An Optimization of Inventory Model at Seaports Using a System Dynamics Approach

By

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Abstract:

Port operation and cargo handling process involves integrated activities which any delay or stoppage result in bottleneck in port process. This in turn leads to a dramatic escalation in ship and cargo dwell times at anchorage, seaport terminals or exit gates. Increasing cargo dwell time not only depreciate port's equipment but also decrease port efficiency dramatically. The objective of this paper is to develop a modeling approach using the concept of System Dynamics (SD) to simulate variables affecting inventory optimization at Emam Khomeani seaports. To find proper actions by which seaports can optimize the inventory, dynamic of various variables such as dwell time, the number of human resources and equipment simulated during 2006 to 2031. The overall results show that warehouse traffic is highly sensitive to cargo dwell time, while this is less for the quay inventory variable. The analysis shows that the 30% reduction of cargo dwell time in inventory fluctuations is much more than the 30% increase in work force. One solution could be increasing storage area which, apart from being a very expensive investment, may be not feasible due to space limitations. Consequently, terminal operators are trying to decrease average dwell time. In order to do so, the main factors which influence the number of days a container stays in the terminal need to be determined.

Keywords: Stock inventory optimization, Cargo dwell time, System dynamics model

Introduction:

Time index is one of the most important indices in evaluating port performance. From the time a vessel reports at anchorage to the time it is cast off from the berth, several factors are involved in a sequence. Any delays at each stage can lead to delays in the

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entire port system. The time duration for which an entity stays in the port for service is called the dwell time of the entity. The entity could be cargo or ship. The period from when a vessel reports at anchorage to when it is cast off from the berth is referred to as vessel dwell time. So what is important for a ship owner is reducing port time (Turn round time). Dwell Time (DT) represents the total time a container spends in one or more terminal stacks. The dwell time of cargo and vessels broadly reflects the efficiency of ports. Therefore, measures taken to reduce dwell time impact efficiency.(Merckx, 2005)(planning commision, 2007).

Hence, it is important to note that the average DT plays an essential part in accounting for the whole terminal capacity (Chu & Huang, 2005). Extending turn round time and delay in cargo departure raises cost of ship owners, freight rate and ultimately the cost of transportation. Ship and cargo dwell time are also leads to unnecessary cargo movement, prolongation of storage time and consequently demurrage. In turn, idle time, directly and indirectly can affect the market economy and raise the price of cargos and services. In the real world all the causes and effects are interrelated. Therefore, the analysis of a phenomenon without knowing these relationships (in this case storage capacity, and related variables) and determining the scope of the study of each one will not be possible.

Following this, the fundamental objective of the current study is to develop a dynamic model for seaports with feedback loops and time delays to investigate and simulate inventory levels by systematically regulating factors (control variables) such as cargo dwell time, workforce, and equipment across the port chain.

This will ultimately lead to speeding up cargo movement, reducing port costs, improving port efficiency and faster delivery of merchandise on the market.

Problem Statement, Importance and Significance of the Study:

Cargo owners are requested by law to provide their consignments' documents for the customs clearance within a specified period of time. During this period consignment are maintained at storage area. Although, on some occasions, customers may prefer to use the port as a warehouse in the supply chain rather than as a node in the total intermodal logistics chain (Raballand et al., 2012). The process of maintaining these goods in port results in increased cargo traffic, dwell time, and consequently reduced efficiency. In order to prevent the deposition of goods at ports, generally a specific period of time is assigned for clearing and departure of goods based on the volume of cargo handling. The dwell time of cargo, containers, and vessels broadly reflects the efficiency of ports. Thus, measures adopted to reduce dwell time influence efficiency (planning commision, 2007).

Dwell time (DT) is represented by the total time a container spends in one or more terminal stacks (Otjes et al., 2007). A DT container can be affected by several factors such as gateway operations, internal network availability and efficiency, and customs rules and regulations. Receivers, especially those of goods, can be identified as one of the primary stakeholders influencing DT time. They have the authority to decide when to deliver import containers or export containers. Furthermore, it has been found that the stacking area required is linearly related to the average container time at a container terminal (Little, 1961).

In many ports in Iran, failure of the cargo handling equipment, Low storage Tariff, the complexity and timing of the customs clearance and discharge procedures, it has led to the deposition of a huge amount of goods in these ports. Importers tend to deliver their containers not immediately after completing clearance procedures, but rather as the expiration of the 10-day free storage period approaches. For example, the amount of cargo sediments at anzali port in 2010 were about 806 thousand tons which is accompanied by an increase of 40% compared to 2009. This is despite the fact that the total discharged cargo in Anzali port was 3.4 million tons. The statistics also show that the ports of Amir Abad and Noshahr contain 300,000 tons and 500,000 tons of sediment cargo, respectively.

In the system of entering and leaving the goods from / to the port due to the existence of different organizations, different structures and individual operations of individuals based on reactions, we face a number of problems. If an inappropriate policy is implemented in the real world, the real environment (structures) will be changed and will cost a lot and its consequences will be unpredictable without simulation.In this regard, SD is purpose-oriented, based on feedback, which is simple and effective in comparison with other systems analysis methods and can be used as an efficient method in the modeling of inventory optimization.

System dynamics represents complex systems and analyzes their dynamic behavior over time (Forrester, 1968). According to Coyle (1996), "System Dynamics deals with the time-dependent behavior of managed systems with the aim of describing the system, understanding how information feedback governs its behavior through qualitative and quantitative models, and designing robust information feedback structures and control policies through simulation and optimization" (Coyle, 1997). Thus, the primary objectives of the system dynamics approach are (Maani and Cavana, 2007; Sterman, 2006; Ford, 2010): (i) to clarify the endogenous structure of a specific system under study; (ii) to identify the interrelationships among different elements of the system under study; and (iii) to consider various simulation alternatives and explore the system's changes. According to the above, the main objective of the current research is to optimize the inventory levels at Imam Khomeini Port and develop solutions to reduce cargo dwell time by implementing optimal policies.

Based on preliminary studies, it is expected that reducing cargo dwell time in ports will lead to excellent performance.

Research Questions:

1- What are the most important factors affecting the inventory level of ports?
2- What role do each part of the Quay, warehouse and exit gate play in the level of inventory?
3- What practical solutions (applied policies) exist to control the traffic of goods in ports over time?

Literature review:

There has not been much research on the cargo dwell time in foreign ports, perhaps the most important factor is the absence of cargo sediment in large volumes in the major container ports of the world. Specifically, Hoffman (1985) formulated the required yard size as a function of dwell time, the height of stacked containers, peak hour, and the total number of containers used per year (Hoffman, 1985). In this case, the average DT indicates an essential part in determining and influencing the total terminal capacity in the model (Chu & Huang, 2005).

