Bojan Beškovnik, Ph. D.
Intereuropa, Globalni logistični servis, d.d.,
Vojkovo nabrežje 32, SI-6000 Koper
Slovenija

Review article
UDK: 621.869.8:656.615
65.012.4
Received: 2nd September 2008
Accepted: 7th October 2008

MEASURING AND INCREASING THE PRODUCTIVITY MODEL ON MARITIME CONTAINER TERMINALS

The following article presents the possibilities of optimization on a maritime container terminal, in order to increase the system productivity and optimize the terminal capacity. Specifically this paper provides a perspective on maritime container terminal productivity - how it is measured, the methodology of the measurement used and the factors that affect the elements of productivity. Moreover, some actions of the productivity improvement, which do not request special investments and are under the control of planning service and its productivity specialists, are described.

The management of a maritime container terminal is a complex process that involves a vast number of economic and operational decisions. The management must develop details and strategies on the measures of productivity and establish an adequate decision support model to increase it. The proposed model facilitates the adoption of new technologies and work rules on a long-term period but, at the same time, enables the implementation of middle and short-term strategies that improve productivity in a manner consistent with the fundamental interests of the entire system. In this context, the paper proposes a special working place for the productivity quality manager, which should develop different quickly adoptable strategies and solutions. With its important planning role, this person can support the terminal managers in the evaluation of the best development and optimization decisions.

Key words: *maritime container terminal, productivity, limiting factors, optimization model*

1. INTRODUCTION

On a macro level, a maritime container terminal can be defined as a facility, which enables the transhipment of intermodal transport units or containers between various modes of transport. The main focus is always on the seaside, where sea transport represents the primary service of the system. In other words, a maritime container terminal is a place where containers leave and enter by different means of transport, such as vessels, trains and trucks; the terminal is hence the basic intermodal node in the logistics network and for this reason, all operations involved in the flow of containers have to be optimized.

The basic role of a maritime container terminal is the transfer and storage of full and empty containers. As far as resource allocation is concerned, the terminal can be interpreted as a system allowing container flows to be directed from their sources to final destinations. From the economic point of view, the system has the objective of maximizing the profit. In this respect, efficient container handling at terminals is important in reducing transportation costs and keeping shipping schedules. With the productivity optimization, a maximum global productivity and an optimum operation of global supply chains can be achieved.

For maritime container terminals, it is characteristically that a vast number of different players have their own self-interests. On the one hand, terminal operators would like to reduce the costs per unit handled in the port and to obtain higher efficiency, and, on the other hand, a carrier strives to minimize ship in-port time. Other subjects have their interests, which have to be considered as well, because their decisions have direct impacts on the system productivity.

The performance of different maritime container terminals is determined by different elements, which are changing continuously. A range of internal and external factors influences the productivity of a maritime container terminal as a system. In addition, very often the main problem of increasing productivity is the lack of balance between the capacity of different elements and the disco-ordination in consecutive operations. An increase of efficiency of a container terminal is mandatory to ensure sufficiently short lay time for container vessels in the port and to achieve further reduction of terminal operating costs. The management of a maritime container terminal must develop mechanisms to measure productivity and to increase it without high financial investments.

2. CONTAINER TERMINAL PRODUCTIVITY

Due to the continuously increasing container trade and larger container vessels, many terminals are presently operating at or close to their capacity. In

addition, considering the trend towards larger container vessels, the pressure on the seaside operations is higher than ever before. This is the reason why the need for efficient terminal operations is more important than ever.

An efficient system is the one that performs a quick transhipment of containers to and from ships and the dispatch of containers by train or truck from the system. The efficiency of a maritime container terminal mostly depends on the smooth and efficient handling of containers. Handling systems and the automation level are the basic elements of productivity. There are four basic types of container handling systems engaged in loading and discharging operations at a maritime container terminal: berth cranes, chassis, straddle-carrier and transtainer systems. The last one is the most popular in major intermodal terminals as its characteristic renders possible higher container storage capacity in the yard. Of course, special attention must be given also to the labour force, as terminals still significantly depend on it.

