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The study on inland container terminal logistics system simulation

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The Study on Inland Container Terminal Logistics System Simulation

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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 material is 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.

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ABSTRACT

Title of Dissertation: **The Study on Inland Container Terminal Logistics System Simulation**

Degree: **Mater of Science in International Transport and Logistics**

Inland container terminal logistics is an organic system, made of interactive and dynamic components in a limited terminal space. Those components usually are containers, ships, berths, yards, trailers, RTG and SCC. Because of the fast-developing global containerization, most of inland container ports are facing great challenges and chances. This dissertation does research on simulation of the inland container terminal logistics system.

At the beginning of this dissertation, a literature review on both of the domestic and abroad researches of inland container terminal logistics system and an object-oriented approach to model the whole inland logistics system are given. Then the dissertation introduces the basic components, layout, loading and discharging work flow of inland container terminals and the production scheduling rules.

After go over the basic theoretical principles of the object-oriented approach, the dissertation analyzes on structure and sub-systems of the inland container terminal logistics system and its sub-modules. By using the finished system model which is based on an object-oriented approach and characteristics of the work flow, a computer simulation model is made based on the software of EXTEND and is verified by the data of an actual terminal. At last, the model is used to analyze the machine deployment and benefits of using flexible scheduling way also provides decision support for the terminal's production management.

KEYWORDS: Inland container terminal, Simulation, Work Flow, Object-oriented approach, EXTEND

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List of Abbreviations

CPT	Ceres Paragon Terminal
CTS	Container Terminal System
CY	Container Yard
DCC	Dangerous Cargo Container
ET	External Trailer
FCL	Full Container Loaded
IT	Internal Trailer
LCL	Less than Container Loaded
POD	Port of Destination
REFCON	Refrigerated Container
RIWTE	Research Institute for Water Transport Engineering
RTG	Rubber-Typed Gantry
SCC	Shore Container Crane

Chapter 1 Introduction

1.1 Research Topics Source and Significance

The inland container terminal, which provides the minimized interruption and the maximized increase at the point of modern logistics, is gradually strengthening its strategic position and exercising greater influence in the system of modern international, domestic trading and inland transportation.

Inland container port, as the pivot of inland container transportation connecting the transportation by sea and by land, attaches great importance in container transportation. As much application of modern new high tech in the port work and the expanding, speeding, atomizing, digitalizing, and informationizing of loading and production system, the port scale is greater and more efficient. The expansion capacity of circulation makes great difference between the result of traditional terminal design method and the effect of modern terminal operation. To accommodate the development of modern terminal, the design method of terminal needs to be continually improved and the concept of that innovated. It requires the researchers to think all elements of the terminal system as a whole, to analyze study and improve the container terminal system from the systemized and gathered point of view, to scheme and plan the existing container terminal more reasonable to meet the requirement of inland container transportation more efficiently and effectively.

Since the inland container terminal system is typical dispersed, the imitation of inland container terminal and the building-up of a convincible system model becomes the most significant premise. Without an actual system, the best way is to transform the schemed inland container terminal system into imitation model and to evaluate and amend it through operating imitation model on computer. In this way, the unreasonable design and investment could be revised before the system built up, which avoids waste of money, human labor and time. Certainly, we can also operate the current system by imitation and improve the system or provide foundation for management and decision. To follow the fast development of inland container transportation and the subdivided requirements of inland container terminal in each aspect, we need to accomplish more precise imitation work.

1.2 Research Content of This Dissertation

(1) Analyze on work flow of inland container terminal

First of all, the paper analyzes layout and cargo-handling technology of the inland container terminal, even specialized equipment and operational characteristics. Especially pay attention on Import and export process and production scheduling rules.

(2) An object-oriented approach to model the inland container terminal logistics system

After going over the basic theoretical principles of the object-oriented approach, according to analysis about structure of the inland container terminal logistics system, we try to make its system model by using the object-oriented approach.

(3) Simulation model about inland container terminal logistics system based on EXTEND

According to the finished system model based on an object-oriented approach and the process characteristics, a computer simulation model of inland container terminal logistics system is made based on the software of EXTEND and is validated by the data of an actual inland container terminal. At the end, realize simulate application and cartoon demonstration.

(4) Verification and application of this simulation model

According to the finished system model based on an object-oriented approach and the process characteristics, a computer simulation model of container terminal logistics system is made based on the software of EXTEND and is verified by the data of an actual terminal. At last, the model is used to analyze the machine deployment and scheduling and provides the decision support for the terminal's production management.

Chapter 2 Method of Research

2.1 The Current Research Situation of Inland Container Terminal Logistics System Modeling and Simulation

2.1.1 The Abroad Researches

Imitation is probably the best method of researching any important system, especially for extremely complicated and enormous system, so it is usually recommended to be used when people analyze container terminal system.

Park and Noh use Monte Carlo imitation method and SLAM imitation language to measure the terminal capacity in 1987[1]. Lai and Lam analyzed the instruments division strategy of several large container yards in 1994[2]. Ramani suggested imitation valued more than analyzed lining theory in 1996, which provided a foundation for terminal modelization[3]. In 1994, Hayuth made an imitator by imitating a dispersing event[4]. But the above imitation model and imitator all simplified the container terminal to a large extent, which could not make a complete picture of the modern terminals with advanced instruments. Therefore, some researchers have begun to imitate with object-oriented of the imitation software. For

1 Park, C.S., Noh, Y.D. (1996), A port simulation model for bulk cargo operations, *Simulation*, Vol.48, No.6, pp .236-246.

2 Lai, K, Lam, K.(1994), A study of container yard equipment allocation strategy in Hong Kong, *International Journal of Modeling and Simulation*, Vol.14, No.3, pp.134-138.

3 Ramani, K.V.(1996), An Interactive Simulation Model for the Logistics Planning of Container Operations in Seaports, *Simulation*, Vol.66,No.5,pp.292-300.

4 Hayuth Y, et al. (1994), Building a Port Simulator, *Simulation*, Vol.63, No.3, pp.179-189.

example, to research container terminal by imitation, Luca used MODSIM and Michael used GPSS/H in 1998[5] and Yuri used Proof[6], A.A.Shabayek used WITNESS in 2002[7]. Not only do these software systems contain modelization, imitation operation and result turning out, they also contain model analysis, system planning, statistic analysis, two or three dimension animation display functions and etc. It doesn't require much computer knowledge nor programming skill from the researcher, neither does it require much knowledge of imitation theory or calculation method to use the imitation language. In this way researchers can concentrate their primary attention on system modelization and analysis, which is beneficial to increasing imitation efficiency as well as quality.

Now it has been a universal phenomenon in some advanced countries that they apply computer imitation in terminal work, such as container terminal in Los Angeles, U.S., Amsterdam, Netherlands and Port of Bussan, Korean. Container terminal 1051 of Ceres Paragon Terminal (CPT) in Amsterdam, Netherlands is one of the examples. CPT, starting operation in last year, is the first terminal that leading large container vessels into concave pond and loading and unloading containers by multiple onshore container cranes at the same time. Since the large vessel whirl waters was put into consideration, the terminal container yard was divided into two unmatched area, the northern and the southern area, by the position of concave pond. Most containers of the onshore crane work on the northern shore can only be transported for deposition on the southern container yard through the path from the terminal to the inland. At

5 Michael, R. (1998), , Animation and Visualization of Seaport Operations, *Simulation*.Vol.71, No.2, pp.96-106.

6 Yuri M .et al.(1998), A Modeling and Simulation Methodology for Managing t he Riga Harbor Container Terminal, *Simulation*, Vol.71, No 2, pp.84-95.

7 A.A.Shabayek, W.W.Yeung (2002), A Simulation Model for the Kwai Chung Container Terminals in Hong Kong, *European Journal of Operational Research* 140, pp.1-11

the time of choosing an alternative of terminal planning and designing, the transportation of the inland point of a port becomes one of the most important problems. The U.S. Company Jordan Woodman Dobson (JWD) intimated and evaluated the transportation by computer[8], putting the influence of front, container yard and door work into consideration, and confirmed a reasonable design. Through the study of influence to the loading containers by the operation conditions and management style of the port system, the company successfully predicted and analyzed the reasonability of the working process, found the crucial point of the system and achieved the aim of increasing the whole nature and profit of the system at the end.

Viewing from the abroad publicized documents, the application of computer imitation technology at the container port can be divided into following types:

(1) Analyzing by imitation the circumstance of import through lining theory and descending calculation, so as to set up decision basis for port investment and to discuss influence over port efficiency by dynamic porting distribution.

(2) Imitating the process of loading and unloading work of in port vessels to study the problem of dispatching onshore container cranes and to decrease container destruction rate by designing container yard plan; imitating the process of container unloading and exporting, to analyze the transportation status in the container yard and to discuss the equipment of port transportation instruments and application of automatic cars; imitating the status of container placing in the yard to analyze strategies of handling import and export containers. In order to

8 Peng Chuansheng (2002), Study on an example of container terminal simulation by computer, *RIWTE transaction*, 2002.(2):pp.26-33

increase the utilization rate, we have to discuss the container placing strategies in the yard chiefly.

(3) Analyzing by imitating the whole container port, discussing the capacity of container transportation in CY under the updated working or management method, supporting for designing some container port plan, designing reasonable logistic plan for transportation in the port, scheming for improvement of port working process and instruments, analyzing management methods for new ports through imitation.

2.1.2 The Domestic Researches

In our country, though the efficiency of container terminal loading is increasing rapidly, the inneglectable problems such as terminal disposition, landing capacity, amount and advancement of instruments and the skills of the workers are still existing. Under the circumstance, in domestic, people began to imitate dynamic container terminals by computer. The water transportation research institution of ministry of communications studied the work efficiency of domestic container yard through computer automation imitation technology. The research contains the container yard operation conditions, management methods, and the relevance of disposition of inland transportation and the terminal works efficiency. The developed imitation model of container terminal, bounded with dispatching and boarding port, includes all management and work process within the terminal. Besides the dispatching of transportation capacity, people also researched the statistic time interval, the average transportation capacity at the crossing and roads and the maximized transportation capacity for each division.

Professor Bie She An of Tianjin University suggested to take advantage of the circulated internet imitation method to combine the lining theory[9], internet planning skill and computer imitation skill, by which we can imitate the operation of port and to acquire the usage status of port boarding and warehouse. The concrete imitation of loading way can produce a reasonable draft. Professor Zhen Hong of Shanghai Maritime University developed a dynamic graphic imitation system which is useful for DDS and evaluation of port production dispatching CE improvement rules according to Concurrent Engineering Theory, Visual Basic 4.0and graphic software AutoCAD14.0.By comparison between the program operation results and some practical port dispatching scheme, he deeply researched the reasonable dispatching of container yard[10]. The primary researching work of that system is on the front of port yard, which simplified the part of CY of the port. The port logistic technique center of Logistic Engineering College, Wuhan University of Technology, using the method of computer imitation on the WITNESS imitation basis, applied the imitation method to east jetty container terminal of Tianjin and No. 5 Project of Shanghai Wai Gao Qiao container yard, by which the whole plan of container terminal has acquired an effective evaluation.

