A Flight Simulator for Sea Port Capacity Improvement: A Case Study of Rajaee Port of Iran

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Abstract

This paper introduces an Integrated Port Capacity Dynamics Model (IPCDM), for evaluating development scenarios of SHAHID RAJAEE commercial port which is located in the north shore of Persian Gulf. In order to allowing an integrated assessment of policy scenarios, this model encompasses or includes six interlinked modules: ships, cargo, tugboat, berth equipment, yard equipment, and yard space. The model, therefore, is capable of policy analysis in any of these sectors. (See the picture.)

For ease of use by port managers, a policy analysis dashboard of the model has been built in ITHINK, which provides a suitable environment for our client, Port and Maritime Organization of Iran (PMO). This approach has also been used for 6 other major ports of Iran and flight simulations of these IPCDMs are now a vital part of strategic planning procedure at PMO.

***Keywords**: Seaport Capacity simulation, system dynamics, Flight Simulator, Transportation investment, Persian Gulf*

Introduction

importance of trade issue:

The idea of shipping and seaborne trade as the catalyst of economic development is not new. Adam Smith, often regarded as the father of modern economics, saw shipping as one of the stepping stones to economic growth. A business working in a country town without links to the outside world can never, he argued, achieve high levels of efficiency because the very small market will limit the degree of specialization. Adam Smith saw shipping as the source of cheap transport which can open up wider markets to specialization, by offering transport for even the most everyday products at prices far below those that can be achieved by any other means (Stopford, 2009).

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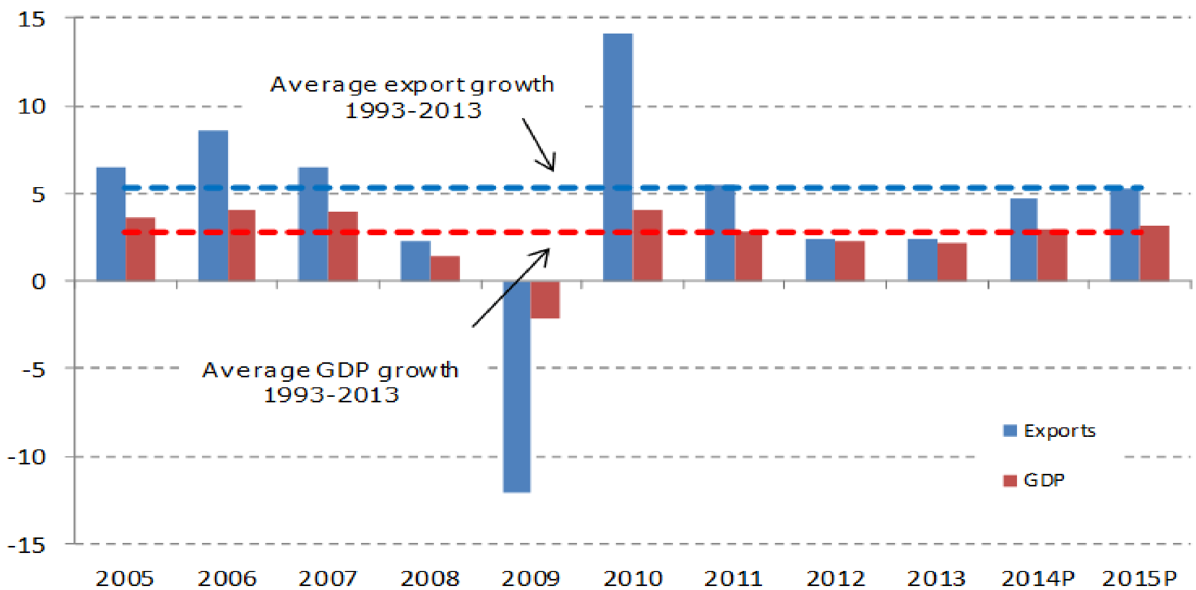
As business has become more international and developing countries have taken their place alongside the OECD countries, maritime industry provided the vehicle for an extraordinary growth of trade. As world trade statistics show, for a number of decades, world trade has grown on average nearly twice as fast as world production. This reflects the increasing prominence of international supply chains and hence the importance of maritime transportation.

Figure 1: Growth in the volume of world merchandise trade and GDP, 2005-15a (WORLD TRADE ORGANIZATION 14 April 2014)



Importance of seaports:

Therefore, Seaports by converting land transportation to sea transportation and vice versa have an important role in trade and maritime industry.

