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Practical Solutions for Reducing Container Ships' Waiting Times at Ports Using Simulation Model

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Abstract: The main challenge for container ports is the planning required for berthing container ships while docked in port. Growth of containerization is creating problems for ports and container terminals as they reach their capacity limits of various resources which increasingly leads to traffic and port congestion. Good planning and management of container terminal operations reduces waiting time for liner ships. Reducing the waiting time improves the terminal's productivity and decreases the port difficulties. Two important keys to reducing waiting time with berth allocation are determining suitable access channel depths and increasing the number of berths which in this paper are studied and analyzed as practical solutions. Simulation based analysis is the only way to understand how various resources interact with each other and how they are affected in the berthing time of ships. We used the Enterprise Dynamics software to produce simulation models due to the complexity and nature of the problems. We further present case study for berth allocation simulation of the biggest container terminal in Iran and the optimum access channel depth and the number of berths are obtained from simulation results. The results show a significant reduction in the waiting time for container ships and can be useful for major functions in operations and development of container ship terminals.

Keywords: container ships; waiting time; access channel depth; quay length; simulation model; enterprise dynamics; berth allocation

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1 Introduction

Marine transportation is one of the most efficient, effective, safe and environmentally sound ways to transport people and goods. Ports are at the center of global, intermodal freight systems that connect deep-sea and short-sea shipping routes to remote interior regions through a system of inland waterways, roads, railways and pipelines. As such, ports are an important cornerstone of the macro-infrastructure in the countries and regions where they operate. In the last decade, global shipping has experienced explosive growth. Increasing world trade and globalization, developing markets in Asia and the relatively low cost of transportation have all contributed to this growth, resulting in high demand for more terminals, distribution centers and production plants. Globalization also has led to increased competition among ports and increased requests from the traditional port management organizations for more efficient operations. To attract waterborne commerce and decrease shipping costs, ports and operators are now planning for the next generation of vessels with increased draft even though these ports are not equipped to accommodate such vessels through channels leading to them.

The harbor design often requires a formal and appropriate assessment of the port, terminals and berths. The design of the mooring systems for specific berths and ships provides the data on the loads on the mooring equipment and on the motions of the moored ship. This information allows for simulating port operations to determine bottle necks for berth allocation and to reduce the waiting time of ships in port. The access channels, turning basins and berthing places have to be dimensioned and aligned, the ships to be serviced have to be considered, as well as the environmental conditions, the available tugs and the aids to navigation, in order to minimize the waiting times.

Physical limitations such as channel depth, storage yard space, berthing facilities, and landside productivity determine how much throughput a port can potentially handle in a given year. The proper planning and management of port operations in view of the ever growing demands in global trade represents a big challenge because of restrictions such as the length of the quay and depth of access channels which causes increased difficulties for berthing operations planning and the loading and unloading of ships.

Shippers and carriers are using larger ships in global trade to gain transportation efficiencies and cost savings, which have enormous importance in this very competitive market. While large ocean-going-vessels, such as those used for waterway barge transport, are substantially less efficient and cost efective EDRG (2012).

An important capacity consideration is the size of the vessel a port can accommodate. Along with other factors, channel width and depth establish the maximum size vessel that can be call into a port. Access channels are the initial points of entry to ports and harbors. The absence of a verified design methodology often leads to conservative estimates on channel size, which gives rise to increased initial/maintenance dredging costs. The depths of most navigation channels gradually decrease over time due to sedimentation, since these channels behave as a sediment trap. Maintenance costs are a critical element in the economic feasibility of a port, particularly when a relatively long access channel requires

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frequent dredging. The present study examines the influences of dredging access channels in Iran's RAJAEE port in reducing container ships' waiting times by using a simulation model. Simulation can guide terminal managers with evaluating all the terminal key resources (cranes, barges, tugs, quays, etc.) to understand their interactions with vessel delays and to assess and mitigate the risks arising from them. A list of challenges that a simulation model can help to tackle include (Dahal *et al*., 2007).

- Minimizing infrastructure investment while maintaining a high service level
- Evaluating the peak utilization for different equipment in the terminal
- Determining the number of cranes
- Evaluating if the envisioned or current terminal layout is capable of coping with future market demands
- Assessing quay extension investment
- Assessing the impact of vessel schedules on the service level
- Understanding the impact characteristics on the terminal performances
- Assessing the risk of a higher variability of vessel arrivals
- Implementing new strategies to optimize crane allocation
- Assessing the impact of a new fleet composition
- Understanding the correlation between waiting times, quay occupancy and vessel arrival patterns
- Estimating if and how the hatch composition affects the terminal performances

Many different parameters enter into the planning, design and operation of deep-draft navigation channels. For example, in the planning of a navigation channel, a design ship, typically the maximum size ship from the projected user fleet is selected on the basis of economic analyses. The two main design dimensions of navigation channels are width and depth, and these must be determined to accommodate the design vessel. Likewise, for safe operations within a channel, it is necessary to consider the effects of winds, waves, tides, currents, visibility, and navigational aids. The density and type of traffic (one-or two-way traffic), ship speed, turning basins, and tug assistance are other factors that need to be considered with the operations of channels (Demirbilek and Sargent, 1999).

Today with global trade, the density areas of the port and container ports, restrictions such as the length of the quay, the depth of the access channel, and the number of tugs and tide conditions, have made double the difficulties of berthing operations planning and the loading and unloading of ships. Thus, due to the complexity and nature of the problems, using the enterprise dynamics simulation approach as a flexible and efficient solution is proposed. In this study the objects of the simulation model can be explained as follows:

1) Simulated berth allocation process in Rajaee port.