From all the above domestic and abroad research, there is still discrepancy in depth and range between the domestic and abroad container terminal research by imitation. Especially the domestic work in development of some comparably complicated container yard model is less, due to lack in realization that imitation plays a great part in provision of decisive foundation in the process of operation management. Most of the computer application in domestic ports only stays at the statistic process. Though some of the ports are developing the management information system, for

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9 Bie She'an (2001), Distinct Element Method and Problems about Discontinuous Medium in Port and Coastal Engineering, *Marine Science Bulletin*, 2001,(2):18-21

10 Zhen Hong(1999),Research on Dynamic Graphic Simulation of Container Harbor Production Process , *Journal of Image and Graphics*, Vol.4 (A), No.6,pp.503-506

example the EDI model program developed by the 4 ports (Shanghai, Ningbo, Tianjin and Qingdao) organized by Ministry of Communications is going to be tested and put into exertion one by one, but the application of port computer has not been promoted into the range of port production dispatch or decision support. According to survey, the current computer application in domestic ports is limited to post production statistic handling and delivery of statistic showing productive progress between the port bureau and the loading company.

2.2 Method of Discrete Event System Modeling

The researches on modern inland container terminal system contain variety of subjects. It includes optimizing terminal layout system, forecasting port throughput, developing transport scheduling, allocating reasonable terminal resources, transmitting and processing logistics information. Common theories and techniques contain analytic methods (queuing theory, the optimization method), and simulation.

Among these methods, the system simulation, due to the following advantages, has become an important tool in the present studies on container terminal system.

(1) It meets the people's thinking habits and contributes to systems analysis. System Simulation is based on actual observation of the data collected to establish the dynamic model. This model not only reflects the physical characteristics of the system, but also reflects its logic features, which is closer to reality and easier for analyzing the system.

(2) It has good adaptability for the complex system and is conducive to resolving the impact of random factors. The model established by system simulation is a stochastic model. It embodies the changes of system parameters affected by the

random factors that occurred in the model.

(3) It can help to optimize the system. System simulation is a kind of indirect optimization method. There is no absolute optimal solution for multi-objective, multi-factor and multi-level system (i.e. Container Terminal System). Simulation system enables people to modify the parameters and simulation repeatedly based on dynamic operating results, seeking the approaches to improve the system behavior.

2.2.1 Simulation Model Design and Implementation

To enable the model run on computers, it needs to change the system model to simulation model (also called computer model). This is an indispensable step from model to computer simulation. Generally, there are three steps to convert a system model into a simulation model that can be run on computers.

(1) Designing simulation strategy, specifically, to determine the control logic and simulation clock propulsion mechanism of the simulation model;

(2) Constructing simulation model, namely, to determine the specific activities of the model;

(3) Designing and implementing simulation program, namely, to achieve simulation strategy and simulation using certain program design methods and language.

2.2.2 Simulation Strategy

To convert system model into computer model, first of all, it needs to choose control logic and clock propulsion mechanism of the simulation model as a whole, i.e., determine simulation strategy. Simulation strategy is crucial to simulation model, which reflects the nature of simulation model and determines the simulation structure fundamentally. So far, discrete events form three basic simulation strategies, which are event scheduler, activity scanning and procedure interaction. All the other simulation strategy is based on these three types of strategies.

2.2.3 Simulation Model Design

Determining simulation strategy identifies a simulation model algorithm only. Under the guidance of simulation strategy, a detailed design of the simulation model would be required before the completion of the simulation program design. The convenience and feasibility of the computer operation needs to be concerned also during the simulation model design. No matter what simulation strategy adopted, simulation model can be divided into following three levels of design:

Level 1 -- Master Control programs (responsible for arranging the time of the next incident occurred, and to ensure the completion of the correct activities when next incident occurs.

Level 2 -- Basic model unit programs (describing the interactions between incidents and entities and among entities, which is the main concern of the modelers);

Level 3 -- Public subroutine (used to generate random variables, produce report on simulation results, collect statistical data, etc.).

2.2.4 Simulation Model Implement by Computer

Simulation strategy and the design method of simulation model have been described.

However, the simulation model is in the form of computer programs, so that all the simulation models have to be realized by computer language ultimately. In order to reduce the programming workload for the simulation users, a variety of Event System Simulation Language have been developed. These simulation languages mainly provide the support of the first and third levels for simulation model, organize the common activities in simulation model using different simulation strategies, and implement with senior programming language, hence provide users with a common modeling and simulation framework for implementation. With the support of the simulation languages, users can concentrate on the second level, namely, the code description of incident routines, activity routines or processes in terms of the stated form.

2.3 Brief Introduction about EXTEND

EXTEND system simulation software is the common simulation program that developed by the United States company which called Imagine That. It is the system simulation software that has the largest users, more than 10,000, throughout the world. EXTEND is a powerful, advanced simulation tool. It can be used to develop the dynamic model in various fields. EXTEND modules can be used to create models, explore related flows and the interrelation, and then, optimize the possible solution by changing the assumptions.

Environment in Extend simulation provides a powerful tool for model builders with different levels of modelling. The users can build an accurate and credible model efficiently. The advanced design of EXTEND can reduce the total time used in programming, validation and simulation model analysis. Model builders can use pre-built components of modelling in EXTEND to build a model quickly and even can doing system analysis with little programming. Simulation tool developers can use MODL, a compiled language which in EXTEND to develop more new modelling components for fitting any requirements. All of those working above can be finished without external interfaces and code generators and just within a single, self-contained software program.

Modeler can easily create completely interactive interface module through the drag drop method. These can be stored in the own built module database and repeatedly used in further modeling process. EXTEND provides more than 600 system functions that can achieve the integration with database, Excel and other database sources, fully utilizing the resources of Windows operating system and link to Delphi, C++ Builder, Visual Basic and Visual C++ code.[11]

In addition, the visual animation, effective debugging tools and transparency of the modeling can help us to valid and confirm models. The transparency of EXTEND model can show how does the model operate to the modeler very easily. It includes the operation method of the interactive model and the interactive debugging tools that can display the interrelationship between modules. Open source model enables the modeler to see every detail in the process, including the triggering events, allocation of resources and even to see how the time allocation of each event is resolved. These tools reduce the time needed to determine the model.

As contemporary simulation software, EXTEND contains the following features[12]: usable module, end-user interface development tools, and flexible user-defined mechanisms for generating reports and charts, and integration with other application systems. In addition, EXTEND contains a message passing-based simulation engine,

11 *User's guide for EXTEND v6*, Imagine That, Inc., 2002,O2-O5
12 *User's guide for EXTEND v6*, Imagine That, Inc.,2002, O27-O31

providing a rapid operating and flexible modeling mechanism. EXTEND modules can be easily built and combined together, and it makes EXTEND been widely recognized by many industries, including communications, manufacturing, services, health, logistics and military.

2.3.1 The Main Features of EXTEND[13]

Some features of EXTEND or the functions of EXTEND can not found in other simulation software. Therefore, the user can concentrate on the modelling process and build a model more quickly and model running and introduce something in this model to other people also becoming much easier. These unique features of EXTEND are including:

Interactivity: Even during a model is running, both of parameters and model logic also can be amended at the moment in EXTEND. The excellent interactivity can quickly answer and reanalyze any problems.

Reusability: Both of modelling components and hierarchical sub-models can be saved in libraries, and reused by any other simulations, even can be used by other modellers. Obviously, this characteristic increases productivity and consistency during model designing.

Scalability: The hierarchical structure of EXTEND is unlimited, so it can be used to build an enterprise model which might contains hundreds of thousands of blocks.

Visibility: Block icons which are pre-designed by EXTEND are specifically to

13 *http://www.imaginethatinc.com*

express the structure and behaviour of the model.

Connectivity: Extend supports the COM model (ActiveX/OLE) and ODBC. Unlike other simulation software, these technologies have been implemented in EXTEND as modelling components, and can be used only by a drag and drop operation and without any programme steps

Extendibility (on-limit): The blocks are made by using EXTEND’s compiled language and integrated development environment. They are open source which means that all of the blocks allow modification and enhancement. This characteristic accelerates the evolution of modelling techniques, because that the user can improve and create new components on their own.

Third Party Support: Currently, EXTEND is becoming the first choice of simulation engine than any other simulation software by more and more third party used in applications. The key point is its integrated development environment.

2.3.2 Basic Elements Provided by EXTEND

Modules -- Most of the EXTEND modules composed of the icon. Dialog box is used to input data and check data and connection ports. Each module has been given an action or process. Programs in the module will deal with the information after receiving them. In the simulation, such information will thereby transmit from one module to the next one. There is no difference in nature for different modules. Any module can create, modify and display information and, many modules can implement several functions.

Library – It is the place to store modules. The fully definition of the module is stored in the library (e.g., program, icon, dialog, etc.).

Dialog -- Most modules have dialog. Usually, during simulation process, input and setup in the dialog box before viewing the simulation results.

Connection port for each module -- Most of the EXTEND modules have a small box on both sides, input and output ports respectively. The set of two ports is generally pre-defined, in order to know the specific functions in advance.

Module and the connections between modules -- In the model, the connection represents the information flow between the modules. The process of simulation is the repeated calculations and actions through the connections. Each repeat is called the step for continuous model or the time for discrete event model.

Chapter 3

Object-Oriented Approach to Model the Inland Container Terminal Logistics System

3.1 Working Flow of Inland Container Terminal and Operational Characteristics

3.1.1 The Characteristics of Inland Container Terminal Operation[14]

Due to the special status of the inland container terminal in logistics transportation system, here are some features of terminal production.

(1) Production of Continuity

Terminal production is usually 24-hour continuous day and night operations. Container terminal, as a sector of service industry, the production have to swift, accurate, timely, and minimize the time of cargo stay in terminal.

(2) Collaborate in Organize

Container terminal is a confluent point of various modes of transport, and actually, itself is a complex mixture. Terminal operation has to coordinate people, machinery, yard, the tally department and some other various departments, and make them to be formed an organic whole. If one sector is off, it will seriously

14 Chen Quyuan(1998), *Management of Container Terminal Operation*, Dalian Mritime University

affect the efficiency for the operation of whole terminal.

(3) Imbalance Production

This imbalance is mainly manifested in : the imbalance of volume of import and export containers in time, the imbalance of type of import and export containers, the imbalance of the time of ships arriving and leaving , the imbalance of the size of arrival ships and so on.

