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UTJECAJ TOKA DOLAZAKA BRODOVA NA OPTEREĆENJE SLAGALIŠTA KONTEJNERSKOG TERMINALA

INFLUENCE OF THE SHIP ARRIVAL PROCESS ON THE LOAD OF CONTAINER YARDS AT THE CONTAINER TERMINAL

SAŽETAK

Kontejnerske luke omogućavaju kontejnerskim brodovima obavljanje ukrcaja i iskrcaja kontejnera. Izgradnja lučkih kapaciteta je skupa, a tokom obavljanja djelatnosti prekrcaja brodova dešavaju se izvjesni zastoji. Ona se manifestiraju u određenom vremenu čekanja lučkih kapaciteta uzrokovanih ili neravnomjernim dolascima brodova ili čekanjem na započinjanje ukrcajno-iskrcajnih manipulacija. Međutim, čekanje broda na početak rada je također skupo, stoga je zajednički interes luke i brodara da se minimizira broj brodova i duljina vremena čekanja brodova. U ovome se radu istražuje utjecaj toka dolazaka brodova na opterećenje slagališta kontejnerskog terminala u Rijeci s obzirom da su ti kapaciteti ograničeni prostorom, ali i kapacitetima lučke pretovarne mehanizacije. Moguća su tri toka dolazaka u kojima kontejnerski brodovi pristižu na pristan i to: skladišno kontrolirani, ravnomjerni i nekontrolirani dolasci. Prikazani su realni podaci dobiveni evidencijom kontejnerskog prometa i stanjem opterećenja slagališta. Predlaže se način postavke modela za praćenje opterećenja kapaciteta terminala.

Ključne riječi: *tok dolazaka brodova, kontejnerski terminal, opterećenje slagališta*

SUMMARY

Container ports allow container ships to carry out the loading and unloading of containers. The construction of port facilities is expensive, and during the performance of the transshipment vessels occur with certain delays. This is manifested in a certain time mode of the port facilities caused or with irregular arrivals of the ships or with waiting for the cargo loading/unloading procedure to start. However, waiting for the ship to start the transshipment processes is also expensive hence the common interest of the port and the shipping companies to minimize the number and length of time waiting for ships. This paper explores the impact of the ship arrivals to the loading of container terminal yards in Rijeka, with respect that these capacities have a limited space, as well as limited port facilities and reloading equipment. There are three possible arrival processes in which container ships can arrive at the berth: warehouse controlled, uniform and uncontrolled arrivals. The paper deals with the real data obtained from the records of the container transport and of the loading conditions of container yards in the port of Rijeka. Tenets models are proposed for monitoring the load capacity of the terminal.

Key words: *arrival processes, container terminal, load of yards*

1. UVOD

Analiza utjecaja toka dolazaka brodova na popunjenost slagališta može koristiti u procjeni i optimizaciji različitih scenarija koji se javljaju na pristanu i slagalištu. Uslijed različitih tokova dolazaka brodova na pristan, na slagalištu terminala dešavaju se konstantne oscilacije u ukupnom broju kontejnera, koje su također u direktnoj zavisnosti od intenziteta otpreme kontejnera s kopnenim transportnim sredstvima. Problem je odrediti onaj kapacitet slagališta, koji će zadovoljiti potrebe tokova dolazaka kontejnerskih brodova uz predviđeni konstantan broj kontejnera u otpremi.

Učinkovitost ukrcajno-iskrcajnog procesa na kontejnerskom terminalu u direktnoj je zavisnosti od toka dolazaka kontejnerskih brodova, gdje se uočavaju skladišno kontrolirani, ravnomjerni i nekontrolirani dolasci, te njihov različiti utjecaj na opterećenje slagališta terminala. Potpuno nekontrolirani tok dolazaka predstavlja uvjete koji su najgori za sve njezine sudionike. Uzrokuju brojna brodska kašnjenja i iziskuju veće skladišne kapacitete. U odnosu na njih, skladišno kontrolirani dolasci predstavljaju najbolje uvjete. Oni uvažavaju skupa brodska kašnjenja, te optimalan kapacitet slagališta. Postavljanjem prioriteta među brodovima koji se nalaze u dolasku prema terminalu s obzirom na njihovu veličinu ili dnevne troškove, unaprijedit će se učinkovitost svih triju tokova dolazaka, te smanjiti ukupni gubici prouzročeni vremenom čekanja.

U ovom se radu istražuje važnost toka dolazaka kontejnerskih brodova na opterećenje slagališta kontejnerskog terminala. U tu svrhu obavljeno je praćenje dolazaka brodova da bi se ocijenio njihov utjecaj na učinkovitost ukrcajno-iskrcajnog procesa. Korišteni su podaci o vrstama, tipovima i kapacitetima brodova koji su pristizali na terminal te način dolazaka – s ili bez prioriteta, dobiveni od koncesionara kontejnerskog terminala u Rijeci. Pri istraživanju slagališta kontejnerskog terminala analizirane su mogućnosti prihvata i otpreme kontejnera.

