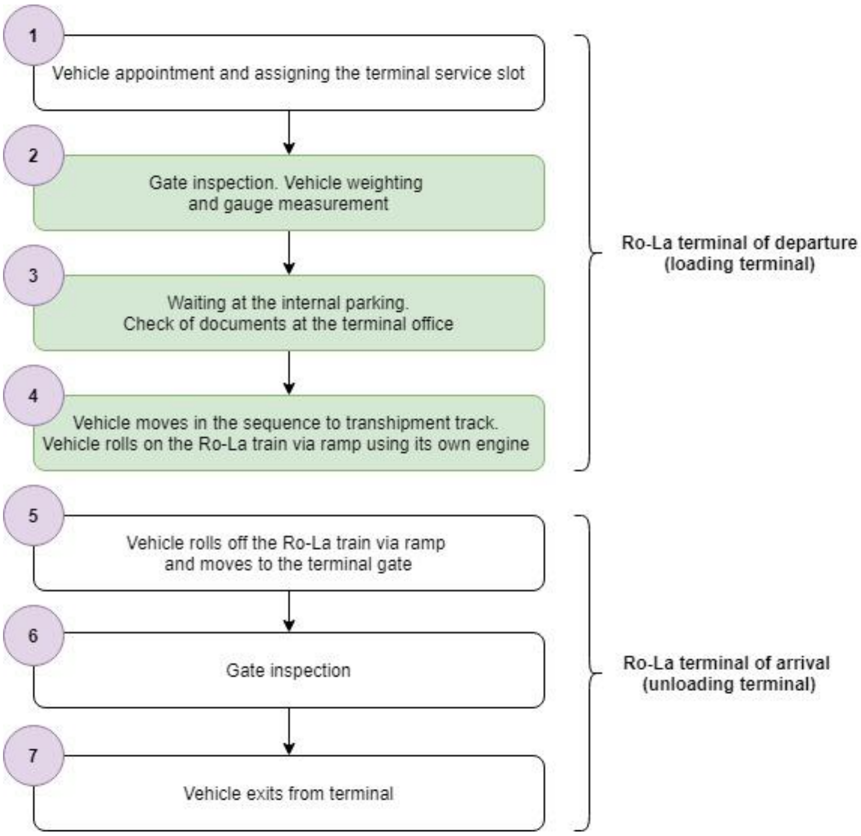

Figure 37. Flowchart of vehicle handling process at the Ro-La terminal

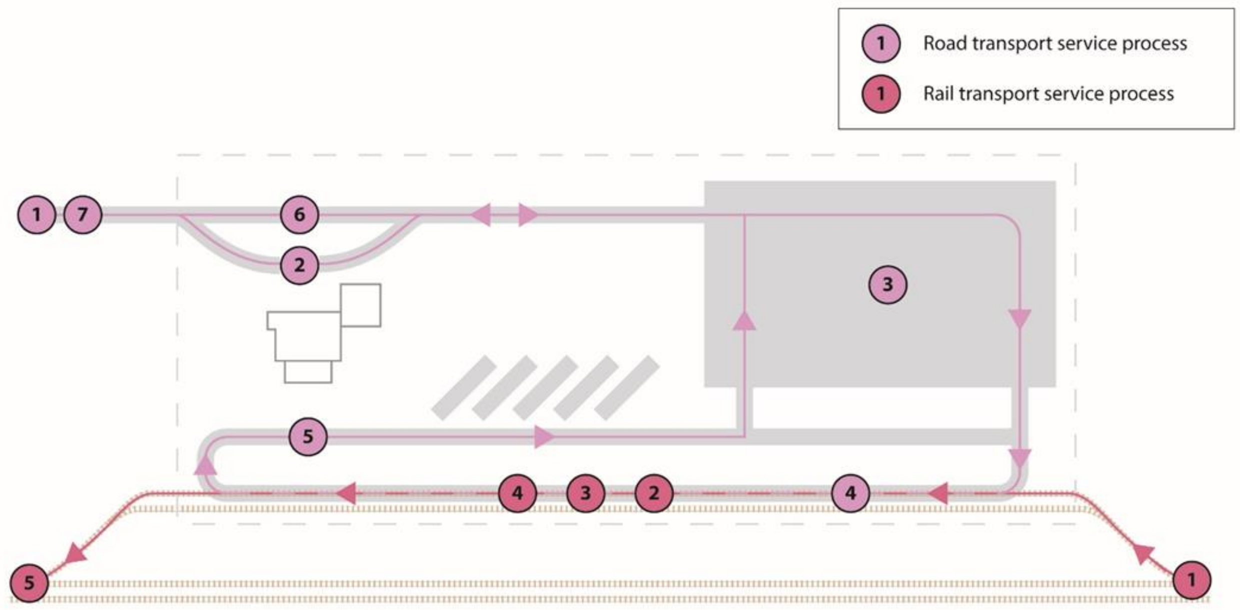

Figure 38. Terminal service process map of the Ro-La terminal

4.7. Handling processes of the Modalohr terminal

Below are presented flowcharts of intermodal train and vehicle handling processes at the Modalohr terminal (Fig. 39 and 40). The green colour indicates the processes stages within terminal service slots. In addition, the analysed processes map was shown on the terminal plan (Fig. 41).

