International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:6, No:7, 2012

Simulation-Based Optimization in Performance Evaluation of Marshaling Yard Storage Policy in a Container Port

Mohammad Reza Ghanbari, Parham Azimi, Farrokh Abdollahi

***Abstract*—**Since the last two decades, container transportation system has been faced under increasing development. This fact shows the importance of container transportation system as a key role of container terminals to link between sea and land. Therefore, there is a continuous need for the optimal use of equipment and facilities in the ports. Regarding the complex structure of container ports, this paper presents a simulation model that compares tow storage strategies for storing containers in the yard. For this purpose, we considered loading and unloading norm as an important criterion to evaluate the performance of Shahid Rajaee container port. By analysing the results of the model, it will be shown that using marshalling yard policy instead of current storage system has a significant effect on the performance level of the port and can increase the loading and unloading norm up to 14%.

***Keywords*—**Simulation Modeling, Container Port, Marshaling Yard, Storage Policy

I. Introduction

THE dramatic increasing of sea-freight container transportations and the developing trends for using containers in the multimodal handling systems through the sea, rail, road and land in nowadays market cause general managers of container terminals to face challenges such as increasing demand, competitive situation, new investments and expansion of new activities and need to use new methods to fulfil effective operations both along quayside and within the yard. This development has reached to 7 or 9 % in a year [1] and it is predicted that this increase will have a rate of about 10 % until 2020 [2] while for other sea transportation means; the rate will be just 2 % annually.

Shahid Rajaee Container Port (SRCP) as the biggest container port in Iran is in the south of Iran in the entrance of the mouth of Persian Gulf, which trades goods and is connected to more than 80 well-known ports throughout the world now. Terminals 1 and 2 with the storage capacity of 168,000 TEU (Twenty Equivalent Unit) are able to do 3,100,000 TEU container operations a year in this port. The performance of SRCP indicates its increasing development in container operations in recent years, such that this development is noticeably observed in reputable world ranking reports.

Mohammad Reza Ghanbari, Young Researchers Club, Qazvin Branch, Islamic Azad University, Qazvin, Iran, (E-mail: ghanbari_mrg@yaho.com).
Parham Azimi, Department of Industrial Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran, (E-mail: p.azimi@yahoo.com).
Farrokh Abdollahi, No. 5, Bahar Shiraz St., Dr. Shariati Ave., Tehran, Iran, (E-mail: Abdolahi_60@yahoo.com).

According to the statistics in the international journal of cargo system, the rank of SRCP with 2,590,000 TEU was 44 in 2010, among all ports in the world [3].

Review of previous researches shows that most researches have used queuing theory as a method for estimating the performance of the port system such as Kozan [4]. But most of these researches have made some special assumptions to simplify the real word problems [5]. For example, most researches just considered a single queue for internal operations while in a real port, there are several queue networks which increase the complexity of the problem and decrease the power of analytical methods like queuing theory in solving such problems. Won Young Yun [6] concluded that simulation method is an effective option for system analysis of all container ports. Besides the method of solving the port problems, classification of the problems have also created variety in previous researches. According to classification which is in the [7], our study is a strategic problem with planning type and related to transfer and storage subsystems so that the managers of SRCP should consider. The management of yard operations involves several decision problems: the design of storage policies at the block and bay level according to the specific features of the container (size, weight, destination, import/export etc.); the allocation, routing and scheduling of yard cranes; the design of re-marshalling policies for export containers [1]. Chung et al. [8] proposed a methodology based on a graphic simulation system to simulate the use of buffer space to increase the use of handling equipment and reduce total container loading time [9]. Vis et al. [10] proposed to use buffer areas in the transfer quay-yard, so that the process can be decoupled in two sub processes: unloading and transportation. An integer programming model determines the minimum size of the fleet such that each container is transported within its time window. Analytical results are validated by simulation: numerical experiments show that the model provides a good estimate of the number of vehicles needed. Lee et al. [11] addressed a yard storage allocation problem in a transhipment hub with the objective of reducing reshuffling and traffic congestion. They aim to assign containers to sub block locations as well as yard cranes to blocks and propose a mixed integer linear programming model which minimizes the number of cranes needed to handle the total workload. Lee and Hsu [12] presented a model for the container re-marshalling problem: in order to utilize yard space more efficiently and speed up loading operations, they propose to re-marshal containers in such a way that they fit the loading sequence.