2. TOKOVI DOLAZAKA BRODOVA NA KONTEJNERSKI TERMINAL

Tokovi dolazaka brodova na kontejnerski terminal mogu se podijeliti u tri osnovne grupe

1. INTRODUCTION

The analysis of the impact of the ships arrivals on the availability of container yards can be used in the evaluation and optimization of different scenarios that may appear at the berth and the yard. Due to the different arrival processes of ships at a berth, constant fluctuations in the total number of containers, which are also directly dependent on the intensity of transporting containers with land transport means, can appear at the terminal yard. The problem is to determine the capacity of yards which will meet the needs of the arrival processes of container ships, provided a constant number of containers in the shipment.

The efficiency of the loading/unloading process at a container terminal depends directly on the process of the ships arrivals: warehouse controlled, uniform and uncontrolled arrivals and their different effects on the load yards of a terminal. Totally uncontrolled arrival processes represent conditions that are the worst for all its participants. Numerous delays caused by shipping and require higher storage capacities. Compared to them, warehouse controlled arrivals represent the best conditions. They appreciate the expensive shipping delays, and the optimal capacity of a yard. Setting priorities among the ships arriving to the terminal with respect to their size or cost of daily expenses, will improve the productivity and efficiency of all three arrival processes and reduce the total losses caused by the waiting time.

This paper explores the importance of the ships arrival processes to load yards of a container terminal. For this purpose the monitoring of the ship arrivals in order to assess their impact on the productivity and efficiency of the loading/unloading process. The data on the types and capacities of the ships arriving at the terminal and on the type of arrival - with or without priorities, are derived from the concessioner of the container terminal in Rijeka. By examining the container terminal yards, the capabilities of handling containers are analyzed.

2. SHIP ARRIVAL PROCESSES

The ship arrival processes can be divided into three main groups of arrivals: controlled, uniform and uncontrolled arrivals.

dolazaka: kontrolirani, ravnomjerni i nekontrolirani dolasci.

Skladišno kontrolirani dolasci događaju se u situacijama kada dolasci mogu biti planirani od strane kontejnerskog terminala. Namjera terminala je održavanje određenog broja kontejnera na slagalištu u okviru kojeg se ostvaruju optimalni rezultati. Pod tim se podrazumijeva funkcioniranje terminala s minimalnim vremenom čekanja na utovarno-istovarne manipulacije i ostvarivanje pozitivnih ekonomskih učinaka.

Za ovaj model toka dolazaka karakteristično je da se dolazak sljedećeg kontejnerskog broda podudara s vremenom kada je osigurano dovoljno mjesta na slagalištu za prihvat novog broja kontejnera. Pritom treba uzeti u obzir da ukupan broj kontejnera na slagalištu ne prijeđe maksimalni kapacitet ili da padne ispod razine koja je neophodna za rentabilno poslovanje. Zbog toga je potrebno odrediti optimalan broj kontejnera na slagalištu koji će zadovoljiti potrebe svih sudionika ovoga sustava. U tom procesu parametri koji utječu na navedene kalkulacije jesu kapacitet kontejnerskih brodova, vrijeme potrebno za utovarno-istovarne manipulacije, kapacitet slagališta i kapacitet otpreme.

Međutim, ne smije se zaboraviti i treba uzeti u obzir i kašnjenja koja su prisutna u planiranim vremenima dolazaka brodova. Ona su posljedica nepredviđenih okolnosti kao što su vremenske neprilike, štrajkovi na terminalima, različiti kvarovi, i sl. Osim toga i razne promjene na svjetskom tržištu mogu povećati ili smanjiti ukupan broj kontejnera u dolasku ili odlasku. Stoga, prilikom planiranja optimalnog kapaciteta slagališta treba predvidjeti i rezervne kapacitete koji će biti raspoloživi ukoliko dođe do nepredviđenih promjena u dolascima brodova i količinama tereta, a koji bi mogli imati za posljedicu veći priliv kontejnera na slagalište od planiranog.

Ravnomjerni dolasci pojavljuju se u situacijama kada su dolasci brodova u ravnomjernim intervalima. Takva ravnomjernost može biti rezultat godišnjih planova, odnosno ugovora. To se postiže na način da se unaprijed odrede vremenski intervali u tjednu u kojima se mogu očekivati brodski dolasci određenih brodara.

Nekontrolirani dolasci čine varijantu najnepovoljnijih dolazaka. U tim slučajevima pojav-

Warehouse controlled arrivals occur in situations where arrivals can be scheduled by the container terminal. The intention of the terminal is to maintain a number of containers on the yard within which to achieve optimal results. This implies the functioning of the terminal with a minimal waiting time for the loading/unloading procedures thus achieving positive economic effects.

For this model of the arrival process it is characterized that the arrival of the next container ship coincides with the time when you provide enough space on the yard to accept a new number of containers. It should be noted that the total number of containers on the yard does not exceed the maximum capacity or fall below the level necessary for profitable operations. It is therefore necessary to determine the optimal number of containers on the yard that will meet the needs of all participants in this system. In this process, the parameters that influence these calculations are the capacity of container ships, the time required for the loading/unloading procedures, the capacity of a yard and the delivery capacity.