These days, the increasing volumes of goods require larger and more extensive terminal capacities because of the establishment of massive vessels. One solution might be to increase the terminal size. However, this may not be feasible due to space limitations and the high cost associated with such an investment. So, operator employees working in ports tend to reduce the average DT. Consequently, they must clarify and identify the important and most influential variables that affect the number of days a container spends in the terminal. Today, there are few practical research studies that focus on quantifying the determinants of DT exists. The first researcher to analyze the impact of DT on terminal capacity was Merckx (2005). He was a brilliant inventor who developed a mechanism to assist terminal operators optimize terminal capacity by implementing various pricing models according to a variety of dwell time charging systems.

In 2009, “Rodrigue” attempted to demonstrate how logistics companies utilize seaport terminals for shipments, as well as manage distribution centers and storage areas, making full use of the free-of-charge time mechanism in the terminal's yard. By contrast, employees of terminal operators reflect on this action by limiting DT and terminal availability. He discussed and indicated that extending the gate hours at a marine terminal could decrease the container DT.

In his study, Huang (2008) concluded that extending the container DT, i.e., keeping it at the dock longer, will raise costs, reduce terminal efficiency, and ultimately result in increased expenses. (Huang et al., 2008). Some of the main factors affecting DT identified in the research literature and agreed upon by all researchers are as follows:

“1) terminal location; 2) efficiency of terminal operations; 3) implemented port policies such as monetary penalties for shipment delays. and transit or longer gate hours. 4) customs; 5) carrier or carriers; 6) domestic connections available; 7) transportation method used; 8) cargo in transit; and 9) business relationships established between the parties involved” (Moini et al., 2008; Rodrigue et al., 2008).

Moini et al. (2008) utilized genetic algorithms to assess the primary factors influencing container dwell time and measured their long-term impact on terminal productivity (Moini et al., 2012). In addition, he investigated and analyzed the importance of obtaining information about the recipients of the land and the type of transported goods, reaching acceptable results. Based on the results of this study, it is expected that the prediction ability of the desired models will increase. Moini (2012) established a relationship between truck gate activities and unloading operations in a marine container terminal using both analytical and simulation methods. He used data mining techniques to identify the significance of the determinants mentioned above in DT. In line with the same direction, Korunioti et al. (2015) proposed the development of a methodological framework that combines and analyzes models with large, aggregated, and differentiated data to predict the dwell time of containers in a sea terminal. Due to the capability of regression models to handle big data, advanced regression models were employed for this study. These models effectively demonstrated the impact of the receiver and container goods on DT (Korunioti et al., 2015).

In addition, if the exact day of unloading a container from the terminal is known in advance, operators can make the necessary forecasts and organize the yard accordingly to carry out the operation. This planning allows them to retrieve containers more easily for efficient picking, minimize return movements, and utilize available capacity more fully and effectively. The importance of this information is also highlighted in Zhao and Goodchild's (2010) study, where they developed a simulation model to assess and explore how the utilization of information impacts the efficiency of a marine terminal. The results showed that when the day of the truck's arrival is predetermined and accurate, there was a significant reduction in unproductive movements, which, in practice, will decrease unnecessary costs (Zhao and Goodchild, 2010).

In order to address the lack of information flow, several container port terminals have designed and implemented Truck Appointment Systems (TAS). TAS is primarily functions as a system that reserves, reviews, and executes binding transactions for a specific number of transactions (limited by the capacity of each terminal) within a predefined time frame, typically one hour. One of the first Terminal Appointment Systems (TAS) was implemented at the seaports of Los Angeles and Long Beach to tackle traffic congestion and air pollution issues. As you know, air pollution is one of the main problems in ports due to the extended idling of ships. (Giuliano & O'Brien, 2007). Limited research has been conducted on quantifying the factors influencing DT. It is not easy to predict when a container will be picked up from a seaport terminal. It is crucial to make informed decisions at the tactical and operational levels when designing terminal policies. Additionally, at the strategic level, the ability to make effective decisions is essential. It is beneficial to make investments in the medium and long term.

The result indicates that given the volume of investment, the benchmark that had more operations volume was closer to the acceptable efficiency scale.

Between these two concepts there are some other works done on ports and marine transport, some of which predict port performance using SD. These works have focused on port cargo flow as well. Haydarpour et al. (2017) have presented a model for simulating the overall performance of container terminals in ports using a system dynamic approach. The focus of this paper is to predict the performance of the container terminal in terms of the number of unloaded and loaded containers, the turnaround time, and the berth occupancy of the container terminal (Heydarpour et al., 2017). In the critique of this article, it is worth noting that constructing a new quay is time-consuming. Therefore, it is not recommended to do this in new ports to increase their capacity. Munitic et al. (2003) in a paper entitled "Dynamic Models of the Flow System of Cargo in Ports" used a simulation model to examine the work processes of ports (Munitic et al., 2003). Oztanriseven et al. (2014) reviewed articles that utilized system dynamics in marine transport (Oztanriseven et al., 2014). However, there is a lack of studies on using the SD approach for inventory optimization or to study causal relationships.

Methodology:

The modeling steps in this study include three levels of conceptualization, formulation and model validation tests. At the conceptualization level, the problem statement and the boundaries of the model (conceptual border, time border, and geographical border) are determined based on the main objective defined, along with the introduction of the important key variables of the model.

At this stage, the primary mechanisms of cause and effect, as well as the creation of influence diagrams and stock and flow diagrams for materials, are also implemented. In the first stage, a conceptual model or a cause-and-effect model is created based on the identified problem. This model includes elements and causal relationships among them. According to the cause-and-effect diagram, it will be possible to estimate the behavior of the various important variables and the behavior of the entire system.

In the second stage, a simulation model illustrating the stock and flow diagram of the problem statement is constructed based on the conceptual model and the actual data under study. At this stage, the behavior patterns of the various variables and parameters can be observed based on graphs and logical numbers. The formulation section includes defining variables for level and rate, parameter estimation, and model development in DSS Vensim software.

In the third stage, the model is simulated, and the policies are evaluated. Ultimately, cumulative error tests and extreme tests have been used to establish assurance about the correctness and improvement of the model. The research methodology involved studying bibliographic and field resources related to the operational process of cargo handling and dwell time at ports.

A. **Conceptual model**

The causal loop diagram is a graph that simply illustrates the causal relationships between system variables. With this tool, people's mental models are easier to comprehend. In the present article, the following system for warehouse inventory management is considered using the SD approach.

