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Research on simulation of rational utilization of coal berths at Qingdao port

Fengming Yu

World Maritime University

Shanghai, China

Research on Simulation of Rational Utilization of Coal Berths at Qingdao Port

By

Yu Fengming

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no materials are included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

Yu Fengming

Supervised by

Professor Zong Beihua

World Maritime University

Abstract

Title of Research paper: **Research on Simulation of Rational Utilization of Coal Berths at Qingdao Port**

Degree: **MSC**

With the development of modern logistics concept, as the key node of supply chain coal ports not only face the fierce competition among ports, but also take a part in the competition among supply chains of coal transportation industry. Especially under global environment of fuel shortage, coal port is an important resource the supply of which lags behind the demand; therefore, the coal port is always the bottle-neck of coal transportation. Therefore, proposing a systematic method for evaluation of coal port capability is benefit to find the bottle-neck of logistics capability of the coal port, it also helps to improve the coal port logistics capability and encourage the rapid growth of coal logistics industry.

Coal port system is a very complex system. The formation of its capability has many aspects of restrictive factors, which should be analyzed in systematic and integral view. Based on a systematic and integral view, with the simulation software of ARENA the dissertation made a thorough study on the concept and the influencing factors of coal port berth system and established a simulation plate —— form for evaluation of coal port berth occupancy. This dissertation extended the research area of simulation and evaluation of coal port logistics capability, it mainly includes the follows:

Firstly, the dissertation systematically described the theory foundation and basic simulation theory of coal port logistics system; it also analyzed the composition and evaluation index of berth system. Coal port capability is defined as the comprehensive processing capabilities of logistics hardware resources under the production plan and scheduling management, it can also be considered to be the comprehensive capability of the visible factors of coal port logistics system including ships, trains, belt, shipping-machine, car-dumps, etc which is influenced by the invisible elements including ship scheduling, train scheduling, yard stacking strategies, service strategies, handling-device-state information, production scheduling strategy, personal management, etc.

Secondly，combined the characteristics of coal port logistics system, the dissertation put forward the application method and steps of the simulation and evaluation of logistics capability of coal port system. It described the basic thinking and method of building simulation model including the modeling method of conceptual model (conceptual model includes the hierarchical model, object model, dynamic model), and basic thinking of building the simulation model of coal port logistics system with the new software of Witness.

Lastly this dissertation took the Qianwan port of Qingdao coal port for application example to apply the method of the simulation and evaluation which has been put forward in the dissertation.

Through the simulation and evaluation of coal port berth allocation, it has found out the bottle-neck restricting coal port and provides reference for the development of the modern coal port industry.

This research work concerned in this dissertation will benefit the design and management of coal port.

Key words: Berth Occupancy, Simulation and Evaluation, ARENA, coal port,

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List of Abbreviations

FCFS	First-Come-First-Served
SBAP	Static Berth Allocation Problem
DBAP	Dynamic berth allocation problem
DEDS	Discrete event dynamic systems

1 Introduction

1.1 Background and Meanings

As the gradual development of economy and the increase trade between countries and regions, shipping industry has an unprecedented development. However, in practice the problems and contradictions emerge attendantly, such as the increase of phenomenon of the vessels waiting for berth, the port size both in new construction and renovation and expansion, and how to improve the port's services efficiency and service levels through scientific management and organization under existing equipment conditions. All of these raised higher requirements of research in port systems. This article is put forward under such a situation.

Port system is complex and their terminals are the center of port operations. Main scale of a port is embodied in the number of berths. Berth system is an important integral part of the port system as well as the core links of transportation, which is necessary to have systematic study. Berth systems involve many contents, which is difficult to use mathematical formulas to describe and solve. Systematic studies on the berth system have gone from a static analysis and calculation to the dynamic simulation. Now the accuracy of the calculation has increase and the theoretical study has gone more and more thorough. Berth system is a discrete, stochastic system. Practice has proved that simulation and optimization methods are more and more applied to the study of discrete and stochastic systems.

In China, the monopoly position of large coal ports in the northern part stays relatively stable. But with the development of modern logistics, now coal ports, as an important node in the supply chain, face not only the fierce competition between ports, but also the competition in the whole supply chain. The goals for the coal port construction are not only the "world's largest and most powerful", but rather a sustainable and fast development.

The throughput of coal port has connection with a number of factors, including ship size, transportation capacity, the number and time intervals ships arrival and other factors. Therefore, the actual capacity of the coal port has far from the original design. Through simulation study of the coal berths allocation, I can more in-depth, timely and effective analysis and optimize of the efficiency of the coal port, optimize the port resources and enhance the turnover of the port in order to establish a foundation to build a modern coal port.

1.2 Research Purpose

Through modeling and simulation analysis of the coal terminal berths system, this thesis hopes to achieve the following objectives:

(1)Through the systematic analysis of coal berths, simulation software will be applied to establish the simulation framework of berth allocation in order to guide the simulation programming of berths allocation.

(2)By application to establish a system simulation framework for the preparation of coal berths system simulation model and analysis of the program, the author is going to achieve the following two goals:

①Simulate and analysis of coal terminal in Qingdao port by application of the program, and analysis the pattern of the number and time intervals ships arrival.

②Evaluate berth evaluation index and analysis the existing arrangement of berth to identify problems and to modify, in order to optimize the berths allocation.

In this thesis, the author is trying to introduce Object-Oriented Analysis and simulation theory to optimize berth uses the Qingdao coal port. It can be said that studying on the coal berths simulation model has important theoretical significance and practical application value.

1.3 Research Methodology

Simulation is the imitation of some real thing, state of affairs, or process. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes.

The theory of simulation will be used in Chapter 2 to interpret which software to choose. Analysis of the evaluation index will be used in Chapter 3. In Chapter 4 and 5 the simulation model will be established and the data will be analyzed.

1.4 Content and Structure

Basing on a lot of literature of computer simulation on the design of coal port and the application of port management, this paper is going to make a number of principal researches as following:

(1) The systematic analysis for coal port. The author discussed the characteristics of coal port operation and the system constitutes, and analyzed the process of import and export and handling process model.

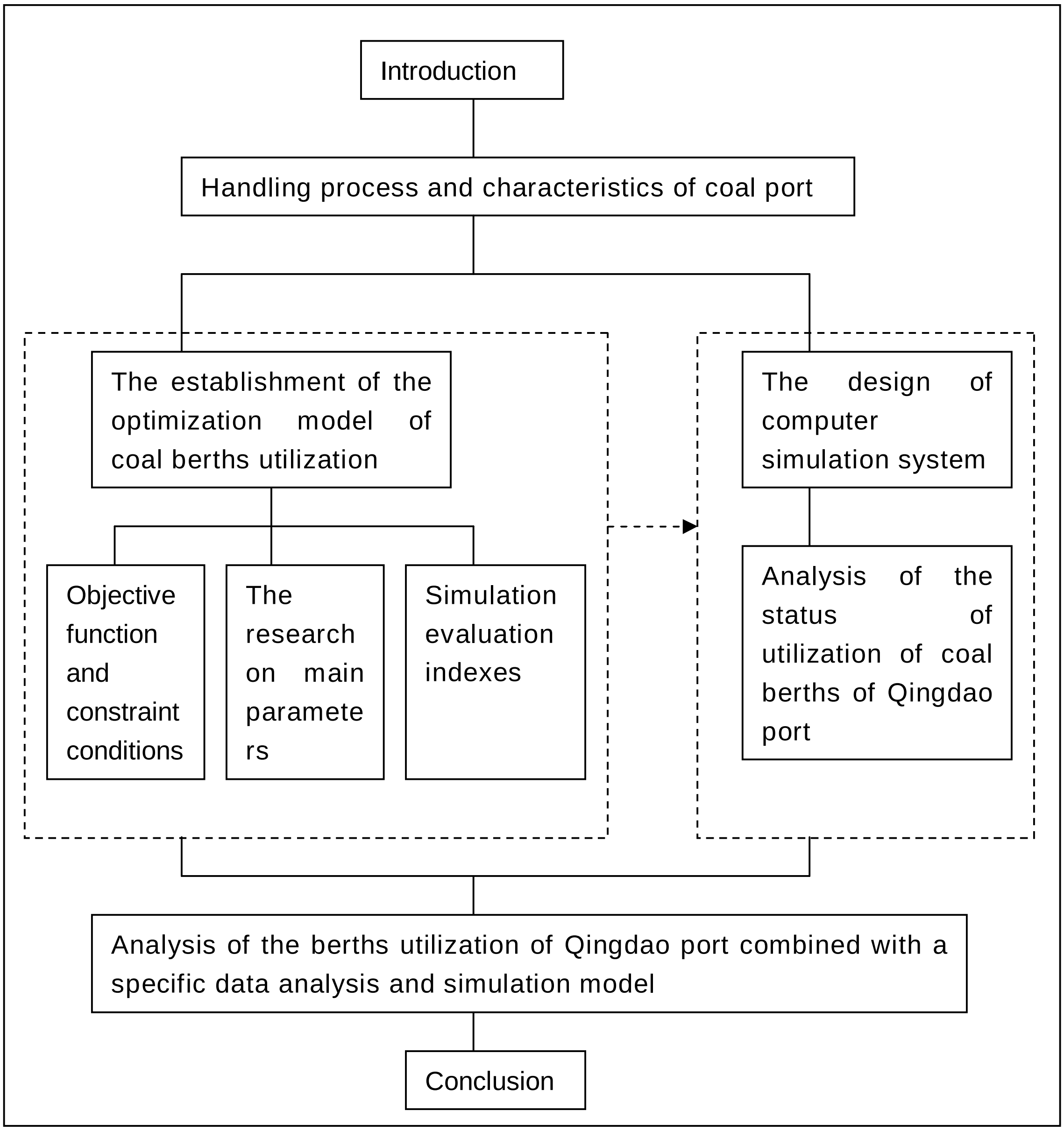
(2) Modeling of berths system of coal port. Combining queuing theory and computer modeling technique and using cycle queuing network theory, author made research on design of coal port berth system and allocation of machinery and equipment of the port, and set up corresponding computer simulation models.

(3) Berth system simulation of coal port. By the application of ARENA software, author carried on the simulation of the whole operation of coal port and the implementation of digital computer simulations.

(4) System planning. In the system planning, the author has completed the following key areas: ①In the case of certain distribution of ship arrival and cargo density of the ship (that is certain throughput of the port) to confirm the port scale for development (that is mainly the determination of the number of berths); ②Under the certain umber of berths, the study of reasonable allocation of mechanical equipment.

The structure of this thesis is as below:

Figure 1-1 The structure of this thesis


Introduction
Handling process and characteristics of coal port
The establishment of the optimization model of coal berths utilization
The design of computer simulation system
Objective function and constraint conditions
The research on main parameters
Simulation evaluation indexes
Analysis of the status of utilization of coal berths of Qingdao port
Analysis of the berths utilization of Qingdao port combined with a specific data analysis and simulation model
Conclusion

2 Basic Theory of System Simulation

2.1 Introduction

In this chapter, first the author will talk about the literature review of this thesis, and a brief introduction of the system and system simulation, the introduction of the ARENA software, and the most important one, the dispersion characteristics of the port system.

2.2 Literature Review

2.2.1 Berth allocation problem

With the rapid development of the shipping industry, berth allocation problem has aroused widespread concern and research.

Some foreign scholars have carried out large number of studies on the berth allocation problem, and also they raised a lot of theories and models. The considerable progress has been made, which began to apply to the actual terminal operations. From the view of description of the berth allocation problem, the existing theoretical research can be divided into two broad categories: discrete berth allocation and the continuous berth allocation.

(1) Overview on discrete berth allocation problem

E. D. Edmond and Maggs R.P. (1978)[1] first adopt queuing theory models to solve the port berth allocation and cargo handling problems. To improve berth utilization ratio of HIT terminal in Hong Kong as the goal, Lai, K.K.and Shih, K. (1992)[2] introduces the heuristic algorithms to solve the berth allocation. However, they use a First-Come-First-Served (FCFS) allocation strategy to allocate berths in terms of the right-to-port container. Brown, G. G. et al. (1994, 1997)[3][4] have studied static berth allocation in naval ports. They create the allocation model adopting mixed-integer programming and heuristic algorithms respectively, aiming for the maximum sum of benefits for ships while in port. Berth allocation in naval ports has substantial differences from berth planning in commercial ports. Based on the assumption that the ships arrived at port are the same, Chan, W. T. and Imai, A. (1996)[5] use heuristic algorithms to undertake a study on berth allocation. Imai, A et al. (1997) [6] have proposed static allocation model of container terminal berth. Their study assumes a static situation, where ships to be served for a planning horizon have all arrived at the port before the berth allocation planning process. They studied this Static Berth Allocation Problem (SBAP) to find a non-inferior solution while maximizing the berth performance and minimizing the dissatisfaction with the order of service. Based on the SBAP model of a container terminal, Imai, A et al. (2001)[7] proposed dynamic berth allocation problem (DBAP) model for the multi-water depth configuration. They established a DBAP model targeting the minimum time of the ships in port, adopting Lagrangian relaxation. Legato, P et al. (2001)[8] divided the coming ships into different levels to carry out berth allocation. What's more, they established simulation model to solve the problem. Kim, H. K et al (2003)[9] use mixed-integer model to describe the berth allocation problem. They apply the Simulated Annealing (SA) to seek the approximate optimal solution of the model, suggesting two heuristic algorithms based on the duration-of-stay of containers and the sub-gradient optimization. In order to solve the problems like large-scale container ships and limited length of quay, Imai, A et al. (2007)[10] create saw-toothed coastline model of berth allocation to meet the requirement of berthing large container vessels, thereby enhancing berth utilization. Kim and Moon (2003)[11] propose the establishment of a mixed-integer model to describe the berth allocation problem, and using simulated annealing obtained sub-optimal solution.

