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CARGO LOADING AND UNLOADING EFFICIENCY ANALYSIS IN MULTIMODAL TRANSPORT

ABSTRACT

The paper presents assessment of the impact of the processes handling efficiency on the transport process based on research done in the real object, using the same technologies and material handling equipment. The aim of the paper was to confirm the importance of loading and unloading processes of palletized cargo as an initial and final link of multimodal transport by developing methods proposal for monitoring and assessing the effectiveness of cargo operations as well as the development of measures and comparison estimators. The analysis of the manipulation operations duration throughout the transport process is based on the percentile rates of manipulation and carriage in total transport process duration and the percentage of manipulating time in the duration of the carriage. These indicators and the examined loading and unloading times are the basis for the development of scheduling algorithms for optimizing transport processes on the scale of the entire transport chain. This data is also helpful input to support strategic decisions on the allocation of financial resources for the development of infrastructure and terminal equipment, warehouses and other facilities.

KEY WORDS

loading process; unloading process; cargo handling efficiency

1. INTRODUCTION

Nowadays, the most characteristic feature of the transport forced by the significant increase in trade and the need to maintain competitive advantage is the flexibility and responsiveness to the changing customer needs.

This trend is visible not only in the regional transport chains, but also and mainly in the international and multimodal transport, which also considers a number of external factors that affect the process implementation.

This changing perspective forces the companies to take more flexible planning techniques for the whole supply chain in which transport plays a crucial role. It is important, therefore, to find and use the appropriate tools to measure the effectiveness and productivity of the transport processes and to enable elimination of these processes that do not create added value. These in turn have a huge impact on the construction of rational and viable labour standards of handling possibilities [1-4].

A thorough analysis of obtained results in this way is one of the first steps to be taken in the formulation of appropriate strategies and allocation of funds for the necessary infrastructure and technology improvements. The development of the transport system in fact depends on an adequate level of process and proper funding sources diversification into different undertakings in this field. One of the main funding sources can be found in the transport policy [5].

The transport and logistics systems are strongly correlated. Efficiencies of the processes depend on each other and this should not be interpreted as outsourcing. Important role in the integration can be defined in logistic centres and container terminals [6, 7]. Some research has been conducted on the relationship between local logistics and transport systems [6].

The transport processes can be analysed by many novel methods for optimization and quality services, for example by neural network, intelligent transport systems and more [8, 9].

Proper organization of technological processes is an interesting issue and widely described in the literature [10]. Additional information on previous research in this area to preserve the intellectual cohesion is presented in the following paragraphs of the paper. This

issue, however, is a novelty in the analysed case study, where the main objective is to obtain savings through lean management of processes. Hence, the first step is to analyse the work of cargo loading and unloading processes presented in this paper.

2. INTERNATIONAL TRANSPORT PROCESSES

The process of transportation is a set of regulations and administrative operations carried out in a specific order in relation to the movement of cargo by different means of transport. For the purpose of integrating different transport modes very important are standard technologies. One of the most common standards is intermodal transport [11, 12]. The main transport process elements are also called phases: loading, freight carrying and unloading. Depending on the complexity of the transport process also some additional operations may occur, such as preparing the cargo for transport, warehousing, cargo acceptance and handling of the cooperating means of transport, as well as activities related to forwarding service recipients.

It is extremely important that the implementation of the transport process is strictly matched with a specific technology. A comprehensive transportation process should consist of the following technological processes:

- temporary storage of cargo at the sender's or in the multimodal terminals or warehouses,
- execution of loading operations in each phase of carriage,
- carriage of goods by various means of transport.

Another important issue is the proper organization of technological processes. This should be done in such a manner that different steps are followed immediately one after the other, without interruptions. To achieve this goal it is necessary to coordinate the subprocesses with the vehicles working.

In addition, it is essential to coordinate the activities of all the relevant stakeholders in the process of transport, and thus also both of the sender and the receiver of cargo and transport, including indirect links in the complex process of transportation.

The overall duration of the transport process, as well as the balance of the elements differ depending on different factors, such as:

- average distance cargo transport,
- localization of distribution points and cargo transportation conditions,
- capacity of the vehicle,
- technical speed of vehicle movement,
- technical vulnerabilities of cargo transport,
- the level of mechanization degree of loading mechanisms construction,
- construction of highways surface and other [13].

