



Optimizing a container terminal and facilities assignment using a simulation approach by ED software: a case study of Iran

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Abstract: These days container transportation is one of the fastest and cheapest ways to carry the cargoes with an extent volume. Some features of maritime transportation are reducing loading and unloading costs, reducing transportation risk, better using of deck space and etc. In this paper we use a simulation optimization model to make a better assignment of facilities cooperating in loading and unloading operation (LUO) at berth in order to minimize the ships waiting time. To validate the experiments, a real case study is taken. The case is one of the national container terminals in Iran named "Shahid Rajaei" which has been located near the Persian Gulf. Comparing the output of the model and real data implies the good efficiency of the model.

Keywords: Container terminal, Trucking, Berth allocation problem, ED simulation approach, facilities assignment, case study.

I. Introduction

Nowadays container ships play an important part in transportation industry. This kind of carrying is one of the fastest and cheapest ways for high volumes of goods. Shahid Rajaei is one of the largest container ports in Iran shown in figure 1. This harbor has been located in Hormozgan province and near the Persian Gulf. Shahid Rajaei – as the largest container terminal of Iran – has the highest volume of container operations showing economic and commercial aspects of it. This terminal includes one-container and two-container parts and accepts all Feeder and Liner ships – 21 Liner ways travel to the harbor. Shahid Rajaei terminal development project consists of building a new terminal in scope of the port which is supposed to increase the container capacity. So we determined the issue as an important task and tried to do it under a simulation project.

Since deciding about investing in harbors includes a lot of factors about which uncertainty is an inseparable part, so a comprehensive analysis of container terminals before any kind of measure is an essential matter. One of the ongoing disturbances of the terminal is increasing coastal (fixed) cranes, moving and enclosure ones, lift trucks and other facilities.

The paper is based on the real data which has been produced in statistical systems. The data includes container ships, length of coastal ways, operations and arrival time of ships, facilities, number of docks and etc. Also investigating the issue shows that maintenance operations have not been propounded yet and therefore we have included the subject in our study.

II. Literature review

With the extension of computer technology and gained successes in harbors, simulation approach has been widely applied in solving and programming problems related to container terminals. During the last decade a noticeable development has been occurred in the subject of container transportation suggesting need for optimization and close competition in harbors. Mazza and Legato (2001) have presented a logistic simulation model related to processes of ships' arrival to the dock, their berthing and also return operations in container terminals and studied the berth programming. Kia and colleagues (2002) considered the computer simulation in performance of container terminals and also compared the capacity of terminal with the same in past. Investigations of Shabayek and Yeung (2002) implied that development of which matters brings forward the estimations of a simulation model to the reality in a terminal. R. Stahlbock and S.Vo (2008) presented a paper with the subject of operations research in container terminals in which many aspects have been considered. Sun and friends (2012) studied a general simulation model for Mikro port that was a three-level programming model with the goal of preparing a flexible and integrated system for container terminals. Arango (2011) considered an optimization technology based on simulation for programming and assignment of ships' berthing in dock space resulted in changing the management of the dock. Cortés and friends (2007) also focused on transportation process and applied Arena software for simulation of serveel harbor. Some authors have focused on programming and investing problems. For example Afandizadeh and Allahviranloo have presented a fuzzy

integer programming for optimization of investing in harbors. Analysis methods also should be applied in second stage when comparing to the simulation technology because of complication and uncertainty of container systems. Papers which have studied the investment issue are too rare but it is pointed that Nam and colleagues (2009) studied the berthing operation and a special kind of cranes for container terminals in Korea resulted in the fact that most of cranes should be participated for increasing productivity. Demirci (2003) also surveyed a simulation problem in a harbor of Turkey and found that a large number of bottleneck points have been settled by the use of simulation technology.

Different authors have focused on BAP – ships assignment for berthing- for example Imai (2001) and Nishimura (2001) pointed the matter, they also applied a genetic algorithm for conformity with the reality. Park and Kim (2003) and LIU (2005) surveyed the problem considering quay cranes and intended to optimize the number of them. Imai and friends (2007) developed an approach in MUT – multiple container terminals. At the beginning, they presented an approach based on continues assignment and then solved the problem with a genetic algorithm. Imai (2003) had considered the relation between ship ways and harbor.