3.1.2 Working Flow of Inland Container Terminal

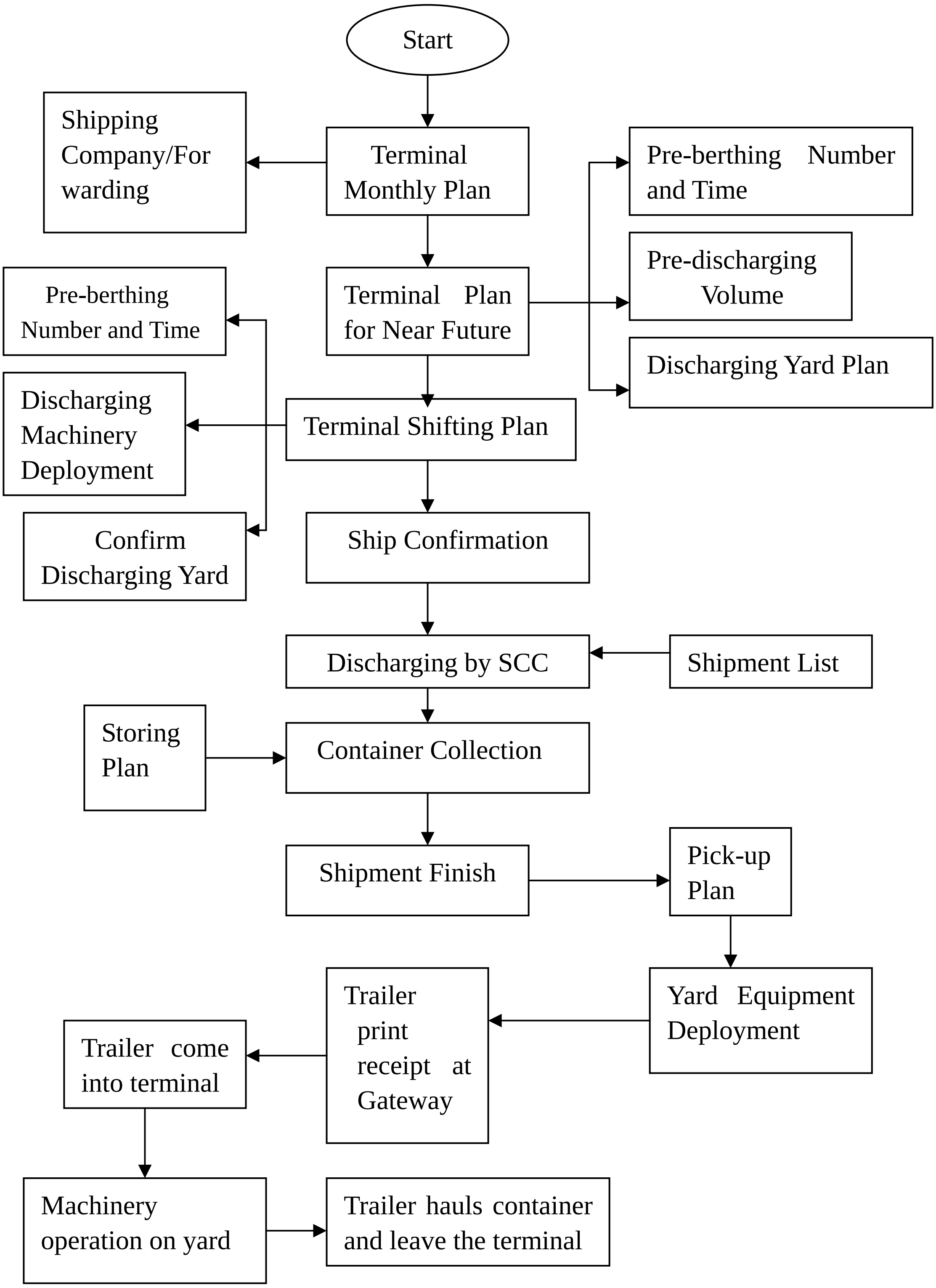
Compared with general terminals, inland container terminal have the primary advantages of high speed on turn over between ship and car and faster transportation. However, whether the container can be handling and transport smoothly in terminal, the reasonable scheduling for machinery of the terminal is the key point.[15]

3.1.2.1 The Imports Flow of Inland Container Terminal

The imports flow of inland container terminal is shown in figure 3-1.

15 Chen Quyuan(1998), *Management of Container Terminal Operation*, Dalian Mritime University

Figure 3-1 Imports Flow of Inland Container Terminal



Source: Port of Nanjing

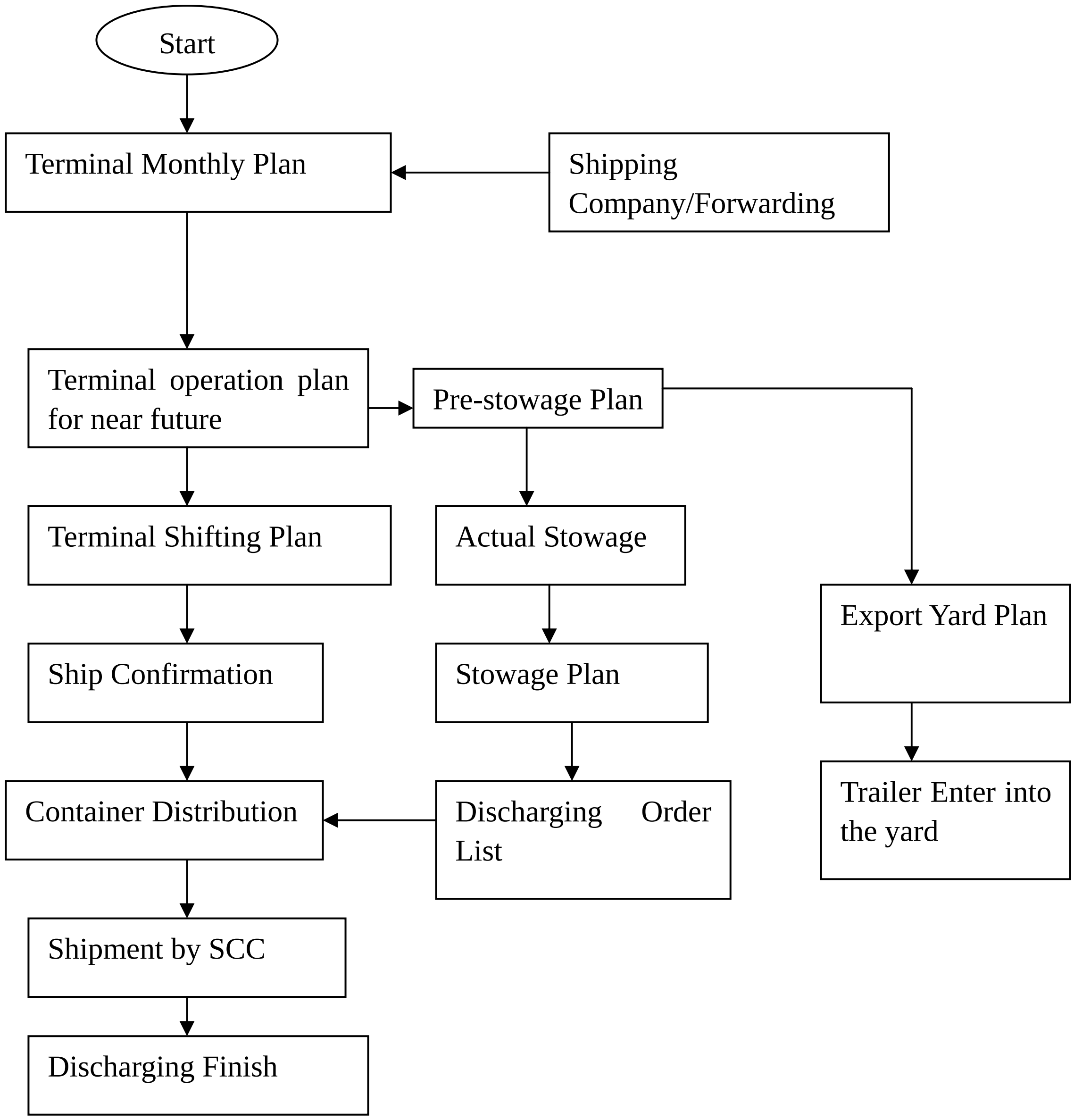
After the terminal received the ship plan for the near future, if the ship has import containers, the terminal have to remain space on import yard in advance. Generally, the specific discharging yard is already designated in terminal shifting plan and makes machinery arrangement in advance. At least four hours before the ship start working, terminal planning staff compiles landing list and Yard planning staff make landing stack plan in accordance with the rules of stacking rules. Discharging operation is start. The driver of SCC discharge containers in accordance with the landing list, and the crane drivers stack containers according to stacking plan. The Empty container is hauled into empty container zone, and some containers are arranged for direct pickup should be shipped out of terminal by external trailer. If ask for pick up the goods as FCL, consignee should transact applying formalities one day ahead and convenient for the terminal making the mechanical arrangement. External trailer drivers go to pick up containers with certain documents, first, take receipt at entrance, and then go to the designated yard to take the container，leave the receipt at exist, and then leave terminal. Yard planning staff command machinery move the LCL cargo to stripping area according to the stripping plan.

3.1.2.2 The Exports Flow of Inland Container Terminal

The Exports Flow of Inland Container Terminal is shown as figure 3-2.

As the same with import operation, in order to finish container shipment smoothly, inland container terminal have to collect information and documents of the export containers and do preparation work in advance. After the terminal received the ship plan for the near future, if the ship has export container, the terminal have to remain space on export yard in advance for container collection. After the terminal received the ship plan for the near future, if the ship has export container, the terminal have to remain space on export yard in advance for container collection. External trailer drivers enter the terminal by first take receipt at entrance, and then go to the designated yard to discharge the container， leave the receipt at exist, and then leave terminal. The yard planning staff commands the SCC begin to shipment according to the shipment list

Figure 3-2 Exports Flow of Inland Container Terminal



Source: Port of Nanjing

3.2 Cargo Handling Technology of the Inland Container Terminal

Reasonable handling technology is an important component of terminal project programming. There are lots of factors such as port, sea-route, characteristics of ship size, categories and attributes of import and export cargoes, even cargo flow are all have to be take into account.

Reasonable handling process and equipment should pay attention on perfect combination of handling equipment, harmonize the operation between the front and the rear, and reduce turnover sectors during operating, it will help for raise production efficiency.

In addition, handling equipment selection have to consider lots of factors together such as handling efficiency, ship size, the height of water and so on. Especially in some inland container terminal, due to the technical constraints, we should pay more attention to the selected device should help for ensure production safety, improving the environment condition, reduce working intensity for workers, reduce handling costs, improve working efficiency, and shortening the time of ship stay in terminal.

All these characteristics above are must be considered when we research on inland container terminal handling technology and facilities. At present, the river port container terminal handling technology and equipment mainly types of inland container terminal handling technology and facilities engaged in are[16]:

(1)Handling technology scheme for vertical face wharf

16 E.Kozan. *Optimising Container Transfers at Multimodal Terminals*. Mathematics and Computer Modeling 31 (2000) pp.235-243

(a) Ship-SCC-Trailer-Cargo Owner

(b) Ship-SCC- Fork Lift Truck -Container Yard-Trailer-Cargo Owner

This technical scheme has advantage of high handling efficiency by using SCC. However, the equipment acquisition and maintenance costs also higher, it adapt to the special container terminal which has larger container throughput and lower height of water. For instance, both of Nanjing port and Yangluo port in Wuhan along Yangtze River are using SCC in terminal operation.

(2)Handling technology scheme for the terminal which have its apron with small size, throughput is not large and with big height of water.

(a) Ship-RTG-Yard-Trailer-Cargo Owner

(b) Ship-RTG-Trailer-Cargo Owner

The characteristics of this kind of handling technology is that can using gantry crane directly to do handling work from ship to the yard and reduce equipment investment. This scheme is more suitable for some inland terminal with small and medium sized berthing ships and not huge volume of cargo handling.

3.3 Production Scheduling Principles of Inland Container Terminal

3.3.1 Ship Berthing Principle

The time of ship arrival is affected by many random factors, so that when several ships arrived at the same time, some ships have to wait in anchorage. This is requires ships berthing and handling according to some certain priority principles. Generally, there are several priority principles as follows[17]:

(1) Priority of berth adaptation

According to the size of the vessel, large ship has to berthing large berth, and small ship berthing small berth.

(2) Priority of important transport materials

Such as military supplies, supplies for emergency, agriculture support goods, energy supplies for urgent should be handling priority.

(3) Priority of time limitation goods

Such as: frozen foods, agricultural products should be handling priority.