Although container terminals have increased their capacity to process a greater number of containers per year, the rapid growth in container cargo volume poses a constant need for optimal use of port resources that reduces operating costs and increases cargo throughput [14]. The unloading operations themselves can be further decomposed into multiple issues in literature. Some researchers planned efficient ordering for quayside cranes to pick up containers from a vessel [15] and some studied the routing problem, which seeks the optimal sorting and stacking of containers at storage that minimizes the handling time [16].

As of 2009 approximately 90% of non-bulk cargo worldwide has been moved by containers stacked on transport ships [17]. It should be emphasized, however, that the success of a reliable, safe and fast multimodal transport depends primarily on efficiency of intermodal freight shipping containers loading and unloading processes carried in small consolidation points of network (*Figure 1*), because there the time and cost of making freight operations per one unit of goods are the greatest.

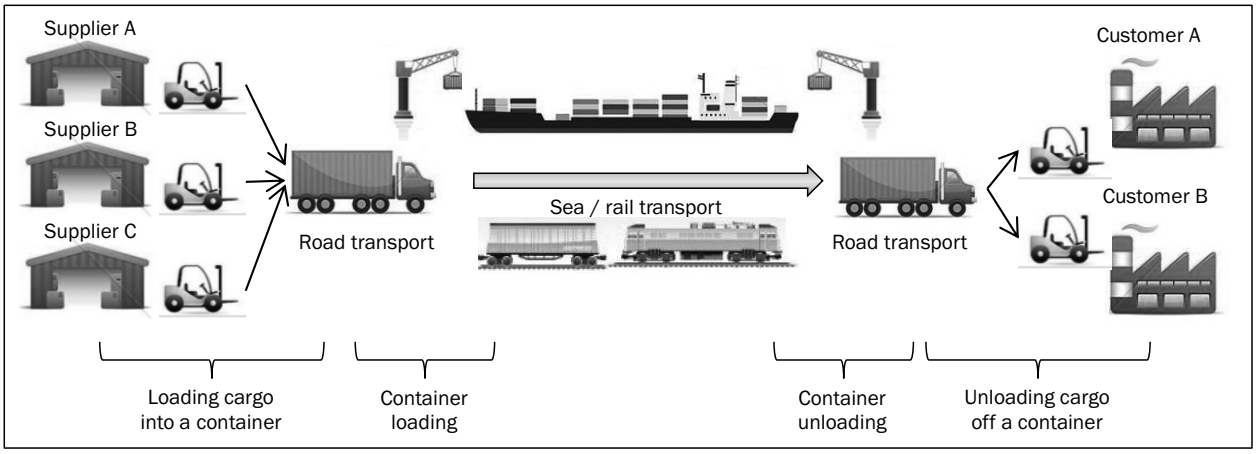

Figure 1 - Loading and unloading operations at the points of consolidation and deconsolidation in intermodal transport network

The transportation of container cargo between different modes has become highly standardized in the intermodal shipping industry.

3. ANALYSIS OF CARGO LOADING AND UNLOADING PROCESSES

The purpose of the research was to analyze the cargo loading and unloading processes in a time function, and the analysis of the efficiency of loading with the example of a consolidation warehouse.

3.1 Object and Research Method

The subject of research was the analysis of the efficiency of cargo handling processes using time measures according to loading and unloading operations of the same product with the same material handling equipment. Because of the importance of handling equipment and technology used the research has been conducted according to loading repeatable technology for universal transport truck. This eliminated the need of the load unit analysis because it has been reduced to standardized EURO pallets. The scientific problem, which has led to the clarification of the research problem relates to the methods for assessing the effectiveness of processes and transport operations. The loading units were standardized euro pallets with the plastic packaging for the dairy products, packaged in cartons with dimensions of 400 x 400 x 600 mm with 6 pieces in a single layer (*Figure 2*a), four layers on the euro pallet (800 x 1,200 mm). The weight of one pallet was 181 kg and the weight of cargo loaded was 33 x 181 kg = 5,973 kg. The cargo of 33 pallets was loaded from warehouse ramp into Krone semi-trailer of standard dimensions: 13.6 x 2.48 x 2.80 m with sliding roof. The manipulating operations of these processes and measuring times method are presented in *Figure 2*b.