2.1. The main impacts on productivity

At present, there are a variety of types of maritime container terminals around the world differing in shape, layout, handling technology, automation level, process organization, etc. Maritime container terminals also differ between regions, countries and very often within certain countries. A typical maritime container terminal consists of three subsystems: a berth, container yard and delivery zone. Thus, they consist of several components, which have different impacts on the productivity of the entire system:

- A vast number of different berths with specialized berth cranes of different types,
- Loading and driving lanes for trucks, with different length and position,
- Transhipment zones with several loading tracks under gantry cranes,
- Loading/discharging tracks, capable of accommodating an entire train, which differ in length and position on the terminal,
- Storage areas, with different shapes, technology and static capacity,
- Check in/out gates or entry points, etc.

The layout of a certain terminal has a very strong impact on the infrastructure and suprastructure of different subsystems and on the entire system because it determines the position of subsystems, connections between them, technology to be used, etc. The layout of a terminal depends on different elements:

- Local availability of space, on the inland side as well as on the sea side,
- Rail and road regional and local network,
- Quantities of maritime and continental cargo flows,
- Technical concept of using the suprastructure of the terminal,
- Number of inland and maritime container terminals in the surroundings, etc.

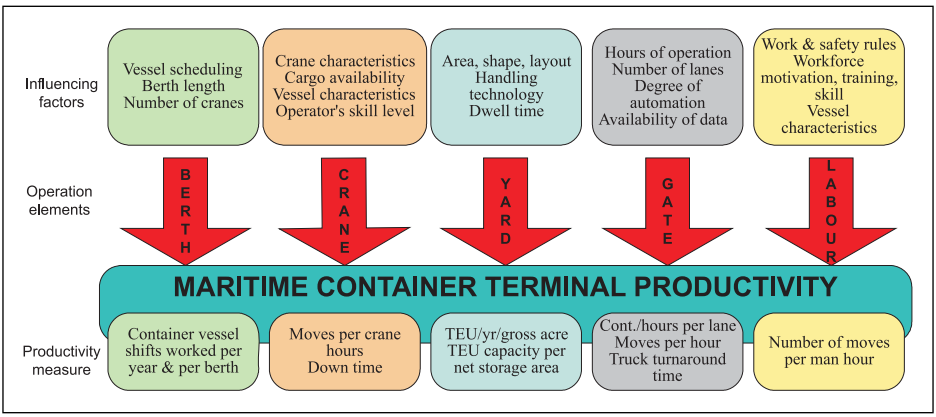

Figure 1: Productivity elements at maritime container terminals

Source: Prepared by the author

2.2. Limiting factors

Factors influencing the system productivity can be divided into two main groups, internal and external factors. Internal factors are most often under the control of the operator and the management of the terminal. This group includes terminal configuration and layout, capital resources invested, development strategies and labour productivity. The management of the terminal has an influence on these limiting factors but very often, certain decisions are not under their control (expanding the layout over actual borders).

In the second group are external factors, which are beyond the control of operators and the terminal management. This group contains trade volumes, shipping lines calling the port and the ratio of import or export containers or containers in transhipment. Some other external factors must be considered too (the size and type of ships accommodated by a terminal, landside capacities of rail and highway systems) because all these factors directly influence on the terminal productivity.

The properties of a container can be analysed separately, as this is a cargo unit and it is difficult to classify it under an internal or external limiting factor. The size, weight, origin and destination port, cargo characteristics are all very important factors, because they have impacts on the vessel stowage as well as on determining a location in the container yard. In addition, internal manipulations in the system, safety controls, time and type of dispatch are also directly connected and have important impacts on the efficiency and productivity of a single subsystem and of the system as a whole.