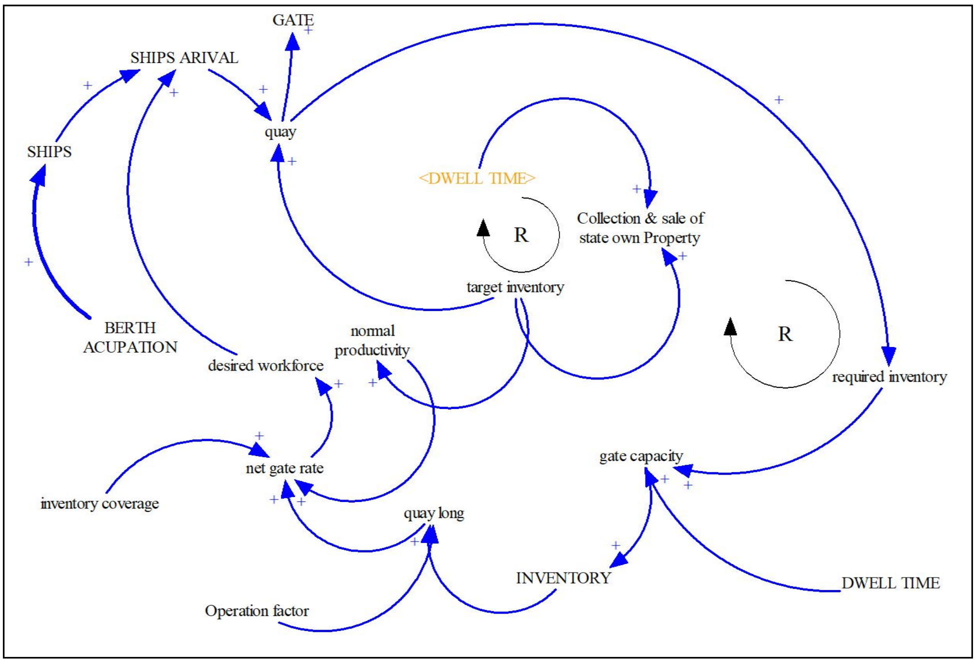
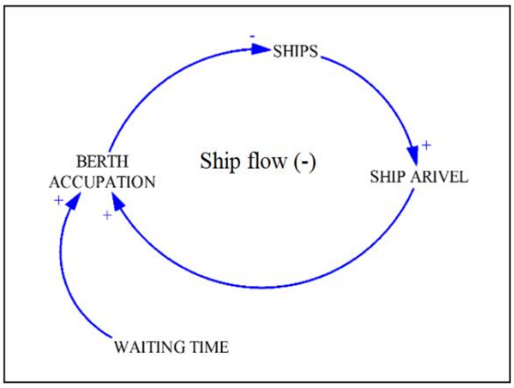


Figure 1: causal loop diagram for the cargo handling and inventory at sea ports

Figure 1 shows a cause-and-effect diagram of the port cargo handling system. Each arrow represents a cause-and-effect relationship. The positive (negative) sign on the arrow indicates that an increase (decrease) in one variable leads to a corresponding increase (decrease) in another variable. For example, in Figure 1, as cargo dwell time increases, the volume of goods in the warehouse and at the quay will also increase, leading to a reduction in output from the port's gates.

The reason for this is to increase the cargo dwell time. There is a feedback relationship between productivity and the quantity of goods leaving the port. This relationship is negative, indicating that a decrease in productivity will lead to a reduction in the output of goods through the port.



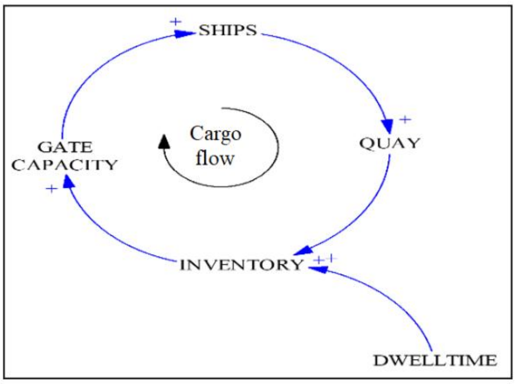


Figure 2: Influence Diagram of cargo flow   Figure 3: Influence diagram of ship flow

Figure 2 illustrates the flow of the ship's arrival and the berth occupancy rate. The waiting time, as a negative exogenous variable, affects the berth's occupancy rate. The increase in waiting time is considered a moderating factor in the ship arrival loop. As the floating entrance reaches the quay, the volume of cargo entering the warehouse increases, thereby increasing the clearance at the exit gate. The cargo dwell time, as an exogenous variable, also has a positive effect on inventory (Figure 3).

The sum of the arrival ships to the Quay is influenced by factors such as the percentage of berth occupation, the number of incoming ships and arrived ships to the port, respectively. The entrance cargo to the quay withdrew from the port without passing through the customs formalities due to the internal transit process or going out to the exit door, taking into account the amount of work done.

B: Stock & Flow Diagram

Based on the cause and effect diagram, one can use the stock and flow diagram to better illustrate the structure of the model and system processes. That's why the causal structure of the system must be explored before creating stock and flow diagrams. The stock and flow diagram is a graph illustrating the interaction between the variables of a system. This graphic diagram can serve as the foundation for developing a quantitative simulation model (Kirkwood, 1998).

The stock variables are, in fact, the accumulation variables (e.g., the amount of water stored behind the dam). Generally, the variables describe the state of the system. The rate variables express the rates at which stock variables can change. For example, the total amount of water stored behind the dam (stock variable) changes with the input and output flows, which are the rate variables.

In this paper, the system boundary is defined as starting from the moment the goods arrive at the port (import) until they depart from the exit gate of the port (see Fig. 4).