(4) Priority of the larger vessel and liner

(5) First come, first service

3.3.2 Mechanical Control Principles

After the ship is berthing, the terminal needs to make machinery deployment according to the real condition of container ship. The main work is to arrange appropriate number of SCC. Number of deployed SCC is related by number of bays and whether has enough distance between the two bays nearby. In addition, it also related by whether the liner shipping and with pressing time or not. For instance, a berthing container ship with 3 bays and with enough space between the two bays

17 Zhen Hong (1999), *Port Production Scheduling Process Optimization*. Shanghai: Shanghai Science and Technology Literature Press.

nearby to arrange one SCC for operating. In such circumstances with pressing time, we can arrange 3 SCC for handling. Instead, arrange for 2 SCC, or even one.

After fix the number of SCC and storage plan, basically, equipment for handling one ship could be confirmed. Generally, one SCC should match with 4 or 5 trailers, and the number of RTG should be arranged according to the container distributed situation on yard. In usual, one region has 1.5 RTG, and containers of the same ship should be put in 1 to 3 regions according to the different volume[18].

3.3.3 Yard Storing Principle

Yard management is an important sector of terminal operation. Handling speed increasing depends on reasonable arrangement of slot in yard to a large extent. Reasonable arrangements for container slot and zone not only can reduce the rolling rate and the time of waiting container of SCC, improve the handling speed, but also can improve both of yard utilization rate and terminal accessibility to maximize extent, reduce product cost of the terminal. The basic rule of stacking is to prove the safety of container stacking and reduce rolling rate.[19]

(1) Basic stacking principles in yard

(a) To stack container with different sizes, empty containers and heavy containers, containers with FCL and LCL in separate;

(b) To stack import and export containers in separate;

(c) To stack REFCON, special cargo container, DCC in relevant specific purpose

18 Zhang Jieshu(2005), Simulation Study on Microscopic Production Scheduling of Container Terminals, *Journal of System Simulation*, 2005 Vol.17 No.10, pp.2560-2563

19 Zheng Zhihong (2002), Application of Yard Plan Management on Container Terminal, *Shipping Mnagement*, 2002.(3): pp.28-29

slot;

(d) To stack containers according to ship's name, voyage, POD, weight class in separate;

(e) Containers in one ship can not be stacked in same zone;

(f) Margin of adjacent and isolated row may not exceed 3 layers;

(g) If the container region of RTG is “4 over 5”, here are two layouts of containers stacking. One is set the driveway of trailer in one side of Road (commonly called 1 plus 6), see figure 3-3 (a) below. Another is to set driveway of trailer in the middle (commonly called 3 plus 1 plus 3), see figure 3-3(b) below. For convince of trailer access, usually we prefer to use the first one. The latter one also has its advantages, such as fewer times of container reversing, a good sight for gantry crane driver operating, shorter walking distances for gantry cranes.

For safety considerations, the first row close to the driveway should not higher than two tiers, and the second row should not higher than three tiers. That is, the maximal number of containers can be put in one bay one is 21 units.

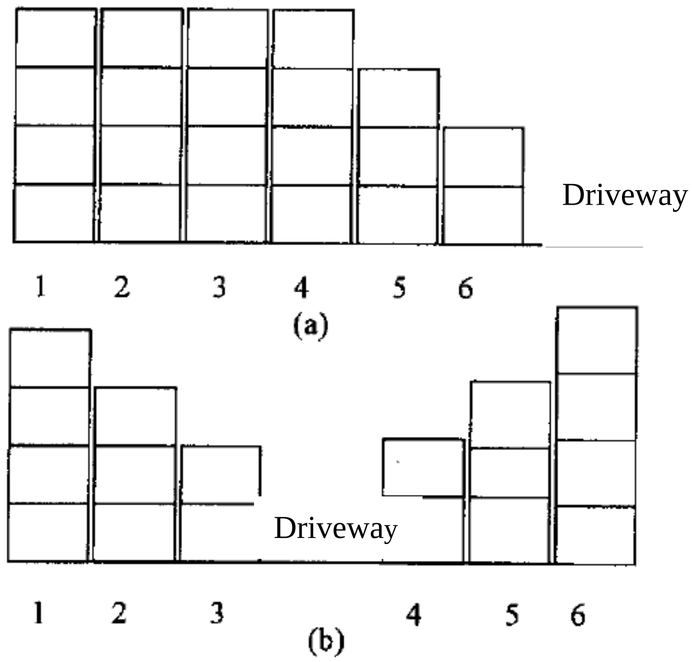


Figure 3-3 Max number of containers can be stored on one bay

Source: Port of Nanjing

(2) Principles of import container yard arrangement

Storing the import containers in terminal have to obey some certain principles, in order to reduce the rolling rate when pick up containers, and improve discharging speed. Generally, here are 4 principles as follows:

(a) Containers which are needed to be transferred should be stored together;

(b) In one bay, containers with same B/L number should be but in same row;

(c) Deploy the number of zones should according to the volume of containers, to avoid traffic overcrowding when container volume is huge;

(d) Storage area should be located near by berth as close as possible, and try to minimize across of drive route of trailers.

(3) Principles of export container yard arrangement

Suppose that containers going to Hong Kong and Singapore are classified as three classes by heavyweight from light to heavy which are A1, A2, A3 and B1, B2, B3. As shown in figure 3-4, considering yard utilization rate, loading efficiency and container volume of discharging port, generally, export container yard arrangement have to obey following principles:

(a) Stacking by slots

Containers with same port of destination and same tonnage should be stacked in one slot as figure 3-4(a).

(b) Stacking by slots and bays

Containers with same port of destination are stacked in one slot, and meanwhile, the same bay of this slot should be used in storing containers with same tonnage as figure 3-4(b).

(c) The heavy container should be put over the light container

Heavier containers should be stacked on the two bays nearby the driveway, and the lighter containers are stacked on the two inside bays, however, the heavier containers may be put over the lighter containers, as shown in figure 3-4 (c). Because that we often put the heavier containers below when ship loading, it lower the center of gravity of ship in order to improve the navigation stability of the ship.

(d) Stacking by bays

Containers with same port of destination and same tonnage are stacked in the same bay. But containers with different port of destination and different tonnages can be stacked in different bays in the same slot, as shown in figure 3-4(d).

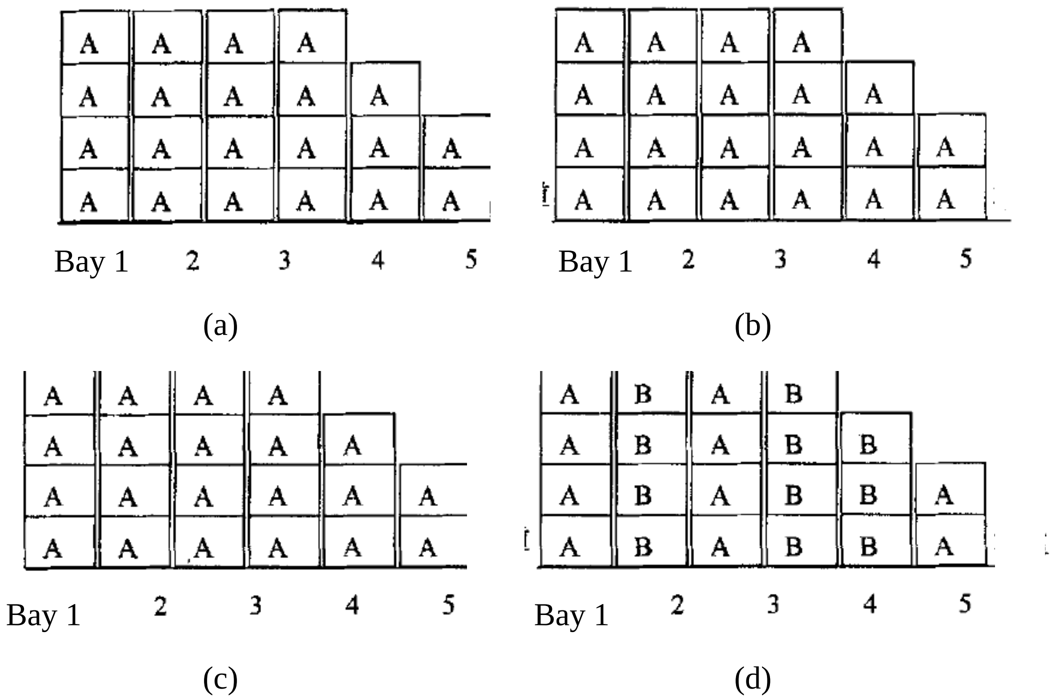


Figure 3-4 Yard Storing Principles

Source: Port of Nanjing

3.4 The Structure and Sub-System of Inland Container Terminal Logistics System

3.4.1 The Structure of Inland Container Terminal Logistics System

An inland container terminal logistics system is constituted by several interrelated logistics processes. In this system, container flowing and relations among every sector inside are shown in figure 3-5.

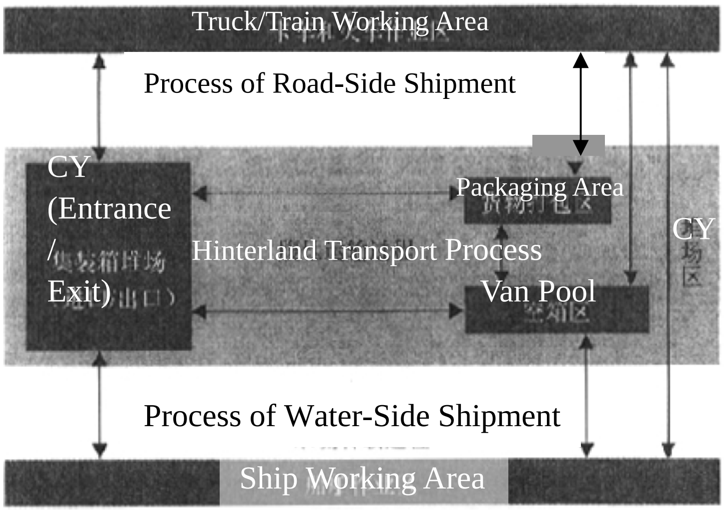


Figure 3-5 Structure of Inland Container Terminal Logistics System

Source: Yangtze River Container Transport Co.

Container ship would be assigned to a suitable terminal after it entered the port. The ship working area equip with SCC for loading and unloading ships. All containers waiting for handling have to through the temporary storage glacis below SCC, and then progress loading or discharging operation by SCC. Due to limited space of apron, the glacis is one of bottlenecks in the process of water-side transshipment. Transportation between apron and hinterland is completed by straddle carrier and trailer. Some special containers such as REFCON and DCC need to transported to specific storage area. Most of import containers are shipped to a pre-planned yard first, and then transported out of the terminal. Only a small number of import containers do not need intermediate transition and these containers will be sent to the highway or rail transport vehicles directly. In a word, both of container transshipment and container transport between apron and yard are related to water-side transshipment process.

Containers transport by road or rail should be cleared on working area of truck or train. After completed the necessary formalities, these containers will be transported to different container yards. The process of road side shipment is finished by special truck and crane. However, there are some inside transportation among some different areas of hinterland (such as container yard, van pool), these transportation including some as transport container from van pool to packaging area, and from packaging area to container yard, etc.. Those are all the part of hinterland transportation.

3.4.2 The Sub-System of Inland Container Terminal Logistics System

In inland container terminal system, container loading, unloading and handling machinery response for transport and handling of containers are RTG, SCC, internal trailer and external trailer.

The basic operations in inland container terminal are collection, pick-up, loading and discharging of container.

These operations occur interactively and simultaneously, as shown in figure 3-6 below.