(2) Overview on continuous berth allocation problem

While in the above mentioned articles, the entire terminal space is divided into several berths and the allocation is planned based on the divided berth space. Under continuous berth allocation approach, ships are allowed to be served wherever the empty spaces are available to physically accommodate the ships.

Lim, A. (1998)[12] first used the concept of continuous rather than discrete berth allocation, and transformed berth allocation problem into two-dimensional packing problem with capacity restriction. He addressed a problem with the objective of minimizing the maximum amount of quay space used at any time with the assumption that once a ship is berthed, it will not be moved to any other place along the quay before it departs. He also assumes that every ship is berthed as soon as it arrives at the port. However, he did not consider the issues including loading conditions of the ships and customer satisfaction. On the other hand, Li et al. (1998)[13] solve the continuous berth allocation problem both for with and without the ship's movement restriction. Their objective is to minimize the total work time of the schedule. Guan et al. (2002)[14] developed a heuristic for this kind of problem with the objective that minimizes the total weighted completion time of ship services. They studied the berths arrangement along a straight line, and assume that each work require the same continuous berth.

In recent years, China has just begun to undertake studies on the berth allocation, mainly around the container terminal, and most studies are the expansion or application of foreign existing researches.

Zhang, Y. T. (2005)[15], based on the concept of discrete berth allocation, established a dynamic berth allocation model with the objective that minimize the total time of ships in port. He used the basic genetic algorithm and the virtual software to simulate berth allocation process. Han, X. L and Ding,Y. Z. (2006)[16], using backtracking algorithm, established a integer programming model both considering resource of berths and Quay cranes with the objective that minimize the Generalized time. Cai, Y., Zhang, Y. W. (2006)[17] point at the issues around container terminal berth allocation and Quay scheduling, establishing simulation optimization model to minimize the overall time of ships in port. This method uses genetic algorithm to generate and evaluate berth allocation, and through simulation models gains a distribution plan of berth and Quay cranes. On the other hand, Zhang, Y., Wang, S. M. (2007)[18] established the dynamic allocation model based on continuous coastline. Considering the impact that distribution of shore cranes affects the time of container handling process, they set up algorithms to determine the allocation of shore cranes and container handling time according to the rules. Through simulation method, they compared and analyzed dynamic discrete berths scheduling.

To sum up, we can see that the research on the berth allocation focused on container terminal. It has following three research directions:

①Compared with discrete berth allocation problem, continuous berth got more attention after being proposed.

②The allocation of berths and Quay cranes combined together to get both optimization.

③The berth allocation models of the above belong to the general model. With the gradual improvement, the researches will be refined classification.

2.2.2 Research method

Based on the theory of discrete event modeling system, Miao, M. et al (2006)[19] use one kind of simulation software, ARENA, to model and simulate container port handling process. They obtained the optimal loading and unloading process system by analyzing the simulation results. Wang, Y. H. et al (2007)[20], taking advantage of the visual simulation software, ARENA and the Arena 3Dplayer, establish simulation model of berth operating system. The model has the animation effects and interactive features, which can demonstrate the service process and interact with users. While Zhao, W. et al (2009)[21], using another kind of simulation software: WITNESS, carried on simulation on the entire container terminal logistics system, reflecting the terminal loading and unloading process. From the various results of operations they could determine the reliability of the model and the research conclusions, and then provide technical support and services on the actual operation and management of terminals.

2.2.3 Existing problems

(1) Researchers often compared the results obtained from simulation with empirical data, and constantly modify the simulation model in order to complete the simulation task. Since the majority of simulation programs use the enumeration method, this artificially reduces the feasible region of the optimal solution. But it is also difficult to take system modeling verification, validation and accreditation, which creates difficulties and doubts for the analysis of the models.

(2) The stochastic and complexity of port logistics system creates deviations between the optimization model and the actual situation, which caused disparity in theoretical study and practical application.

(3) Most articles are aimed at optimization and simulation of container terminal. Current researches focus on yard operation problem, crane scheduling problem, container stocking, ships arriving, transportation and other material flows.

Simulation model can be used to evaluate the berth allocation problem; however, as a test and validation tool, it can only evaluate a given design, not provide more assistant decision making function. Recently, simulation optimization method is proposed to overcome these limitations. Combining the simulation analysis and the optimal decision-making mechanism, the simulation optimization method cannot only enhance intelligent decision making of the simulation, but also build the complex system model easily that is more difficult by traditional optimization methods. In this paper, simulation optimization method for berth allocation problem in coal terminals is proposed. Meanwhile, methods to improve the computation efficiency of simulation optimization are designed. There are the difficulties but also the innovations in this research.

2.2.4 The introduction of discrete system theory on the simulation

Simulation is one kind of process that setting up a simulation models which can be operating on a computer and conducting experiments through reasonable abstract of the system which has been researched on.

Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviors of a selected physical or abstract system. Simulation can be used to show the eventual real effects of alternative conditions and courses of action.

Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes [22].

Essentially, one system is constituted by three factors, that is, the system, simulation models and trials. System is the principles of the question and the purpose of systems analysis. The trial is a means of solving the problem to get the result, while simulation model is the bridge connecting system and trials. A simulation model, which can be identified and running on computer, must be established if author wants to use computer to accomplish her simulation. Through analyzing the system, first the author should set up simulation model which describing behavioral regularities of the system, and then convert the model to a computer simulation program. Simulation process is the process to get the solution of simulation models. By simulation analysis can accurately hold the inherent laws of the systems. During n the simulation process, the following two areas are very important: one is to establish accurately simulation models and other is to get the right result.

The time in discrete events system is continuously changing, while the system status will be stimulated by random events, which will be changed in a certain time point.

2.2.5 Features of System Simulation

System simulation is not one kind of optimization[23]. Using the method of simulation to reflect objective reality correctly and veritably, which is an effective method to analysis and research, the advantages of simulation system can be represented in the following aspects:

(1) The expansibility of time. System simulations can complete the simulation on the practical operation of the system in certain time. The actual operation of system may be long but simulation can complete the process for a short time to get the results. Also the actual operating process may be very short, by simulation will enlarge the actual period of time, and the every detail change of system state could be investigated.

(2) Repeatability. System simulation is one kind of abstract of relationship between logical, quantity and even space in actual process. As a scientific experiment, the system simulation can be repeated many times, reproduce the actual operation of systems and the relationship between various parts in the system, and also get the accurate simulation results under the same conditions of simulation.

(3) Predictability. Designing simulation models reasonably, author can explore the system operation in different conditions and the degree of influence of the various factors by changing the parameter values or other simulating conditions. By changing the conditions of simulation, the author also can make optimizing plan through simulation process and final decisions.

(4) Economically. Through the system simulations, the author can carry on pre-judgment on the system which has not put into actual production to know its feasibility, reliability and whether it can achieve the desired results, and reduce the risks in the actual implementation.

(5) Advancement. System simulations can achieve the hypothesis which can hardly be achieved in practice or restricted by actual conditions. Such as in port operation, the hypothesis of the different conditions of the vessels arrival cannot be tested and verified by the restrictions of the actual operational requirement, which only can be received by the methods of simulation testing.

Cause these characteristics make system simulation a wide application.

System simulation, as a kind of scientific experiments and a powerful tool which lead people realize the objective world, has been widely used in production and research fields.

2.2.6 Introduction of Simulation Tool

Arena is one of the leading simulation tools in the world, with the characteristics like modeling methodology of flow chart, hierarchical model, widespread pattern of graphics, full simulation support and so on.

Customized simulation languages, such as GPSS, SIMSCRIPT, SLAM with the advantages of flexible modeling, cost a lot of time to study specific programming. Owing to certain grammatical rules, programme is complex and difficult to make mistakes. General process languages, such as VISUAL BASIC, C/C++, FORTRAN, are especially the same situation. Meanwhile, in recent years the general emulator is a good solution to change the complexity of the special simulation language and common language by using intuitive and typical operating such as graphical user interface, menus and dialog boxes which is mouse droved. It is simple and easy to use. During simulation, the programmer only needs to choose some elements to construct a simulation model, as such simulated modules, link them together, and run the simulation model. The visual images animation in the system will change with the model running. But at the same time, for the purpose of achieving the usable goal, the simulator goes from one extreme to the other to lose its modeling flexibility. Arena is a kind of software which has visual integration simulation environment. It integrated the advantages of general procedures language, simulation special language and emulator, and applied the system structure which is object-oriented and hierarchical. It combines the advantages of modeling ease and flexibility.

On the one hand, Arena provides the templates which can be choosing and alternate. These templates composed of animated simulation models and analysis modules, which can be used to build the model of a wide range.

To use and organize easily, modules have been classified into different classes of templates. Thus, through switching template, the programmer can get completely different modeling structure and ability. And also a model could be built by missing these different modules.

On the other hand, Arena keeps modeling flexible through complete system. The hierarchical structure in modeling of Arena is from bottom to the top with the rising modeling level. In the bottom, the available process such as VISUAL BASIC,C/C++、FORTRAN to build a model, is often used to meet special requirements of the complexity of the decision-making rules and external data choosing. Block and elements panel are composed by SIMAN modules, which can operate more flexible modeling. The general modules are the most commonly used during the modeling process. Arena modules are composed by general modules, support modules and transport modules. The standard version of Arena software consists of SIMAN modules, Arena modules and the general program of process template language. Modules of application solutions are some common templates created by System Modeling Company, such as modules used for advanced manufacturing, process reengineering, program control center and other industries. The application modules can be created by users fit for their own companies. Now users have set up modules including auto manufacturing industry, snack bar, forest inventory control and others. The professional edition of Arena consists of the standard edition and the modules created by the users.

During the construction process, all the required modules and codes could be acquired from above templates. What's more, regardless of the positions of the modules in the system, there is uniform visual user interface provided by Arena software. It is for easy use and flexibility of modeling.

Arena applied the method of process mapping, which means to establish a particular system when researching the entity flow in the system. Arena model is composed by the graphics which expressing processes. Through these processes entity could implement movement in the system.

In plain terms, establishing model in Arena software is that describing process by putting modules and linking them together in order to achieve the entity flow. This kind of model include unless one source module which bring entity into system and one or more receiver modules which lead entity leave the system.

2.3 Discrete Time System Simulation

2.3.1 The Basic Elements of Discrete System

The rules that the changes of physical quantities over time cannot be described by continuous functions, only can get the value at the discrete moment. This kind of system is known as discrete system.

Usually elements are called for the most basic institutions which composed a discrete system simulation model. After generalization and classification, the basic elements of discrete system simulation include entities, properties, events and activities, and time, etc. Entity is the basic elements described the system. Entities in discrete system can be divided into two categories: temporary entities and permanent entities.

Temporary entities are the one that only exist in a system for a period of time. Such entities come from outside of the system, pass through the system and finally leave. For instant, ship arrival is one kind of temporary entity, which reached the system follow certain rules and then departed from the system after loading and unloading. While permanent entities are the one that permanently reside in the system, such as berths and loading and unloading machines in the berth system. Permanent entities are the necessities to keep the system activities. Attributes are the characterization of the entities through the aspects such as species, quantity, states and so on.

Incidents would cause changes of system status, such as ship arriving and leaving, the beginning and end of the handing process in the berth system.

Activities in the discrete events system are usually used to show the process between two events which can be distinguished. It indicates the swift of the system status. For example, an activity is generated from ships arriving to berthing, which makes the system status (the queue of wait berth) changing. Another activity is generated from ships getting berthing to leaving, which makes the queue of wait berth reducing by one ship and/or makes the service counters (berths) from busy to vacancy.

Process is composed of several sequencing events and activities, which is used to describe the logical and sequential relationship between the events. For example, a process is generated from a ship reaching the port, after waiting on a queue and accepting service, to leaving the port.

2.3.2 The dispersion analysis of the port

Coal port system with closed yard is one kind of discrete event dynamic systems (DEDS) which has the characteristics of multicomponent, multilayered and more uncertainty. Port production operation system is composed of shipping operating system, terminal operating system, stocking system and cargo distribution and transportation system. These four systems can be viewed as the subsystems of the port production operation system. The ingredients of the handling process system include docks, anchorage grounds, handling equipments, stevedores, cargoes, and information. In these systems, several discrete events, not continuous variables, the play a decisive role in the system behavior process; cargo handling system complied the Man-made rules rather than the physic laws. Discrete events means the events or activities occurred in discrete points in DEDS. The moment on this occasion lies on the deepening process of the system. Vessels reached the port and vessels departure are some typical discrete events. In the DEDS of the terminal system, the occurrence of a discrete event drives the change of the system status, and also stimulates new discrete events according to the operating rules in the system in order to form the evolutionary processes of the system status.

For example, the event of train arrival will lead the changes of tipplers status and strike various handling and transportation machineries working, while the operation of the equipments will change the status of yard and approach belt.

On the other hand, the changes of yard status maybe bring the changes of ships berthing and the status of appearance belt, consequently further change the yard status. Right now the yard status may be influence the status of trains waiting in a queue and the approach belt. Events delivery and counterchanging persistently express the dynamic actions of the entire terminal logistics system. However, events changes are not inevitable, which based on the deepening level of the system behaviors and status necessarily. Obviously, in the evolution process of the dock status, the changing point of the status will show an asynchronous, and the evolution of system is up to the complex interaction between different discrete events.

