applied sciences

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Analysis of Operations upon Entry into Intermodal Freight Terminals

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Received: 24 May 2019; Accepted: 21 June 2019; Published: 23 June 2019

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Abstract: The design of intermodal freight terminals requires extensive research and a thorough analysis of the technical, financial and organizational aspects. In the paper, the operation of the reposition of large cargo containers (one of the types of intermodal transport units, ITUs) on the dedicated places is subjected to a discussion. The analysis is carried out with the use of a vehicle equipped with a telescopic arm, such as a reach stacker. The considered storage facility is reduced to a block characterized by spatial accumulation given in the paper. The description of the procedure for the execution of the handling operation from the arrival of a tractor-trailer with a container into a terminal, followed by the ITUs being set aside in a dedicated place and, in the end, the departure of the truck without load, is given in the paper. The activities are described in detail in order to present a descriptive model of particular operations upon entry to the intermodal freight terminal. Moreover, the paper contains relevant figures illustrating the various steps of realization and the analysis of duration of activities supported by actual realizations. The durations of the individual activities described in the paper are experimental, and the results have been validated on real-world intermodal freight terminals. Therefore, the authors believe that the obtained values may be used in analytical, simulation and numerical models of intermodal freight terminals.

Keywords: intermodal transport; intermodal terminal; intermodal transport unit; container; reach stacker; inland intermodal freight terminal; land container terminal

1. Introduction

The design of inland intermodal freight terminals (IFT, known also as land container terminals) requires a knowledge of logistics and transportation processes related to the operation of such facilities. This requires a knowledge of technical equipment, functional and spatial systems or even the duration of individual activities related to the operations of intermodal transport units in an intermodal freight terminal. As given in Transport Research and Innovation Portal TRIP (2006) [1], IFT "are the weakest links of the intermodal transport chain system and a major generator of costs. Therefore, it is necessary to study and investigate issues related to these terminals, in order to improve their effectiveness and efficiency and make the intermodal freight transport more competitive and attractive."

The main subject of the paper is to present the process associated with operations on intermodal transport units (a large cargo container of type A, belonging to one of four container classes, namely A, C, D, and E), including *inter alia*:

- the arrival of a tractor-trailer with an intermodal load unit into the gate of an intermodal freight terminal,
- the handling and transport service with use of a vehicle as a reach stacker (a reach stacker is a vehicle used for the short distance handling of intermodal cargo containers in small terminals or medium-sized ports),

- departure of a tractor-trailer without an intermodal load unit.

The content of the paper has been prepared to discuss the elementary components of the process and to analyse the duration of handling and transport operations from taking a large cargo container from a tractor-trailer using a reach stacker to the placement of a load unit at the appropriate layer of the sector at a storage yard in an intermodal freight terminal. The appropriate diagrams given in the paper illustrate the individual steps of the process.

The issues specified in the paper are given to increase the knowledge related to the operations in terminals involving intermodal transport, and they are an important element to simulate the operating process of a particular logistics facility (as planned for future research). It is highly important to estimate the duration of operations that take place in terminals dedicated to intermodal transport. The following claim is adopted as the research problem in the paper. The issue of the duration of operations rarely occurs in the literature due to the fact that it is a diverse matter depending on a specific terminal that is taken into consideration. It is worth mentioning here that Zając and Świeboda (2015) [2], after Boysen and Fliedner (2010) [3], stressed that land container terminals (which are the subject matter of this paper) are less described in the literature than maritime terminals. Furthermore, Wang and Zhu (2019) [4] stated that most intermodal freight terminal operations research is focused on container ports. Every logistics facility of this kind is different in its functional, spatial and other aspects. However, it is of high importance to introduce parameters in the design of new terminals based on adequate parameters of real-world and existing facilities or of the simulation models of existing or designed terminals. This might ensure decreasing the overall costs of functioning of a company operating in a terminal, which is one of the sources of competitive advantage (Zwolińska, 2014) [5]. This paper discusses the analysis of chosen operations upon entry into intermodal freight terminals, which generally requires very precise observations, results and conclusions. The following operations associated with a terminal, after the entry of intermodal transport units into the terminal will be discussed in future papers, creating a new approach to the problem.

Section 2. of the paper includes a literature review of the problem. Section 3. contains the methodology used in the study of the main paper's matter. Section 4 precisely discusses the process of large cargo containers arrival into an intermodal freight terminal, and delivery by means of road transport. In Section 5, the handling activities of large cargo containers by a reach stacker are specified. These are differentiated into the aspect of the height of containers' storage in the adequate area. The last section of the paper summarises it.

