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SIMULATION MODEL OF RESOURCES ALLOCATION OF CONTAINER TERMINALS

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ABSTRACT

A large amount of capital is invested in developing container terminals in order to cope with the growth of trade and, at the same time, to increase the level of efficiency. Managing a container terminal becomes a difficult and challenging task due to its complexity. Simulation model has the potential of being extremely useful in assessing and analyzing different strategies in the planning and management of the terminal. The simulation model is also useful for forecasting the likely effects on system performance of any physical and policy changes. In this study an efficient simulation model for container terminal planning is developed. The model assists in making informed decisions on the logistic management of terminal operations and the optimal utilization of resources.

Keywords: *Simulation, planning, terminal, ARENA*

ABSTRAK

Sejumlah peruntukan yang besar dilaburkan bagi membangunkan terminal kontena untuk mengimbangi keperluan ekonomi negara yang pesat dan juga pada masa yang sama untuk meningkatkan tahap kecekapan terminal tersebut. Pengurusan terminal kontena menjadi semakin sukar dan mencabar disebabkan peranannya yang semakin kompleks. Model simulasi merupakan teknik yang sangat berfaedah bagi menilai dan membuat analisis tentang pelbagai strategi dalam pengurusan terminal ini. Model simulasi juga bermanfaat bagi tujuan peramalan prestasi sistem terhadap perubahan struktur fizikal atau polisi sektor ini. Dalam kajian ini sebuah model simulasi telah dibangunkan. Model ini dibangunkan bagi membantu pihak pengurusan membuat keputusan guna meningkatkan kecekapan operasi pelabuhan dan juga mengoptimumkan penggunaan sumber pelabuhan.

Kata kunci: *Simulasi, perancangan, terminal, ARENA*

INTRODUCTION

Seaports are important trade gates for most countries. Yet for a long time, the study of ports have not attracted the interest of many researchers. Only when the revolution of containerization took place in the mid-1960s, did attention begin to focus on port studies (Sabria, 1986; Taleb-Ibrahimi, 1989). Currently, a large amount of capital is invested in this transportation mode in order to cope with the growth of trade and, at the same time, to increase the level of its efficiency. Traditionally, the port serves as an interchange, where facilities and services for storage and transit of cargo are provided. However, this traditional role of ports has been changing rapidly as port users begin to re-examine their costs somewhat more intensely than they did in the past, especially in the wake of rising competition and costs of operations (Klang Container Terminal). Ports are therefore no longer perceived merely as idle players in the transport chain to provide transit and storage facilities and services.

The high growth of economy in Malaysia has had a substantial impact on the expansion of the seaport industry. It is estimated that almost 95% of external trade of Malaysia is sea borne and seaport industry has always played a vital role in promoting international trade (Hassan, 1993).

The quality of services provided by the container terminals can influence the efficiency of the overall transportation chain. It has become the main agenda of the port management in this era to improve the operational services of the port. A simulation study was conducted at a new container terminal in Malaysia to improve the efficiency of the port's operation. In the study, a simulation model was developed to assist the management in optimizing the utilization of the port's resources.

In addition, the highly stochastic nature of port operations, as well as the complexity of interactions among the port sub-systems, makes simulation more preferable over other analytical methods. Simulation models have the potential of being extremely useful in assessing and analyzing different strategies in the planning and management of the port. Simulation models are also useful for forecasting the likely effects on system performance of any physical and policy changes (Collier, 1980).

This project uses a statistical analysis method to measure the input and output of the model. For the input analysis section, the study presents the data collection method and assumptions used. The model is built using Arena, a simulation software used for discrete event simulation. The output analysis and model experimentation were carried out after the completion of model building using Arena. The verification and validation of the output model showed the reliability and credibility of the model built to sufficiently represent the real system accurately.

The statistics collected from the simulation model include service utilization of each of the berth, primer movers' utilization and Rubber Tyre Gantries utilization. Finally, some recommendations are presented for the improvement of the container operations at the terminal.