2.3.3 The dispersion characteristics of the ports

The DEDS model of the coal port must base on the dispersion characteristics, including the following factors[24]:

(1) The discontinuous essence of the discrete events. The physical condition of the docks has inherent dispersion characteristics, such as the arrival of the trains and ships, and the working conditions of the roll-rooms. Of course, by adopting the method of successive approximation, successful analysis can be worked out under some circumstances, but could not avoid the discrete essence of the questions in any case.

(2) The continuous essence of most performance measurements. Despite of the discrete essence of the DEDS model of the coal port, the great majority of performance measurements in the analysis are regulated by the continuous variable, such as the terminal capacity, Vehicle waiting time, average stocking time of yard and so on. According to the definition, "time" is also a continuous variable.

(3) The fundamentality of the Probability. In the port logistic system, uncertainty elements (such as the disturbances, the arrival time and the malfunction of the equipments) are usually actual existence. Therefore, the modeling aiming at port system often has to gather a lot of data in order to make a probabilistic modeling.

(4) Multilayer. Coal port logistics system is a system with the characteristics of multicomponent and multilayered, which obviously exists gradability.

(5) Concurrency. Concurrency means that several events happen in the same time. It is mainly caused by the essence of DEDS and the complex relationship between the events.

In order to reach higher level on the dynamic controls of the terminal DEDS, a model must be established and adopted which is able to lead out the trends of the DEDS and the excessive processes of the coal port. Therefore, compare with the continuous variables dynamic system, the modeling and analysis of DEDS have much difference no matter on the integrity or on the unity.

On the modeling and analysis of the coal port, the author must fully consider the inherent dispersion characteristic of the above system, which makes more accurately response of the port reality. And that is the difficulties of modeling and analysis in DEDS.

Summary

In this chapter, the basic theory of system simulation has been briefly introduced. Port segmentation is a complex system which is also a discrete random queuing system, using the simulation analysis to solve port system is a kind of effective method.

3 The Establishment of the Simulation Model about Berths Assignment

3.1 Introduction

Around the berth allocation problem， a lot of researches have been done by both domestic and foreign scholars, including Imai et al who have carried on systemic researches on the optimization of berth allocation, put forward the Static Berth Allocation Problem (SBAP) of the discrete berths and Dynamic Berth Allocation Problem (DBAP), and also the optimization of the consecutive berth allocation problem and the different solutions.

The aim of simulation is that actualizing the nature of activities or systems under the not existing situation in the actual system. Through the above research of the handling process of the berth system and the statistical analysis of the relevant data, theoretical basis was provided for the development of the simulation model of the berth system.

In this chapter, a simulation model will be established under the ARENA simulation platform, which lays the foundation for the final experiment of simulation model experiment and the data analysis.

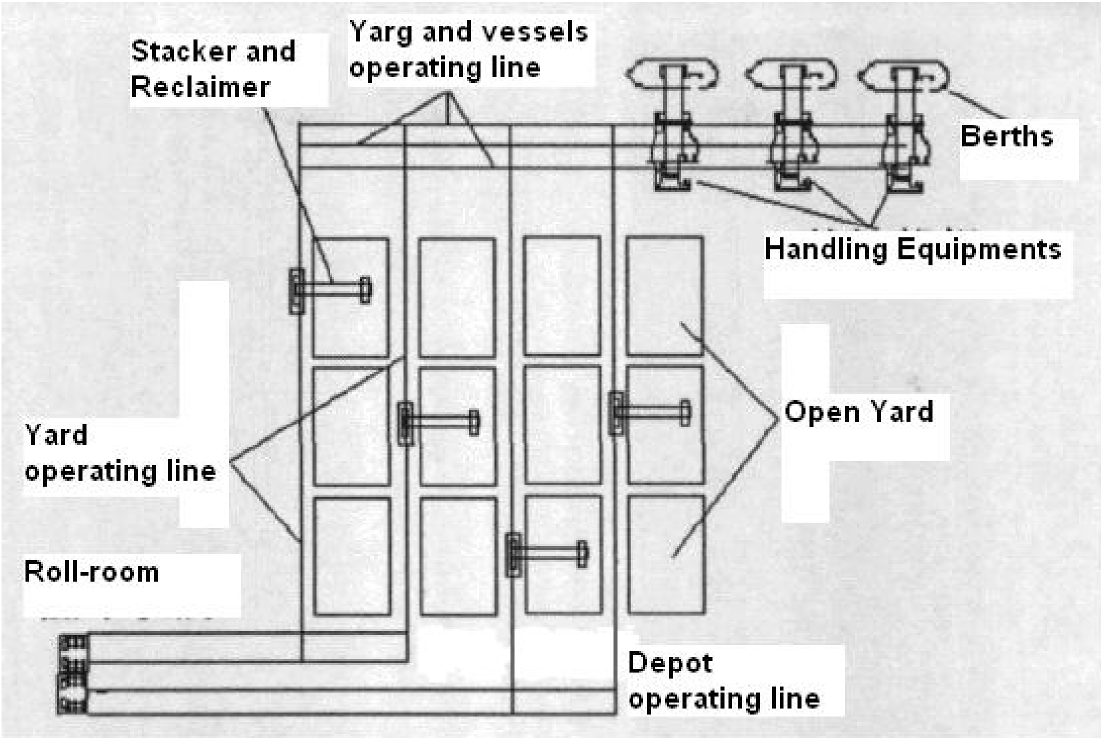
3.2 The basic elements of the coal port system

3.2.1 Infrastructure and Equipment Configuration of the Terminal Operation

The handling process in the coal port plays a determinate part on the allocation of handling machinery in the port logistics system, the process organizations of handling, the labor quota and labor productivity[25]. The integrated assessment of the economic benefits in the terminal is also based on the operating effects of the coal port production process.

Modern coal port is a complicated system. Different types of the dock have big differences not only in basic infrastructures and equipment configuration but also in the combined technological level of operating process. Therefore, the logistics capacities of the coal port system are varied. The traditional coal port use open yard to stock store coal (as Figure 3-1). Such conventional design has perfect technology and relatively few initial investments[26].

Figure 3-1 The basic traditional components of coal port



Berth is the term used in ports and harbors to define a specific location where a vessel may be berthed, usually for the purposes of loading and unloading. Most berths will be alongside a quay or a jetty (large ports) or pontoons (small harbors and marinas). Berths are either general or specific to the types of vessel that use them in the process. The size of the berths varies from 5-10m for a small boat in a marina to over 400m for the largest tankers.

Apron is a part of terminal area that from the quay line alongside the pier to the yard.

Coal yard, the area where stock coal, is the hub of the whole coal port. When export, the coal have been transported to the yard in advance by trains through the approach yard system in order to wait for the ship arrival. While import, the coal have been transported from the ships to the yard by transportation equipments in order to wait cargo distribution to every customer.

Rail transportation system, mainly used for coal evacuation and collection for inland, is an important component of the coal port transportation system.

Transfer tower is an important device which link with belt conveyer corridor transportation in the coal export. Within the tower, coal has been transported to the tower top in a certain speed by belt conveyer, and then partial ship to the tower bottom.

Roll-room can take on handling arriving trains, and tipping two or three cars every operation.

The main handling equipments in the coal port include stacker and reclaimer, tippler, belt conveyer, ship loading cranes and so on.

3.2.2 The handling Operation Process on the Coal Port

The main function of a coal port is to transfer and storage coal, which mainly based on the implementation of the unit functions (such as the trains, belt conveyer, ships in transfer unit, the yard in the storage units) and the actual situation of the port. The different needs of trade lead different logistics functions of the coal port. So according to the different beginnings and endings of the coal in the logistic activities of the coal port, the operating process mainly consists of three parts: yard-vehicle operation, yard-ship operation and direct loading operation[27].

(1) Yard-vehicle operation

The operation process is the coal transportation process between vehicles and the yard, including approach unloading process and appearance loading process. These two sub-processes share the same transportation equipment, therefore it is important to coordinate the assignment of the operations through rational management in order to improve the throughout of the whole port.

(2) Yard-ship operation

The operation process is the coal material handling process between ships and the yard, including appearance shipment process and approach loading process. These two processes also occupy the same equipment, if there cannot be effective coordination between loading and unloading processes, the capacity of the port will be affected.

(3) Direct loading operation

Through effective management, the yard-train operation and yard-ship operation could meet the smooth operation of the whole coal port. To further enhance the rapid reaction capability of the port and reduce the costs, direct loading operation usually will be increased. The advantage of this process is that no need to stock coal in the yard and saving the stockpiling costs. But it takes the resources of both loading and unloading, superadded the different work efficiency of the handling equipments, the efficiency bottleneck of the machineries will easily be produce, which result in the low working efficiency of the whole port.

The process of direct loading operation includes ship-ship direct loading operation and ship-vehicle direct loading operation. The former one means that when the cargoes have been unloaded then transported directly to another berth for shipment trough conveyer equipment, and not need access to and get out the yard. This is also called the loading and unloading ship process.

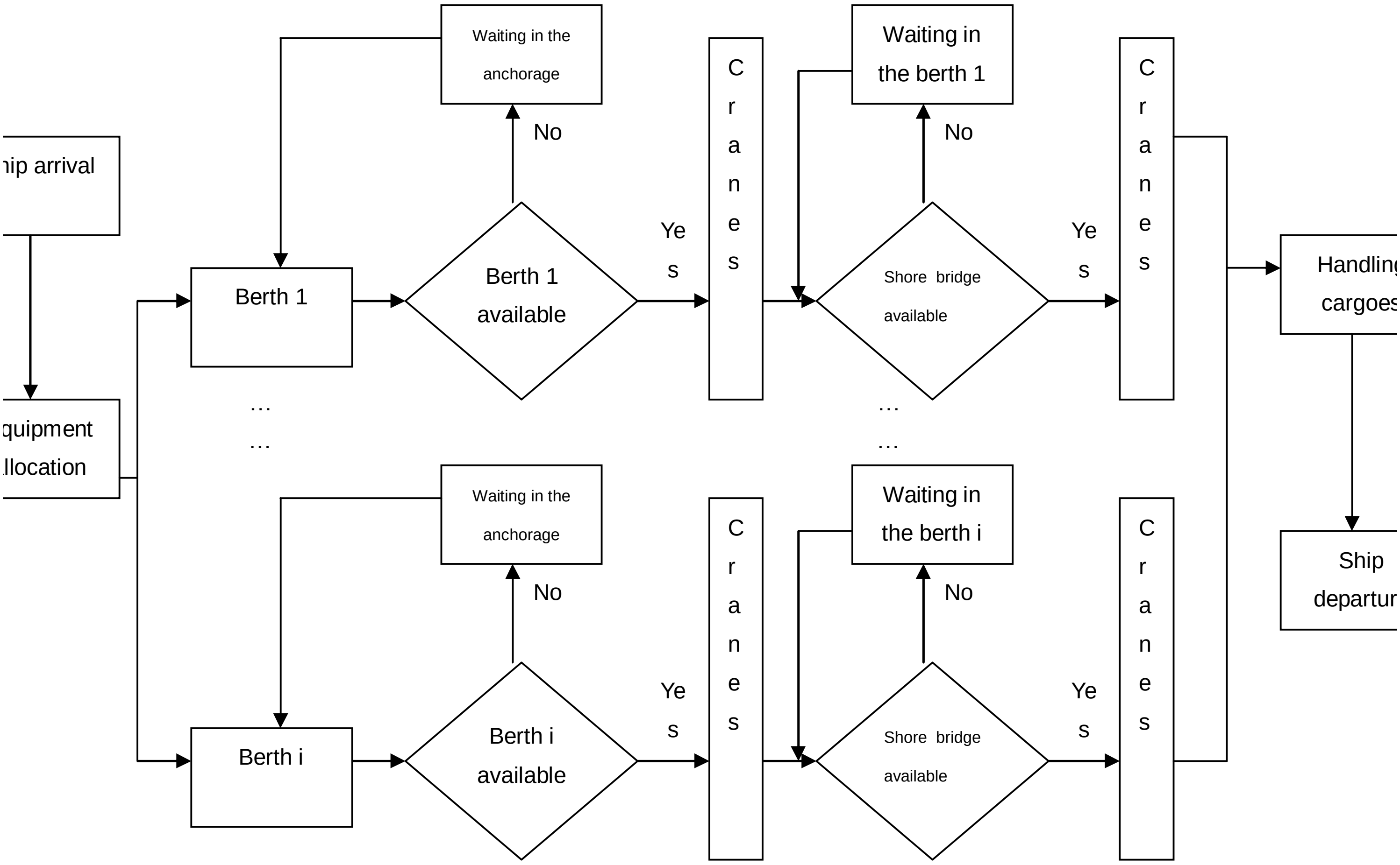
The process of ship-vehicle direct loading operation can be divided into two parts. When export, belt conveyor links with the shipping line, letting coal material transport directly to the frontier ships after tippler, which need not go through the yard. This is called the export ship-vehicle direct loading process. While import, coal could be directly unloaded from the ship and loaded into the truck by transmitting machineries, without going through the yard.

3.3 Problem Description

The optimized configuration of berth system means that through the reasonable allocation to ship berthing for the arriving ships and choose appropriate berthing sequence, the efficiency of port operations could be improved, consequently attracting more ship calling the port. In the last chapter, a detailed introduction has been done on the characteristics and process of the berth system, which laid a foundation for establishing an effective mathematical model[28].