2) Calibration and Validation of the simulation model.

3) Reduced ship waiting time by making a change in the access channel depth.

The growth in container transportation has led to an increased demand for the service at container terminals that now have to serve several vessels per day, load and unload thousands of containers per day, and have to do so in a timely manner in order to reduce the time liner ships have to spend at the terminal and thus gaining a competitive advantage over its neighboring ports in the region. This competitive advantage helps the port increase its customers and thus its profits (Ali *et al.*, 2011) Port capacity depends upon channel depths, channel widths, turning basin size, sufficient bridge heights, and port support structures with sufficient dock and crane capacity to load and unload goods. USACE provides detailed guidance for the design of inland waterways, the guidance for coastal access channels is not comprehensive. The USACE guidance defines authorized depths and widths for navigable channels (Demirbilek and Sargent, 1999) .Berth Allocation refers to the problem of allocating vessels to berths while minimizing the total service times of vessels. In recent years, simulation has become an important tool for improving operation and performance of ports. According to research by Saanen (2000), Merkuryev *et al.*(1998) it can be concluded that the simulation results provide valuable information to support the decisions made by programmers,operators and terminal managers. Beneficial applications of simulation in support of complex management of container ports have been demonstrated by Bruzzone *et al.*(1999). Highlights of this study have implications for several applied examples. Experimental results have indicated the advantages of the simulation approach in terms of reusability, flexibility, time of modeling and estimation of the operations. Legato *et al*. (2000) modeled the line of logistics activities related to import, ship berthing and departure processes in a container port. They could use the process simulation to provide a model of the queuing network in a port. The good results and validation of output from the model in this study show that the simulation approach can be a viable solution to this problem. Kim and Moon (2002) presented a mixed-integer-linear-programming (MIP) model which was formulated for the berth-scheduling problem. The simulated annealing algorithm was applied to the berth-scheduling problem to find near-optimal solutions. Experimental results showed that the simulated annealing algorithm obtains solutions that are similar to the optimal solutions found by the MIP model. A numerical experiment showed that the computational time and quality of solutions depend on the number of vessels and the ratio of the overlapped area of rectangles when they are positioned at their least cost locations to the total area of the rectangles. The numbers of optimal berth and quay cranes were studied by Nam *et al*. (2002) at a port in Busan (Korea).

Several operational models in four different scenarios were presented and their operations were evaluated through simulation experiments. The results showed that sharing the quay cranes with the next berths could be effective in improving efficiency. Yun and Choi, (2003) proposed an Object-Oriented Simulation Model for analyzing terminal containers (including: gateway, container yard, berth and equipment, such as transfer cranes, gate cranes, trailers and yard tractors). The system's model uses a set of goals in the programming language of the Object-Oriented Simulation Model, so that the comparative model can control and manipulate it. Outcomes of statistical analysis of resources may be used to assess the capacity and operative efficiency of a terminal. Hartmann (2004) has provided the approach for generating realistic data scenarios in port container terminals, as inputs to the simulation model and test optimization algorithms. In this study, a scenario includes data about "reaching the ships, trains and tractors during the time" and some information about "the containers which are picked up or delivered" and users are able to control various parameters of a kind. Meng *et al.* (2009) stated that the berth allocation is the most important issue for reducing the ship's queuing time. When the port is heavily congested with different types of vessels, effective berth allocation techniques could optimize the berth utilization and reduce the ship's queuing time. They propose a simulation method to achieve the optimized allocation plan based on dynamic decision making. Bierwirth and Meisel (2010) presented a thorough review of the previous attempts in solving the berth allocation and quay crane assignment problems. Particular focus in their article is put on integrated solution approaches which become increasingly important for the terminal managemet. He *et al.* (2012) imply that the berth allocation is an important part of port operations and is also the key link of logistics. The authors established a 0-1 programming model to minimize both the ship's retention time in port and the distance between the berth and target storage yard.

In this paper, incerising of the access channel depth and quay length were studied as two practical solutions to reduce container ships' waiting times. Simulation methods and Enterprise Dynamics (ED) software were used for the simulation process. A view of the simulation model is shown in Fig. 1.