The dynamic nature of issue:

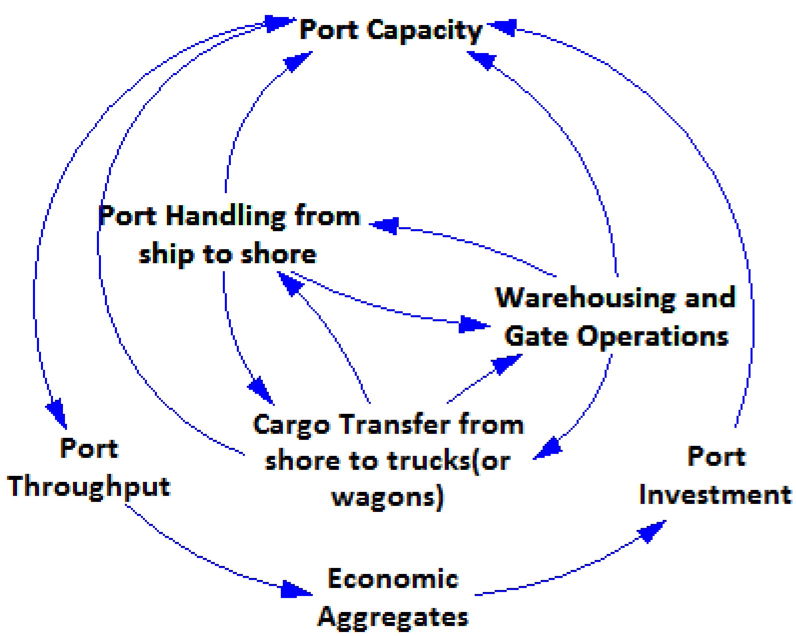
Essentially, transportation systems are complex, because of different stakeholders or agents which bring feedbacks and lagged responses. (Khaled et al., 1994)

There are many determinants to port capacity – labor relations, number and type of cargo handling equipment, quality of backhaul area, port access channel, land-side access, customs efficiency and the interrelationships among these items, to name but a few.

How port capacity is then defined? How the interrelation between these factors affects the port performance? What is the real bottleneck of port capacity and when will it show up? Considering time lag and gestation period of investment in ports, what is the right time for investing on new equipment?

The most realistic way to answering these questions and representing the dynamic performance of such systems is to delineate the feedback causal structures that describe such systems. SD is particularly suitable for the dynamic behavior of systems. (Shepherd, 2014)

So, with the aim of finding the exact bottlenecks of the port capacity and understanding the whole underlying system, port authorities must consider the port handling processes from ship to shore, transfer procedures from shore to wagons and trucks, and warehousing and gate operations, with a whole system approach. From a broader perspective, the port capacity influences and is influenced by the Economic aggregates which leads to a rise in port investment.



The SD platforms also offer specialized tools, which aid in the calibration of models, optimization of policies and thus improve ease of use through flight simulators which all contribute to the understanding of the whole underlying system. (Khaled et al., 1994)

Literature Review

The importance of the transportation dynamics provoked some researchers to elaborate on it. Abbas and Bell (1994) outlined the modeling approach used in system dynamics (SD) and listed the advantages of the approach compared to traditional transport modeling. In particular, they suggested the approach would be well suited to strategic policy analysis and as a support tool for decision-making.

In 2014, Oztanriseven has conducted a literature review of SD applications in the field of Maritime Transportation Systems (MTS). The research finds the evidence in the literature that SD can be used to study and improve the MTS. SD is applied to many aspects of the MTS studies including maritime disruption studies, port-related studies, and vessel-related studies.

Maritime disruption studies use SD to model disruption complexities and uncertainties in the MTS. Their goal is to recover to the pre-disruption throughput level. (Omer et al. 2012; Croope and McNeil, 2011)

Vessel related studies use SD model to successfully explain the behavior of the ship market by only considering fleet size and fleet utilization data. (Engelen et al. 2009; Dikos et al. 2006)