2. Literature Review

Intermodal freight terminal design and utilisation have recently become one of the most important and the most frequently discussed research areas in logistics and transportation. Researchers construct and study analytic, numerical and simulation models of intermodal freight terminals. Zając and Świeboda (2015) [2] described a method for distributing containers on the storage yard terminal while unloading a container train, whereas Kostrzewski and Nader (2015) [6] discussed elementary formulas that describe containers allocation in a storage-yard terminal. Iris et al. (2018) [7] studied in detail the handling of containers in an intermodal yard. They focused on the problem of ship loading operations in a maritime intermodal freight terminal and aimed at integrating the aspects of operational stowage planning with the assignment and scheduling of transport vehicles, based on realistic and important aspects of the loading operations. Braekers et al. (2014) [8] considered a full truckload vehicle routing problem in drayage operations around intermodal container terminals. They analyzed and compared three different models and algorithms for a bi-objective optimization of drayage operations (operations connected to the transport of goods over a short distance). Intermodal transport technologies are described in Nowakowski et al. (2008) [9], whereas some design rules of container terminals are expressed in Steenken et al. (2004) [10]. Several papers are related to the location of intermodal transport terminals, e.g., Ližbetin (2019) [11]. Simulation methods are widely used in a range of issues concerning the design and operations of containers automatic storage systems. Kemme (2013), in [12] (pp. 203–333) (also in the paper of Kemme, 2011 [13]), presented a stochastic simulation model used in order to research the RMCG system (*rail-mounted gantry cranes system*) in a marine container terminal. The author considered issues of strategic and operational planning of a terminal, presented alternatives of a system and some effects of the implementation of various planning and operating strategies in the field of this system. As Saanen et al. (2004) [14] and Schütt (2011) [15] claimed that simulation methods are very often used in all kinds of issues related to intermodal freight terminals problems, containers, etc., at all stages of the life cycle of these types of logistics facilities. Petering et al. (2009) [16] identified more than 40 simulation models, whose aim is to study container terminals. Issues concerning the design of automated marine container terminals using the methods of simulation can be found in many works, such as: Dulebenets et al. (2015) [17], Saanen (2004) [14], Saanen (2011) [18], Duinkerken and Ottjes (2000) [19], Legato and Mazza (2001) [20], Liu et al. (2002) [21], Liu and Dong (2008) [22], Vis and Harika (2004) [23], Nazari (2005) [24], Parola and Sciomachen (2005) [25], Zauner (2005) [26], Gunther and Kap-Hwan (2006) [27], Briskorn et al. (2006) [28], Alessandri et al. (2007) [29], Dai et al. (2008) [30], Petering et al. (2009) [16], Wiese et al. (2009) [31], and Wiese et al. (2010) [32]. Optimisation issues (exact optimisation approaches, heuristics and metaheuristics ones) must not be overlooked when considering various problems related to intermodal freight terminals. Referring only to a few selected works, the following can be mentioned. Ursavas and Zhu (2016) [33] proposed a stochastic dynamic programing approach to model the berth allocation problem and characterized optimal polices under the stochastic arrival and handling times for vessels of various classes, such as large intercontinental deep-sea vessels or feeder ships and barges. The berth allocation problem for feeder ships and large intercontinental deep-sea vessels was also examined in Emde and Boysen (2016) [34]. The authors suggested a mixed integer linear programming model. Umang et al. (2017) [35] suggested a mixed integer linear programming model for the real-time management of berth allocation with stochastic arrival and handling times. Zhen et al. (2017) [36] proposed an integer programming model in order to study a problem related to the operational level of daily planning of berth allocation and quay crane assignment considering tides and channel flow control constraints. Meanwhile, Iris et al. (2015) [37] focused on two, mutually dependent, important optimization problems on the quayside of maritime terminal operations: the berth allocation problem, which enables the allocation of berthing positions and times for vessels, and the quay crane assignment problem, which determines the number of quay cranes to be assigned for (un)load operations. Their research was based on the model presented in Meisel and Bierwirth (2009) [38] with an original extension to the mentioned model. The berth allocation problem, together with the quay crane assignment problem, was also researched by Xiang et al. (2018) [39]. In the last paper, a reactive approach (a reactive schedule is developed once an uncertainty occurs) for the integration of two problems was suggested. In order to solve the problem, the authors provided a rolling horizon optimization algorithm. Furthermore, Dulebenets et al. (2018) [40] proposed precise and comprehensive mixed integer linear programming model, as in the previously mentioned paper, albeit for the berth scheduling problem. A year before, the first author of the previously mentioned paper proposed a novel memetic algorithm with a deterministic parameter control to facilitate the berth scheduling for both discrete and continuous berthing layout cases at maritime intermodal freight terminals and to minimize the total vessel service cost (Dulebenets (2017) [41]). Li et al. (2017) [42] proposed a multi-objective berth and quay crane coordinated scheduling model (optimization approach).

As was mentioned above, Zając and Świeboda (2015) [2], after Boysen and Fliedner (2010) [3], stressed that land container terminals are less described in the literature than marine terminals (e.g., Di Francesco et al. (2016) [43]). Therefore, new approaches to the research on land container terminals are believed to be advisable. According to the knowledge of the authors and results from the literature research, analyses of the duration of operations in real facilities are rarely published. Certainly, there are numerous studies in which intermodal transport is analysed from different points of view and using different methods; however, it is important that quantified parameters connected to the time of operations are as close as possible to the actual conditions. Zając and Świeboda (2014) [44] compared the total time of transport with and without cargo, taking into consideration 4 layers of stack in the storage area. However, they did not present the durations of each particular elementary operation. Barysienė (2012) [45] presented an evaluation of technologies in intermodal freight terminals, involving multiple different operations; however, the paper does not contain any durations of these operations. Similar actions were taken in the research of Stoilova and Kunchev (2017) [46]. Alicke (2002) [47] mentioned the duration of transhipment operations and presented a proper mathematical model; however, the actual durations were included in a numerical representation of the model without mentioning the particular values in the paper.