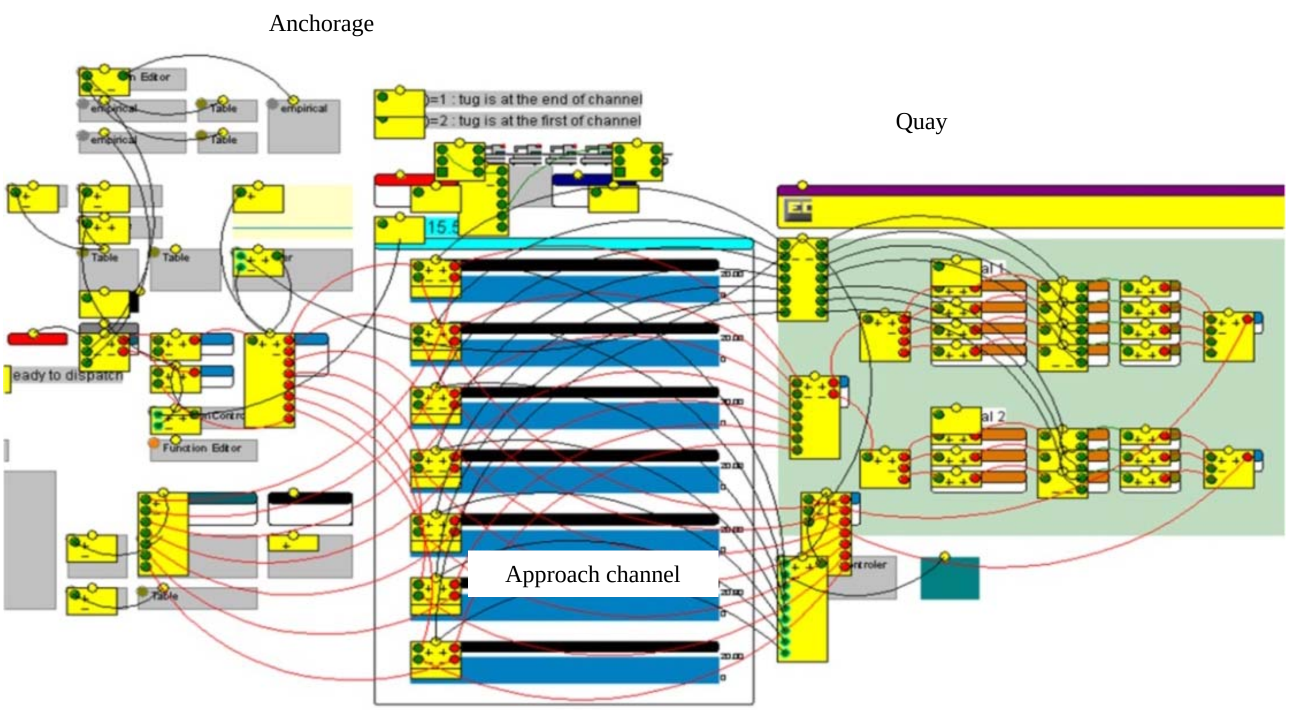

Fig. 1 A view of the simulation model

2 Simulation model

The simulation model contains the terminal characteristics including the number and size of the quays and the available loading equipment. It was also taken into account seasonality in demand, and variability in demand. Furthermore, the model takes the infrastructure elements such as: loading equipment, conveyors, tugs, and barges including failure patterns into account. Typical processes that can be part of the model include: vessel arrival (patterns, arrival windows, and queuing rules), quay allocation, and equipment allocation, berth processes (mooring, paperwork, loading, offloading etc.), departures, maintenance and failures and weather conditions for navigation and departures. Other constraints such as access channels, tugs and port entry windows can also be part of the simulation model.

Generally, simulation of a system where its variable modes occurs only at a point of time discretization "momentous spot," is called discrete event simulation. In fact, in this type of situation, a system in discrete moments of time will be updated. Therefore in this research discrete event simulation software ED is used to be employed in designing random processes, discrete events and dynamic designs. Applications of this simulation software are used in the process of model production, transportation (rail, airport and port industries), logistics and warehousing. In this research, the ED logistics package has been put in use to model production. In short, capabilities of this package includes, potential for operation model production of those like machineries, operators and robots, equipment to transfer materials such as cranes, tanks and also in warehousing (Banks, 2011; Halverson, 2009). ED software founded on the basis of the atoms concept as components of particles of model production. An atom not only may represent a machine, service or a product, but also have the capability to take part in nonphysical characterizations, such as diagrams, tables or context of models. In the present research 4D Script software programming language, a number of key commands are used for the production of the model (Brito, 2010; Cakaj, 2010). The conceptual model of the simulation model shows all processes that inputs do from arrival time until departure time. The Conceptual Model or Process Graph of Simulation Model indicates all processes of a simulation model quality as from entering up to leaving the system. (Fig. 2)