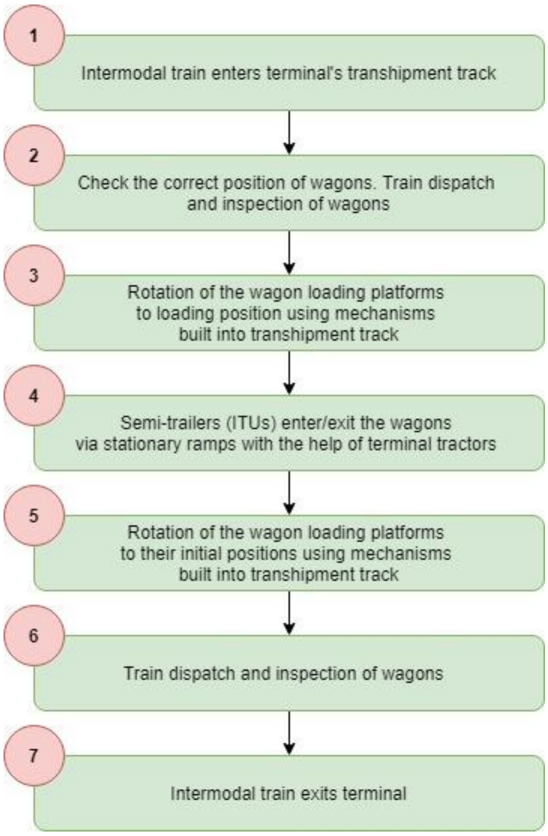

Figure 39. Flowchart of intermodal train handling process at the Modalohr terminal

