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Improving Logistics Processes in Inland Container Terminal

Abstract

This paper focuses on the application of two approaches: Business Process Redesign (BPR) and Discrete Event Simulation (DES) in an attempt to enhance the basic logistics processes in inland container terminals. The goal of the paper is to identify the weaknesses and potential problems in the execution of current logistics processes, as well as to redesign such identified weaknesses and problems. The main contribution of the paper is to show how DES and BPR can be used in restructuring of container logistics processes in inland container terminals. Its original feature is a novelty, a holistic approach in rationalization of container logistics processes in inland intermodal terminals, creating models of the current (AS-IS) and improved (TO-BE) states. Models show that DES and BPR represent an easily accessible and effective tool in the analysis of terminal processes in container terminals. Therefore, it can be efficiently used for monitoring the current situation, identification of weak spots in a particular system and for creating any necessary preconditions for improvement of business processes.

Key words: inland container terminal, Business Process Redesign, logistics processes in inland container terminal, Discrete Event Simulation.

1. Introduction

Intermodal terminals, as areas of concentration of cargo flows and confrontation of various modes of transport, play an important role for the efficiency of global economy. Steeply rising container flows have resulted in crowded terminals, congestion and prolonged dwell times for containers [26] so that today container terminals, as a part of intermodal terminals, are faced with major challenges regarding the way how the escalation of container traffic demand is to be successfully handled? Hence, container terminals are in a constant search for solutions to manage additional demands, since otherwise they risk losing business to their competitors. Redesigning of logistics processes in container terminals, in order to realize the overall improvement, is one of possible solutions and in this paper we show how the well-known concepts of Business Process Redesign (BPR) and Discrete Event Simulation (DES) can help in achieving successful changes in container logistics processes.

In the past several years DES models were proposed as an optimization tool in container terminals [7]. The DES has been particularly useful to describe the logistical operation of the main system terminal modules [1]. Simulation models are well applicable due to stochastic and dynamic nature of container terminal processes. Using simulation modelling provides a systematic approach for understanding the relative and interactive impact of factors/parameters for different scenario settings [13], what is important because usually in practice there is a lack of detailed databases and simulation is then the only way to find important relations between influencing parameters in the observed system. On the other hand, business process modelling is a very important activity both in management and utilization of resources in a particular working system. It describes how business operations are conducted which typically include graphical display of activities, events and control [27]. Many organizations have been applying this approach since early 1990s and have reported dramatic benefits.

Since DES is a widely applied methodology in container terminals and modelling of business processes is one of the main restructuring business concepts today, the research problem of this paper is the attempt to merge these two methodologies and to apply the outcome to a real inland container terminal. More concretely, the paper deals with the modelling and simulation of basic logistics processes at the container terminal. Accordingly, paper's main contribution is to show how DES and BPR can be used to enhance and optimize container logistics processes in inland container terminals. The aim of this research is to describe the real container terminal logistics processes and to create conditions to determine possible weaknesses in the functioning of the existing system (AS-IS model), and to develop a model of improved conditions that eliminates the weaknesses (TO-BE model).

In order to adequately cover the research problem, the paper is organized in five sections. In the next section discussion is redirected on modelling and simulation, with the focus on modelling and simulation in logistics and intermodal terminals. Section 3 deals with the theoretical background of the BPR through its basic concepts, application in container terminals and methodology approach for implementation in inland container terminals. Section 4 is the core of our paper, where AS-IS and TO-BE models of inland container terminal are presented and evaluated. In section 5, we conclude the paper with final observations, practical application and recommendation for future research on the purposefulness of using the presented restructuring approach in inland container terminals.