3. Methodology

The quantitative aspects of intermodal freight terminals, such as the duration of activities and operations connected to handling and transportation, are not very often described in the literature with a precise manner. Therefore, the main issues of this paper were developed according to an empirical method that included numerous local visits to selected intermodal freight terminals, the recording and analysis of videos politely conveyed by intermodal freight terminal personnel and management, or an appropriate documentation [48–51] politely conveyed by intermodal freight terminal personnel and management as well.

In Poland, in 2017, there were 30 active intermodal freight terminals, including 6 maritime and 24 inland intermodal freight terminals [52]. The total annual handling capacity of intermodal terminals amounted to 2.7 million TEUs (TEU—Twenty-foot Equivalent Unit) in inland intermodal freight terminals, while in maritime intermodal terminals it was 8.8 million TEUs [52], which is not an impressive value compared to the 740 million TEUs worldwide according to Xiang et al. (2018) [39]. The intermodal freight terminals (land container terminals only) selected for this research were characterised by the following ranges of parameters:

- terminals area: 28,000–80,000 (m^2),
- terminal throughput: 110,000–250,000 (TEU/year),
- storage capacity: 2700–4000 (TEU),
- number of rubber tyre gantry cranes: 0–4 pieces,
- number of reefer plugs: 60–76 pieces,
- operating length of rail siding: 4×650 (700) (m).

Not every land-based intermodal freight terminal is equipped with gantry cranes, therefore it was decided to analyse the mean of transport that is most commonly used in domestic intermodal freight terminals. According to the Central Statistical Office (Główny Urząd Statystyczny), Polish inland intermodal freight terminals were operated by 46/36 different container carriers (where: the first number is for 2017, and the second one is for 2016) of which 25/30 pieces were reach stackers and 21/6 pieces were container straddle carriers, straddle carriers and side lift carriers (automated lifting vehicles) listed in total [52,53].

4. The Process of Large Cargo Containers Received Into an Intermodal Freight Terminal, Delivered by Road Transport

The process described in the section is essential for understanding the degree of complexity of large cargo containers offtake into IFT. The process is included in the durations of operations given in Section 5. The arrival of large cargo containers into intermodal freight terminals is only possible when based on making a monitoring note for loading unit before, via e-mail or with the use of a computer system. A monitoring note is initiated by a customer who is obliged to transfer the key data to an intermodal freight terminal. These data concern *inter alia*:

- a type of an intermodal transport unit (compatible with the ISO standard),
- an identification number of a large cargo container,

- a place of origin and a destination of one,
- a specification whether an intermodal transport unit is loaded/empty, and a type of freight if an intermodal transport unit is loaded,
- a registration number of a tractor-trailer,
- an identity of a driver,
- the data of a provider,
- the gross weight and net weight (tare) of a large cargo container,
- external dimensions, in the case of the transportation of an oversized freight, with detailed dimensions beyond the nominal intermodal transport units (length/width/height),
- the IMO class for the transportation of dangerous freight [54],
- the dedicated temperature of cooling/heating in the case of refrigerated or heated cargo containers,
- other additional information.

The data from a monitoring note enable the identification of a large cargo container during its offtake at an intermodal freight terminal area and help to determine the storage place on a set-aside area. This is particularly important in the case of medium and large size terminals, where numerous intermodal transport units are stored. This enables their efficient identification and thus shortens the duration of load handling.

In this chapter, the general procedure of the offtake of large cargo containers into an intermodal freight terminal is given, starting with the arrival of a load unit on a tractor-trailer, followed by its storage and then, finally, the departure of a tractor-trailer (without any load) from an internal area of logistics facility.

4.1. Preliminaries—Administrative Services

The preliminaries—administrative services are as follows:

1. Preliminaries connected to a monitoring note of an offtake large cargo container with specifying data.
2. Confirmation and data acceptance by an employee of an intermodal freight terminal.
3. Arrival of a tractor-trailer with a unit load and parking outside of an intermodal freight terminal.
4. Report of a tractor-trailer driver in an administration building in order to complete formalities, including *inter alia*:
    - transfer of relevant documents to the terminal dispatcher,
    - data verification noted in a computer system with the ones presented by a driver,
    - informing the driver about any discrepancies in order to contact the shipper in order to explain the problem,
    - in the case of positive verification—planning of a storage place for a large cargo container, informing the operator of a lifting device about the intended operation in order to take a load unit from a tractor-trailer truck and deliver it to a dedicated storage place,
    - navigation of a driver to a place of load service.
5. Return of a driver to a tractor-trailer and driving to a free line at the entry gate (marked by, e.g., a green traffic light arrow), and turning off a vehicle engine during an inspection by an employee of a terminal.