Each time the individual loading / unloading operations were done the length and the duration of transport were analysed. The human factor which is always present (e.g. the operator's behaviour) was intentionally excluded from the research, and the analysis was only focused on the technical operation activities. Registration of time began at the moment of load collection and ended strictly at the moment of unloading. During the research the workers were fully informed about the aim of the measures and the need to preserve the nominal parameters in order to avoid accelerations or decelerations. All anomalies in the behaviour of the operator interrupted the measurement and the research was re-started (with another process). The results presented in the paper include a full process in nominal terms in the regime of the operator

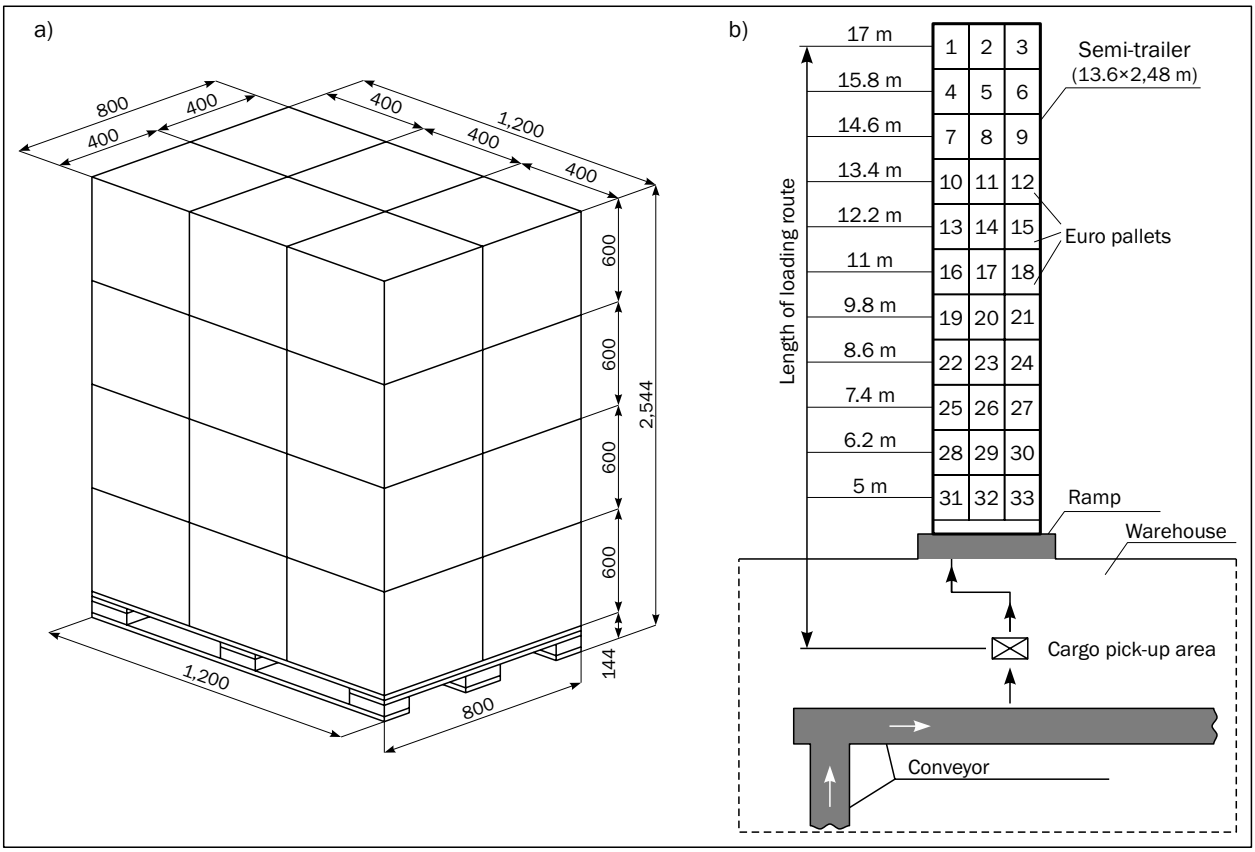

Figure 2 - Scheme and method of analysed handling processes:
a) loading unit dimensions, b) cargo loading scheme (research method)