2. Modelling and simulation

2.1. Modelling and simulation in logistics and intermodal terminals

The need for optimization using methods of operations research in the operation of container terminal has become increasingly important in recent years. This is due to the fact that logistics, especially of large container terminals, has already reached a degree of complexity where any further improvement requires scientific methods [31]. Terminal operators prefer to explore whether new management methodologies can improve the terminal performance before investing in new equipment or enlarging the area of the terminal [29]. In recent years, simulation has become an important tool to improve terminal operation and performance [31] and today simulation can provide help to decision makers in creating development strategies [29]. One of the main motivations for developing a simulation model or using any other modelling method is that "it is an inexpensive way to gain important insights when the costs, risks or logistics of manipulating the real system of interest are prohibitive" [18], and also that it allows testing of several strategies and scenarios [30]. The complexity of the observed system could be one of the reasons for using modelling and simulations in logistics and Disney et al. [11] explain it as "to enable a model to mimic completely real world supply chains, a large and complex model has to be built in our minds, this is beyond the capability of most people, but the use of computers can help considerably". Steenken et al. [31] conclude that "different logistics concepts, decision rules and optimization algorithms have to be compared by simulation before they are implemented into real systems". Cartenì and Luca [7] suggested that: "simulation can help to achieve various aims: overcome mathematical limitations of optimization approaches, allow a more detailed and realistic representation of terminal characteristics, support decision makers in daily decision processes through assessment of "what if" scenarios and make computer-generated strategies/policies more understandable".

From presented statements of different researchers, we could draw a simple conclusion about the purposefulness of using modelling and simulation in logistics and intermodal terminals and say that it is not always possible and economically justified to experiment with real systems. It could be too risky, too expensive, or simply it could be too complex and impractical. The whole idea of modelling in container terminals is to find solutions to real logistics problems through the risk free space of virtual world (simulations).

2.2. DES & container terminals

DES is widely used in solving optimization problems, which are related with logistics, supply chains and intermodal transportation. The complexity of container terminals makes it impossible for all interactions to be described by a mathematical model. Because of this increased complexity and the required level of detail, DES is the appropriate tool for analysis [6]. Most papers on the subject of optimization of container terminals are papers related to port container terminals. Summarized and analyzed literature reviews about DES as a methodology approach for simulation of operations in port container terminals, could be found in [7, 31, 35]. In mentioned papers, researches suggested that a more integrated and holistic approach to the optimization of container terminal is required, since they noted that most of the papers deal with separate parts of the terminal, without taking into consideration their impact on other subsystems [31, 35]. On the other side, inland container terminals are less frequently observed and analyzed by researches. The reasons are because port terminals are the most important link in the global supply chain, with significant container throughputs and impacts on world economies, while inland container terminals are usually rail/road terminals, and they are important for the development of regional economies and industrial regions where they operate. In literature there are different approaches to the optimization of inland terminals and only a few papers based on DES, which are listed here [2, 3, 12, 19, 29].

3. Business process redesign

In theories of Business Process Redesign, organizational hierarchies and the representation of organizations in terms of different functions are replaced by a process-oriented perspective [21]. According to Davenport [9] BPR represents the analysis and design of work flows and processes within an organization. Due to Fordism and Taylorism, companies are traditionally viewed in terms of functions and divisions. On the other side, the BPR philosophy is pushing enterprises to go back to the basics and re-examine their very roots [23]. It is focused on observing the companies as a series of key processes and the achievement of order of magnitude levels of improvement in these key processes means redesigning them from the beginning to the end, employing whatever innovative technologies and organizational resources are available [10]. With a business process as the underlying concept, BPR is very similar to the concept of business process re-engineering, which represents the fundamental rethink and radical redesign of business processes enabling the improvements in critical performance measures such as cost, quality, service and speed. Hence, the main difference between the concepts of Business Process Redesign and business process re-engineering is that re-engineering assumes a much broader scope than the specific focus of process redesign. Process redesign is concerned with how to articulate a process, while re-engineering can refer to all aspects of restructuring an organization processes [20].

3.1. BPR & container terminals

Paixa and Marlow [26] proposed application of BPR in ports, stating that "BPR may help port operators to overcome some of the drawbacks presented by existing port layouts since this work is being carried out on existing, sometimes very old, facilities rather than on greenfield projects". According to Regattieri et al. [28], application of BPR to logistics processes is named as logistics process re-engineering. Although there is a large amount of literature dealing with BPR, however, there are a very few sources that discuss this process applied to the intermodal transport and container logistics [26, 8]. To the best of our knowledge this is the first paper that shows how to apply BPR and DES methodologies on logistics processes in inland container terminal.

3.2. Methodology approach for implementation of BPR in inland container terminal

Most methodologies for conducting redesign are the intellectual property of large consulting firms. Among different methodologies, Nissen [24] pointed out Davenport [10]'s five steps framework for process redesigning as one that provide "a start-to-finish guide to undertaking process improvement, answering questions such as what steps need to be taken and in which order". The proposed framework was adopted, and adjusted for the purpose of this research, with the addition of two more steps in methodology (steps 5 and 7), Figure 1.