ANALYTICAL MODEL VERSUS SIMULATION MODEL IN PORT STUDIES

There are a number of methods that have been used by the researchers in port studies. The most popular method has been computer simulation (Collier, 1980; Dover, 1982). Besides this, there are also analytical methods that have been used, such as queuing theory, linear programming and network analysis (Mytton,1978).

Among the various mathematical methods, queuing theory is the most commonly used by many researchers. It is also one of the earliest methods used in port planning. Many queuing models have been developed to analyze port congestion problems. The objective of queuing theory is to find a way of reducing the queue length and provide service to customers in the most efficient manner. There are several factors to be considered in any queuing system, such as the arrival pattern, the service pattern, the service mechanism, the queue capacity, and the queue discipline.

The first queuing model was developed in 1955 in the UK steel companies, to estimate the cost of the time ships spent in a port (Edmond & Maggs,1978). Mettam (1967) and Wanhill (1973) applied queuing technique in the planning and design of a port system to forecast the likelihood of congestion and delay as a ship waits for a berth. In their work, many assumptions were made to enable them to model the port using this technique. For example, they assumed that the arrival time follows a Poisson distribution, while the service time follows a negative exponential distribution. However, this assumption might not be the case for many port systems. Also, their models were not capable of any priority assignments. The models do not have the flexibility compared with simulation models and therefore are less adaptable to present port complex situations. The other disadvantage is that their models were also incapable in providing detailed results.

De Weille and Ray (1974) also used a queuing model to find out how many berths a port should have in order to minimize ship waiting time at the port. In their work, they used the assumptions, like Mettam (1967), for the arrival of ship and service time at berth to follow a Poisson and an exponential distribution, respectively. They also assumed that the berths have the same service rate, and that the service to a ship is done on a first-come-first-serve basis. The model assumes that the berth has the same service time for all ships, while in reality a port might have some specialized berths, and different types and sizes of ships, which may have different service times.

Noritake and Kimura (1985) and Radmilovich (1992) also analyzed the movement of ships at ports using the queuing theory. The berth capacity of the port was determined by the number of berths available and the average rate of handling cargo at each berth. The studies conclude that there is no definitive way to establish the number of berths or capacity in a port, because the variables that affect them are numerous. The cargo-handling rate also varies from port to port due to weather conditions, institutional and administrative practices, characteristics of commodities and the degree of mechanization of cargo handling operation at each port.

Dover (1982) discussed the application of operational research techniques in a port domain. Among them are queuing theories, critical path analysis, inventory model, equipment replacement model and linear programming. He found that computer simulation is particularly useful in cases where mathematical solutions have not been developed.

Analyses using queuing theories are relatively suitable for straightforward or simple problems. It has become difficult to include factors that must be considered in the total systems approach, such as seasonal variations in demand, different patterns of ship arrival, variable vessel service time, different types of vessel, limitation of berths, and so forth (Nilsen & Abdus-Samad, 1977). Therefore the method of discrete-event simulation becomes more suitable for such complex systems.

The technique of simulation is preferable to real system assessments, because of its ability to experiment with the real system without actually incurring any direct capital investments. Such a technique can be used for modeling a complex process and model, which are difficult to solve mathematically.

Nilsen and Abdus-Samad (1977) and Guise (1982) described and compared methods using the queuing theory and simulation approach, and suggest guidelines under which the two techniques should be used. They described that the queuing models are quicker and less costly, but less flexible and produce less detailed results, and cannot be applied to more detailed situations. The queuing theory can be used effectively in a simple port problem with certain assumptions. If the problem to be modeled becomes too complex, with too many parameters involved, then queuing theory becomes unsuitable and simulation should then be adopted.

System Description

This study focuses on the activities of transporting containers between the wharf area and the yard area of the Container Terminal under study. Two main port resources are used for these activities; i.e. prime movers and Rubber Tyre Gantries (RTGs). The loading process of export containers begins at the yard and is completed at the wharf. The unloading activity begins when the containers are discharged from the arrival ship and transported to the yard using prime movers. At the yard area RTGs are used to unload the containers from prime movers for stacking at the assigned zones. Figure 1 illustrates the unloading process of import containers. The yard is used as a temporary storage area before containers are transported out of the port area.