Few papers have developed in port simulation and optimization measures. Cortés (2007) studied the transportation operations in a harbor and argued all kinds of loading, towers and scenarios. Demetro (2005) and Legato (2009) considered a simulation model about cranes programming.

III. Problem definition

Accurate definition of the problem has the most effects on the model simulated. If the problem is defined incorrectly, it will cause lots of time for analyzing. So it is important to define the problem obviously and document it as an essential property.

Although the harbor has been developed in the container part, the management has determined to extend it more. We aim to find the optimum number of cranes based on the available capacity and also the ships' waiting time until the end of unloading process, so we are going to balance the mentioned time. Ships anchored in the harbor for unloading are included in staying charges meaning that it is paid an amount of money for an hour of sleeping. So we are to optimize the average sleeping expense which has not been investigated before.

A. Container ships

There are three types of ships including large of 150 meters, 200 meters and small ones of 60 meters. The arrival of large ships is in a linear schedule but it is randomly for the small ones (Features of the ships have been shown in table 1). The time between two successive arrivals of large ships is constant so that their arrival distribution is linear. For example the time between two successive arrivals for large ships of 150 meters is constantly 10 (h) and never changes. But since small ships arrive in harbor randomly so we consider poison process for them meaning that the time between two successive arrivals follows exponential distribution with the parameter of $\lambda=1/5$. In this way we have used the daily and monthly statistics in December, January and February of 2013-2014 by ports organizations.

Table 1: Ship features

type of arrival	time between successive arrivals (hour)	average TEU	length (meter)	type of ship
Linear	6	1500	150	Big-150
Linear	8	2200	200	Big-200
Random	4	140	60	Small-60



Figure 1. The location of Shahid Rajaee port

Cranes and facilities

3.2.1. Tow:

As a ship is settled at a certain distance of port, its engines are turned off and the first action to do in this stage is that the small boats known as tows carry the ship to the dock. We have considered four tows in the paper.

3.2.2. Coastal (fixed) crane:

There are some coastal cranes which have been fixed in the dock doing unloading operations from the ship by designed rails. They are components of the harbor and we have considered two of them.

3.2.3. Moving cranes:

Moving cranes are applied to accelerating the unloading process and they are rented from non-governmental organizations. We have used two moving cranes in the study.

3.2.4. Lift trucks:

Lift trucks are applied to carrying containers – which are in the temporary storage – to the permanent ones or outer cargo trucks. If there is any truck in the dock, the container will be placed on it otherwise it will be stored in the permanent storage. There are also two lift trucks applied under the determined policy in the problem.

3.2.5. Cargo trucks:

Given container transportation system is connected to the outer cargo trucks carrying the containers to the out of the dock. The operations are done in a special policy.



Figure 2. Berthing in the harbor

3.3. Policies and assignment:

We aim to follow a policy based on reality to be applied to development of the container part. So we have considered lower and upper bounds for the number of coastal (fixed) cranes, moving ones, towers and lift trucks shown in table 2. We have also accomplished maintenance system for towers and moving cranes in the aspect of container ships for the first time that will be explained in the concerned part.

There are also special policies in different parts of carrying and lift trucks described in simulation scenario. As shown in table 2, upper and lower bounds let us do sensitivity analysis for gaining optimal solution. For example, the number of fixed cranes is actually two and the upper bound four shows the development potential of wharf. These policies have been taken to make the model more actual.

Table 2: Upper and lower bounds for development

Facilities	Lower bound	Upper bound
Fixed crane	2	4
Moving crane	2	3
Lift truck	1	2

3.4. Simulation flowchart:

Simulation scenario involves ships arrival, data partitioning, services and ships departure which has been shown in figure 3. First, the ship arrives in system and then it is categorized into large or small ones. It should be considered that ships arrival time, capacity, length and their priority are different and the ships are kept waiting until an unoccupied wharf is found for assignment. Then it is checked whether the tower is ready or not and if the answer is no, we will ask whether it is working or being served by maintenance system and the wharf is assigned as well. As the wharf assignment and ship berthing is done, the coastal cranes begin to work and it is determined whether there are enough or not. If there aren't enough fixed cranes, the moving ones are applied – if they are ready and do not need maintenance. As cargoes are moved to the temporary coastal storage, they are analyzed and it is commanded for departure. Then the lift truck begins to unload from temporary storages under the assumed policy and the cargoes are taken to transportation system or permanent storage. The transportation

system involves trucks with the capacity of 20 containers and if there isn't any truck, the containers will be moved to outer storage by the lift trucks.