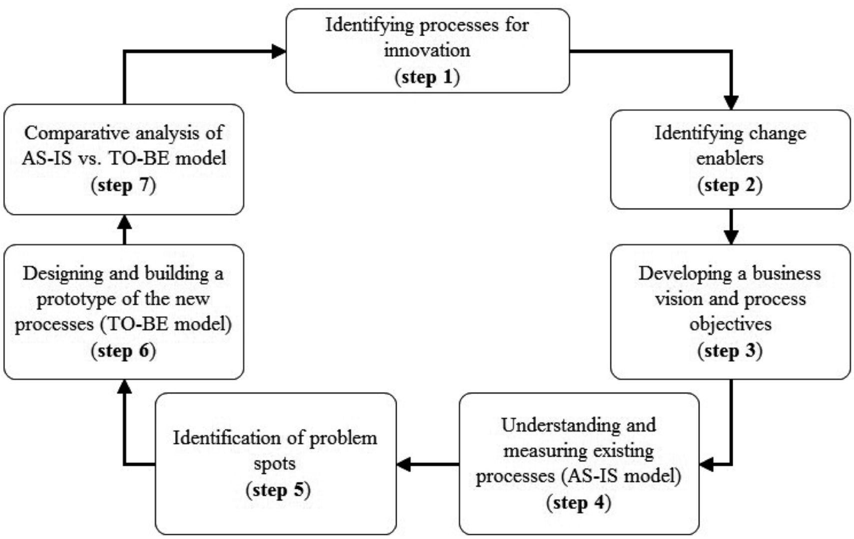

Figure 1 - Methodology framework for implementation of BPR (adapted from [10])

To summarize, BPR is enabled by business process modelling. A business process model represents an abstraction of a business that shows how business components are related to each other and how they operate [21]. The key element for describing a specific business model is process mapping, enabled by process maps. Process maps provide a critical assessment of what really happens inside a given company (process identification or mapping AS-IS processes) and they also serve for designing a new solution (modelling TO-BE processes). Business process modelling and the evaluation of different alternative scenarios (TO-BE models) for improvement by simulation are usually the driving factors of the business redesign process [32]. In the following section of this paper, the proposed methodology for container logistics process redesign is presented on the example of an inland container terminal.

4. Case study of inland container terminal

The case study was carried out on the example of a road/rail terminal in Serbia. By Wiegmans et al. [37] classification, terminal could be categorized as an M-terminal type. It is a government property with good road and rail connections. The terminal is currently under the process of reconstruction and transformation, and all the data used in this paper are related to the period of the terminal operation before the transformation phase.

4.1. Identifying processes for innovation

Organizations are generally recommended, because of the disruption and stress caused by redesign, not to attempt to redesign more than one major process at a time [25]. For that purpose we consulted the top management (terminal manager and head of accounting) and together we agreed that there were two key business processes to be distinguished in the terminal: the unaccompanied and accompanied transport. According to the terminal manager, unaccompanied transport is the dominant service provided by the terminal, with a share of 95% of all cargo flows through the terminal. A large majority of mentioned flows are from container transport (mainly from big regional ports). Other modes of unaccompanied transport (transport of trailers and swap-bodies) and accompanied transport (Ro-La service) are fairly irregular and insignificant by the quantity as compared with container traffic. Having in mind the fact previously mentioned the terminal logistics processes regarding the unaccompanied container transport have been chosen for the key business (logistics) process redesign

4.2. Identifying change enablers

Hayes et al. [16] established efficient operations as a key source for a firm's competitive advantage. In order to improve the competitive status and productivity in the fierce competitive environment between container terminals, Choi et al. [8] suggested that beside adopting the latest technologies and renovation of terminal facilities, the efficient execution of terminal business processes is another very important factor. This suggestion agrees with Davenport's views, where IT, organizational and human factors are identified as the most important process change enablers and treated as equal partners in effecting process changes in a particular organization [10]. Currently, the terminal has not been provided with a modern terminal operation system based on IT. Its future management plans include the installation of a modern IT system, which will allow container tagging and tracking during their movements within the terminal.