However, do not forget to take into account the delays that are present during the scheduled times of arrival of the ship. They are the result of unforeseen circumstances such as weather conditions, strikes at the terminals, different faults, etc. In addition, various changes on the global market can increase or decrease the total number of containers arriving or departing. Therefore, when planning the optimal capacity of a yard, the available spare capacity should be provided, if unexpected changes in the ship arrivals and cargo volumes could occur, resulting in a greater inflow of containers on the yard than planned.

Uniform arrivals occur in situations when the ship arrivals are at uniform intervals. Such uniformity may be the result of annual plans and contracts. This is achieved in the manner that pre-determined time intervals are given in the week in which they can expect to ship arrivals of certain shippers.

Uncontrolled arrivals are the worst variant of arrivals. In these cases the largest shipping delays appear and the costs are the highest. These are the worst conditions for all participants in this system. A company cannot plan, during the unloading and loading procedure,

ljuju se najveća brodska kašnjenja i najveći troškovi. To su najnepovoljniji uvjeti za sve sudionike ovoga sustava. Brodari ne mogu planirati vrijeme trajanja istovara, odnosno utovara, kao i vrijeme koje će proteći prije nego započnu s manipulacijama, a s druge strane kontejnerski terminali ne mogu planirati rad na pristanima i veličine skladišnih kapaciteta.

Kod spomenutih vrsta tokova dolazaka brodova na pristan, broj kontejnera i vrijeme u prekrcaju se ne mijenjaju već su samo različito raspodijeljena vremena dolazaka brodova.

3. ANALIZA OPTEREĆENJA KAPACITETA KONTEJNERSKOG TERMINALA

Shema 1. prikazuje osnovni koncept procesa rukovanja kontejnerima na terminalu.

Na kontejnerskom terminalu u Rijeci praćen je broj dolazaka i veličine kontejnerskih brodova u razdoblju od tri godine (razdoblje od 01. 01. 2008. do 25. 11. 2010. godine), kao i broj kontejnera u manipulacijama. U tablici 1. je prikazano prosječno vrijeme potrebno za manipulacije na pristanu prema stvarnom broju kontejnera na brodu za ukrcaj/iskrcaj, dobiveno na temelju svih brodova pristiglih na terminal u razdoblju od tri godine.

Navedeni podaci u tablici 1. dobiveni su na temelju analize broja kontejnerskih brodova

the time that will elapse before you start to manipulate another hand and container terminals cannot plan the work at the berth as well as the storage capacity.

For the above-mentioned different ship arrivals at a berth, the number of containers and the time of transshipment do not change, but the time of the ship arrivals is only differently distributed.

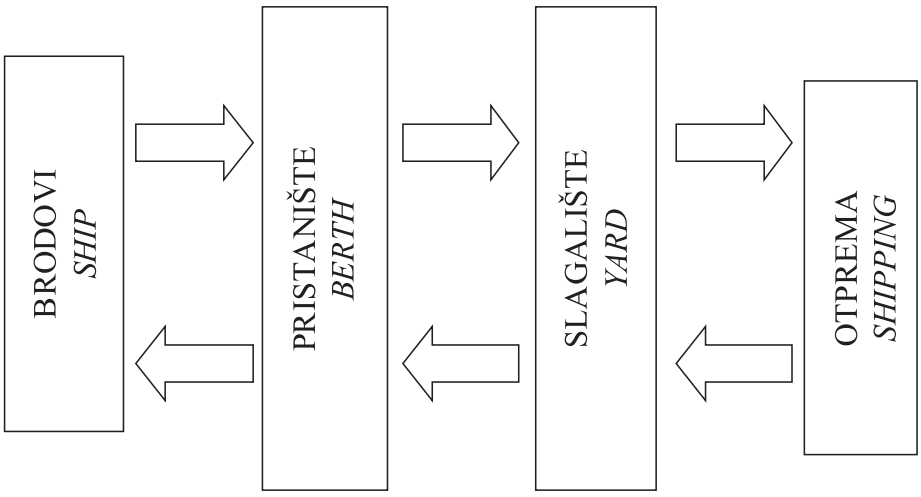
3. ANALYSIS OF THE LOAD CAPACITY OF A CONTAINER TERMINAL

Scheme 1 shows the basic concept of the process of handling containers at the terminal.

At the container terminal in Rijeka, the number of arrivals and the size of container ships for a three year period (from 1st January 2008 to 25th November 2010) and the number of containers handled can be seen. Table 1 shows the average time needed for handling at the berth to the real number of containers loaded or unloaded derived on the basis of all the ships arrived at the terminal for a period of three years.

The data in Table 1 are obtained from the analysis of the number of container ships berthing in the three-year period with a certain amount of containers for loading/unloading operations. Therefore, these data can be used for

Shema 1. Slijed kretanja kontejnera na kontejnerskom terminalu
Scheme 1 *The sequence of movements of containers at a container terminal*



Izvor: autori
Source: *Authors*

Tablica 1. Prosječno vrijeme ukrcajno/iskrcajnih operacija na kontejnerskom terminalu riječke luke u razdoblju od 2008. do 2010. godine prema broju kontejnera

Table 1 *Average time for loading/unloading operations at the container terminal in Rijeka from 2008 till 2010 regarding the number of containers*