Usually after or before a vessel arriving in the harbor, according to relevant information and optimizing strategy the terminal manager will allocate the berth to every ship and several handling equipments serviced for the berthing ship. Figure 3-2 presents the flowing chart/flowing chart of process from ships arrival, getting berthing, handling, to departure finally.

Figure 3-2 The operation process of the ship in the harbor



The main simulation aims in this thesis are to determine the reasonable amount of the berths of the coal port under the environment of certain throughput. Therefore, author only need make statistics of the berth occupancy and the time Ships waiting in queue to determine the reasonable number of berths in the circumstance of certain throughput according to the simplified model. Thus, the simulation model has been simplified as follows: without consideration the utilization of the yard and the allocation of the handling machineries near the berth and in the yard, regarding the combination of handling machineries and yard as an ideal condition. The description of this berth system is as below: the ships enter into the system in accordance with certain rules, and then get into the outer harbor basin; after meeting the conditions, ships enter into interior basin waiting in a queue and calculate the waiting time at this time; according to the berth occupancy, the ships are arranged to get berthing and statistics for the utilization of the berth; after the handling operation, ships leave the berth, and disappear from the system.

3.4 The Objective Function, Frontier, and Assumptions of the Model

Minimizing the comprehensive cost could use queuing theory to solve. In this thesis, the objective of the model is minimizing the total cost of the whole process of the cargo transportation, and establishing the objective function of minimizing the average cost of each day. The factors need to be considered including: the comprehensive investment of the docks, harbor basin and the handling equipments of each berth, the cost of the port and the expenses for ships daily mooring in the port[29].

According to the conditions which should be satisfied when comprehensive cost is minimized, the author could deduce that the relationships between the changes of queue length for ships waiting and the various cost index and view it as the optimal conditions of the number of berths.

Based on the analysis of the composition of the comprehensive expenses, comprehensive cost consists of two parts: one is the investments of the berths and corresponding facilities, the construction and operation of the equipment; secondly, the time value of the ship in port including loading and unloading time, stay in port, waiting berth time, the piloting time and the impact of the natural conditions to the handling time. All the expenses are expressed by unit cost multiplied by the corresponding value[30].

$$C_s = C_{ct} + C_{ap} + C_{bs}$$

C_s : Integral cost

C_{ct} : Construction and operation cost of the berths

C_{ap} : Construction cost of other facilities to attach to the berths

C_{bs} : Berth staying at berth time cost

$$C_{bs} = C_{wk} + C_{wt} + C_{bd} + C_{bo}$$

C_{wk} : Loading and unloading time cost

C_{wt} : Waiting time cost

C_{bd} : The time cost for ship getting alongside and unberthing

C_{bo} : Other time cost

Above all, the simulation model of this thesis is an operating simulation model of the berth system. The simulation purposes include the following aspects. (1) The actual operating process could be reproduced. (2) By simulation study investigates the quantity relationship between input and output data. (3) Certain processes could have potential impact on the actual operation, which is difficult to achieve. By changing conditions, a good conclusion could be worked out in the simulation.

The time in the coal port berth system is divided into processing time, queue time, etc. The simulation model should define model elements distinctly and legibly as follows: the existing resources, flow entities such as vessels or vehicles, processes, the routing control, and service time.

The frontier of the port berths system is the whole process from ships arrival to departure. Many factors should be considered, including port hardware aspect (such as quantity of different types of unloading machineries, configuration of handling equipments, etc), production organization management aspect (which refers to principle of the sequence of the ship arrival and the arrangements of berth allocation), weather factor, pilotage duration and other factors. All of these draw great impacts on the simulation index including the cycle stage of ships in port, the relationships between different vessels, the Berth usage and so on[31].

In this simulation model, one type of berths and one type of the ships have been designed.

Considering the position of the berths system in the port system, the normal operation of port system is inseparable with the coordination of other systems. Therefore assumptions have been established ad follows：

(1) The time of vessel loading and unloading has relations with the deadweight capacity and handling machinery efficiency. In other words, assuming that the ship has an ideal load, the handling operation time will not be affected by the factors of port collection and transmission system and the yard system.

(2) The value of berth number does not consider the restraints of length of shoreline. The length of the berths is determined by the summation of the length of the largest tonnage ship and the safety buffer distance.

(3) Every ship must and can only berth for one time, without considering the case of ships shifting after getting berth.

(4) Each berth can only service a ship.

3.5 Random Variable

Random events and random variable are the indispensible concepts in the discrete events system. In the handling process system of coal port, there are several random variables which obey a certain distribution, including the time Interval of ship arrival, the deadweight, the service time of various machines and equipments and so on[32]. In the establishment of a simulation model, these random variables should be produced or obtained by certain method.

This thesis studies on the utilization of coal port. Therefore it is necessary to have an analysis on the form of the turnaround of a ship before establishing the model, and illuminate the objective function involved in the time limits of the ship in port.

In the actual process, the turnaround of a ship is consist by operative lay-time, non-operative lay-time and the time at anchorage caused by physical factor. In this thesis, author only consider the operative lay-time.

Operative lay-time means that the necessary time at anchorage in the transport process, which could be further divided into handling process time, technology time, and the shifting time.

(1) Handling process time

Time for loading and unloading cargo includes the time for preparation and ending of opening cargo hold and closing cargo hatch cover, loading and unloading time and subsidiary operation time.

(2) Technology time

Technical time is consisted of ship going alongside and unberthing, the fleet organizing and disbanding of the towboat transport ships.

(3) Shifting time

Shifting time means that the elapsed time for a ship shift from one berth to another due to the handling plan or the restraints of ports own conditions.

3.6 The Determination of the Simulation Elements of the Optimization Model of the Berth Allocation

3.6.1 The Sequence Attributes of the Arriving Ships

Actually, the attributes of the ships relevant to the berth system should be considered mainly from the following several aspects: the size and structure of the hull, the deadweight, the actual handling amount (cargo loading capacity and unloading capacity), ship's mooring conditions, the position of the cargo palletizing on the ship, etc[33].

But according to the simulation purposes, a reasonable abstraction about the sequence attribute of ship arriving has been made, and has been described as following two aspects: ship types (divided by tonnage) and the interval distribution of the arrival time of each type of ship. The arrival time and the interval are described in terms of probability distribution.

In the actual analysis of the port system, it is necessary to make clear mathematical statistics and analysis to the practical data of the interval of ship arrival and also make proceed fitting and inspection. In the following example, the author adopts the actual data of the Qingdao port from October to December in the year 2009 to analysis and simulation.

3.6.2 Berth Attributes

Description for berth attributes could be divided into berth ability (distinguished by the berth name) and the state parameters of berth (divided into two kinds: leisure and busy).

3.6.3 Attributes of Handling Machineries

In order to simplify the design process, the handling machineries of the coal terminal have been simplified in this thesis[34]. The attributes of handling machineries could be described from two aspects, including mechanical quantity and mechanical efficiency. In this thesis, the number of handling machines of each berth is fixed, while the handling efficiency has different values in order to observe the change of the objective function.

3.7 Simulation Evaluation Indexes of Berth Allocation

To verify reliability of the model and to evaluate the simulation system through the model running, a unified standard is needed. According to the objective of the simulation model, main performance parameters are defined as follows[35]:

(1) Berth occupancy

Berth occupancy is one indicator reflecting the berth usage, which is determined by integrated information about the density of ship arrival, the handling capacity of front loading and unloading system and the scheduling of vessel approach and berthing. It is the indicator which reflects the degree of occupation of the berths[36].

Calculation formula:

Berth occupancy (%) = (Berths occupied hours / Calendar berths hours) x100%

The occupied time accords to the fixed number of berths. In the research of this thesis, the calculation berths utilization means the ratio of the time berth occupied to the length of simulation time. If it is too high, it may mean a mechanical handling capacity failure of machineries, or it might be too much vessels or other factors, which need specific analysis.

(2) The average time for waiting berth

If the combination of the grading berth has only one kind, the average time for waiting berth refers to the sum of the waiting berth time of all ships waiting in queue divided by the quantity of the ships.

(3) The average number of ships queuing

The concept of the average number of ships queuing means that the average statistics of the number of ships waiting for service at intervals of certain simulation time.

The average number of ships queuing = the number of ships waiting / the total number of ships arrival

(4) The time Ships waiting in queue

After the ship arriving, if there is any free berth, the ship could immediately get berthing after all the procedure, and leave the harbor after the service of loading and unloading. While if the berth was busy, the ship should wait in the harbor anchorage, and get berthing in order. Therefore, the time Ships waiting in queue was produced.

(5) Throughout capacity of the berth system

It is divided into two parts: design value and actual value. The previous one is determined by the cargo types and ship types. The improvement of the throughout capacity depends not only on the mechanical quantity and mechanical efficiency, but also on the coordinate operation between every relevant subsystem in the whole logistics chain, including frontier transportation system and stockpiling system. Therefore, the desired effect and the ideal state could be produced.

According to the simulation objective, the author can choose the related parameters to make the statistical data, reflected by the pie chart, histogram or time sequence diagram, which provides basis in the analysis. This thesis will select the above parameters as the basis of berths system of the coal port.

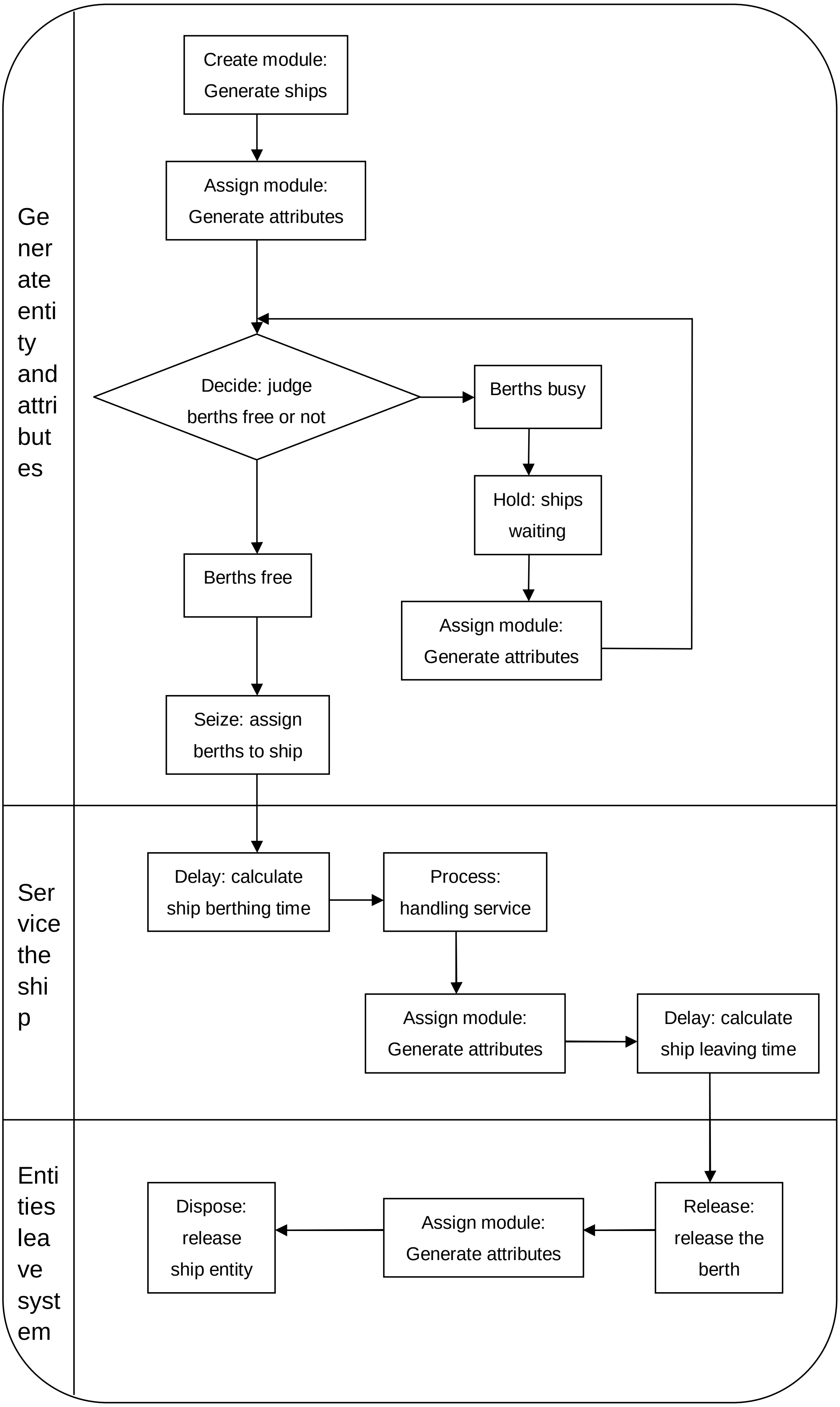
3.8 System Simulation Process

In this thesis, the simulation model is established based on the queuing theory of the discrete event system[37]. At the initial state of the simulation model, all of the berths are leisure. That is, at the initial state, there is no ship in the port. At the beginning period of model running, there are only arriving ships without departures. In this way, after a period time of running, the ships in the port could reach the balance state, and the operating parameters of the port are basic stability.

3.8.1 Module Processes of the Model

Model module chart is shown as figure 3-3.