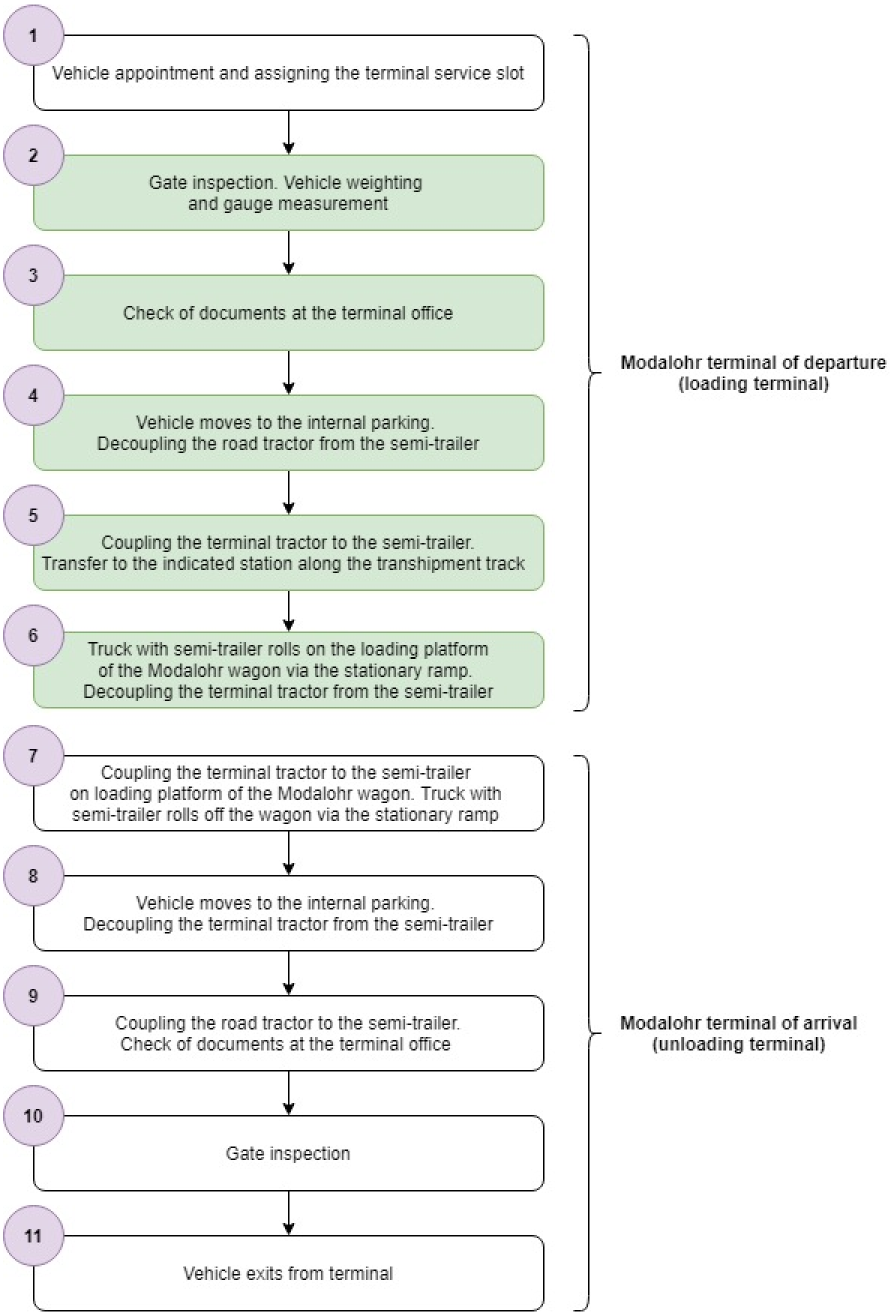

Figure 40. Flowchart of vehicle handling process at the Modalohr terminal

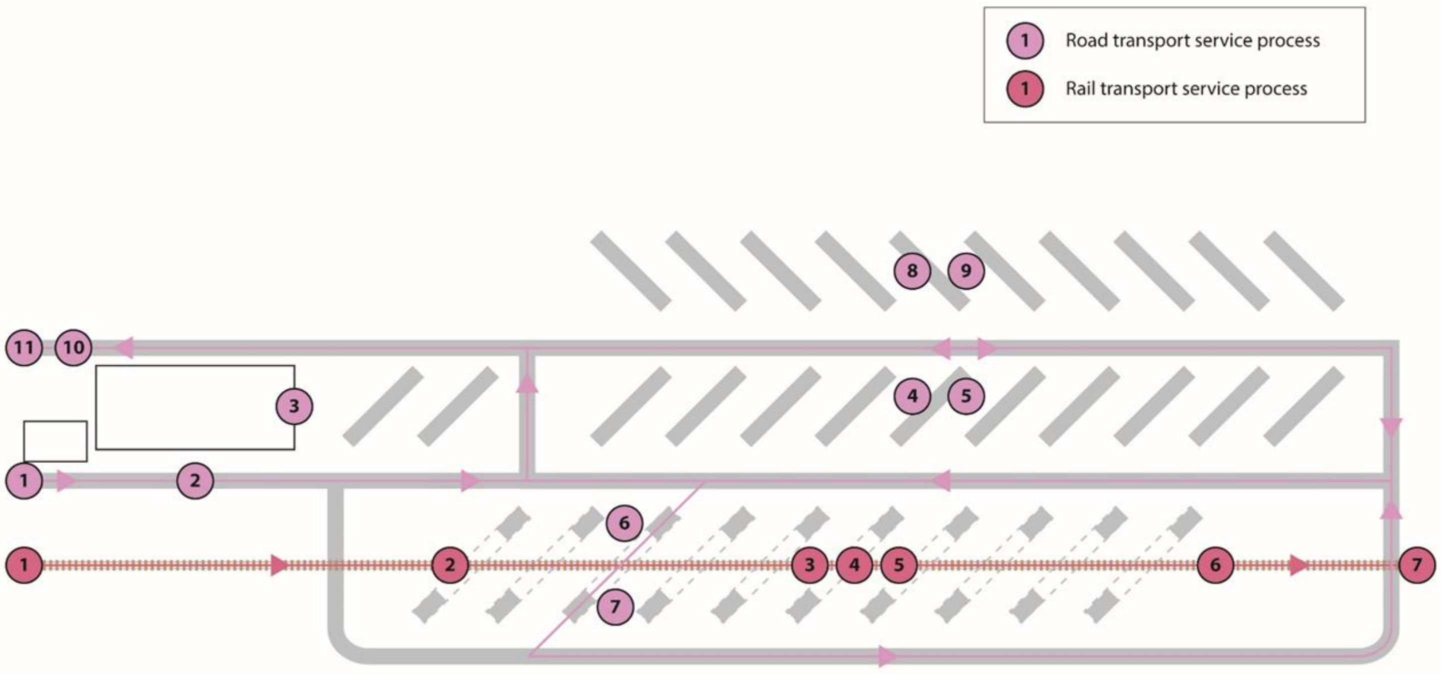

Figure 41. Terminal service process map of the Modalohr terminal

4.8. Handling processes of the Cargobeamer terminal

Below are presented flowcharts of intermodal train and vehicle handling processes at the Cargobeamer terminal (Fig. 42 and 43). The green colour indicates the processes stages within terminal service slots. In addition, the analysed processes map was shown on the terminal plan (Fig. 44).

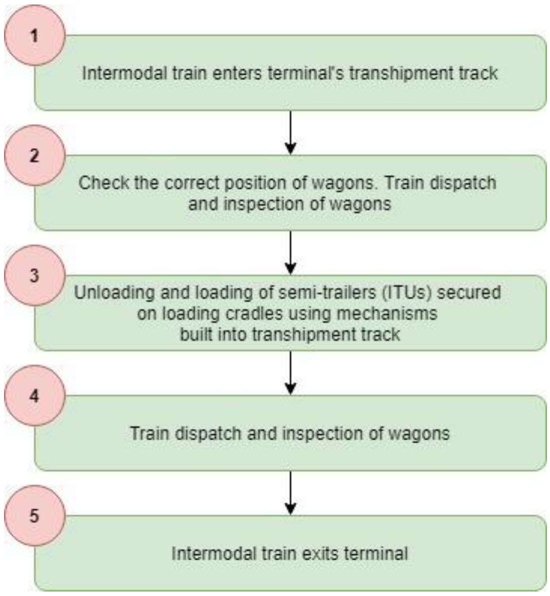

Figure 42. Flowchart of intermodal train handling process at the Cargobeamer terminal