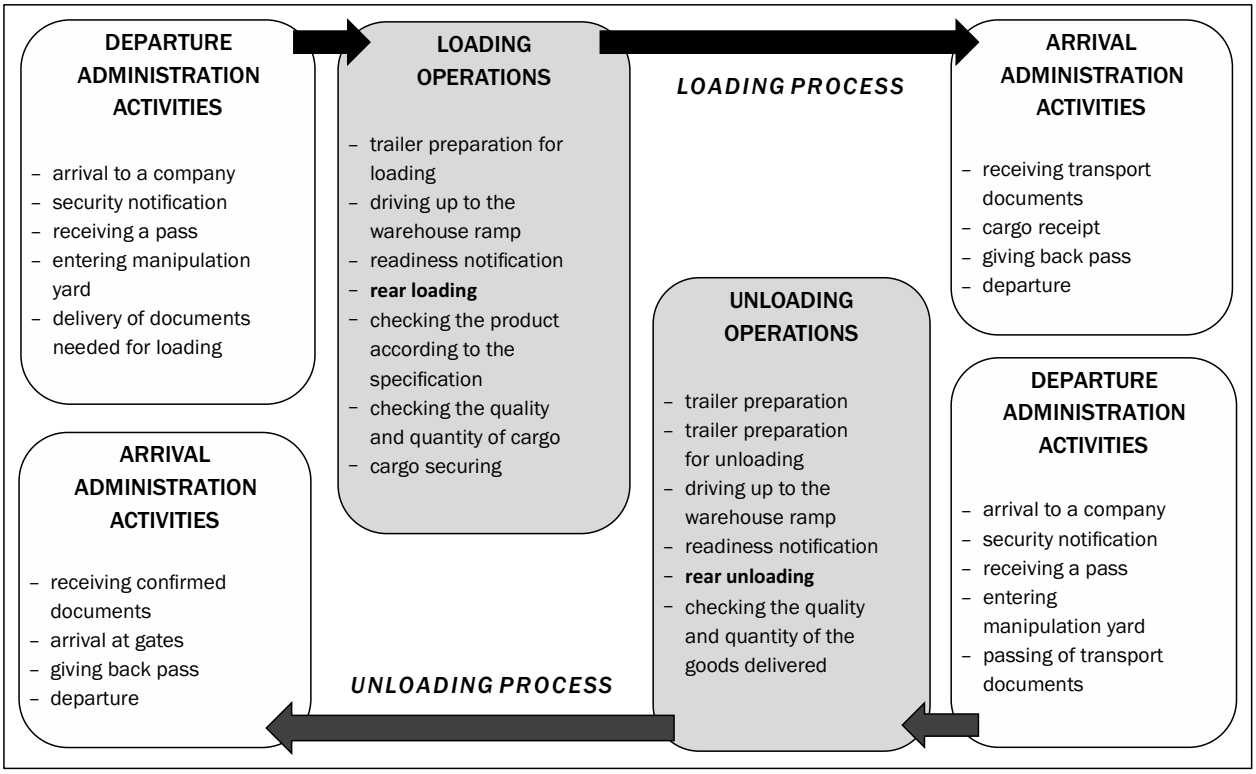

Figure 3 - Analyzed handling processes

while maintaining full real conditions. The research had an active experiment character and was based on a real object and did not rely on a special process modelling, or easier or more convenient load positioning. It preserved all the realities of the transport process and recorded only those results that smoothly implement the entire transport process.

There were two steps of research according to rare loading and unloading operations. The schematic administration and other handling activities which were within the scope of research are presented in *Figure 3*.

3.2 Research Results

The first step of the research was connected with rare loading of the semi-trailer. Particular times were measured from the time of the arrival of the truck with semi-trailer to the gate of the company, where the loading manipulations took place, and are shown in *Table 1*.

