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Simulation Modeling and Analysis of Customs-Regulated Container Terminal Operations with Multimodal Transportation

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SIMULATION MODELING AND ANALYSIS OF CUSTOMS-REGULATED CONTAINER TERMINAL OPERATIONS WITH MULTIMODAL TRANSPORTATION

by

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ABSTRACT

SIMULATION MODELING AND ANALYSIS OF CUSTOMS-REGULATED CONTAINER TERMINAL OPERATIONS WITH MULTIMODAL TRANSPORTATION

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Old Dominion University, 2014
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World trade has been increasing dramatically in the past two decades and, as a result, container exchange has grown significantly. Consequently and to meet this increase, several container terminals are expanding and many new ones are being established. A port with one or more container terminals is considered a complex system in which many entities interact to accomplish seamless handling of containers inbound and outbound. The level of complexity is drastically heightened for container terminals containing multimodal transportation systems as they typically involve ships, rail, and trucks arriving to one or more terminals delivering containers of different sizes to several types resources including quay cranes, rubber tyred gantry cranes, straddle carriers, and more. Simulation can be a useful tool to assist in predicting the behavior of the system and its performance under unforeseen circumstances as well as to study possible modifications to the components of the port system. In this thesis, a generic discrete-event simulation model is constructed to simulate port operations with different associated resources and stations including loading/unloading, customs station, container yard and more. The analysis will entail studying various scenarios motivated by changes in different parameters to measure their influence on relevant outcomes including throughput, resource utilization and waiting times.

This thesis is firstly dedicated to my inspiration, best friend and cherished husband Mohammad, for being by my side through every step of this challenging path and for all the support, assistance and understanding that you always offer. I could not have done it without you.

This thesis is also dedicated to my loving parents Aladdin and Mayada, for devoting your life to me, my brother and sister, and for all the sacrifices that you have made to help us succeed. Thank you for all the motivation and for believing in me and encouraging me since the beginning of my studies, you are truly the best parents anyone could have asked for.

And to my Aunt Alia who has been a source of encouragement and inspiration to me throughout my life, a very special thank you for helping me through the challenging tests of my high school and for enabling me to pursue bigger dreams.

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Last but not least to my brother and sister Ahmed and Maisa and my Grandmother Huda, along with the rest of my family and friends for always having faith in me and seeing me achieving the hardest tasks. Thank you from all my heart.

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CHAPTER 1

INTRODUCTION

Container terminals in ports are considered the main logistical intermodal point where different types of transportation modes (ships, trucks and rail) meet to exchange cargo. The United States alone has 361 seaports which are the gateways for more than 80% of the foreign trade; which makes the United States the world's largest importer and exporter [1].

In the container terminal system, material handling processes take place utilizing different resources and vehicles in order to transport cargo containers as well as loading, unloading, and storage areas. This system is of greater complexity in maritime container terminals, that is, container terminals involving transshipment of containers between land vehicles and sea vessels.

Because of the multiple-components nature and the complexity of such systems, researchers tend to use simulation for the purpose of creating a smaller duplicated version of the system, for better familiarization with its processes and interactions and to be able to introduce solutions and test scenarios on the simulated version of the system in order to avoid the risks, waste time and money associated with disturbing the real system.

Thus, constructing a simulation model that matches the attributes of the container terminal and accurately demonstrates the operations and activities occurring in such a system can be of significant analytical benefit.

1.1 Container Terminals

A container terminal in a port (Figure 1) is a place on a shore or a coast where ships or container vessels berth in order to transfer goods or individuals to or from land and where containerized cargo is stored transiently until they are sent to their final destination [2]. The process in a container terminal starts by the arrival of vessels / ships, trucks or rails/trains. Depending on the port's policy, a portion of incoming containers run through the customs department for inspection upon arrival. Containers are then moved by quay cranes and are exchanged by loaded or, at some instances by empty ones. Loaded containers are either moved to storage area, transported to the container yard by yard trucks or rubber tyred gantry cranes (RTG) or moved from one transportation method on to another [3, 4].

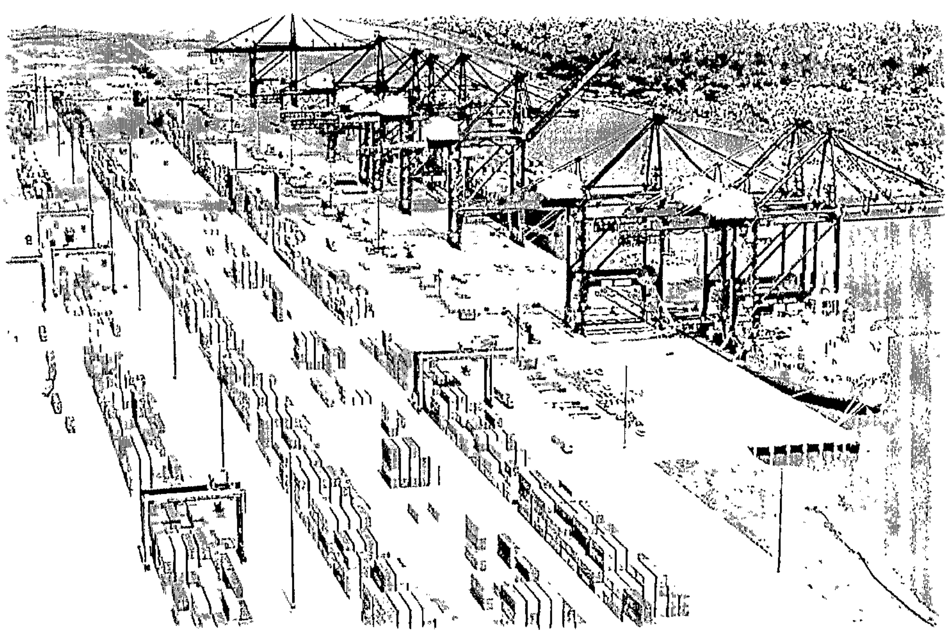

Figure 1: Container Terminal [5].

1.2 Discrete Event Simulation and Ports

Simulation encompasses the different techniques and applications of using computer software to mimic a real system for the purpose of studying it. Discrete Event Simulation refers to the type of simulation which deals with separated and different events that take place at a specific time in the system [6]. The real system that will be studied and simulated in the presented work is a container terminal; the operations that occur in a container terminal system are composed of a sequence of discrete events in time. An extensive amount of research and many studies have been conducted recently to explore and analyze the container terminal system using simulation by creating a container terminal replication and imitation models in order to anticipate the current and future situations and to prevent delays, reduce costs and accomplish optimal terminal configuration [4, 7, 8].

There is a number of simulation software that supports discrete event systems. This work will be carried out using Arena software platform. Arena is a robust and well-established discrete event simulation software that combines the flexibility of the simulation-specific programming languages and the ease of use of the high level simulators.

1.3 Research Question

This thesis addresses the simulation of terminal operations in general, but mainly focuses on modeling a modern maritime container terminal with modern resources, where cargo is transported from ship to inland and vice versa. In order to do that, data were collected from different papers and ports around the world in order to develop a generic and reliable simulation model that can be adapted for usage with any new port with decreased effort in customization of the model. The general approach for this work was initiated by Kotachi *et al.* [9].

The overall objective of this work is to reflect the interactions of the real system in a simulated environment, to create a platform that would allow sensitivity analysis, and to develop a tool that would be able to give numeric outcomes of the system highlighting areas and opportunities of improvement. The proposed simulation model makes analyzing some measures simpler, like the average resource utilization, the total number of containers that pass through, the average waiting time in queues among others and resources allocation. The proposed simulation model will also incorporate customs' operations to realize their influence in a container terminal and construct a platform for what-if scenarios for finding the most efficient resource allocation and behavior.

1.4 Chapter Organization

There are six chapters in this thesis: A general description of the project as well as an explanation of the problem is included in the Introduction; Background introduces the terminology, theory and ideas related to this work; Related Work covers and analyzes some of the research done by others that is related to this work. The actual stages of developing the simulation model and a description of how the underlying problems were addressed are given in the Methodology. To put these methods into practice, the next chapter introduces a Case Study of a real system where the developed model is implemented and the obtained results and performed analysis are discussed. Finally, the

Conclusion and Recommendations chapter gives a summary of the accomplished objectives and discusses possible improvements and expansions in the future.

CHAPTER 2

BACKGROUND OF THE STUDY

In order to build a knowledge infrastructure for the succeeding chapters, and to understand the topics that will be covered, the theoretical background will be presented in this section. This chapter will cover a detailed description of the events that occur in the container terminal and will cover the main topics in the literature with which this thesis is concerned.

2.1 Container Terminal

At a container terminal, cargo containers are transshipped between different transportation modes. The terminal is referred to as a *maritime container terminal* if the involved transportation modes include ships and land vehicles. A maritime container terminal is a serialized facility that lies on a cost where ships can dock for delivering and picking up containers. If the transportation modes include only land transportation, the terminal is referred to as an *inland container terminal.* Inland container terminals are usually situated near major cities and are, in most cases, connected by rail to maritime container terminals. Both types of container terminals usually contain storage facilities for both loaded and empty containers. Loaded containers are stored for relatively short periods, whereas empty containers may be stored for longer periods awaiting usage.

The interactions at the container terminal begin by the arrival of one of the intermodal transporters, that is, ship, train or truck. Then, containers and cargo get transported from one mode of transportation to another depending on its content and destination [10]. The succeeding sections will explain the details of the container handling process and the types of resources and equipment usually used in a modern container terminal. Figure 2 shows a view of a container terminal.

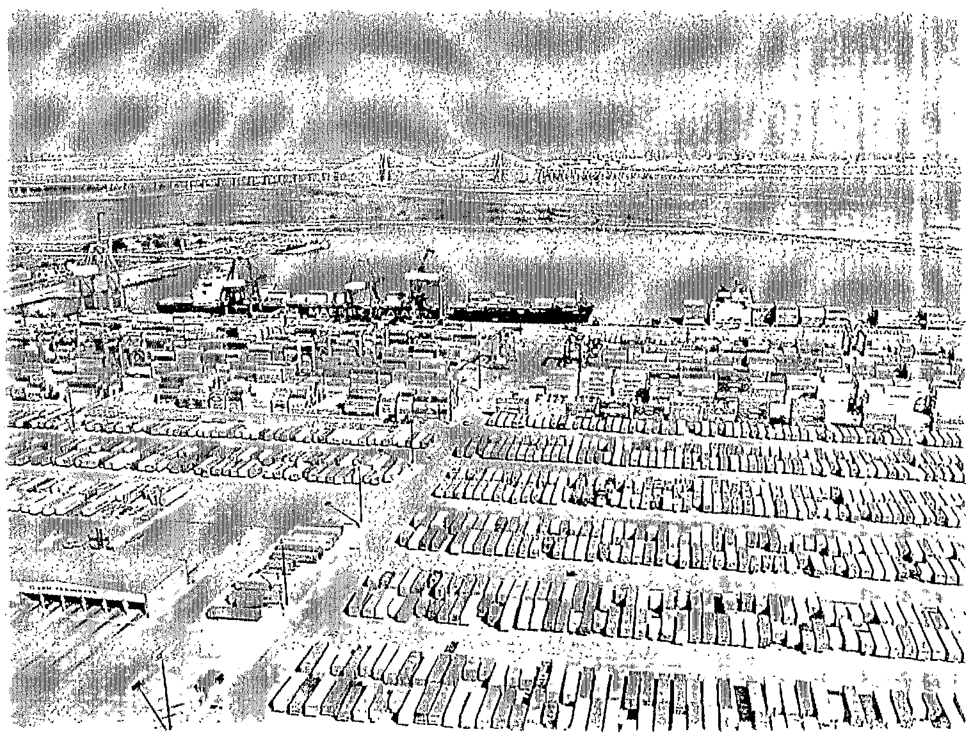

Figure 2: Container Terminal of the Port of Houston [5].

2.2.2 Port Resources

In this section, the resources and equipment that exist in most container terminals will be introduced and their functions will be described in detail.

Containers: Also called freight containers, are standardized 8x8x20 feet or 8x8x40 feet steel aluminum or fiberglass boxes, used for moving materials and cargo all around the world, either through water by ships or vessels or through land by trucks and trains/rail (Figure 3). They are also called TEU (Twenty-foot Equivalent Unit) or FEU

(Forty-foot Equivalent Unit). A container has specially made corners that make it easy for the terminal resources to lift it or pick it up [10, 11].

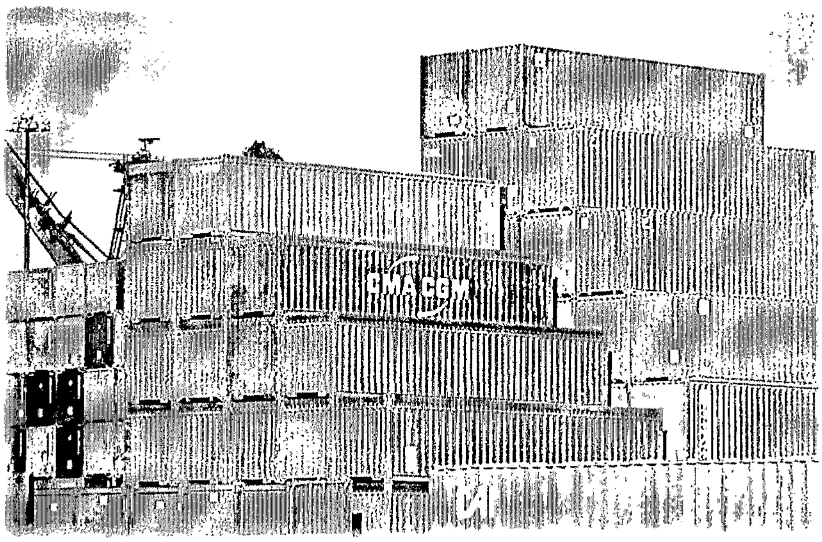

Figure 3: Containers [5].

Container Yard: A container yard is where all the containers are stored and takes the greatest space in a container terminal. It is usually located close to the shore where ships berth; to minimize the travel time for the transporting yard trucks. Containers stored in the yard are in a set of containers stacked next and on top of each other, which is called sections, zones, or stacks as shown in Figure 4 [11].

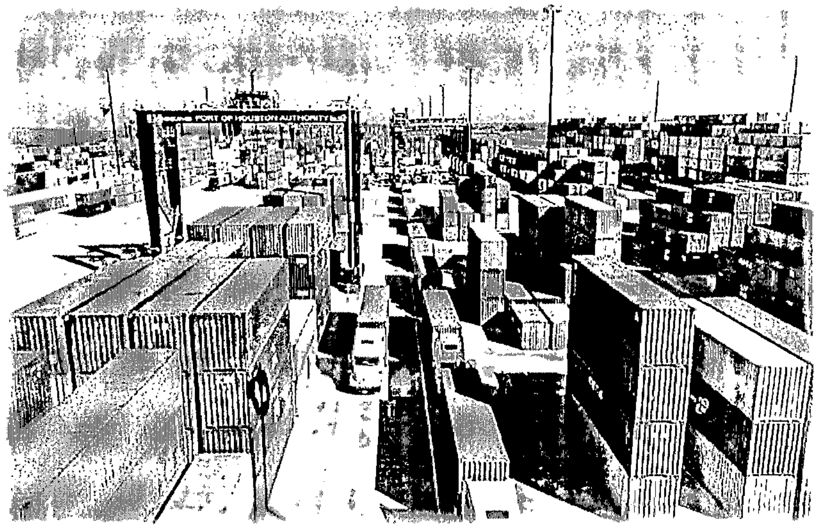

Figure 4: Container yard [5].

Quay Cranes: Cranes or quay cranes (Figure 5) are electric powered machines that lift and lower heavy objects and can also move horizontally along the length of the dock. In a container terminal, they transfer containers from the ship to a yard truck for unloading, after which, the yard truck will transfer the container to the storage area. They also perform loading the ship where they move the containers from the yard truck to the ship [2]. Cranes should also be separated by more than 50 ft. when working together, to prevent any crane confliction [11].

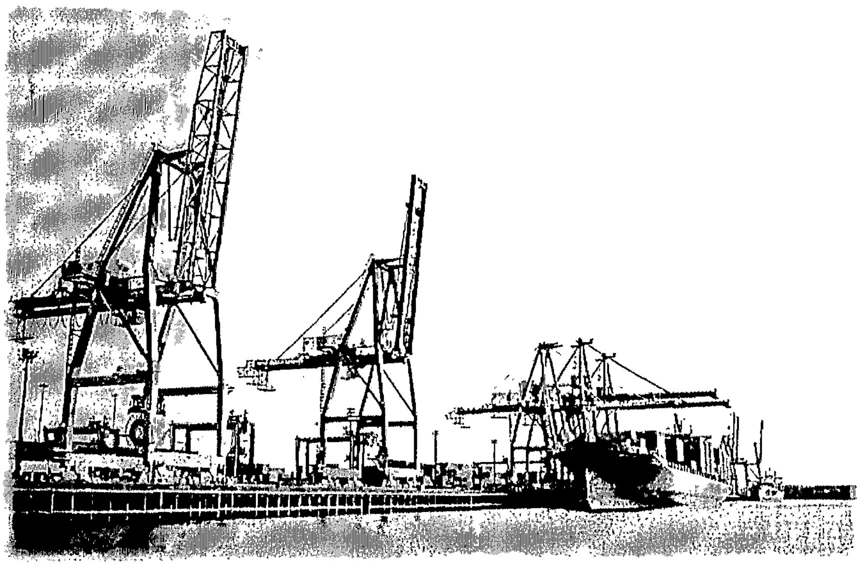

Figure 5: Idle and Working Quay Cranes at the Port of Houston [5].

Rubber Tyred Gantry Cranes (RTG): These are rubber tyred mobile gantry cranes which are able to move over containers on a container stack, left it up then transfer it to a yard truck (Figure 6). It is used for stacking containers within the stacking area or the container yard. They are also capable of transferring containers from trains or trucks to the stacking area and vice versa [12].

Figure 6: RTG Crane Picking up a Container [5].

Yard Trucks: Yard trucks are trucks that operate inside the container terminal facility only, and are responsible for transporting containers from incoming ships and trains to the storage area and vice versa (Figure 7). Yard trucks drive up to the quay crane unloading a ship or to an RTG unloading a train to receive a container for transportation to other locations.

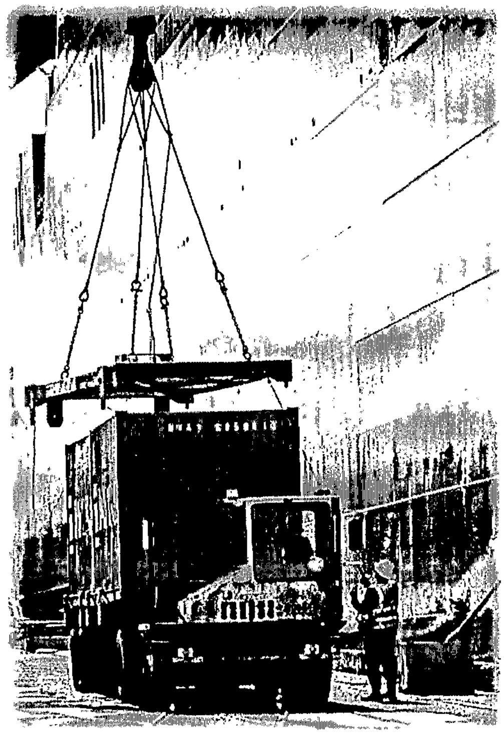

Figure 7: Container Loading onto a Yard Truck [5].

Ships: Ships or vessels are large boats, and are one of the main transport modes in a maritime container terminal; they are responsible for transporting containers by water to and from the container terminal (Figure 8). There are different container ships with different capacities of containers or cargo. Vessels make several stops to other terminals before and after berthing at one container terminal. The pier space, where the ship docks, is called a berth. There may be more than one berth in one terminal, depending on the terminal size and the number of available cranes [10]. A ship may also occupy more than one berth depending on its length.

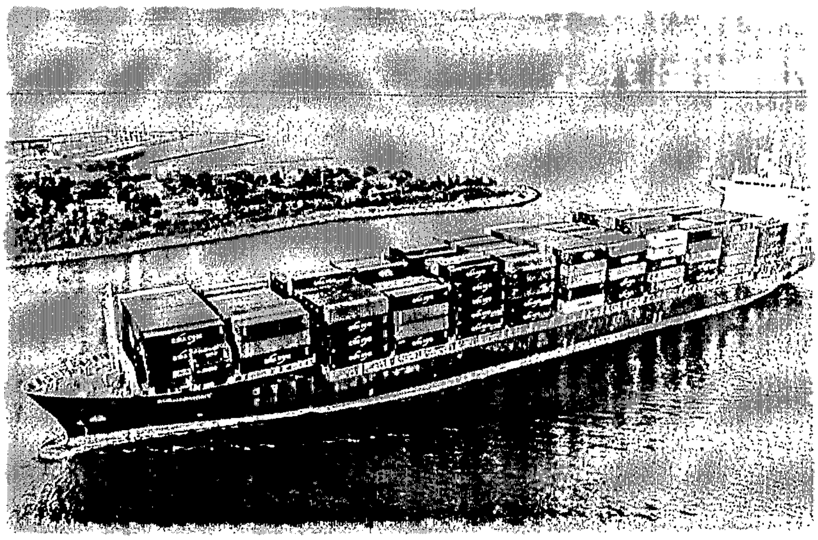

Figure 8: Container ship [5].