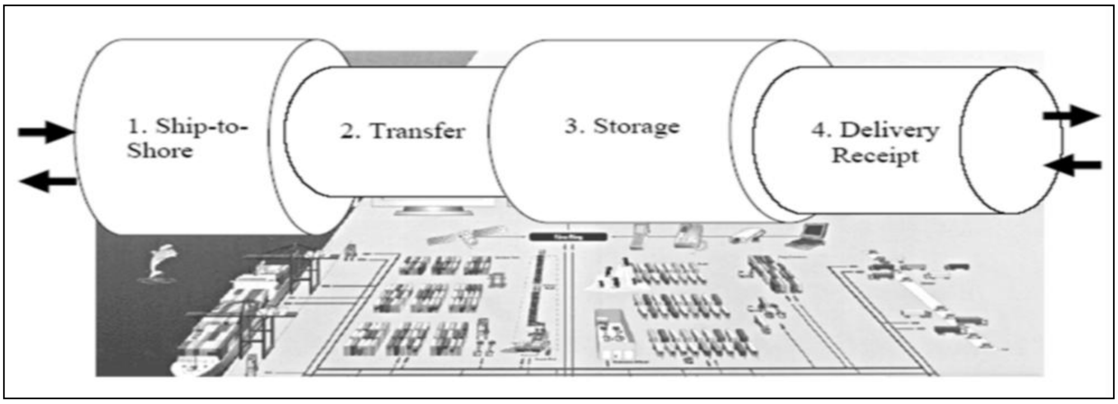


Figure 4: A Schematic view of entering cargo to port

The main activity of entering cargo from the sea involves three parts as follows. 1- Entry of the ship to the berth 2- Cargo discharging from the vessel and 3-transfer of goods to the warehouse or container yard (in the case of container) 3- Loading of goods from the warehouse and exit from the port gate.

1- Arrivals of the ship to the quay: In this subsystem, the total ship's presence in the port can be divided into four periods of waiting time, maneuvering time, service time (idle time + operation time) and sailing time.
   In the concepts of port, ships after declaration of notice of readiness (NOR) at anchorage

Waiting for a period of time (Waiting Time) to start maneuvering operation by pilot for mooring at the quay.in Imam khomeini port, it takes about an hour to get pilot boat to the ship at the harbor and start the maneuvering operation. It is worth noting that the expected time for the pilot to reach the harbor at Imam Khomeini Port is a fixed standard, with a time index set to one hour. Maneuvering time is a delay before berthing, which begins with the start of maneuvers and ends with the closure of the rope craft to the quay.

2- Cargo discharging from the vessel: Depending on the type of goods (cereals, containers or public goods), different equipment and warehouses are applied to discharge cargo from the vessel.

The length of the authorized storage of goods in customs warehouses from the date of delivery of the goods to these places is three months. If justified by customs authorities, clearance can be extended for another two months -Article 24 of the Customs Code(Ministry of Industry, 1993). If the customs formality procedure and payment of due are not made by the cargo owner, the goods are subject to abandoned regulations by organization of Collection and sale of state own property.

Load trucks will leave considerable time waiting to exit from the port gate, leading to truck congestion at the port of departure. This depends on a variety of factors, such as the number of servers, the service delivery rate, and the productivity factor. Considering this factor in the dynamics of the systems, gate congestion at sea ports can be partially reduced. Productivity coefficient, one of the criteria used to rate the system, is the percentage of time the system is operational.

Now, based on the identified important variables, the stock and flow diagram of the port operation is illustrated in Figure 5. In the current diagram, the variables related to the quay, the warehouse, and the exit door are stock variables, which are part of a conveyor belt process. The quantity of available cargo at the quay is enhanced by the variable of the number of ships entering the quay, which is a rate variable, in other words fed.
The amount of available cargo is also reduced or depleted by the variables of the output vessels and the discharge variables, both of which are the rate variables.

The stock inventory is placed at the request of the cargo owners under the supervision of regulatory agencies such as customs, quarantine and standard, and leave the port gate. Or, due to neglect of cargo owner duty, the goods will be subject to a time lapse of more than 4 months. In the latter case, the goods are subject to abandoned regulations and are seized by organization of Collection and sale of state own property.

After the necessary inspections, the cargo owner receives a permission to load and disembark from the port. At each of the three rates of this conveyor belt process, various factors such as waiting time, dwell time and queuing length can affect the stock inventory.

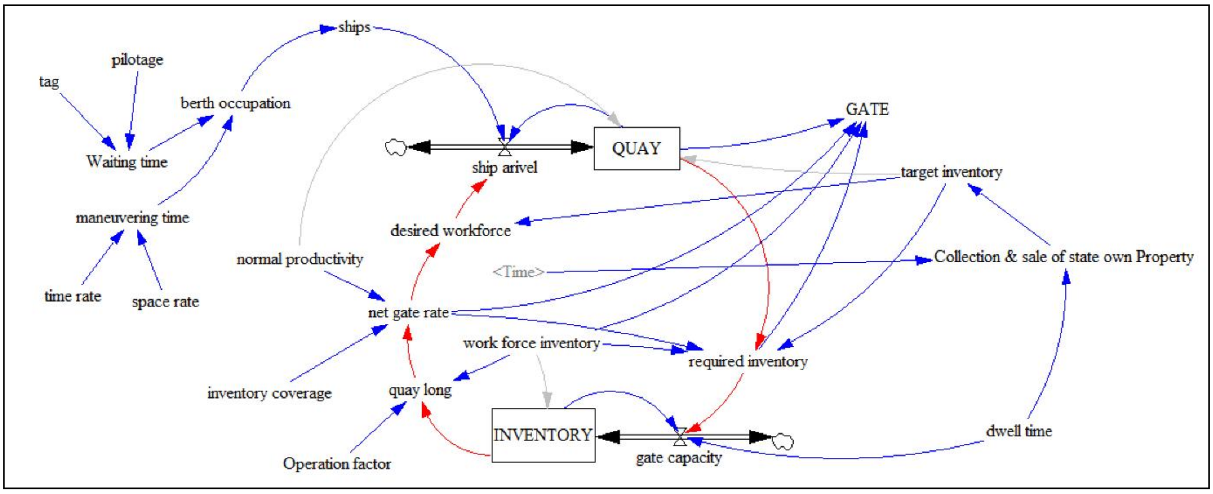


Figure 5: Stock-flow Diagram of port operation

Model Equations:

Variables of the model are summarized in Table 2, then, based on the cause-and-effect diagram, some of the model equations are as follows.

Table 2: Levels and rate variables based on acronyms

Abbreviation	Variable Name	Abbreviation	Variable Name
TIN	Target Inventory	MT	Maneuvering Time
RIN	Required Inventory	WT	Waiting Time
IN	Inventory	BO	Berth Occupation
DT	Dwell Time	SA	Ship arrival
WFIN	Work Force Inventory	Q	Quay
DW	Desired workforce	*G*	Gate
NP	Normal Productivity	*COLL*	Collection & Sale
GC	Gate Capacity	*QL*	Quay long
ST	Space Rate	NGR	Net gate Rate
TUG	TUG	TR	Time Rate
		PIL	Pilotage

Table 3: List of Model Equations

Equations	**variable**
$MT=ST*TR$	Maneuvering Time
$WT=PIL*TUG$	Waiting Time
$BO=MT*WT$	Berth Occupation
$SA=100+(DW-Q)/S$	Ship arrival

*G= Q*RIN*NGR/WFI*	G
ZIDZ(target inventory, QUAY*net gate rate) * work force inventory	Required Inventory
Operation factor*(INVENTORY/work force inventory)	Quay long
normal productivity*inventory coverage*(quay long)	Net gate Rate
ZIDZ(target inventory, net gate rate)	Desired workforce

Based on a stock and flow diagram, stock (level) variables accumulate depending on the disparity between input and output streams. Therefore, the stock variables are formulated as follows:

$$Stock(t) = \int_{t_0}^{t_n} [Inflow(t) - Outflow(t)]dt + Stock(t_0)$$

Whereas $Stock(t)$ is a level variable at time t , $Inflow(t)$, input flow at time t and $Outflow(t)$, output flow at time t and t is a time between t_0 and t_n ($t_0 \leq t \leq t_n$).