Brod *Ship* (TEU)	**Br. dizalica u radu – 1** *No. of cranes - 1*			**Br. dizalica u radu – 2** *No. of cranes - 2*		
	Trajanje operacija(sat:min) *Time (h:min)*	**Br. kont.** *No. of cont.*	**TEU**	**Trajanje operacija(sat:min)** *Time (h:min)*	**Br. kont.** *No. of cont.*	**TEU**
0 - 100	4:15	47	70	2:45	91	99
101 - 200	6:55	100	152	5:15	120	177
201 - 300	10:45	163	239	7:00	177	257
301 - 400	13:50	226	340	8:50	234	344
401 - 500	15:40	279	429	11:05	305	454
501 - 600	17:20	354	543	12:50	375	546
601 - 700	28:10	446	667	15:45	422	643
701 - 800				17:00	529	746
801 - 900				18:20	584	853
901-1000	38:40	660	997	21:15	633	951
1001-1100				22:45	719	1051
1101-1200				23:35	803	1140
1201-1300				25:00	837	1244
1301-1400				25:55	933	1327
1401-1500	45:15	879	1422	28:40	977	1456
1501-1600				28:20	1007	1533
1601-1700				30:00	1294	1685
1701-1800				34:50	1219	1760

Izvor: Obrada autora prema podacima poduzeća *Jadranska vrata d.d.*
Source: *the authors according to the data of the company "Adriatic Gate" Inc.*

koji su u trogodišnjem razdoblju pristizali na pristan s određenom količinom kontejnera za ukrcajno/iskrcajne manipulacije. Stoga se mogu koristiti pri planiranju rada na pristanu tako da se odredi potrebno vrijeme za prekrcajne manipulacije određenih količina kontejnera u odnosu na broj korištenih obalnih kontejnerskih dizalica.

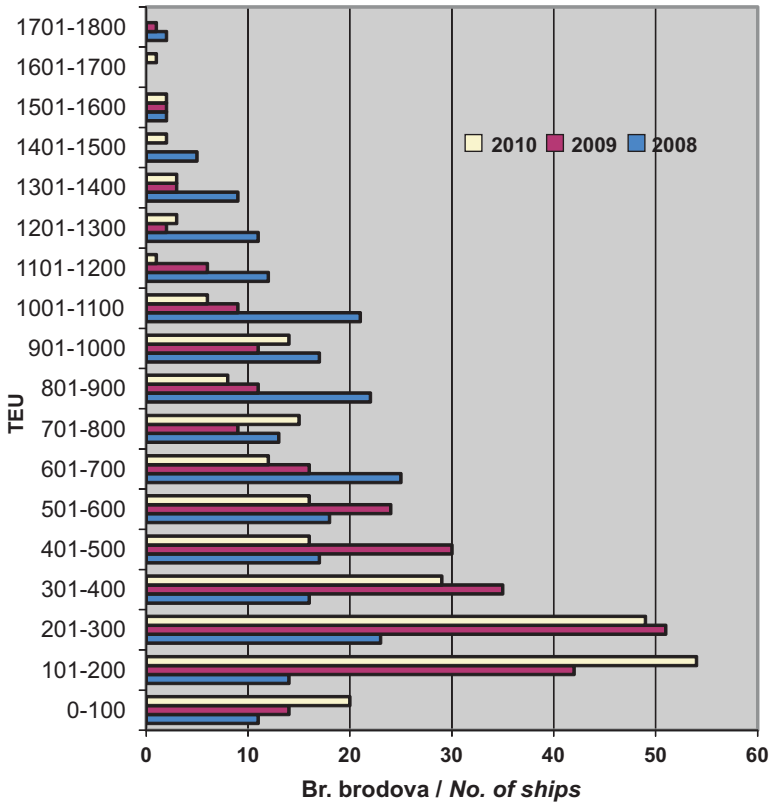
Grafikon 1. prikazuje broj brodova koji su pristigli na riječki terminal s ukupnim prekrcanim brojem kontejnera.

S obzirom da na riječkom kontejnerskom terminalu postoji samo jedan glavni pristan u duljini od 295 m s dubinom od 11 do 12 m, prioritetni raspored u dodjeljivanju pristana je neophodan zbog smanjivanja vremena čekanja brodova. Pomoćni pristan u duljini od 164 m s dubinom od 10 do 11 m koristi se kao rezervni, ali samo za brodove do 250 TEU-a u prekrcajnoj manipulaciji i to u slučajevima kada je glavni pristan zauzet ili se očekuje drugi brod većih prekrcajnih količina i značajki.

planning the work at the berth in a way to determine the time needed for transshipment operations of a certain number of containers in relation to the number of used shore-based container cranes.

Given that the Rijeka container terminal has only one main berth of 295 metres in length, with 11 to 12 metres in depth, the priority in the allocation of the landing schedule is necessary for reducing the waiting time of ships. An extra berth length of 164 metres and ranging from 10 to 11 metres in depth is used as a backup, but only for ships of 250 TEUs in transshipment operations and only in those cases when the main berth is busy or is expected to ship second major transshipment volumes and characteristics.