Trucks: Trucks are heavy automotive vehicles and are one of the inland transportation modes (Figure 9). Trucks arrive to the container terminal either empty for picking up an incoming container or full for dropping off an outgoing container. Trucks have to drive to the container storage area, so that an RTG can transfer a container from or onto a truck [10].

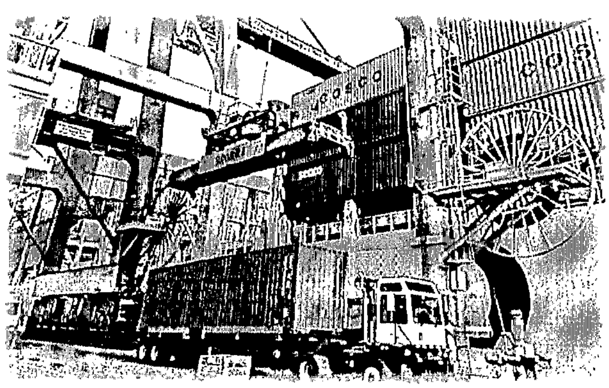

Figure 9: Container Loading on a Truck [5].

Trains: Trains or rails are another mode of inland transportation. They arrive to the container terminal according to a schedule, for delivering and/or picking up containers (Figure 10).

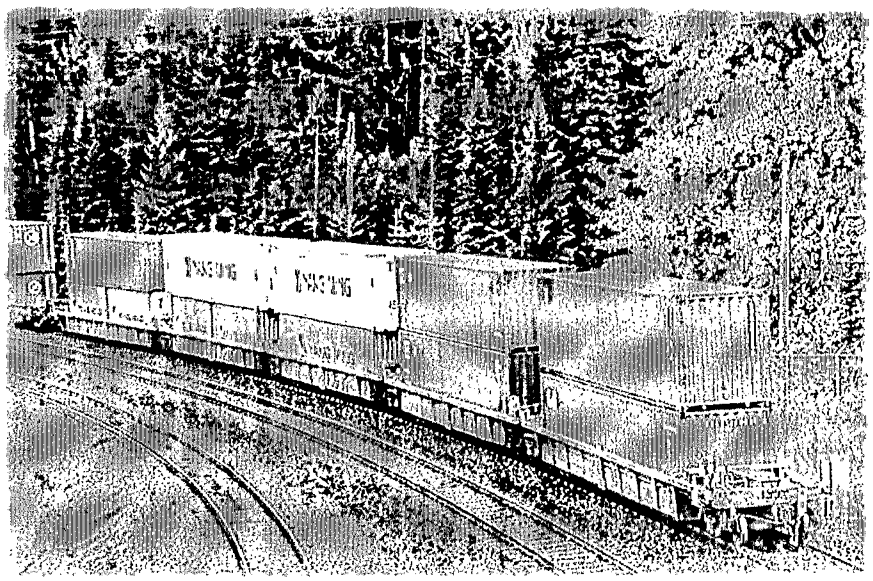

Figure 10: Train with Containers [13]

2.2.3 Ship Cycle

When a ship arrives to the terminal and seizes a berth, quay cranes are used to unload the ship by moving the containers from the ship board to the mobile yard truck. The yard trucks are usually available to receive containers from the crane. However if no yard truck is available, the crane will have to wait for an empty yard truck. The yard truck transports the containers to the container yard or the storage area and parks in the assigned isle and waits to be processed. An RTG transfers the container from the truck to the stack of containers. This process continues for several hours or a day until the ship is emptied from all the containers that need to be unloaded. After unloading the ship, the loading process begins and follows the same steps explained earlier but in a reversed order; the RTG transfers container from the container stack onto the yard truck, which travels to the ship, and lastly the crane transfers the container from the yard truck to the ship's board until the ship is loaded with all the assigned containers before setting sail and departing the port.

2.2.4 Train Cycle

The process of containers arriving from land is done through trucks or rail. When a train arrives, it stops underneath an idle RTG which moves vertically above the train allowing some isle space for the yard truck to park. The RTG then unloads the containers from the train to an idle yard truck. The yard truck then travels to the container yard where another RTG unloads the containers from the yard truck to the container stack and the empty yard truck travels back to the train unloading area to be loaded again. This process continues until the containers are unloaded from the train before the train loading process starts. Loading the train follows similar steps like unloading but in a reversed order. Yard trucks transfer containers from the container yard to the train loading area and the RTG loads them to the train. This process continues until all the assigned containers are on the train then the train departs the port.

2.2.5 Truck Cycle

For inbound trucks that bring containers to the container yard, the handling process is a little different. Most arriving trucks come loaded with a container to be transferred to the container yard. However, there is some percentage of arriving trucks that come empty; just to pick up containers and leave. Loaded trucks drive to the assigned container yard isle to be unloaded after going through some security check points or customs. An idle RTG would transfer the containers from the truck to the stack of containers. The truck then either leaves empty or it drives to another container stack isle to receive another outbound container from an RTG. Arriving empty trucks that come for a pick up only simply follow the same truck loading part mentioned above.

2.2.6 Customs

Customs is a government entity in charge of collecting tariff revenue, protecting the country from smuggling and illegal goods, and processing people and goods at ports of entry as well as perform other selected border security duties. Customs officers are present at every international airport, seaport, and all land border crossings. As all authorized ports are recognized customs areas. A customs department is usually established within the container terminal in order to prevent illegal trade and fraud. The customs authority controls the trade by controlling the flow of goods, cargo and containers whether it was an import or an export [14] (Figure 11).

As customs officers need no probable cause to search, detain, or seize anything or any person, security check points and customs usually initiate complications in the port activity because of the likelihood of creating longer queue lines and delays in the movement of cargo, containers and other terminal resources that handle the containers around the port. Generally speaking, port authorities coordinate with customs but do not control their process; therefore, they may cause bottlenecks in the system despite having an efficiently run port.

Figure 11: Customs Officer Inspecting a Container [5].

2.2 Simulation

According to the Merriam Webster Dictionary, simulation is the process of making something look like something else for the purpose of studying it and helping others to train on it [15].

Simulation has been around for the last four or five decades, but its uses and complexity have changed during the years. At its early years in the late 1950s and 1960s, simulation was very complex and expensive where only big corporations could afford utilizing it. During the 1970s and early 1980s, computers became faster and the simulation as we know it today started to emerge. However, simulation was only used at the occurrence of a disaster, to determine why a disaster occurred and what the cause is. This type was popular in the automotive and heavy industries. In the recent past, during the late 1980s, personal computers and animation was introduced; which helped businesses be more familiarized with simulation. Although simulation was still being used in the cases of failure but larger firms were more familiarized with it and many started requesting it before the beginning of production. It was not until the 1990s when simulation started to really develop, simply because of the improvement of computers and animation and the ease of use and integration with other packages which made many small firms adopt simulation and use it at the early stages of their projects [6].

The methods in which simulation is used has also changed, where its employment has started to occur earlier in the design phase of the project then updated as changes are being made to the real system. The only barriers that were preventing simulation from being a universally accepted and utilized tool are the time and skills required to develop the model [6].

2.2.1 Discrete Event Simulation

Modern simulation models, usually, require computer software to simulate what is called a system, which is the environment that the simulation study is concerned about. The simulation model will create an imitation or a copy of the real system, in order to study it and better understand it. Systems are categorized into two different types, discrete and continuous systems. A discrete system is one in which the contents of the system change instantaneously at different and separated points in time. A continuous system is one in which the system's contents change continuously with respect to time [16]. In this work, the focus will be mainly on discrete types of systems.

Discrete event simulation is concerned with creating a copy of a real system in which the contents or the particles in that system act independently and in separate sets of points in time. Each of these points is called an event; an event is that point in time where the state of the system will change. An example of an event is the arrival of a particle to be processed which changes the state of the system from idle to busy. The particles or the contents that makes up the system are called entities in the simulation language [16].

2.2.2 Simulation with Computer Software

When the digital world started developing and computers appeared in the 1950s and 1960s, people started using the basic programming languages to write simulation models for complicated systems. It was very helpful with some of the routine chores like statistical bookkeeping and list processing. However, it was monotonous and mistakes can easily be made because everything needed to be written and codded from scratch.

After that, simulation-specific programming languages appeared and helped a lot with simulation and are still popularly being used, like SIMAN and GPSS. Nevertheless, they were difficult to learn and an investment of time and effort was required in order to effectively learn how to use them. Thus, numerous high level simulator products were developed, that operate with built-in graphical user interface, which is a lot easier to learn and use. Most of them are, however, somewhat domain-restricted; for example for manufacturing or communications use only.

Many versions of commercial discrete event simulation software are available; a brief summary of four popular ones and their features is shown in Table 1.

Table 1: Summary of Commercial Simulation Packages.

Software	*Company*	*Paradigms*	*Editions*	*Reference*
Arena	Rockwell Automation	▪ Discrete Event	▪ Standard ▪ Professional including OptQuest for Arena	[17]
Simio	Simio	▪ Object Modeling ▪ Discrete Event ▪ Continuous	▪ Express ▪ Design ▪ Team ▪ Enterprise ▪ Scheduling ▪ OptQuest for Simio ▪ Evaluation ▪ Academic	[18]
FlexSim	FlexSim	▪ Object Modeling ▪ Discrete Event ▪ Continuous	▪ FlexSim Simulation (no limitation)	[19]
AnyLogic	AnyLogic	▪ System Dynamics ▪ Discrete Event ▪ Agent-Based	▪ Advanced ▪ Professional ▪ Educational ▪ Researcher	[20]

Arena combines a user friendly interface found in the high level simulators with the flexibility of the simulation specific programing, and it can also be used with the general purpose languages like Microsoft Visual Basic and C programming [6]. The core of Arena is the SIMAN simulation language; Arena is also compatible with Microsoft components and allows the user to import drawings, images, and 3D models.

Arena software also includes multiple helpful tools such as the Input Analyzer, the Output Analyzer, and the Process Analyzer. The Arena Input Analyzer can fit the most suitable distribution and its parameters to an existing set of data. The Arena Output Analyzer compares multiple systems, creates confidence interval and determines warm up periods to reduce initial biases and it also performs correlation analysis. The Arena Process Analyzer, aids with what-if scenarios management and analyzing results [21].

Arena provides simulation modeling animation on its workspace including simple graphics like the entity flow, queue lines and the status of a resource. The latest version of Arena provides a more advanced visualization capability as its Visual Designer is a well-constructed 3D animation tool (Figure 12).

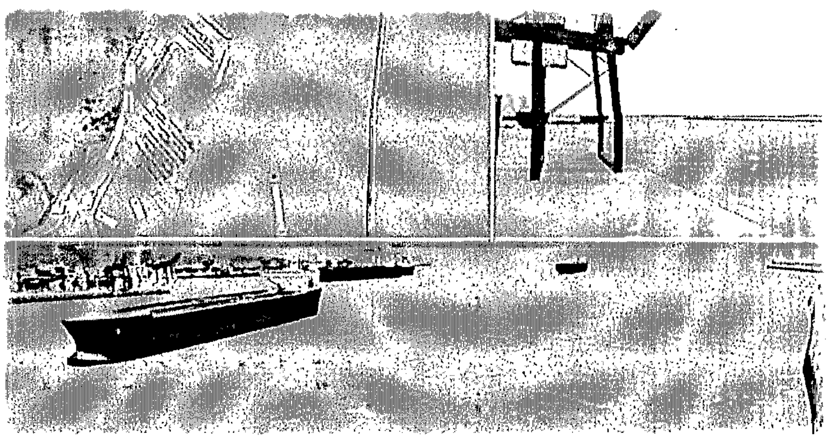

Figure 12. Arena Visual Designer Example of Port Simulation [17].

CHAPTER 3

RELATED WORK

The content of this chapter will explore several areas of research related to this work. These areas include container terminal peer-reviewed research material of utilizing discrete-event and other simulation models that focus on investigating container terminal designs, analyzing port operational decisions, configuring checkpoints in ports, as well as optimization of handling and transportation processes in the port.

In order to create an understanding of what the scholars have already accomplished in these areas and to construct a platform to extract related techniques and useful insights, they will be introduced and discussed in this chapter.

No extensive research has been found in the literature on evaluating the effects of security measures and customs policies on port dynamics and the implications of parameter changes in such stations on delays, throughput and overall performance of the port. This work will, therefore, aim to fill this gap.

3.1 Discrete Event Simulation and Port Operations

The efficiency of a container terminal has been the main concern for the terminal's management and authorities since the beginning of sea trade. Simultaneously, the application of simulation methods in container terminals was developing rapidly. Simulation has been used in container terminals for more than two decades.

In 1988, Chung *et al.* developed a simulation model to increase the utilization of material handling equipment and reduce container loading time at the Port of Portland [11]. Their research presents the idea of creating a buffer area located between the container storage area and the dock area (Figure 13), where containers can be stored temporarily while waiting to be loaded onto a ship. The objective was to consider the effect of this area on the container terminal's operations and whether or not it will reduce bottlenecks caused by the transtainers (which in this case is an RTG or a yard crane).

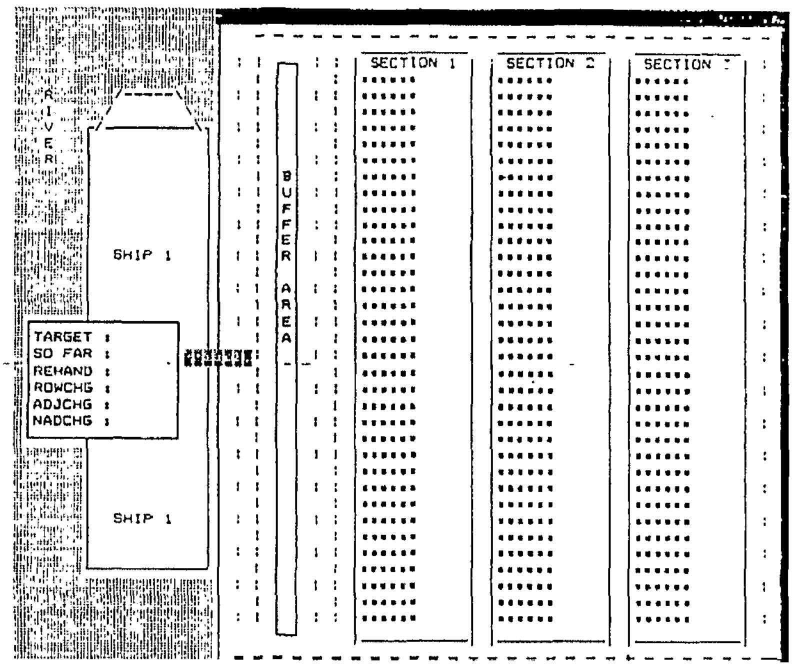

Figure 13: Dock Overlay Showing the Buffer Area [11].

The buffer area in their research can serve two scenarios. The first one they called "re-handling" in which a transtainer is scheduled to pick up a container from the container stack; however this container is located at the bottom of the stack and is to be loaded onto the ship first, followed by the containers on top of it. Their work, proposed that in such cases, that the transtainers pick up the container on top and store it in the buffer area, then go back and pick up the scheduled container from the stack's bottom fulfilling the required order. The second scenario they called "sweeping operations", where the transtainer is scheduled to leave the current section or stack of containers and work on another one; however, the transtainer will have to come back to this section later on to pick up containers. They propose, therefore, in such cases, that the transtainer is to transfer the containers that will be moved from the current section to the buffer area, before moving on to the new section or stack of containers.

Chung *et al.* were able to perform 96 simulation runs, observing a significant improvement of the flow of the port operations when their idea for the first scenario was applied, which resulted in a reduction of 4% in the total loading time. However, they concluded that using the buffer area in the sweeping scenarios did not reduce the total time; because, while the transtainer will be moving the containers to the buffer area, the cranes will be idle because it will be waiting for the scheduled containers to arrive from the new sections.

Nevins *et al.* (1998) utilized object oriented programming to develop a discrete event simulation model that was implemented in PORTSIM evaluating complicated operations occurring in seaports [22]. They intended to explore how object oriented programming concepts such as data abstraction; data encapsulation as well as inheritance can be beneficiary in such a context. Such features allowed them to construct different types of cargo (different object classes) as well as creating shared attributes and functions across the model (by using inheritance and encapsulation techniques). The goal from their work was to study the complex operations in seaports in the context of military mobility in order to determine the throughput capability of the port and to be able to create a prototype of the port for the purpose of measuring the effectiveness of any plan changes in the seaport.

In 2009, Matthew Petering of the University of Wisconsin was the first to introduce the direct connection between the containers' block width and the long run performance at a container terminal [2]. A discrete event simulation model written and compiled in Microsoft Visual C++ 6.0 was designed to consider this study, where four different cases were studied: a small terminal and a large terminal, and two different container size configurations: less equipment and more equipment. Nineteen different layout scenarios were tested for each of the small terminal configurations, whereas fourteen were tested for each configuration case of the large terminal (Figure 14). In each of these different scenarios, the total yard storage capacity, the number of storage zones, as well as the number of containers in each zone were manipulated in order to introduce changes to the system. Ten simulation replications were performed for the small terminal configuration and six replications for the large terminal. It was found that the average quay crane work rate is concave with respect to block width and that the optimal block width configuration ranges between 6 to 12 rows, depending on the size and shape of the terminal. Additionally wider blocks require less equipment whereas blocks with thinner width require more equipment optimally. It was concluded eventually, that the overall performance of the port improves as the shape of the terminal becomes more like a square.

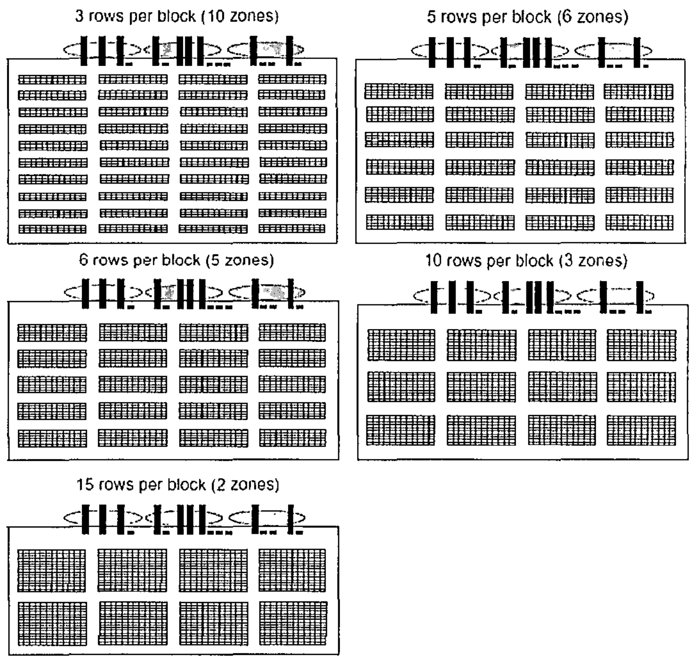

Figure 14: Different Yard Configurations with Varying Block Widths and Equal Yard Capacity, for the Same Scenario [2].

Petering has recently presented a system that determines real time container storage locations and investigates the effect on the overall long run of the container terminal [23]. The container terminal that was considered in this work is a vessel to vessel transshipment terminal, meaning no other transportation modes are involved other than vessels to transfer containers. He had two objectives; the first was to assess the importance of minimizing the container travel distance from quay to storage during unloading, and from storage to quay during loading; as well as minimizing yard truck congestion when containers are being stored and when containers are being retrieved. The second objective was to find specific real time storage locations that will maximize GCR (Gross Crane Rate).

Petering's work considered a terminal that operates 24 hours a day and 365 days a year. Three week long simulation replications were performed and about 400 million crane lifts, and 276 different scenarios. The experiment considered two different terminal settings, a shallow terminal with 5 vessel calls per week and a deep terminal with 10 vessel calls per week. The second terminal has more vessel calls per week but less cargo throughput per vessel, lower maximum container stacking height and a smaller share of the 20' containers than in the first terminal (Figure 15). He considered three main equipment sizes for each setting: scarce, less, and more of yard trucks and yard cranes per quay crane. With these different settings, he proposed that many different and unique scenarios can be created from the setup above. For each scenario mentioned, he set a number of stacking restrictions and penalties in order to reach the best stacking method to achieve the goals of the study.