4.3. Developing process vision and process objectives

To develop a process vision it is important to make connection with the overall strategy of a particular organization. In practice there is often a gap between the process execution and the defined strategy. The pioneering article by Hayes and Wheelwright [17] linked operations aspects of processes to business strategy, and made a "road map" for further connections. Generally, today, in order to connect a process execution with the defined strategy firms are focused on four dimensions of process performance: cost of service, variety of offered services, quality, responsiveness on given demand [5]. In the case of intermodal terminals Wiegmans et al. [37] have found that minimisation of costs and maximisation of profits are the main internal goals of intermodal terminals, which is quite far away from the situation in other industries which are more compressed by external goals of higher competition and customer satisfaction. Beside the minimisation of costs and maximisation of profit, the strategy of a particular terminal is also related with its geographical position. The terminal is located at an important intersection of transition corridors, and there are indications for the freight transport on those corridors to grow in future [4]. Today, Chinese companies have full control of the Piraeus port container terminals and they are also planning to buy another big Greek port, the port of Thessaloniki. Consequently, there are bilateral agreements in place since recently between the Chinese consortium and governments of South East European countries on the renovation of the Budapest-Belgrade railway line, for the purpose of more efficient container transportation from ports of Thessaloniki and Piraeus to Budapest. Therefore, according to the management of the observed terminal, the terminal market future strategy is to offer as lower transit time as possible of containers through the terminal, thereby to attract additional container transports. Accordingly, the most important tasks to be fulfilled by optimized processes are to reduce the processing time of containers in transit, increase the available capacity and reduce the operation costs.

4.4. Development of the AS-IS model (understanding the existing processes)

In order to understand existing processes, there is a common practice to create a process map model of existing processes in an organization (AS-IS model). Process maps are graphically described processes that help to structure the information collected during the case analysis or process improvement project [5]. For business process modelling we used the iGrafx 2011 software (academic version), which is often used in researches dealing with similar problems of process modelling [14, 15, 21, 22, 33, 34]. iGrafx supports mapping and simulation of business processes using process maps and DES. While forming the AS-IS model, several databases were used: data on the company internal structure and container turnover, interviews with the terminal manager, data about employees and their working activities, time and various activities performance costs, as well as data about employees' wages and costs generated by the use of machinery.

The observed inland container terminal consists of several working sectors which perform different business and logistics activities necessary for handling container flows within the terminal. The most common stream of activities for container flow in the terminal consists of the following activities: upon arrival of containers at the terminal, the receiving sector forwards notice of arrival to the administrative sector. The dispatcher in the administrative sector gives permission for the container to be released in the terminal operating sector. Further container manipulation depends on whether the containers need to be transhipped from the terminal or stored in the stacking area. If they need to be transhipped, they are loaded on train compositions or trucks; if they are intended for storage, they are unloaded in the operational zone of the crane and picked up by forklifts to be delivered to the storage sector. The process of dispatching containers from the storage is also done by forklifts, where containers are picked up from the storage and transported to the crane. The crane lifts up the containers and performs their loading on trains or trucks. The loaded containers are registered by the dispatcher and dispatched from the terminal. Time distribution for each activity is determined by field measurements or by interviewing yard workers and managers. Based on the previous description, and using mentioned data, the terminal is simulated and as a result the AS-IS model is created and presented in Figure 2. Each activity within the AS-IS model is associated with: particular resource, cost of execution, and time needed for the execution of the observed activity.

Based on the simulation of existing activities by the AS-IS model, container processing times throughout sectors are determined and presented in Table 1. As resulting from Table I, containers obviously spend most time in the stacking area, which is expected due to the nature of the container business. Also, container waiting time is significant in terms of resources. It is particularly striking in the stacking area and represents requests for the dispatch of containers when resources are busy, out of work, or requests made on weekends.

Table 1. Average processing time per TEU by the sector of the AS-IS model

Sectors	Number of TEU units	Average work time (minutes)	Average waiting time		Average storing time (minutes)	Average processing time (minutes)
			waiting time (minutes)	waiting time when resources are out of the schedule (minutes)		
Administrative	12000	2	2	0	/	4
Reception	12000	7	8	0	/	15
Operations	12000	8	12	0	/	20
Stacking area	3000	42	113	115	4132	4402

Processing time throughout sectors is a good indicator of bottlenecks within the terminal and in order for bottlenecks to be identified, two process performance indicators were used (capacity and implied utilization). For calculating capacity and implied utilization of particular sectors, the following formulas were used [30]:

$$\text{Capacity} = \frac{60\left[\text{minutes}\right] \bullet 8\left[\text{hours}\right] \bullet 261\left[\text{working days}\right]}{\text{processing time}\left[\text{minutes}\right]} \bullet \text{N}\ ;^{1} \tag{1}$$

$$\text{Implied utilization} = \frac{\text{current throughput}}{\text{capacity}} \bullet 100\% \tag{2}$$

1 N- number of containers that could be served simultaneously, ie. it is the number of parallel (flows) or services that could be served in a particular sector. The reception and administrative sectors can serve 5 containers simultaneously, operation 2, and storage sector can store 1500 containers simultaneously.