The yard of the Rijeka container terminal covers an area of 56,100 m^2 and is spread across 30 sections. The static capacity of the yard is 6,500 TEU. The burden of the yard in relation to the ship operations with the types of containers (full/empty) is shown in Figure 2 covering



Grafikon 1. Broj brodova prema ostvarenim prekrcajnim jedinicama kontejnera
Figure 1 *The number of ships as per container units transshipment*

Izvor: Obrada autora prema podacima poduzeća Jadranska vrata d.d.
Source: *the authors according to the data of the company "Adriatic Gate" Inc.*

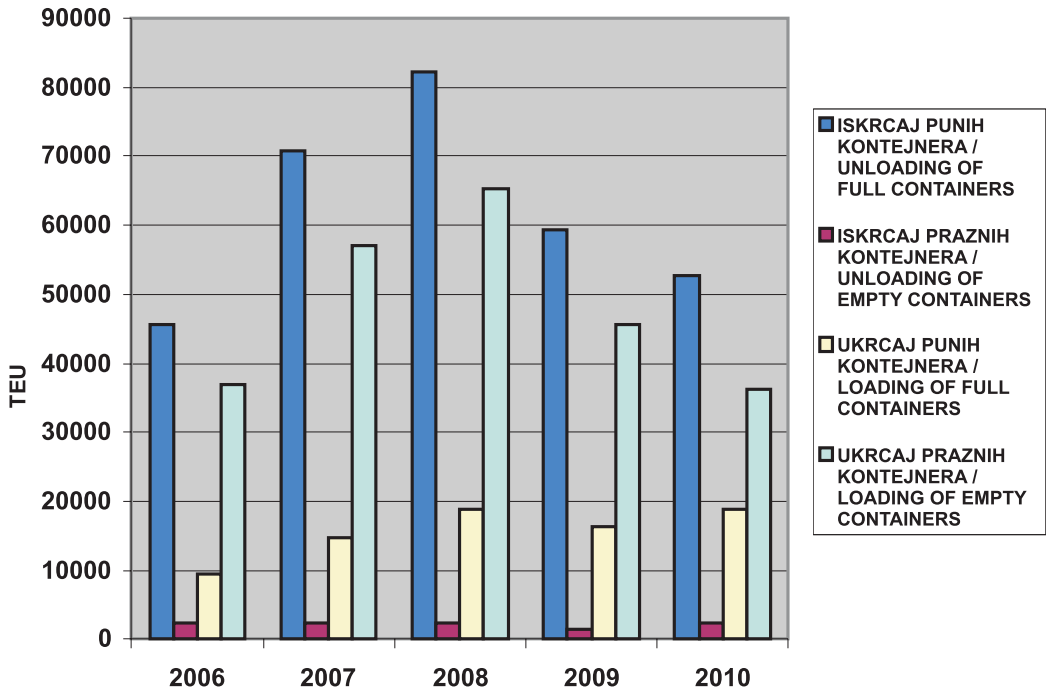
Slagalište kontejnerskog terminala u Rijeci prostire se na površini od 56.100 m^2 i raspoređeno je na 30 sekcija. Statički kapacitet slagališta je 6.500 TEU-a. Opterećenost slagališta u odnosu na brodske manipulacije s vrstama kontejnera (puni/prazni) prikazan je na grafikonu 2. za razdoblje od 01. 01. 2006. do 25. 11. 2010. godine.

U tokovima dolazaka brodova važno je pratiti raspoloživost slagališnog prostora za pune i prazne kontejnere. Također je važan pokazatelj i vrijeme zadržavanja kontejnera na slagalištu, koje za kontejnerski terminal u Rijeci u prosjeku iznosi 7 – 10 dana. Dolaskom brodova na terminal u skladu s grafičkim prikazom (Grafikon 2.) slagalište se popunjava s novim količinama i tek neznatno prazni s otpremom punih kontejnera, dok je situacija s praznim kontejnerima potpuno suprotna. Praznih kontejnera ima puno više u otpremi pa se s dolascima brodova kontejnerski terminal rasterećuje u dijelu slagališta namijenjenom za uskladištenje praznih kontejnera.

the period from 1st January 2006 to 25th November 2010.

In the ship arrival processes, it is important to monitor the availability of the yard space for full and empty containers. The important factor is also the length of time that the container units spend at a container yard terminal. For the port of Rijeka, this time is from 7 to 10 days on an average With the arrival of the ships at the terminal, as shown on the graphical display (Figure 2), the yard is filled with new volumes and slightly empty with the loading of full container, while the situation with empty containers is completely opposite. There are a lot more empty containers in shipping, and with the arrivals of ships the container terminal is unloaded in the part of the yard intended for the storage of empty containers.