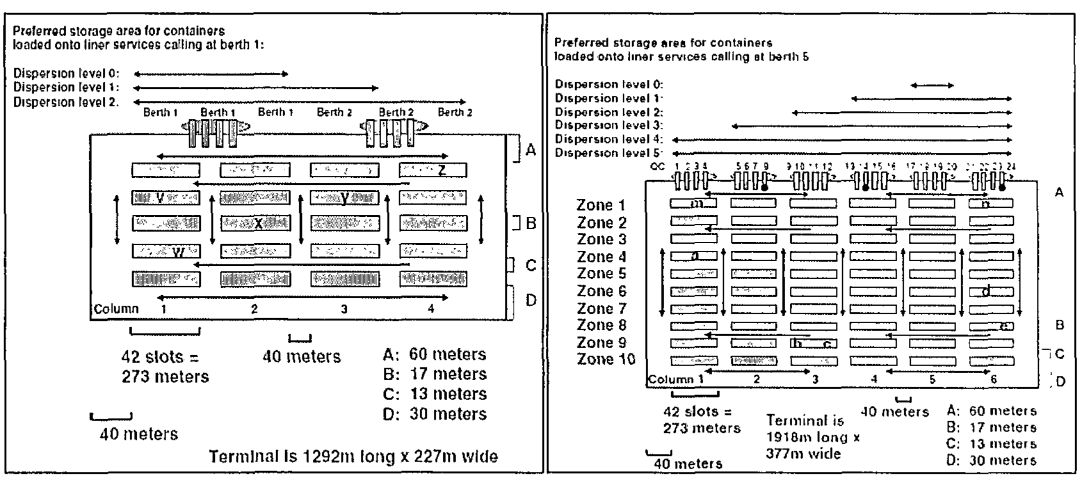

Figure 15: Layout of a 2-Berth Terminal (left) vs. a 6-Berth (right) Terminal [23].

Petering concluded that maximum container dispersion and restrictive yard cranes deployment systems will results in the highest GCR in the six different scenario terminals. He also concluded that a stacking strategy that is penalty based will improve GCR depending on the terminal by 1% to 7%; and that the advantages of a penalty based stacking strategy will increase as the terminal size gets larger or as the terminal equipment gets scarce. However, random storage systems are still considered a good system, especially with terminals that have more equipment, as the penalty based experiments results showed an improvement of only 1% to 2%.

3.2 Port Simulation and Arena

In 2007, Cortes *et al.* simulated the transportation of different types of cargo like containers, cements, steel, iron etc. that depart from and arrive to the Seville inland port in Spain [24]. From data collected from the annual reports of the Port Authority of Seville, they were able to build a simulation model using Arena software that simulated vessels arrival and departure, dock assignment, truck arrival and departure, the different container terminals, cereal and cement facilities and some other docks. Two berths are assigned to receive container vessels involving three different terminal companies, each with an average capacity of 700 TEUs. The cranes working on these berths have a 30 container per hour performance. The simulation model was run for 90 days providing results from the arrival of 166 vessels to the port of Seville, and the total time the vessel spent in the dock and in the system was calculated. No details were provided regarding the simulation model as the focus was primarily on the different port operations. The results of their work concluded that the port resources are capable of handling the current flow of freight and cargo, except for the rare and short-term situation when there are some difficulties in the port like down time and weather circumstances.

Kulak *et al.* developed a simulation model using the Arena software in conjunction with a Visual Basic application at one of the biggest container terminals in Turkey in 2013 [12]. This study was to reconsider the terminal's operations, identify bottlenecks and optimize performance; as some comparative empirical studies made using Data Envelopment Analysis, classified this terminal as one of the most inefficient container terminals.

In order to perform improvements on the port's operations, current port configuration was analyzed under different workloads to understand what is causing the bottlenecks. From the initial performance analysis of the terminal, Kulak *et al.* identified yard cranes as the major bottleneck in the system, thus they suggested to either replace yard trucks with straddle carriers (which are self-loading type of vehicles) or increase the number of yard cranes. Their results for exchanging the 33 yard trucks by 21 straddle carriers showed a great improvement in the total handling rate of containers by around 30,000 to 50,000 TEUs per Year. To explore the second option, they increased the number of yard cranes doubling their number, i.e. from 9 to 18. When comparing to the current terminal configuration, the total handling rate of containers increased by 50% reaching to more than 600,000 TEUs in total per year. They decided to adopt the second option since the seaport authority did not want to introduce new equipment to the container terminal.

Another strategy Kulak *et al.* proposed to solve the bottleneck problem is to improve resource allocation, i.e., storage yard allocation and truck allocation. They created new allocation models based on their base model which is the model with the doubled amount of yard cranes. For yard allocation, they assigned the outbound containers location to be close to the berth location where the assigned vessel is scheduled to berth in. A significant improvement was noticed in the total container handling rate when applying this strategy. The reason is that the overall travel time for trucks was decreased because the new location of the outbound containers is located closer to where the vessels would berth.

For truck allocation, Kulak et al. discussed that at the current situation, the 30 available yard trucks do not work under any specific assignment rule; and because of the special layout of this port (Figure 16), the trucks might have to travel long and unbalanced distances. In their experiment, they apply a dedication strategy where each berth has a specific number of trucks, unless the berth is idle; then a priority rule is used to re-allocate the trucks.

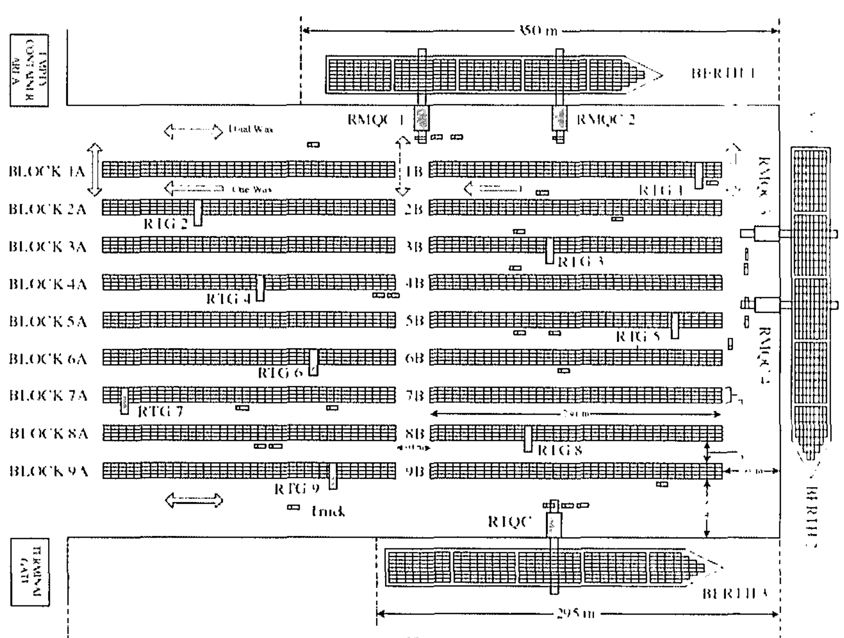

Figure 16: Terminal Layout [12].

Kulak et al.'s results showed that the total container handling rate can be increased with this allocation for a number of 30 yard trucks; however if the number of yard trucks is 27, both strategies work well; but the lower the number of trucks, the lower the total container handling rate will be.

Kulak *et al.*'s simulation model helped with analyzing the port operations and forecasting methods to resolve bottlenecks and also emphasize on future developments and changes to the operation and the configuration of the operation system.

3.3 Container Terminal Simulation and Security Measures

It was mentioned at the chapter's outset that not a comprehensive amount of literature and research work were found regarding the effects of different security measures and customs delays on the port operations. The most relevant publications in that topic are discussed in this section.

In 2008, Ding *et al.* proposed a fuzzy simulation optimization model based on discrete event simulation and heuristic algorithm for the optimal configuration for checkposts [25]. They created three modules: simulation module, interface module and optimization module. The optimization module is responsible for generating data for the simulation module, whereas the interface module transfers the generated data from the optimization module to the simulation module. The results from the simulation module are then sent back in a feedback loop to the optimization module via the interface module similarly. OptQuest engine was adopted as a simulation optimizer integrating tabu search, scatter search, integer programing, and neural networks into one search algorithm.

Ding *et al.* validated their findings by applying it in the Free Trade Port Area in the north port in China. Their results showed that the best way to utilize the checkpost is by reducing the resource redundancy with the current traffic volume and also conclude that more research should be conducted where other factors that might affect the port should be considered, such as road network structure and traffic operation modes.

In 2010, Longo presented a simulation model that assists in applying better operational policies and practices on the flow of inspected containers in a container terminal [26]. He created a simulation model, which describes the container terminal operations and contains most of the important resources and activities in a terminal, like vessels, forklifts, cranes, tractors, and trucks as well as the processes of loading/unloading and transferring containers, etc. The container cycle in this study follows any other cycle, when vessel arrives to the seaport; containers are moved to the storage area. Also in this study, Longo applied an inspection area in the simulation model, where the model assigns a percentage of the incoming containers for inspection, and this selection is based on container history information, container configuration information or any alert information. The simulation model was used to study the impact of the container inspection on the overall container terminal operations and productivity.

Longo concluded that the incorporation of container inspection process with the other container terminal operations is simply a matter of optimal trade-off between having more advanced technology and equipment that would speed up the inspection process and between finding a better organization of the internal container resources that aids with inspection like officers and yard trucks.

In 2013, Yeo *et al.* analyzed the relationship between seaport security levels and container volumes by building a system dynamics model [27]. The use of system dynamics in their work demonstrates how this method helps in understanding the behavior of a complex system over time. They were able to test their findings by applying it to actual data collected from the seaport in Korea, using which, they were able to build three interrelated models including a base model, an optimistic scenario model and a pessimistic scenario model. A different security level was applied to each model.

Yeo *et al.* concluded that applying high security measures will cause decreasing competitiveness which will results in significant loss of market share. On the other hand, applying low security measures will increase port attractiveness for the stakeholders and also increase the number of containers processed. However, if a security breach occurs, which is more likely in an optimistic scenario, it will have a significantly negative impact on the port and will cost the authorities time, money and multiple delays (Figure 17). Consequently, it was concluded that these results should initiate more research interest in this area so that the different impacts can be further analyzed and studied.

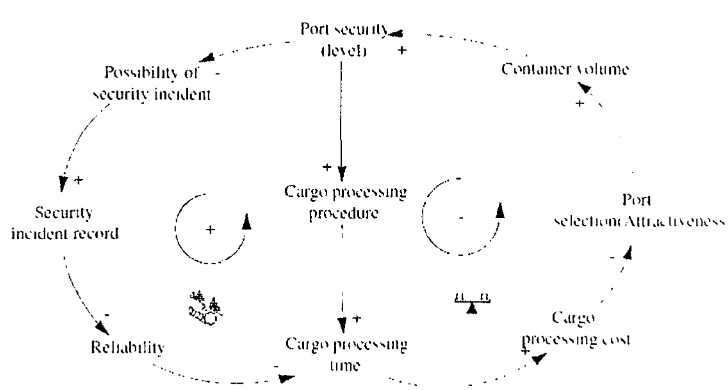

Figure 17: Causal-loop Diagram of the System Dynamics Model [27].

CHAPTER 4

METHODOLOGY

Most container ports operate in similar manner, or at least, are composed of common components. A generic platform that can be tailored to any port will, therefore, be of great benefit. This will be approached using simulation, which will aid in constructing different scenarios and testing their outputs without making any changes to the real system and without costing the port authorities any money.

The work presented in this thesis introduces a methodology for developing a discrete event simulation model using the simulation software Arena 14.0 to model any container terminal and can also be utilized to study the different operations and the flow of incoming and outgoing containers and resources in the terminal.

In this chapter, methods to achieve the research goal as well as the approaches and techniques that were undertaken to develop a discrete event simulation model for a container terminal will be presented.

4.1 Overview

This chapter provides in its outset a general outline and description for the design and development of the discrete event simulation model. A description of the software capabilities as well as the primary aspects of the model design is provided later. The remainder of the chapter will introduce the development of the main components of this simulation model as well as some unique features that can be adopted and calibrated to similar systems.

The first component deals with developing a discrete event simulation model that imitates a generic container terminal system. In order to create simulation software that mimics the real system, the latter is to be thoroughly studied and its operations, components, resources and schedules are to be comprehended. Investigating the design of such complex model is therefore an essential step toward achieving the other goals of this work. In addition, sensitivity analysis will be conducted to evaluate different scenarios including, among others, changes in the number of resources. More details will be discussed later in this chapter and the results will be discussed in Chapter 5.

4.2 Data Collection

To simulate the activities and operations occurring in the port, real data and descriptive statistical metrics are to be collected to describe the port. These metrics include the number of terminal resources' like: quay cranes, rubber tyred gantry cranes, yard trucks; as well as storage capacities and dimensions. Data regarding the port layout and activities can also be obtained from open-source data repository, other similar ports, as well as previous studies and researches conducted on ports activities. The data collected can be categorized as follows:

- ***Arrivals:*** Inter-arrival times (the time between consecutive arrivals in a queuing system) of the main entities to the container terminal: ships, trucks and train.
- ***Processing times:*** The time it takes various transporters and resources to load/unload a container from one spot to another: quay cranes, RTGs, trucks, and yard trucks.
- ***Traveling times:*** The distances and velocities it takes the resources for traveling in the port system: yard trucks, ships, trucks, and train.

- ***Availability:*** The number of available terminals, cranes, RTGs, yard trucks in the container terminal.
- ***Capacity:*** The maximum number of containers that these resources can hold: container yard, ship, train as well as berth capacity and the number of ships the terminal can hold.

4.3 Design

After studying the real system thoroughly and building an overall understanding of the on-going container terminal operations, a conceptual model can be inferred and constructed to assist with creating the model and make it a seamless, less complicated task. In this section, the design of the conceptual model and the Arena simulation model will be described. Details regarding operations, activities and implementations of this work will be thoroughly clarified and explained in the succeeding sections.

4.3.1 Conceptual Model

The conceptual model was built in order to facilitate the building and the understanding of the simulation model. The *entities* moving within the port include ships, trucks, trains and containers. The *resources* in the model include quay cranes for loading and unloading (ships), RTGs for stacking and unloading (containers), ship berths, and storage areas or container yard. The *processes* in the model are constructed based on the operations that take place at the container terminal including loading/unloading containers from sea or land, moving containers to the container yard or around the port to another transportation mode, as well as the movement of trucks through customs. Figure

18 shows a flow chart of the basic port activities and processes involved as described in detail in Chapter 2.

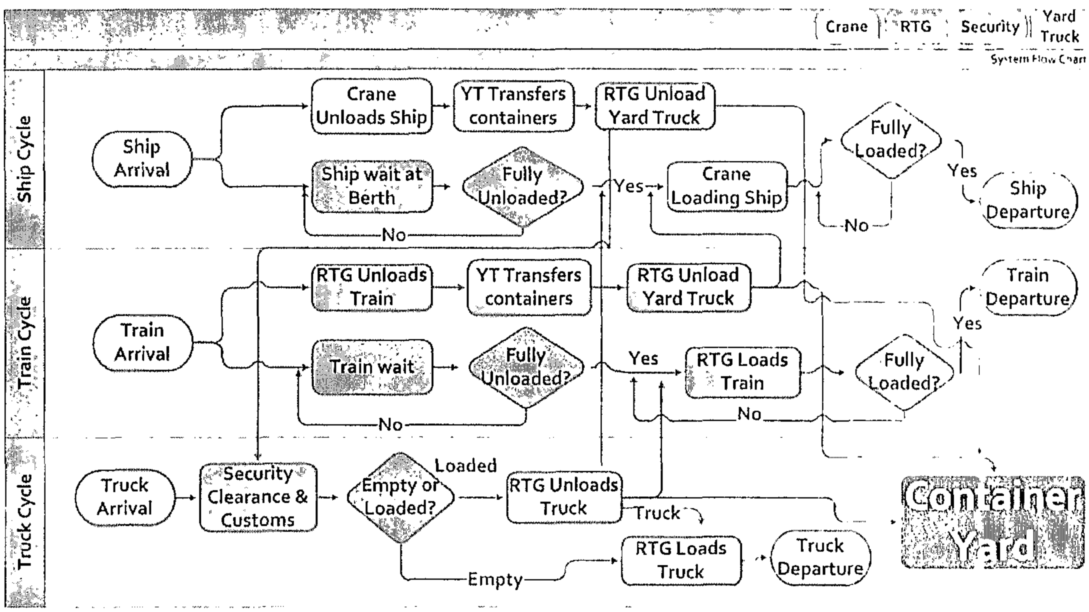

Figure 18: Flow Chart of Port Operations.

Another flow chart was created for the customs operations to show the detailed processes involved as it is a primary interest of this work. Figure 19 shows the operations and steps that a container-loaded truck must go through in order to get inspected and processed. The *entities* moving within the customs cycle include trucks and containers. The *resources* include entrance gates, X-ray scan aisles, scan results personnel, and physical inspectors. The *processes* in the customs cycle include checking the driver's ID and schedule, getting an X-ray scan of the container, waiting for the X-ray results, physical inspection (if needed) and settlement of administrative paperwork, fees and issues.

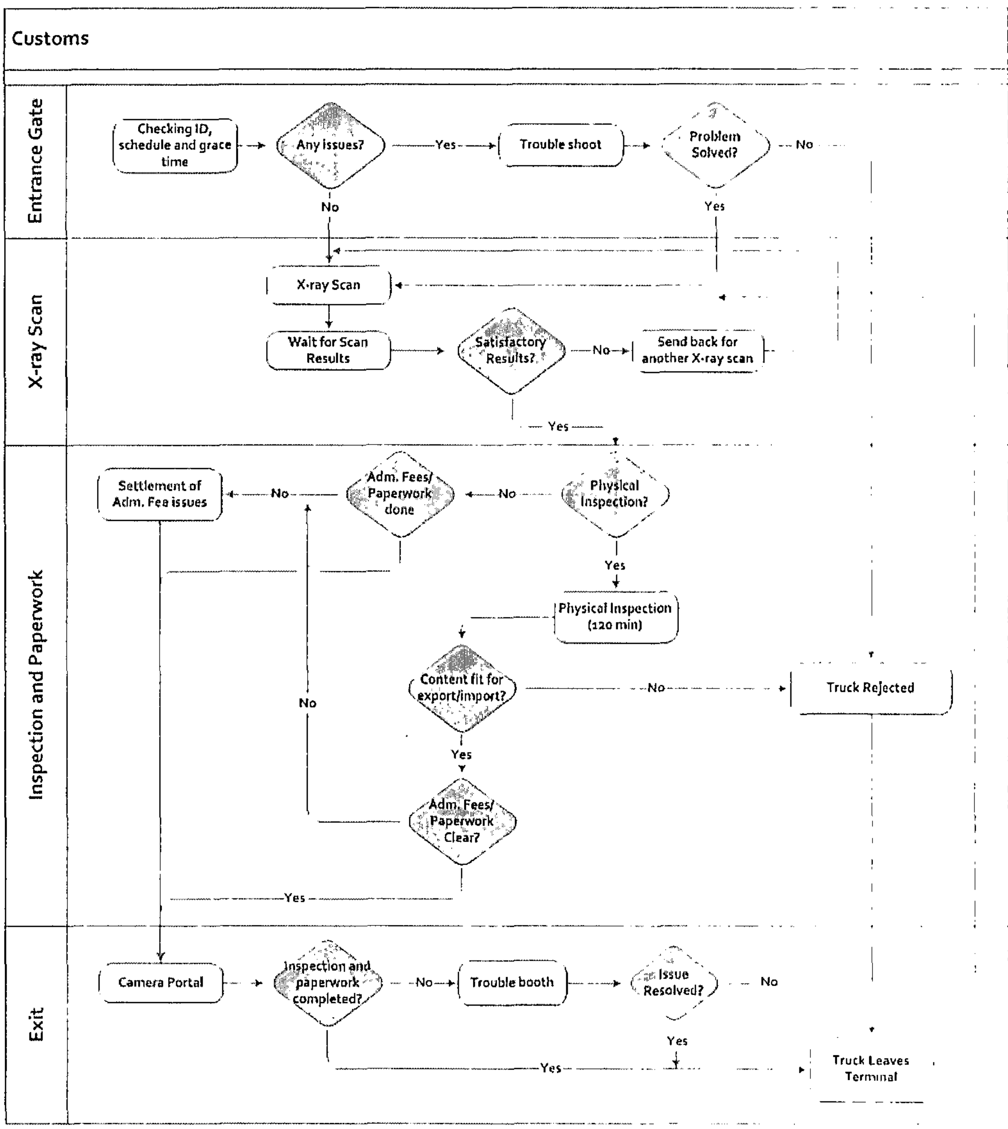

Figure 19: Flow Chart of Customs Operations.