Figure 3-3 Model module chart


Generate entity and attributes
Create module: Generate ships
Assign module: Generate attributes
Decide: judge berths free or not
Berths busy
Hold: ships waiting
Assign module: Generate attributes
Berths free
Seize: assign berths to ship
Service the ship
Delay: calculate ship berthing time
Process: handling service
Assign module: Generate attributes
Delay: calculate ship leaving time
Entities leave system
Release: release the berth
Assign module: Generate attributes
Dispose: release ship entity

3.8.2 Introduction of the Variables in Simulation Model

Table 3-1 Model Variables

Serial number	Variables	Comments
1	Ship	The attributes of the entities
2	Queue	Set up the queue for entities
3	Berth Num	The serial number of berths, used for statistical data module

3.8.3 Input Parameters of the Simulation Model

The initialization parameters of simulation model mainly include the time distribution of the ship arrival, ship deadweight distribution, the distribution of operation speed and services time, etc[38]. Specific input parameters are shown as table 4.2:

Table 3-2 Input Parameters

Serial number	Data item	Comments
1	Distribution of the ship arrival	Input in the create module
2	Ship deadweight distribution	Setup in the assign module
3	Machine handling efficiency	Setup in the assign module
4	Time for ship alongside and unberthing	Setup in the assign module
5	Berth number	Setup in the set module

3.8.4 Detailed Design of Simulation Model

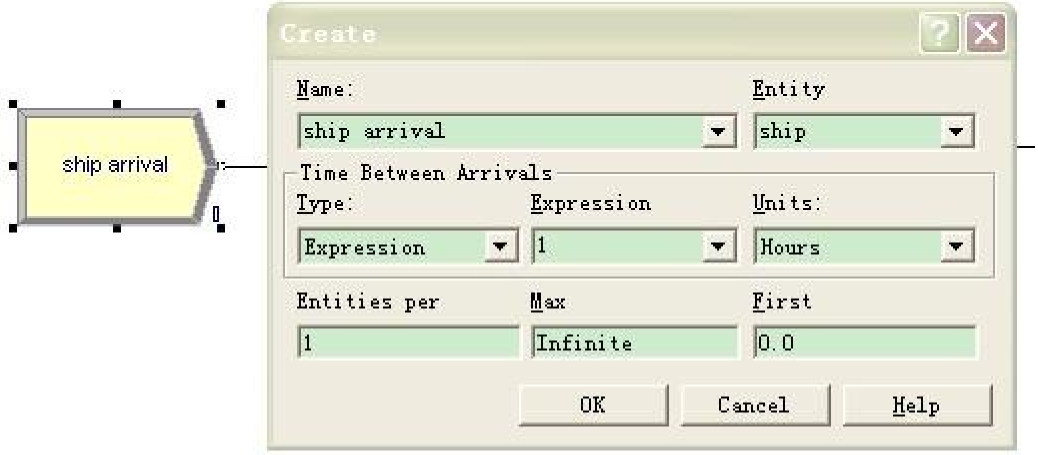
Simulation model is divided into three service modules, respectively (1) Generate entities and attributes, (2) Service the ships, (3) Entities leave system, end.

（1）Generate entities and attributes

The logical module and Settings of parameters of this part are as follows:

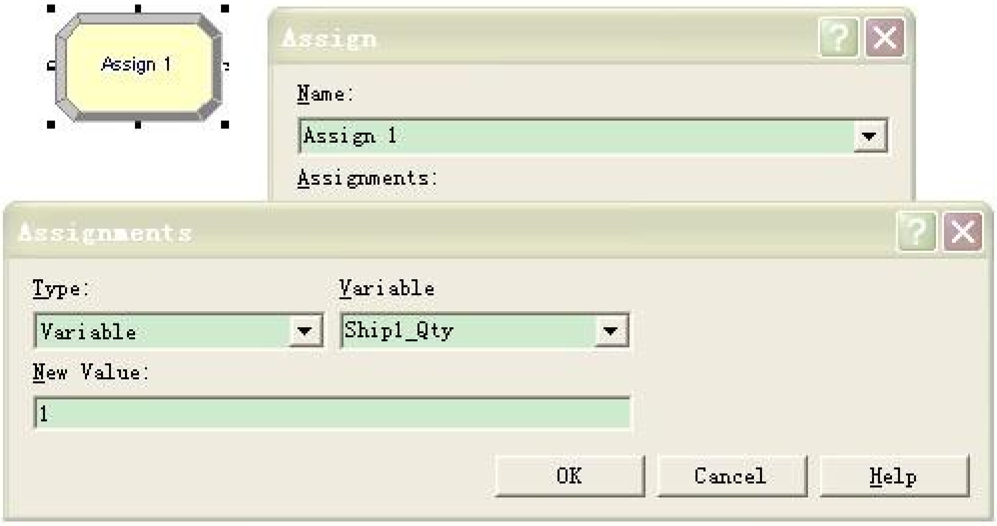
①Create module: generate the arriving ships, the distribution is decided by the actual data, the unit is hour.

Figure 3-4 Create module setting



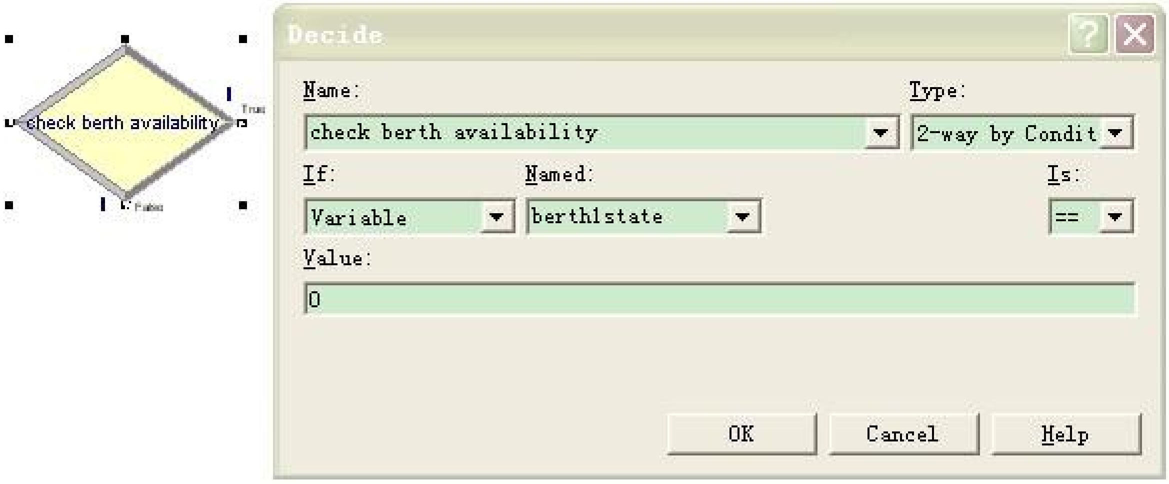
② Assign module: distribute attributes to different entities; give a value assignment to the variable "Ship1_Qty" in the model, whose significance is distribution of the ship deadweight.

Figure 3-5 Assign module setting



③Decide module：The author needs to check the availability of a berth. By defining the variable for berth availability as "Berth1State", the author checks the condition of berth as follows: if a variable "Berth1State"is 0, which means a berth is available, then continue to next stage assign module. Otherwise, if a variable “Berth1State”is 1, go on to next stage hold module which is a queue mode.

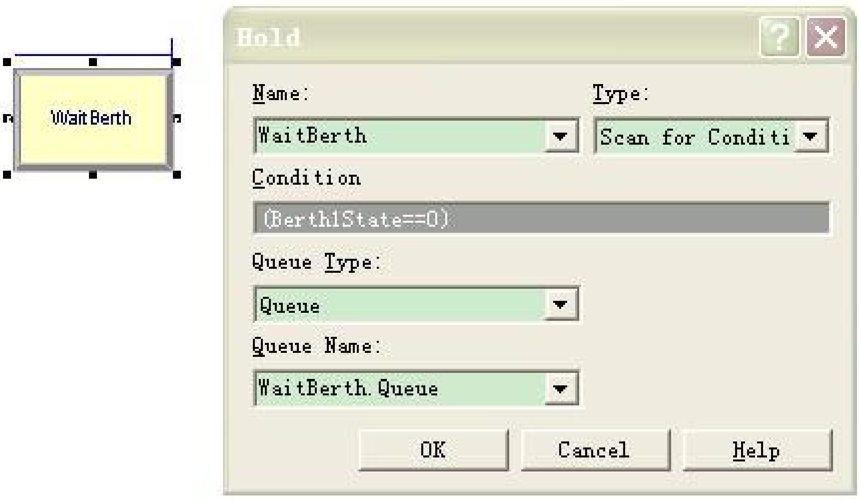
Figure 3-6 Decide module setting



④Hold module：This hold module will hold an entity in a queue to either wait for a signal, wait for a specified condition to become true or be held infinitely.

This module checks the condition of berth with the type of “scan for condition” and holds an entity in the queue until is satisfy the condition such as “Berth1State==0”, which means that the berth will be available for the ship which is waiting. In terms of “Queue Type”, this Hold module should select “Queue” with the “Queue Name” of “WaitBerth. Queue”.

Figure 3-7 Hold module setting



⑤Assign module: the author needs to assign some variables, including the total number of ship entering the model, the ship waiting time and the average number of ship waiting in the queue.

The total number of ship arrival define as EntitiesIn(ship).

And the formation of ship waiting time is:

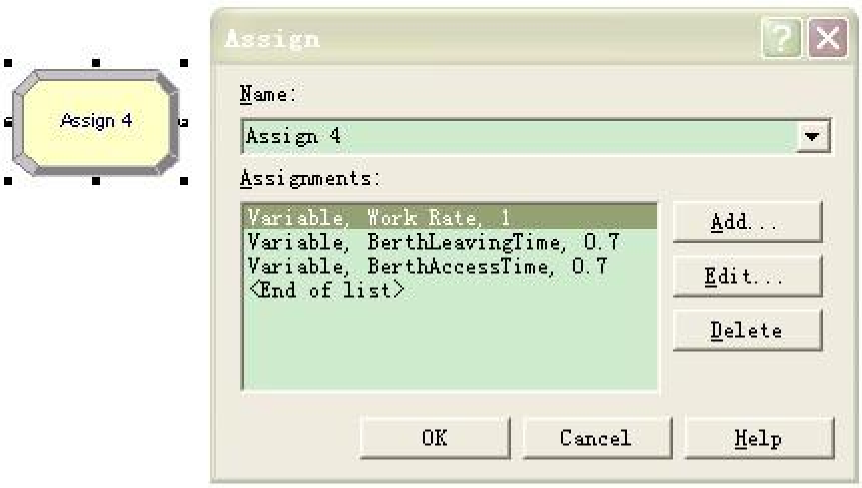
Ship_Queue_TAVG = TAVG(WaitBerth.Queue.WaitingTime)

The formation of average number of ship waiting in the queue is as follow:

AvgShipWaitNo = DAVG(WaitBerth.Queue.NumberInQueue)

In another Assign module, handling mechanical efficiency rate has been set and defined as Work Rate whose specific values will be decided in the next chapter in the actual simulation in the next chapter, and the unit is Ton/Hour. In addition, there is the ships get alongside and unberth time, which is BerthAccessTime and BerthLeavingTime respectively, and the unit is Hour.

Figure 3-8 Assign module setting



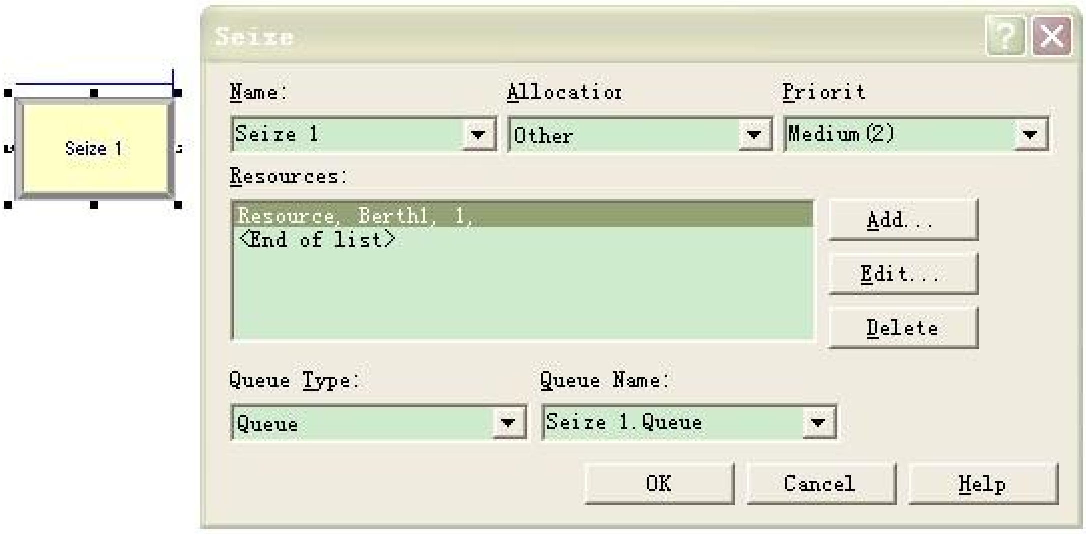
⑥Seize module：This module allocates units of one or more resources to an entity. This may be used to seize units of a particular resource, a member of a resource set, or a resource as defined by an alternative method, such as an attribute or expression.

In this model, one resource of “Berth1” is allocated to an entity of “ship”.