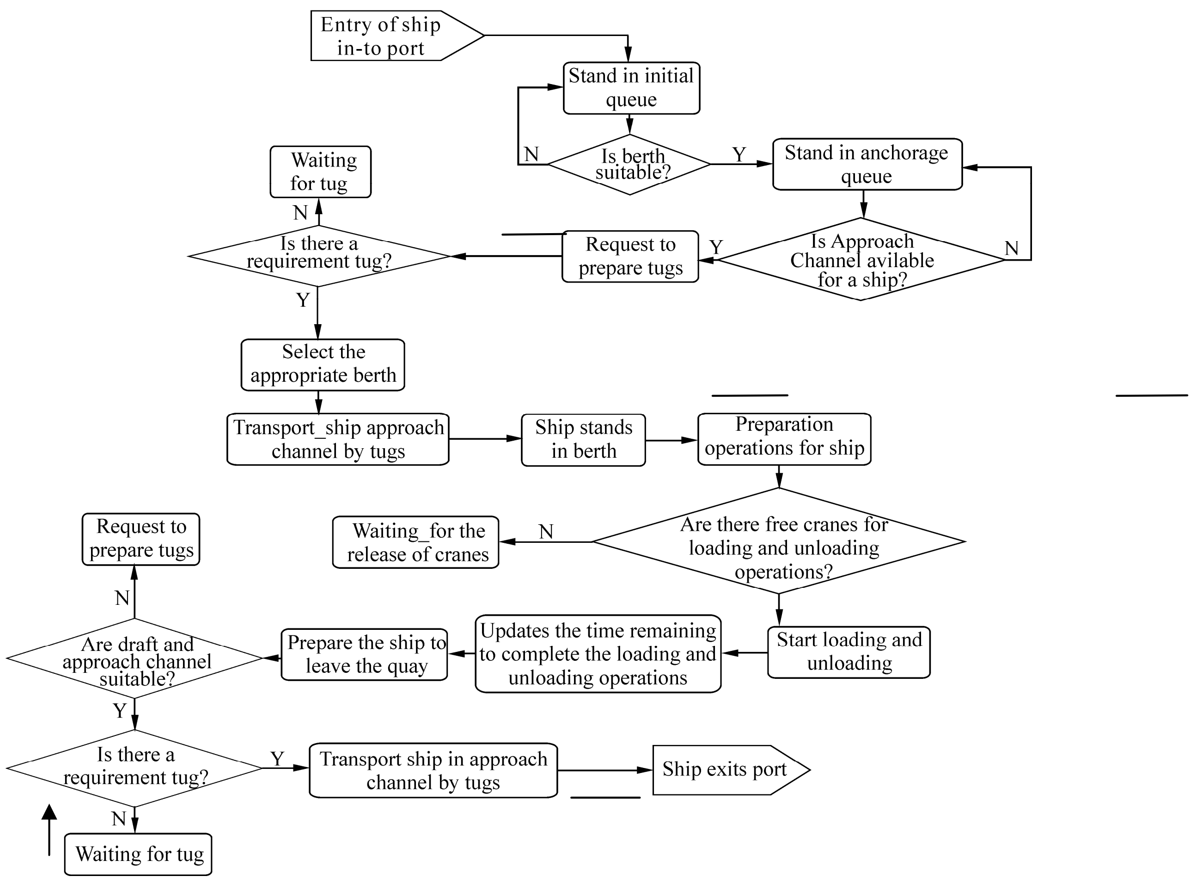

Fig.2 Conceptual model

3 Defined features in the simulation model

The container sector in Iran is a fast-growing market. The main container port is located at Bandar Abbas (Iran's RAJAEEport), but growth of the container sector will be limited by physical constraints in the near future. (Such as the length of the quay, the depth of the access channel and the number of tugs and sea tide conditions).

The distance of Iran's RAJAEE port to Tehran is 1501 Km, 30 Km to the province's Capital and 40 Km to the nearest airport. The connection of this port to Tehran and other parts of the country is possible via roads and railways.

Iran's RAJAEE port connects to more than 80 ports worldwide and has the highest rate of cargo transit in the country. A large volume of cargo being shipped towards Central Asia passes through this port.

Iran's RAJAEE port, as the biggest container port of Iran that is in charge of handling the highest volume of container operations plays a very important and vital role in Iran's economy and Trade. Terminal containers at RAJAEE port provide services for all linear and feeder ships and 21 linear shipping lines which are in traffic in this port.

Iran's RAJAEE port is a multipurpose port and it has two container terminals. A general view of the quays in this port is presented in Fig.3. One of the advantages of terminal 2 over terminal 1 is the difference between drafts. The drafts in terminal 1 are between 8 and 12 meters but terminal 2 has drafts between 14 and 16 meters. So it is possible for the berthing of the large ships in terminal 2. The quay position and capacity in the two terminals are not comparable to each other.

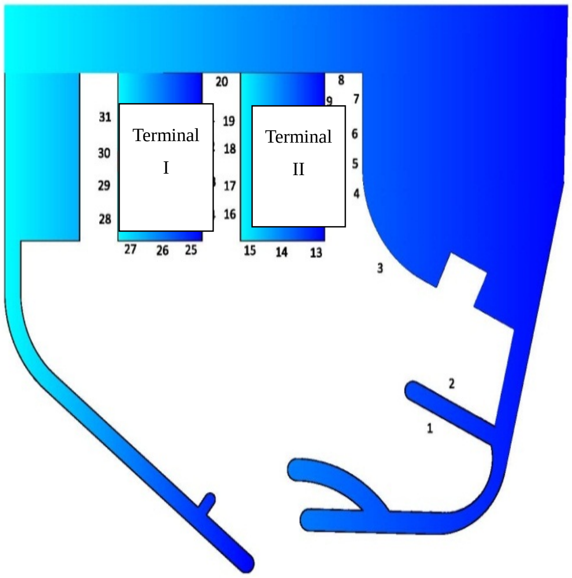

Fig.3 A view of Iran's Rajaee port

The main objective was to find an efficient solution for reducing container ships' waiting times in Iran's RAJAEE port. The beginning steps of the simulation model is for identifying assumptions, boundaries and determining the key index system. General assumptions of the simulation models can be divided into two categories of structural assumptions and assumptions about the data. Structural assumptions used are about the performance of the system and the system boundaries. The simulation model in this study is done based on the modeling of discrete berths and it is assumed that there are a certain number of berths at each terminal for ships. (Table 1). Assumptions regarding the data include the consideration of two types of ships (liner and feeder) by the specifications of the draft and volume of the container (Table 2). Instituting specifications of the simulation model including behavioral features of each one are outlined in Table 3.

Table 1 Length and depth of different berths of terminals

Number of terminal	Number of berth	Berth length/m	Initial depth of berth draft/m
1	4	340	12
1	5	300	12.5
1	6	270	12.5
1	7	250	11.7
2	25	370	16
2	26	370	16
2	27	370	16

Table 2 Classification of ship types and their characteristics

Type of ship/ Percentage	Average length /m	Average draft /m	Percentage of ships (with this length & draft)
Liner 65.80	173	8.6	35.26 %
	222	12.8	38.28 %
	279	14.5	21.37 %
	316	14.5	5.09 %
Feeder 34.20	77	5.1	13.42 %
	136	6.7	37.34 %
	165	8.2	33.60 %
	216	12.5	15.65 %

4 Calibration of the simulation model

Calibration tests will eliminate doubt about the model results from the simulations and that they can improve the situation that has been used in the real system. Comparing overall process model and conduct, with the real system is generally the purpose of determining the validity of models.(Perros, 2009).