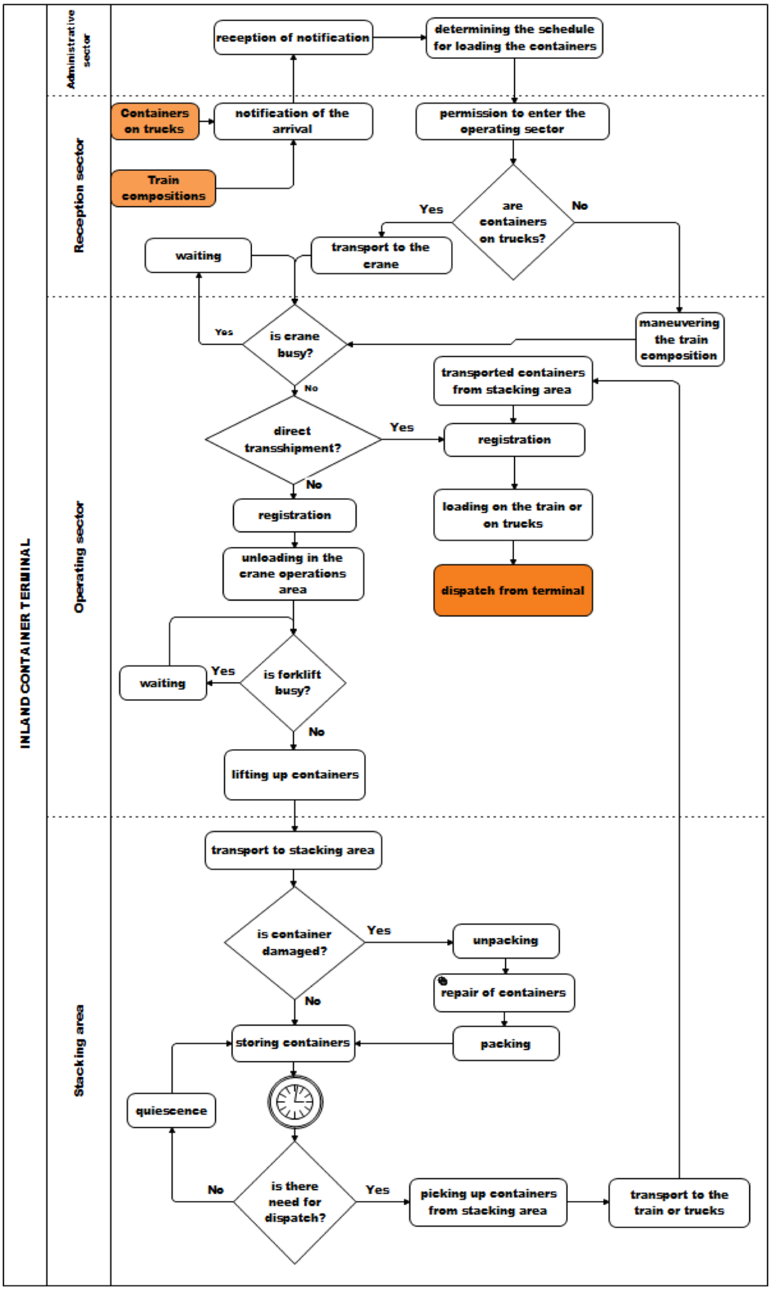

Figure 2 - The AS-IS model of an inland container terminal

From Table 2 it is clear that the operations sector has the smallest capacity of all and that other sectors have a relatively small utilization and could handle additional container traffic. Consequently, it could be concluded that the operations sector represents the terminal bottleneck. Therefore, by causality the maximum throughput of the entire terminal is directly determined by the capacity of its weakest link, in this case by the capacity of the operations sector. The operations sector low capacity is preventing the terminal management to make potential arrangements with biggest regional forwarders and carriers and in that way to attract additional container traffic to the terminal.