IV. Simulation and model details:

We have developed an efficient and complicated model for port simulation which is based on the following assumptions – some of these assumptions are discussed for the first time in systems for container ships:

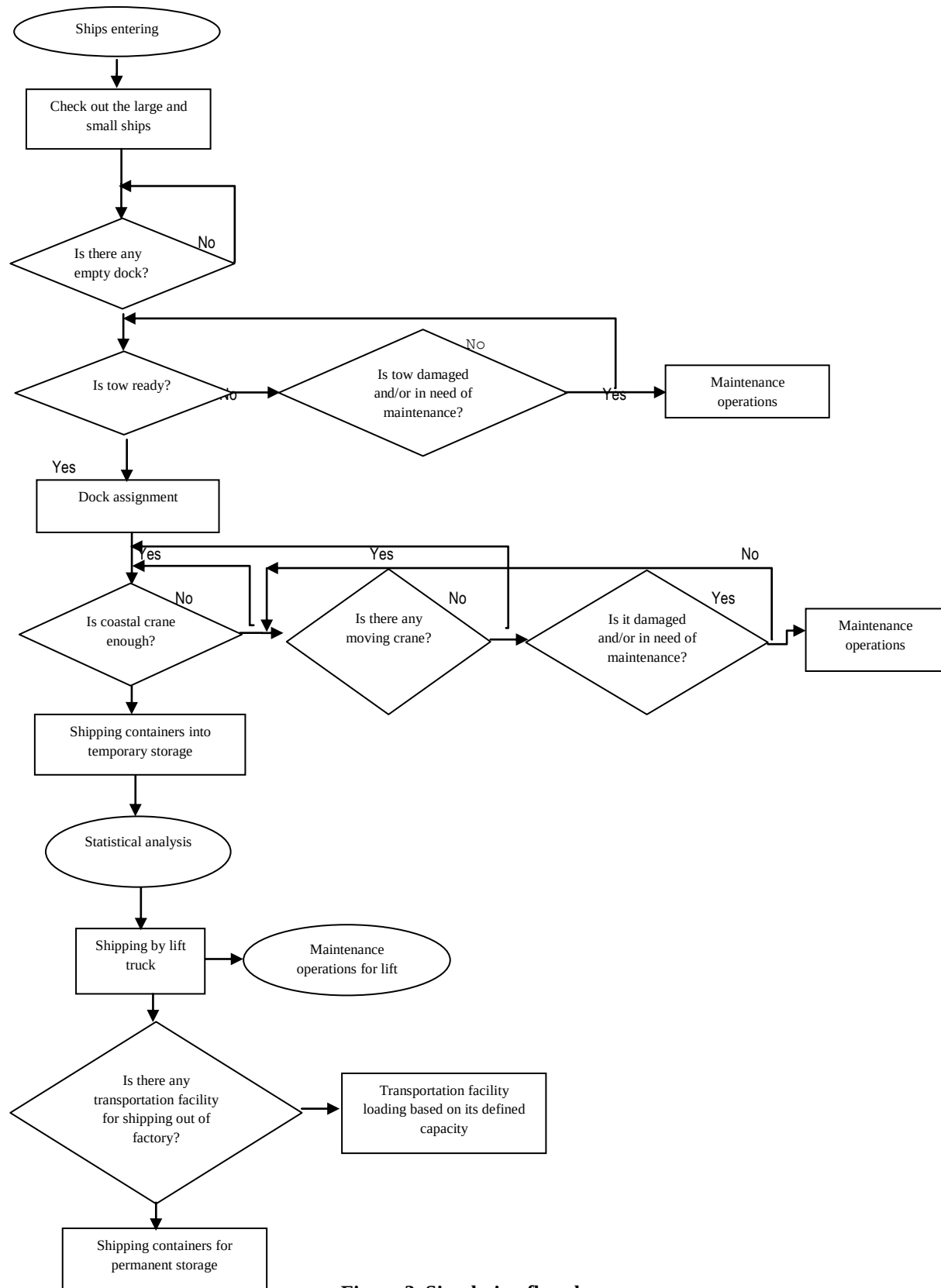


Figure 3. Simulation flowchart

- Demand forecast is accurate enough and the paper is based on detailed assumptions such as time between two arrivals and etc.
- Costal cranes are in need for maintenance operations and they don't always work well. They need maintenance after ten times unloading operations.
- Moving cranes which are privately owned, need periodic inspections and maintenance in every ten days and for two hours.
- All ships berth immediately upon providing the conditions and leave the wharf after loading process.
- There is no limit on the depth of water (tide).

The mentioned simulation model is based on four systems including ships arrival and their berthing, allocation of resources and equipment, maintenance operations and transportation. These systems are listed above

A. Arrival and berthing of ships

This is the driving force of the whole system because all the next steps start from here and special rules also arise from it. For example, 200-meter ships come once every 8 hours.

B. Allocation of resources and equipment

When a ship enters the resource allocation system, the associated equipment - if available - is allocated, otherwise waits as long as conditions allow.

C. Maintenance system