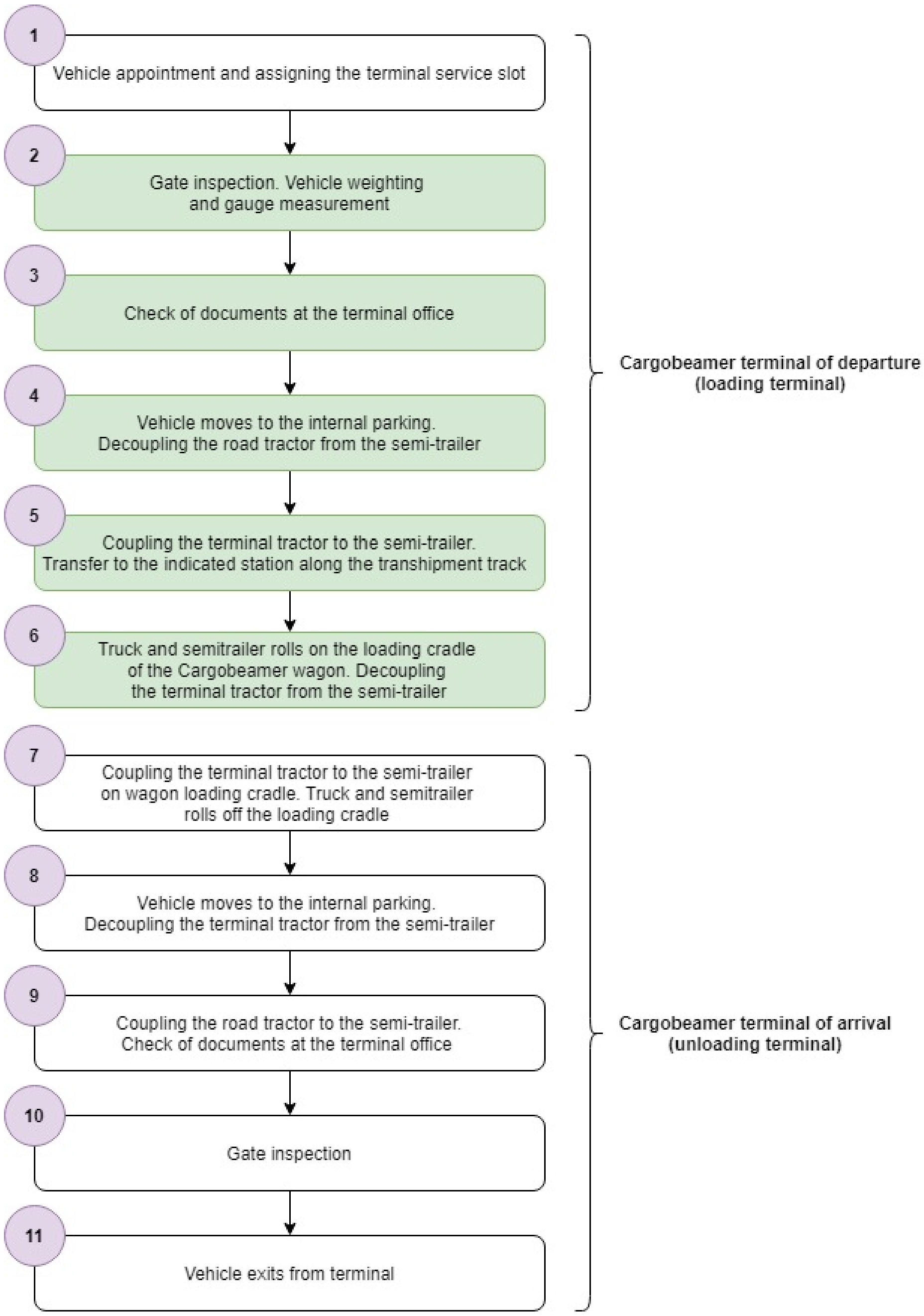

Figure 43. Flowchart of vehicle handling process at the Cargobeamer terminal

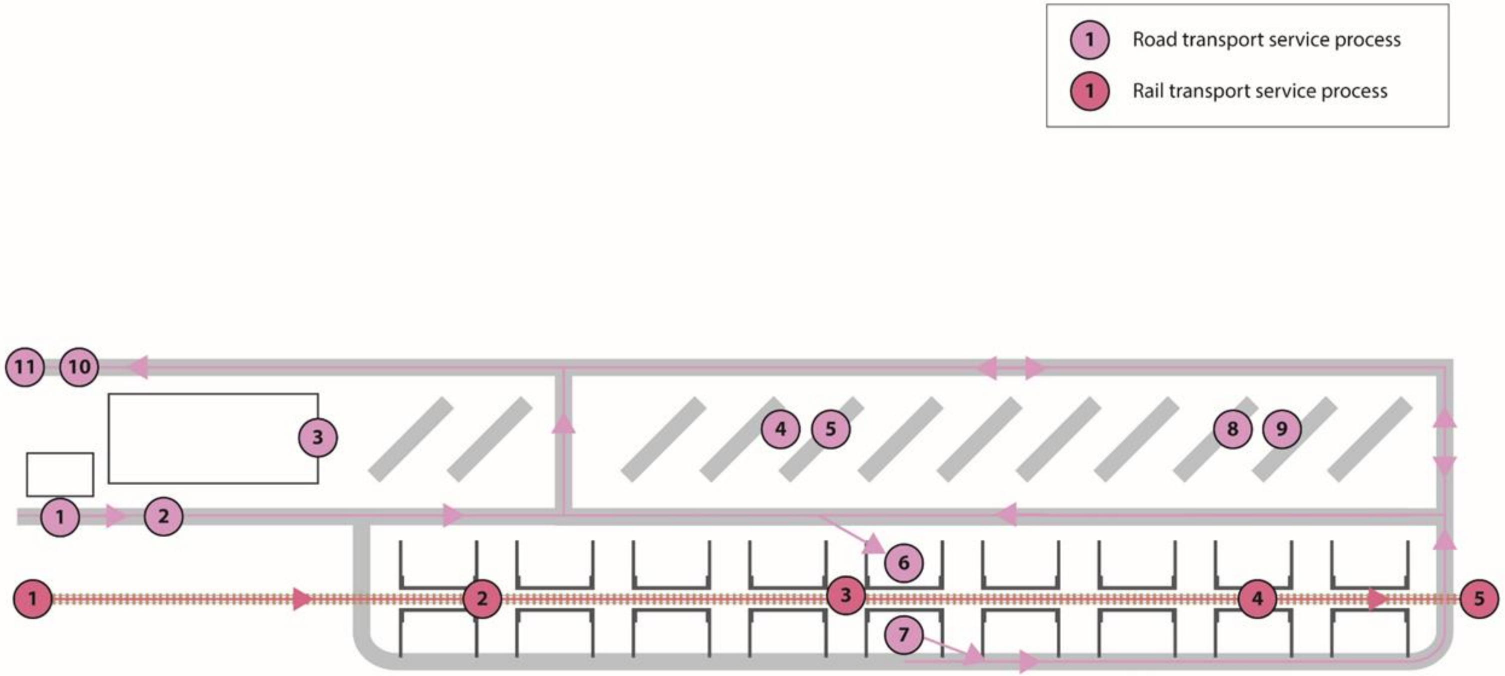

Figure 44. Terminal service process map of the Cargobeamer terminal

5. Performance indicators of combined transport terminals

5.1. Technological performance indicators

The most important performance indicators of combined terminals relate to the storage and transhipment processes carried out at the terminal. They allow for objective comparison of terminals and are the basis for the ongoing monitoring and development of terminal processes. Key technological measures of combined terminals include:

1. throughput of terminal entrance gate,
2. throughput of storage yard,
3. transhipment capacity of handling equipment,
4. terminal transhipment capacity,
5. terminal capacity utilization rate.

The first three measures relate to the three most important terminal handling processes. The smallest value among these three measures determines the terminal transhipment capacity. And terminal transhipment capacity is the basis for calculating terminal capacity utilization rate. The methodology for calculating all measures is given below.

5.1.1. Throughput of terminal entrance gate

The throughput of terminal entrance gate determines the number of intermodal loading units that can be checked at the entrance gate of the terminal during the year.

$$C_g = n_g \cdot \frac{1440}{T_g} \cdot b \cdot 360$$

where:

C_g – throughput of terminal entrance gate [ITU/year],

n_g – number of entrance traffic lines,

T_g – average time at gate [min] (T_g=5÷15 min),

b – ITUs per vehicle coefficient (b=1,75 for standard semi-trailer).

5.1.2. Throughput of storage yard