In continuation by definition of scenarios that are along with some changes in entrance information, the results model exit simulations for model calibration will be considered. For the implementation of the simulation model, there must be a warming up and observation time for the model to be made clear. With regards to estimating the arrival time between two ships (about 8 hours) and also the ship's time in port, the time for warming up and observation time are considered respectively to be 1 week and 3 months. Also 50 independent observations before the execution are recommended.

Scenario of berthing ships: The purpose of this scenario is to study and evaluate the impacts of the berthing methods of ships on the indexes such as waiting time while at anchorage and operation time. In short, the methods are shown in table 4.

Scenario to increase entrance rate of ships anchorage: Average time between arrivals in 2009 to 2011 as compared to the average arrival time in 2006 to 2008, have decreased about 25%. So for the scenario of increasing the arrival rate of ships to anchorage, the 25% average decrease in arrival time between two ships entering is utilized.?

The scenario for changing the percentage of entering ship types to anchorage: In this scenario, the percentage of the change of the impact of various types of ships which enter the anchorage will be studied. For this purpose, percentage of entering liner ship types are considered equal to 0%, 50% and 100% respectively.

Queuing discipline policies for ships at anchorage: The ships which stay at the anchorage areas are to wait in queue and are generally arranged by different regular rules. In a preliminary state the ships in queue are generally arranged by entering time to the anchorage area.

Simulated models which have been calibrated for 2006 to 2008 data are used to predict port situations between 2009 to 2011. With different tests to determine the important parameters of model simulations, preliminary depth of access channel was found to equal 11 meters and estimated loading speed of the crane to equal 17.5 containers per hour. According to the results achieved, the berthing scenario based on strictly random estimates, calculated the average waiting time for ships at anchorage better than the other methods. Also the simulation model result matches up well with the real data (Fig. 4 and Fig. 5).

Table 3 Defined subjects and particulars in simulation model

Analysis	Quantities total or calculation method	Features List	Subject
Quantity 1 means liner ship and quantity 2 means feeder ship.	Bernoulli(65.45,1,2)	Type	Ship
Ship's length is obtained on the basis of ship's type of discrete distribution.	Liner={173,222,279,316} Feeder={77,136,165,216}	Length (Meter)	
Number 1 refers to ships which are intended to proceed from anchorage toward the port and number 0 for ships which are intended to leave the quay.	{0,1}	Movment Course (Towards Quay or Departing Quay)	
N represents the total number of ships that have been produced in simulation.	{1,2,…,N}	Number of Inward Ships	
The color green for a ship indicates suitable conditions to enter the access channel and the color red indicates a warning that at the moment, at least one of the necessary accommodating conditions for the entry of ships to the access channel is not available.	{G, R}	Color	
Full details of classification deep draft ships are summarized in Table 2.	Calculated on separating by type and length of the ship.	Draft	
-	Is determined by length and GRT of the ship.	Number of Loaded/Unloaded Containers Per Box	
Is assumed not to exceed 30 minutes (1800 seconds)	Min{1800,Weibull(3316.23,2.10)}	Prepration Time (from Berthing up to Operation Onset)	
While at the beginning moments of loading and unloading operations there is a sufficient figure of crane coefficient, loading and unloading time length is calculated on the basis of the following relationship: (Total Operation (Box))/(QC_{Norm}*25) In this regard QC_{Norm}enacts a coefficient of the number of cranes needed for the ship. In cases where the number of the cranes are not available, loading and operations with the number of the existing cranes has been started and when extra cranes for loading and unloading are added, the remaining time to complete loading and unloading operations, is calculated and will be used in the simulation model.	Based on the number of loaded/unloaded containers, loading/unloading speed of each crane, and also the number of cranes assigned for each ship.	Containers Loading and Unloading Time	
Is assumed not to exceed 1 hour (3600 seconds)	Min{3600,Pearsont5(8771.35,3.30)}	Unberthing Time	
The number 1 indicates that at the moment, the ship has all necessary conditions including suitable water depth, the availability of channel and suitable location for berthing and by all means is ready to move forward. Otherwise, this figure of time equates to zero.	{0,1}	Ship's Situation to Enter Access Channel	
NT indicates number of terminals (in here NT=2) and the assigned berth is elected according to a berthing method as soon as a ship enters the access channel.	{1,2,…,NT}	Number of Allocated Berths	
With the assumption of discrete quay length, the entering ship chooses one of the suitable places for berthing.	{1,2,….,NB_i}	Berthing Location in Entering Terminal	

-	This time, at the moment the ship leaves the anchorage is calculated as the time difference between the ship leaving the anchorage and the time it reached the anchorage.	Waiting Time at Anchorage	
-	This time when the ship departs from anchorage is calculated as the time difference between the ship leaving the terminal and arriving at the port.	Waiting Time in Port	
The deep draft access channel is upgraded over time based on its initial quantity and changes in sea level due to the tides.	Initial depth of draft of access channel is considered equal to 11meters.	Draft Depth at Any Time	Access Channel
The number 1 indicates that a ship in the access channel from anchorage is toward the port. Toward the port on the move. The number 0 indicates that the ship is in the access channel and departing the port.	{0,1}	Movment Course of Ships in Access Channel	
"I" indicator is used for terminals	I=1,2	Number of Terminal	Quay
This figure is fixed during simulation.	L_i	Terminal Length	
While a ship is moving from anchorage to port, occupied length of the quay that the ship is supposed to enter will be updated in accordance with the ship's length.	$[0,L_i]$	Occupied Terminal Length at Any Time	
Number of berths for first and second terminals will be respectively considered to be 3 and 4.	NB_i	Number of Berths at Terminal	
-	Depth of any berth, in time, will be updated on basis of initial and tidal effects.	Draft Depth of Each Berth in Any Terminal	
-	In the initial state, there are 6 standby tugs in the port for shipment.	Number(Quantity)	Tug
Time duration to pass through access channel is calculated by continuous uniform distribution function with least time limit of 30 minutes and over 60 minutes. Also time for a free tug move without towing any ship in access channel considered roughly 20% of the time when towing a ship in the access channel.	Uniform[30,60]	Time Length to Pass Access Channel (Minutes)	
The number 0 means that a tug is engaged with serving floating object. Number 1 is equivalent to tug being free at anchorage. Number 2 indicates that the tug is idle and stays along the quay. The assumption is that tugs after completed towage of floating objects, will stay at their present position (beginning or the end of access channels).	{0,1,2}	Availability at Any Moment Including (Location Position)	