The terminal has five wharves and each wharf is assigned six prime movers for transporting containers between the wharf and the yard areas. In addition to this, five zones are designated in the yard area namely; Zone A, Zone B, Zone C, Zone D, and Zone E. There are two bridges that connect the wharf area to the yard area. For each zone there are at least 11 blocks available to stack the containers.

In order to avoid collision among the prime movers that move containers between the wharf and the yard areas, a few rules are followed. The first rule is that the prime movers must take the bridge that is closest to the zone for transporting the containers in the yard. The second rule is that the prime movers must enter the block from the left and leave the block at the right side regardless if it is a loading or unloading activity.

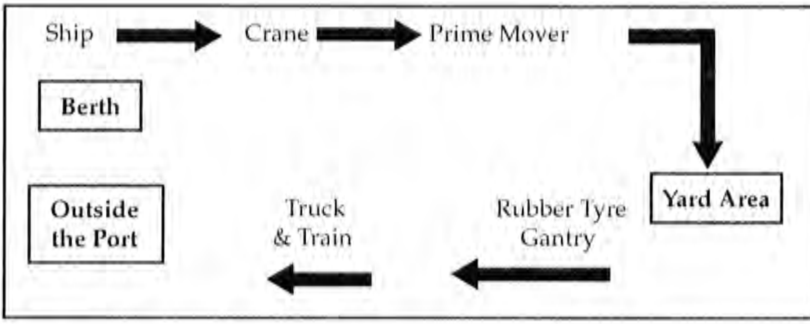

Figure1
Operational process for container unloading at port

The loading process of export containers starts at the yard area when containers are unloaded from Rubber Tyre Gantry (RTG) to the prime movers. The prime mover transports the export container to the wharf and returns to yard area for transporting other containers. The cycle is complete when all the required containers are transported.

OBJECTIVES OF STUDY

The aim of the study is to develop a simulation model, which can be used to improve the performance of loading and unloading activities at the port under study. In order to achieve the stated aims, the following objectives were identified and pursued:

- to create a simulation model that is capable to mimic the port operations using the ARENA software.
- to increase the utilization of port facilities such as prime movers and Rubber Tyre Gantries.

SIMULATION STUDY APPROACH

In any simulation study there is a structured approach to conduct. This approach is not necessarily unique but in general it has some common elements (Centeno, 1996). Figure 2 presents the general simulation process as proposed by many simulation modellers (Gogg & Mott, 1993). A similar approach has been applied in developing a simulation model at the container terminal under study. As presented, the simulation modelling flow is very easy to comprehend, useful and handy in guiding a modeller with a simulation modeling project.

Understanding the problem clearly will make the modeling task easier. An accurate definition of the problem formulation can dictate the level of details required in the model and may indicate specific areas where special care must be taken (Sadowski, 1991). The aims and objectives will determine how the model will be defined, what aspects of the system will be simulated, and what assumptions can adopted to simplify the building of the model (Shannon, 1998). The model development will adhere to the goals and objectives and will be completed in phases of increasing complexity. The model will first capture the basic logic of the system and the logic flow.