A continuous ratio between full and empty containers is very important to control with respect that the container terminal has a limited space for the yard, and it must not lead to a situation that there are not enough free spaces to



Grafikon 2. Kontejnerski promet (puni/prazni) u brodskim manipulacijama na terminalu riječke luke od 2006. do 2010. godine
Figure 2 *Container traffic (full/empty) in ship operations at the port of Rijeka from the year 2006 to the year 2010*

Izvor: Obrada autora prema podacima poduzeća *Jadranska vrata d.d.*
Source: *the authors according to the data of the company "Adriatic Gate" Inc.*

Tablica 2. Stanje kontejnera na kontejnerskom terminalu u Rijeci za pojedine datume u 2010. g. prema ostvarenom mjesečnom učinku brodskih manipulacija
Table 2 *Status of the containers at the Rijeka container terminal for certain dates in the year 2010 according to the monthly achieved ship operation*

2010	**Status kontejnera** *Container status*	**Br. kont.** *No. of cont.*	**TEU**	**Mjesečni promet utovar/istovar** *Monthly traffic loading/ unloading (TEU)*	**Mjesečni promet puni/prazni** *Monthly traffic full/ empty (TEU)*
kolovoz / *August*	puni / *full*	1275	1829	4624 / 4649	6223 / 3060
	prazni / *empty*	1517	2323		
UKUPNO / *TOTAL*		2792	4152		
rujan / *September*	puni / *full*	1016	1523	5286 / 5267	7203 / 3350
	prazni / *empty*	1252	1912		
UKUPNO / *TOTAL*		2268	3435		
listopad / *October*	puni / *full*	781	1164	4230 /4338	5360 / 3208
	prazni / *empty*	1534	2303		
UKUPNO / *TOTAL*		2315	3467		
studeni / *November*	puni / *full*	847	1299	4418 / 4531	5955 / 2994
	prazni / *empty*	1391	2073		
UKUPNO / *TOTAL*		2238	3372		

Izvor: Obrada autora prema podacima poduzeća *Jadranska vrata d.d.*
Source: *the authors according to the data of the company "Adriatic Gate" Inc.*

Kontinuirani omjer između punih i praznih kontejnera vrlo je važno kontrolirati s obzirom da je kontejnerski terminal ograničen prostorom za slagalište, te se ne može dovesti u situaciju da nema dovoljno slobodnog prostora za smještaj novih količina kontejnera. U tablici 2. prikazano je stvarno stanje količina kontejnera na terminalu za određene datume u odnosu na mjesečni promet brodskih manipulacija.

Podaci (Tablica 2) se temelje na prosječnoj otpremi kontejnera (vagoni i kamioni) od 245 TEU/smjena od 8 sati. Za kretanje ukupnog prometa od 120.000 TEU do 180.000 TEU otprema kontejnera (vagoni i kamioni) kreće se u rasponu od 230 TEU/smjena do 290 TEU/smjena.

4. PRIJEDLOG POSTAVKE MODELA PRAĆENJA OPTEREĆENJA TERMINALA

Da bi se postigla bolja iskoristivost kapaciteta pristana i slagališta te smanjilo vrijeme čekanja, odnosno troškovi prouzrokovani čekanjem brodova na slobodan pristan, bilo bi neophodno primijeniti model simulacije toka dolazaka brodova na kontejnerski terminal. Ravnomjerni, skladišno kontrolirani ili nekontrolirani dolasci različito se manifestiraju na stanje i opterećenost slagališta. Zbog potrebe usklađenja kapaciteta slagališta i intenziteta dolazaka brodova određenih kapaciteta važno je utvrditi koji tokovi dolazaka brodova stvaraju najpovoljnije učinke na slagalište, odnosno, za koje tokove dolazaka brodova kontejnerski terminal pokazuje najbolje poslovne rezultate i omogućava svim sudionicima neometan protok kontejnera bez nepotrebnih zastoja i dodatnih troškova.

Logika modela treba polaziti od simuliranih dolazaka brodova na pristan, iskrcaja /ukrcaja brodova i postupka smještaja kontejnera na slagalište. Nadalje, treba promatrati stanje slagališta nakon obavljenih manipulacija i ocijeniti popunjenosti slagališta s obzirom na njegov statički kapacitet. Također je u modelu potrebno izvršiti izračun popunjenosti terminala s obzirom na omjer punih i praznih kontejnera, koji se u tom trenutku nalaze na slagalištu. Potom, procijeniti vrijeme potrebno za otpremu kontejnera na temelju stvarnih otpremnih kapaciteta, zbog osiguravanja slobodnih pozicija na slagalištu za dolazak novog broda sa zahtijevanim novim prekrcajnim količinama.

accommodate new container volumes. Table 2 shows the actual state of the containers quantity at the terminal for specific dates in respect of monthly ship manipulation.

The data (Table 2) are based on the average shipping containers (wagons and trucks) of 245 TEU/shift of 8 hours. To move the total turnover of 120,000 TEU to the 180,000 TEU shipping containers (wagons and trucks) is in the range of 230 TEU/shift to 290 TEU/shift.

4. PROPOSED MODEL SETUP OF MONITORING LOAD TERMINAL

To achieve a better capacity utilization of the berth and the yard and to reduce waiting times and costs caused by waiting for ships to berth free, it would be necessary to apply a simulation model of the ships arrival processes at the container terminal. Uniform, controlled or uncontrolled storage arrivals manifest itself differently on the condition and load of the yard. Due to the need of adjusting the capacity of yards and the intensity of arrivals of ships of certain facilities, it is very important to determine which arrival processes create favorable effects on the yard, i.e., those arrival processes for which the container terminal shows the best business results, and allows all participants a smooth flow of containers without unnecessary delays and additional costs.