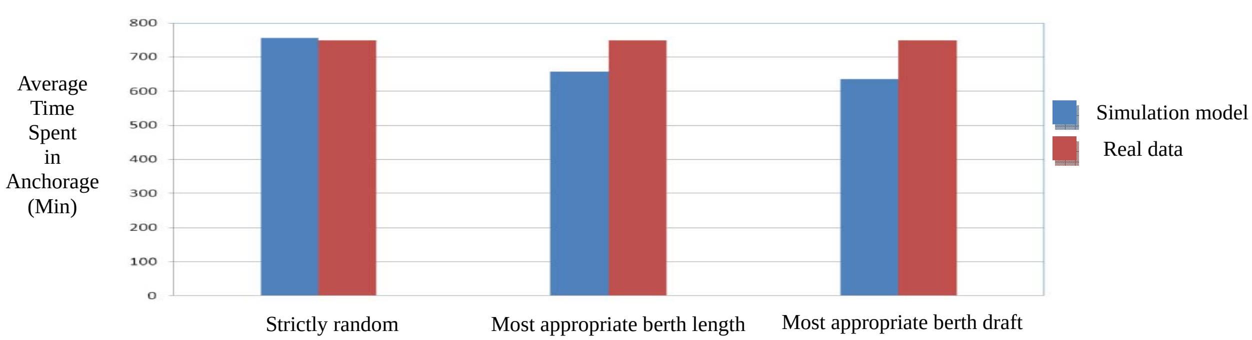

Fig.4 Comparison of time at anchorage area in simulation model and real data in different berthing scenarios (2006-2008)

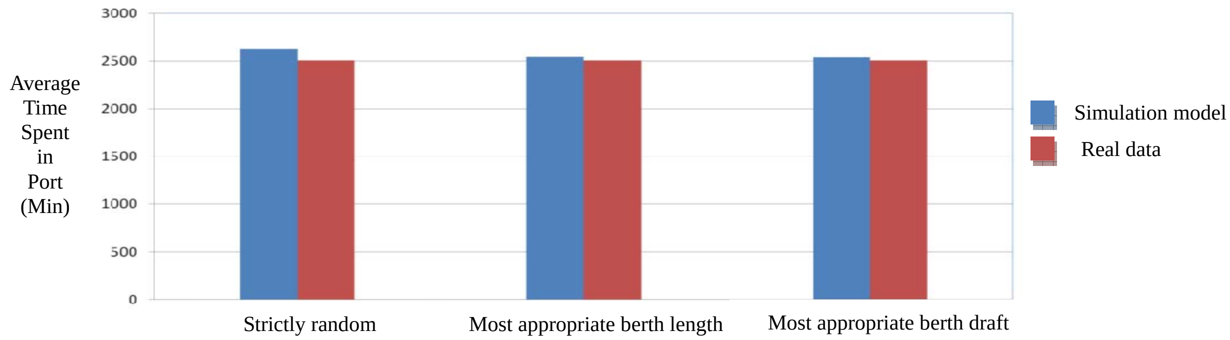

Fig.5 Comparison of average time spent in port in simulation model and real data in different berthing scenarios (2006-2008)

Table 4 Scenarios for selection of ship berthing allocation

Berth Selection Method	Analysis
Strictly Random	In this case, out of preferred berth location for each ship in terminal, one is selected by random. When only one suitable location is available, the ship will be berthed at that location.
Most Appropriate Length	In this case, the ship will be selected for the berth in accordance with parity of its length. In other words, a berth which has the least length difference with the ship, minimum length of the berth will be not useable.
Most Appropriate Berth Draft	In this case, the ship will be selected for the berth which has the slightest difference in draft depth. In another words, a berth which has the least draft difference with the ship will be selected.

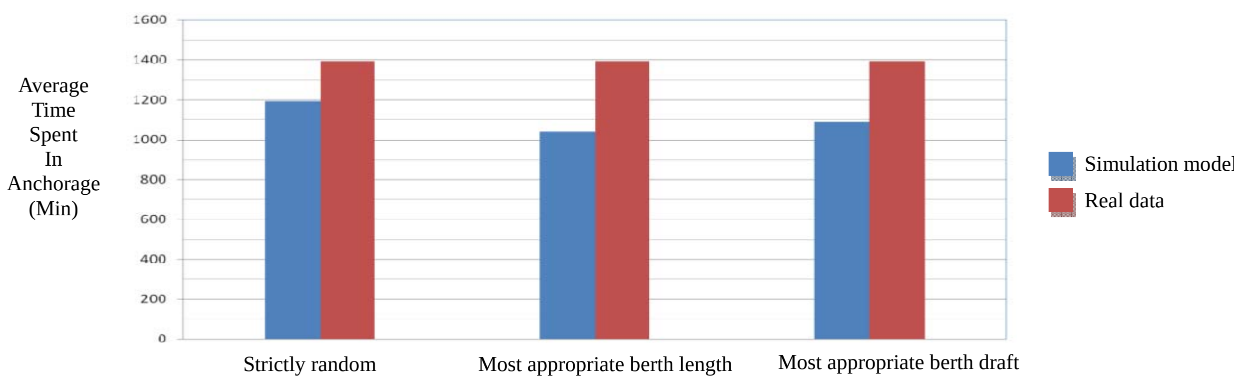

Fig.6 Comparison of time at anchorage area in simulation model and real data in different berthing scenarios (2009-2011)