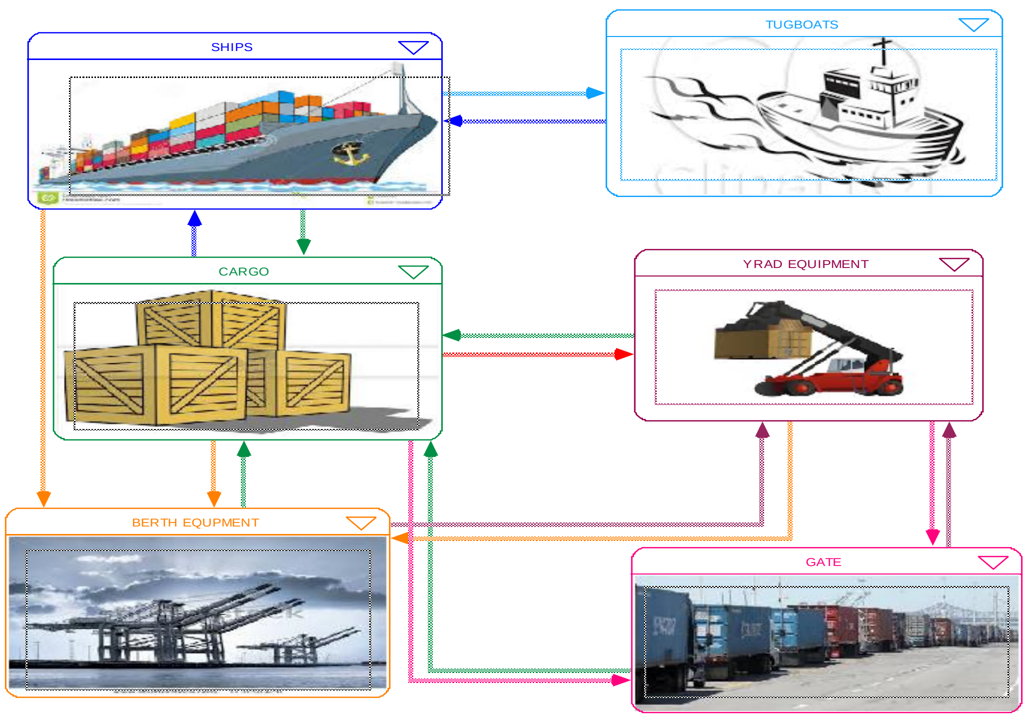
Port related studies are limited in number though SD simulation is a powerful tool to handle the complex port transshipment processes. Dundovic et al. (2009) and Dvornik et al. (2012) and Munitic et al. (2003) applied an SD model to study port-handling processes considering loading and discharging operations from ship to shore, transfer operations from shore to wagons and trucks, and warehouses.

Despite the fact that SD is applied to many components of the MTS, Academic researches which address port operations from a System Dynamics (SD) perspective is still remarkably scarce in contrast to the typical discrete event-driven simulation approaches. (Oztanriseven, 2013) Specifically in Iran, in which maritime transportation plays a vital role in economics of the country, an study of the port capacity with the help pf simulation models seem to be necessary.

The main structure of the model:

Based on literature review and extensive work of identifying the real interrelationships among system elements in Rajaee Port of Iran, and structural and behavioral validation tests of model and also conducting more than 100 verification sessions with our client, Port and Maritime Organization of Iran (PMO), the final Integrated Port Capacity Dynamics Model (IPCDM), have been developed. The IPCDM consists of six interlinked subsystems. These subsystems have been named Ships, Cargo, Tugboats, Berth Equipment, Yard Equipment and the Gate. The name of each module originates from the main stock-flow of that module.

Figure 2-Modules of IPCDM for Rajaee port and their interrelationships



Identifying material flow within port:

The Ship flow: Considering the inflow from seaside to shore as the origin of the demand for service at ports, the first flow of port performance model would be ships flow. The ships flow encompasses different stages that a vessel deals with, during its presence at port. Any vessel that approaches the port must first be assigned to the berth with the aid of tugboats and pilots, then be involved in the cargo loading/unloading processes and finally leaves the port, with the help of tugboats and pilots for the second time. These are the main stages that any vessel has to deal with, during its presence at port.

The tugboat and pilot flow: The second flow of the model is the tugboats and pilots working flow, which deal with ships maneuvering, berthing and unberthing.

The cargo flow: The flow of ships converts to the third flow which is cargo flow. The process of cargo handling is mainly performed by berth equipment. In accordance with reality, cargo is divided into three groups; the first group is supposed to be handled directly from (to) road truck to (from) ships by means of berth cranes (it, mainly food stuff, doesn't need to be stored in the port yard), the second group, like container and general cargo, needs warehousing and deals with yard cranes and terminal trucks too and the third group, like liquid bulk and Ro-Ro, is unrelated to cranes and trucks.

Berth equipment flow: The fourth flow of the model is the flow of the berth equipment working which consists of berth cranes flow and terminal trucks flow (we name them vessel trucks from now on). While berth cranes are responsible for loading and unloading process of the ships, Vessel trucks move the cargo between berth and yard. off course some cargo which the berth cranes deals with, must be transported directly from ships to their customers with the help of trucks that come from port gates (we name them road trucks from now on).