Throughput of the storage yard determines the number of intermodal loading units that can be stored on the terminal's storage yards during the year.

.

$$C_y = V_y \cdot r = \frac{S_y \cdot h \cdot w \cdot z}{s} \cdot \frac{360}{T_y}$$

where:

C_y – throughput of storage yard [ITU/year],

V_y – capacity of storage yard [ITU],

r – annual storage yard turnover,

S_y – storage yard area [m^2],

h – number of storage layers (h=3÷4 for containers),

w – coefficient of space utilization of storage yard (w=0,45 for handling with reachstackers RST, w=0,60 for handling with gantry cranes RTG or RMG),

z – fill factor of the storage yard throughout the year (z=0,7÷0,8),

s – storage space needed for 1 ITU [m^2],

T_y – average storage time per ITU [days] (T_y= 5÷10 days).

5.1.3. Transhipment capacity of handling equipment

The transhipment capacity of handling equipment determines the number of intermodal loading units that can be transhipped by the terminal's primary handling equipment during the year. Primary handling equipment on combined terminals include: RTG gantry cranes, RMG gantry cranes and reachstackers RST.

$$C_h = n_h \cdot \frac{(P_h \cdot T_h \cdot 360 \cdot R_h)}{a}$$

where:

C_h – transhipment capacity of handling equipment [ITU/year],

n_h – number of handling facilities,

P_h – productivity of one handling facility [ITU/h] (P_h= 20÷30 ITU/h for gantry crane RTG or RMG, P_h= 12 ITU/h for reachstacker RST),

T_h – average daily working time of handling facility [h] (T_h=12 h for two shifts, T_h=18 h for three shifts),

R_h – technical availability of handling equipment (R_h= 0,80÷0,95),

a – coefficient of simultaneous work of handling equipment (a= 1,00÷1,25).