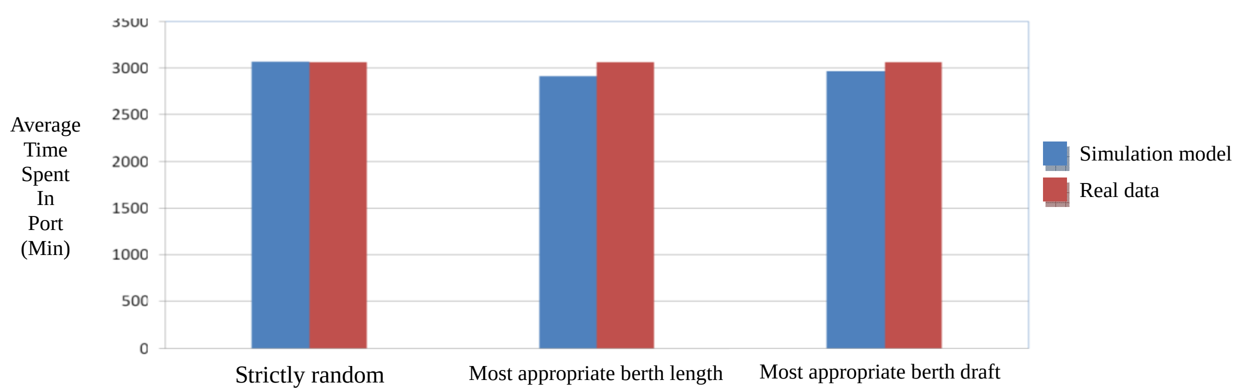

Fig.7 Comparison of average time spent in port in simulation model and real data in different berthing scenarios (2009-2011)

5 Validation of simulation model

In this section, results of model simulations for the current status of the port in various scenarios for berthing of ships are presented. For comparison simulation model results given by the real data and with consideration to the fact that arrangement of anchorage in reality is a First In-First Out (FIFO) scheme, therefore in all scenarios arrangement of queues are considered in the FIFO scheme. Also the arrival ships rates are in accordance with the real data between 2009 and 2011 following a negative distribution view with 389.17 minutes. Also percentage of the liner type is the primary (65.45%). According to the results achieved, simulation model has managed, time waiting for a ship in anchorage and also the time of the ship in port was predicted with proper care. (Fig.6 and Fig.7)

6 The impacts of increasing the depth of access channels through dredging

Port locations and sites are preliminarily constrained and quality of maritime access related to the depth of the waterway system and port access channels. As is clear, time optimization of berth allocation requires the identification of main bottlenecks for the process of providing service to container ships. One of these bottlenecks is the depth of access channels that acts as constraints on the berth allocation process. Any vessel must have appropriate draft with the access channel. Otherwise the ship will have to wait for the tide to increase the depth of the access channel.

The accessibility of a port depends upon several factors, such as the depth of its access channel, which also determines the depth of the docks or basins. In this case it is assumed that one or a few meters of the access channel is added to the minimum depth. This process further increases the extent of its efficiency, and will continue. Such a strategy can reduce "average time spent in port" in regards to two areas, anchorage (applied to the vessels ready to arrive) and at berth (vessels ready for departure). More specifically, the amount of waiting time at the anchorage area after evacuation of the berth which occurs with every vessel, because of needed allocation for the next vessel, such conditions is due to the lack of a sufficient depth access canal with regard to the tidal effects, this is a considerable decrease. Also, some of the ships leave the berth after their loading has been completed, so no problems for smooth departure from the port occurs. Perhaps the amount of imposed waiting time for the next ships coming into the anchorage area also (for quicker evacuation of quays) decreases. Tables 5, 6, 7 and 8 describe the effects of increasing the depth of the access channel (Depth of available access channels equals 11m). In this paper, the strictly random method for the berthing scenario is used.

Table 5 Effects of increasing the access channel depth in the rate of 11.5 meters

Index	Average	Standard deviation	Low limit /95%	High limit /95%	min	max
Average time in anchorage (minutes)	223.4	92.11	197.85	248.94	104.89	580.59
Average handling time (minutes)	1562.95	49.4	1549.25	1576.65	1470.91	1715.83
Average berthing time (minutes)	1774.63	51.74	1760.28	1788.98	1670.96	1932.36
Average time spent in port(minutes)	2087.98	114.42	2056.25	2119.71	1882.68	2479.58
Terminal 1 utilization rate (%)	50.65	1.77	50.16	51.14	47.33	54.92
Terminal 2 utilization rate (%)	31.64	3.4	30.69	32.58	23.31	39.09