The problem is modelled as a multi commodity flow with side constraints: the model is able to re-position export containers within the yard, so that no extra re-handles will be needed during the loading operations. A solution heuristic is discussed and computational results over synthetic instances close to real ones are provided. Yin and Yang [13] proposed game theory to evaluate the layout of marshalling yard. The evaluation index system and the gaming model are established by AHP and game theory, respectively. The solving method applied to the game model of marshalling yard is proposed and the practical application shows that game theory approach can provide good decision support for the layout of the marshalling yard. As the results we can say that few recent researches considered validation process according to historical data. In this paper we have proposed a general model for all subsystems in SRCP in order to create a robust degree of integration among logistic chain in the port for the examination of SRCP performance. Using the simulation software (Enterprise Dynamic 8.1) and the existence of its 3D graphic utilities besides its animation environment, caused to carry out a good verification process of the model. In the used model, there are 3 subsystems of ship to shore, transfer and storage and it covers a considerable integration of the container transportation chain in the port. Another outstanding point in the current research is considering the detailed configuration of unloading, loading and transferring of containers equipment with stochastic repair and maintenance times for gantry crane which have not been studied in the previous researches so far. The purpose of the current study is to create a model for SRCP in order to evaluate the performance of the port in two cases and to compare the results. The case one is the current storage system of the containers in the yard and the second is our proposed model for storing the containers in a buffer area near the quay so called "marshalling yard". For this reason, we have used loading and unloading norm as an important performance index. In section II, a description of the problem has been explained. In section III, the process of modelling is mentioned. In section IV, the simulation output is examined to compare two cases and finally in section V, the summary of the results are indicated.

II. Problem Description

A container terminal (CT) is a place where ships can be berthed near the quay and can give some services to vessels by gantry cranes (GC). The given services include: unloading the container from the vessel or loading the container on the vessel. Container terminals can be viewed as a temporary storage area, so the containers can be kept there from the time of unloading till the moment of delivering to the customers. Therefore, the unloaded container from the vessels by GC should be transferred to suitable places in the yard.

To do so, the containers in SRCP are loaded on some internal trucks after unloading in order to be transported to the container yard (CY). With respect to the fact that the unloaded container is import (IM), refrigerator (RF), tranship (TR) or empty (EM), it should be moved to the related blocks determined in the CY.

As soon as the trucks arrive to the CY, other equipment called Rubber Tyred Gantry Cranes (RTGC) start unloading trucks and arrange the containers in predefined blocks.

As mentioned before, a container may be kept in the CY from one hour to several days, and then it is taken away from the CY either to be loaded on the vessel or to be delivered to the customers. TR containers are the ones which are usually unloaded from bigger ships in the terminal and for reloading on ships that depart toward other container terminals in or out of country. They are temporarily being kept in the port. These types of container together with EX containers -which are in the related blocks in the CY-, are being used to load on vessels by RTGCs.

The loading and unloading norm is one of the most important performance factors of a container port. This index explains the rate of the loading and unloading containers per hour for each vessel. Before offloading a vessel in the quay, the expected loading and unloading norm for each vessel is calculated as follows:

$$\frac{LOA * 6.5}{23} = \text{Norm (Moves/ Hr.)}$$

This equation consists of LOA which is the length of overall the vessel and tow constant numbers. The obtained norm shows the number of loading and unloading movements per hour that must be done for giving a standard service to the specific vessel. A decrease in the value of the norm could be costly for the owner of container ports. Therefore, an increase in this index to the greatest possible value is among the first goals of container port studies. In this regard, selection appropriate strategy for storing containers in the yard and optimal use of equipment can contribute to increase the norm value.

The problem starts when a vessel arrives to the port and a part of its load has to be unloaded. Each container can follow one of two possible routes: One way is directly to its predetermined location in the yard, the other is first to a buffer location and later to its final location. According to these routes, two problems arise. Therefore in this study we have compared these two cases:

- The first problem is the current policy for unloading containers and transferring them to the final location from the berth to the yard directly which is shown in Fig. 1.
- The second problem is our proposed policy for creating a marshaling yard near the berth to keep containers temporarily and to transfer them to the yard later which is depicted in Fig. 2.