Accordingly, the equations for the stock variables including the Quay and the inventory will be written as follows:

$$Quay(t) = \int_{t_0}^{t_N} [SA(t)]dt + TIN * P(t_0) \qquad \text{Quay}$$

$$IN(t) = \int_{t_0}^{t_N} [GC(t)]dt + WFIN \qquad \text{Inventory}$$

Whereas the values of each variable in time t_0 are in fact the same initial value of the variable. The rate of Seized goods ordered by collecting and selling property sales organization according to the specified time, as follows:

If T> DT, then Coll= 50/80

In this way, the cargo dwell time is determined as the major factor in the amount of inventory, the amount of outlet from the quay and the amount of seized cargo. Target Inventory is the amount of inventory that the port intends to apply according to the optimal strategy. Initial required inventory is the minimum inventory requirement that should not be lower than this point. Inventory Coverage, is called the maximum inventory to be stored in the warehouse.

In the proposed model, considering the three mentioned variables (target inventory, initial required inventory and the inventory coverage) the amount of optimal storage capacity according to the port policy is changed.

Validation of the research model

In order to validate the inventory model, some conventional tests are used, such as boundary efficiency, units' consistency, parameter evaluation, cumulative error test, and extreme value test.

Dimensional Consistency Test:

The dimensional Consistency test is to answer the question of whether the dimensions of the variables are balanced on both sides of the equation or not (Sterman, 2006). Are the dimensions defined in equations appropriate? (Mousavi Haghighi & Tajik, 2014). The consistency of units was verified by simulation software, namely Vensim DSS (Model> Unit Check), which was confirmed with a positive response to the test.

Boundary efficiency: Are the important concepts and variables related to the subject within the model boundary and are relative to the model of the endogenous? (Mousavi Haghighi & Tajik, 2014). The boundary efficiency of the model was verified by experts' opinions.

Time Boundary efficiency: Indicates whether the trend of the key variables of the pattern is changed using the opening interval. In this regard, the inventory level does not change despite the increase in timeframe from 1410 to 1420 (figure 6).

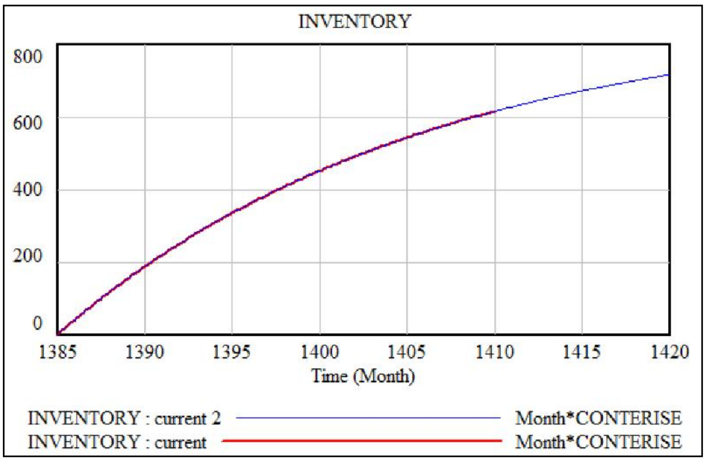


Figure 6: Time boundary Efficiency test

Cumulative error testing indicates that simulation results are not sensitive to changes in the time unit. For example, if the time unit was originally one year and we change it to six months, the results must remain the same as before. For this purpose, the research unit was changed from year to month (Figure 7). As the results did not change, we can say that the model is also successful.

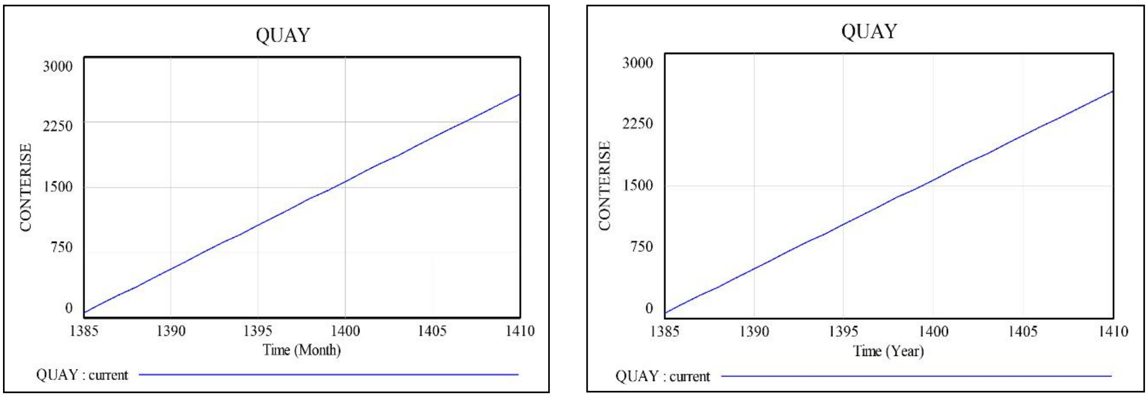


Figure 7: Implementations of the model after the cumulative test

Parameter Verification Test: Parameters and their numerical values should have real-world system equivalents. "Do the parameters correspond conceptually and numerically to real life?" Are the parameters in terms of real systems recognizable, or are some parameters contrived to balance the equations? If the values selected for the parameters consistent with the test information available about the real system? (Martis, 2006). Parameter evaluation test emphasizes on reasonable initial values of stock variables and parameters. According to port experts, model parameters have been approved.