The logic of the model should be based on the simulated arrivals of the ships to the berth, unloading/loading of ships and containers in the process of accommodation of containers on the yard. What should be further considered is the state of the yard after the manipulation and the occupancy rate of the yard with respect to its static capacity. It is also necessary to calculate the occupancy of the terminal in the model with respect to the ratio of full and empty containers, which are at that time located on the yard. Then, to estimate the time required for shipping containers on the basis of the actual departure of capacity in ensuring free positions on the yard for the arrival of a new ship with the required new transshipment volumes.

To obtain high-quality and reliable model results, it is necessary to collect and include the following input data:

- simulation parameters (simulation time, terminal capacity)

Za dobivanje kvalitetnih i pouzdanih rezultata modela potrebno je prikupiti i uključiti sljedeće ulazne podatke:

- parametre simulacije (razdoblje simulacije, kapacitet terminala),
- vremena dolazaka brodova (očekivano – *expected arrival times* ETA i stvarno – *actual arrival times* ATA),
- značajke brodova (kapacitet broda, gaz broda, duljina broda, količina kontejnera namijenjena prekrcaju),
- značajke i kapacitet pristana (duljina pristana, gaz na pristanu, brzina i kapacitet obalnih dizalica na pristanu, maksimalan broj brodova na paralelnim manipulacijama),
- značajke i kapacitet slagališta (statički i dinamički kapacitet, oblik i način slaganja kontejnera na slagalištu, brzina i kapacitet pretovarne mehanizacije na slagalištu),
- značajke otpreme kontejnera (duljina i kapacitet cestovne i željezničke infrastrukture na terminalu, brzina i kapacitet pretovarne mehanizacije namijenjene ukrcaju kamiona i vagona, prosječno vrijeme zadržavanja kontejnera na terminalu, prosječno zadržavanje kamiona i vagona na lučkom području prilikom odvijanja pretovarnih manipulacija),
- početna stanja prije započinjanja simulacije (stanje kontejnera na terminalu – puni/prazni),
- vrste tokova dolazaka brodova (nekontrolirani, skladišno kontrolirani i ravnomjerni dolasci), te
- prioritetne postavke (prioriteti pojedinih brodara za pojedine sate ili dane u tjednu prilikom dodjeljivanja veza i započinjanja pretovarnih manipulacija, prioritetni status vagonske otpreme u odnosu na kamionsku otpremu kontejnera i sl.).

Ulazne informacije u model trebaju biti definirane veličinom i gazom kontejnerskih brodova, količinom kontejnera predviđenim za ukrcaj, odnosno iskrcaj, te intenzitetom dolazaka brodova na terminal. Prihvatni kapacitet je determiniran s brojem pristana, njihovom duljinom i dubinom. Na operativnoj obali su kontejnerske dizalice određenih prekrcajnih kapaciteta. Slagalište je ograničeno skladišnom površinom, odnosno statičkim kapacitetom. Dinamički kapacitet u zavisnosti je od kapaciteta skladišno-manipulativnih

- time of arrival of the ship (as expected - *expected time of arrival* ETA, and as actual - *actual time of arrival* ATA),
- characteristics of ships (the capacity, the depth and the length of the ship, the quantity of containers intended for transshipment),
- features and capacity of the berth (the length of the berth, the draft of the berth, the speed and capacity of cranes at the berth, the maximum number of ships on parallel manipulation),
- features and capacity of the yard (static and dynamic capacity, mode and technique of stacking containers in the yard, speed and capacity of the transport/transshipment equipment in the yard),
- features of shipping containers (the length and the capacity of road and rail infrastructure at the terminal, the speed and the capacity of the reloading equipment for loading trucks and wagons, the average retention time of containers at the terminal, the average retention of trucks and wagons in the port area during the course of the manipulation),
- initial state before starting the simulation (number of full and empty containers),
- ships arrival processes (controlled, uniform and uncontrolled), and
- preferred settings.

The input into the model should be defined by the size and draft of the container ships, the amount of container provided for loading and unloading, and the intensity of arrival of ships at the terminal. The carrying capacity is determined by the number of landings, their length and depth. At the operational shore, container cranes are a certain transshipment capacity. The yard is a limited storage space and a static capacity. The dynamic capacity depends on the capacity of the warehouse-handling equipment and on the forwarding capacity of the terrestrial infrastructure. The shipment of containers is defined by the terminal ability to make a number of shipping containers in a unit of time.

The results of a simulation model should be given in the form of statistical graphs and tables from which the best could be read the provided data. Primarily, data relating to waiting times of ships and the state of occupancy of the yard

sredstava i otpremnih kapaciteta kopnene infrastrukture. Otprema kontejnera definirana je sposobnošću terminala da obavi otpremu određenog broja kontejnera u jedinici vremena.

Rezultati modela simulacije trebaju biti dani u obliku statističkih grafova i tablica iz kojih se najbolje mogu očitati dobiveni podaci. Prvenstveno treba dobiti podatke koji se odnose na vremena čekanja brodova i stanje zauzetosti slagališta s obzirom na različite dolaske brodova i njihove prioritete, koji su vrlo važni za operatere kontejnerskih terminala i morske brodare.