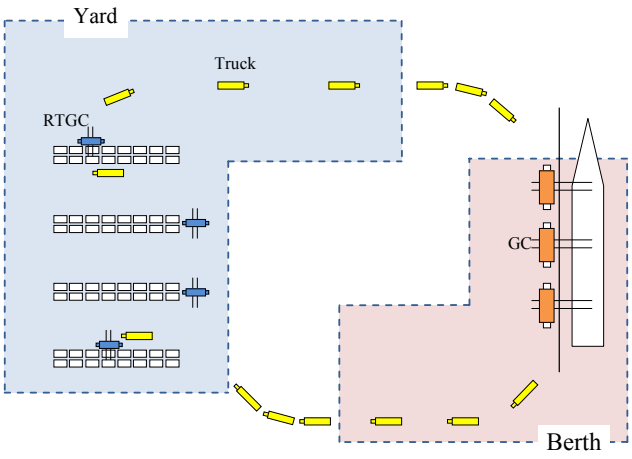

Fig. 1 The current policy to transfer container from the berth to the yard directly

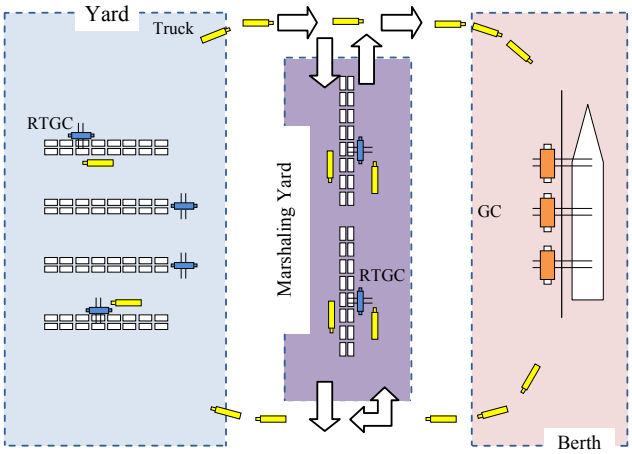

Fig. 2 Proposed policy to create marshaling yard near the berth

SRCP is using direct route for transferring containers to the yard. In current storage system at SRCP, the yard is segregated based on container type and containers are stored according to the specified blocks. Arrived containers therefore, have a specific destination in the yard. But in our proposed model, some of containers are brought to the blocks directly and other containers are temporarily placed in the so-called "marshaling yard". In the marshaling yard, containers are placed randomly. No locations in this part of the yard are reserved for specific containers. Since reservations of blocks lead to temporary non-occupation, the marshaling yard in general allows a higher occupation rate than direct rout policy. As soon as more truck is available, these containers must be brought to the corresponding destination. At present in SRCP, none of containers are currently brought to the marshalling yard and they are moved to their predetermined locations in the yard.

Of course, marshaling yard policy is not efficient from the perspective of the number of load and unloads that have to be performed by RTGC and terminal trucks [14].

Nevertheless, marshalling yard also has advantages: Since all different types of containers are mixed here, one set of RTGCs located in marshalling yard is sufficient and no time-consuming RTGC-movements between sub blocks have to be performed. Naturally, a higher level of segregation therefore, leads to lower productivity of the GCs during the unloading operation because in the current policy all containers go to the predefined locations.

As mentioned before, in this work we are going to study two policies of unloading and transferring the containers from vessel to yard and compare these policies from the perspective of evaluating the norm index.

III. Simulation Modeling

In this section we explain the details of the marshaling yard model. The structure, the input data, the warm up period and the validity of the model have been described in this section.

A. Model Architecture

The structure of the marshaling yard model consists of 3 subsystems which provide entrance resources of the main framework of the model. These 3 subsystems are the same as the model of current storage system which is developed by Azimi and Ghanbari [7]. Indeed the resources for two models are the same; therefore, 3 subsystems in two models exactly resemble each other. The containers are generated in subsystem 1 and then the containers are placed on the vessels. After that in subsystem 2, the vessels enter to the port. The enter arrival time of the vessels follows exponential distribution with the average of 9.41 hours which is obtained from historical data. Finally in subsystem 3 the vessels enter to the anchorage and will wait to prepare entrance condition to entre to the main framework of the model. More detailed information about these subsystems has been shown in [7].

B. Main Framework of the Model

In the main framework of the model, we describe the method of loading and unloading of a vessel, the equipment for these purposes, the movement of containers from the berth to the yard and vice versa and the method of storing containers in the yard and marshaling yard. Also main difference between current storage system at SRCP and our proposed policy is clarified in this section.