Extreme Condition Test: The model structure and output should be plausible for any extreme and unlikely combination of levels of factors in the system. For example, if in-process inventories are zero, production output should be zero (Sargent, 2010). Extreme condition tests were carried out in this paper assuming zero delivery of goods to the berth and a constant rate of dwell time. As shown in Figure 5, if the maneuvering equipment (Tug) or manpower is idle, the inventory level is zero (right figure). Also, if the cargo deposition in the warehouse is zero, the inventory level decreases and moves downwards (as shown in the left-hand figure), confirming the assumptions of this test.

It is necessary to note that the success in assessing the validity of a model does not indicate that it is fully consistent with reality or its full validity, but it indicates the usefulness of a model (soshil,1387).

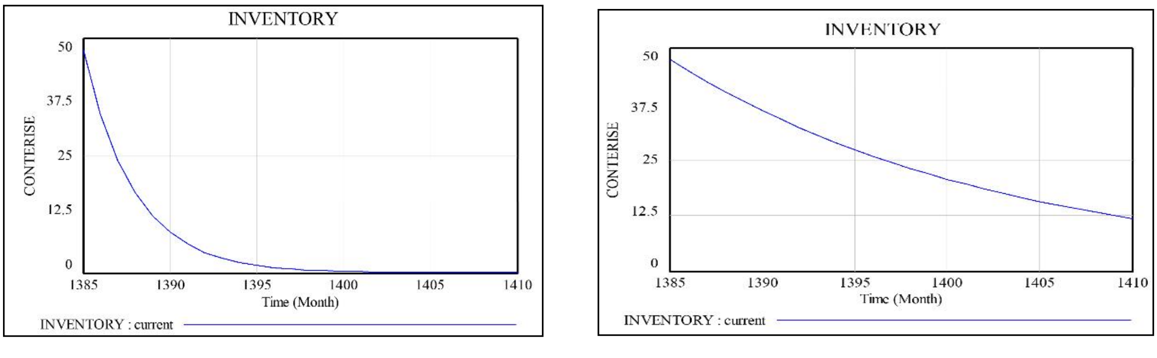


Figure 8: Implementations of the model after Extreme condition test

Error calculation tests

In addition to reproducing the pattern behavior to ensure simulated results, key variables errors were also calculated based on the following methods.

A. Root Mean Squares Percentage Error

Based on the current index, the difference between actual and simulated data is minimal. More simulation results can be trusted. The error rate in this method is calculated based on the equation below.

$$RMSPE = \sqrt{\frac{1}{\theta}\sum_{i=1}^{\theta}\left(\frac{y_{T+i}^{s} - y_{T+i}^{a}}{y_{T+i}^{a}}\right)^{2}} * 100$$

That in this equation:

y_{T+i}^{s} : Pattern variable simulation results,

y_{T+i}^{a} : Real data

θ : Represents the number of observations

According to this, Whatever the amount the RMSPE is closer to zero, means the less error and the nearest to 100% indicate a high error rate.

B. Identify the roots of the error

Another way to measure the deviation of simulated values from actual data is to calculate the **U-Theil's** that is obtained according to equation number six.

$$UT = \sqrt{\frac{\frac{1}{\theta}\sum_{i=1}^{\theta}(y_{T+i}^{s} - y_{T+i}^{a})^{2}}{\frac{1}{\theta}\sum_{i=1}^{\theta}(y_{T+i}^{s})^{2} + \frac{1}{\theta}\sum_{i=1}^{\theta}(y_{T+i}^{a})^{2}}}$$

The value of UT will always be between zero and one, Whatever the amount the UT is closer to zero, means, the simulated values and the actual deviation are less than each other. Regarding the importance of error in prediction, recognizing and reducing the sources of error can be very effective in increasing the trust in the results of the model. (Senge & Forrester, 1980) (1996) considers the roots of error caused of three factors:

a. Fundamental Error: When model outputs are not compatible with data that is called systematic error.

b. Deviation Error: When the variance between real data and simulation is very different.

C. Unequity Covariance: When the results of the pattern and the data are not correlated, which is called a non-systematic error. The below equation is used to calculate the roots of the error.

(1) $U^{m} + U^{s} + U^{c} = 1$

In the optimum mode, the lower the systematic and non-systematic errors, the higher the performance accuracy of the simulation model. In other words, it is ideal for the total of these errors to sum up to one. These variables are derived from relations eight, nine, and ten.

(2) $$U^m = (\overline{Y}^s - \overline{Y}^a)^2 / [\frac{1}{\theta}\sum_{i=1}^{\theta}(Y^s_{T+i} - Y^a_{T+i})^2]$$

(3) $$U^s = (SDS - SDA)^2 / [\frac{1}{\theta}\sum_{i=1}^{\theta}(Y^s_{T+i} - Y^a_{T+i})^2]$$

(4) $$U^c = [2 * (1 - r) * (SDS * SDA)] / [\frac{1}{\theta}\sum_{i=1}^{\theta}(Y^s_{T+i} - Y^a_{T+i})^2]$$

That in this equations:

$\overline{Y}^a$: Average real data

$\overline{Y}^s$: Average simulation data

SDS: Standard Deviation Simulation

SDA: Standard Deviation Actual

R: Correlation coefficient between actual and simulated data

The results of the error calculation tests in Table 4 are presented in relation to the key variables of the model. The results indicate that the error levels for all variables studied are at an acceptable level.

Table 4: Results of statistical tests of model validation

Test	Ship arrival	Gate Capacity
RMSPE	0.2232	0.2077
UT	0.1859	0.1278
U^m	0.6621	0.0009
U^s	0.0862	0.0276
U^c	0.2517	0.9715
U^c+U^s+U^m	1	1

7.2. Behavior Reproduction Test

How well does the model reproduce the historical reference mode? (Senge & Forrester, 1980). The purpose of this test is to compare the simulation results with the actual data to ensure the validity of the pattern behavior. In other words, in this case, simulated behavior is replicated to compare it with real data (Mousavi Haghighi et al., 2017). As shown in the figures below, actual information and simulation results of the input and output capacities of the container door are presented for the years 1385 to 1396. These graphs demonstrate that the behavior of the analyzed variable is accurately simulated.