When an entity “ship” enters this module, it waits in a queue until all specified resources are available simultaneously.

Seize module is accompanied by “Queue Type” with a name of “Queue Name”: “Seize 1. Queue”.

Figure 3-9 Seize module setting



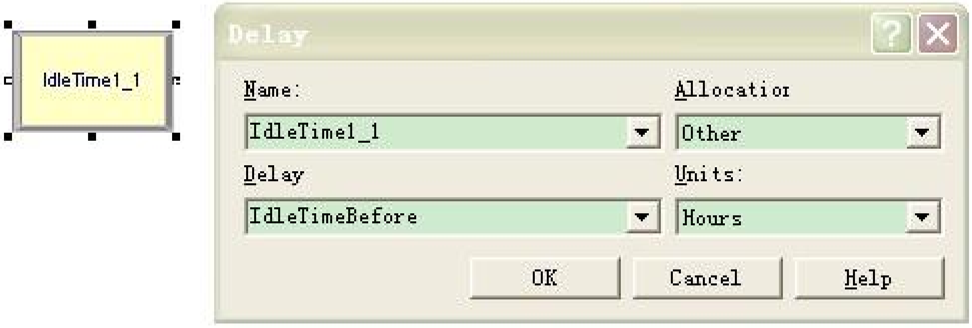
（2）Ships receive services

The logical module and Settings of parameters of this part are as follows:

①Delay module：it delays an entity by a specified amount of time. When an entity arrives at a Delay module, the time delay expression is evaluated and the entity remains in the module for the resulting time period. The time is then allocated to the entity’s value added, non-value added, transfer, wait or other time.

Arranging the handling operations, there is a preparation before loading and unloading and the reorganization after handling, which will consumes time. Therefore, there is a definition of a time delay, defined as IdleTimeBefore and IdleTimeAfter respectively.

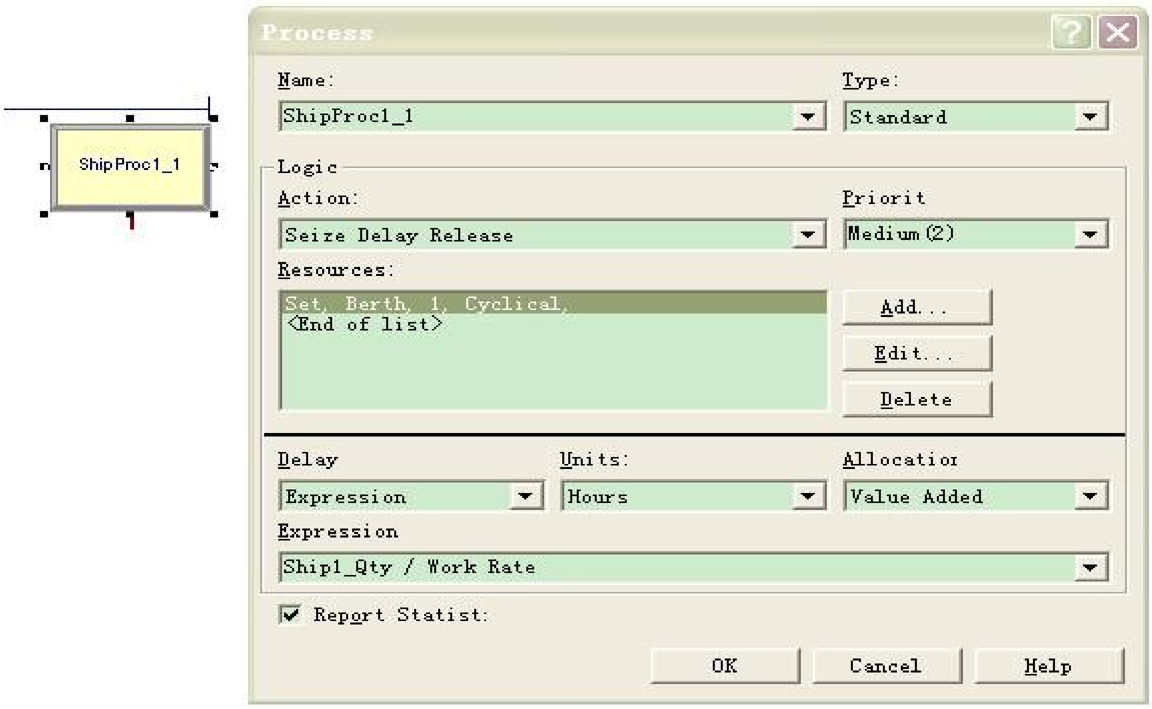
Figure 3-10 Delay module setting



②Process module: is intended as the main processing method in the simulation. Options for seizing and releasing resource constraints are available.

In this module, the handling machineries provide service, and defining the service time. The loading and unloading machineries of each berth is fixed, the berths are defined as a “Set”. The detail amount of berths will be set in the actual simulation in the next chapter. Service time is a variable. While the ship deadweight “Ship1_Qty” and the handling efficiency “Work Rate” are defined in the former Assign module. Therefore, the formation of service time delay is defined as Ship1_Qty / Work Rate.

Figure 3-11 Process module setting



（3）Entities leave system

The logical module and Settings of parameters of this part are as follows:

① Release module: is used to release units of a resource that an entity previously has seized. When the entity enters the release module, it gives up control of the specified resources. Any entities waiting in queues for those resources will gain control of the resources immediately.

After handling operation, the berth was released.

②Assign module: In this module the indexes which need to consider in the simulation model are set, such as the berth occupancy, whose formulation is as below:

Berth_Occupancy=(ShipProcVATime1+((IdleTimeBefore+IdleTimeAfter)* VarShipProc1))/MAX(0.001,(DaysToBaseTime(TNOW)*24))

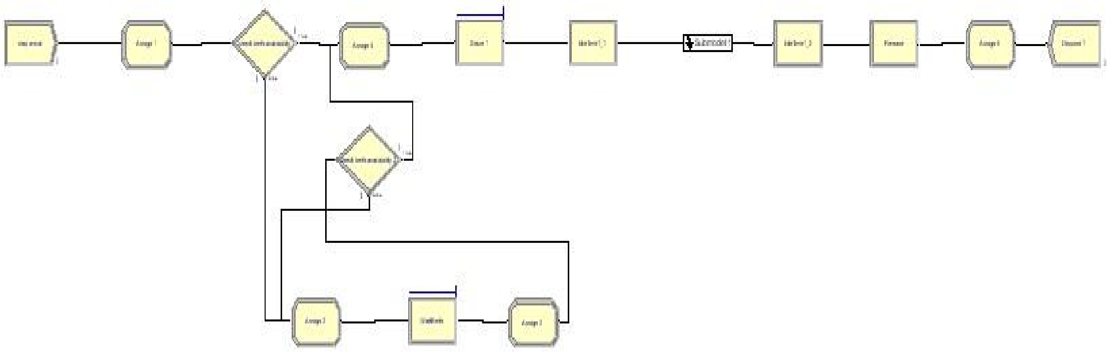
Among this formula, the numerator means the busy time within the simulation period of time, while the denominator means the whole time of the simulation.

③Dispose module: is intended as the ending point for entities in a simulation model. Entity statistics may be recorded before the entity is disposed.

In this module, the entity “ship” has leaved the simulation system.

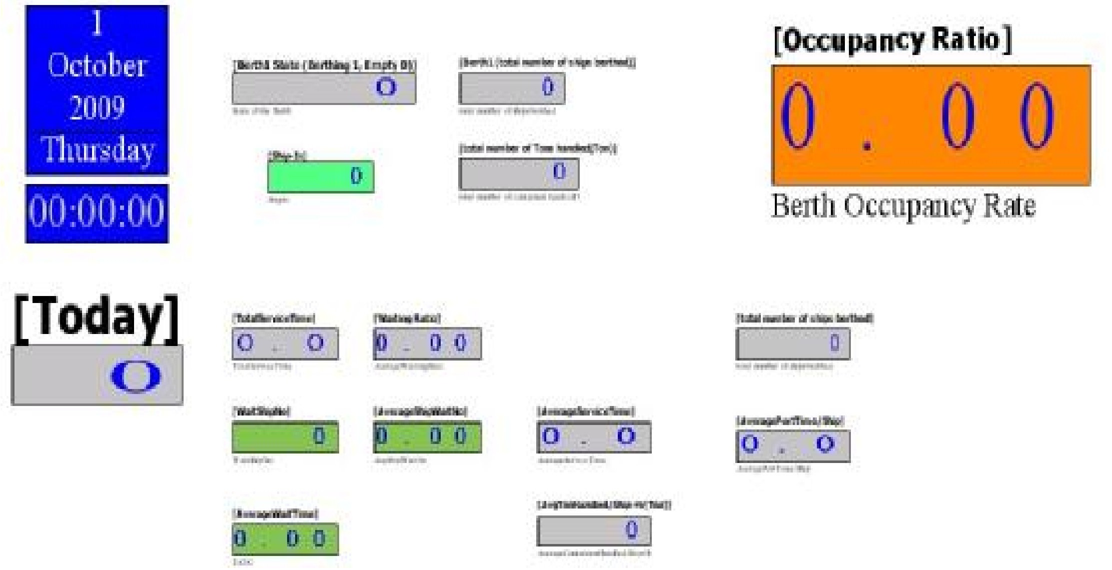
The logical chart of the model is as below:

Figure 3-12 The logical chart



Finally, in order to output the variables and the evaluation index during or after the system running, some data statistic modules have been defined in the model, which are specific settings as shown in figure 3-13:

Figure 3-13 Data statistic module



3.9 The Feasibility Test of the Simulation Model

3.9.1 Modifying the Simulation Model

After establishing the simulation model, the program and model commissioning should be progressed repeatedly, in order to verify the model accuracy and reliability[39]. The main aims of Model testing are to test whether the model correctly reflect the relationship between the operation process in the coal terminal system, and to eliminate the error as possible.

The errors in the simulation model mainly come from the simplification and the hypothesis of the model. Firstly, in order to achieve the establishment of simulation model under certain conditions, simplified simulation model is inevitable. This simplifying could lead to the unsatisfactory accuracy of model to solve the problems which need to be solved. Secondly, due to the complicated system, lacking of data or some fuzzy operating rules, the model usually need to refer to experience or statistical data of other ports, making necessary assumptions for certain operating rules which have larger errors with the actual operation of dock logistics system, leading the differ between the operation mechanism of the system and the actual situation, which also caused the error of the model in a certain extent.

3.9.2 Basic Problems in the Feasibility Test of Simulation Model

After finishing the debugging of the Simulation model, the model could be carried on. According to the simulation objectives, the goal for different conditions should be set down, and carry on the simulation experiment. After the initialization of input data, the simulator could start simulation model, begin to simulate the research content. Through the statistical analysis of the output of the performance parameters of the simulation model which have defined previously, the author could obtained some significant conclusions and reach the simulation research purpose, offering reference to the optimization and management for the coal berths system[40].

Whether the simulation model is correct or not determines the simulation results. Thus checking the correctness of the simulation model is one of the important steps for system simulation, which could be considered from the several following aspects:

(1) The correctness of the operation process. The program flow of simulation model should be in conformity with the logical model of the coal berths system. In the simulation model, the completion of a ship plan is a complete major process of the main dynamic entities (ship plans) in the simulation model. It has a great progress, including concentrated transportation of the coal, the ship arriving, loading and unloading ships, ship leaving and distribution and transportation of the coal. During the whole operation, processes can't make even a mistake.

In addition, besides check total flow of the model, processes of each module also should be checked. The testing procedures should be carried on repeatedly; all processes cannot have any mistakes.

(2) The correctness of the basic input data. For example, the handling efficiency of the machinery is correct or not.

(3) The correctness of the distribution type of the variables.

Such as the time intervals of ship arrival, which could be get through the statistics of the historical data, its distribution function could be drawn after data analysis, fitting, hypothesis inspection or other methods.

(4) The inspection of the input and output data. According to the collecting data of actual operation in the same type of coal dock, the author input the relevant parameters into the simulation model, such as shipping sequence and deadweights. Through the simulation, the output of the simulation model could be inspected, such as the data of the shipment time after finishing a certain loaded quantity, If does not conform to the actual, the author should analyze the causes, and then do the corresponding modification.

Summary

In this chapter, first the main problems in the design of berth system simulation model are introduced in detail, from four aspects. The first one is the operation flow of the coal system; secondly, the boundary conditions and the assumptions of the simulation model; three is the descriptions of several important physical attributes including the ship sequence attribute, the berth attribute and handling mechanical attributes; the last one in the contents of evaluation index of berth system. And then the simulation model of Qingdao coal port has been established on the ARENA simulation platform. According to the characteristics of coal port system simulation, the simulation elements are determined. The author has introduced the development process of the simulation model, providing the foundation for the final simulation analysis and solve engineering problems.

4 The Simulation and Data Analysis of Coal Berths in Qingdao Port

4.1 Introduction

In chapter 4, the simulation model of coal berths system has been established, while the target of simulation model is to get the simulation data, solving practical problems.

In this chapter, firstly, the simulation test parameters and conditions are introduced, through changing the number of berths and mechanical handling efficiency to determine the various solutions. Then the author operate the simulation model, getting large numbers of data and comparative analysis, in order to provides the reasonable suggestions for the engineering problems in the design and management of the dock.

4.2 Overview of Qingdao Port

Located in the Yellow River basin and on the western Pacific Rim, Port of Qingdao is an important hub of international trade and sea-going transportation. Being a natural deepwater port, free of silt and freezing, the port has established trade relations with over 450 ports in more than 130 countries and areas[41].