As Fig. 3 shows, in the current storage system, containers are being unloaded in the berth and stored in the predetermined blocks directly and will remain in the yard till the time they leave the terminal. Also export containers or empty containers that are transported for loading will remain for loading on the vessel after being placed in the defined blocks.

In Fig. 4, there is an additional area i n the yard so called "marshaling yard". The space of marshaling yard is assigned to import containers. Therefore, import containers are brought to the marshaling yard for storing temporary and other containers are transferred to the yard directly. As soon as more RTGC and trucks are available, the containers in the marshaling yard must be brought to the corresponding. The process of loading containers is the same as current storage system.

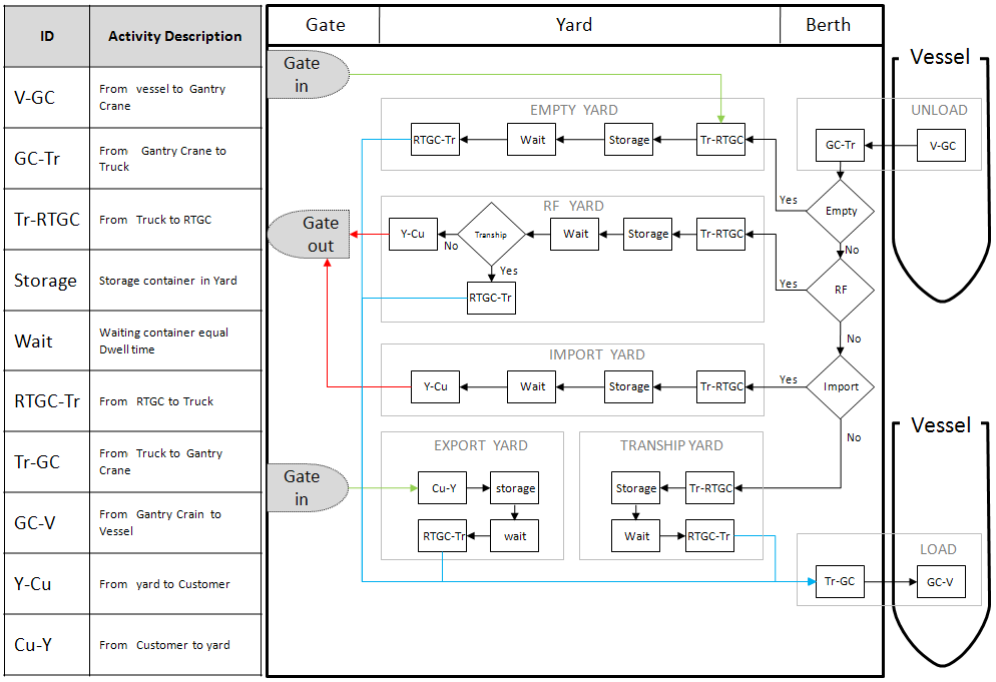

Fig. 3 The main structure of the current storage system

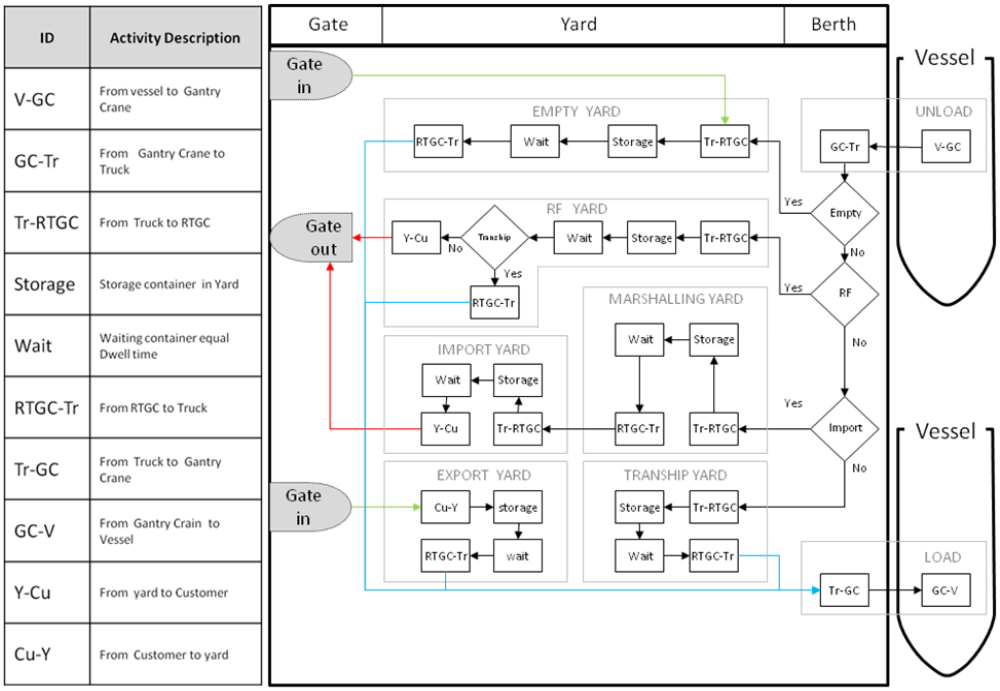

Fig. 4 The main structure of the marshaling yard system

C. Data Collection

The data needed for creating the model was collected and analyzed through recorded documents available in SRCP in2010 and 2011. In this regard, data is related to the arrival of 935 vessels into SRCP including the arrival times, berthing times, operation times, the number of loaded and unloaded containers, the length of vessels and departure times from the port. The rest of information is about the equipment and the yard. To obtain the most appropriate distribution functions and carry out the statistical analysis, the data is examined by Easy Fit software. By analyzing the historical data, was distinguished that the containers types and sizes follow an empirical distribution. Also Analyzing the arrival time of all

vessels to the port and using the chi-squared test, showed that the period of time between the arrivals of two consecutive vessels has an exponential distribution with the average of 9.41 hours.