4.2. Activities at Entry Gate

Activities at the entry gate—the entry of a tractor-trailer with a large cargo container into an intermodal freight terminal—are as follows:

1. Execution of a load unit control at an entry gate by a terminal employee, which takes into account *inter alia*:

- verification of data in documents with actual data, including: the identity of a driver, the registration number of a vehicle, the identification number and type of transported large cargo container, seal numbers as well, as other activities,
- visual assessment of the technical condition of a vehicle and load unit,
- in the case of empty containers, inspection of the cleanliness of a load unit interior,
- in the case of containers with hazardous materials, validation of assays and possible appending of appropriate labels with information about the type of transported cargo,
- removal of unnecessary and misleading labels.

2. Confirmation of positive verification, printing an entry ticket with the location of a handling place where the container lifting device carries out its operation.
3. Finding incompatibilities results in the withdrawal of a loaded tractor-trailer from an entry gate outside of IFT.

4.3. Servicing Activities Connected to Handling and Storage Services on Large Cargo Containers With Use of a Reach Stacker

Servicing activities connected to the handling and storage services on large cargo containers using a reach stacker are as follows:

1. Passing of a tractor-trailer into a dedicated cargo service place.
2. Stoppage of a tractor-trailer in front of a designated location in order to release mounting devices on a large container that is placed on a tractor-trailer.
3. Approach of a tractor-trailer to the front-end of a large container by a lifting device (stoppage of a vehicle by audio signal—klaxon—received from the operator of a reach stacker).
4. Raising of a load unit by a lifting device.
5. Departure of an empty tractor-trailer back to the exit gate.
6. Setting aside of a large container on a place indicated by a dispatcher.
7. Departure of a reach stacker to realize other handling and transport activities.

The detailed lists of activities connected to a large cargo container operation, together with the durations of individual operations, are given in Section 5 of the paper.

4.4. Activities at an Entry gate—Exit of an Empty Tractor-Trailer

The activities at an entry gate—exit of an empty tractor-trailer (without a large cargo container)—are as follows:

1. Passing of a tractor-trailer to the open line of exit (signposted by, e.g., a green traffic light arrow), stopping in front of a barrier, and turning off an engine,
2. Accomplishment of control activities by an employee of an exit gate, including:
    - registration data of a tractor-trailer,
    - an identity of a driver,
    - confirmation of an information system terminal to leave an empty vehicle,
3. Positive verification—departure of a tractor-trailer from an internal part of the intermodal freight terminal (in the case of negative verification: explanation of incompatibilities).

5. Handling Activities of Large Cargo Containers by Reach Stacker

In this chapter, the selected activities related to the handling and storage of intermodal transport units are discussed. The example of large type A cargo containers is shown. The overview of the activities is enhanced by an analysis of their duration times. In these activities, a vehicle with a telescopic arm type, i.e., a reach stacker, is applied.

Among the operations while using a reach stacker, there are the following:

1. Operation No. 1—raising a large type A cargo container from a tractor-trailer,
2. Operation No. 2—setting aside a large type A container on a first layer stack (ground), within a prescribed sector of a storage yard,
3. Operation No. 3—setting aside a large type A container on a second layer stack, within a prescribed sector of a storage yard,
4. Operation No. 4—setting aside a large type A container on a third layer stack, within a prescribed sector of a storage yard.

Schematic drawings of the elementary operation are given in Figures 1–4, and the durations of each operation are specified in Tables 1 and 2.

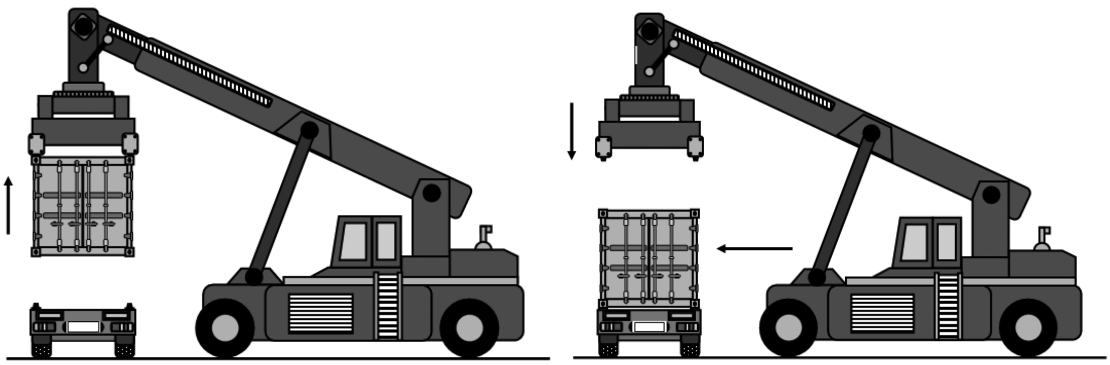

Figure 1. Operation No. 1—raising a large type A cargo container from a tractor-trailer. Source: own work.