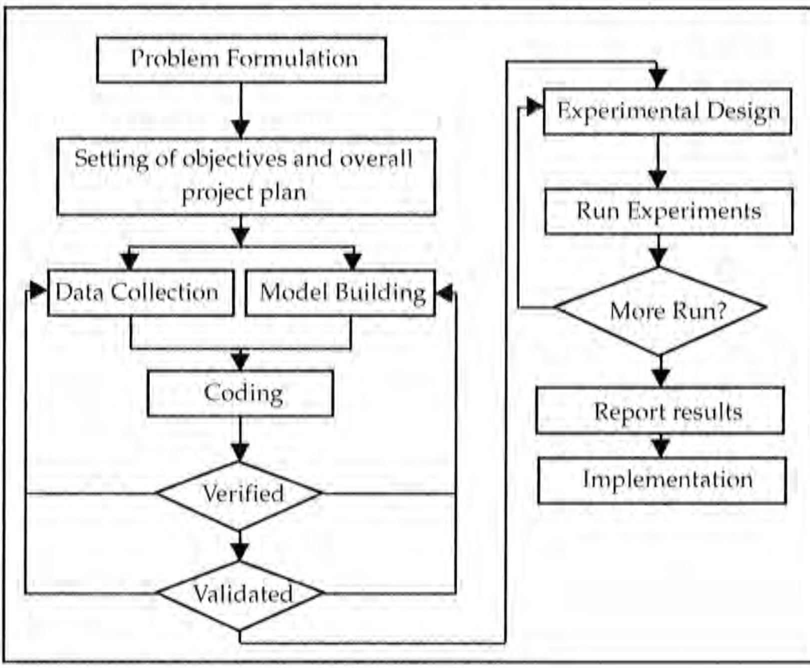

Figure 2
Simulation modeling processes

After the system has been flow-charted and organized, pertinent information about the system's operations and control logic is collected. Operation characteristics, such as operation time and set-up time, are collected for each element in the system. The modeler must be knowledgeable about programming and/or a simulation package. Model verification ensures that the model behaves in the way it is intended. Therefore the input data should be correct. Model validation ensures that the model has successfully captured the operational characteristics of the system and behaves the same as the actual system.

Operational assumptions are also established for system elements when actual data are in short supply or non-existent. System elements are assumed to operate in a certain manner for the purposes of the simulation model. Simulation experiments are expensive in terms of time, labor of experimenter, and cost of computer time. The DOE methodology provides a structure for the modeler's learning process (Kelton, 1998). Using the DOE methodology can also determine how system parameters can be compared in order to analyze the system.

Simulation has to be run more with many replications. Law and McComas (1991) recommended that the simulation runs should be between 3 to 5 times and the average of these runs is recorded. The focus on the output analysis should be on the performance measures. The performance measure is actually the input to the decision-making and it gives insight to the understanding of the system behavior. The model document should describe a data structure, the key elements of the model, the general flow of logic, and all variables, and queues. The ultimate reward from developing a simulation model is to gain information that can be used to improve decision making with the system. The success of the implementation phase depends on how well the previous steps have been performed. It is also contingent upon how thoroughly the analyst has involved the ultimate model user during the entire simulation process.

MODEL INPUT

In this study, three months of data was collected through historical data and system observations. The port has a detailed record of its daily operational activities. The input data for the model is divided into two parts; the input for unloading process and the loading process. The input data for the unloading process include the number of unloaded containers, inter arrival time of ship, process time of loading container onto prime mover, process time of RTGs unload container from prime mover, process time of the RTG stacking containers on the block in the yard.

For the loading process, the input data includes number of containers for loading operation, the process time for the RTG's to load containers onto prime mover, process time of crane to offload containers from the prime movers. Other inputs used in the model are the velocity, acceleration, deceleration and the turning velocity factor of the prime movers. Arena Input Analyzer was used to fit an appropriate distribution of this input data. Input Analyzer proposes that the best fit of inter arrival of ships follows a Weibull distribution whereas Normal Distribution is found suitable for many other activities.

MODEL VERIFICATION AND VALIDATION

Model validation and verification is another important aspect in simulation modeling. A simulation model must be verified and validated because the developed model should represent the real process. The model was run for five replications and the average performance measures were recorded. The results were then compared with the historical data to validate the model.

The output generated of the model is based on the five wharves. Table 1 shows the difference of container throughput between the actual data and simulation output. From the data collected, total output from wharf 1 is 343 containers whereas the simulated result is 364 containers. The data collected for total output for wharf 2 is 256 containers whereas the simulated result is 270 containers and the difference in percentage is 5.5%. The model is also validated for wharf 3 and the difference of in percentage between the real process and the simulated result is 10% where the real data for total container is 269 containers and the simulated data is 296 containers. Wharf 4 is also validated with the percentage of 9.6% where the real data is 360 containers and the simulated data is 376 containers. Lastly, the real data for total containers in wharf 5 is 371 containers and the simulated data is 376 containers, which brings a 3.12% difference.