Yard equipment flow: The fifth flow of the model consists of the yard cranes and storage facilities working flows. Yard cranes serve the vessel trucks and road trucks which are waiting in the yard. At the same time, servicing road and vessel trucks will change the level of dwelled cargo stacked in the storages.

Road trucks flow: The last flow of the model is the flow of the road trucks in the GATE module. Gate is responsible for entering and exiting the road trucks. Based on actual operations, Entered road trucks have divided into two groups. The first group goes directly toward berths. They carry the direct cargos. The second group of road trucks goes to the main yard and port storages for loading/unloading processes.

The main feedback loop of the model:

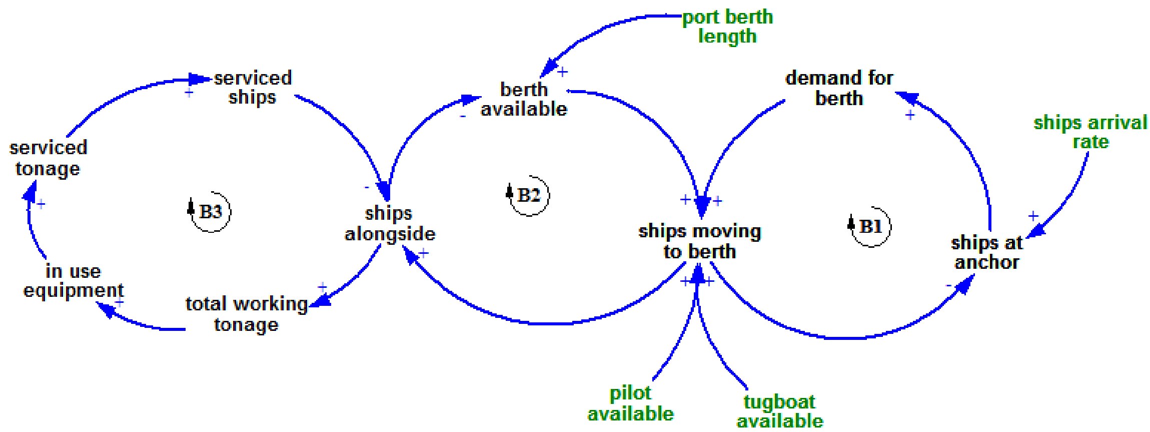
The IPCDM consists of near 500 variables. It is not possible and maybe not necessary to explain all relationships and feedbacks. Therefore, for the purpose of discussing the overall mechanism of the system, below are the major feed-back loops of model which create dynamic structure of the system and usually include more than one module. It should be mentioned that stock-flow model is built in Ithink9.0.2 and causal loop diagrams are designed by VENSIM PLE.

Ship flow dynamics: First of all, ships arrival rate determines the number of ships waiting for berthing at anchor every day. An increase in the number of ships at anchor causes increases in demand for berthing. It leads to the movement of ships to berths. As more ships move to berths, the number of ships at anchor fall, (Loop B1 in Figure 5A) and the number of ships moving to berths rise. Thus the number of ships alongside the berths increases, leading to a drop in the berths' availability and declines in the number of ships moving to berth. (Loop B2 in Figure 5)

As the number of ships alongside the berths increases, the total amount of working tonnage rises. This leads to employing more equipment and as a result the amount of serviced tonnage and consequently the number of serviced ships will increase. The increase in the number of serviced ships causes a fall in the number of ships alongside the berths. (Loop B3 in Figure5)

Other modules of the seaport also include feedback loops that lead to a complex system of interrelationships between ships, cargo, berth equipment, yard equipment, warehouses and gate.

Figure 3- causal loop diagram of ships flow at port



A Dashboard of IPCDM

After calibration and validation of model we designed some dashboards to make flight simulators for different audiences we had in PMO. One that used in strategic planning of PMO is as shown in the following figures:

Figure 4: interface of IPCDM of Rajaee Port (navigation page)