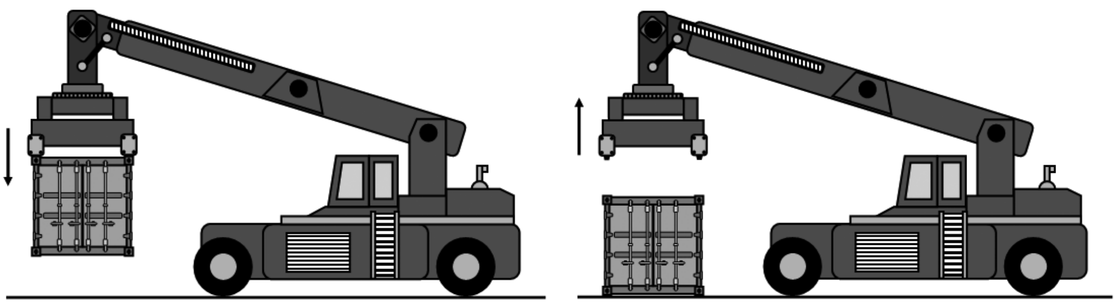

Figure 2. Operation No. 2—setting aside a large type A container on a first layer stack (ground), within a prescribed sector of a storage yard. Source: own work.

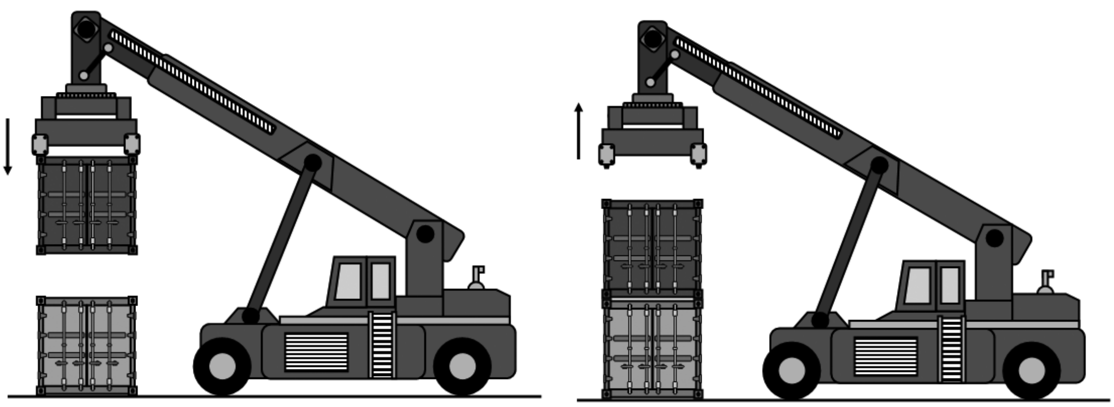

Figure 3. Operation No. 3—setting aside a large type A container on a second layer stack, within a prescribed sector of a storage yard. Source: own work.

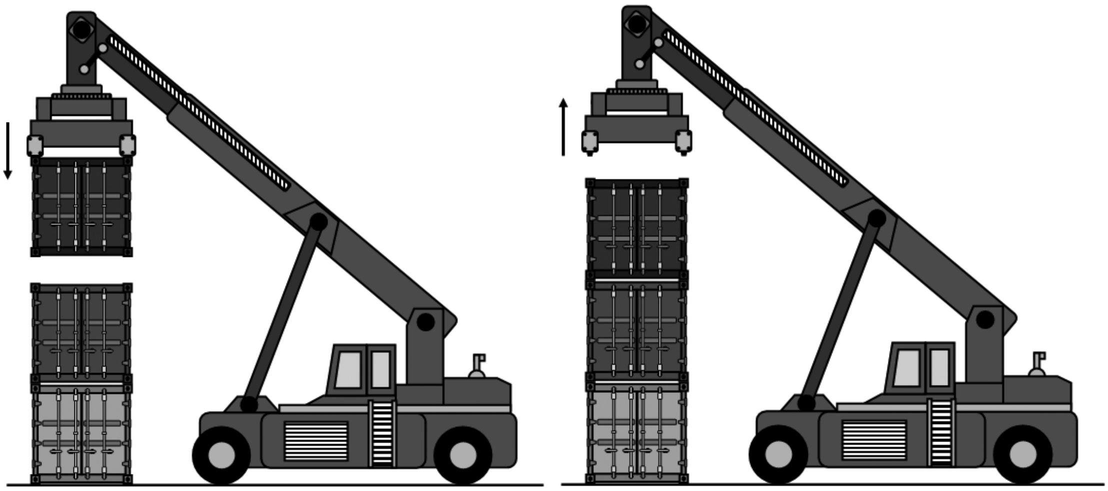

Figure 4. Operation No. 4—setting aside a large type A container on a third layer stack, within a prescribed sector of a storage yard. Source: own work.

The analysis of the Operation No. 1 duration is given in Table 1, and analyses of Operations Nos. 2–4 are given in Table 2.

The working time of the executives responsible for the operations in the real-world intermodal freight terminals allowed for the analysis of 30 transport processes. This limit resulted, among other reasons, from the necessity of waiting for the processes to be realized only in the case of type A containers and the necessity to maintain safety considerations during the measurements.

Table 1. Description of elementary activities which are part of Operation No. 1—raising a large type A cargo container from a tractor-trailer by a reach stacker. Source: own work.