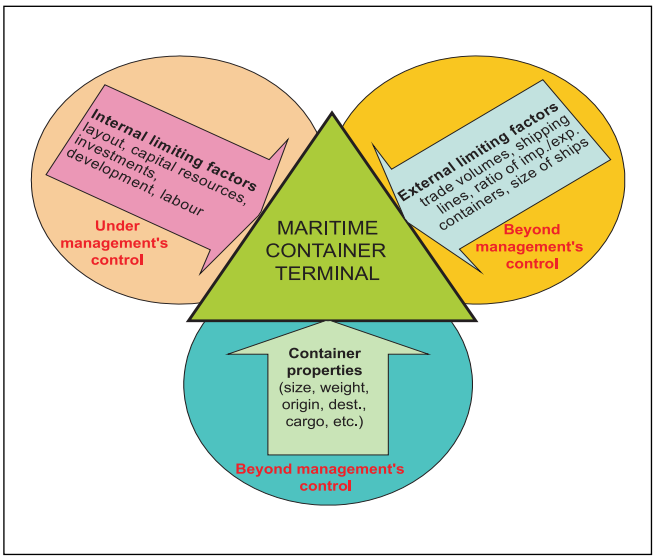

Figure 2: Limiting factors at maritime container terminals

Source: Prepared by the author

2.3. External users' expectations

Direct users of the system services also have impacts on the main activities of maritime container terminals. These users are different external subjects, with different expectations. In addition, their business depends on the terminal efficiency and that is why the port management must consider their priorities and needs. Surely, the most important external subjects are cargo owners, but ocean carriers are the main business partners of a maritime container terminal system.

The main impact arises from the opposite interests between the ocean carrier and the operators. The ocean carriers insist on shorter dwell time for their vessels, while, on the other hand, the terminal operator aims to achieve a higher throughput with a less number of berths and manipulation machinery. The decisions taken by the carriers have direct impacts on the system productivity and efficiency, because they can change the vessels and the timetable on service, or even leave the port with just a few weeks pre-advice. This is the power of ocean carriers, and that is why they are continuously pressing terminal operators. They are measuring and valuing the competitiveness of maritime container terminals through different measurements, but, most frequently, they compare the berth productivity, the dwell time on berths and the waiting time for a free berth.

Besides ocean carriers, other business subjects are important too. These are forwarders, shipping agents, global logistics companies, trucking companies, etc. They all have the same expectations from the container terminal and their decisions influence the system productivity as well. Of course, local external subjects have essentially less influence on the operator's business decisions but their information is also very important to find optimum operational and development strategies.

3. MEASURING AND INCREASING PRODUCTIVITY

3.1. Measuring productivity

A constant productivity measuring is of vital importance for the system. In addition, simultaneous measuring can serve to find opportunities in development and optimization. Container handling productivity is directly related to the transfer functions of a container terminal, including the number and movement rate of berth cranes, the use of yard equipment, berth and yard occupancy, number of vehicles at the entrance into the terminal and the productivity of workers employed at the waterside, landside and gate operations. The basic working parameters of the terminal change continuously, and it is, therefore, very important to check and adjust them frequently.

The process of productivity measuring is a complex process because different elements are in interacting relations and they have important impacts on each other. For example, the terminal transhipment capacity is a decisive characteristic and it must be analysed in detail through various limiting components, such as the infrastructure, terminal work process and organization, type of intermodal services and customer's characteristics. All these elements derive from internal and external impacts, and if only one element changes, all other elements perceive it directly.

For the origin-destination type maritime terminal, landside operations and facilities are one of the most important factors of productivity. In particular, the capacity and efficiency of terminal gates, railway connections and services and road networks determine the performance level of the system. Conversely, for transhipment ports, which are in most cases acting as hub systems, the waterside operation of berths is one of the most important determinants of productivity. Moreover, it is important to distinguish between net and gross productivity, as net and gross productivity vary from system to system. If the systems achieve the same gross productivity, there is no guarantee that the net productivity is at the same level, because the net time is the elapsed time minus the time unable to perform operations (like shift breaks, weather conditions, etc.), which differ from terminal to terminal.