Table 1 shows that the time required to execute all the steps from arrival to departure of the truck in this warehouse was 146 minutes, while the loading itself took more than 39 minutes, which is about 26.7% of the total time. The biggest problem that occurred during this research was the waiting time caused by the queue at the ramp. The exact time and distance of locating the cargo in the semi-trailer according to *Figure 2*b scheme from the first to the thirty-third pallet was considered and presented in *Table 2*. The handling was supported by a pallet forklift with a capacity of 1,500 kg. Lifting on and lifting off times were the same for every loading unit, so that the table presents only the speed of forklift movement.

In the next stage, during the unloading operations, the time needed was specified as shown in *Table 3* and the specification of unloading pallets with the same handling equipment duration in *Table 4*.

The analyzed transport process can be represented graphically using the transport cycles card (*Figure 4*). The transport cycle preparation is one of the key elements in the analysis of logistics processes to assess the transport of various goods [18, 19].

Multiple repetitions of loading and unloading tests allowed to define the average times and speeds measured for this specific case. The average time of loading process was 38.4 minutes and for unloading it was 30.4 minutes. The differences between these times result from other non-quantifiable additional factors that affect the handling process. These include, for example, the ramp and warehouse surface condition, lighting quality, the level of qualifications and psychophysical state of the forklift operator, maintaining general orderliness of the paddock, etc. The duration of other operations is of random nature but can be minimized with organizational decisions.

The basic standard handling time is formed on the basis of individual handling times at the standard warehouse or terminal, and sometimes they are disproportionate to the actual conditions prevailing on

Table 1 - Operation duration measured during the cargo loading process

Operations	Time	Duration [min]
Arrival to a company	6:00	5
Reporting the truck to the facility guard and printing the entrance pass	6:05	8
Waiting for entry	6:13	30
Entrance to the handling yard	6:43	5
Passing the transport documents to the warehouse	6:48	5
Driving to the warehouse ramp and preparing the trailer for loading	6:53	8
Waiting for the delivery of pallets to the cargo pick-up area	7:01	10
Taking the first pallets of goods	7:11	39
Cargo loading	-	
Positioning the last pallet on the trailer	7:50	
Waiting for transport documents preparation	7:50	8
Departure from the ramp	7:58	3
Securing the cargo with transport belts	8:01	15
Driving to exit gate	8:16	5
Passing the exit gate, truck checking, giving back the pass	8:21	5
Departure	8:26	-
Total loading time		146 minutes

Table 2 - Analysis of 33 pallets loading time

Pallet No.	Time [s]	Distance [m]	Speed [m/s]	Pallet No.	Time [s]	Distance [m]	Speed [m/s]
1	100	17.0	0.170	18	70	11.0	0.157
2	100	17.0	0.170	19	69	9.8	0.142
3	97	17.0	0.175	20	67	9.8	0.146
4	94	15.8	0.168	21	63	9.8	0.156
5	94	15.8	0.168	22	61	8.6	0.141
6	95	15.8	0.166	23	60	8.6	0.143
7	89	14.6	0.164	24	59	8.6	0.146
8	89	14.6	0.164	25	59	7.4	0.125
9	90	14.6	0.162	26	55	7.4	0.135
10	86	13.4	0.156	27	52	7.4	0.142
11	84	13.4	0.160	28	49	6.2	0.127
12	82	13.4	0.163	29	46	6.2	0.135
13	82	12.2	0.149	30	45	6.2	0.138
14	81	12.2	0.151	31	40	5.0	0.125
15	77	12.2	0.158	32	35	5.0	0.143
16	76	11.0	0.145	33	35	5.0	0.143
17	76	11.0	0.145	**Total Loading Time**	2,357 s (≈39 min)	Average speed	0.151

the ramp. Therefore, on the basis of the presented analysis, the company standards should be created individually in order to take into account variable factors influencing the increase of handling time standards. These norms need to be taken into account when making strategic decisions on the allocation of financial resources for the development of infrastructure and terminal equipment, warehouses and other facilities.

The analysis also showed a directly proportional dependence of the characteristic share of time to distance, which the forklift needs to make while loading (decreasing line) and unloading (increasing line). It is characteristic for the handling process that a significant part of the total duration time of the process is accounted for by the movement of cargo by handling equipment.