Port of Qingdao has three port areas: Old Port Area, Huangdao Oil Port Area and Qianwan New Port. Qingdao port now exist staff 160 million, with 15 terminals and 72 berths. Among them, 6 berths can dock 50,000 DWT ships, 6 berths can dock 100,000 DWT ships, while 2 berths can dock 300,000 DWT ships.

As a port offering comprehensive services, it can handle a variety of general and bulk cargo, and project equipment. Container, coal, iron ore, crude oil and grain are the five major cargo types of the port, and it also handles fertilizer, alumina, cement, sodium carbonate, rubber, wool pulp, cotton, ironware, lumber, and extra-large shipment. In 2008, the port achieved a record volume of 300 million tons, ranking world's No.7, and it's container volume hit 10.02 million TEU, ranking word's No.10. Port of Qingdao is China's 2nd largest port for foreign trade.

Situated on the eastern end of the new Continental Bridge, Port of Qingdao is the first and largest transshipment port for international boxes, and the top reefer container port.

Besides its large-scale container, crude oil and iron ore facilities, Port of Qingdao is also equipped with a first-class coal terminal and a state-of-the-art grain-handling base, and the largest EDI center in Mainland China.

In 1997, Port of Qingdao became the first port enterprise to be accredited to ISO9002 for cargo and passenger transport.

There are three handling berths in Qingdao coal port as following:

(1) There are 2 special garages with the shipment berth length 566 meters, which depth of water on front edge is over 14.1m, which can satisfy 100000 DWT shipping berthing operation. There are 2 Ship loading cranes with single shipment ability for 4,500 tons/hour. 1 machine used both as stocker and reclaimer, 2 reclaimers, and the total b length of elt conveyor which could reach 9.5 kilometers and high precision automatic metering device, etc. The whole equipment adopts microcomputer control and automation.

(2) One ore berths which has 20 tons discharge, can be used for unloading coal concurrently. The berth length is 420 meters, having 3 bridge-type grab ship unloader which own the maximum lifting capacity of 62 tons, outreach of 44 meters and the discharging capacity is 1200 tons/hour.

There are 2 car dumpers and 2 spiral unloading machine which own the handling capacity of 7600 ton/hour and stockpiling ability of 200 million tons. It could achieve single stack of different types of coal and coal belong to different shippers

4.3 Determination of Relevant Parameters

4.3.1 Main boundary conditions

Using the simulation model for simulation experiment, relevant boundary conditions should be decided, for example, the relevant data of ships[42]. Main criteria to determine the boundary condition are the throughput of the terminal design, the relevant research data of the ships, etc. This simulation model was established based on actual port operation of Qingdao port from October to December 2009. The main parameters of the inductive are as follows:

(1) Length of simulation time.

Terminal operates for three months, and the basic unit for simulation clock is hour. The performance parameters of the system will achieve a stable state.

(2) Ship input conditions. Time for ship arrival is a random variable, according to the distribution of Qingdao port. The number of ship refers to the design throughput and the corresponding data, while the ship deadweight quantity determined by the distribution regularity of Qingdao port and reference data.

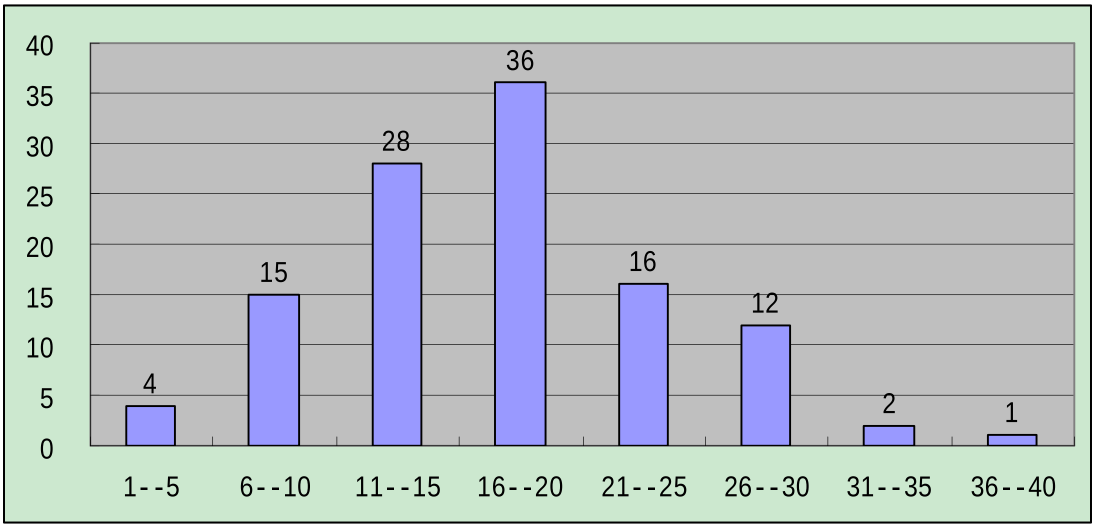
(3) Handling efficiency. The handling capacities of machineries are 2,500 tons/hour, 3,000 tons/hour, 3500 tons/hour, 4,000 tons/hour, 4500 tons/hour, 5000 tons/hour and 5,500 / hour respectively, from low to high.

4.3.2 Pattern Analysis of Ship Arrival

Due to the influence of various factors, the time interval of ship arrival is a random variable. This variable is an important basis for modeling and analysis of the handling production system. Only based on large quantities of data produced in the dock production process, the author could summarize the statistics through the mathematical statistics method.

Figure 4-1 is the distribution of time interval of the ship arrival in Qingdao port from October to December 2009. The horizontal axis of the histogram is the time interval of the ship arrival, and the vertical axis is the frequency. Based on processing and statistic on the sample data, the average time interval of the ship arrival is 17.1 hour (1026 minutes), and the standard deviation is 6.94 hour (416 minutes).

Figure 4-1 the histogram of time interval of the ship arrival



Analyzing by the ARENA Input Analyzer, the function of frequency of the ship arrival is:

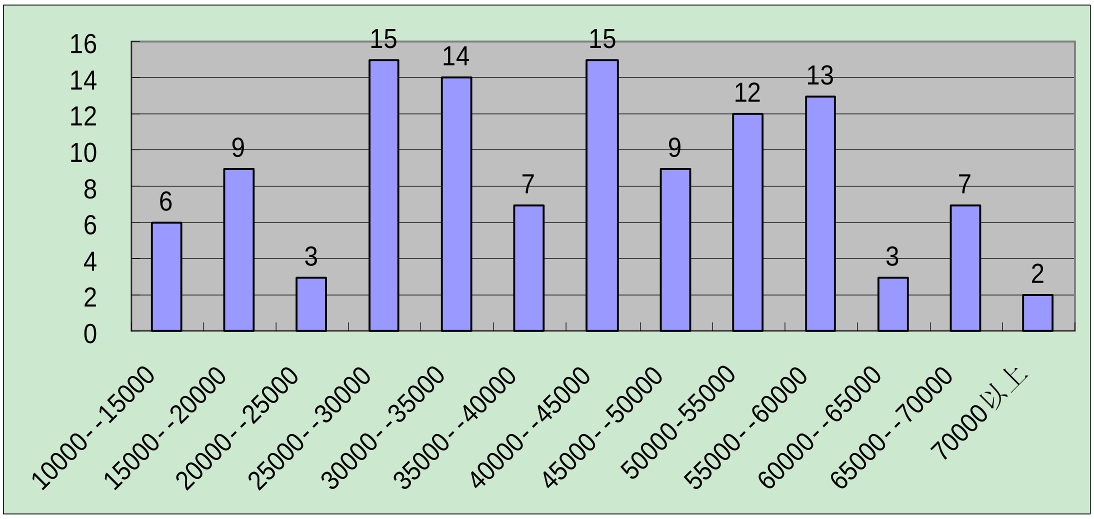
3 + 36 * BETA(2.12, 3.29)。

4.3.3 Pattern Analysis of Ship Deadweight

When analyzing the model of the coal berths system, the load capacity of each ship is also an important random variable. The different load capacity of ships directly influences the efficiency and service time of the berths, which is necessary to make statistical analysis for load capacity of ships according to the reference data[43].

As the figure 4-2 in below, the horizontal axis of the histogram, which adopting 5000 tons as a division unit, is the frequency of ship number of the corresponding load capacity. The author finally could get the average load capacity of 40401 tons and the standard deviation of 15870 tons.

Figure 4-2 the histogram of load capacity of ships



Analyzing by the ARENA Input Analyzer, the function of frequency of load capacity of ships is:

1.06e+004 + 6.45e+004 * BETA(1.43, 1.67)。

4.4 Simulation of Berth System

The relevant parameters have been input into the ARENA simulation model which has been established in the fourth chapter, based on time intervals of ship random arrival and the probability distribution of the ship deadweight to produce a series of simulated samples, simulating the coal terminal production process, gradually accumulated samples statistics, carrying on several times of the simulation experiment, through calculation and analysis to find the optimal berths[44].

Table 4-1 The results of number of handling berths and number of waiting ships

Waiting ships No.	Handling efficiency（Ton / H）						
	2500	3000	3500	4000	4500	5000	5500
1 berth	115	95	68	54	41	29	23
2 berth	92	66	50	34	22	13	6
3 berth	78	56	44	26	14	6	0

4 berth	59	43	27	12	4	0	0

Table 4-2 The results of number of handling berths and average waiting time

Average waiting time（H）	Handling efficiency（Ton / H）						
	2500	3000	3500	4000	4500	5000	5500
1 berth	2.20	0.63	0.37	0.25	0.20	0.15	0.15
2 berth	1.32	0.34	0.21	0.16	0.14	0.12	0.12
3 berth	0.99	0.31	0.17	0.13	0.10	0.10	0.10
4 berth	0.78	0.25	0.14	0.08	0.08	0.08	0.08

Table 4-3 The results of number of handling berths and berth occupancy

Berth occupancy	Handling efficiency（Ton / H）						
	2500	3000	3500	4000	4500	5000	5500
1 berth	0.86-0.91	0.75-0.80	0.65-0.70	0.60-0.65	0.55-0.60	0.53-0.58	0.49-0.54
2 berth	0.87-0.92	0.77-0.82	0.70-0.75	0.63-0.68	0.58-0.63	0.54-0.59	0.49-0.54
3 berth	0.88-0.93	0.77-0.82	0.70-0.75	0.63-0.68	0.58-0.63	0.54-0.59	0.49-0.54
4 berth	0.88-0.93	0.77-0.82	0.70-0.75	0.63-0.68	0.58-0.63	0.54-0.59	0.49-0.54

4.5 Results Analysis

The research of this thesis is based on the complex system modeling theory and the guidance of system simulation technology, according to the actual situation of the handling equipment and operation process of Qingdao Qianwan coal terminal, achieving the simulation on the platform of the ARENA simulation software. Through simulation experiment research of the time intervals of the ship arrival and the terminal performance, we found that time intervals of the ship arrival affect coal throughput, while the changes of numbers of berths and the handling efficiency affect the berths utilization, ship waiting time and other performance indexes which are used to measure the logistics capability of the coal port, and finally explore variation scope of the main performance indexes under limit boundary conditions.

The results of simulation evaluation of the berth ability in Qingdao coal port are as follows:

(1) In the table of output data of the simulation test, when the handling efficiency was more than 2500 Ton/H, the ship waiting time could accept. While the handling efficiency is 2500 Ton/H, ship waiting time is the longest. It can be seen from this that the faster the handling, the shorter the ship waiting time.

(2) In the circumstance that ship deadweight and regular pattern of the ship arrival are fixed, if there are the same amount of berths, handling speed increase, the utilization efficiency going to decline. Because the time of ship waiting in a queue decreases and loading and unloading time shortens. While in the same handling efficiency, the more berths, the higher berths occupancy.

Generally speaking, now Qingdao port has three berths, handling efficiency for single ship is 4,500 tons/hour. The berth occupancy calculated by simulation is 0.58-0.63 logistics. As long as the terminal logistics chain links well, 3 berths can meet the requirements of the annual throughput.

Summary

This chapter is the main content of thesis, mainly is the implementation part of the system. In this chapter, the author first analyzed the purpose of this simulation, and then based on the simulation model, aiming at different purposes, author extracted the corresponding simulation statistics and the evaluation indexes to analyze, and draws conclusions which have some reference value in the actual port planning and scheduling.

5 The Conclusion and Prospect

Along with the rapid development of Chinese economy, port throughput will remain high growth momentum. The coal terminal shoreline, as precious renewable resources, is determined by certain geographical, water depth, weather and other factors, which has a relatively high construction investment costs[45]. Rational utilization of the shoreline can reduce the ship waiting time. Thus the rational usage of berths can not only improve the service level, but also can ensure the economic efficiency of enterprises. Aiming at solving berth allocation problem and full consideration of dynamic and maneuverability, the author has carried on a relatively systematic study on the simulation model, the method and optimization.

5.1 The Conclusion

Based on systemic analysis of the coal port berths system, aiming at how to improve the utilization of coal berths, the author has carried on intensive study on the allocation problems of berths and put forward the simulation research methods. Coal berths system is a complex system. This thesis proposes an evaluation method of simulation system[46]. The author summarizes research results and conclusions are as follows:

(1) Based on the study of berth allocation problems both at home and abroad, and also based on the analysis of actual operation, the author has analyzed the existing procedures of the coal terminal operation, and established a dynamic model and the constraint conditions in order to improve the efficiency of the port.