3.2. Increasing productivity

In a modern maritime container terminal, the most important problem is the coordination between the loading and unloading operations of the vessels and the storage of the containers into the yard. The transfer from and to the gates for land transportation is also important for systems which represent the entrance point for the hinterland. The stops at terminals need to be short, in order not to prolong the total transport/transit times. This requires the employment of fast and sophisticated technologies, with high capacity and a low cost per move as well as of skilled workers.

All these operations are usually subjects of optimizing analysis in the system. Some solutions of optimization in a maritime container terminal can be done without high port investments. These possibilities must be considered firstly. On the other side, the use of new technologies requests more direct financial investments but the impact on productivity is definitely greater. The management of a maritime container terminal must decide which solution is necessary to be performed first, in order to achieve the maximum handling and transport productivity, and, at the same time, to maximize the profit. Certainly, the management of a maritime container terminal prefers solutions of optimization, which can be achieved without high port investments and with results in a very short period. Some of them are easily realizable, such as reducing the container dwell time, reducing the distance between the berth and rail tracks and extended hours of operations at the terminal gate.

4. MODEL TO IMPROVE PRODUCTIVITY

In order to measure productivity and to define the most suitable strategies to increase the performance per subsystem, it is necessary that the management of the terminal sets up its own model how to measure and improve productivity. The easiest way is to have a certain number of specialists in the planning service, which are especially involved in daily measuring productivity processes and, for this reasons, they have real time information for the best solutions. The modelling productivity service should include three basic stages: management level, strategic level and operational level.

The management level consists of long-term decisions regarding the terminal layout, infrastructure and suprastructure of the subsystems, agreements with ocean carriers, etc. The management of a maritime container terminal manages this level and usually the planning service does not have the power to influence such decisions. Of course, their proposals can be evaluated, but without any guarantee to be applied as such.

The knowledge and decisions of the planning service is the basis for the second and third level. Specialists dealing with everyday productivity situations must set up the strategy of improving the performance of the system bottleneck. The second level is, therefore, the strategic level and involves the mid- and short-term actions regarding the use of available ground space, increase or decrease in the number of working hours and shifts, the opening of additional gates, etc. Meanwhile, the third level is the so-called operational level and consists of daily and real-time decisions, which have direct impacts on productivity and efficiency.

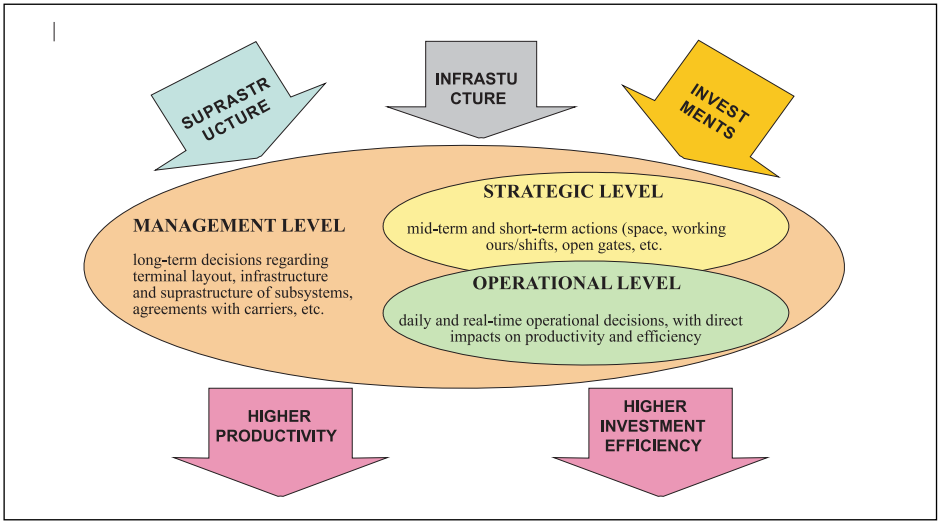

Figure 3: Productivity measuring and improvement model

Source: Prepared by the author

In order to manage and control productivity of the entire system, it is necessary to appoint a productivity quality manager. This function should coordinate the activities of all productivity specialists in the planning service and regularly communicate with the management. The productivity quality manager must get information from the so-called first management level, to be able to coordinate strategies in the second and third level efficiently.