4.3.2 Simulation Software

Simulation is the proper method that most scientists and researchers attain to in order to help them with understanding the dynamics and outputs of a system as well as provide a room for performing tests or evaluations on the simulated system without causing the real system any cost or delays. To this end, the simulation software Arena

14.0 is used in this work to help analyze entity flow and transportations dynamics in the Port. Other supplementing packages of the Arena software were utilized as well, including the Input Analyzer and Process Analyzer.

4.4 Simulation Model Construction

After explaining the nature of the real system in Chapter Two and constructing a conceptual view of the interactions and behaviors involved, computer simulation can be used to mimic this system and translate this conceptual model into a virtual system. In this section the steps needed for building a simulation model will be discussed and a thorough explanation of how the model was built will be provided.

4.4.1 Defining Entities and Resources

One of the first steps for building a simulation model is defining its entities and resources in order to avoid the common mistake of misrepresenting the real system.

Entities:

- Containers: they represent the entities that seize the resources in order to be loaded, unloaded or transferred. They arrive according to the same arrival distribution of the transportation mode that brought them.
- Ships: they represent the entities that bring/take the containers to/from the port by sea.
- Trains: they represent the entities that bring/take the containers to/from the port by land, through railroad.

- Trucks: they represent the entities that bring/take the containers to/from the port by land.

Resources:

- Cranes: they perform the process of loading\unloading a ship. A ship seizes a number of cranes (multiple cranes) according to its (the ship's) size
- RTG (Rubber Tyred Gantry Crane): they perform the process of loading/unloading trains and trucks. They usually work in the container yard, assigned to a specific stack of containers or in the train loading/unloading station.
- Yard Trucks: They perform the process of transporting containers inside the port only among the different port resources.

4.4.2 Outlining the Primary Cycles

In this section, the main cycles in the simulation model will be introduced. Figure 20, below, shows the outlines of the arena building blocks, where all entities arrive to the model through a Create module which is used to model the arrival of all ships, trains and trucks. At the Dispose module, all the entities mentioned previously depart. The model has four different cycles: the ship, train, truck, and customs cycle. Figure 21 shows these four different cycles.

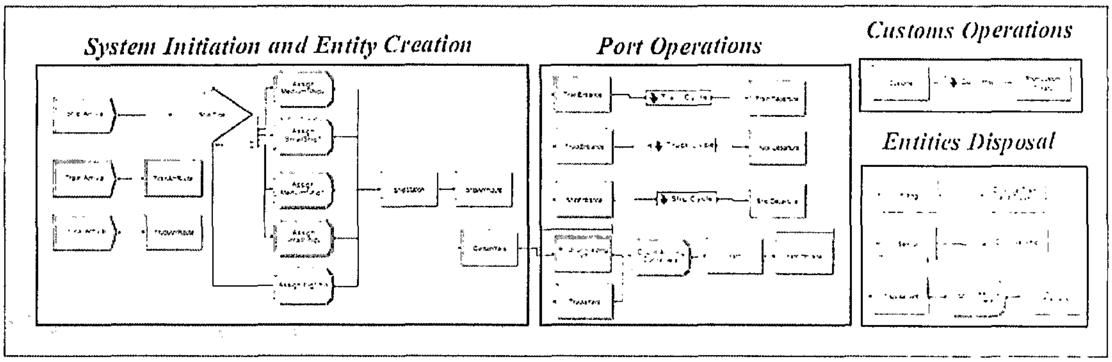

Figure 20: Arena Port Outline Model.

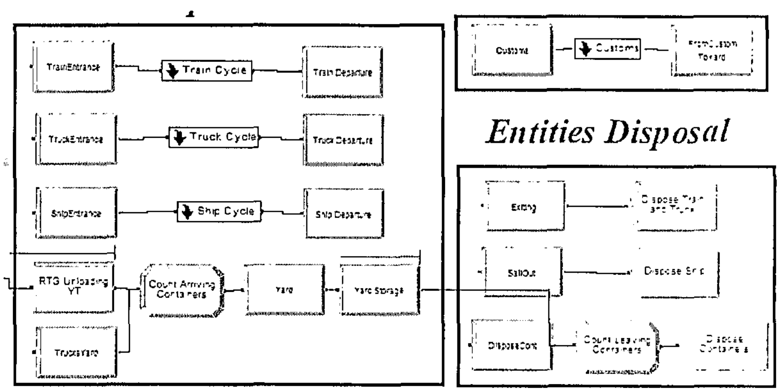

Figure 21: Port Cycles.

4.4.2.1 Ship Cycle

After a *Ship* entity arrives to the model, it will go through a Decide module which will send it into one of five different branches according to a percentage. These branches represent an Assign module that will assign to the ship a new entity type (indicating its size), a new entity picture and also an attribute with values for the containers that will be loaded and unloaded off and onto the ship (Figure 20). Afterward, a new type of ship will enter the ship cycle, where it will move into another decide module that will ask about the type of the ship in order to send it to one of three different branches, each branch is specified for one size of ship only. After deciding on the ship size, the ship will enter a new Submodel where the unloading process will occur. Before the unloading process, the ship will go into yet another Decide module to check the availability of the cranes in order to send the ship to an idle number of cranes that are next to each other, this process is discussed in more detail in Section 4.4.3.5. Furthermore, the ship (as well as the other transportations modes) will follow a similar loading and unloading technique using a Separate module as explained in Section 4.4.3.2.

At the end of the unloading process and before moving to the loading process, the ships will pass into an Assign module where each ship will be labeled with an attribute that can be retrieved later on to indicate which crane did its unloading process in order to ensure that the same crane will do its loading. The containers from the unloading process, on the other hand, will be transported to the container yard through yard trucks.

The loading process will be very similar to the unloading process described; and at the end of this cycle the ship departs the system through a Dispose module and the containers that were supposed to be loaded onto the ship will be disposed as well.

4.4.2.2 Train Cycle

All three transportations modes follow the same loading and unloading technique using a Separate module explained in Section 4.4.3.2. There are, however, some minor differences. Unlike the ship cycle, the train does not need to go through branching to check for availability conditions.

When a *Train* entity arrives, it will move immediately into the train cycle by "Route" and "Station" modules. The train will then go through the same unloading and loading steps that the ship goes through, using Route, Separate, and Hold modules (Figure 22). Both train and containers are disposed at the end.

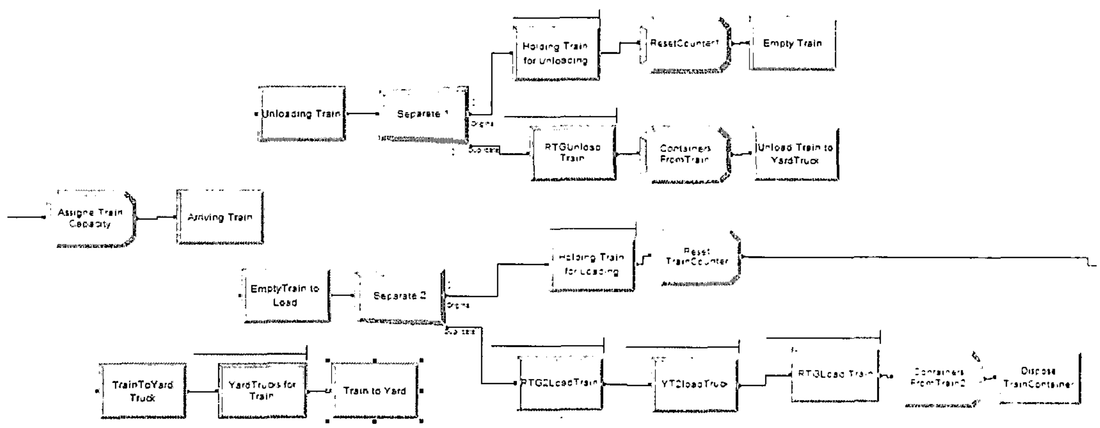

Figure 22: Train Cycle.

4.4.2.3 Truck Cycle

A *Truck* entity follows a similar pattern of arriving trains in Figure 23. However, there is a chance that a truck arrives empty to the port, just for picking up a container and thus does not have to go through the unloading process; this was modeled by using a Decide module right when the truck enters the system in Figure 24. After it has been decided that the truck type is full, there might be a chance that this truck must go through customs first before getting unloaded, so the truck will enter another Decide module as shown in Figure 24, or the full truck will either go to the Customs cycle by Route or proceed to the unloading process by Route as well.

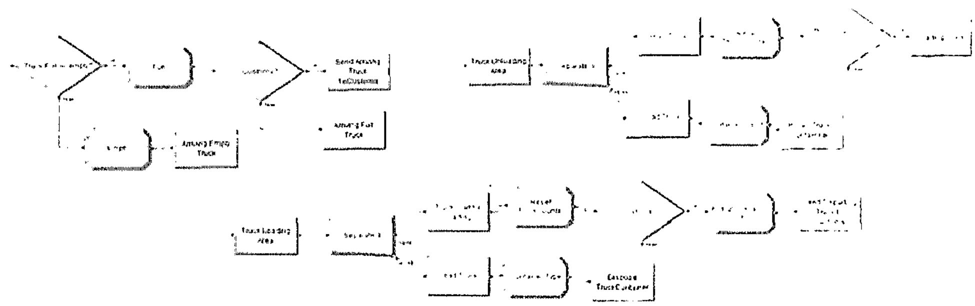

Figure 23: Truck Cycle.

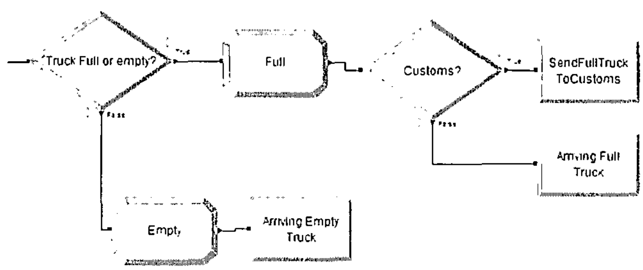

Figure 24: Truck Arriving Full or Empty.

There is another chance that a truck might arrive with a container to drop off only and will be departing the port empty without going through the loading process, so to simulate this scenario another Decide module was used right after the unloading process ends as in Figure 25.

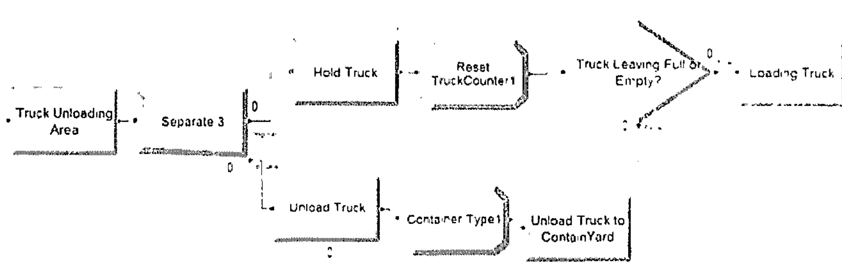

Figure 25: Truck Departing Full or Empty.

Finally, after the truck has been loaded with a container and set to depart the port, there might be a chance that this departing container must go through customs, so the truck will go through another Decide module to either depart the system or go through customs (Figure 26). If it was decided that this truck will go to customs, then it will be assigned an entity type "Departing" in order to distinguish it among the other "Arriving" trucks at the customs cycle.

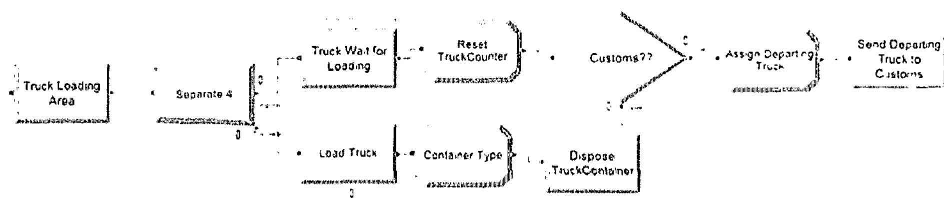

Figure 26: Departing Truck and Customs.

4.4.2.4 Customs Cycle

The custom cycle consists of multiple decision modules and processes (Figure 27). It was created to study the impact of the delays, the processes, and the queue lines on port operations.

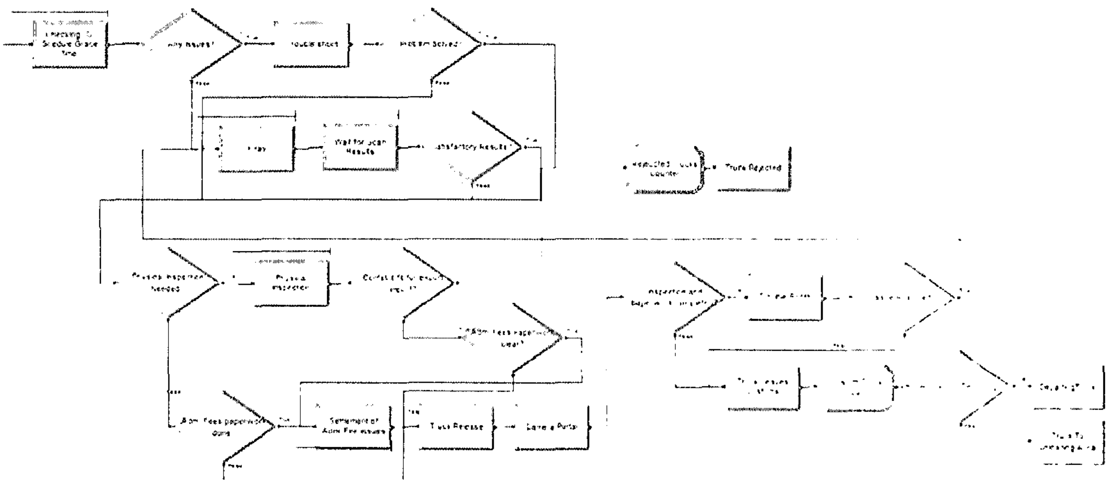

Figure 27: Customs Cycle.

This cycle will receive two types of trucks: arriving and departing trucks. Arriving trucks are ones that just arrived to the system with a container and must go through the customs cycle before entering container terminal, whereas departing trucks are ones that are loaded with a container from the container yard and are ready to depart the system but must go through customs first (Figure 26). At the end of the cycle, each type must be directed to a different destination. In order to do that, they must go through a Decide that will ask about the entity type (Arriving or Departing) then send it to the appropriate direction (Figure 28).

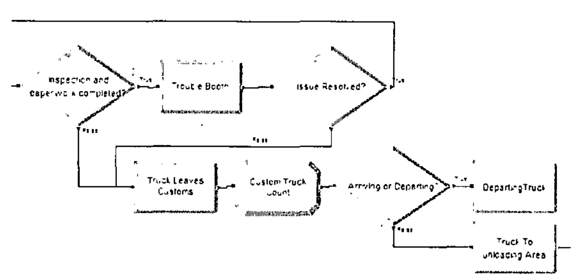

Figure 28: Truck Departing Customs.

4.4.2.5 Containers Cycle

A *container* entity can arrive to the terminal in three different ways, either on a ship, train, or a truck. In the simulation model, containers are created using the Separate module which is discussed in more detail in Section 4.4.3.2. The first process the containers go through is the unloading process where they are removed by a crane if they arrived on ship or by RTG if they arrived on a truck or train. After they are unloaded, a yard truck will drive to the unloading area for ships and trains to transfer the unloaded containers to the container yard. The loading process follows the same reversed steps, where a yard truck will transfer a container from the container yard to the departing ship or train.

4.4.3 Key Aspects and Challenges

After discussing the main cycles of the model where the port activities take place, this section summarizes some of the challenges faced when representing some aspects of the model and describes the techniques developed to address them. Arena is one of the most reliable software packages for modeling discrete-event simulation systems. However, it has some limitations when it comes to customization. This section will, therefore, introduce techniques that attempt to overcome these obstacles. Solving these issues made this model more realistic and added an extra layer of reliability to the produced results.

4.4.3.1 Modeling Different Ship Sizes

The Create module in Arena, allows creating the arrival of one type of entity only, and if more than one type is needed then different Create modules should be used. So in order to create five different ship types, one must add a Create module for each type, but this would complicate the model. To avoid this unnecessarily complication, the different ship types were modeled using both a Decide and Assign modules. So after an entity arrives to the system through the Create module, it enters the Decide module, where it will be sent to one of five different branches that end with an Assign module where new properties will be defined for each entity (Figure 29).

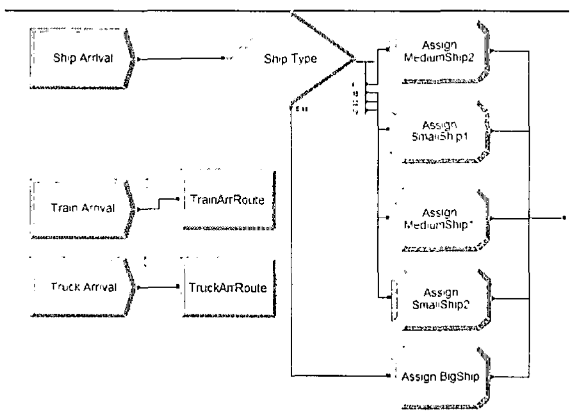

Figure 29: Assigning Different Ship Types.

4.4.3.2 Simulating Containers (Using Separate)

In reality, ships, trucks and trains arrive to the port already filled with containers. One way to model this would be to create a pool of containers in an arbitrary location outside the borders of the port, use Hold and Pick-Up modules to allow a ship, train or truck to pick up the specified amount before having any simulation time pass. Using this method, the transportation entity (ship, train or truck) must drop-off the containers using

Drop-Off. This technique was adapted initially but has proven to be useful only for low values of containers; otherwise when higher values were entered the software would run into memory and space limitations due to the congested system with overloaded containers at one moment.

To address this issue, the Separate module was used. It has proven to be less complicated and works better than the previous method, where it can be modeled with both low and high values of containers. The way this module works is that when an entity passes through it, it will duplicate the number of the entities according to a specific previously assigned number. For example, in this case the *Train* entity entering this block will get duplicated according to the value of the specified amount of containers it should arrive/leave with. The Separate module has two exit points as shown in Figure 30. One of them is for the original entity (Train) to exit from and the other one is for the duplicated entities (Containers). The Separate module has facilitated modeling the different modes of transportations and the containers they came with, especially that it allows for separating them so that each one can be assigned different attributes individually, processed or sent somewhere else. This technique was used for all three transportation modes, ships, trucks, and trains and for both of the unloading and loading processes.

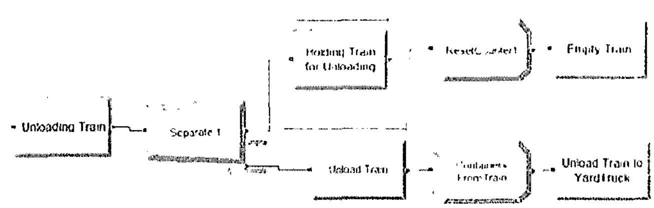

Figure 30: Modeling Containers by Separate Module.

4.4.3.3 Counting Entities for Statistical Measures

The two modeling techniques described earlier have many advantages regarding modeling, however in the results they fail to provide true values because the original entity gets duplicated and will give misleading statistical measures. To solve this issue, different variable counters were created in Assign modules, in order to count the number of arriving and departing ships, trucks and trains and also the number of containers processed when they pass through the Assign module. Variable counters were used for other modeling purposes and that will be discussed in the next section.

4.4.3.4 Using Counters to Send Release Signals to Hold

After entering the Separate module, the original entity is allowed to leave this module right away, however in the real system, the transportation mode bringing in the containers (a train, say), cannot leave the system unless the unloading and loading process has finished. So in order to make this model as close to the real system as possible, the Hold module was used. This module will hold the entity passing through it until some condition set by a variable is met, the status of this variable will be checked before allowing the entity to pass to the next block. Therefore, after the train (in this case) passes through the Separate module and gets duplicated (generating containers), it will go into a Hold module. After the containers are created, they wait in queue to be processed using an RTG (unloading) as shown in Figure 30, afterwards each unloaded container will enter an Assign model where a variable counter was created to count the number of containers processed. Meanwhile, the Hold module keeps checking the release condition, which is when the variable mentioned earlier reaches the specific unloading amount.

When the condition is met, the train will be released. Finally, that variable counter will be set to zero upon the release of the train, so that this process will remain valid for the next train.