Sequence Number of Elementary Activities	Description of Elementary Activity	Duration (s) (Round Average Value)	Duration (s) (Average/Minimum/ Maximum/ st. Deviation Value)
1	Preparation of a reach stacker to raise a large type A cargo container from a tractor-trailer (telescopic arms of the load handling device—extending them, adjusting them to the length of the container and blocking the position of the arms—this part of the operation lasts on average 13 seconds, while the rest, i.e., changing the angle of inclination of the telescopic arm and changing the length of the telescopic arm—the extension—lasts from 1 to 3 s, depending on the analyzed height of the type A container: 1A, 1AAA, 1AAAA—the average for these containers is 3 s).	16	16.043/15.2/ 16.665/0.384
2	Straight passing of a tractor-trailer with a velocity of 5 km/h and a distance of 25 m (the time can be modified according to the well-known physical relation between time, travel route and speed—also applies to operations 3, 6, and 9). Stoppage of a vehicle after an audio klaxon signal of a reach stacker operator when the corners of a large cargo container are in a convenient position relative to the pivots of a clutching device.	18	18.04/17.257/ 18.706/0.329
3	Approach of a reach stacker to a tractor-trailer with a velocity of 5 km/h and a distance of 5 m.	4	4.033/3.236/ 4.708/0.379

Table 1. *Cont.*

Sequence Number of Elementary Activities	Description of Elementary Activity	Duration (s) (Round Average Value)	Duration (s) (Average/Minimum/ Maximum/ st. Deviation Value)
4	Lowering of a clutching device on an upper part of a container, taking into account the time for the pivots arrangement and fitting them to fastening corners and the time for the pivots to lock.	18	18.047/17.111/ 18.802/0.461
5	Raising of an intermodal transport unit from a tractor-trailer and lifting it on a height of 1 m.	4	4.034/3.341/ 4.658/0.334
6	Moving back of a reach stacker to a tractor-trailer with a velocity of 5 km/h and a distance of 5 m.	4	4.045/3.317/ 4.859/0.437
7	Departure of a reach stacker from a tractor-trailer with a velocity of 10 km/h and a distance of 25 m.	9	8.974/8.174/ 9.649/0.421
	Total duration of Operation No. 1	73	73.057/72.258/ 73.866/0.474

Table 2. Description of the elementary activities, which are part of Operations Nos. 2–4. Source: own work.

Sequence Number of Elementary Activities	Description of Elementary Activity	Duration (s)					
		Operation No. 2		Operation No. 3		Operation No. 4	
		(Round Average Value)	(Average/Min./ Max./Stand. Dev. Value)	(Round Average Value)	(Average/Min./ Max./Stand. Dev. Value)	(Round Average Value)	(Average/Min./ Max./Stand. Dev. Value)
1	Straight passing of a reach stacker with a velocity of 5 km/h and a distance of 6 m. Stoppage of a vehicle at a distance of about 1 m from a designated storage area sector.	5	5.025/ 4.288/ 5.712/ 0.366	5	5.104/ 4.217/ 5.891/ 0.456	5	4.973/ 4.094/ 5.785/ 0.4
2	Setting aside a large cargo container on a place indicated by a dispatcher. Change of an angle of the reach stacker arm, adjustment of the position of the container in a storage sector, unlocking the clutch pivots in the corner fittings of a container.	29	28.836/ 28.078/ 29.508/ 0.402	26	25.912/ 25.117/ 26.56/ 0.357	40	40.039/ 39.247/ 40.733/ 0.434
3	Lifting of a clutch at a height of around 0.5 m over the load unit.	2	1.943/ 1.071/ 2.838/ 0.336	2	1.925/ 1.171/ 2.863/ 0.434	2	2.021/ 1.121/ 2.793/ 0.371
4	Moving back of a reach stacker at a 6 m distance.	5	5.063/ 4.272/ 5.938/ 0.436	5	4.934/ 4.143/ 5.539/ 0.362	5	5.074/ 4.313/ 5.702/ 0.341
5	Change of an angle of a reach stacker arm so that transportation would be possible.	0	0	4	4.003/ 3.216/ 4.793/ 0.495	7	7.092/ 6.224/ 7.863/ 0.426
6	A reach stacker clutch setting to start the position (gripper clutch locking time of 1 s).	13	12.965/ 12.369/ 13.701/ 0.399	15	14.941/ 14.055/ 15.898/ 0.464	18	17.993/ 17.166/ 18.77/ 0.473
Total duration of Operations, respectively, Nos. 2, 3, and 4		54	53.989/ 53.225/ 54.931/ 0.446	57	57.039/ 56.187/ 57.99/ 0.45	77	76.845/ 76.223/ 77.586/ 0.353

Analyses were made for 3 different heights of type A containers: 1A, 1AA, 1AAA, and then the average values of the duration of the transport operations and processes were obtained. The values obtained and presented in the paper are the average values of the duration of individual operations. They were expressed in seconds, after rounding their decimals, hundreds, thousands to integers. In Tables 1–3, each time in the last column, the average values, minimum values, maximum values and standard deviation values are given in the order indicated, separated by slashes, without rounding the values to full seconds.