Table 6 Effects of increasing the access channel depth in the rate of 12 meters

Index	Average	Standard deviation	Low limit /95%	High limit /95%	min	max
Average time in anchorage (minutes)	180.82	102.84	152.3	209.34	71.59	675.43
Average handling time (minutes)	1557	46.31	1544.15	1569.84	1440.12	1641.71
Average berthing time (minutes)	1766.54	50.27	1752.6	1780.48	1631.89	1852.32
Average time spent in port(minutes)	2037.51	117.83	2004.83	2070.19	1799.9	2497.63
Terminal 1 utilization rate (%)	50.6	1.96	50.05	51.14	44.2	54.32
Terminal 2 utilization rate (%)	31.28	3.63	30.27	32.29	24.81	37.69

Table 7 Effects of increasing the access channel depth in the rate of 13 meters

Index	Average	Standard deviation	Low limit (95%)	High limit (95%)	min	max
Average time in anchorage (minutes)	167.36	81.26	144.83	189.9	42.93	436.59
Average handling time (minutes)	1566.23	42.64	1554.4	1578.05	1455.4	1663.97
Average berthing time (minutes)	1771.77	43.71	1759.64	1783.89	1652.98	1862.57
Average time spent in port(minutes)	2029.28	96.87	2002.41	2056.15	1857.23	2302.59
Terminal 1 utilization rate (%)	48.4	2.34	47.75	49.05	43.08	52.83
Terminal 2 utilization rate (%)	33.41	3.33	32.48	34.33	25.5	39.56

Table 8 Effects of increasing the access channel depth in the rate of 14 meters

Index	Average	Standard deviation	Low limit (95%)	High limit (95%)	min	max
Average time in anchorage (minutes)	148.9	72.61	128.76	169.04	31.99	423.18
Average handling time (minutes)	1560.46	56.09	1544.91	1576.02	1424.69	1679.28
Average berthing time (minutes)	1767.32	55.23	1752	1782.63	1639.38	1883.59
Average time spent in port(minutes)	2006.69	80.06	1984.48	2028.89	1854.65	2236.93
Terminal 1 utilization rate (%)	48.04	2.13	47.45	48.63	44.36	53.65
Terminal 2 utilization rate (%)	34.03	3.22	33.14	34.93	28.24	43.8

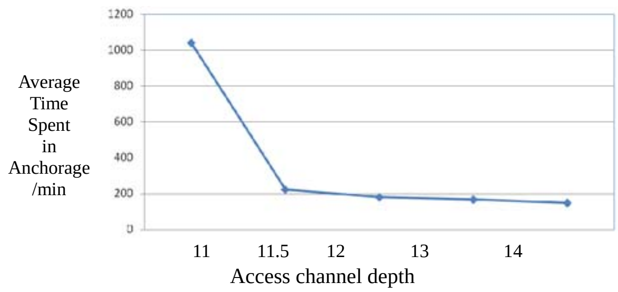

Fig.8 Effects of increasing the access channel depth in reducing average waiting time spent in anchorage

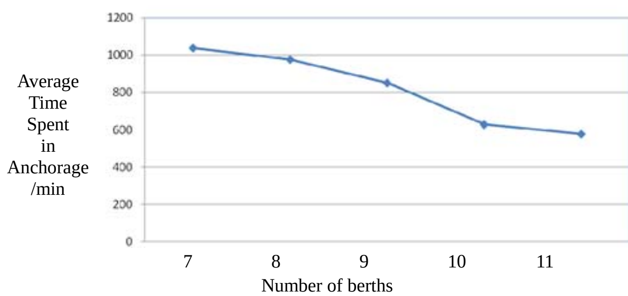

Fig.9 Effects of increasing the number of berths in reducing average waiting time spent in anchorage

7 Effects of increasing the number of berths quay (increasing quay length)

The assumption is that one or several berths which are exactly the same or similar should be added to the existing quay in the container terminal, to the sources added. Such an approach can reduce "Average Time Spent in Port" in the anchorage area during peak periods (high utilization). All of the new berths will be constructed in terminal 2 with a depth of 370 meters and 16 meters draft. According to Fig. 9, the waiting time at anchorage will decrease by increasing the number of berths.

8 Conclusion

As the world's container fleets get upgraded with larger ships, major ports are facing the challenge of accommodating deeper vessel drafts. Nowadays proper planning for standing container ships in port position and the necessity for rapid and orderly loading and unloading them are among the main challenges concerning container ports. Any vessel arriving at anchorage will stay in primary queue where the vessel's situation will be determined constantly and when the vessel possesses the necessary conditions, it will proceed to queue for entering the access channel. These necessary conditions include, appropriate depth of the access channel and existence of at least one proper berth at the quays. At any moment, if the vessel lacks the above mentioned conditions, then it will be directed to the initial (waiting) queue. Therefore the berth allocation of simulation models can help operators to identify the precise restrictions of berthing ships. In order to make better decisions, the simulation model typically produces results such as, quay utilization, crane utilization, turn-around times, waiting times per vessel type (waiting for channel, delays because of weather, waiting for tugs, etc.), tug utilization, landside infrastructure utilization and the usage of the access channel. In this paper two practical solutions are analyzed to reduce waiting time in berth allocation.

1) Determine the access channel depth and 2) Increase the length of the quay. Results have shown that increasing access channel depth to 11.5 meters and increasing the number of berths to 10 will have the affect of reducing container ships'waiting times significantly (Fig.8 and Fig.9). With increasing the access channel depth to 11.5 meters, waiting time will be reduced by approximately 80% as compared to the access channel depth at 11 meters. It should be noted that the average operation time could be increased when the number of berths are increased but the number of cranes are fixed. Because more ships simultaneously can berth with the number of available cranes, loading and unloading operations will be slowed down.

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