Table 2. Process performance indicators of the AS-IS model

Sectors	Processing time [minutes/TEU]	Current throughput [TEU/year]	Capacity [TEU/year]	Implied utilization [%]
Administrative	4	12000	156600	8
Reception	15	12000	41760	29
Operations	20	12000	12528	96
Stacking area	4402	3000	42690	7

Beside the capacity and implied utilization, other important parameters of the terminal efficiency are the transhipment time and average manipulation costs. In AS-IS, the average transhipment time is estimated at 35 minutes, with standard deviation of 11 minutes, while the average manipulation cost per TEU is estimated at 10.51 EUR. The average manipulation cost per TEU is a very important indicator of terminal efficiency, because it can serve as a threshold for determining the minimum level of tariffs for terminal services that are economically justified, since it is often claimed that prices imposed by freight terminals are high [37].

A summarized analysis of the AS-IS model is shown in Table 3. The table consists of key performance indicators, which describe the current situation at the container terminal.

Table 3. Key performance indicators of the AS-IS model

AS-IS model	Current maximum capacity	Implied utilization	Average transhipment time	Manipulation costs per TEU
	12 528 TEU/year	96%	35 minutes	10.51 EUR

4.5. Identification of problem spots

Analyzing the operation of the AS-IS model, interviewing experts at the terminal, and studying simulation reports, we have identified several problems in the execution of current logistics processes:

- Inadequate capacity of the operations sector, due to old and slow handling equipment (Table 2);
- Lack of comprehensive database about container flows and positions at the terminal;
- Cross-functional delay of information flows between the reception and administrative sectors, which increases the retention of the container in the reception sector;
- Waiting time of containers is significantly high (Table 1, columns 4 and 5). In some sectors the waiting time of containers is longer (or equal) than the handling time by resources;
- Forklifts are old, with high maintenance cost and small lifting capacities.

4.6. Development of the TO-BE model (creating improved processes)

While developing the TO-BE model, organizational and structural changes were implemented. To answer the needs of some of the identified problem spots, several TO-BE models were created. These models were compared and evaluated. The TO-BE model presented in Figure 3 is the optimal model according to the criteria of the overall improvements and cost savings that can be realized.