Table 1
Difference of Containers Throughput Among Wharves

Wharf #	Actual Data	Simulation Output	Difference (%)
1	343	364	6.1
2	256	270	5.5
3	260	296	10.0
4	360	376	9.6
5	371	376	3.1

From the sample data, the average utilization of the prime movers is 51.5%, whereas the simulation output shows an average value of 45.1%. The difference between the simulation output and actual data is 6.4%. All values show the output of the throughput using simulation compared with the actual port data and it seems that they are in good agreement.

ANALYSIS OF THE YARD OPERATION

The model developed can be used to evaluate the utilization and performance of two main port resources; prime movers and Rubber Tyre Gantry (RTGs).

Analysis of Prime Movers

Six prime movers are assigned by port management to each wharf. Prime mover utilization is defined as the ratio of the time prime movers are used for loading and unloading the containers to the total available working time. The utilization reflects how busy the port is. High utilization may cause some bottleneck being present in some parts of the activities. Low utilization shows the port resources are under utilized.

From the simulation results, the average utilization of prime movers is 45.1%. It shows that the prime movers do not cause any delay to the loading and unloading operations. The value indicates that the numbers of prime movers assigned per wharf are quite sufficient for handling the containers. The port is keeping more prime movers in anticipation that the throughput will increase in the future. The average utilization of prime movers is computed based on the 24 hours of port operations. Generally the port is more active doing handling of containers during day time. Therefore the port may assign fewer prime movers per berth for night operations.

The model is then simulated with five replications using only five prime movers per wharf and the average simulation results show that the utilization of prime movers increases to 51.5%. When the model is simulated using seven prime movers per wharf the results show that utilization decreases to 43.8%.

Analysis of RTGs

The port has a total of 61 RTGs to use for loading and unloading of containers in the yard area. From the simulation output, the average utilization of RTGs is only 12.2% and with maximum value of 18.3%. It shows that the utilization of RTGs at the port is considered low due to the high number of available RTGs. The port has allocated each block with one RTGs. The low average utilization obtained from the simulation result is based on the assumption that all RTGs are in operation throughout the day.

To increase the utilization of RTGs, it is recommended that the port reduces the number of RTGs in the yard area. It may requirere locating the RTGs to a strategic area in order to allow the sharing of this resource between adjacent blocks. The disadvantage of this move will cause more movements to the RTGs while doing the loading and unloading activities. It will consequently cause a queue to form for the prime movers at the yard area. If this circumstances arise then the number of prime movers assigned per wharf need to be increased. It will cause the increase of operating costs to the port.

The model is then run using a schedule based on the usage of RTGs at the yard area. When no activities of loading and unloading take place, the RTGs are not considered in operation. Based on this circumstance the average utilization of RTGs increased to 35.5%. It is worth to note here that the RTGs are not used only for loading and unloading activities. They are also used for yard clearance where the containers need to be rearranged according to specific requirements. This activity takes place only when no prime movers turn up for loading and unloading activities. Based on this assumption, the average utilization of RTGs is higher than computed and this justifies the allocation of each block with a RTG.

DISCUSSION AND RECOMMENDATION

A simulation model was developed to assist in the management and operation of the Container Terminal under study. The simulation model is used to test ideas for increasing efficiency and improving the performance of loading and unloading activities at the port. Investigations on planning and changes can be tried on the model without disturbing the existing operations. The model offers practical information to the management to make informed decisions. The simulation model shows that the port's existing port resources of prime movers and rubber tyre gantries are quite sufficient for handling the containers.

The research and the simulation models have improved understanding of the inter-relationship of the several physical components of the port and policies adopted by the port management. The process of constructing the simulation models and reviewing the interaction of these components has given an insight into the different operational characteristics at the port. The approach of system analysis is not only beneficial to the modeler, but it is also useful to the port operational officers since it gives a thorough understanding of how the port behaves and not how one thinks it behaves.

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