Vrijeme čekanja brodova različito je u ovisnosti o nekoliko čimbenika, i to: o tokovima dolazaka brodova na pristanište (skladišno kontrolirani, ravnomjerni ili nekontrolirani), vrsti brodova, količinama kontejnera predviđenim za utovar/istovar, statusu prioriteta čekanja i kapacitetu i zauzetosti pristana. Prema navedenim kriterijima model će prikazati prosječno vrijeme čekanja brodova po tipu i veličini s obzirom na intenzitet toka dolazaka brodova. Nadalje može se utvrditi način po kojem je najbolje odrediti prioritetne sheme i ukazati na moguća rješenja koja bi pozitivno utjecala na smanjenje vremena koje brodovi provedu u čekanju. Na temelju rezultata modela mogu se dobiti odgovori, odgovaraju li postojeće veličine i broj pristana traženim potrebama za manipulacijama i može li izgradnja novih ili rekonstrukcija već postojećih pristana povećati kvalitetu usluge u odnosu na zahtijevane investicije.

Postavljanjem modela simulacije dolazaka brodova na terminal može se utvrditi zauzetost slagališta s obzirom na promatrane dolaske brodova. Način na koji se to može postići je prikaz gornje i donje granice unutar kojih se kreće stanje slagališta i zadovoljavaju li postojeći kapaciteti zahtijevane potrebe za određenom razinom prometa. Neosporno je utvrditi da skladišno kontrolirani dolasci brodova imaju najbolji učinak na slagalište, dok neravnomjerni dolasci brodova imaju najlošiji utjecaj. Međutim, pravilnim planiranjem dolazaka brodova i usklađivanjem potreba s morskim brodarima koji zahtijevaju određenu kvalitetu i brzinu usluge na terminalima, kao i davanjem prioriteta po određenom pravilu, može se izbjeći nekontrolirano zagušenje terminala i smanjiti vrijeme čekanja brodova.

Model simulacije potrebno je prilagoditi slagalištu kontejnerskog terminala i to u timskom radu lučkog menadžmenta, odnosno operatera koji

should be obtained, due to different arrivals and their priorities, which are very important for the operators of container terminals and sea shipping.

The waiting time of ships is different depending on several factors, namely: the arrival process of ships on the dock (warehouse-controlled, uniform or uncontrolled), the type of ships, container volumes provided for loading/unloading, status and priority standby capacity and occupancy of the berth. According to these criteria, the model will show the average waiting time per ship type and size, given the intensity of arrivals. Furthermore, one can determine the way in which it is best to prioritize schemes and point out possible solutions that would positively impact on the reduction of time ships spend in waiting. Based on the model results one can get answers if the current size and number of landings corresponds to the required needs for the manipulation and whether new construction or reconstruction of the existing berths can increase the quality of services in relation to the required investment.

By placing a simulation model of the ship arrivals at the terminal, the commitment of the yard, with respect to the observed arrival, can be determined. The manner in which this can be done is to show the upper and lower limits within which the moving state of a yard and whether the existing facilities meet the required needs for a certain level of traffic. It is undisputed to determine if the storage controlled arrivals of the ships have the best effect on the yard, while the irregular arrivals of the ships have the worst effect. However, with a proper planning of the ships arrivals and the matching of needs with the maritime shippers that require a certain quality and fast service at the terminals, as well as with giving priority to the specific rule, an uncontrolled terminal congestion can be avoided and the waiting time of ships reduced.

It is necessary to adjust the simulation model to the container yard in a team work of the port management and the operators who have the necessary knowledge in the way this operation is performed at the terminal and of the programmers who would translate the set model into a computer language and computer-enabled solutions and getting the test model.

imaju neophodno znanje u načinu odvijanja operacija na terminalu i programera koji bi postavljeni model preveo u računalni jezik te omogućio računalno dobivanje rješenja i testiranje modela.

5. ZAKLJUČAK

Važnost praćenja, analize i modeliranja tokova dolazaka brodova na kontejnerski terminal istražena je kroz utjecaj na opterećenje pojedinih elemenata terminala. Opterećenje kapaciteta kontejnerskog terminala razlikuje se u zavisnosti od različitih tokova dolazaka brodova. Logičan je zaključak da skladišno kontrolirani dolasci pokazuju najbolje rezultate s obzirom na opterećenje, odnosno zagušenje slagališta, dok nekontrolirani dolasci imaju najgore značajke u pogledu vremena čekanja brodova i zahtijevanih kapaciteta slagališta. Predložena je postavka modela koji bi trebao ponuditi kvalitetne rezultate i imati pozitivne učinke na sve sudionike koji sudjeluju u procesima na kontejnerskim terminalima. Budući da je u ovome radu predložena postavka modela, smjer daljnjih istraživanja bit će implementacija modela simulacije na kontejnerski terminal, s primjenom na konkretan primjer.

5. CONCLUSION

The importance of monitoring, analysis and modeling the ships arrival process at a container terminal is investigated through the effect on the load of each element of the terminal. The load capacity of container terminals differs depending on the different ships arrival processes. The logical conclusion is that the warehouse controlled arrivals show the best results with respect to load or to the congestion of yards, while uncontrolled arrivals have the worst features in terms of waiting times of ships and the required capacity of a yard. The proposed model should offer quality results and have positive effects on all participants in the processes at container terminals. Since we have proposed a model in this paper, the direction of the future research will be towards the implementation of the simulation model for a container terminal, with application to a real example.

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