We have considered maintenance policy in this system which has been discussed in the literature related to the container ships for the first time.

D. Transportation system

The mentioned system includes trucks with a capacity of 20 containers.

V. Validation of the model

The validation is used to measure the closeness of the model to actual system and it is impossible to reach the complete match between these two, because the best model is actually the real system. However, there are methods for examining the adequacy of the model with respect to the objectives of the project. There are the actual system and its important information in our study and therefore we do compare the gained results from the model with the actual ones. Actual system of the port works 18 hours a day and there is the possibility to extract its outputs by field study or the website of Shahid Rajaei port. Accordingly, we set the model on 18 hours and compared the outputs with reality so that we can validate our model for different scenarios.

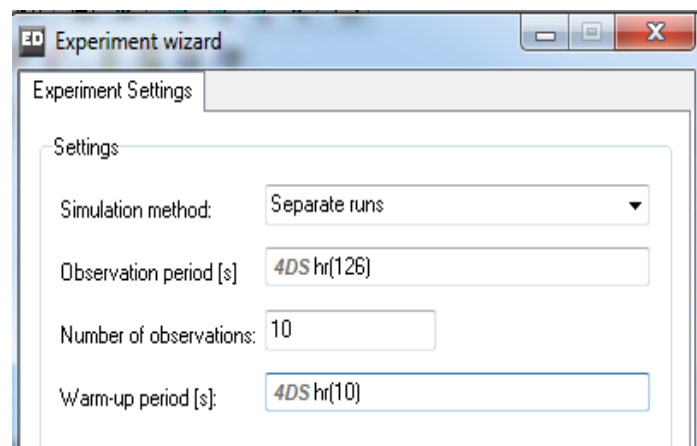


Figure 4. Experimental wizard

These steps are done as shown in figure 4 which displays 7 days and 18 hours per day. The model is run ten times and also setup or warm up time is considered 10 hours. In describing the warm up time, we can say that it is considered until equilibrium is reached. For example, it could be supposed a factory which has recently begun to work and its outputs are not appropriate and in a fixed level until the equilibrium time. The mentioned model could be observed in figure 5.