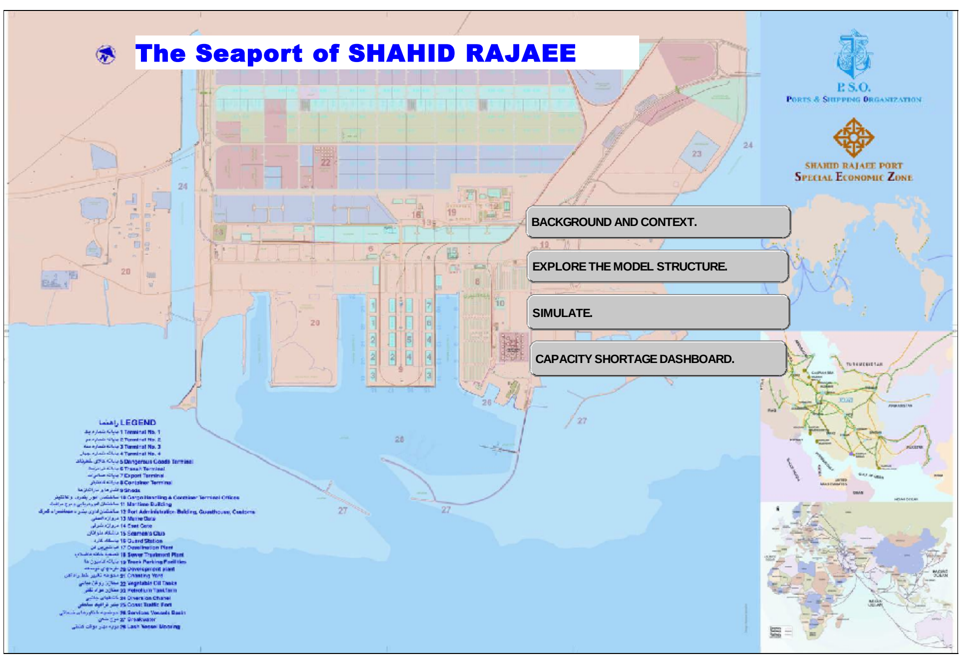


Figure 5: interface of IPCDM of Rajaee Port (simulation page)

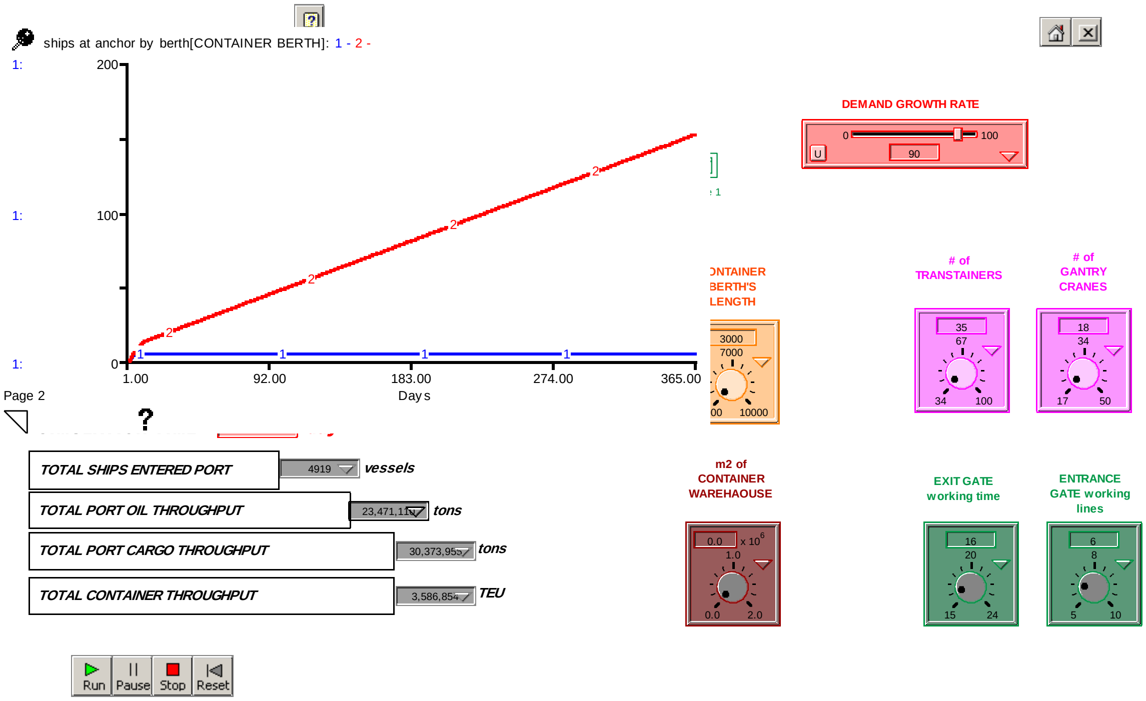
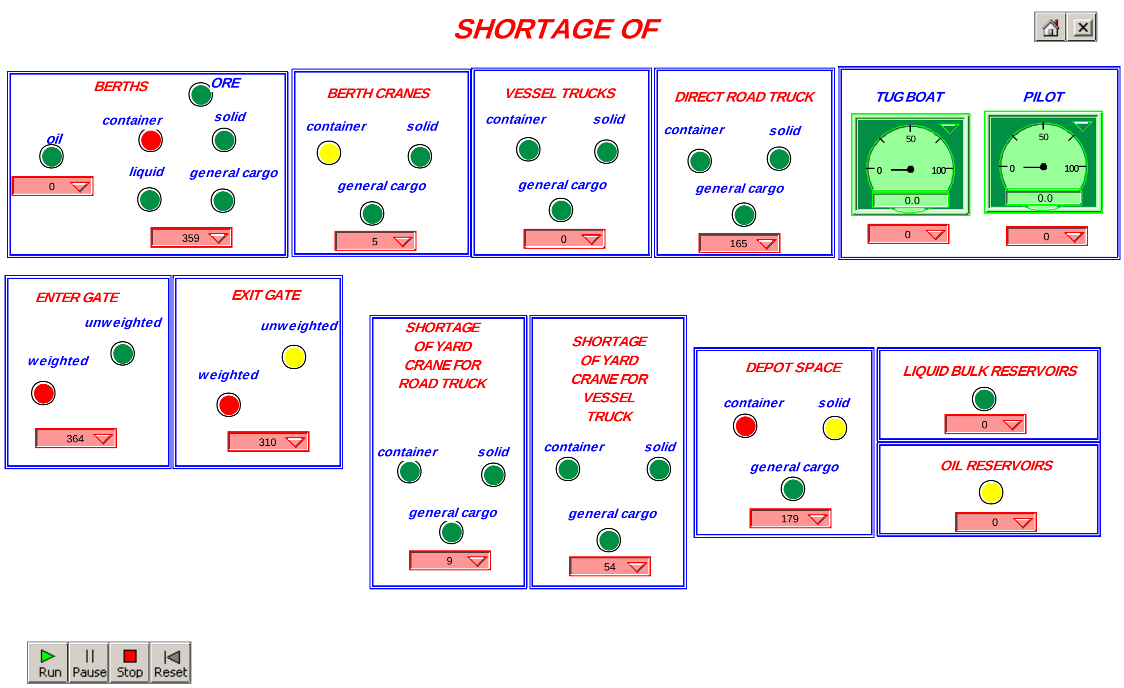