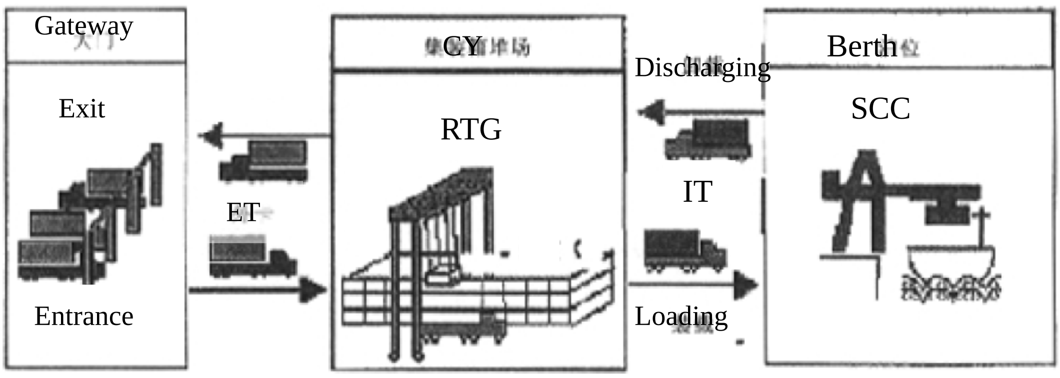


Figure 3-6 Basic Operations in Inland Container Terminal

Source: Source: Yangtze River Container Transport Co.

(1)Container Collection

The export containers hauled by external trailer from gateway to container yard, and be stacked by RTG.

(2) Pick-Up Container

SCC transport the import container onto external trailer, and then external trailer transport these import containers out of terminal.

(3) Container Loading

RTG transship the export containers onto internal trailer, and internal trailer haul these export containers to apron, and then the export containers would be shipment by SCC.

(4) Container Discharging

SCC discharge the import container from ship to the internal trailer, and then internal trailer haul the import to the yard, finally, these import containers stacked by RTG.

According to four basic working processes in inland container terminal, we can divide the inland container terminal logistics system into eight subsystems, which are external trailer sub-system, gateway sub-system, yard sub-system, route sub-system, horizontal transportation sub-system, berth sub-system, vessel sub-system and terminal management sub-system.

(1) External Trailer Sub-System

External trailer go to the terminal for container delivering or pick-up.

(2) Gateway Sub-System

To finished some tasks as document verification and container inspection.

(3) Yard Sub-System

To finished the job of container stacking and taking on yard.

(4) Route Sub-System

This sub-system provides the driveway for external trailer, internal trailer and RTG.

(5) Horizontal Transportation Sub-System

This sub-system response for the container transportation between apron and yard by using internal trailer.

(6) Berth Sub-System

Finish handling work of the ship.

(7) Ship Sub-System

Ship generation, ship arrival, berthing and unberthing, and import and export container generation

(8) Terminal Management Sub-System

According to the generated ship and container volume, make arrangement for berth storing position, machinery scheduling, and plan of container collection and delivery.

3.5 An Object-Oriented Approach to Model the Inland Container Terminal Logistics System

In Object-based world, all of the physical and conceptual entities are seen as targets, each object by a group of attributes and activities pose. Attribute is description for static characteristics of object, and activity is description for an operating sequence of dynamic features of object. It allows object manipulation or update state and contact with other objects.

Object-oriented model take advantages in the following two aspects than analytical model:

(1)Modulized

Independence of object allows model changing without change the structure of the model, for example, target add/ delete;

(2)Class attributes

Building models under diverse degrees of abstract, for example, yard and container regions, it make the model developers can built the model with close and high level of abstract first, and then construct the model with lower level of abstract step by step.

For modeling purposes, each entity were constructed into an object, object characteristics are similar with the reality entities. Using class can deal with the complexity. Because that it provides a unified description for all objects belongs to this class. The autonomy of objects is realized by allows objects contact with each other by messages only.

Reasons for inland container terminal logistics system using object-oriented methodology are[20]:

(1) Correspondence between physical entity and object

Between model entities and system entities, we can establish the one-to-one relationship. For example, for the correspondence between the model elements and physical components make modeling process more intuitive and easier to understand.

(2) Correspondence between level in system and level in model

This clear expression of levels is very important to solve the control problem. Moreover, these levels can be easily completed by classification. Hierarchical modeling has advantages of that it can displayed and control system model under different abstract extent.

3.5.1 Object Diagram of the Inland Container Terminal Logistics System Model

Through the analysis of inland container terminal logistics system and its subsystem, we can find the logistics objects which are SCC, RTG, driveway, internal trailer, external trailer, container yard, berth, gateway, ship and container.

The relationship between vehicle and internal and external trailer is generalization – specialization structure. According to the same principle, the relationships between tracks and driveway, among machines, RTG, SCC, and gateway, among buffers, gateway, berth, yard and ship, parts among ship and container are also generalization - specialization structure.

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20 J. J. Black, O. O. Mejabi, *Simulation of complex manufacturing equipment reliability using object oriented methods*, Reliability Engineering and System Safety 48 (1995), pp. 11-18.

And generally, the relationships among driveway, external driveway and internal driveway, among yard, import container region and export container region, among gateway, exist and entrance, among container, import container and export container are whole - part structure.

3.5.2 Characteristic Diagram of the Inland Container Terminal Logistics System Model

Attributes and activities of objects describe the object itself. In table 3-1, it shows the attributes and activities of objects in this system model. Attributes of object describe both of dynamic and static activities and aftereffect after activities. An attribute is a certain value own by each object in a same class. To simulation needs, we must add some specific and unique attributes to some certain objects. For example, container needs to add the attribute “In - Out” to indicate that it is export or import container. And attribute "destination" here is point out the position where this container would be hauled by trailer.

Table 3-1 attributes and activities of logistics objects of inland container terminal

Class	Object	Attribute	Activity
Machines	SCC	Speed, Productivity, Operational Type, Working State, Failure Rate	Loading, Discharging, Maintenance, Driving, Waiting
	RTG	Speed, Productivity, Operational Type, Working State, Failure Rate	Loading, Discharging, Maintenance, Driving, Waiting
Buffers	Gateway	Enter, Leave, Service Time, Occupancy Condition	Checking, Waiting
	Yard	Storing Volume, Occupancy Rate, Occupancy Condition, Working State	
	Anchorage	Number of Berthing Ships, Occupancy Condition	
	Berth	Occupancy Condition	
Parts	Ship	Type, Handling Volume, Mode of Operation	Generating, Waiting, Berthing, Unberthing
	Container	Import Container, Export Container, Empty Container, Full Container, Size	Generating, Loading, Discharging, Storing, Transit
Vehicle	Internal Trailer	Speed, Working State, Failure Rate	Maintenance, Driving, Waiting
	External Trailer	Speed, Working State, Failure Rate	Maintenance, Driving, Waiting
Route	Driveway	Direction, Max Driving Speed, Max Number of Vehicles	

3.5.3 Relationship Diagram of the Inland Container Terminal Logistics System Model

The connection sketch map of all logistics objects of inland container terminal above are shown in figure 3-7.

Container may exist in vessel, SCC, RTG, internal trailer, external trailer, even in the yard. For instance, there is one-to-more instance connection relationship between the two objects external trailer and gateway, which means a gateway might serve more than one external trailers, but one external trailer can be served by only one gateway. In addition, there is more-to-more instance connection relationship between ship and SCC, one ship might handle by more than one SCC, and one SCC can handle more than one ships.

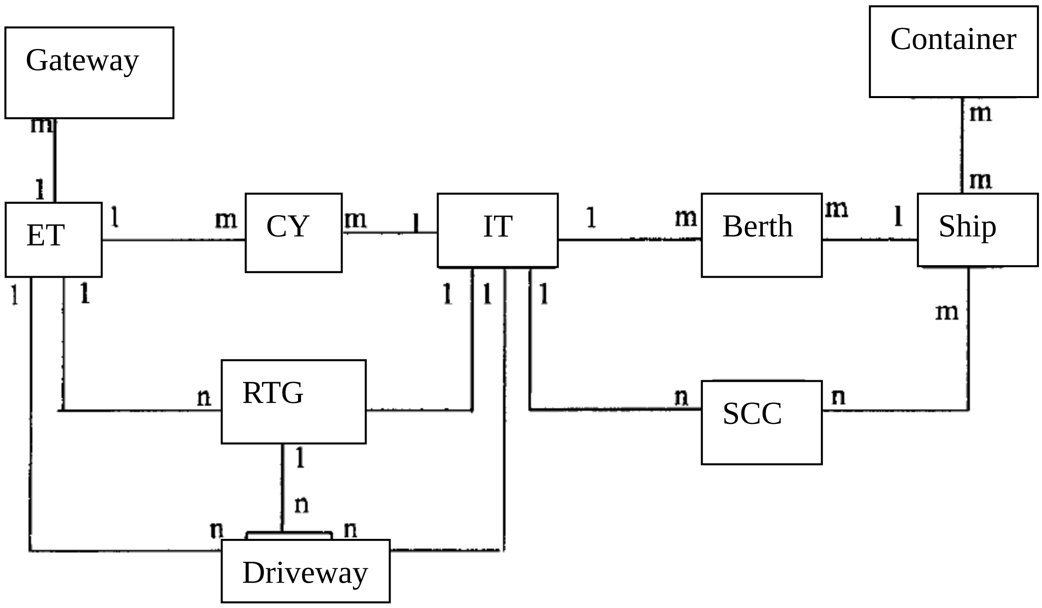

Figure 3-7 Instances connection sketch map of inland container terminal logistics system model

These objects above achieve dynamic links between themselves by message inter-sending. They make the system to becoming a dynamic whole. Vessel object is the driving energy for the whole system, and activities of other objects are all introduced by it. For example, the vessel object sending message to container object, then the container object implement the generate activity; the vessel sending message to SCC object, then the SCC object the implement loading and discharging activities.

Chapter 4

Simulation Model about Inland Container Terminal Logistics System Based on EXTEND

4.1 Simulation Target and Strategy of Simulation Model

4.1.1 Simulation Target

The study on simulation of the inland container terminal logistics system is aimed to analysis the performance of the port during the tasks, including loading and unloading, transport, storage etc., and help the decision-maker to improve the planning and management level of the port. The main issues concerned are: the relationship between the quantity and the through ability of the facilities, the balance between utilization of berth capacity and ships in port time, the relationship between quantity and utilization of equipment capacity, the comparison and optimization of the mechanical scheduling plans, the relationship among storage strategy, utilization of capacity and through ability of storage field, the optimization of the machinery quantity, the relationship between driveway amount of passageway and throughput, etc..[21]

The target of this simulation model is to optimize the mechanical configuration and scheduling in the entire inland river container terminal, shorten ships in port time to

21 R. L. Ward, W .V. Huang, *Simulation with Object-Oriented Programming*, Computers and Industrial Engineering 23(1-4)(1992), pp. 219-222

improve port competitiveness using the existing resources.

4.1.2 Simulation Strategy

Simulation strategy, as the core of simulation model, reflects the nature of simulation model. It decides the structure of simulation model fundamentally. When the simulation is running, the event controller implements the next event and supervises the object to update its state. Each object changes its state and update time through the state transition network. This mechanism is able to support the modelling from a simple buffer to a complex machine (e.g.: SCC, RTG) and show animation and result at the appointed time.