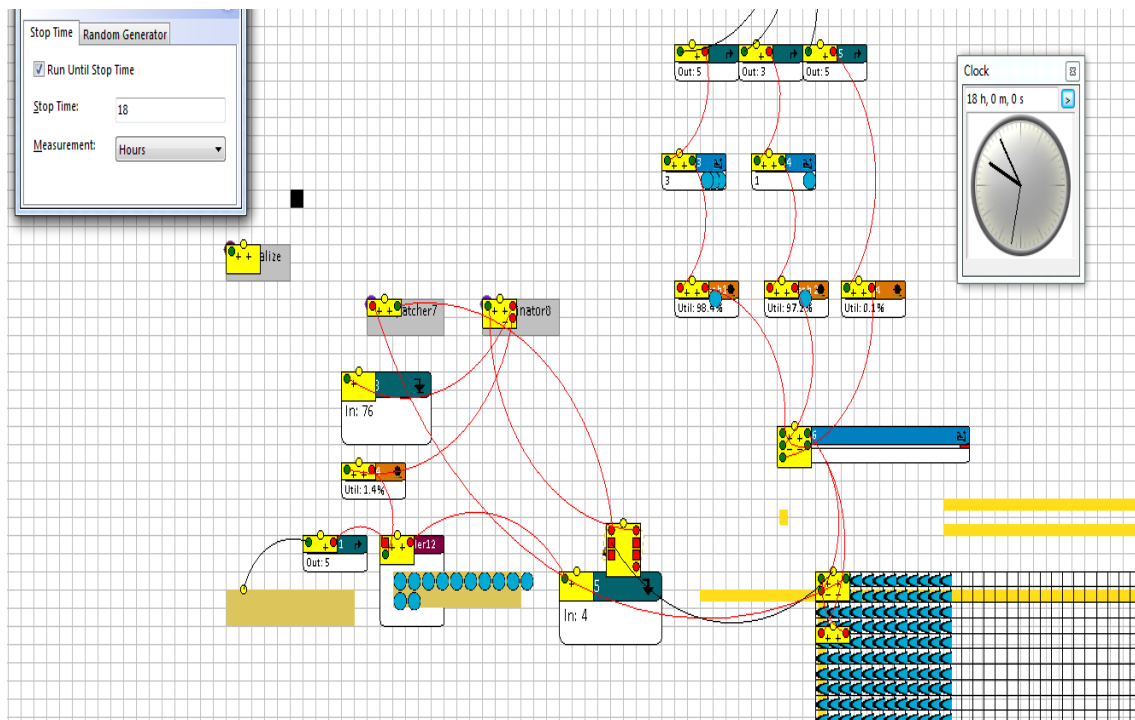


Figure 5. Simulation model

Figure 6 shows the analysis of software can be viewed on the number of containers in internal storage. For example, there is an average of 120 and a maximum of 133 containers in the storage and also the number of outer trucks is observable in which 3 and 4 are the minimum and maximum range. Next output shows the number of containers shipped by lift trucks from the internal to external storage which is an average of 38. Also at the end you can see that the average number of ships waiting to load is obtained 2.86 which is close the number declared by Shahid Rajaei port (3 ships on average) and the next model results can be completely trusted as well. As seen in figure 6, the simulation has been performed 18 hours showing three large ships of 200-meters and a large one of 150-meters in the queue of loading, departure of 4 trucks with the capacity of 20 containers, 120 containers in the storage of wharf and also shipping 76 containers to the external storage.

Now we evaluate the system in real mode in June 2013 and obtain the average output of external truck with the capacity of 20 containers. It is interesting that the average output is exactly the number 4 which was obtained in our calculations as well. But one container is being filled and because the port is off for 6 hours, the truck will have to wait this time – such issues arise in real systems. Now, after considering the validity of the model and its accuracy, different scenarios can be implemented on it.

Results Table						
Observation	648000					
Warmup period	10					
Number of observations	10					
Simulation mode	Separate run					
Description:						
Atom:	Ground Store					
		Average	St.Deviation	L-bound(95%)	U-bound(95%)	Minimum
content		120.10	10.72	112.43	127.77	104.00
						Maximum
						133.00

Results Table						
Observation	648000					
Warmup period	10					
Number of observations	10					
Simulation mode	Separate run					
Description:						
Atom:	Sink15					
		Average	St.Deviation	L-bound(95%)	U-bound(95%)	Minimum
khoroj		3.80	0.42	3.50	4.10	3.00
						Maximum
						4.00

Results Table							
Observation	648000						
Warmup period	10						
Number of obs	10						
Simulation method	Separate run						
Description:							
Atom:	Sink13						
		Average	St.Deviation	L-bound(95%)	U-bound(95%)	Minimum	Maximum
khoroaji		38.20	6.37	33.64	42.76	26.00	46.00