4.4.3.5 Seizing Crane(s) According to Ship Size

Any terminal at a port has a specific number of berths, which is where the ship can park for loading and unloading; also each berth is normally served by one crane. Usually, a small size ship occupies one berth, a medium size berth occupies two and finally a large ship can occupy up to three berths. That way, a terminal is able to serve multiple ships at the same time. This is considered challenging to model for several reasons. At first, the cranes were modeled as a set of resources; however, it was impossible to control each individual crane when it belongs to a whole set providing no capability to assign the incoming ship a specific berth according to its size. Furthermore, the ship should seize multiple cranes (when needed) that are adjacent to each other; as it is unrealistic to seize cranes that are far away from each other. In order to address both issues, a new technique was developed.

Three different Submodels were created for each ship size. After a ship arrives to the system and has been assigned a type and a capacity, it arrives to a Decide module that will send it to one of three branches according to its size as shown in Figure 31. Each ship then will enter a specific Submodel; then the three types will go through the same process explained below however with different parameters.

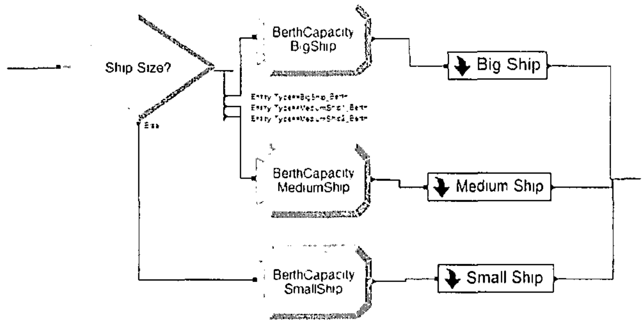

Figure 31: Assigning Ships According to their Size.

After the ship enters its assigned Submodel, the ship will enter another decide that will send it to one of six branches Figure 32. A size "big" ship requires occupying three berths and will need three cranes to unload the containers. The Decide module will check the condition whether there are any set of three idle cranes that are next to each other and will send the ship to that branch, otherwise if all are busy it will send it to a Delay module that will make the ship wait for some time then go back to the Decide module and check on the cranes' status again. The reason there are six different branches is because the Decide module will check on the status of Cranes 1,2,3 then Cranes 2,3,4 then 3,4,5 until it reaches Cranes 6,7,8 which are the last three adjacent cranes in this model.

The cycle in Figure 32, occurs six different times in the model, one for unloading a ship and another for loading, plus there are three different ship types, so in total six cycles. However in the other ship size cycles the Decide condition differs. The medium size ship cycle requires two cranes for unloading, so the Decide will check for any two idle adjacent cranes, while in the small ship size cycle the Decide will check for any one idle crane because small ships require only one berth (one crane). So for the medium size ship cycle there will be seven different branches checking for the status of Cranes 1,2 then 2,3 then 3,4 until reaching Cranes 7,8, and for the small ship size cycle the Decide module will be checking on the status of Crane 1, then Crane 2 then Crane 3 until reaching Crane 8.

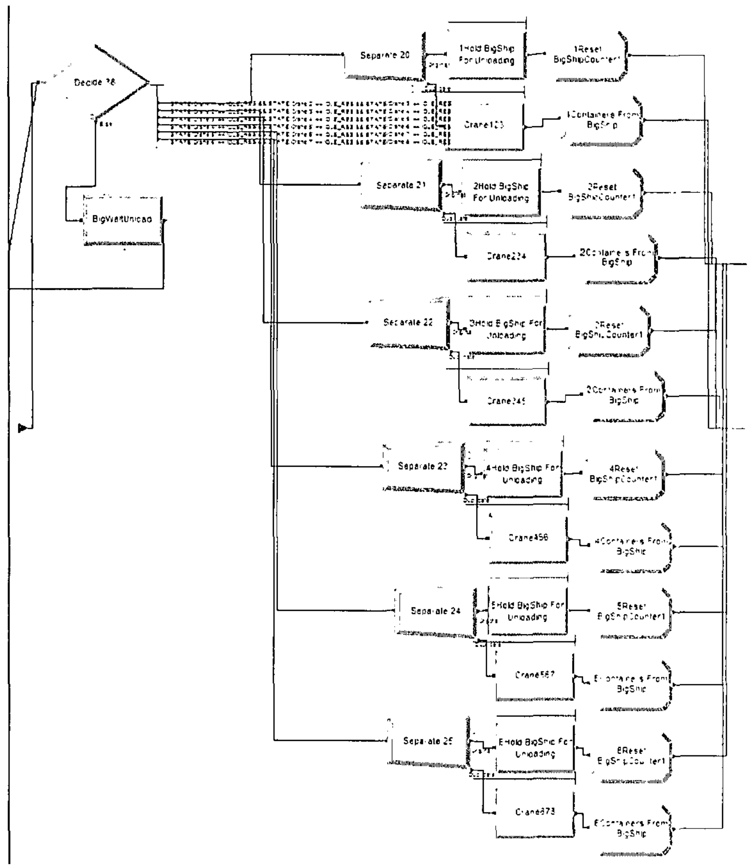

Figure 32: Unloading Big Ship Submodel.

For all six different cycles, after the ship is sent to one of the branches of idle cranes, the process of duplicating the ship into containers will occur like mentioned in Section 4.4.3.2 earlier (Figure 33).

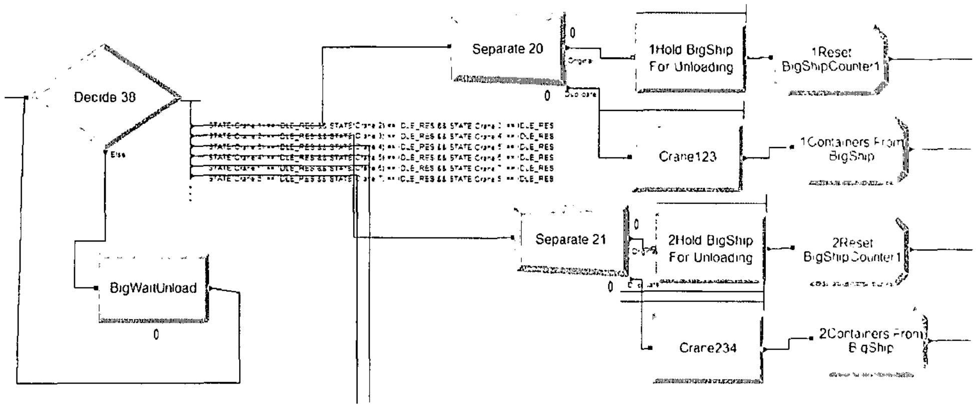

Figure 33: Choosing Crane According to Ship Size.

4.4.3.6 Involving RTGs and Yard Trucks in Loading Processes

One of the other down sides of using the Separate module is that it will create the required number of containers to be loaded or unloaded without having to go through any other resources in order to be moved or transferred like what usually happens in the real system. For example in the loading ship cycle, when the ship entity enters the Separate module it will be duplicated into the number of containers required, then they will be ready to be processed by cranes, however in the real system, the containers that are to be loaded onto the ship, must first be handled by an RTG at the container yard from the container stack onto a yard truck, which in turn will transfer this container to the crane in order to be loaded onto the ship.

So in order to prevent this issue from underutilizing the resources, two processes were added right after the Separate module, as shown in Figure 34: one for the RTG process and the other for the yard truck process. With that, after duplication, each container must go through these resources before getting loaded onto the ship by cranes.

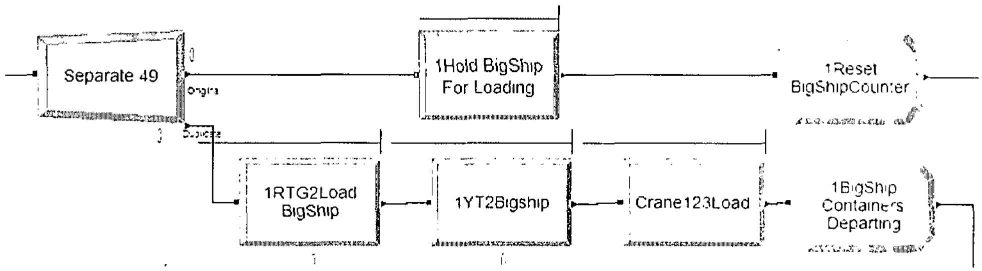

Figure 34: Involving RTGs and Yard Trucks after the Separate Module

4.4.3.7 *Ensuring that the Same Crane Performs Both Unloading and Loading*

After creating the new modeling technique of assigning the cranes according to ship size, an error was noted after running the model and watching the animation. For instance, when Crane 1 and 2 were unloading a ship and by the time this ship finishes the unloading process, another ship arrives to the system at the same time, so instead of sending the first ship for loading where the same canes (Cranes 1 and 2) would do the loading process, the model considers the newest ship arrival with higher priority and allows it to seize the two cranes. This is wrong in reality, because the same cranes that unload the ship will naturally do the loading process as well; another ship can seize the cranes only after the first ship has left the berth. So to address this issue, the Hold block that was holding the ship until the unloading process was complete was manipulated. The original holding condition was that all the containers must be processed by the cranes before the ship starts the loading process; however, this puts the cranes in a temporary idle state allowing another ship to seize it. In order to keep the cranes busy at all times, the holding condition was changed to: hold the ship until all the (Containers-1) have been processed, i.e., the ship will be released when the container before last is processed. This way the ship will be released before the last container gets processed by the cranes, and by the time this ship reaches the loading cycle it will be able to seize the same cranes from the unloading cycle because the cranes will not have the chance to change their status from busy to idle.

4.4.4 Animation

Another one of Arena's features is the ability to animate most of the behaviors and activities in the model. Running the model in a moderately slow speed and being able to watch the model as it runs, track entities' arrival, processing, and movements adds a significant level of validation to the model and provides an enormous help with finding errors and debugging them. As primitive as the animation in the 2D version of Arena model is, it has great benefits for the user. Many problems and errors were able to be fixed just by watching the animation of the model and making the necessarily changes.

The animation of Route and Station modules allows transferring entities to a specific station which corresponds to a physical or logical location where processing occurs. These features help with animating the movement of the transportations modes plus the movement of containers in the model. In addition, it helps keep the model organized and less complicated without connecting multiple lines to one block. This was put into great use when modeling yard trucks moving containers from different locations as shown in Figure 35, the block "Unload Train to Yard Truck" is a Route for sending containers to the container yard, whereas only one station was created for the container yard to be able to receive containers coming from three different locations, Figure 36 shows the block "ContainYard" which is a Station.

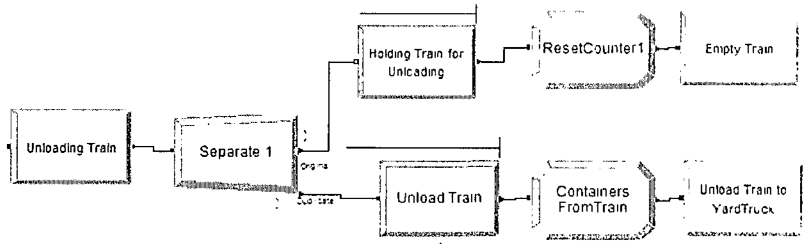

Figure 35: Route for Sending Unloaded Containers from Train to Yard Truck.

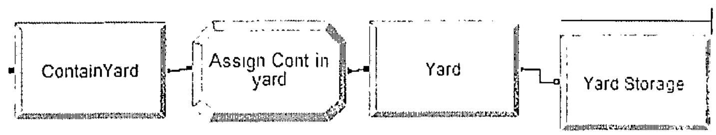

Figure 36: Modelling Container Yard as Station for Receiving Unloaded Containers.

CHAPTER 5

CASE STUDY

In this chapter, a case study is introduced where the work of this thesis is implemented in a real life example. The simulation model constructed in this work will be put into effect and the relevant results of the simulation will be collected. Furthermore, output analysis will be performed to build ground for inferring relevant information and drawing conclusions.

5.1 Background

The container terminal that this case study is based on is of the New Doha Port project. This container terminal is being built in Doha, Qatar located in Western Asia on the coast of the Arabian Gulf. It is still under construction; however, the first terminal is expected to be functioning in 2016. Two more terminals are expected to launch in several succeeding years.

This terminal will be one of the world's deepest seaports in a strategic location where it will connect the internal Qatar rail and the Gulf Co-operation Council rail. It will have state of the art technology and can accommodates up to two million TEUs per year. The length of the Basin of the new Doha port will be 3.8 kilometers and 700 meters wide, with an access channel of 10 kilometers long, 300 meters wide and 15 meters deep and a quay wall of 10 kilometers [28].

By February 2016, the port will have 8 ships-to-shore cranes and then another 4 cranes within the following 24 months. At the same time, the port will have 26 RTG cranes and another 12 RTG cranes to follow by the end of 2018, in addition to 45 tractor units (yard trucks) and 45 trailers [29].

5.2 Data Collection

This section will review the required data collected from the Doha container terminal regarding both the terminal and customs operations.

5.2.1 Port-Related Data

Some of data required to run the model for this work were collected from Milaha Maritime and Logistics [30], which is the company that runs the existing Doha Port. Ship's arrivals were collected from historical data from Qatar Ports Management Company for all of the year 2011 for the current Doha port. Around 300 ship arrivals were recorded for a period of seven months.

Port specific details that this thesis work is mostly based on is collected mainly from the port's website [31] in addition to information collected from the actual site in Doha. Such information include the number of terminals; number of resources like: quay cranes, rubber tyred gantry cranes, yard trucks; storage yard capacities, container storing process; as well as the terminal's internal layout, dimensions and capacity. Other data that assisted with this work were collected from different container terminals around the world and different research studies [3, 12, 32], in order to supplement making this model as generic and flexible as possible.

The data collected can be categorized as follows:

- *Inter-arrival Times:* Ships, trains, and trucks inter-arrival times.

- *Processing Times:* Cranes (loading/unloading containers from/to ship), RTG (loading/ unloading containers) processing times.
- *Traveling Times:* Yard truck traveling time (transferring and moving containers around the port).
- *Entities:* Containers, ships, trucks, and trains

According to Milaha Maritime and Logistics [30], the new Doha port will have five different ship types with different capacities visiting the port for exporting and importing containers, and their percentage arrival and their capacities were also provided.

This container terminal is considered an import container terminal where ships arrive with 100% of their capacities as imported containers and leave the terminal with 25% of their capacity as exported containers (empty containers in general). Whereas the train arrives to the terminal with 25% of its capacity with containers for export and departs with 100% of its capacity with imported containers.

The new port will have a rail for transferring imported containers, however the current port currently is not served by rail, and so data regarding rail arrivals and processing times were collected from other related studies [3, 12].

5.2.2 Customs Related Data

To be able to model the customs' operations, one must understand the customs activities and processing times. Materials and data regarding the customs processes and operations were also provided by the Doha port authorities [30, 33]. This information includes the different stations a loaded-truck must go through in order to get inspected and finish the required paper work, processing times and delays. More details about the customs activities can be found in Chapter 4, under the Conceptual Model section.

5.3 Input Data Analysis

The ships' inter-arrival times [30], were analyzed using Arena Input Analyzer to find the most appropriate fit. The collected inter-arrival times for ships were provided for seven months, but the simulation model was to run for almost a year, so in order to supplement the data sets, the provided data were augmented using a regression trend. The best distribution to fit the collected data was found to be Weibull distribution. Details of the distribution summary can be found in Table 2 and Figure 37 shows the histogram representing the collected data.

Table 2: Distribution fit summary for ship arrivals.

Distribution Summary	Distribution	Weibull
	Expression	-0.001 + WEIB(8.44, 1.06)
	Square Error	0.000861
Chi Square Test	Number of intervals	10
	Degrees of freedom	7
	Test Statistic	3.97
	Corresponding *p*-value	> 0.75
Kolmogorov-Smirnov Test	Test Statistic	0.0269
	Corresponding *p*-value	> 0.15

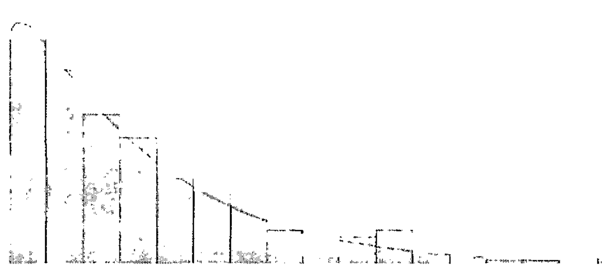

Figure 37: Ships Inter-arrival Distribution.

5.3.1 Assumptions

The main concern of this work was to create a simulation model that can mimic the real system as closely as possible. However some assumptions had to be made in order to exclude elements of minor relevance and to reduce unnecessary complexities. These assumptions can be relaxed in future work when considering other aspects and details of a container terminal. The main assumptions of the simulation model include the following:

- Personnel and staff running the port and operating the resources are considered embedded in the system and available whenever needed to reduce complexity.
- At this stage, the port is not affected by holidays, weather or any down time delays and does not differ between working shifts. Also, the model does not consider rare events due to inexperienced operators.
- Empty and full containers are modeled and treated the same way.
- The container yard does not have specific zones for containers nor has specific stacking strategies or methods, nor a capacity limit; however, this can be accounted for in future work.

5.3.2 Run Parameters

In general, simulation models can be categorized as either terminating or nonterminating simulations. A terminating simulation is one for which there is a specified length of the simulation run; whereas no such condition is present for nonterminating simulations. A nonterminating simulation is usually concerned with the steady-state measures of the systems and often involves a warm up period to eliminate the transient state or initial oscillations of the system and prevent it from affecting the steady-state measures [6].

When simulating the container terminal, however, it is not possible to perform runs with infinite lengths to provide steady-state measures. Nonetheless, this steady-state can be approximated if appropriate run parameters were used since the aim is to generate statistically significant results.

To better describe the model's behavior, it was initially run for a relatively long period of time (three months) and some instantaneous performance measures were monitored. These performance measures include:

- Number of containers in queue to be loaded by RTG to Train.
- Number of containers in queue to be loaded by RTG to Truck.
- Number of trucks in X-Ray queue.
- Number of containers in queue to be loaded by Crane 1 to ship.
- Number of containers in queue to be unloaded by RTG from yard truck.
- Waiting time in queue for containers to be loaded by RTG to Train.
- Waiting time in queue for containers to be loaded by RTG to Truck.
- Waiting time in queue for containers to be loaded by Crane 2 to ship.
- Waiting time in queue for containers to be unloaded by RTG from Yard Truck.

Figure 38 and Figure 39 show the behavior of these performance measures in time throughout the run. It is noticed that some oscillations occur in the beginning of the run as the simulation is initiating, up until day 30. After that time, most of the performance measures seem to reflect a steady-state behavior. It can be concluded from this result that a 30-day warm-up period will be sufficient and longer replication length will be needed to approximate a steady-state system.

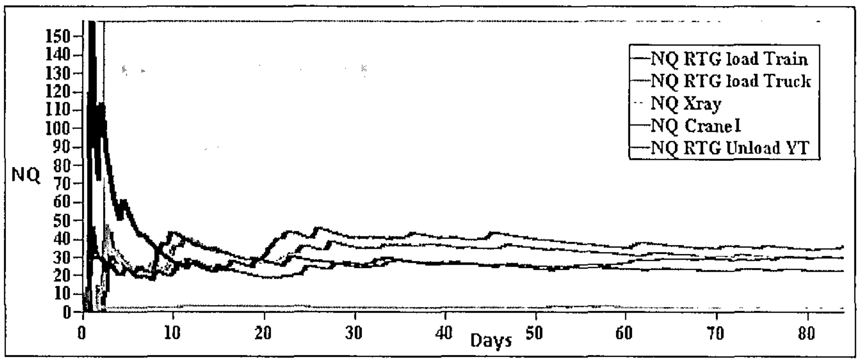

Figure 38: Number in queue behavior in 3-month run.

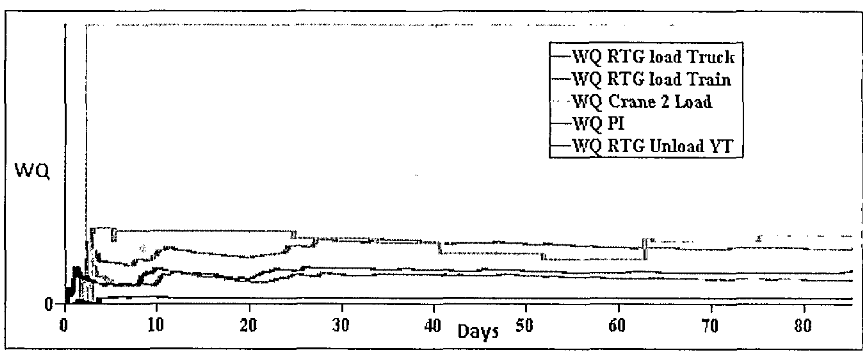

Figure 39: Waiting time in queue behavior in 3-month run.

Since the aim is to produce statistically significant results, multiple replications would be necessary when running the model. However, since 30 days is considered a, somewhat, long period; and since each replication would have to pass through this warm-up period, another technique can be used.