Table 3 - Operation duration measured during the cargo unloading process

Operations	Time	Duration [min]
Arrival to a company	7:03	4
Reporting the truck to the facility guard and printing the entrance pass	7:07	6
Waiting for entry	7:13	77
Entrance to the handling yard	8:30	5
Passing the transport documents to the warehouse	8:35	7
Driving to the warehouse ramp and preparing the trailer for unloading	8:42	9
Waiting for the delivery of pallets to the cargo pick-up area	8:51	15
Taking the first pallets of goods	9:06	31
Cargo unloading	-	
Locating the last pallet at the warehouse ramp	9:37	
Waiting for transport documents return	9:37	7
Departure from the ramp	9:44	6
Passing the exit gate, truck checking, giving back the pass	9:50	6
Departure	9:56	-
Total loading time		173 minutes

Table 4 - Analysis of 33 pallets unloading time

Pallet No.	Time [s]	Distance [m]	Speed [m/s]	Pallet No.	Time [s]	Distance [m]	Speed [m/s]
1	90	17.0	0.188	18	60	11.0	0.183
2	91	17.0	0.186	19	59	9.8	0.166
3	82	17.0	0.207	20	53	9.8	0.185
4	80	15.8	0.197	21	51	9.8	0.192
5	77	15.8	0.205	22	47	8.6	0.183
6	76	15.8	0.208	23	45	8.6	0.191
7	74	14.6	0.197	24	41	8.6	0,209
8	74	14.6	0.197	25	41	7.4	0.180
9	72	14.6	0.203	26	38	7.4	0.195
10	71	13.4	0.189	27	36	7.4	0.206
11	69	13.4	0.194	28	35	6.2	0.177
12	65	13,4	0.206	29	29	6.2	0.214
13	63	12,2	0.194	30	32	6.2	0.194
14	64	12,2	0.190	31	20	5.0	0.250
15	63	12,2	0.194	32	21	5.0	0.238
16	61	11	0.180	33	20	5.0	0.250
17	61	11	0.180	**Total Unloading Time**	1,861 s (≈31 min)	Average speed	0.268

Figure 6 presents the average loading and unloading speed which is similar.

3.3 Handling Efficiency

In the planning of loading and unloading processes, especially over long distances, such as in the case of multimodal transport, an important factor is to determine the handling process efficiency indicators. They are usually a relatively transparent quotient expressed in percentage.

$$P_m = \frac{C_m}{C_c} \cdot 100\%$$

$$P_j = \frac{C_j}{C_c} \cdot 100\% \quad (1)$$

$$P_t = \frac{C_m}{C_j} \cdot 100\%$$

where:

P_m – total handling time percentage index,

P_j – total driving time percentage index,

P_t – handling time to driving percentage index,

Object of the process: loading of 33 pallets
Starting point: warehouse ramp
Ending point: interior of semi-trailer

Cycle no.	Distance [m]	Transport process				Cycle number	Cycle average time [s]	Total average time [s]
		What	From	How	To			
1	5.0					3	93.33	280.0
2	6.2					3	86.00	258.0
3	7.4					3	81.33	244.0
4	8.6					3	76.17	228.5
5	9.8					3	71.67	215.0
6	11.0					3	67.33	202.0
7	12.2					3	60.33	181.0
8	13.4					3	52.17	156.5
9	14.6					3	46.83	140.5
10	15.8					3	39.33	118.0
11	17.0					3	28.50	85.5

Legend: euro pallet; temporary storage (ramp of warehouse); front forklift (capacity of 1,500kg); semi-trailer

Figure 4 - Transport cycles card for loading process of semi-trailer with 33 pallets

C_m [min] – total handling time (loading or unloading),
C_j [min] – total driving time,
C_c [min] – total duration of transport process.

The exemplary research was done only by road, transporting the 33-pallet load from Siemianowice Śląskie (PL) to Ochsenfurt (DE) – 830 km (route 1, 2) and from Siemianowice Śląskie (PL) to Ochsenfurt (DE) – 810 km (route 3, 4). To analyse the contribution to handling in the whole transport process the percentile rates based on the measured time were calculated and are shown in *Table 5*.