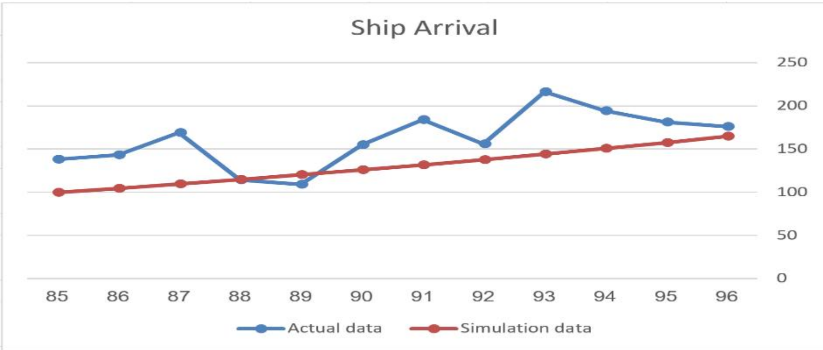


Figure 9: Results of behavior reproduction tests of ship arrival

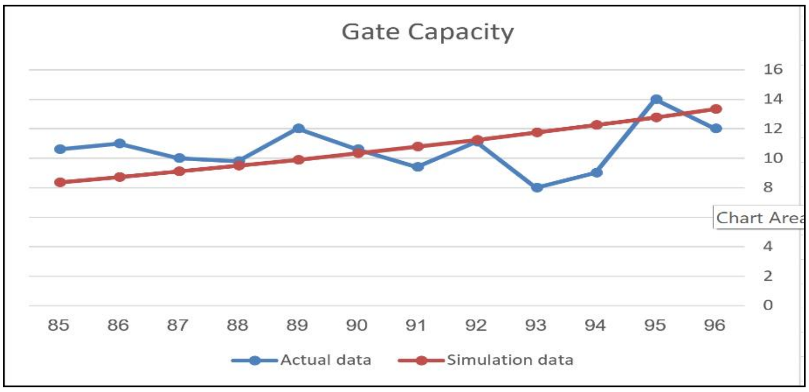


Figure 10: Results of behavior reproduction tests of Gate Capacity

Simulation Scenarios & Sensitivity Analysis:

After verifying the structure and behavior of the model, the researcher analyzes the policies, or in other words, scenarios, to enhance the performance of the design model and the results obtained from the implementation of these policies (Mousavi Haghighi & Tajik, 2014).

In this section, the sensitivity of inventory and the number of inbound vessels will be measured relative to the time of deposition of goods. For this purpose, the cargo dwell time is changed by 50% and the effect on the variables is examined. As shown in figure 11, the effect of this change on the stock is very high.

It can be mentioned that policies such as changing storage tariffs that lead to changes in sedimentation time can have a significant effect on inventory behavior. But, as the figure 12 shows, this change has little effect on reducing the arrival of the floating port.

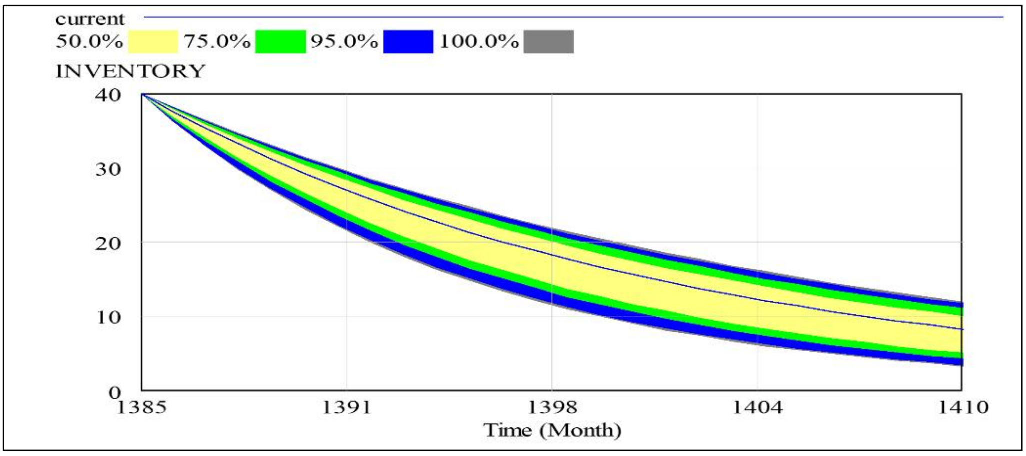


Figure 11: Stock inventory changes relative to the time fluctuations of the cargo dwell time

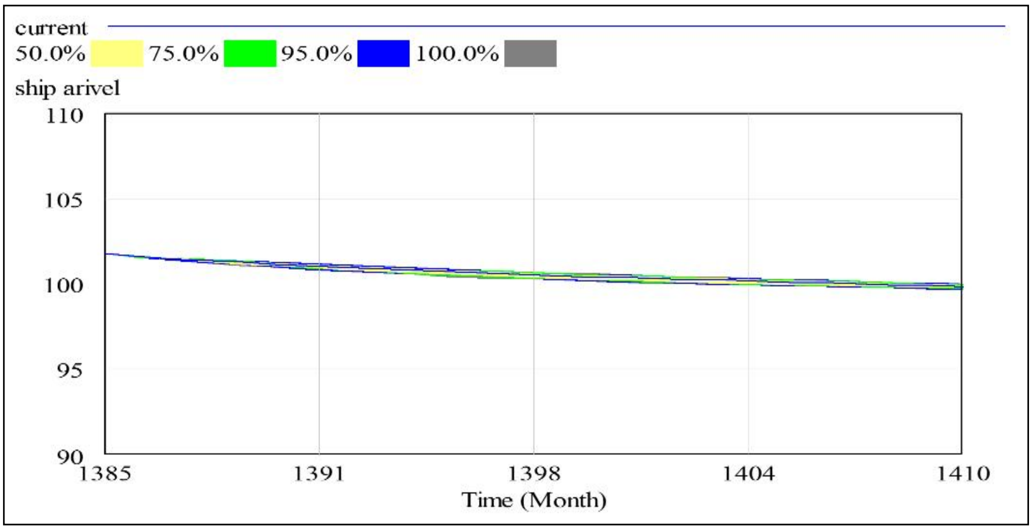


Figure 12: Ship arrival changes relative to the time fluctuations of the cargo dwell time

Various scenarios are currently being considered for the development of key variables. Each scenario is based on a specific policy or a combination of policies.

Since the dwell time is the most important variable affecting inventory, the scenario is designed based on the behavior of dwell time.

Scenario 1: The effect of reducing the cargo dwell time on stock inventory and labor requirements

As mentioned earlier, the dwell time may fluctuate with respect to the port's policies. For this purpose, inventory behavior has been simulated in conditions of increasing and decreasing of 30% of cargo dwell time. Figure 13 shows that the inventory level is varied with the cargo dwell time, as the inventory level decreases with the reduction of the cargo dwell time. This is while the quay stock response is indifferent to changes in the cargo dwell time. The reason for this could be the fact that the arrival of a float to a port and the discharge of goods depend on a large and distinct policy of domestic port policy.