Based on the analysis of the durations of simple operations, the duration of the transportation cycle, that is to say of taking a large type A container from a tractor-trailer by a reach stacker and setting it aside in a prescribed storage area (including storing in subsequent layers), was developed. The steps describing the cycle are given below, and their duration are presented in Table 3, while their figural identification is presented in Figure 5.

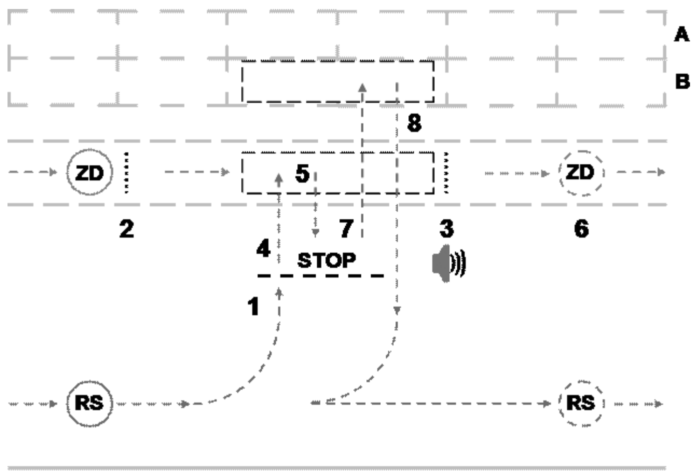

Figure 5. The scheme of a transportation cycle: from picking up of a large type A container from a tractor-trailer by a reach stacker to setting it aside in a prescribed storage area. Source: own work.

The transportation cycle, which includes raising a large type A container from a tractor-trailer by a reach stacker and setting it aside in a prescribed storage area (as shown in Figure 5.), can be described as the following set of steps:

Step No. 1. Passing of the reach stacker (RS) into a dedicated cargo service place designated by an intermodal freight terminal dispatcher. Stoppage of a reach stacker perpendicularly to lanes for road vehicles (and to a cargo storage area) at a distance that guarantees a collision-free preparation to carry out a transhipment. Preparation to take a type A container from a semi-trailer. Waiting for the arrival of a tractor-trailer with a large type A cargo container.

Step No. 2. A tractor-trailer (ZD) driving along a cargo storage area and stopping at a suitable distance before the designated transhipment area in order to conduct the operations, which include:

- A driver bypassing around a tractor-trailer to ensure that the pivots securing a transported load unit are released (lack of release could result in the raising of a tractor-trailer while it takes a large container with a clutching device),
- confirmation by a driver of the readiness to carry out the transhipment operations (including a hand gesture or a klaxon signal).

Step No. 3. Straight passing of a tractor-trailer at a low velocity of 5 km/h (distance of 25 m). Stoppage of a vehicle after a klaxon signal of a reach stacker operator when the corners of the large cargo container are in a convenient position, which means perpendicularly, relative to the pivots of a clutching device.

Step No. 4. Approach of a reach stacker to a tractor-trailer with a low velocity of 5 km/h in order to raise a load unit. Correction setting of a reach stacker arm and position of a vehicle so that a gripper clutch is located directly above the fastening corners of the large cargo container.

Step No. 5. Lowering of a clutching device on the upper part of a container, pivots arrangement and fitting them to the fastening corners, and pivots locking. Raising of large cargo container. Slight moving back of a reach stacker at a distance that allows unobstructed moves from the tractor-trailer from a place of loading activities.

Step No. 6. Departure of an empty tractor-trailer along a cargo storage area.

Step No. 7. Straight passing of a reach stacker in order to place a large cargo container in a designated storage area sector. Placing a load unit in a designated level in a containers column (so-called storage layer) including setting adjustment so that a placed container's corner fittings are in exactly the same positions as the corners of the container in the layer below (this concerns the second and subsequent layers).

Step No. 8. Moving back of a reach stacker, change of the angle of a reach stacker arm so that transportation is be possible, and change of the moving direction and departure in order to realise the next handling and transport operation.

The summary of the durations of the individual steps is given in Table 3.

Table 3. The combinations of operations pairs: Operation No. 1 and No. 2, No. 1 and No. 3, and No. 1 and No. 4. Source: own work.

No. of Step	Storage Layer 1		Storage Layer 2		Storage Layer 3	
	Step Duration (s)		Step Duration (s)		Step Duration (s)	
	(Round Average Value)	(Average/Minimum/ Maximum/Standard Deviation Value)	(Round Average Value)	(Average/Minimum/ Maximum/ Standard Deviation Value)	(Round Average Value)	(Average/Minimum/ Maximum/ Standard Deviation value)
1	25	25.114/24.195/ 25.916/0.409	25	24.979/24.092/ 25.805/0.454	25	24.948/24.204/ 25.898/0.4
2	90	89.889/89.119/90.709/0.442	90	90.105/89.07/ 90.837/0.42	90	90.084/89.284/ 90.973/0.431
3	18	17.976/17.2/ 18.864/0.407	18	17.994/17.3/ 18.844/0.42	18	17.996/17.106/ 18.74/0.413
4	19	18.954/18.031/ 19.625/0.442	19	19.092/18.359/ 19.819/0.45	19	19.137/18.329/ 19.746/0.404
5	11	11.138/10.2/ 11.843/0.411	11	11.072/10.143/ 11.943/0.411	11	11.085/10.398/ 11.805/0.427
6	9	8.763/8.157/ 9.749/0.421	9	9.061/8.359/ 9.821/0.357	9	9.084/8.319/ 9.82/0.417
7	36	36.085/35.397/ 36.85/0.36	33	33.009/32.296/ 33.612/0.322	47	47.057/46.516/ 47.891/0.313
8	27	27.008/26.04/ 27.734/0.411	33	32.997/32.103/ 33.661/0.407	39	38.895/38.202/ 39.717/0.382
Total duration	235	234.945/234.079/ 235.68/0.359	238	237.997/237.101/ 238.691/0.356	258	258.014/257.216/ 258.754/0.438