4.2 Structure of Simulation Model

4.2.1 To Simplify and Abstract the Model

(1) The ship is composed of two parts: one is defined as workpiece in order to form the properties and distributions of the ship; another is defined as buffers in order to store the containers. The SCC is responsible for loading and unloading containers from internal trailer, therefore it composed of two parts as well: one is defined as machine, which is used to loading and unloading the ship; another is defined as buffer, which is used to store the containers in SCC.

(2) The model assumed the scheduling of RTG as the ideal condition, namely, it can always be loaded or unloaded when the trailer reaches the storage field and the time of loading or unloading is the work cycle time defined by RTG.

(3) The model does not consider the influence of 45' containers, fridge-freezer, open containers, over height containers and other special containers.

(4) It ignores the operation of storage, shifting and turning containers in the storage field.

4.2.2 Elements of Simulation Model

To transfer the objects in system model into the elements in simulation model, it has to create the elements in simulation model. It includes three steps: defining elements, displaying elements and detailing elements.

(1) Defining Elements

Defining elements is mainly about determining which type the element belongs to and what the name is. According to the attributes and activities of the objects in system model mentioned above, the elements can be defined as follows:

Parts -- Container;

Parts and Buffers --Vessel;

Buffers and Machines -- Gateway;

Buffers -- Berth, Yard, Container Zone, Anchorage;

Tracks -- Lane;

Machines and Buffers -- SCC, RTG;

Vehicles -- Internal Trailer, External Trailer;

Attributes -- Name, Size, the Volume of Import and Export Containers, Operation Mode of the Ship, Arrival Time of Ship, the time of ship begin to work, Size of Container, Attributes of Container;

Variables -- Average Interval of Ship Arrival, Time of Container Collection by Ship, Ship Berthing per Ship Times, Time of Ship Stay in Terminal, Operating Time of Vessel, Working Time of SCC, Working Time of RTG, Speed of Trailer, Quantity of Trailer, Quantity of Container in each Container Yard, Time of Passing Gate, Proportion of Ship Size, Proportion of Container Size.

(2) Displaying Elements

EXTEND provides real-time animation simulation, which is helpful for system confirmation. It is because the confirmation of system including the correction of the system recognition behavior (from system input to its operation logic), which maintain certain degree of accuracy.[22]

EXTEND provides the library and external graphics file input port, so that users can draw pictures or choose photos by their own in terms of the external properties of elements and import them into the library. In addition, EXTEND provides the layer to display elements hence users can put elements in different layers in terms of the need. The unneeded layer can thereby be either closed or frozen during debug process to hide the elements belong to the layer. On the other hand, the SCC will not be covered by the ships or internal trailer, because that if the model displays the platform of the inland terminal, the SCC layer should above the layer of both ship and internal trailer.

(3) Detailing Elements

Detailing elements is the third step and Figure 4-1 presents an interface of detailing vehicle – internal and external trailers. To enable the model to reflect the actual situation of the problem studied, the user has to provide the information that what does every element will do and how the accessories and vehicles transported between elements, that is, connect elements.

22 Won Young Yun, Yong Seok Choi, A simulation model for Container-Terminal Operation Analysis using an Object-Oriented Approach, Int. J. *Production Economics* 59(1999), pp. 221- 230

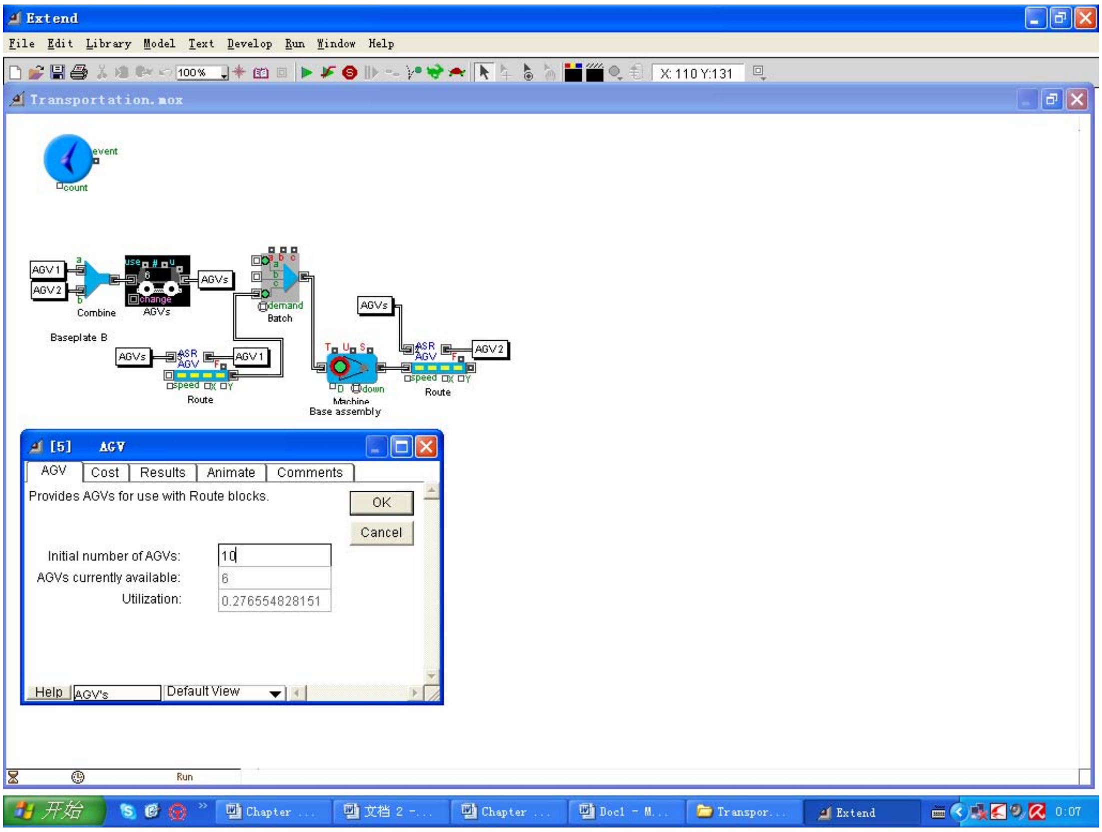

Figure 4-1 Detailing Elements—Vehicle (Internal & External Trailers)

4.2.3 Sub-Modules of Simulation Model

As we discussing in chapter 3, the inland container terminal logistics system contains 8 sub systems, including: external trailer, gate, container yard, road, berth, vessel, horizontal transportation and terminal management. According to these sub systems, the model in this paper consists of the following 9 modules which are shown in figure 4-5.

(1) Sub-Module of External Trailer

Numbers of clients can deliver or pick up containers at same time. According to the work plan, appoint external trailers to haul containers to the designated container yard or to go to the designated area to pick up containers.

(2)Sub-Module of Gate

To set the numbers of import and export gateway lanes completed document verification, container inspection and other functions.

(3) Sub-Module of Yard

Zoning management is based on the attributes and the types of import and export Container, it can setting the numbers of RTG and its performance parameters, and also can set the size of the container zone and layers of stacking. Containers for shipment are stacking in different areas by different destination port, tons, container sizes and customers. According to different size of ships and handling volume, make arrangement and implementation of yard working plan, and following some certain strategies, make scheduling operation for RTG and internal trailers.

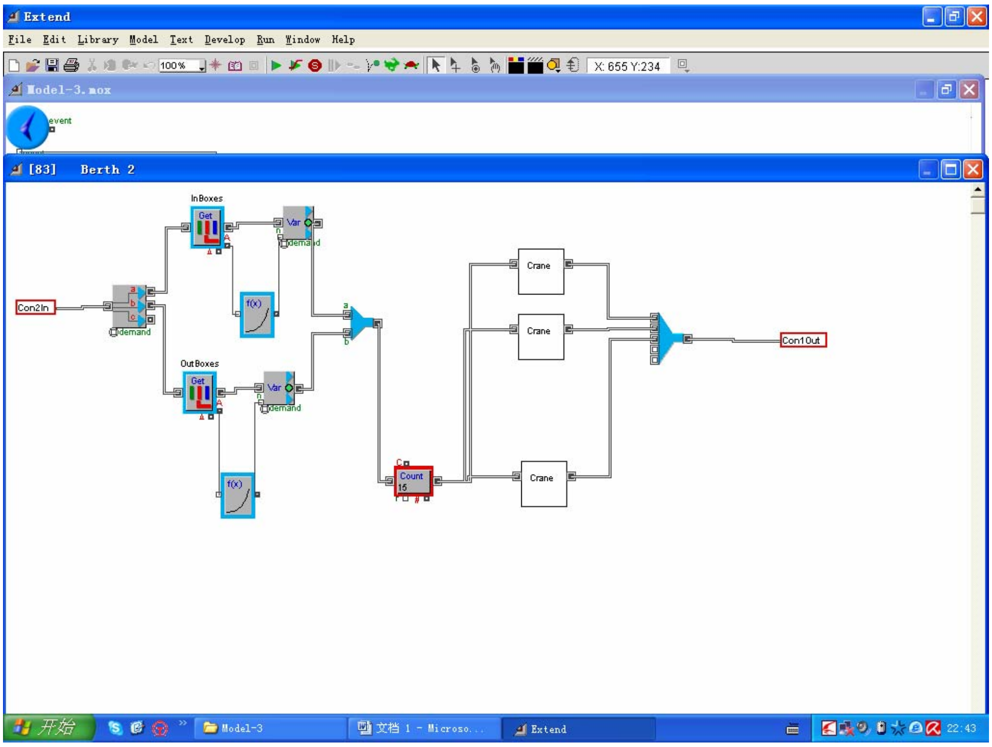

Figure 4-2 Sub-Module of Yard

(4) Sub-Module of Lane

Identify the number of lanes, parking signs, regulate directions of traffic, and the highest speed, and manage the internal trailers, external trailers and lanes respectively.

(5) Sub-Module of Berth

Make arrangements and the implementation for handling plan and setting the number of SCC and its performance parameters. According to different ships and volume of containers, and based on some certain strategies, do scheduling for operation of SCC and internal trailers.