4.1. Setting different strategies

Searching adequate middle- and short-term strategies is a complex process, especially in the systems, where an organic expansion is present because the situations are changing very fast and it is difficult to measure the productivity

efficiently. Anyhow, a productivity quality manager must establish tools and processes to do it in the best possible way. With a detailed analysis of the actual situation, it is possible to take different quickly adoptable solutions.

Some very common roles are valid for all maritime container terminals. The efficient use of an available space in the yard relates to the number of full and empty containers stored in a given area of the system. Improving the utilization of a ground space typically reduces the operational accessibility to containers; that is, the ground space utilization and the container accessibility are inversely related. The challenge is, therefore, to define the container accessibility in relation to the ground space utilization based on terminal operational targets and unique physical characteristics.

The major factors influencing both the berth occupancy rates and the dwell-time are the same in all systems. The number and size of the arriving container ships, configurations of the stowage plans, number of cranes, length of the berth and navigation constraints are some of the factors, which limit the entire system. The berth occupancy is usually based on the length of a container ship and the time she spends at the berth. However, high berth occupancy may result in a congestion where container ships are queuing to be served, which would lead to high turn-around times equating to bad service for container ships. In most cases, the productivity quality manager cannot influence these factors, and, therefore, must focus his activity mostly on operational elements.

In the operations theory, the crane productivity on berths depends on the number of lifts per time unit per vessel in the system. The mentioned handling rate is an indication of the crane operator's efficiency and directly affects the productivity of the entire system. This is also the most important performance measure to a shipping line in rating a terminal; therefore, this is an issue for the productivity quality manager to work on. Another closely related measure that shipping lines use is the vessel turnaround time (the average time the terminal takes to unload and load a docked vessel). As this is an operational activity, which depends on actual decisions, the planning service and productivity quality manager should focus on it very carefully. Some easy and prompt actions can be taken in this respect. For example, reducing the distance between berth, yard and loading/unloading rail tracks could decrease the vessel's dwell-time and at the same time increase the efficiency of the terminal space use. Putting the loading/unloading tracks directly behind the container yard or partly even under the berth cranes could reduce the high number of moves per container between unloading from a ship and loading onto the train or trucks. Certainly, such decisions require financial investments but are very interesting where some expansion is planned.

Another important measure, which does not require any investments, is the container dwell time (the average time a container remains stacked on the terminal and during which it waits for some activity to occur). The productivity

quality manager can shorten the amount of free time allowed (the term "free time" refers to the number of days a container can remain in the system once it has been unloaded from a ship before charging a storage fee), in order to free up the container storage space and to speed up the operational processes. Moreover, the productivity quality manager can change the method of calculating free time; especially where the free time for all containers counts when the last one is unloaded from a ship even if the first container was unloaded a few days before that.

The most important facility on the inland side of a maritime container terminal is the gate entrance for the trucks and rail lines. The gate must be designed in such a manner as to provide the required number of lanes needed at peak, or close to peak hours of the traffic volume for both directions (import and export), and at the same time to provide economically an optimal gate throughput. The productivity quality manager must find the exact balance, which is possible with the use of new identification and information technologies.

4.2. Importance of labour productivity

Labour forces, or workers, are of great importance especially in the systems where the degree of automation is low. This is valid for more than ninety percent of all maritime container terminals in the world. Port systems in the USA face big problems of labour forces every day as trade unions are very strong, even on that level to obstruct the use of automation technology.