5.1.4. Terminal transhipment capacity

Terminal transhipment capacity is equal to the smallest value among: throughput of terminal gate, throughput of storage yard and transhipment capacity of handling equipment,

$$C_t \in \{C_g, C_y, C_h\}$$
$$C_t \leq C_g \quad \wedge \quad C_t \leq C_y \quad \wedge \quad C_t \leq C_h$$

where:

C_t – terminal transhipment capacity [ITU/year],

C_g – throughput of terminal entrance gate [ITU/year],

C_y – throughput of storage yard [ITU/year],

C_h – transhipment capacity of handling equipment [ITU/year].

A properly constructed and organized combined transport terminal should have the transhipment capacity that is equal to or close to the value of throughput of storage yard and transhipment capacity of handling equipment. The rule is that the throughput of terminal entrance gate is much greater than the terminal transhipment capacity. If one of the three analysed values, i.e. the throughput of entrance gate, throughput of storage yards or transhipment capacity of handling equipment, is significantly lower than the other ones, it determines the so-called terminal's capacity bottleneck.

5.1.5. Terminal capacity utilization rate

To verify the correct operation of the terminal, the indicator of the terminal capacity utilization is calculated.

$$e_t = \frac{T_t}{C_t}$$

where:

e_t – terminal capacity utilization rate,

T_t – actual terminal transhipments [ITU/year],

C_t – terminal transhipment capacity [ITU/year].

The correct value of the terminal capacity utilization rate is 0,35÷0,50. This means that the terminal should achieve an average utilization level of its transhipment capacity up to 50%. If this level is exceeded, an investment process should be started to increase the terminal transhipment capacity or to expand the terminal area, that is a long-term process by nature. Exceeding value is also an indication to take organizational changes that affect the terminal's throughput and transhipment capacity. These changes may concern, among others:

1. increase the stacking height at storage yard,
2. reduction of the average storage time per ITU,
3. extension of the terminal's working time.

Changes of an investment or organizational nature should result in an increase in terminal transhipment capacity. All terminal processes should be adapted to this new value of terminal transhipment capacity. For example, increasing productivity of handling facilities, which resulted in the increase in terminal transhipment capacity, should be combined with activities aimed at increasing the throughput of storage yard. If the decision is made to increase the area of storage yard, the formula for calculating the new storage adjusted to the planned terminal throughput needs is given below:

$$S_y^n = \frac{C_y^n \cdot s}{h \cdot w \cdot z \cdot r}$$

where:

S_y^n – new storage yard area [m^2],

C_y^n – planned throughput of storage yard [ITU/year],

s – storage space needed for 1 ITU [m2],

h – number of storage layers (h=3÷4 for containers),

w – coefficient of space utilization of storage yard (w=0,45 for handling with reachstackers RST, w=0,60 for handling with gantry cranes RTG or RMG),

z – coefficient of filling the storage space during the year (z=0,7÷0,8),

r – annual storage yard turnover.

5.2. Organizational and economic performance indicators

Organizational and economic performance indicators of the combined transport terminal refer to the efficiency of processes taking place at the terminal. These indicators are used to monitor and improve the quantitative and qualitative nature of individual processes and their respective tasks. The improvement of the organization of terminal transhipment and storage processes is associated with many activities including improving access to transport infrastructure and handling equipment (investment activities) as well as improving the quality of the terminal's operations (organizational and process improvements). The most important areas of activities related to the management of combined terminal processes are presented in Figure 45. In terms of improving the terminal transhipment and storage processes, activities translating into measurable effects include[18]:

1. adaptation to the network of intermodal connections,

[18] Best practices for the management of combined transport terminals, DIOMIS Project, 2007

2. development of comprehensive logistics services related to storage and transhipment,
3. development of IT tools supporting terminal management,
4. tailor-made terminal management systems,
5. system of incentives and penalties for better utilisation of storage yards,
6. automatic identification of intermodal transport units and vehicles,
7. introducing appointment system for transhipment and storage processes,
8. just-in-time performance of terminal services.

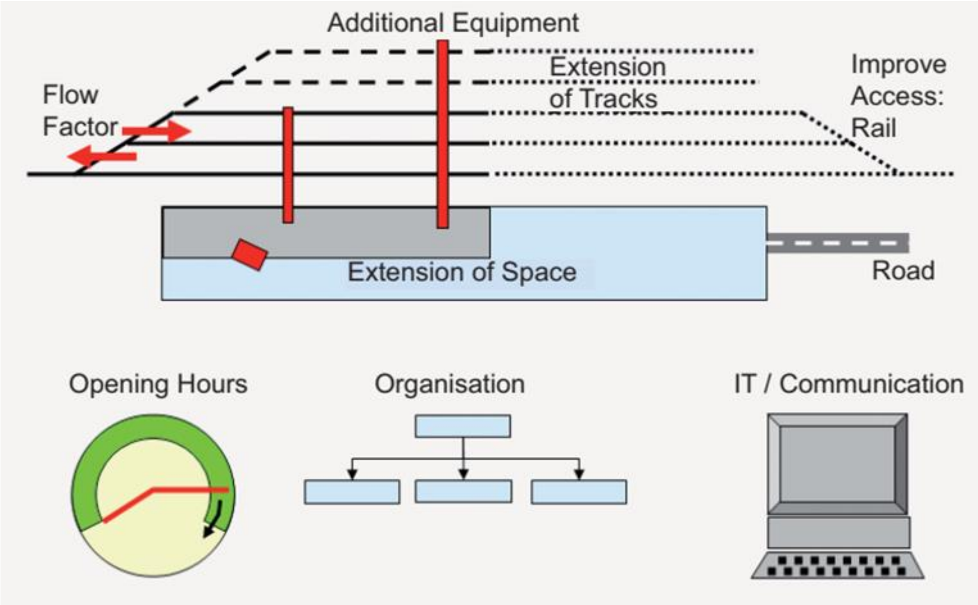

Figure 45. Methods to improve the efficiency of combined terminal processes
Source: Best practices for the management of combined transport terminals, DIOMIS Project (Workpackage A4), 2006, ISBN: 2-7461-1308-2.