Results Table							
Observation	648000						
Warmup period	36000						
Number of obs	10						
Simulation method	Separate run						
Description:							
Atom:	Queue23						
		Average	St.Deviation	L-bound(95%)	U-bound(95%)	Minimum	Maximum
content		2.86	0.11	2.78	2.94	2.71	2.99

Figure 6. The primary model output

VI. Scenario analysis

In this paper we implemented a number of scenarios and the results will be presented:

The first scenario involves the development of the transportation system to have a more realistic model including four types of transportation with different percentages and container capacity shown in table 3. The mentioned system can be applied in different real cases in container network in future. Be noted that this scenario makes the system more flexible so that it can be barely seen a half full truck after 18 hours of working otherwise the system is a major weakness that the truck must wait 6 hours for the system to go back to work – it is abundantly found in real cases. Figure 7 shows how the scenario is applied.

The second scenario has been considered in order to accelerate containers shipping, decrease workload on lift trucks, and also increase the outputs. As shown in figure 8, the second lift truck idle time is only 32%, then in almost all cases, employed and it requires a more appropriate policy to reduce the working pressure. To consider the problem, a second lift truck was added to the system with a particular policy stating that if there are more than 20 containers in internal storage, the second lift truck will be applied beside the first truck. We have also presented the formula making the second truck work in terms of reaching the top 20 which has been shown below:

$$\text{if}(\text{Content}(\text{in}(2,c)) < 20, 1, \text{dUniform}(1,2))$$

This formula should be inserted in the atom connecting the two lift trucks.

Table 3: Different types of trucks and their capacity

capacity	% of employment	type of vehicle
12	13%	1
18	26%	2
20	44%	3
16	17%	4

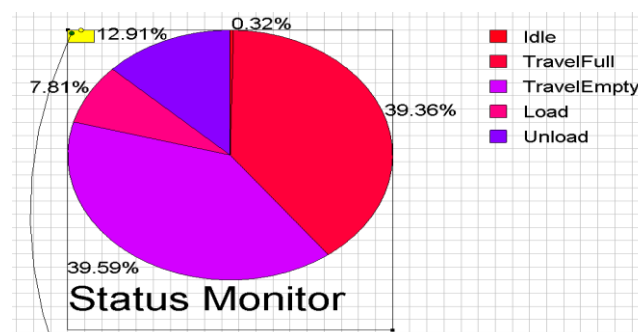


Figure 7. Working pressure of lift truck before scenario

Now after doing this scenario, we analyze the obtained results including the number of containers in internal storage and the working pressure to see the resulting change. As shown in figure 10, with the adoption of the policy on the use of two lift trucks at the same speed, the inventory level in storage has been reduced and also the working pressure of lift trucks decreased so that it caused a better performance.

Results Table						
Observation	648000					
Warmup period	36000					
Number of lot	10					
Simulation mode	Separate run					
Description :						
Atom :	Ground Store					
		Average	St.Deviation	L-bound(95%)	U-bound(95%)	Minimum
content		99.10	13.16	89.68	108.52	81.00
						Maximum
						114.00

Figure 8. Output after doing scenario

In the third scenario, we have examined the issue of increasing the number of cranes and for this purpose, the upper bounds of fixed and moving cranes – three from each – were placed and put into our analysis. In this regard, the obtained results showed a considerable improvement in the system, thus in the absence of restrictions can increase the number of cranes.

VII. Conclusion

In the world around us, there are many real examples that analysts are interested to improve their performance and the main purposes of these improvements include reduced costs, increased customer satisfaction, improved system efficiency and increased income. In our model inspired from a real case in the port, the goals are also to increase performance and improve the working conditions of facilities regarding the maintenance program. We adopted an optimal policy for lift trucks and observed a considerable improvement in storage and also evaluated a second policy on increase in the number of cranes and noted the gained improvement. It is also worth mentioning that we were looking at the issue that what can be added to models and papers of past to have a more realistic system.

VIII. Future study

From the applicability point of view, there are different features to be considered in the study in order to get closer to the reality and we will try to advance towards these actual features that are: (i) addressing tides assumption which can have a great influence on the model and its constraints, and (ii) considering sleeping costs about ships waiting in the harbor meaning that we can compare the mentioned cost with the cost of buying cranes and do a proper analysis.

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