For the productivity measure, the gross labour productivity is more important than the net one. The net labour productivity contains only man-working hours, meanwhile gross labour productivity is a measure of a suprastructure productivity, which is defined by the number of crane moves per person-hour, number of trucks per gate entrance, number of containers per rail line, etc. It has been acknowledged that, where terminals are operated under difficult labour conditions and more restrictive regulatory, this has a direct impact on a lower productivity or throughput per terminal space. Work and safety rules, workforce motivation, training and handling equipment characteristics directly influence gross labour productivity; therefore, the productivity quality manager should be focused on all these elements to find a balance between the labour satisfaction and the productivity.

Certainly, it is impossible to completely satisfy the needs of labour forces and specially, because the question of money is not always present. However, as the pressure of increasing traffic flows on maritime container terminals becomes stronger and stronger, the terminals are forced to increase the number of hours and shifts that terminal gates are open. Terminal gate operations can be expanded during the traditional workweek and for the weekends as well. Gate hours are often a limiting factor because even though vessels can be unloaded 24 hour a day or 7 days a week, the flow of containers through the ter-

minal stops in the container yard if the gates are not available to release boxes to the carriers or consignees. The same situation is valid for rail lines, as in most terminals the railway system does not work during weekends, especially on Sundays.

4.3. Importance of investments on productivity

Substantial investments and improvements in both the physical capacity and the operational efficiency are necessary to accommodate ever-greater volumes of containerized cargo. It has to be considered also that terminals often have extremely long economic lives and only extremely limited alternative uses. Within these characteristics, the most important economic aim or benefit of investment in the ports is to reduce the ship's turn-around time. In such investments, the economic principles embrace the technical ones, in the sense that the minimum amount of productive resources should be used to fulfil the purpose of the investment. For these reasons, the productivity quality managers are under pressure to choose solutions where, with limited resources, they must achieve maximum results. A special field is the economic improvement of the terminal operations, where some indicators must be used constantly in order to evaluate the improvement. One of them is the investment efficiency index, which is defined as the rate between the resources invested in the system and the productivity achieved with them. This index can be represented as the unitary cost of the transport cycle (USD/cycle).

The total inactivity cost of equipments (i.e. the cost of equipment waiting) is another indicator that also enables an optimum in the container handling equipment. This cost can be obtained by adding the inactivity costs of the handling equipment on the yard and berth and includes the fixed cost of purchasing the equipment plus the operating costs (i.e. maintenance, fuel and labour), which cannot be rejected during inactivity periods.

The basic criteria for an adequate investment are as follows:

- to choose between a range of projects proposed by the planning and development office,
- to decide the most appropriate time of the projects proposed,
- to decide whether to renew the old equipment, to continue to use it, or expand the facilities with a completely new equipment/technology.

The container terminal users feel the immediate benefits of such an investment immediately; meanwhile the positive returns for the investor are subject to a time lag, emerging when the revenues start to exceed the costs. A time lag period must be precisely defined in order to get real plans of the system financial revenue. Of course, all investment solutions must be a part of the investment and development strategy and terminal operators must have a clear idea how to exploit new technologies and new solutions, enabling the entire system to achieve optimal commercial results.

5. CONCLUSIONS

The main role of a maritime container terminal is the transfer and storage of full and empty intermodal units or containers. The performance of maritime container terminals is of crucial importance for ocean carriers and cargo owners. An increase in the system productivity is mandatory to ensure a sufficiently short lay time for container vessels in the port and to achieve further reduction of the terminal operating costs.

For this reason, the management of a maritime container terminal must develop mechanisms to measure productivity and to increase it when necessary. In this paper a model is developed and proposed, which involves a special working place for a productivity quality manager. This function has a special role in the planning model that consists of three proposed levels. Each level deals with different time oriented strategies. The lower level is the operational level, which includes real time actions and measures, in order to obtain a higher operational productivity. With a correct application of the proposed model, it is possible to control simultaneously the productivity of the infrastructure and suprastructure of the terminal and find where and how to increase the productivity of the entire system and to secure the desired optimization of the system.