Figure 6: interface of IPCDM of Rajaee Port (capacity shortages page)



Conclusion

Trying to keep pace with the trade growth, the port managers should decide when and where to invest in ports. This paper proposes an Integrated Port Capacity Dynamics Model (IPCDM) for simulating the port system, which includes six interlinked modules representing the important elements of the system that work together allowing an integrated scenario evaluation.

The model applied to the port of SHAHID RAJAEE – the most important commercial port of Iran in Persian gulf- in order to define the port's capacity for handling different types of cargo and to provide port managers with a platform for policy analysis and decision support. Based on usefulness of work for our client, Port and Maritime Organization of Iran (PMO), these approaches have also used for 6 other major ports of Iran and flight simulations by these IPCDMs are now a vital part of strategic planning procedure in PMO.

In order to simulate the terminal capacity, the following steps must be taken:

1- Setting the parameters of IPCDM based on databases of the port at the interface tab of the model and simulating the system with the base data.
2- The maximum capacity of container terminal of the port ca be estimated through sensitivity analysis of the model by introducing different growth rates for ships arrival rates and watching the behavior of the ships at anchorage (if the number of ships at anchor shows a systematic increasing trend in ships waiting at anchorage).
3- Different policies for improving the maximum capacity of container terminal could be introduced through sensitivity analysis, and finally the most effective strategy would be selected.

The validation of the model was done by comparison of generated and actual behavior of key performance indicators of the port at a certain throughput level (the base scenario).

Simulations are conducted using ITHINK® software version 9.0.2 using Euler integration with a time step of 0.083 days. Results were not sensitive to use of Runge-Kutta integration methods or smaller time steps.

Acknowledgment

Creating IPCDM would not have been possible without the help of staff members of the Strategic Studies and Investigation Center of Iran Port and Maritime Organization and colleagues in ARYASAHM economic research company. So, we would like to express our deepest gratitude to them.

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