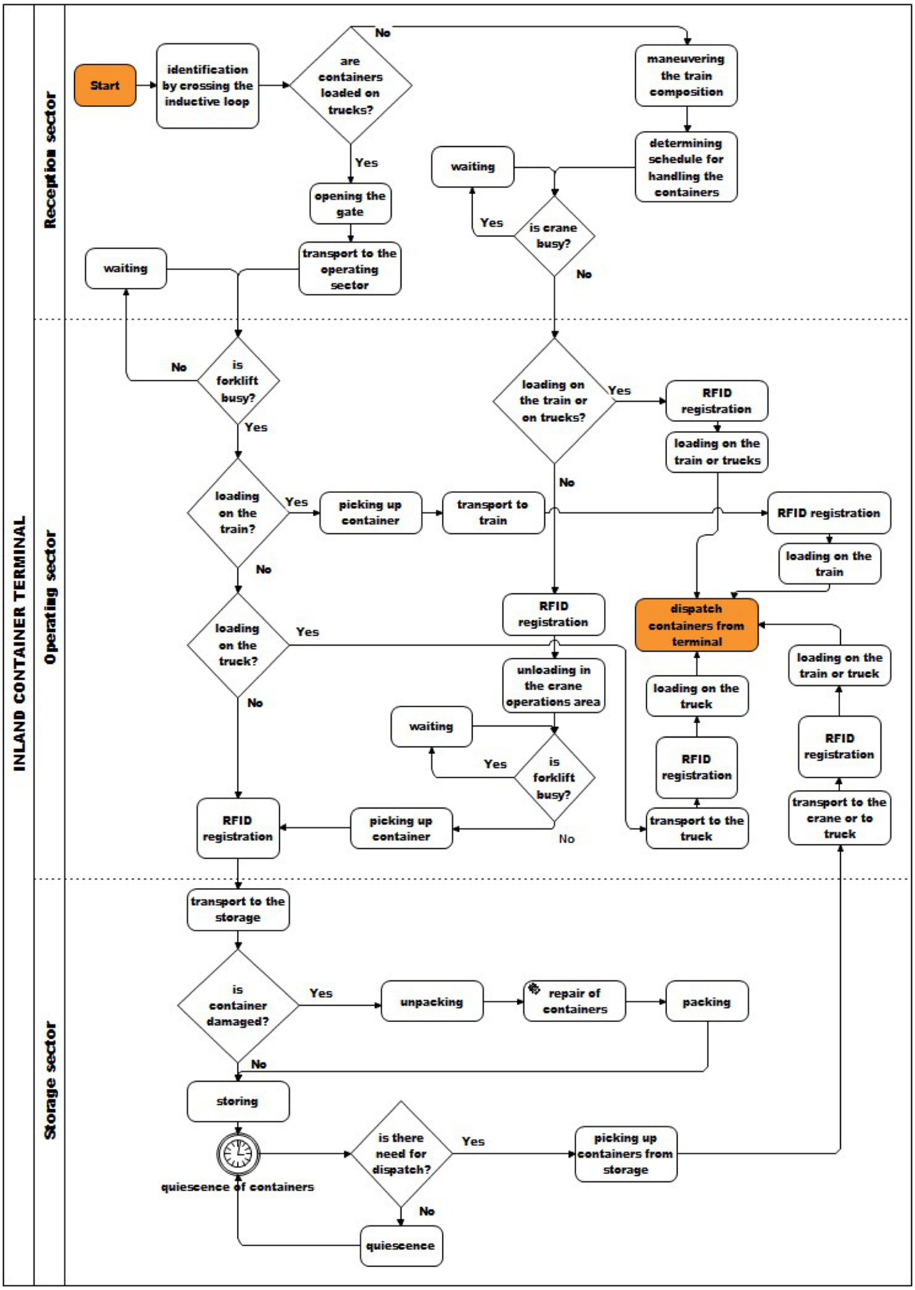

Figure 3 - The TO-BE model of the inland container terminal

Some of the changes introduced by redesigning can be physically seen in the TO-BE process map. On the other hand, changes in the internal structure of processes, such as: which resource to perform an activity, priorities in executing activities, changes in operating policies etc., couldn't be simply seen by studying the TO-BE process map. Their impact on the functioning of the terminal is seen through key performance indicators. The presented model has a lot of "know how" gained from yard workers consulted during the model development and their suggestions as to what changes will or won't work for the observed terminal were also taken in consideration. In the TO-BE model simulation of tagged containers (through the RFID technology) the replacement of three old forklifts with one reach stacker is implemented. The reach stacker is inserted in the simulation instead of three old forklifts in order to see the effect it would produce on the terminal productivity, provided such an investment by the terminal manager, and whether in that way the low capacity problem in the operations sector would be solved. In that sense, the manager can use the presented TO-BE model as a decision supporting system for justifying new investments in the terminal.

Table 4. Average processing time per container by the sector of the TO-BE model

Sectors	Number of TEU units	Average work time (minutes)	Average waiting time		Average storing time (minutes)	Average processing time (minutes)
			waiting time (minutes)	waiting time when resources are out of the schedule (minutes)		
Reception	12000	3	4	0	/	7
Operations	12000	6	1	0	/	7
Stacking	3000	24	58	61	4064	4207

From Table 4, it is clear that the TO-BE model shows a reduction in the container processing time throughout all working sectors. Administrative sector is excluded from simulation, since owing to the installed RFID tracking dispatcher the administrative sector is informed on any current location of containers and it can handle the necessary permissions and documents before the containers arrive at the terminal. The drop in the processing time required for handling one TEU directly influences the working capacity of sectors, Table 5. A noticeable capacity increase is seen in the operations sector, from 12 528 TEU/year (Table 1) to 35 794 TEU/year (Table 5).

Table 5. Process performance indicators of the TO-BE model

Sectors	Processing time [minutes/TEU]	Current throughput [TEU/year]	Capacity [TEU/year]	Implied Utilization [%]
Reception	7	12000	89486	13
Operations	7	12000	35794	34
Stacking	4207	3000	46665	6

Simulating transhipment time through the TO-BE model estimated at 13 minutes, with standard deviation of 7 minutes, while the average manipulation cost is estimated at 5.51 EUR. The most important key performance indicators of the TO-BE model are summarized as shown in Table 6.