For the length of vessels we obtained an empirical distribution which is divided into 15 spans. Each vessel carries a number of containers to the port for unloading, and each vessel loads a specific number of containers and leaves the port. The number of the containers is chosen according to an empirical distribution taken from the historical data.

According to the data gathered in the actual operations, the number of movements for each GC follows the normal distribution with the average of 21 moves/ hour and the standard deviation of 5.56. On the other hand, the service time of a GC has lognormal (180.83, 49.86) distribution in the real world which was used in the simulation model.

With the analysis of the 10 GCs available in SRCP, and supposing that the mean time before repair (MTBR) is equal to zero, and also supposing that the mean time to repair (MTTR) for each GC follows the empirical distribution, the related index of mean time to failure (MTTF) for all GCs follows Weibull distribution.

According to the technical specifications of RTGCs, the service time for every loading and unloading by a RTGC is equal to normal distribution with the average of 84.25 seconds and the standard deviation 18.92. The number of RTGCs determined for the model is 41 cranes. For each block there is one dedicated RTGC. The yard layout of current storage system and marshaling yard policy is depicted in Fig. 5 and Fig. 6 respectively. Indeed in the proposed layout we assigned the blocks 1, 2, 3 and 4 to the marshaling yard which were for empty containers in the current system. The storage capacity of these 4 blocks is over 3,500 TEU.

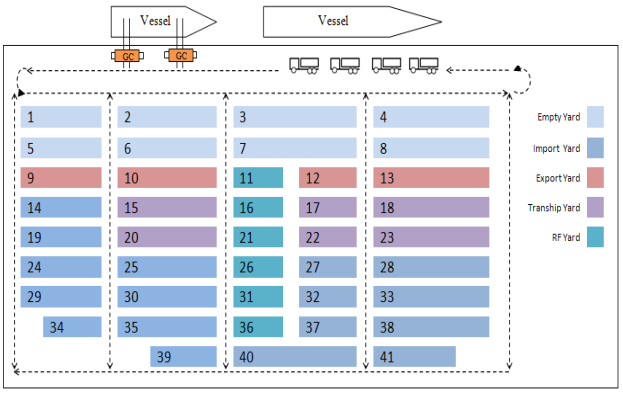

Fig. 5 Current SRCP yard layout

In two cases, 50 trucks are handling the containers between the berth, marshaling yard and container yard. The highest speed for movements of the trucks in the port area is 25 Km/hr. The routes of trucks and one-way or two way routes can be observed in Fig. 5 and Fig. 6.