For the analysed similar transport processes, it turned out just like in the case of loading and unloading measurement times, that the handling time percentage index may differ (in this case from 3.06% to 4.24%) which further confirms the need to analyse time efficiency parameters for proper transportation planning.

4. CONCLUSION

The purpose of this paper and research presented was to develop a proposal for the methods of monitoring and assessing the effectiveness of cargo operations as well as the development of measures and comparison estimators (such as time function measurement or the average speed of the loading estima-

Table 5 - Handling time efficiency indicators

Route	Transport process total time (min) - C_c	Driving time (min) C_j	Handling time (min) C_m	Total handling time percentage index - P_m	Total driving time percentage index - P_j	Handling time to driving percentage index - P_t
1	1,676	742	70.18	4.19%	44.27%	9.46%
2	1,608	783	68.18	4.24%	48.69%	8.71%
3	1,735	825	53.02	3.06%	47.55%	6.43%
4	1,695	823	55.43	3.27%	48.55%	6.74%

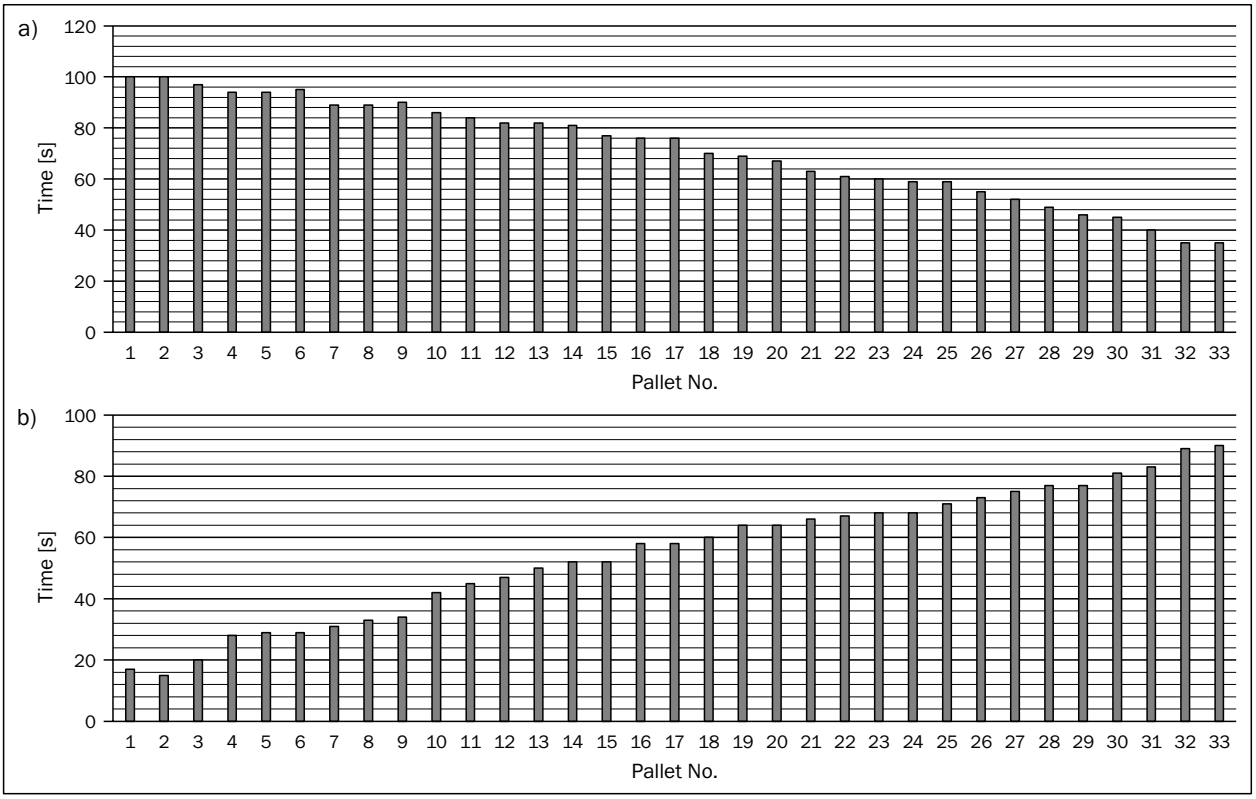

Figure 5 - Duration of handling process: a) loading, b) unloading

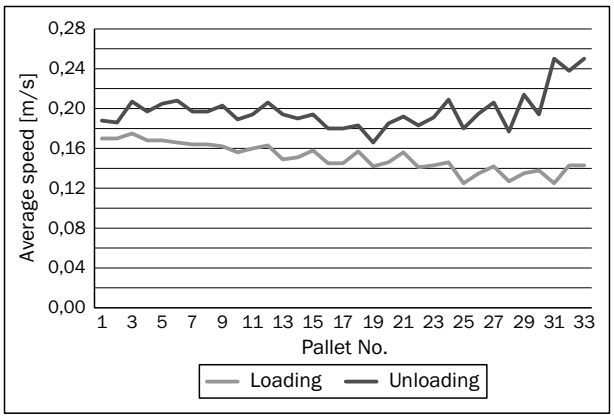

Figure 6 - Loading and unloading process average speed

tors). It may also be assumed that the goal of the optimization process can be used to maintain a constant speed of unit loading (with the given standard deviation). This gives an opportunity to significantly facilitate the management of the manipulation work especially for those which are implemented equally, and on a larger scale where the number of docking points of the facility is big – it may also concern efficient entire fleet management.

These measures and estimators may provide a basis for comparing different methods of loading. At the same time it may improve the quality of decisions made by the management according to the selection of appropriate technology, equipment and systems for loading.

The following specific conclusion was drawn:

a) The use of suitable handling equipment and coordinating the whole process of loading or unloading directly affects improving the efficiency of the entire transport process, especially for long distances (international transport) or when many handling operations are required (multimodal transport).