(2) Thorough the systemic analysis of berths system of the coal port, the author has studied on the structure and characteristics of coal berths system, and determined the evaluation indexes of the simulation.

(3) The author has established the complete process of the simulation assessment methods of the coal terminal, and discussed the

corresponding methods and theory, which based on the simulation modeling methods of the ARENA software.

(4) Taking the Qingdao Qianwan coal port for example, the author has carried on the practice on the application of the evaluation method of simulation optimization, and explored the port system as a whole to achieve the optimal number of berths and handling efficiency, so as to provide an important basis for optimizing the berths system.

5.2 Research Prospects

This thesis has made a systemic simulation on the operation process of the berths system of Qingdao Qianwan port, which had universality of the berth system to a certain extent. But due to a lot of random factors of the terminal system, many problems need to be considered in the simulation process, involving multiple disciplines and fields, for example, operations research, logistics technology, the simulation technology, etc[47]. The limitations of the simulation software as well as the limitations of the factors such as time and individual ability, makes development of the system are not perfect. Therefore, in the basis of this thesis, the following job could be carried on:

(1) The author could further perfect the mathematical model of berths allocation which could better reflect the actual port berths resource allocation. This mathematical model still exists many assumptions, such as the model did not consider ship shifting and less consider the rear of the resources of berths, assuming it could satisfy the demand of handling ships. However, in some actual situation, the ships will be shifting, and the speed of rear resources will also restrict speed of ahead.

(2) This ARENA program could be improved. The program in this thesis has relatively high generability, but due to the limited level of computer programming, the author did not visual interface, and the program has a poor visibility. If using the visualization of the interface, there will be more maneuverability.

Appendix

Appendix 1

The Data of Qingdao Port from October to December, 2009

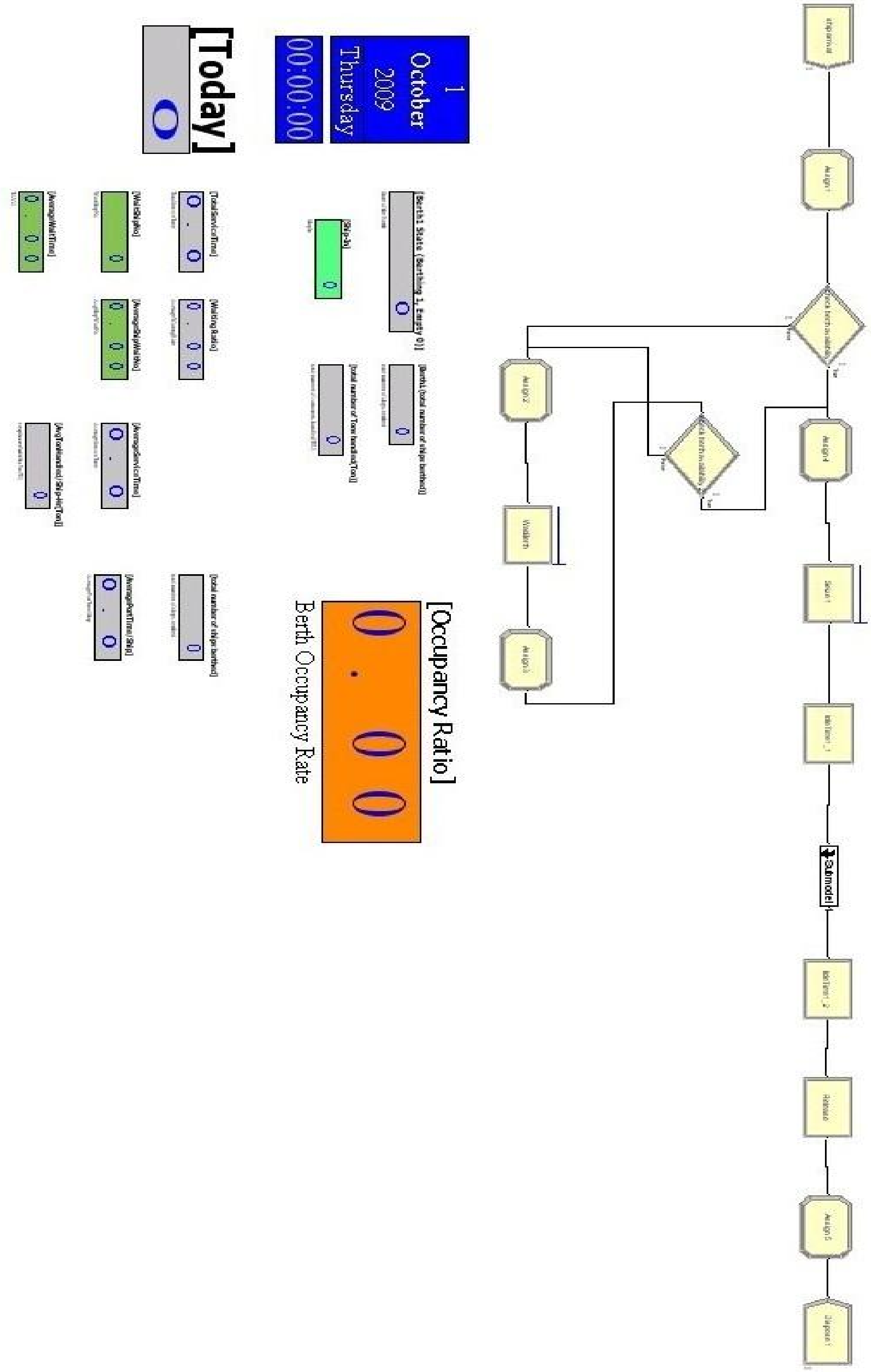
NO.	Ship's size	Berthing and Unberthing			
	Capacity	Berthing	Handling Started	Unberthing	Ship arrival time interval
	ton				
1	63950	10/01:23	10/02:01	10/03:04	-
2	28250	10/02:19	10/02:20	10/03:16	17.00
3	50430	10/04:14	10/04:15	10/05:06	19.00
4	17350	10/04:20	10/04:21	10/05:03	6.00
5	64300	10/05:18	10/05:19	10/06:13	22.00
6	49800	10/07:07	10/07:09	10/07:17	13.00
7	36420	10/08:07	10/08:09	10/09:02	24.00
8	60100	10/09:06	10/09:06	10/10:09	23.00
9	31615	10/09:23	10/10:01	10/10:13	17.00
10	58160	10/10:15	10/10:16	10/11:10	16.00
11	44000	10/11:09	10/11:10	10/11:23	18.00
12	38000	10/12:00	10/12:01	10/12:12	15.00
13	49000	10/12:11	10/12:13	10/12:22	11.00
14	66900	10/13:01	10/13:02	10/13:18	14.00
15	20600	10/14:16	10/14:19	10/15:06	15.00
16	40000	10/14:22	10/14:23	10/15:12	6.00
17	26800	10/15:15	10/15:16	10/15:22	17.00
18	25060	10/16:08	10/16:09	10/16:18	17.00
19	57160	10/16:17	10/16:19	10/17:06	9.00
20	70000	10/17:09	10/17:10	10/18:02	16.00
21	17280	10/18:12	10/18:13	10/18:18	27.00
22	41300	10/18:20	10/18:21	10/19:08	8.00
23	51080	10/19:15	10/19:15	10/20:01	19.00
24	68020	10/20:02	10/20:03	10/21:05	11.00
25	66905	10/20:23	10/21:01	10/21:19	21.00
26	55160	10/22:08	10/22:09	10/23:07	9.00
27	21605	10/23:04	10/23:05	10/23:12	20.00
28	53440	10/23:17	10/23:19	10/24:03	13.00
29	30000	10/24:05	10/24:06	10/24:17	12.00
30	57145	10/25:07	10/25:09	10/25:23	26.00
31	25445	10/25:18	10/25:19	10/26:13	11.00

32	31080	10/26:14	10/26:15	10/27:01	20.00
33	34340	10/26:21	10/26:21	10/27:12	7.00
34	48020	10/27:13	10/27:14	10/28:11	16.00
35	55165	10/28:09	10/28:10	10/29:11	20.00
36	52480	10/28:23	10/29:01	10/29:23	14.00
37	12600	10/29:20	10/29:20	10/30:07	21.00
38	30320	10/30:23	10/31:01	10/31:20	27.00
39	41300	10/31:16	10/31:17	11/01:09	17.00
40	26290	11/02:03	11/02:03	11/02:12	11.00
41	11000	11/02:20	11/02:20	11/03:03	17.00
42	55060	11/03:00	11/03:01	11/03:22	4.00
43	36260	11/04:11	11/04:12	11/04:22	35.00
44	34690	11/05:00	11/05:01	11/05:16	13.00
45	44000	11/05:20	11/05:21	11/06:13	20.00
46	25560	11/06:15	11/06:16	11/07:12	19.00
47	36180	11/07:17	11/07:19	11/08:09	26.00
48	50290	11/08:17	11/08:19	11/09:07	24.00
49	12580	11/09:10	11/09:10	11/09:20	17.00
50	30025	11/09:22	11/09:22	11/10:15	12.00
51	55515	11/10:08	11/10:09	11/10:15	10.00
52	23165	11/11:14	11/11:15	11/11:22	30.00
53	47430	11/11:20	11/11:21	11/12:11	6.00
54	34680	11/12:13	11/12:14	11/13:00	17.00
55	53900	11/13:02	11/13:04	11/13:20	13.00
56	25560	11/13:22	11/13:23	11/14:12	20.00
57	41300	11/14:17	11/14:19	11/15:11	19.00
58	29590	11/15:12	11/15:13	11/15:19	19.00
59	36130	11/16:17	11/16:19	11/17:10	29.00
60	45600	11/18:08	11/18:09	11/18:16	15.00
61	42530	11/18:18	11/18:19	11/19:11	10.00
62	57320	11/19:11	11/19:12	11/20:10	17.00
63	44000	11/20:05	11/20:06	11/20:20	18.00
64	25560	11/20:23	11/21:01	11/21:18	18.00
65	45160	11/21:09	11/21:09	11/21:22	10.00
66	31980	11/22:08	11/22:09	11/22:20	23.00
67	46750	11/22:19	11/22:20	11/23:03	11.00
68	51080	11/23:10	11/23:11	11/23:23	15.00
69	28410	11/24:09	11/24:10	11/24:20	23.00
70	13600	11/25:08	11/25:09	11/25:17	23.00
71	42530	11/25:19	11/25:19	11/26:10	11.00
72	59800	11/26:09	11/26:10	11/27:02	16.00
73	44000	11/27:06	11/27:07	11/27:18	21.00
74	25520	11/28:04	11/28:05	11/28:23	22.00

75	31980	11/28:20	11/28:21	11/29:16	16.00
76	27320	11/29:09	11/29:10	11/29:16	13.00
77	66900	11/30:01	11/30:01	11/30:21	16.00
78	45060	11/30:23	12/01:00	12/01:17	22.00
79	34340	12/01:02	12/01:03	12/01:14	3.00
80	14605	12/02:08	12/02:09	12/02:18	30.00
81	36000	12/02:18	12/02:19	12/03:13	10.00
82	28480	12/03:17	12/03:19	12/04:01	23.00
83	54020	12/04:14	12/04:14	12/05:05	21.00
84	17340	12/05:08	12/05:09	12/05:22	20.00
85	29000	12/07:08	12/07:09	12/07:18	24.00
86	69450	12/07:18	12/07:19	12/08:19	10.00
87	51080	12/08:11	12/08:13	12/08:19	17.00
88	75060	12/09:00	12/09:01	12/09:18	13.00
89	54300	12/10:07	12/10:09	12/11:06	31.00
90	54020	12/11:09	12/11:09	12/12:02	26.00
91	53900	12/12:04	12/12:06	12/12:21	19.00
92	31980	12/12:18	12/12:19	12/13:08	14.00
93	41300	12/13:09	12/13:10	12/14:01	15.00
94	66900	12/14:20	12/14:21	12/15:16	11.00
95	30020	12/15:00	12/15:01	12/15:10	4.00
96	34300	12/16:02	12/16:02	12/16:19	26.00
97	55160	12/17:07	12/17:09	12/18:01	29.00
98	18480	12/17:17	12/17:19	12/18:11	10.00
99	44690	12/18:03	12/18:04	12/18:16	14.00
100	57140	12/18:18	12/18:19	12/19:05	15.00
101	25440	12/19:12	12/19:13	12/20:01	18.00
102	43890	12/21:08	12/21:09	12/21:20	20.00
103	21350	12/21:22	12/21:22	12/22:07	14.00
104	66900	12/22:01	12/22:02	12/23:00	3.00
105	16260	12/23:16	12/23:17	12/24:02	39.00
106	55600	12/24:19	12/24:20	12/25:01	27.00
107	10600	12/25:01	12/25:01	12/25:16	8.00
108	18480	12/25:21	12/25:21	12/26:07	20.00
109	43440	12/26:03	12/26:03	12/26:23	6.00
110	16130	12/27:09	12/27:10	12/27:18	30.00
111	41080	12/28:08	12/28:09	12/28:23	23.00
112	35060	12/28:19	12/28:20	12/29:16	11.00
113	49000	12/30:09	12/30:09	12/30:17	16.00
114	57980	12/31:00	12/31:01	01/01:01	15.00
115	18485	12/31:19	12/31:20	01/01:07	19.00

Appendix 2

The running interface of ARENA software



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