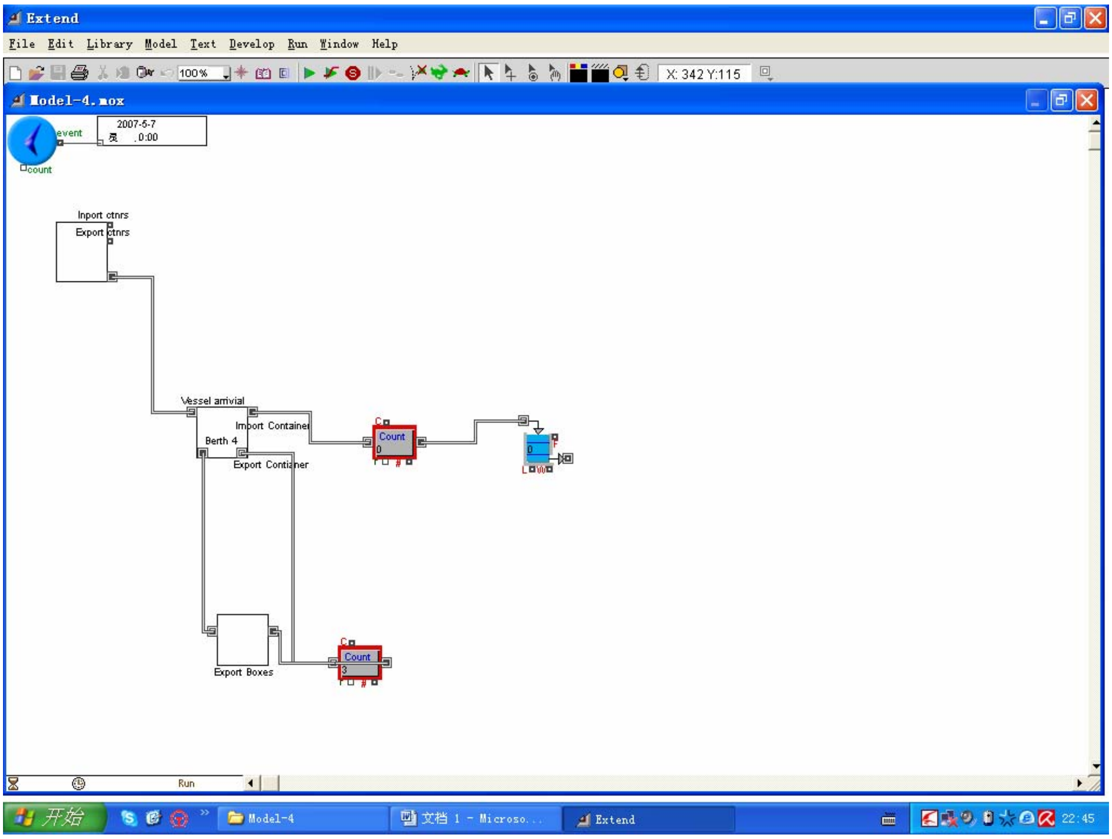

Figure 4-3 Sub-Module of Berth

(6) Sub-Module of Horizontal Transportation

According to the working plan, the internal trailers have to haul export containers from the yard to the front of terminal or hauling import boxes from the front of terminal to the yard.

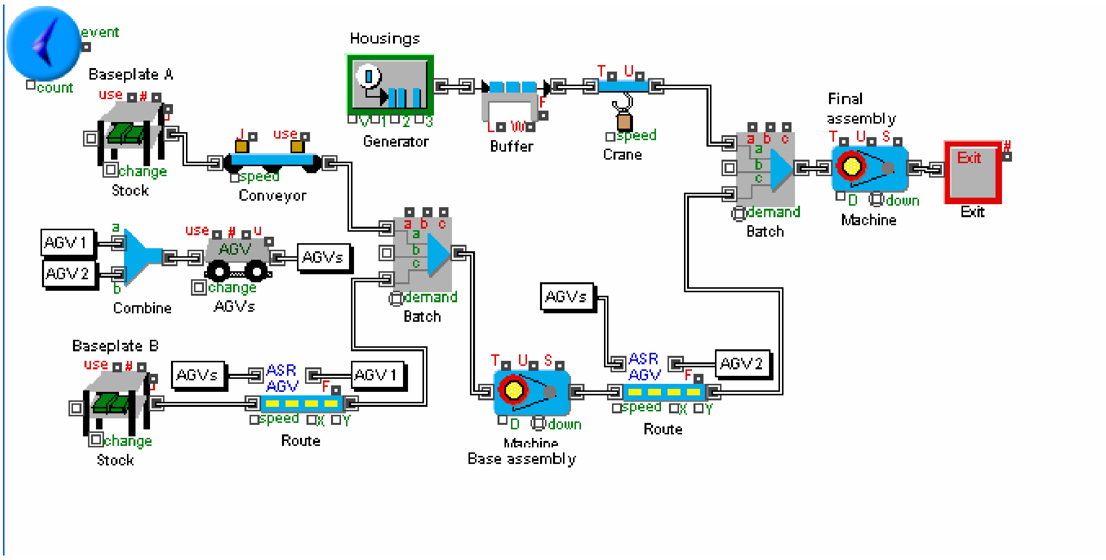

Figure 4-4 Sub-Module of Horizontal Transportation

(7) Sub-Module of Ship Generation

Both of vessels and containers are generated by a certain distribution mode. And the size of vessel, volume of container, container size, even the operating mode of the ship also generated by following some statistical rules.

(8) Sub- Module of Plan the Operation in Terminal

According to the generated ships and volume of container, make arrangement for berth and stacking positions for different clients, different types of import and export containers.

(9) Sub-Module of Performance Parameters Statistics

To Statistic the throughput, lifting equipment utilization, berth utilization, yard utilization, time of the ship stay in terminal, waiting time of ship in terminal, capability of the ship, operational capability of machinery, the waiting time of external trailer in terminal, operating costs of terminal, accessibility of gateway, the utilization rate of internal trailer, density of traffic within terminal.

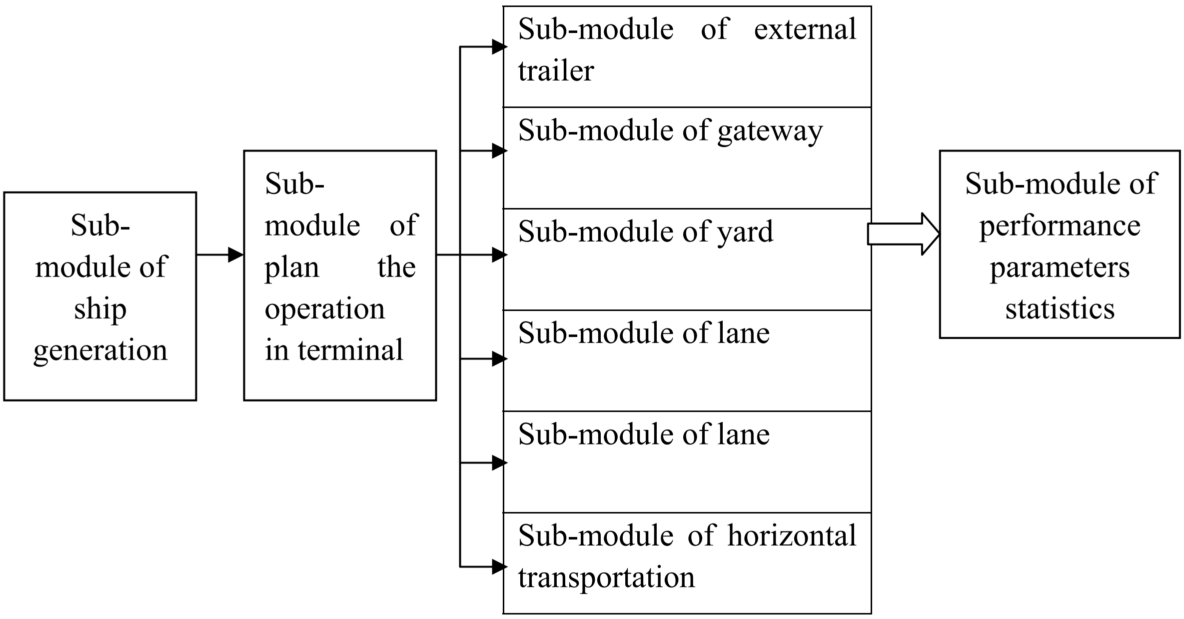

Figure 4-5 Structure of the Simulation Model

The whole simulation model is shown as figure 4-6 below.

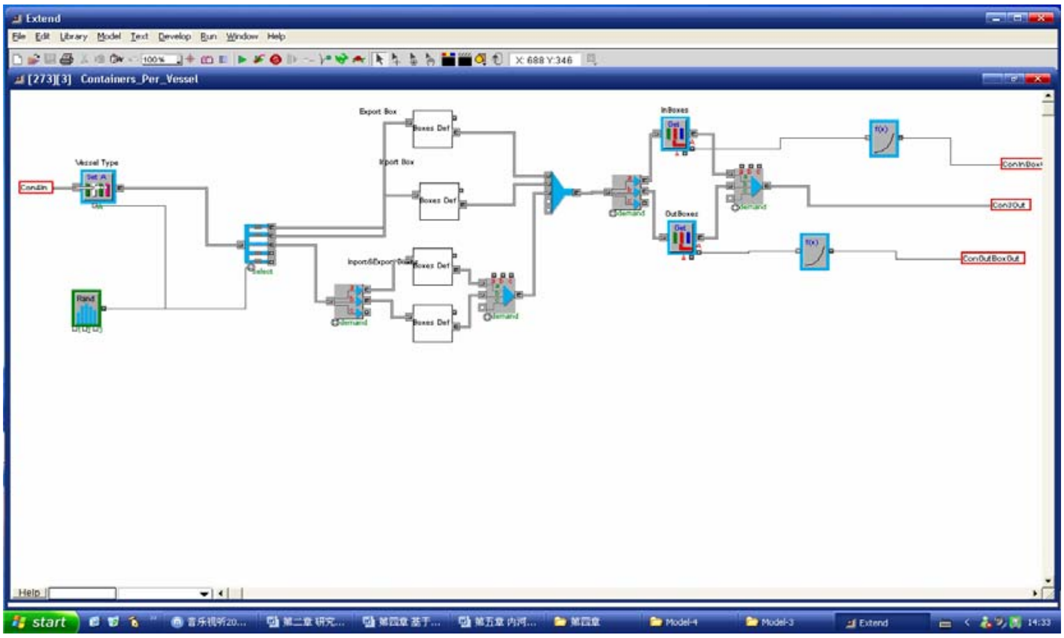

Figure 4-6 Inland Container Terminal Simulation Model

4.3 Implementation of Simulation Model

4.3.1 Random Event Distribution of Simulation Model

The logistics system of inland river container terminal has many sections, therefore its implement is affected by lots of stochastic factors, including ship arrive time and its throughput, ship arrive/departure and its preparation time, the efficiency of loading and unloading machine and its maintenance rate, the time of external trailer enter in and collect the containers, the time of trailer pass through the main gate, etc.. It is unrealistic and unnecessary to consider all the stochastic factors. Through analyzing the principle of inland container terminal activities, the mainly stochastic events are[23]:

(1) Stochastic distribution of ships arrival interval

[23] Zhen Hong (1999), *Port Production Scheduling Process Optimization*. Shanghai: Shanghai Science and Technology Literature Press.

Abundance of abroad statistics shows that the most of the ship arrival obey Poisson's distribution[24]. The probability of n ships arrivals in time t is shown in equation 4-1:

$$P_n(t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad n = 0, 1, \cdots \qquad \text{(Equation 4-1)}$$

The letter λ in this equation mean the average number of ships arrive at terminal during unit period.

Let the arrival moment of the is τi（i=1,2,……），τ0=0，and make τi=τi-τi-1. τi, the arrival interval of the ship is independent of each other, and with same distribution. Its distribution is negative exponential distribution[25]，and shown as equation 4-2：

$$A_0(t) = P\{T \ge t\} = \begin{cases} e^{-\lambda t}, & t > 0 \\ 1, & t \le 0 \end{cases} \qquad \text{(Equation 4-2)}$$

In this equation, λ=1/T, and the mathematic expectation and variance of T are shown as equation 4-3:

$$E[T] = \frac{1}{\lambda}, \quad \mathrm{var}[T] = \frac{1}{\lambda^2} \qquad \text{(Equation 4-3)}$$

24 Gu Qitai(1999),*Discrete System Modeling and Simulation*, Beijing:Tsinghua University Press.
25 Lu Ziai, Lin Minbiao (1999). On Numerical Simulation of Port Service System[J]. *Journal of Hohai University (Natural Sciences)* Vol 27(3), pp.17-21.

According to the data of an actual inland container terminal, the parameter of ship arrival interval distribution is λ= 240mins.