Table 6. Key performance indicators of the TO-BE model

TO-BE model	Current maximum capacity	Implied utilization	Average transhipment time	Manipulation costs per TEU
	35 794 TEU/year	34%	13 minutes	5.51 EUR

4.7. Comparative analysis

In order to evaluate the AS-IS vs. TO-BE model, a comparative analysis of key performance indicators has been carried out and the conclusion is that the organizational structure and distribution of work activities in the AS-IS model cause longer processing time of containers, with lower max capacity and higher manipulation costs (Table 1, Table 3). The AS-IS and TO-BE model transhipment times have also been compared. Transhipment time is a very important performance parameter for managers, because it allows them to have better insight in current operation capabilities while planning future operations at the terminal. The average transhipment time in the AS-IS is 35 minutes, whereas in the TO-BE model 13 minutes on the average are required to complete all the activities related with the transhipment of one container. The TO-BE model has a significantly lower transhipment time, what is important for terminals as they strive for a higher quality rating of their services in the eyes of customers. One of the measures for quality is the time trucks spend at the terminal. The shorter the time needed for completing the activities related to transhipment of containers, the shorter the time trucks and train compositions will spend at the terminal. For containers arrived on trucks the targeted service time is 30 minutes from their arrival [38]. In addition, by comparison of two models by the resource utilization criterion, the TO-BE model results in yielding much more balanced resource utilization (Figure 4). Balanced utilization contributes to better use of existing resources and a more balanced wear and tear of the resources.

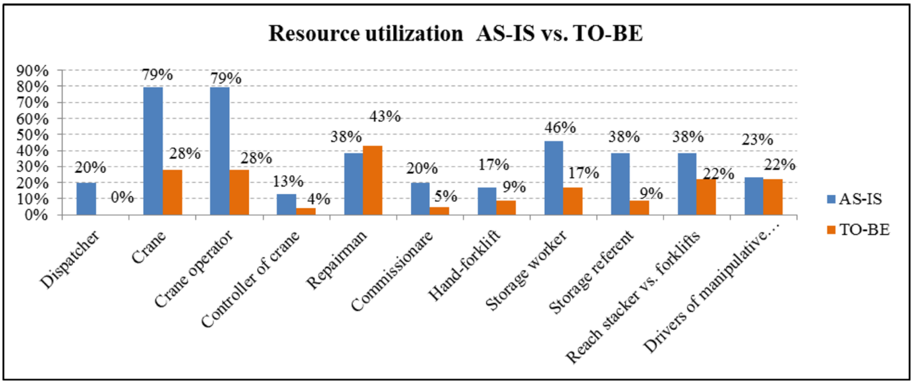

Figure 4 - Comparison of resource utilization of AS-IS and TO-BE models

5. Conclusion

In business logistics micro-and meta-systems, processes can be represented as a series of related logistics activities, which are executed using the resources of the working system in order to create value for the customers. The efficiency of executed processes directly affects the overall efficiency of the entire logistics subject. This paper directly deals with this kind of problem. The main research hypothesis in the presented paper was to examine the possibility of application of BPR and DES on basic logistics processes to the inland container terminal. The aim of the paper was to identify any weaknesses, quantify and improve any key functional parameters of the particular inland terminal. To support the aim and research hypothesis, two models were created that efficiently performed the identification of problem spots (AS-IS) and created a more organized and cost-effective system for the functioning of the existing logistics system (TO-BE). The obtained research results show that the use of BPR and DES of logistics processes in container terminals is fully justified and recommendable. Research limitations are related with the implementation of redesign changes in the TO-BE model, what was out of the scope of this paper. Findings from this paper have two practical implementations. The first one is to use the AS-IS model for an insight in the current situation at the terminal. The second implementation is to use the TO-BE model as a decision support system for evaluating different solutions in the execution of logistics processes and also for making arguments in respect of machinery and equipment investment planning. Basically, the TO-BE model can be used for any kind of "what if" analysis, which is of interest to terminal managers. Further research should be focused in two directions. Firstly, to be in correlation with the level of investments the government is ready to make. The funds the government is able and willing to invest in intermodal terminals are not high compared with the developed countries of Central Europe. So, future research should be focused on determining the optimal ratio between the amount of cost savings and investments implemented in the TO-BE model. In that way, optimal TO-BE scenarios could be created, depending on the amount of investments vs. savings. The second direction for future research focus to take is a more global view of the terminal and its future position in the regional market share in containers turnover. Ports have problems with space and congestion. As an answer, ports are expanding to the hinterland by linking with inland container terminals to which they redirect some of their activities such as customs clearance, container storage, cargo consolidation/ deconsolidation, etc. In future, the observed terminal will need to fight for container traffic with other inland container terminals in the region and a new TO-BE simulation scenario should be created in which the terminal takes over some port activities and acts as a distant dry port for main ports of the region.

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