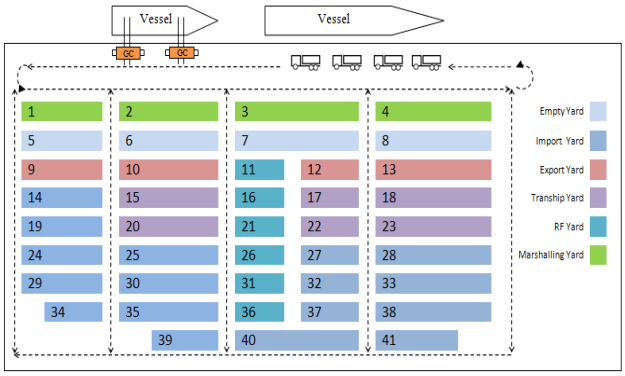

Fig. 6 Marshaling Yard layout

D.Warm up Period

In the beginning of the simulation, the model is empty without any inventory. Therefore, the data obtained from it may not be appropriate for analysis. To avoid this matter a period of time is taken into account for the model as the warm-up period. This is the passing time for the system to move from a state of instability to a relative stability. There is variety of methods for determining this warm up period. In this study we have used the Welch method [15]. This method is based on the repetition in the different time periods of simulation and drawing the graphic diagram for the moving average of the index. The index that was used here is the number of departed vessels. According to the results, the value of this index is between 1 to 35 week periods and for each period; ten different replications were done in the simulation model. Finally by drawing the graphic diagram of the moving averages, it was shown that after week 13, the model has a stable behavior. Therefore, in the analysis of the model, 13weeks is considered as the warm-up period. Fig. 7 shows this fact.

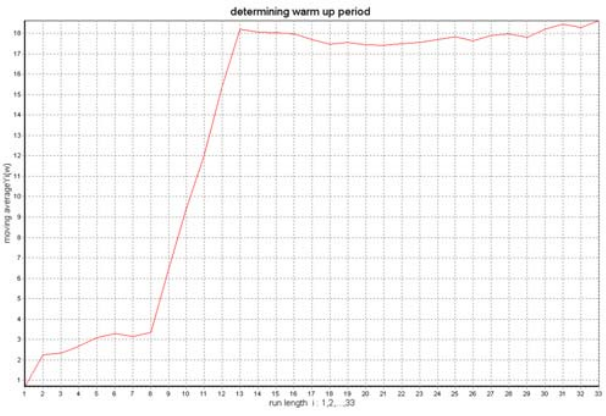

Fig. 7 Determining the Warm up Period

E. Verification and validation of the model

Regarding the fact that the presented model has been constructed in a graphical environment, and the simulation software has several tools for creating animation and 3D environments, the model has enough accuracy regarding verification aspect.

But whereas the proposed model for the marshaling yard is a new policy in the port and it is not performed in the port until now, we do not have any feedback from this policy and any data from actual system. Therefore, we cannot carry out statistical validation to compare the simulation model with the real system. With knowing this fact, the verification process is sufficient to ensure the model works well.

IV. Experimental Results

In this section we are going to analyze the marshaling yard policy by carrying out appropriate experiments. We use design of experiment to compare the following alternatives:
Alternative 1: current storage system for transferring and storing the container in the yard, directly.
Alternative 2: marshaling yard policy, for storing import container in a temporary area (marshaling yard) and transferring them to the yard later.

According to the model which was explained in section 3, we ran the simulation model and recorded output results. Also we apply loading and unloading norm as a performance index for the purpose of comparison of two alternatives.

In the first step we determine needed replications for running the marshaling yard model. According to the [15] and by using Chung method, we concluded that the sufficient number of replications is 10.

After that we carried out the experiments with the following characteristics for the marshaling yard model:

- The observation period is determined to be 1 year.
- The number of replication is 10.

The warm-up period is 13 weeks.

The output results of the experiments are given in the TABLE I.

TABLE I
Output Results of The Marshaling Yard Model Experiments

replication number	Mean loading and unloading norm (Moves/Hr.)	replication number	Mean loading and unloading norm (Moves/Hr.)
1	53.72	6	57.20
2	54.82	7	53.89
3	56.49	8	59.61
4	57.61	9	58.88
5	63.56	10	62.77

Also we gathered the norm index for the current storage system from the historical dada. Therefore, we have two sets of data. The first data set includes 395 loading and unloading norm indexes which are collected from the actual system and the second data set includes 10 loading and unloading norm indexes which are related to the output of the model.