The other alternative in this case is to make one single really long run (one full year) so as to have to pay the warm-up period only once; but break this run into multiple batches that represent, if sized correctly, multiple uncorrelated replications. As the model is to approximate the throughput for a full year; and since the 30 days will be eliminated from the calculations, one more month will be added to the replication length (totaling with 13 months).

To this end, the simulation model will be run for one replication of 395 days and 24 hours. This period is long enough to be used to construct batches of size 50 days each. Each batch will then be considered an individual replication to construct multiple independent and identically distributed observations. Since the initial conditions generally affect the desired measures of performance and so does the process's initiation phase, a warm-up period of 30 days will be used. The base unit of time in the model will be in hours.

5.4 Simulating the New Doha Port

After feeding the collected data from the Doha port into the constructed Arena simulation model, the simulation model was run. Figure 40 shows a snapshot of the animation as the model is running.

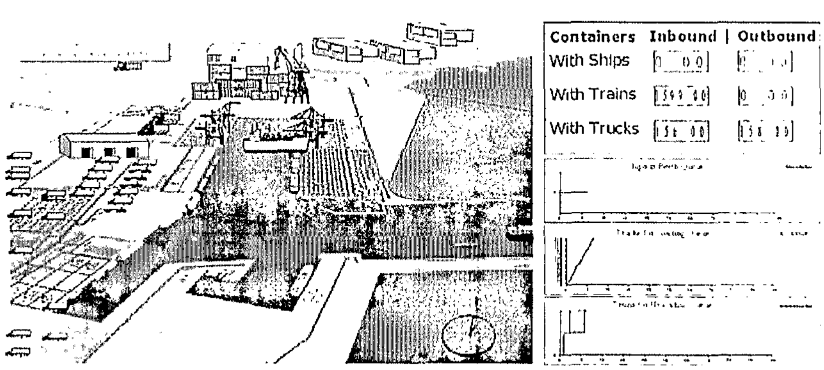

Figure 40. Snapshot of the Model's Animation

5.5 Arena Process Analyzer

Arena 14.0 software includes several beneficial tools for the modeler, one of which is Arena Process Analyzer or PAN that helps significantly with performing changes on the model in a scenario-based fashion to allow for evaluating the impact of some particular components of the model on the overall outcome. PAN operates on Arena program files, after running any model, the output file will be available to use for scenarios and it can be created without running the model as well.

PAN assisted with running the different scenarios created as explained in the following sections, without the need to access the model on multiple occasions to make necessary changes for each scenario; PAN allows creating and running multiple scenarios at the same time and on the same window. In summary, PAN is a tool that would allow running a series of scenarios on the same simulation model after changing some model parameters for each scenario.

5.6 Results and Discussion

In this section, the simulation model results for container terminal with a customs department will be reported. Outcomes such as total number of containers processed, resources utilizations and waiting times in queue will be compared, discussed and analyzed. The replication length for the simulation model was 395 days and 24 hours per day, where the base time unit for the simulation model was in hours.

5.6.1 Generic Port with Customs Operations

The simulation model representing the first phase of the New Doha Port project involving the first container terminal with the customs department was run and the results were recorded. Three different groups of statistics will be reported, *Entities Statistics*, *Queues Statistics* and *Resources Statistics*. A report showing the detailed results is included in Appendix A.

Table 3: Entities Statistics

Entity	Number of Entities Handled in the System
Containers Throughput	1,972,923
Number of Ships Out	1,126
Number of Trains Out25	1,531
Number of Trucks Out	738,780

Regarding *Entities Statistics*, Table 3 shows the data collected involving the number of entities processed in the model. It can be observed that the maximum number of containers handled throughout the port including both export and import in one year reached 1,972,923; which is considered a decent approximation to the anticipated rate of containers throughput of the new Doha port of 2 million containers per year.

Table 4: Waiting Time in Queue (in hours)

Entity Waiting Time in Queue	Average Waiting Time in Hours
Physical Inspection	0.11
Crane Unload Ship	5.52
RTG Unload Train	0.63
RTG Unload Truck	0.53
RTG Unload YT	0.75
Yard Trucks for Ship	0.63
Yard Trucks for Train	0.40

Regarding *Queues Statistics*, Table 4 shows some of the data collected for waiting time in queues (in hours) for some of the different queues in the system. It is observed that on average, not much time is spent in queue lines, which indicates having quick processing times but, at the same time, less utilized resources.

Regarding *Resource Statistics*, Table 5 shows the results for the average instantaneous utilization for all the involved resources. The table shows that cranes' utilization varies while for RTG and yard trucks there is only one value; it is because the latter two were modeled as a set of resources working in a cyclical manner, this way these resources would be identical in their preferences and processes as well as their utilization. Each crane, on the other hand, was modeled as an individual and independent resource, because different ship sizes require different numbers of cranes.

Given the low utilization values for both RTG and yard truck (Table 5), sensitivity analysis will be conducted in the next section to address that.

Table 5: Resource Statistics

Resource	Average Utilization
RTG Set	0.74
Yard Truck Set	0.56
Crane 1	0.61
Crane 2	0.58
Crane 3	0.50
Crane 4	0.44
Crane 5	0.38
Crane 6	0.33
Crane 7	0.24
Crane 8	0.12
Physical Inspection	0.52
Customs Entrance Gate	0.68
X-ray Lane	0.84
X-Ray Scanner Results	0.98

5.6.2 Sensitivity Analysis

After constructing the model and collecting results of the current settings, sensitivity analysis was performed to test different scenarios aiming to increase utilization and improve performance. These scenarios include changing the number of resources and capacities. The results of the analysis are then compared to the original scenario.

The three factors taken into consideration as parameters of the sensitivity analysis are: number of RTGs, number of yard trucks, and number of physical inspection bays in the customs department.

Scenario #1: 2 Physical Inspection Bays, 22 RTG and 35 Yard Trucks

The least utilized resources in the customs are the physical inspection bays (Table 5). In order to increase the utilization of this resource, the number of these bays will be reduced from three bays in the original scenario to two bays.

Both RTGs and yard trucks are underutilized as well (Table 5), so the number of RTGs will be reduced from 26 to 22 and the number of yard trucks will be reduced from 45 to 35.

Table 6 shows that the reduction of the number of resources had a noticeable impact on the number of entities handled in the system, a difference of an average of 40 thousands containers per year. Table 7 shows that the average waiting time in queue increased for most processes, when compared to the original scenario. On the improvement side, however, this change has increased the utilization of these resources;

RTGs were increased by almost 10% and yard trucks were increased by 15% while the physical inspection bays were increased by almost 30%.

Table 6: Scenario #1 Entity Statistics

Entity	Number of Entities Handled in the System	
	Original Scenario	Scenario #1
Containers Throughput	1,972,923	1,932,793
Number of Ships Out	1,126	1,046
Number of Trains Out	1,531	1,486
Number of Trucks Out	738,780	737,384

Table 7: Scenario #1 Waiting Time in Queue (hours)

Waiting Time in Queue	Average Waiting Time in Hours	
	Original Scenario	Scenario #1
Physical Inspection	0.11	0.93
RTG Unload Train	0.63	2.02
RTG Unload Truck	0.53	1.87
RTG Unload YT	0.75	2.33
Yard Trucks for Ship	0.63	3.34
Yard Trucks for Train	0.40	2.47

Table 8: Scenario #1 Resource Statistics

Resource	Average Utilization	
	Original Scenario	Scenario #1
RTG Set	0.74	0.85
Yard Truck Set	0.56	0.70
Physical Inspection	0.52	0.79

From Table 7, it is shown that the average waiting time in queue is not very high and an increase in the waiting time can be traded off for an increase in the utilization. Therefore, in order to better optimize the usage of the RTGs and yard trucks, other scenarios will be proposed in the succeeding sections where the number of these resources will be further reduced.

Scenario #2: 2 Physical Inspection Bays, 20 RTG and 30 Yard Trucks

This scenario proposes reducing the number of RTGs and yard trucks even further to reach 20 RTG and 30 yard trucks. This decrease in the number of resources has impacted the number of containers processed throughout the port as well as the number of other entities leaving the system (Table 9). It can also be observed that the waiting time in queue has increased due to this reduction (Table 10).

Table 9: Scenario #2 Entity Statistics

Entity	Number of Entities Handled in the System	
	Original Scenario	Scenario #2
Containers Throughput	1,972,923	1,834,742
Number of Ships Out	1,126	1,019
Number of Trains Out	1,531	1,444
Number of Trucks Out	738,780	736,066

Table 10: Scenario #2 Waiting Time in Queue (hours)

Entity Waiting Time in Queue	Average Waiting Time in Hours	
	Original Scenario	Scenario #2
Physical Inspection	0.11	0.89
RTG Unload Train	0.63	6.38
RTG Unload Truck	0.53	5.76
RTG Unload YT	0.75	7.25
Yard Trucks for Ship	0.63	8.10
Yard Trucks for Train	0.4	5.50

Table 11 shows the average utilization for both RTGs and yard trucks, and when compared to the utilization of Scenario #1 from Table 8; it can be concluded that utilization of the resources is significantly improving as the number of resources is being reduced. The RTGs utilization has reached 90% which is a preferable utilization percentage; however the waiting time in queue must be taken into consideration before any decisions can be made. In this case, the waiting time has increased by almost 5 to 8 hours for most stations when compared to the original scenario.

The average yard truck utilization has reached 73%, in order to increase utilization level; another scenario will be studied in the next section.

Table 11: Scenario #2 Resource Statistics

Resource	Average Utilization	
	Original Scenario	Scenario #2
RTG Set	0.74	0.89
Yard Truck Set	0.56	0.73
Physical Inspection	0.52	0.79

Scenario #3: 2 Physical Inspection Bays, 19 RTG and 27 Yard Trucks

This scenario proposes reducing the number of RTGs and yard trucks even further to reach 19 RTG and 27 yard trucks. This reduction has impacted the container throughput and the number of entities out (Table 12). The goal behind creating this scenario is to increase the resources' utilization which has reached 75% for yard trucks and 91% for RTGs. It can be proposed that another scenario can be implemented in order to reach at least 90% yard truck utilization; however the corresponding increase in the waiting time in queue should be considered as well.

Table 13 shows the average waiting time of containers to be processed by yard trucks and RTGs; the waiting time for yard trucks has reached 8 hours for containers coming from ship, while the waiting time for RTGs has reached 12 hours for an RTG to unload a yard truck, where both numbers are very high and unreasonable.

Table 12: Scenario #3 Entity Statistics

Entity	Number of Entities Handled in the System	
	Original Scenario	Scenario #3
Containers Throughput	1,972,923	1,766,535
Number of Ships Out	1,126	989
Number of Trains Out	1,531	1,441
Number of Trucks Out	738,780	736,005

Table 13: Scenario #3 Waiting Time in Queue (hours)

Entity Waiting Time in Queue	Average waiting time in hours	
	Original Scenario	Scenario #3
Physical Inspection	0.11	0.87
RTG Unload Train	0.63	11.94
RTG Unload Truck	0.53	10.39
RTG Unload YT	0.75	12.21
Yard Trucks for Ship	0.63	8.33
Yard Trucks for Train	0.4	6.10

Table 14: Scenario #3 Resource Statistics

Resource	Average Utilization	
	Original Scenario	Scenario #3
RTG Set	0.74	0.91
Yard Truck Set	0.56	0.75
Physical Inspection	0.52	0.79

5.6.3 Comparison of Scenarios

The purpose of creating these different scenarios was to find the best outcome where all resources utilization and containers handled can be increased without causing extreme delays and creating longer queue lines. Table 15 is a comparable summary of the original scenario and the three other scenarios that were considered and implemented.

Table 15: Summary of Comparison among all Scenarios

Entity	Number of Entities Handled in the System			
	Original Scenario	Scenario #1	Scenario #2	Scenario #3
Containers Throughput	1,972,923	1,932,793	1,834,742	1,766,535
Number of Ships Out	1,126	1,046	1,019	989
Number of Trains Out	1,531	1,486	1,444	1,441
Number of Trucks Out	738,780	737,384	736,066	736,005
Entity Waiting Time in Queue	**Average Waiting Time in Hours**			
Physical Inspection	0.11	0.93	0.89	0.87
RTG Unload Train	0.63	2.02	6.38	11.94
RTG Unload Truck	0.53	1.87	5.76	10.39
RTG Unload YT	0.75	2.33	7.25	12.21
Yard Trucks for Ship	0.63	3.34	8.10	8.33
Yard Trucks for Train	0.40	2.47	5.50	6.10
Resource	**Average Utilization**			
RTG Set	0.74	0.85	0.89	0.91
Yard Truck Set	0.56	0.70	0.73	0.75
Physical Inspection	0.52	0.79	0.79	0.79

From Table 15, it can be observed that the scenario with the highest resources utilization but yet with no exaggerated queue lengths is Scenario #2; where the resource combination was 20 RTG, 30 yard trucks, and 2 physical inspection bays. This combination produced a throughput of 1,834,742 containers and the resource utilization reached 89%, 73%, and 79% for the RTG, yard trucks, and physical inspection bays, respectively. The combinations with lower number of resources produced good utilizations as well but resulted with extremely high waiting times in queues at the corresponding process stations. It can be proposed, for instance, that Scenario #3 with 19 RTGs and 27 yard trucks is more optimal with regard to the resource utilization; however, the waiting time in queue of a container from a train waiting to be unloaded by a RTG reached 12 hours at one point during the year; that is with no doubt unacceptable. Therefore no further scenarios will be studied in this work.

Scenario #2 is chosen to be a good recommendation for resource reduction, as with the current original scenario, the terminal involves more resources than it needs.

5.7 Validation

In order to validate the constructed simulation model, data are to be collected from the system to represent the main system performance indicators such as: number of handled containers in a year, yearly average waiting time in queue, yearly average utilization, and others. In addition, animation is considered a form of validation as it shows how closely the layout of the simulation model represents the real system.

Animation was incorporated into the Arena model and the flow of entities in the system was monitored and showed a reasonable approximation of the anticipated layout of the new port.

Validating the simulation model using analytical and numerical measures has proven to be a challenging task as the actual system (the New Doha Port) is still under construction and no actual data are available for comparison. However, the first phase of the project, i.e., the first terminal (which this work encompasses) is anticipated to handle 2 million TEUs a year; the simulation model has generated an average of 1,972,923 TEUs in the simulated 395 days. This approximation provides initial validation of the model and motivates collecting data, when available; to better calibrate the parameters of the model.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The overall objective of a simulation model is a consistent imitation of the real system with some applicable realism. A simulation model can aid as a tool to analyze, evaluate and better plan an existing or new system, especially where time plays a large role such as at a container terminal. Managing this time more efficiently can increase its utilization, decrease costs, increase value added activities and maintain an efficient and responsive environment. Simulation principles can be developed effectively to establish this environment through analyzing time based data to successfully provide useful information for various decision-making parameters and implementing them in a virtual construct without disturbing the real system. It was therefore, the intent, to develop such a simulation model that can be made ready to be tailored to (almost) any container terminal system.

The objective of this thesis work is to design a generic discrete event simulation model for a custom-regulated seaport composed of one terminal, and be able to model the flow of entities and the involved operations in any modern but typical port in the world in a seamless manner. The process of the port starts by the arrival of ships, trains and trucks loaded with containers. The cranes, RTGs, and yard trucks provide the needed handling and transportation of containers around the port and from/to the three different kinds of transportation modes.

One primary idea to emphasize here is that the purpose of this work is not to validate the collected data; since no claim is made that all the data are completely accurate and actual. The main goal that this work aims to fulfill is to build a platform that can be considered a reasonable abstraction of the real system and is able to accommodate accurate data when available, in order to provide reliable results.

The complex operations in this system were studied and analyzed, as well as the level of utilization of resources and the impacts of customs on port operations. Four different scenarios regarding changing the number of RTGs, yard trucks, and some of the customs' resources were proposed and implemented in the model, each with the different involved parameters in order to increase utilization and throughput without causing any extreme delays or unacceptably longer queue lines.

After running these different scenarios, it was concluded that for the current input data for this model, some of the number of resources can be reduced in order to achieve higher utilization and meanwhile still provide the required entities handling. The best combination of scenarios was found to be having 20 RTGs, and 30 yard trucks and 2 physical inspection bays in the customs department.

In future work, required data of the new Doha Port are to be collected and statistically analyzed after the port is operational to provide more accurate input distributions for arrival and service times as well as parameters for the different stations and scenarios and also to provide a body for comparison to support the validation effort. In addition, further detailed modeling can be done to include a container yard with a specific number of container zones, each with specified containers stacking and reshuffling strategies; as well as incorporating weather conditions, holidays, and other variables. Such reliable model, when correctly simulated in more details, would assist in decision making to result in an increase in overall system efficiency and account for the highest variation that the system as a whole experiences.

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APPENDIX A: Simulation Results

10:10:24PM **Category Overview** May 2, 2014

Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

System	Average
Number Out	2,507,300

10:10:24PM **Category Overview** May 2, 2014

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	0.3148	0.001619162	0.00	21.9167
Container from Truck	0.08057408	0.000094782	0.03518804	0.1264
ContainerLeavingWTrain	0.3945	0.000103143	0.2885	0.5094
ContainerLeavingWTruck	0.08055384	(Correlated)	0.03504813	0.1265
Containers From Train	0.3946	0.000249059	0.2878	0.5010
Departing	0.5085	0.002011289	0.2204	4.8529
Full Truck	0.03605006	0.000418055	0.00	3.5279
MediumShip1_Berth	0.3222	0.000662355	0.00	10.7500
MediumShip2_Berth	0.3224	0.001476724	0.00	20.4167
SmallShip1_Berth	0.3414	0.001582943	0.00	3.6667
SmallShip2_Berth	0.3423	0.000757090	0.00	5.7500
Train	0.00	0.000000000	0.00	0.00

10:10:24PM **Category Overview** May 2, 2014

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Time

Wait Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	20.1476	(Correlated)	0.00	2663.92
Container from Truck	14.1932	0.854427091	4.7652	41.3143
ContainerLeavingWTrain	2.6338	0.565435499	0.1187	15.9343
ContainerLeavingWTruck	0.5204	0.216586535	0.00	7.4940
Containers From Train	15.3576	0.646997635	5.8259	43.2321
Departing	1.6461	(Correlated)	0.00	29.8149
Full Truck	0.2892	0.064937358	0.00	24.0105
MediumShip1_Berth	15.3138	(Correlated)	0.00	2257.07
MediumShip2_Berth	16.3631	0.769754581	0.00	1076.08
SmallShip1_Berth	15.1845	(Correlated)	0.00	3462.76
SmallShip2_Berth	16.6446	0.597467140	0.00	1611.30
Train	152.21	(Correlated)	10.0394	312.05

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	0.1812	0.001693364	0.08333333	2.8081
Container from Truck	0.1167	(Correlated)	0.1167	0.1167
ContainerLeavingWTrain	0.2500	0.000000000	0.2500	0.2500
ContainerLeavingWTruck	0.1667	(Correlated)	0.1667	0.1667
Containers From Train	0.2333	(Correlated)	0.2333	0.2333
Departing	0.6743	0.000528281	0.4299	1.7854
Full Truck	0.6732	0.000398761	0.4319	1.3712
MediumShip1_Berth	0.1846	0.000529214	0.08333333	2.8969
MediumShip2_Berth	0.1832	(Correlated)	0.08333333	2.7415
SmallShip1_Berth	0.1934	(Correlated)	0.08333333	2.7917
SmallShip2_Berth	0.1864	0.000533412	0.08333333	2.8099
Train	0.8495	0.002292860	0.7114	0.9910

Total Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	20.6436	(Correlated)	0.2464	2667.52
Container from Truck	14.3904	0.854452495	4.9512	41.5401
ContainerLeavingWTrain	3.2783	0.565469157	0.7241	16.5998
ContainerLeavingWTruck	0.7677	0.216587544	0.2017	7.7596
Containers From Train	15.9856	0.646962453	6.4312	43.8867
Departing	2.8289	(Correlated)	0.7419	32.6697
Full Truck	0.9984	0.065097140	0.4319	26.8471
MediumShip1_Berth	15.8206	(Correlated)	0.2486	2259.40
MediumShip2_Berth	16.8687	0.769664536	0.2504	1078.69
SmallShip1_Berth	15.7192	(Correlated)	0.2620	3464.95
SmallShip2_Berth	17.1733	0.598011559	0.2599	1613.29
Train	153.06	(Correlated)	10.8642	312.93