The combined transport terminal provides service to means of transport, prioritising regular intermodal trains and container barge lines. Close cooperation with big intermodal transport operators ensures high cargo turnover, but the condition is high quality of service at the terminal. The transhipment and storage potential of the rail-road terminal should meet the high requirements associated with service to high frequency and fixed timetable intermodal trains speeding up to 160 km/h. From the intermodal transport customers' point of view, it is most desirable to change block and liner trains service into direct and shuttle trains service (Fig. 46). The number of regular shuttle trains operated is a measure of the combined terminal efficiency and determines its position in the transport and logistics network.

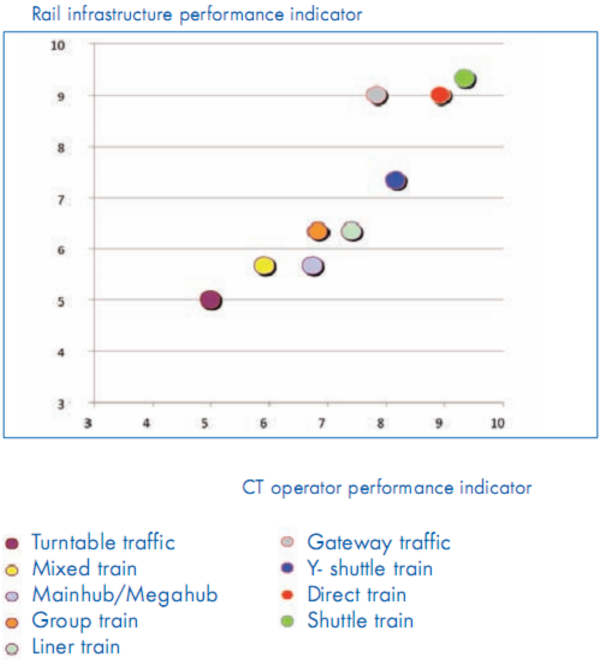

Figure 46. Efficiency of intermodal rail connections
Source: AGENDA 2015 for Combined Transport in Europe, DIOMIS Project, www.uic.asso.fr/diomis/.

The effectiveness of activities related to the development of comprehensive logistics services related to storage, warehousing and transhipment can be measured by the number of these services offered by the terminal. These services include among others: documentation service, completing, repackaging cargo or stuffing/stripping intermodal unit and providing cargo insurance.

The development of IT tools supporting terminal management and professional communication platforms for business transactions is now a necessary condition for the development of combined transport terminals. As logistics operators want to offer their services in a wide range and high quality, the lack of IT solutions supporting terminal operations is the serious obstacle to its development. Currently, the main measure of terminal efficiency is advancement of the TOS (Terminal Operating System) system, i.e. the number of implemented system modules and their functionalities. According to research[19], the TOS system increases the terminal's operational efficiency by about 5-10%, which translates into the terminal's financial profit. Examples of currently used TOS systems are: BLU, GOAL, INTERMAN, KLV2000, TESS. Tailor-made terminal management systems are also used that are better adapted to the conditions and needs of the terminal. This solution involves the problem of terminal system integration with the telematics requirements of the logistics network, which is often an ICT platform shared by various intermodal transport operators. Tailor-made TOS systems are rarely

[19] Best practices for the management of combined transport terminals, DIOMIS Project (Workpackage A4), 2006, ISBN: 2-7461-1308-2.

implemented in smaller combined transport terminals that are not included in the network of big intermodal operators, due to the cost/benefit ratio in relation to generally available systems.

Improvement of the efficiency of terminal processes may occur through the introduction of a system of incentives and penalties for better utilisation of storage yards. The incentive system has the financial nature and is included in the terminal's tariff and contracts with terminal customers. It forces more rotation at the terminal storage areas due to the enforcement of deadlines for pickup of stored loading units.

Figure 47. Semi-automatic identification at the gate of rail-road terminal
Source: www.pccintermodal.pl/terminal-kutno/

Automatic identification of intermodal loading units and vehicles has a significant impact on improving the efficiency of the combined transport terminal. The advantages of introducing automatic and semi-automatic identification is accelerating the inspection process at the terminal gate and allows to prepare automatically documentation needed for further terminal processing. In the case of the semi-automatic identification system, some tasks are transferred to a system operator. There are two basic types of automatic or semi-automatic identification system. The first one is a gate system, consisting of gate portals equipped with cameras located on the entry roads to the terminal (Fig. 47). On the basis of the photographs, the condition of the means of transport and loading units are identified and assessed, then the appropriate documents are automatically generated in the system. The second type of automatic or semi-automatic identification uses RFID[20] chips, which are placed in loading units and vehicles. By means of radio signals they transmit all necessary information to receivers located at the

[20] RFID - Radio Frequency Identification.

entrance gate of the terminal. This identification system is used less frequently due to additional costs on the terminal clients' side and the need for technical integration in the logistics network.