The durations for taking a large type A cargo container from a tractor-trailer and placing it in a denoted place of a storage area sector are given below. These depend on the layer of the container placing and are equal to:

- in the case of layer No. 1: 3 minutes and 55 seconds,
- in the case of layer No. 2: 3 minutes and 58 seconds,
- in the case of layer No. 3: 4 minutes and 18 seconds.

These data were developed according to an empirical method (local visits in chosen intermodal freight terminals), appropriate documentation [36–39], literature [6,55,56] (Kostrzewski and Nader, 2015; Fijałkowski, 2003; and Jakubowski, 2003) and subsequent mathematical analyses. The obtained duration was also verified on the basis of video recordings available on the Internet [57,58]. In general, these are medium values. Their changeability depends more or less on, e.g., the psychosomatic and physiological abilities of the employees of intermodal freight terminals and trailer-tractors drivers.

6. Conclusions

The subject matter of the paper was to present the process associated with the operation conducted on intermodal transport units, for example a large type A container, including *inter alia*: simple operations and combinations of operations (so-called combined cycles) connected to containers service in intermodal freight terminals, such as: handling, raising a load unit from a tractor-trailer, placing it into the appropriate sector in the storage area of a terminal, etc.

The handling and transportation of intermodal transport units upon entry into an intermodal freight terminal is an important element characterising the total cargo handling cycle, from the arrival of the cargo into the transhipment terminal until its release. In view of this matter, it is important that the description of the handling and transportation cycle would take into account the important elements that have an actual impact on the size of such a logistics facility (IFT) and the duration of the cargo operation. In this paper, we presented a detailed example of container operations in 1 to 3 consecutive layers in a container column on a storage area. The activities are described very precisely, step by step, which results in a specific and descriptive model.

The durations of the individual steps described in the paper are experimental, and the obtained values were averaged. These steps are consecutive; however, in reality some of them are realised simultaneously, thus reducing the execution time of a cycle. Furthermore, the duration of each activity is affected by a number of factors, including *inter alia*: a transport operator's experience of a machine/mean, the fatigue of an operator, the height of stacking in the containers column, the condition of the surface of an intermodal freight terminal, lighting and weather conditions, and many others.

Due to the fact that the results have been validated on real intermodal freight terminals and other logistics facilities of this kind, it is possible to use the obtained values in analytical, simulation and numerical models that reflect the work of IFT. In the authors' opinion, real-world parameters of intermodal freight terminal are deterministic because they are received on the basis of orders for cargo operations, and yet orders might be predicted with the use of, e.g., prediction market modelling (Czwajda et al. (2019) [59]). However, after gaining knowledge about these operations, the estimated parameters—which describe the operations—might be treated as stochastic while defining an analytical, simulation or numerical model, which would be taken under consideration in particular research. As Iris et al. (2018) [7] mentioned, terminal optimization problems are stochastic. As mentioned before, the aim of the issues specified in the paper is to increase knowledge related to the operations in intermodal terminals, and these issues are important elements for simulating the operating process of particular logistics facilities in future research. Prior to the construction of a simulation model enriched with stochastic parameters, it is crucial to gain as much information as possible from real-life solutions in order to prepare a stochastic model as a tool of interest for future research. However, before this happens, the authors' attention will be focused on the analysis of other devices and means of transport, used in land-based intermodal terminals, such as: gantry cranes, container straddle carriers, straddle carriers, side lift carriers (automated lifting vehicles), etc.

At the same time, it is worth mentioning that the energy consumption of operations (of various intermodal freight terminal equipment and technologies) is worthy of attention. Energy consumption analysis and emission assessment are up-to-date problems, especially in the context of sustainable development and environmental protection. This would be an important issue for future research, based on the current literature, e.g., valuable research reviews connected to maritime terminals and seaports in relation to energy consumption, such as Iris and Lam (2019) [60].

Author Contributions: Conceptualization, M.K. and A.K.; methodology, M.K.; software, A.K.; resources, M.K.; data acuration, A.K.; writing—original draft preparation, M.K. and A.K.; writing—review and editing, M.K.; visualization, A.K.; supervision, M.K.

Funding: This research received no external funding.

Acknowledgments: The authors would like to thank the Associate Editor, Reviewers for insightful comments and suggestions and Nowak W. for invaluable help in the final linguistic analysis of the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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