The productivity quality manager must find adequate middle- and short-term strategies. This person must establish tools and processes to do it in the best possible way. With a detailed analysis of the actual situation, it is possible to take different quickly adoptable solutions. Some of these solutions are proposed in the paper, including the labour force productivity.

A special field of enhancing productivity is related to investments. Maritime container terminals depend on substantial investments and improvements, in both physical capacity and operational efficiencies. As the infrastructure and suprastructure of a maritime container terminal are very expensive, the productivity quality managers are under pressure to choose solutions where, with limited resources, they must achieve maximum results.

LITERATURE

[1] Bielli, H., Boulmakoul, A., Rida, M. “Objected oriented model for container terminal distributed simulation” European Journal of Operational Research, 2005, pp. 1-21
[2] Choi, Y. S.: Analysis of Combined Productivity of Equipments in Container Terminal, Korea Maritime Institute, Maritime Review, Vol. 3, 2003, p. 57-80
[3] Chu, C., Huang, W.: Determining Container Terminal Capacity on the Basis of an Adopted Yard Handling System, Transport Reviews, Vol. 25, No. 2, 2005, p. 181-199
[4] Dally, H. K., Maquire, F. J.: Container Handling and Terminal Capacity - Container Handling and Transport, C S Publications Ltd, 1983
[5] Dowd, T. J., Leschine, T. M.: Container Terminal Productivity: A Perspective, Washington Sea Grant, University of Washington, Seattle, 1989

[6] Franke, P., Alicke, K., Arnold, D.: Modeling and optimization of the intermodal terminal, IHL, Universitat Karlsruhe, Karlsruhe, 2001
[7] Le-Griffin, H., Murphy, M.: Conteiner Terminal Productivity, Department of Civil Engineering, University of Southern California, Los Angeles, 2006
[8] Rizzoli, A., Gambardella, M.: The Role of Simulation and Optimisation in Intermodal Container Terminals, Istituto dalle Molle di Studi sull'Inteligenza Artificale, Lugano, 2002

Sažetak

MODEL MJERENJA I POVEĆANJA PRODUKTIVNOSTI U LUČKIM KONTEJNERSKIM TERMINALIMA

Ovaj članak predstavlja mogućnosti optimizacije na lučkom kontejnerskom terminalu u cilju postizanja povećanja produktivnosti sustava i optimiziranja kapaciteta terminala. Članak posebno prikazuje pogled na produktivnost lučkog kontejnerskog terminala; kako se produktivnost mjeri, metodologiju mjerenja i faktore utjecaja na elemente produktivnosti. Nadalje, opisane su akcije za poboljšanje produktivnosti, koje ne zahtijevaju posebna ulaganja i pod kontrolom su planske službe te specijalista za produktivnost na terminalu.

Upravljanje lučkog kontejnerskog terminala je kompleksan proces, koji uključuje velik broj različitih ekonomskih i operativnih odluka. Menedžment mora razviti elemente i strategije mjerivosti produktivnosti i uspostaviti adekvatan model odluka za njezino povećanje. Predloženi model olakšava upotrebu novih tehnologija i radnih pravila na duže vrijeme, ali istodobno omogućava implementaciju srednjoročnih i kratkoročnih strategija, koje poboljšavaju produktivnost na način koji je sukladan s ključnim interesima cijelog sustava. U ovom kontekstu, članak predlaže specijalno radno mjesto za menedžera kvalitete produktivnosti, čija je svrha razvoj različito brzo upotrebljivih strategija i rješenja. Sa svojom značajnom ulogom u planiranju, takva osoba može dati potporu menedžmentu terminala u evaluaciji najboljih razvojnih i optimizacijskih odluka.

Ključne riječi: *lučki kontejnerski terminali, produktivnost, limitirajući faktori, model optimizacije*

Dr. sc. Bojan Beškovnik
Intereuropa, Globalni logistični servis, d.d.
Vojkovo nabrežje 32
SI-6000 Koper
Slovenija