In order to compare two alternatives, we use Welch confidence interval approach according to [15]. It assumes the worst-case scenarios of having dissimilar variance between the two data sets. The Welch confidence interval approach is based on the Smith–Satterthwaite *t* test. After calculating the mean and standard deviation summary statistics for each data set, we must calculate the degrees of freedom estimator as with the Smith–Satterthwaite test using the formulation below:

$$\text{d.f.} = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{\left[\frac{s_1^2}{n_1}\right]^2}{n_1 - 1} + \frac{\left[\frac{s_2^2}{n2}\right]^2}{n_2 - 1}}$$

Where:
d.f. = degrees of freedom
s_1^2= sample variance of the first alternative
S_2^2= sample variance of the second alternative
n_1= sample size of the first alternative
n_2 = sample size of the second alternative

As with the Smith–Satterthwaite test, the number of degrees of freedom calculated in this manner will most likely not be an integer. We must round the estimated degrees of freedom downward. The Welch confidence interval can now be calculated with the following formula:

$$\bar{x}_1 - \bar{x}_2 \pm t_{\text{d.f.},1-\alpha/2}\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

Where
$\bar{x}_1$ = the mean of the first alternative replications
$\bar{x}_2$ = the mean of the second alternative replications
t = the t value for the degrees of freedom previously estimated and 1-α/2

The above equation describes the Welch interval at a given level of confidence. The above equation is most commonly seen in its final form with minimum and maximum values that describe the interval at a given level of confidence in this way: [min value, max value].

If the confidence interval covers the value 0, then there is no significant difference between the two simulation model alternatives. Conversely, if the confidence interval does not cover 0, then there is a statistically significant difference between the two simulation models.

Table I represents the loading and unloading norm index gathered from simulation runs. Also the mean and standard deviation of norm index for alternatives 1 and 2 are shown in Table II. To calculate the Welch confidence interval at α level of 0.05, we begin with the degrees of freedom estimator. The degrees of freedom estimator is calculated in Table II.

According to the calculation shown in Table II, the actual confidence interval is: [-10.43, -4.35]. The confidence interval does not cover zero with an α level of 0.05. Therefore, we can conclude that the two alternatives are statistically significantly different. Because alternative 2 has a higher norm index of 57.85 versus the norm index for alternative 1 with a norm of 50.46, under normal circumstances, we would recommend alternative 2.

TABLE II
THE WELCH CONFIDENCE INTERVAL CALCULATIONS FOR NORM INDEX

Alternative	Mean	Variance	n
1 : Actual System	50.46	415.87	395
2 : Marshalling Yard	57.85	11.70	10
d.f		31.90	
round downward d.f.		31	
t for alpha/2=0.025 and 31d.f		2.042	
Welch confidence interval	min value	-10.43	
	max value	-4.35	

Now for getting detailed analysis, we present Table III. Table III exhibits some comparisons between the results of marshaling yard experiments and the current storage system. As mentioned before and by considering the row 1, the loading and unloading norm has an increase of about 14.7 % in the marshaling yard policy annually. This increase means growth in vessels serving, just as it is obvious in the row 2, the mean operation time on each vessel decreases from 17.53 to 15.85 hours.

According to what is stated in the row 3, when we use the marshaling yard policy, we can see an increase in the number of vessels which are abandoned the port in one year. In other words, we can give more services to the vessels by carrying out the marshaling yard policy. Due to decrease in the operating time on each vessel and speeding up the rate of serving, the number of served vessels has been reached to 971 vessels.

TABLE III
COMPARISON BETWEEN THE CURRENT STORAGE SYSTEM AND THE MARSHALLING YARD PERFORMANCES

row	Performance indicator	The average of outputs of the simulation model	Current system
1	Mean loading and unloading norm (moves/ hour)	57.85	50.46
2	Mean operation time on a vessel (hours/ vessel)	15.85	17.53
3	Number of served vessels in one year	971	935
4	Total operation time on all served vessels in one year	15390.35	16390.55

For analyzing this case, it should be mentioned when the rate of vessels serving increases, after that the number of customers which leave the system increases and this status means increase in satisfying the customer demand.

By creating a buffer area near the berth, the trucks travel shorter distance for transferring the unloaded containers from the berth to the marshaling yard and cycle time of this route take a shorter time. Therefore, GCs will wait less for the arrival of the trucks and this is the same as the fact that more times are available for GCs to load and unload, therefore, the number of loaded and unloaded containers by means of GCs is raised and then the loading and unloading norm will improve.