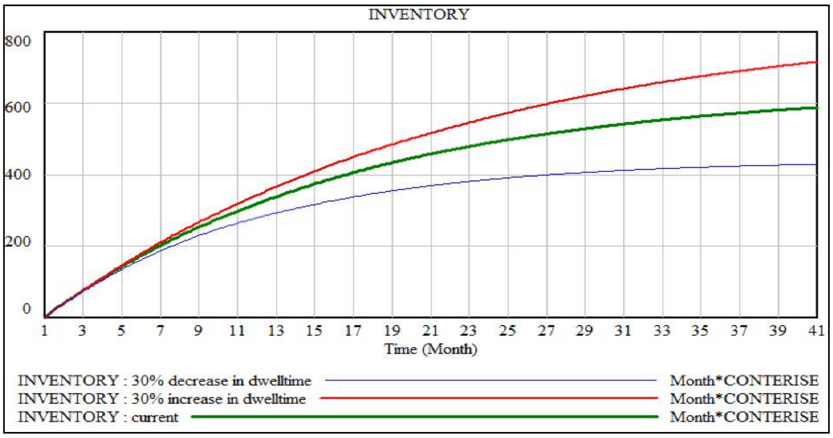


Figure 13: The behavior of inventory after changing the cargo dwell time

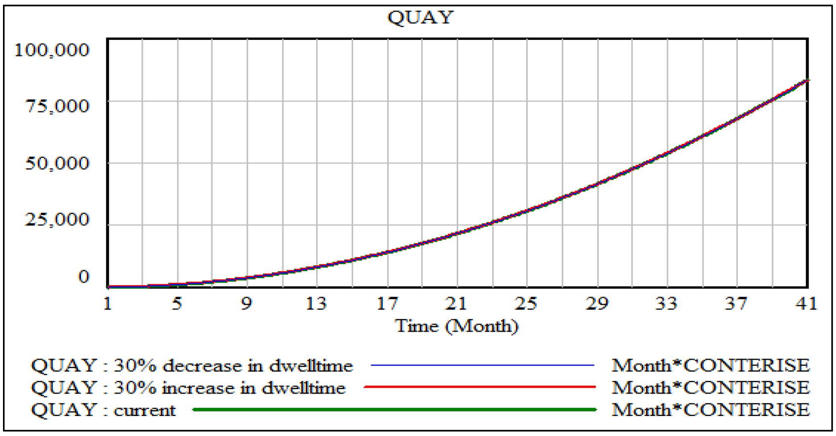


Figure 14: The behavior of the Quay after changing the cargo dwell time

If the traffic is too high and the space required to store the goods is limited, port managers decide to reduce the traffic load as quickly as possible by decreasing the cargo dwell time. By examining the cargo dwell time, it was observed that halving this time reduces the impact on the behavior of the inventory variables.

Scenario 2: Changes in the cargo dwell time and work force simultaneously

in this scenario, a situation is examined in which simultaneously the cargo dwell time is reduced by 30% and the labor force increases by 30%. Model simulation for years to come shows that decreasing the rate of cargo dwell time in reducing warehouse traffic is

more than the effect of increasing the number of work force in reducing warehouse traffic figure14.
In this scenario, to determine the impact of the variables, the cargo dwell time and labor force are each reduced by 30%.

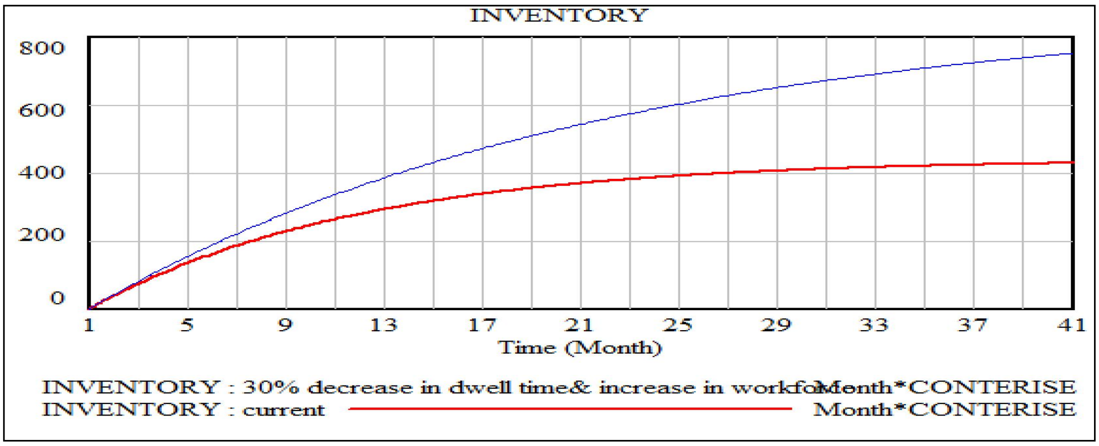


Figure 15: The behavior of the inventory after changing the cargo dwell time & work force simultaneously

Conclusion:

Dwell time is one of the key indicators of port performance. The ability of the port to attract cargo and subsequently generate revenue for the country very much depends on how efficiently the port can minimize the time vessels spend there.

This will be accomplished through rapid cargo handling and the quick release of the ship and its consignments. Storage operations can significantly enhance the efficiency of berths and overall improve port time indicators. Most of the imported cargo into the country is subject to interior transit (rather than inward transit), which means that cargoes are kept in storage for a period of time.

Therefore, having information on the amount of cargo deposition and inventory capacity can play a significant role in port operational management. This provide predictions for future planning for the development of the storage area and cargo flow.

In the current study, essential and important factors affecting cargo dwell time at seaports were investigated. Moreover, a modeling approach was developed using the System Dynamics (SD) concept by applying the Vensim Decision Support System (DSS) version to simulate various decision-making policies. Since the model has been developed, its validity has been assessed through various tests including dimensional consistency, behavior reproduction, sensitivity analysis, extreme condition, and parameter assessment tests.

In this paper, while determining the reasons for increasing the cargo dwell time, their effect on the performance of the inventory has been simulated up to 2031.

The overall results indicate that warehouse traffic is highly sensitive to the cargo dwell time. If this is done according to the simulation, this issue is less for the quay inventory variable.

An increase of 30% in the cargo dwell time has no effect on inventory traffic until the seven-year period and is rising with a decreasing rate.

The analysis shows that a 30% reduction in cargo dwell time due to inventory traffic fluctuations is significantly greater than a 30% increase in the workforce.

One of the most reasonable policies that managers can use to control cargo traffic in port is to allocate the appropriate cargo dwell time. Factors such as increased workforce and equipment can affect the amount of storage space, which results in the imposition of additional costs to the port.

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