b) The average time of the loading process of 33 pallets was 38.4 minutes and for unloading it was 30.4 minutes with the same handling equipment and the same distance from the trailer to the ramp. The difference between these times results from other non-quantifiable additional factors that affect the handling process (e.g. ramp and warehouse surface condition, lighting quality, the level of qualifications and psychophysical state of the forklift operator).
c) The research brought similar and repeatable times of handling process times according to individual objects (terminals, warehouses). It is therefore necessary to create a separate manipulation time standard for each of them to be able to rationally plan the movement of goods by verified consolidation and deconsolidation points of multimodal transport.
d) Handling time percentage index may differ (in the research object: from 3.06% to 4.24%) which further confirms the necessity to analyse the time efficiency parameters for proper transportation planning.

e) The biggest problem in handling and transport process efficiency measurement is connected with random factors (like trailers waiting to be unloaded because of a bottleneck on the warehouse ramp), which can be reduced with scrupulous planning and algorithm techniques.
f) Research presented in this paper is a part of a more extensive research concerning the analysis of technical factors affecting the efficiency of transport processes, which will be published in subsequent papers.

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STRESZCZENIE

W artykule przedstawiono znaczenie procesów załadunku i rozładunku spaletyzowanych ładunków jako inicjujące i końcowe ogniwo w transporcie intermodalnym. Ocenę wpływu procesów manipulacyjnych na efektywność całego procesu transportowego oparto o badania na rzeczywistym obiekcie, przy użyciu jednakowych technologii i urządzeń przeładunkowych. Analizę czasu trwania czynności manipulacyjnych w całym procesie transportowym oparto na procentowych wskaźnikach udziału manipulacji i przewozu w całkowitym czasie procesu transportowego oraz udziału manipulacji do czasu trwania samego przewozu. Podane wskaźniki i zbadane czasy załadunkowo-rozładunkowe, są podstawą dla tworzenia algorytmów optymalizacji procesów transportowych na skalę całego łańcucha transportowego oraz wspomagają decyzje strategiczne dotyczące alokacji środków finansowych w rozbudowę infrastruktury i wyposażenie terminali, magazynów i innych obiektów.

SŁOWA KLUCZOWE

proces załadunku; proces rozładunku; efektywność procesów przeładunkowych

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