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Time

Other Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	0.00	0.000000000	0.00	0.00
Container from Truck	0.00	0.000000000	0.00	0.00
ContainerLeavingWTrain	0.00	0.000000000	0.00	0.00
ContainerLeavingWTruck	0.00	0.000000000	0.00	0.00
Containers From Train	0.00	0.000000000	0.00	0.00
Departing	0.00	0.000000000	0.00	0.00
Full Truck	0.00	0.000000000	0.00	0.00
MediumShip1_Berth	0.00	0.000000000	0.00	0.00
MediumShip2_Berth	0.00	0.000000000	0.00	0.00
SmallShip1_Berth	0.00	0.000000000	0.00	0.00
SmallShip2_Berth	0.00	0.000000000	0.00	0.00
Train	0.00	0.000000000	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	20.6436	(Correlated)	0.2464	2667.52
Container from Truck	14.3904	0.854452495	4.9512	41.5401
ContainerLeavingWTrain	3.2783	0.565469157	0.7241	16.5998
ContainerLeavingWTruck	0.7677	0.216587544	0.2017	7.7596
Containers From Train	15.9856	0.646962453	6.4312	43.8867
Departing	2.8289	(Correlated)	0.7419	32.6697
Full Truck	0.9964	0.065097140	0.4319	26.8471
MediumShip1_Berth	15.8206	(Correlated)	0.2486	2259.40
MediumShip2_Berth	16.8687	0.769664536	0.2504	1078.69
SmallShip1_Berth	15.7192	(Correlated)	0.2620	3464.95
SmallShip2_Berth	17.1733	0.598011559	0.2599	1613.29
Train	153.06	(Correlated)	10.8642	312.93

Other

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Other

Number Out

	Value
BigShip_Berth	252796.00
Container from Truck	170607.00
ContainerLeavingWTrain	248160.00
ContainerLeavingWTruck	675147.00
Containers From Train	62854.00
ContainersInYard	0.00
Departing	202634.00
Empty Truck	1025911.00
Full Truck	1016691.00
Leaving Trains	0.00
MediumShip1_Berth	174009.00
MediumShip2_Berth	80609.00
Ships	1068.00
SmallShip1_Berth	26984.00
SmallShip2_Berth	130803.00
Train	312297.00
Truck	683809.00

WIP

	Average	Half Width	Minimum Value	Maximum Value
BigShip_Berth	595.88	143.358	4.0000	4586.00
Container from Truck	268.36	14.64616	70.0000	803.00
ContainerLeavingWTrain	7.0814	0.455845286	0.00	77.0000
ContainerLeavingWTruck	12.8454	0.041461789	0.00	57.0000
Containers From Train	109.63	8.48283	0.00	531.00
ContainersInYard	0.00	(Insufficient)	0.00	0.00
Departing	48.5239	(Correlated)	0.00	235.00
Empty Truck	45.1522	12.01696	0.00	484.00
Full Truck	65.3675	11.62784	8.0000	446.00
Leaving Trains	0.00	(Insufficient)	0.00	0.00
MediumShip1_Berth	313.63	25.98444	2.0000	1869.00
MediumShip2_Berth	155.17	34.95426	0.00	2159.00
Ships	0.00	(Insufficient)	0.00	1.0000
SmallShip1_Berth	48.4984	7.12436	0.00	523.00
SmallShip2_Berth	257.58	20.25683	2.0000	1397.00
Train	116.49	20.41480	4.0000	1205.00
Truck	19.5151	0.047212794	2.0000	41.0000

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
1RTG2Load BigShip.Queue	1.5369	0.228680535	0.00	5 7099
1RTG2Load MedShip.Queue	0.8969	0.340512371	0.00	6.4295
1RTG2Load SmShip.Queue	0.4874	0.125761559	0.00	5.7279
1YT2Bigship.Queue	1.1860	0.331904765	0.00	5.1043
1YT2Medship.Queue	0.5604	0.218418838	0.00	5.3330
1YT2SmShip.Queue	0.3881	0.119910866	0.00	5.6802
2RTG2Load BigShip.Queue	1.2276	(Correlated)	0.00	4.9651
2RTG2Load MedShip.Queue	0.7333	0.230085128	0.00	5.3040
2RTG2Load SmShip.Queue	0.5729	0.212621469	0.00	4.1151
2YT2Bigship.Queue	0.8546	0.284253812	0.00	5.6519
2YT2Medship.Queue	0.4467	0.189923025	0.00	5.3932
2YT2SmShip.Queue	0.4213	0.300170242	0.00	6.0191
3RTG2Load BigShip.Queue	1.8835	(Correlated)	0.00	5.6863
3RTG2Load MedShip.Queue	0.8223	0.201262793	0.00	4.5361
3RTG2Load SmShip.Queue	0.6030	0.244357892	0.00	5.3078
3YT2Bigship.Queue	1.0996	(Correlated)	0.00	5.9755
3YT2Medship.Queue	0.7214	0.346245731	0.00	5.0453
3YT2SmShip.Queue	0.2811	0.132571412	0.00	2.0373
4RTG2Load BigShip.Queue	1.2430	0.304132649	0.00	4 8062
4RTG2Load MedShip.Queue	0.6139	0.135474658	0.00	2.1665
4RTG2Load SmShip.Queue	0.9890	0.380552403	0.00	5.6878
4YT2Bigship.Queue	1.3553	0.523934458	0.00	4.8416
4YT2Medship.Queue	0.5256	0.248627961	0.00	4.1931
4YT2SmShip.Queue	0.6469	0.246720222	0.00	3.5157
5RTG2Load BigShip.Queue	1.8926	(Correlated)	0.00	5.7634
5RTG2Load MedShip.Queue	0.8772	0.220863148	0.00	3.8194
5RTG2Load SmShip.Queue	0.9147	0.398836467	0.00	5.9025
5YT2Bigship.Queue	1.3821	(Correlated)	0.00	4.8321
5YT2Medship.Queue	0.6681	0.196693638	0.00	3.9661
5YT2SmShip.Queue	0.6391	(Correlated)	0.00	4.6037
6RTG2Load BigShip.Queue	2.1716	(Correlated)	0.00	7.4724
6RTG2Load MedShip.Queue	1.0122	0.302709884	0.00	5.8782
6RTG2Load SmShip.Queue	1.1203	(Correlated)	0.00	5.0529
6YT2Bigship.Queue	1.3530	(Correlated)	0.00	5.2675
6YT2Medship.Queue	0.8342	0.413824753	0.00	5.3585
6YT2SmShip.Queue	0.6158	(Correlated)	0.00	3.6025
7RTG2Load MedShip.Queue	1.3270	(Correlated)	0.00	7.0119

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
7RTG2Load SmShip.Queue	0.9075	0.280962725	0.00	4.0723
7YT2Medship.Queue	1.3035	(Correlated)	0.00	6.9282
7YT2SmShip.Queue	0.6439	0.379355074	0.00	4.5666
8RTG2Load SmShip.Queue	1.1681	0.386357989	0.00	4.7418
8YT2SmShip.Queue	1.6429	0.596452237	0.00	4.2953
Checking I.D.Scedule Grace time.Queue	0.04261172	0.002626295	0.00	0.8579
Crane1.Queue	5.5296	0.216647423	0.00	14.8517
Crane12.Queue	5.6191	0.253857880	0.00	16.6228
Crane123.Queue	12.5935	0.808503195	0.00	33.6610
Crane123Load.Queue	6.7191	1.68235	0.00	27.5152
Crane12Load.Queue	2.7989	0.748065956	0.00	25.4243
Crane1Load.Queue	2.1009	0.618213621	0.00	25.6653
Crane2.Queue	5.5399	0.334256240	0.00	15.2126
Crane23.Queue	5.4180	0.374121089	0.00	17.3293
Crane234.Queue	13.1530	(Correlated)	0.00	32.1100
Crane234Load.Queue	7.4418	(Correlated)	0.00	23.8861
Crane23Load.Queue	2.2099	0.756767671	0.00	17.8334
Crane2Load.Queue	2.4868	1.00369	0.00	25.8468
Crane3.Queue	5.7934	(Correlated)	0.00	19.2928
Crane34.Queue	5.6060	0.300667013	0.00	15.7879
Crane345.Queue	12.5702	1.85279	0.00	31.8634
Crane345Load.Queue	7.5877	(Correlated)	0.00	29.7135
Crane34Load.Queue	2.0480	0.683145041	0.00	17.6348
Crane3Load.Queue	1.4698	0.317198771	0.00	11.0960
Crane4.Queue	5.6768	0.309277254	0.00	16.5947
Crane45.Queue	5.6647	0.452104540	0.00	22.9067
Crane456.Queue	12.4968	(Correlated)	0.00	31.4094
Crane456Load.Queue	3.6869	(Correlated)	0.00	15.1669
Crane45Load.Queue	1.9171	(Correlated)	0.00	20.5583
Crane4Load.Queue	1.7695	0.506141430	0.00	12.1263
Crane5.Queue	5.4267	0.430785604	0.00	18.5385
Crane56.Queue	5.3421	0.477084142	0.00	15.4198
Crane567.Queue	12.0459	1.30588	0.00	30.0347
Crane567Load.Queue	6.3747	(Correlated)	0.00	29.3481
Crane56Load.Queue	2.0795	0.774204123	0.00	17.5686
Crane5Load.Queue	2.6490	(Correlated)	0.00	24.0089

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Crane6.Queue	5.5161	0.585927608	0.00	18.9593
Crane67.Queue	5.3264	0.466486301	0.00	16.9075
Crane678.Queue	12.7763	1.59688	0.00	32.4366
Crane678Load.Queue	7.5038	(Correlated)	0.00	29.3018
Crane67Load.Queue	4.3627	(Correlated)	0.00	30.4499
Crane6Load.Queue	4.7320	(Correlated)	0 00	31.2328
Crane7.Queue	5.9550	0.997221689	0.00	20.3196
Crane78.Queue	5.3088	0.710496659	0.00	16.9112
Crane78Load.Queue	1.6881	0.628253134	0.00	10.9947
Crane7Load.Queue	3.0113	2.19815	0.00	29.1306
Crane8.Queue	5.4412	0.605228749	0.00	14.9833
Crane8Load.Queue	2.6112	1.18075	0.00	12.8875
Physical Inspection.Queue	0.1111	0.012357665	0.00	2.6557
RTG Unloading YT.Queue	0.7490	0.276401358	0.00	7.4963
RTG2LoadTrain.Queue	0.8841	0.242675090	0.00	7.2332
RTGLoad Train.Queue	1.0173	0.240687889	0 00	7.0584
RTGLoad Truck.Queue	0.5204	0.216547506	0.00	7.4940
RTGUnload Train.Queue	0.6340	0.228177867	0.00	7.0729
RTGUnload Truck.Queue	0.5348	0.227682987	0 00	7.4946
Settlement of Adm.Fee issues.Queue	0.1354	0.014991176	0.00	3.2241
Truck Wait for Loading.Queue	0.02955420	0.002573042	0.00	1.8056
Wait for Scan Results.Queue	1.1747	(Correlated)	0.00	8.3181
X ray.Queue	0.07845375	0.006298035	0.00	1.2443
Yard Storage.Queue	11.4679	0.731274866	4.1371	41.3143
YardTrucks for Ship.Queue	0.6304	0.145878140	0.00	6.9265
YardTrucks for Train.Queue	0.4022	0.110727541	0.00	6.8175
YT2loadTruck.Queue	0.7327	0.099945376	0.00	6.8725

Other

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
1RTG2Load BigShip.Queue	2.9313	1.15974	0.00	603.00
1RTG2Load MedShip.Queue	1.5896	0.812792336	0.00	202.00
1RTG2Load SmShip.Queue	0.6914	0.206586561	0.00	88.0000
1YT2Bigship.Queue	2.2620	1.03856	0.00	542.00
1YT2Medship.Queue	0.9931	0.496246096	0.00	202.00
1YT2SmShip.Queue	0.5505	0.205549518	0.00	86.0000
2RTG2Load BigShip.Queue	0.9203	0.654630764	0.00	539.00
2RTG2Load MedShip.Queue	0.6985	0.274285902	0.00	193.00
2RTG2Load SmShip.Queue	0.2875	0.136567494	0.00	86.0000
2YT2Bigship.Queue	0.6406	0.496033341	0.00	486.00
2YT2Medship.Queue	0.4255	0.216157263	0.00	201.00
2YT2SmShip.Queue	0.2114	(Correlated)	0.00	84.0000
3RTG2Load BigShip.Queue	1.2860	1.48427	0.00	589.00
3RTG2Load MedShip.Queue	0.6624	0.265507783	0.00	203.00
3RTG2Load SmShip.Queue	0.2496	0.125869016	0.00	87.0000
3YT2Bigship.Queue	0.7508	0.677986587	0.00	448.00
3YT2Medship.Queue	0.5811	0.362808261	0.00	203.00
3YT2SmShip.Queue	0.1081	0.061253048	0.00	78.0000
4RTG2Load BigShip.Queue	1.0539	0.571711566	0.00	563.00
4RTG2Load MedShip.Queue	0.5822	0.234157310	0.00	193.00
4RTG2Load SmShip.Queue	0.4552	0.232920601	0.00	88.0000
4YT2Bigship.Queue	1.1491	0.889561538	0.00	536.00
4YT2Medship.Queue	0.4984	0.321067122	0.00	179.00
4YT2SmShip.Queue	0.2978	0.158413113	0.00	83.0000
5RTG2Load BigShip.Queue	1.8822	1.43499	0.00	562.00
5RTG2Load MedShip.Queue	0.4609	0.203093293	0.00	182.00
5RTG2Load SmShip.Queue	0.2443	(Correlated)	0.00	85.0000
5YT2Bigship.Queue	1.3746	1.01565	0.00	562.00
5YT2Medship.Queue	0.3510	0.212832024	0.00	182.00
5YT2SmShip.Queue	0.1707	0.151032221	0.00	85.0000
6RTG2Load BigShip.Queue	1.6783	1.74105	0.00	605.00
6RTG2Load MedShip.Queue	0.4941	0.259160918	0.00	179.00
6RTG2Load SmShip.Queue	0.2344	0.192233316	0.00	80.0000
6YT2Bigship.Queue	1.0457	0.993066426	0.00	562.00
6YT2Medship.Queue	0.4072	0.320415279	0.00	179.00
6YT2SmShip.Queue	0.1288	(Correlated)	0.00	79.0000
7RTG2Load MedShip.Queue	0.4208	0.334625551	0.00	191.00

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
7RTG2Load SmShip.Queue	0.1771	0.089563071	0.00	85.0000
7YT2Medship.Queue	0.4134	0.371700212	0.00	153.00
7YT2SmShip.Queue	0.1256	0.086072723	0.00	79.0000
8RTG2Load SmShip.Queue	0.1784	0.104780739	0.00	88.0000
8YT2SmShip.Queue	0.2509	0.153029339	0.00	88.0000
Checking I.D.Scedule Grace time.Queue	1.2339	0.081201609	0.00	39.0000
Crane1.Queue	31.0917	4.35975	0.00	358.00
Crane12.Queue	39.3755	7.90513	0.00	776.00
Crane123.Queue	95.5111	32.73967	0.00	2409.00
Crane123Load Queue	12.8153	6.44354	0.00	729.00
Crane12Load.Queue	4.8992	1.92598	0.00	206.00
Crane1Load.Queue	3.0170	0.783133946	0.00	133.00
Crane2.Queue	11.1525	2.96152	0.00	357.00
Crane23.Queue	20.5104	5.26069	0.00	815.00
Crane234.Queue	41.3285	25.34242	0.00	2288.00
Crane234Load.Queue	5.5788	4.24196	0.00	778.00
Crane23Load.Queue	2.1049	0.882041359	0.00	278.00
Crane2Load.Queue	1.2455	0.588383296	0.00	106.00
Crane3.Queue	9.8653	2.54676	0.00	353.00
Crane34.Queue	17.9713	4.88741	0.00	744.00
Crane345.Queue	30.0610	19.45588	0.00	2179.00
Crane345Load.Queue	5.1806	4.64526	0.00	485.00
Crane34Load.Queue	1.6497	0.775605542	0.00	176.00
Crane3Load.Queue	0.6084	0.176547465	0.00	79.0000
Crane4.Queue	10.1440	2.91185	0.00	343.00
Crane45.Queue	21.5560	6.32202	0.00	785.00
Crane456.Queue	41.7828	18.50640	0.00	2240.00
Crane456Load.Queue	3.1259	2.05759	0.00	536.00
Crane45Load.Queue	1.8180	(Correlated)	0.00	179.00
Crane4Load.Queue	0.8145	0.368265136	0.00	123.00
Crane5.Queue	5.5624	2.35411	0.00	321.00
Crane56.Queue	11.2879	4.54424	0.00	732.00
Crane567.Queue	43.1409	22.85069	0.00	2160.00
Crane567Load.Queue	6.3397	4.64680	0.00	555.00
Crane56Load.Queue	1.0925	0.621113256	0.00	161.00
Crane5Load.Queue	0.7076	0.643398758	0.00	93.0000

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Crane6.Queue	4.7309	(Correlated)	0.00	331.00
Crane67.Queue	10.4612	3.71221	0.00	813.00
Crane678.Queue	36.3804	24.20374	0.00	2323.00
Crane678Load.Queue	5.7992	5.17251	0.00	605.00
Crane67Load.Queue	2.1296	1.60980	0.00	195.00
Crane6Load.Queue	0.9901	(Correlated)	0.00	129.00
Crane7.Queue	4.5158	1.35174	0.00	351.00
Crane78.Queue	6.6948	3.01940	0.00	797.00
Crane78Load.Queue	0.5353	0.395005593	0.00	153.00
Crane7Load.Queue	0.5875	0.565949615	0.00	86.0000
Crane8.Queue	3.3933	1.81349	0.00	358.00
Crane8Load.Queue	0.3988	0.312288488	0.00	110.00
Physical Inspection.Queue	0.1612	0.020268653	0.00	8.0000
RTG Unloading YT.Queue	50.6341	24.03999	0.00	935.00
RTG2LoadTrain.Queue	25.0231	7.25187	0.00	789.00
RTGLoad Train.Queue	28.8090	7.34153	0.00	743.00
RTGLoad Truck.Queue	40.1074	15.52146	0.00	540.00
RTGUnload Train.Queue	4.5421	1.96849	0.00	186.00
RTGUnload Truck.Queue	10.4187	3.92445	0.00	148.00
Settlement of Adm.Fee issues.Queue	0.1238	0.014844232	0.00	7.0000
Truck Wait for Loading.Queue	2.2776	0.181924882	0.00	113.00
Wait for Scan Results.Queue	35.7616	(Correlated)	0.00	258.00
X ray.Queue	2.3887	0.189094759	0.00	45.0000
Yard Storage.Queue	999.00	(Insufficient)	999.00	1000.00
YardTrucks for Ship.Queue	38.0972	10.14081	0.00	862.00
YardTrucks for Train.Queue	2.8814	0.743827681	0.00	164.00
YT2loadTruck.Queue	20.7361	3.05067	0.00	678.00