A frequently undertaken action leading to the improvement of the terminal operational efficiency is the introduction of appointment system for transhipment and storage processes. This is directly related to the system of allocating terminal service slots for means of transport served on terminal. In addition, an electronic reporting system is mandatory for means of transport on their way to the terminal. The appointment system is beneficial for the terminal, carriers and consignees by improving transit time of deliveries throughout the entire logistics chain.

Just-in time performance of service provided to means of transport and loading units at the terminal depends on a number of organizational achievements, including: improved availability of transhipment equipment and storage area, increased process automation, prioritization of means of transport and loading units, increased flexibility of working time and exchangeability of work stations, high motivated terminal crew. These organisational activities allow to adjust terminal capacity for variable market demand for its transhipment and storage services. The measure of terminal services punctuality is the number of delays resulting from the fault of the terminal and related claims for customers.

Conclusions

The presented analysis allows us to learn about the current state of technology and organization of combined transport terminals in Europe. Among other available scientific and project publications, this analysis is distinguished by its focus on land terminals, including terminals with access to inland waterways, excluding terminals in seaports. Core service of all analysed terminals is handling intermodal loading units, i.e. containers, swap bodies, semi-trailers and articulated vehicles, using combined transport technologies. The study is a comprehensive and easy-to-understand analysis and it is intended to fill a gap in the market of transport and logistics publications.

The main goal of classification and thorough technical and operational analysis of combined transport terminals, with an emphasis on the analysis of the terminal handling processes, has been achieved. The chapters of the analysis refer to specific research areas and are interrelated by consistently referring to the same representative types of terminals, infrastructure elements and categories of transhipment equipment. Proposing multi-criteria classification and standardization of nomenclature of combined transport technologies and processes seem to be one of the major achievements of this analysis.

An additional goal of the study is to create a compendium of practical knowledge that will support investment decisions in the construction or modernization of combined transport terminals, particularly those undertaken by institutional investors. Infrastructural investments related to combined terminals require consideration of a wide spectrum of technical, technological, economic and social factors. This analysis objectively relates to technical, technological and organizational factors that form the basis of economic calculations.

The increased demand for intermodal transport in Europe is a direct reason for combined terminal investments. Especially in Central and Eastern Europe, which has a great potential to increase the use of intermodal units in transport and logistics processes, many ongoing projects in the field of modernization and construction of combined terminals can be identified. Such a project realized by the City of Bydgoszcz is also the inspiration for the implementation of this analysis. Considering the external market conditions for the construction of a new terminal in this part of Europe, there is a need for recommendations, which should be addressed to potential investors and terminal operators. These recommendations and identified measures to improve terminals in BSR are as follows:

1) Studies preparing for infrastructure investment should include as accurate as possible demand forecast of intermodal transport services in the perspective of up to 30 years. The category of transport node in which the terminal will be located should be specified, taking into account, international, national and local nodes. It is necessary to determine the economic potential of the terminal service area, i.e. the number of intermodal loading units (ITU) that can be generated by industry and habitants in the close and distant area of terminal road haul service. As a distant service area, it is recommended to take up to 90 minutes of road travel time to/from the terminal.

2) The choice of terminal location should be multi-criteria, of which the most important groups of criteria are related to access to transport infrastructure and the economic potential of the terminal service area. In the first group of criteria, locations with access to transport infrastructure of international significance within TEN-T (Trans-European Transport Network) Corridors. Where possible, trimodal terminals should be constructed with access to the waterway network. In the second group of criteria, large areas for investment are preferred, i.e. large rail-road terminals should have a minimum area of 50 ha near the economic or investment zone.
3) The selection of primary and secondary handling equipment should be a multi-stage investment process. The handling capacity of the terminal should be increased together with the increased handling and storage needs. It is crucial to avoid overinvesting in terminal infrastructure and handling equipment and to start terminal services as soon as possible. The latter aims to accustom carriers and intermodal transport operators to the new terminal and the services it offers in the transport and logistics network. The most common in market practice is a gradual terminal transition from stage of primary handling by reachstackers, through introducing gantry cranes (RTG or RMG), up to the stage of implementing a wide spectrum of handling and transport services on several transhipment fronts. The latter stage is related to the terminal cooperation with one large or several smaller logistics centres guaranteeing sufficient cargo volume, i.e. at a level above 0,1 million ITU.
4) The new terminal should be managed with the use of dedicated TOS (Terminal Operating System), that should gradually expand with the development of terminal. The terminal should be adapted to the automation of terminal processes, starting with appointment system and inspections at terminal gate up to selected transhipment operations. However, this does not mean that the conventional terminal will transform into a fully automatic combined terminal. Technological and social barriers will strongly prevent this process. It is important today that the new terminal should offer to its clients complex energy monitoring and carbon footprint tracking, i.e. monitoring of CO_2 emissions.

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