As cited in the row 4, in spite the fact that the number of served vessels has been increased in one year from 935 to 971, but the total time of vessels serving is faced a decrease and this decrease make a good potential opportunity for the port to develop the volume of loading and unloading operations.

By supposing that the number of served vessels in the current storage system is 935 in a year and the average of the service time to each vessel is 17.53 hours and the rate of loading and unloading norm is 50.46 moves per hour, the capacity of loading and unloading is estimated about 827,000 moves annually. On the other hand, by carrying out the marshaling yard policy this amount will reach to 890,000 moves of container which demonstrates an increase about 7.62 % in the volume of loading and unloading operations.

V. CONCLUSIONS

In this paper, we presented a simulation model of marshaling yard policy based on integration of subsystems and considering detailed specifications of transferring equipment. By analyzing the results of the model and considering the loading and unloading norm as a performance indicator, it was shown that applying the marshaling yard policy can some advantages in comparison with the current system in SRCP. Because, it can increase the rate of vessels serving besides it will increase the loading and unloading capacity of the port whereas performance of this policy does not need any capital investments in equipment. The experiment results showed that in marshaling yard policy the loading and unloading norm has an increase of about 14.7 % which can improve the volume of loading and unloading operations up to 7.62% in a year.

REFERENCES

[1] I. Vacca, M. Bierlaire, M. Salani, "Optimization at Container Terminals: Status, Trends and Perspectives," *7thSwiss Transport Research Conf*. Monte Verita /Ascona, September 12-14. 2007.

[2] L. Henesey, P. Davidsson, J. A. Persson, "Agent Based Simulation Architecture for Evaluating Operational Policies in Transshipping Containers," *Multi agent System Technologies*, LNAI, Vol. 4196, Springer, pp, 73-85, 2006.

[3] D. Nazari, "Hundred Container Ports in the Word," *Port and See*, 97-98, 2011.

[4] E. Kozan, "Comparison of analytical and simulation planning models of seaport container terminals," *transportation planning and technology,* 20 (3), 235–248, 1997.

[5] A. A. Shabayek, W. W. Yeung, "Simulation Model for the Kwai Chung Container Terminals in Hong Kong," *European Journal of Operational Research*, 140, 1-11, 2002.

[6] W. Young Yun, Y. Seok Choi, "A Simulation Model for Container Terminal Operation Analysis Using an Object-Oriented Approach," *Int. J. Production Economics*, 59, 221-230, 1999.

[7] P. Azimi, M. R. Ghanbari, "Simulation Modeling for Analysis and Evaluation of the Internal Handling Fleet System at Shahid Rajaee Container Port," *World Academy of Science, Engineering and Technology Proceedings*, 78, 644-655, 2011.

[8] Y. C., Chung and S. U. hawa, "A simulation analysis for a transtainer-based container handling facility," *Computers and Industrial Engineering*, 14 (2) 113-125, 1988.

[9] A. Cartenì, G. E. Cantarella, G. E. De Luca, "Simulation of a Container Terminal through a Discrete Event Approach: Literature Review and Guidelines for Application," Technical Paper, Dept. of Civil Engineering, University Of Salerno, *European Transport Conference, 2009 Proceedings.*

[10] I. F. A., Vis, R. de Koster, and M. Savelsbergh, "Minimum vehicle fleet size under time-window constraints at a container terminal," *Transportation Science,* 39: 249–260, 2005.

[11] L. H., Lee, E. P., Chew, K. C., Tan and Y. Han, "An optimization model for storage yard management in transshipment hubs," *OR Spectrum*, 28: 539–561, 2006.
[12] Y., Lee, and N. Y., Hsu, "An optimization model for the container pre-marshalling problem," *Computers and Operations Research*, 34: 3295–3313, 2007.
[13] Y. Yong and Y. Yang, "Evaluation of Marshaling Yard Layout with Game Theory," *Proceedings of the 2010 International Conference of Logistics Engineering and Management*, Volume V.
[14] S. P. J. Hilkens, M.s Thesis, "Pre-stacking at a large transshipment terminal trade-off between the costs of segregation and quay crane productivity," Eindhoven University of Technology, 2002.
[15] A. M. Law, W. D. Kelton, Simulation Modeling and Analysis, 3rd Ed. New York: Mcgraw Hill. 2000.