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Adm issues settlement	0.4581	0.011472336	0.00	1.0000
Crane 1	0.6154	0.020680178	0.00	1.0000
Crane 2	0.5791	0.025874655	0.00	1.0000
Crane 3	0.5044	0.045311023	0.00	1.0000
Crane 4	0.4359	0.039107665	0.00	1.0000
Crane 5	0.3764	0.042390929	0.00	1.0000
Crane 6	0.3257	0.050947333	0.00	1.0000
Crane 7	0.2402	0.052736527	0.00	1.0000
Crane 8	0.1168	(Insufficient)	0.00	1.0000
Entrance Gate	0.6756	0.003089983	0.00	1.0000
Physical Inspectors	0.5242	0.011091708	0.00	1.0000
ResultScanner	0.9791	(Correlated)	0.00	1.0000
RTG 21	0.7391	0.022709417	0.00	1.0000
RTG 22	0.7388	0.022524305	0.00	1.0000
RTG 23	0.7387	0.022468982	0.00	1.0000
RTG 24	0.7394	0.022475750	0.00	1.0000
RTG 25	0.7385	0.022587493	0.00	1.0000
RTG 26	0.7388	0.022682403	0.00	1.0000
RTG 1	0.7382	0.022712227	0.00	1.0000
RTG 10	0.7381	0.022672127	0.00	1.0000
RTG 11	0.7385	0.022548371	0.00	1.0000
RTG 12	0.7390	0.022686218	0.00	1.0000
RTG 13	0.7387	0.022678346	0.00	1.0000
RTG 14	0.7388	0.022473857	0.00	1.0000
RTG 15	0.7391	0.022541197	0.00	1.0000
RTG 16	0.7392	0.022714119	0.00	1.0000
RTG 19	0.7386	0.022557940	0.00	1.0000
RTG 2	0.7387	0.022477025	0.00	1.0000
RTG 20	0.7396	0.022363361	0.00	1.0000
RTG 3	0.7384	0.022665399	0.00	1.0000
RTG 4	0.7387	0.022376180	0.00	1.0000
RTG 5	0.7386	0.022544283	0.00	1.0000
RTG 6	0.7388	0.022511776	0.00	1.0000
RTG 7	0.7387	0.022564279	0.00	1.0000
RTG 8	0.7386	0.022647164	0.00	1.0000
RTG 9	0.7380	0.022680944	0.00	1.0000
RTG17	0.7385	0.022550352	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
RTG18	0.7386	0.022572683	0.00	1.0000
Trucks RTG 1	0.00	(Insufficient)	0.00	0.00
Xray lane	0.8368	0.003921572	0.00	1.0000
Yard Truck 26	0.5645	0.031572936	0.00	1.0000
Yard Truck 1	0.5639	0.031616511	0.00	1.0000
Yard Truck 10	0.5643	0.031780529	0.00	1.0000
Yard Truck 11	0.5638	0.031707832	0.00	1.0000
Yard Truck 12	0.5637	0.031888087	0.00	1.0000
Yard Truck 13	0.5642	0.031702186	0.00	1.0000
Yard Truck 14	0.5642	0.031756628	0.00	1.0000
Yard Truck 15	0.5637	0.031705392	0.00	1.0000
Yard Truck 16	0.5642	0.031620617	0.00	1.0000
Yard Truck 17	0.5640	0.031767387	0.00	1.0000
Yard Truck 18	0.5635	0.031826085	0.00	1.0000
Yard Truck 19	0.5629	0.031839732	0.00	1.0000
Yard Truck 2	0.5638	0.031660487	0.00	1.0000
Yard Truck 20	0.5629	0.031917572	0.00	1.0000
Yard Truck 21	0.5629	0.031692604	0.00	1.0000
Yard Truck 22	0.5635	0.031651887	0.00	1.0000
Yard Truck 23	0.5638	0.031571776	0.00	1.0000
Yard Truck 24	0.5635	0.031799253	0.00	1.0000
Yard Truck 25	0.5640	0.031689030	0.00	1.0000
Yard Truck 3	0.5640	0.031695790	0.00	1.0000
Yard Truck 4	0.5640	0.031662773	0.00	1.0000
Yard Truck 5	0.5636	0.031800296	0.00	1.0000
Yard Truck 6	0.5644	0.031677215	0.00	1.0000
Yard Truck 7	0.5646	0.031719465	0.00	1.0000
Yard Truck 8	0.5644	0.031769229	0.00	1.0000
Yard Truck 9	0.5646	0.031557754	0.00	1.0000
Yard Truck27	0.5639	0.031835208	0.00	1.0000
Yard Truck28	0.5648	0.031679270	0.00	1.0000
Yard Truck29	0.5640	0.031599023	0.00	1.0000
Yard Truck30	0.5638	0.031503861	0.00	1.0000
Yard Truck31	0.5638	0.031634057	0.00	1.0000
Yard Truck32	0.5634	0.031720779	0.00	1.0000
Yard Truck33	0.5635	0.031853397	0.00	1.0000
Yard Truck34	0.5639	0.031641969	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Yard Truck35	0.5634	0.031686756	0.00	1.0000
Yard Truck36	0.5638	0.031670572	0.00	1.0000
Yard Truck37	0.5633	0.031610490	0.00	1.0000
Yard Truck38	0.5641	0.031606906	0.00	1.0000
Yard Truck39	0.5628	0.031662627	0.00	1.0000
Yard Truck40	0.5640	0.031436111	0.00	1.0000
Yard Truck41	0.5640	0.031513901	0.00	1.0000
Yard Truck42	0.5638	0.031632300	0.00	1.0000
Yard Truck43	0.5635	0.031376011	0.00	1.0000
Yard Truck44	0.5636	0.031769090	0.00	1.0000
Yard Truck45	0.5640	0.031836918	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Busy	Average	Half Width	Minimum Value	Maximum Value
Adm issues settlement	0.9163	0.022944673	0.00	2.0000
Crane 1	0.6154	0.020680178	0.00	1.0000
Crane 2	0.5791	0.025874655	0.00	1.0000
Crane 3	0.5044	0.045311023	0.00	1.0000
Crane 4	0.4359	0.039107665	0.00	1.0000
Crane 5	0.3764	0.042390929	0.00	1.0000
Crane 6	0.3257	0.050947333	0.00	1.0000
Crane 7	0.2402	0.052736527	0.00	1.0000
Crane 8	0.1168	(Insufficient)	0.00	1.0000
Entrance Gate	0.6756	0.003089983	0.00	1.0000
Physical Inspectors	1.5727	0.033275125	0.00	3.0000
ResultScanner	6.8539	(Correlated)	0.00	7.0000
RTG 21	0.7391	0.022709417	0.00	1.0000
RTG 22	0.7388	0.022524305	0.00	1.0000
RTG 23	0.7387	0.022468982	0.00	1.0000
RTG 24	0.7394	0.022475750	0.00	1.0000
RTG 25	0.7385	0.022587493	0.00	1.0000
RTG 26	0.7388	0.022682403	0.00	1.0000
RTG 1	0.7382	0.022712227	0.00	1.0000
RTG 10	0.7381	0.022672127	0.00	1.0000
RTG 11	0.7385	0.022548371	0.00	1.0000
RTG 12	0.7390	0.022686218	0.00	1.0000
RTG 13	0.7387	0.022678346	0.00	1.0000
RTG 14	0.7388	0.022473857	0.00	1.0000
RTG 15	0.7391	0.022541197	0.00	1.0000
RTG 16	0.7392	0.022714119	0.00	1.0000
RTG 19	0.7386	0.022557940	0.00	1.0000
RTG 2	0.7387	0.022477025	0.00	1.0000
RTG 20	0.7396	0.022363361	0.00	1.0000
RTG 3	0.7384	0.022665399	0.00	1.0000
RTG 4	0.7387	0.022376180	0.00	1.0000
RTG 5	0.7386	0.022544283	0.00	1.0000
RTG 6	0.7388	0.022511776	0.00	1.0000
RTG 7	0.7387	0.022564279	0.00	1.0000
RTG 8	0.7386	0.022647164	0.00	1.0000
RTG 9	0.7380	0.022680944	0.00	1.0000
RTG17	0.7385	0.022550352	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Busy	Average	Half Width	Minimum Value	Maximum Value
RTG18	0.7386	0.022572683	0.00	1.0000
Trucks RTG 1	0.00	(Insufficient)	0.00	0.00
Xray lane	0.8368	0.003921572	0.00	1.0000
Yard Truck 26	0.5645	0.031572936	0.00	1.0000
Yard Truck 1	0.5639	0.031616511	0.00	1.0000
Yard Truck 10	0.5643	0.031780529	0.00	1.0000
Yard Truck 11	0.5638	0.031707832	0.00	1.0000
Yard Truck 12	0.5637	0.031888087	0.00	1.0000
Yard Truck 13	0.5642	0.031702186	0.00	1.0000
Yard Truck 14	0.5642	0.031756628	0.00	1.0000
Yard Truck 15	0.5637	0.031705392	0.00	1.0000
Yard Truck 16	0.5642	0.031620617	0.00	1.0000
Yard Truck 17	0.5640	0.031767387	0.00	1.0000
Yard Truck 18	0.5635	0.031826085	0.00	1.0000
Yard Truck 19	0.5629	0.031839732	0.00	1.0000
Yard Truck 2	0.5638	0.031660487	0.00	1.0000
Yard Truck 20	0.5629	0.031917572	0.00	1.0000
Yard Truck 21	0.5629	0.031692604	0.00	1.0000
Yard Truck 22	0.5635	0.031651887	0.00	1.0000
Yard Truck 23	0.5638	0.031571776	0.00	1.0000
Yard Truck 24	0.5635	0.031799253	0.00	1.0000
Yard Truck 25	0.5640	0.031689030	0.00	1.0000
Yard Truck 3	0.5640	0.031695790	0.00	1.0000
Yard Truck 4	0.5640	0.031662773	0.00	1.0000
Yard Truck 5	0.5636	0.031800296	0.00	1.0000
Yard Truck 6	0.5644	0.031677215	0.00	1.0000
Yard Truck 7	0.5646	0.031719465	0.00	1.0000
Yard Truck 8	0.5644	0.031769229	0.00	1.0000
Yard Truck 9	0.5646	0.031557754	0.00	1.0000
Yard Truck27	0.5639	0.031835208	0.00	1.0000
Yard Truck28	0.5648	0.031679270	0.00	1.0000
Yard Truck29	0.5640	0.031599023	0.00	1.0000
Yard Truck30	0.5638	0.031503861	0.00	1.0000
Yard Truck31	0.5638	0.031634057	0.00	1.0000
Yard Truck32	0.5634	0.031720779	0.00	1.0000
Yard Truck33	0.5635	0.031853397	0.00	1.0000
Yard Truck34	0.5639	0.031641969	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Busy	Average	Half Width	Minimum Value	Maximum Value
Yard Truck35	0.5634	0.031686756	0.00	1 0000
Yard Truck36	0.5638	0.031670572	0.00	1.0000
Yard Truck37	0.5633	0.031610490	0.00	1.0000
Yard Truck38	0.5641	0.031606906	0.00	1.0000
Yard Truck39	0.5628	0.031662627	0.00	1.0000
Yard Truck40	0.5640	0.031436111	0.00	1.0000
Yard Truck41	0.5640	0.031513901	0.00	1.0000
Yard Truck42	0.5638	0.031632300	0.00	1.0000
Yard Truck43	0.5635	0.031376011	0.00	1.0000
Yard Truck44	0.5636	0.031769090	0.00	1 0000
Yard Truck45	0.5640	0.031836918	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Scheduled	Average	Half Width	Minimum Value	Maximum Value
Adm issues settlement	2.0000	(Insufficient)	2.0000	2.0000
Crane 1	1.0000	(Insufficient)	1.0000	1.0000
Crane 2	1.0000	(Insufficient)	1.0000	1.0000
Crane 3	1.0000	(Insufficient)	1.0000	1.0000
Crane 4	1.0000	(Insufficient)	1.0000	1.0000
Crane 5	1.0000	(Insufficient)	1.0000	1.0000
Crane 6	1.0000	(Insufficient)	1.0000	1.0000
Crane 7	1.0000	(Insufficient)	1.0000	1.0000
Crane 8	1.0000	(Insufficient)	1.0000	1.0000
Entrance Gate	1.0000	(Insufficient)	1.0000	1.0000
Physical Inspectors	3.0000	(Insufficient)	3.0000	3.0000
ResultScanner	7.0000	(Insufficient)	7.0000	7.0000
RTG 21	1.0000	(Insufficient)	1.0000	1.0000
RTG 22	1.0000	(Insufficient)	1.0000	1.0000
RTG 23	1.0000	(Insufficient)	1.0000	1.0000
RTG 24	1.0000	(Insufficient)	1.0000	1.0000
RTG 25	1.0000	(Insufficient)	1.0000	1.0000
RTG 26	1.0000	(Insufficient)	1.0000	1.0000
RTG 1	1.0000	(Insufficient)	1.0000	1.0000
RTG 10	1.0000	(Insufficient)	1.0000	1.0000
RTG 11	1.0000	(Insufficient)	1.0000	1.0000
RTG 12	1.0000	(Insufficient)	1.0000	1.0000
RTG 13	1.0000	(Insufficient)	1.0000	1.0000
RTG 14	1.0000	(Insufficient)	1.0000	1.0000
RTG 15	1.0000	(Insufficient)	1.0000	1.0000
RTG 16	1.0000	(Insufficient)	1.0000	1.0000
RTG 19	1.0000	(Insufficient)	1.0000	1.0000
RTG 2	1.0000	(Insufficient)	1.0000	1.0000
RTG 20	1.0000	(Insufficient)	1.0000	1.0000
RTG 3	1.0000	(Insufficient)	1.0000	1.0000
RTG 4	1.0000	(Insufficient)	1.0000	1.0000
RTG 5	1.0000	(Insufficient)	1.0000	1.0000
RTG 6	1.0000	(Insufficient)	1.0000	1.0000
RTG 7	1.0000	(Insufficient)	1.0000	1.0000
RTG 8	1.0000	(Insufficient)	1.0000	1.0000
RTG 9	1.0000	(Insufficient)	1.0000	1.0000
RTG17	1.0000	(Insufficient)	1.0000	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Scheduled	Average	Half Width	Minimum Value	Maximum Value
RTG18	1.0000	(Insufficient)	1.0000	1.0000
Trucks RTG 1	1.0000	(Insufficient)	1.0000	1.0000
Xray lane	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 26	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 1	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 10	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 11	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 12	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 13	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 14	1.0000	(Insufficient)	1.0000	1 0000
Yard Truck 15	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 16	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 17	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 18	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 19	1.0000	(Insufficient)	1.0000	1 0000
Yard Truck 2	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 20	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 21	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 22	1.0000	(Insufficient)	1.0000	1 0000
Yard Truck 23	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 24	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 25	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 3	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 4	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 5	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 6	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 7	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 8	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck 9	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck27	1.0000	(Insufficient)	1.0000	1 0000
Yard Truck28	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck29	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck30	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck31	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck32	1.0000	(Insufficient)	1.0000	1 0000
Yard Truck33	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck34	1.0000	(Insufficient)	1.0000	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Number Scheduled	Average	Half Width	Minimum Value	Maximum Value
Yard Truck35	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck36	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck37	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck38	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck39	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck40	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck41	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck42	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck43	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck44	1.0000	(Insufficient)	1.0000	1.0000
Yard Truck45	1.0000	(Insufficient)	1.0000	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Scheduled Utilization

	Value
Adm issues settlement	0.4581
Crane 1	0.6154
Crane 2	0.5791
Crane 3	0.5044
Crane 4	0.4359
Crane 5	0.3764
Crane 6	0.3257
Crane 7	0.2402
Crane 8	0.1168
Entrance Gate	0.6756
Physical Inspectors	0.5242
ResultScanner	0.9791
RTG 21	0.7391
RTG 22	0.7388
RTG 23	0.7387
RTG 24	0.7394
RTG 25	0.7385
RTG 26	0.7388
RTG 1	0.7382
RTG 10	0.7381
RTG 11	0.7385
RTG 12	0.7390
RTG 13	0.7387
RTG 14	0.7388
RTG 15	0.7391
RTG 16	0.7392
RTG 19	0.7386
RTG 2	0.7387
RTG 20	0.7396
RTG 3	0.7384
RTG 4	0.7387
RTG 5	0.7386
RTG 6	0.7388
RTG 7	0.7387
RTG 8	0.7386
RTG 9	0.7380
RTG17	0.7385

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Scheduled Utilization

	Value
RTG18	0.7386
Trucks RTG 1	0.00
Xray lane	0.8368
Yard Truck 26	0.5645
Yard Truck 1	0.5639
Yard Truck 10	0.5643
Yard Truck 11	0.5638
Yard Truck 12	0.5637
Yard Truck 13	0.5642
Yard Truck 14	0.5642
Yard Truck 15	0.5637
Yard Truck 16	0.5642
Yard Truck 17	0.5640
Yard Truck 18	0.5635
Yard Truck 19	0.5629
Yard Truck 2	0.5638
Yard Truck 20	0.5629
Yard Truck 21	0.5629
Yard Truck 22	0.5635
Yard Truck 23	0.5638
Yard Truck 24	0.5635
Yard Truck 25	0.5640
Yard Truck 3	0.5640
Yard Truck 4	0.5640
Yard Truck 5	0.5636
Yard Truck 6	0.5644
Yard Truck 7	0.5646
Yard Truck 8	0.5644
Yard Truck 9	0.5646
Yard Truck27	0.5639
Yard Truck28	0.5648
Yard Truck29	0.5640
Yard Truck30	0.5638
Yard Truck31	0.5638
Yard Truck32	0.5634
Yard Truck33	0.5635
Yard Truck34	0.5639

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Scheduled Utilization

	Value
Yard Truck35	0.5634
Yard Truck36	0.5638
Yard Truck37	0.5633
Yard Truck38	0.5641
Yard Truck39	0.5628
Yard Truck40	0.5640
Yard Truck41	0.5640
Yard Truck42	0.5638
Yard Truck43	0.5635
Yard Truck44	0.5636
Yard Truck45	0.5640

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Total Number Seized	Value
Adm issues settlement	8017.00
Crane 1	221802.00
Crane 2	257819.00
Crane 3	239354.00
Crane 4	194164.00
Crane 5	179712.00
Crane 6	162454 00
Crane 7	115457.00
Crane 8	52340.00
Entrance Gate	253661.00
Physical Inspectors	12711.00
ResultScanner	266785.00
RTG 21	81980.00
RTG 22	82075.00
RTG 23	82052.00
RTG 24	82018.00
RTG 25	81947.00
RTG 26	81982.00
RTG 1	81970.00
RTG 10	81867.00
RTG 11	82017.00
RTG 12	82094.00
RTG 13	81878.00
RTG 14	81995.00
RTG 15	82127.00
RTG 16	82047.00
RTG 19	81903.00
RTG 2	82007.00
RTG 20	81997.00
RTG 3	81845.00
RTG 4	81963.00
RTG 5	81951 00
RTG 6	82123.00
RTG 7	81925.00
RTG 8	81944 00
RTG 9	81892.00
RTG17	82006.00

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Total Number Seized

	Value
RTG18	82037.00
Trucks RTG 1	0.00
Xray lane	266716.00
Yard Truck 26	21658.00
Yard Truck 1	21641.00
Yard Truck 10	21672.00
Yard Truck 11	21661.00
Yard Truck 12	21679.00
Yard Truck 13	21677.00
Yard Truck 14	21699.00
Yard Truck 15	21652.00
Yard Truck 16	21653.00
Yard Truck 17	21669.00
Yard Truck 18	21649.00
Yard Truck 19	21626.00
Yard Truck 2	21667.00
Yard Truck 20	21640.00
Yard Truck 21	21640.00
Yard Truck 22	21642.00
Yard Truck 23	21672.00
Yard Truck 24	21694.00
Yard Truck 25	21680.00
Yard Truck 3	21679.00
Yard Truck 4	21640.00
Yard Truck 5	21660.00
Yard Truck 6	21681.00
Yard Truck 7	21705.00
Yard Truck 8	21705.00
Yard Truck 9	21663.00
Yard Truck27	21668.00
Yard Truck28	21710.00
Yard Truck29	21682.00
Yard Truck30	21671.00
Yard Truck31	21680.00
Yard Truck32	21674.00
Yard Truck33	21652.00
Yard Truck34	21690.00

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Total Number Seized	Value
Yard Truck35	21649.00
Yard Truck36	21663.00
Yard Truck37	21635.00
Yard Truck38	21700.00
Yard Truck39	21661.00
Yard Truck40	21645.00
Yard Truck41	21710.00
Yard Truck42	21687.00
Yard Truck43	21606.00
Yard Truck44	21650.00
Yard Truck45	21624.00

User Specified

Time Persistent

Variable	Average	Half Width	Minimum Value	Maximum Value
1ArrivingContainers	452616.25	(Correlated)	66358.00	829301.00
1DepartingContainers	616536.11	(Correlated)	85651.00	1143622
ContFromTrain	35871.03	(Correlated)	4636.00	67397.00
ContFromTruck	99565.90	(Correlated)	14170.00	184840.00
ContLeavingwTrain	141617.05	(Correlated)	18154.00	266261.00
ContLeavingwTruck	393652.16	(Correlated)	55616.00	730774.00
CustomTruckCounter	147503.76	(Correlated)	20940.00	273403 00
RejectedTrucks	739.21	(Correlated)	109.00	1382.00
ShipContainersIn	317309.28	(Correlated)	47744.00	577096 00
ShipContainersOut	81288.11	(Correlated)	11944.00	146613.00
ShipIn	636.99	(Correlated)	89.0000	1157.00
ShipOut	611.55	(Correlated)	70.0000	1126.00
TrainIn	837.51	(Correlated)	107.00	1577.00
TrainOut	811.88	(Correlated)	102.00	1531.00
TrucksIn	398706.91	(Correlated)	56407.00	740216.00
TrucksOut	397880.76	(Correlated)	56146.00	738780.00

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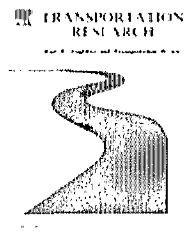

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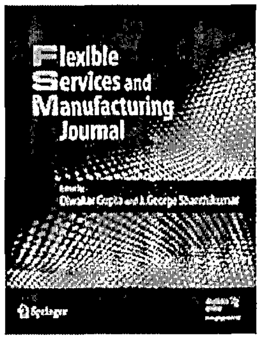

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Author: Matthew E. H. Petering

Publication: Flexible Services and Manufacturing Journal

Publisher: Springer

Date: Jan 1, 2013

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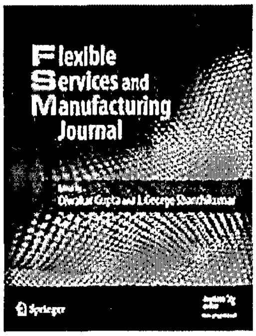

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