(2) Stochastic distribution of arrived ship type and throughput

The throughput of the arrived ship is different. However, the distribution of throughput is not continuous, but gathers around several discrete values decided by the type of ship. For the ships berth in CTS, container handling volume of ship (TEU) distribution is the normal distribution and its probability is shown as equation 4-4.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2} \quad 0 < x < \infty \qquad \text{(Equation 4-4)}$$

In this equation， μ and σ on behalf of the mean and variance of volume x . Probability distribution function of handling volume is shown as equation 4-5：

$$F(x) = P\{X \le x\} = \int_0^x \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2} dx \quad 0 < x < \infty \qquad \text{(Equation 4-5)}$$

According to the data of CTS, the statistics on the mean μ and the variance σ for proportion of different types of ships and handling volume of are shown as following:

Export	Ship size 1	μ=28, σ=6	take up 30%
	Ship size 2	μ=56, σ= 12	take up 50%
	Ship size 3	μ=112, σ=24	take up 20%

Import	Ship Size 1	μ=18, σ=6	take up 30%
	Ship Size 2	μ=36, σ=12	take up 50%
	Ship Size 3	μ=72, σ=24	take up 20%

Therefore, exports or imports volume of ships within the scope [μ - σ, μ + σ].

(3) Stochastic distribution of arrived ships' assignment (loading, unloading or both)

The mainly operations for container ships in port are unloading only, loading only and loading after unloading. The operation used for a specific arrived ship is a stochastic event. It is a discrete type of binomial distribution in terms of the character of distribution. After analyze the information of CTS arrived ships, the distribution of arrived ship operation modes are:

Loading	take up 10%
Discharging	take up 10%
Both (Loading + Discharging)	take up 80%

(4) Working time of SCC and RTG

According to CTS information, the handling time of SCC obeys the normal distribution, i.e., the average time and variance for handling a container are:

$$\mu=3\text{mins}，\sigma=0.19$$

The loading and unloading time of RTG obey Erlang Distribution, i.e., the average time and order for loading or unloading one container are[26]:

$$m=2.1\text{mins}，k=2$$

(5) Time of passing gateway

According to CTS information, the time pass through the main gate obey the normal distribution, i.e., the maximum and minimum time needed for service a container truck are:

26 E.Kozan. Optimising Container Transfers at Multimodal Terminals. *Mathematics and Computer Modeling* 31 (2000) pp.235-243

Min=1min，Max=2mins

4.3.2 Parameters Input

This model is a simplified model based on CTS of an actual inland container terminal. Cargo handling in this terminal is adapt RTG system, SCC response for loading and discharging, if ship, RTG response for loading, discharging and stacking work in yard, and the horizontal transportation from apron to yard and within yard is by internal trailer.

Terminal has 3 berths in total, depth of No. 1 and No. 2 berth are two meters, depth of berth No.3 is 2.5 meters. Each berth has 3 container regions，2 export container regions in front and 1 import container region in the wings. The five berths share 2 van pools. Apron outfit with 1 SCC, the yard outfit with 2 RTG, and the whole terminal owned 6 internal trailers. The gateway of terminal with 3 entrance routes and 2 exit routes.

The main facilities and equipment parameters of the terminal are shown in table 4-1, table 4-2 and table 4-3. And other parameters are shown in table 4-4.

Table 4-1 Parameters of Establishments in Terminal

<table>
<tr><th colspan="2">Gateway Parameters</th><th colspan="2">Yard Parameters</th></tr>
<tr><td>Entrance Route</td><td>3</td><td>Export Container Region</td><td>6</td></tr>
<tr><td>Exit Route</td><td>2</td><td>Import Container Region</td><td>3</td></tr>
<tr><td>Gateway Serving Time（min）</td><td>UN（1，2）</td><td>Van Pool</td><td>2</td></tr>
<tr><td colspan="2"></td><td>Capacity of Each Container Region（TEU）</td><td>25*4*6</td></tr>
</table>

Source: *annual report of 2006*, water transport department in ministry of communications

Table 4-2 Berth Parameters of the Terminal

Berth Parameters	1#	2#	3#
Coastline Length（m）	196	167	194.4
Berth Bathymetric（m）	2	2	2.5
Arrival Interval of Ships（min）	Exp(240)		

Source: *annual report of 2006*, water transport department in ministry of communications

Table 4-3 Parameters of Facilities in Terminal

Basic Attribute	RTG	SCC	Internal Trailer	External Trailer
Speed(kilometer/hour)	8.04	2.7	20（full） 28（empty）	20（full） 28（empty）
Working Time（min）	Erlang(1.5,2)	Normal(3,0.19)		
Quantity of Equipment（unit）	2	1	6	unlimited
Traffic Direction	two-way	two-way	one-way	one-way

Source: *annual report of 2006*, water transport department in ministry of communications

Table 4-4 Parameters of Simulation Model Input

Parameters		Input Value
	Waiting by Ship & Container	
Time for Container Collection by Medium and Small Types of Ship	Sea_time1	1*24*60mins
Time for Container Collection by Large Ship	Sea_time2	2*24*60mins
Time of Berthing and Preparation Working	Jetty_time1	60mins
Time of Unberthing and Prepare for Unberting	Jetty_time2	30mins
Storing Time of Import Yard	CYI_time	6*24*60mins
Storing Time of Van Pool	CYempty_time	10*24*60mins
	Distribution of Ship Size	

Small Size	Ratio_Ssize(1)	30%
Medium Size	Ratio_Ssize(2)	50%
Large Size	Ratio_Ssize(3)	20%
	Distribution of Mode of Ship Operation	
Loading &Discharging	Ratio_Sio(1)	80%
Only Discharging	Ratio_Sio(2)	10%
Only Loading	Ratio_Sio(3)	10%
	Average container Volume of each type of Ship handling	
Discharging Volume by Small Ship	Mean_Si(1)	18 TEU
Discharging Volume by Medium Ship	Mean_Si(2)	36 TEU
Discharging Volume by Large Ship	Mean_Si(3)	72 TEU
Loading Volume by Small Ship	Mean_So(1)	28 TEU
Loading Volume by Medium Ship	Mean_So(2)	56 TEU
Loading Volume by Large Ship	Mean_So(3)	112 TEU
	Standard Deviation of Container Volume of Each Type of Ship Handling	
Small Ship Discharging	SD_Si(1)	6 TEU

Medium Ship Discharging	SD_Si(2)	12 TEU
Large Ship Discharging	SD_Si(3)	24 TEU
Small Ship Loading	SD_So(1)	6 TEU
Medium Ship Loading	SD_So(2)	12 TEU
Large Ship Loading	SD_So(3)	24 TEU
	Berth Choice	
Ceiling for Handling Volume of Berth No.1	berth_sio(1)	76TEU/ship
Low Limit for Handling Volume of Berth No.2	berth_sio(2)	184TEU/ship

Source: *annual report of 2006*, water transport department in ministry of communications

4.3.3 Results output

The operation performance indicators adopted in this simulation experiment are: the berth occupancy rate, the yard occupancy rate, SCC utilization rate, RTG utilization rate, utilization of both internal and external trailers and the average waiting time of ships.

Berth occupancy rate reflect demand for berth, which is the ratio of berth occupied time and the total simulation time, as shown in equation 4-6.

$$\text{Berth Occupancy} = \frac{\text{Engross Time}}{\text{Total Simulate Time}} \qquad \text{(Equation 4-6)}$$

Yard occupancy rate reflect demand for storage field capacity, which is the ratio of stored containers and the total storage capacity, as shown in equation 4-7.

$$\text{Yard Occupancy} = \frac{\text{Stacking Volume in Unit Time}}{\text{Total Storing Capacity}} \qquad \text{(Equation 4-7)}$$

The operation time of both SCC and RTG can be divided into waiting time, idle time running time and working time (i.e. loading and unloading time). Internal trailer and external trailer have running time, idle time and waiting time, neglecting their working time. The utilization of capacity formulas are thereby indicated by equation 4-8 and 4-9 respectively:

$$\text{Utilization of SCC and RTG} = \frac{\text{Walking Time + Working Time}}{\text{Walking + Waiting Time + Leisure Time + Working Time}}$$

(Equation 4-8)

$$\text{Internal Trailer Utilization} = \frac{\text{Walking Time}}{\text{Walking Time + Waiting Time + Leisure Time}}$$

(Equation 4-9)

The total waiting time for each ship is the summation of the time waiting for berth and the time waiting for loading or unloading operation. Therefore, average waiting time for ships is the ratio of the total waiting time for all ships and the number of ships, as shown in equation 4-10.

$$\text{Average Waiting Time of Ship} = \frac{\text{Total Waiting Time of all Ships}}{\text{Number of Berthing Ships}} \quad \text{(Equation 4-10)}$$

Similarly, the average total time of ships in terminal is shown in equation 4-11:

$$\text{Average Total Time in Terminal of Ship} = \frac{\text{Total Time in Terminal of all Ships}}{\text{Number of Berthing Ships}} \quad \text{(Equation 4-11)}$$

The simulation test is implement by running EXTEND program. Before take records of simulation results, preheat for 10 days, and the time for each simulation is 20 days. A series of figures which means arrival time of ships and working time of equipment are generated by computer randomly. The whole simulation contains five-time separate experiments, and the simulation results were shown in table 4-5.

Table 4-5 System Simulation Results

	Berth 1	Berth 2	Berth 3	Berth 1~ berth 3
Average Waiting Time of Ship (min)	2.7	2.3	1.9	1.9
Average Working Time of Ship(min)	7.6	6	5.2	7.2
Berth Utilization Rate（%）	57	53	47	51.6
Yard Utilization Rate（%）	43	50	49	46.6
SCC Utilization Rate（%）	66.8	70.1	69.2	67.3
RTG Utilization Rate（%）	24.9	22.6	23.5	27.9
Internal Trailer Utilization Rate（%）	26.5	26.3	25.9	25.4

From the table 4-5 above, we can see that the occupancy rate of berth No.3 is lower than average value. Because that the small and medium-sized vessels were priority calling at berth No.1 and No.2. The low yard occupancy means yard capacity can meet the current throughput. Utilization rate of SCC is 67.3%, and the utilization rate of RTG is only 27.9 %, which show that there are too many RTG owned by the terminal currently.

Chapter 5

Verification and Application of Inland Container Terminal Logistics System Simulation Model

5.1 Verification of Simulation Model

To validate the simulation model can accurately reflect reality of inland container terminal operation or not is the most important issue in this simulation. Because that both of inland container terminal operation and system simulation are random, the statistical characteristics output by real system will be same as the output by simulation system. Comparison of historical data use in this model and simulation results are shown in the table 5-1.

And from the figure 5-1 below, we can see that simulated value of SCC usage rate is a little higher than the value in real operation. This is because the simulation model does not take the maximum number of SCC allowed by a ship into account. Meanwhile, simulated value of RTG usage rate is slightly lower than the actual value. Because that the terminal did not use all of RTG in the yard. Decrease in utilization of SCC also led to the growth of utilization of internal trailer. However, the simulated and actual value is basically same. Therefore, it can confirm that using this model to evaluate the performance of inland container terminal logistics system is reliable.

Table 5-1 Comparison of historical data and simulation results

	Historical data (%)	Simulation Results (%)	Error （%）
Berth Occupancy Rate	51	51.6	0.6
Yard Occupancy Rate	47.3	46.6	0.7
SCC Utilization Rate	60	67.3	7.3
RTG Utilization Rate	32	27.9	4.1
Internal Trailer Utilization	22	25.4	3.4

Source: historical data here is comes from *annual report of 2006*, water transport department in ministry of communications

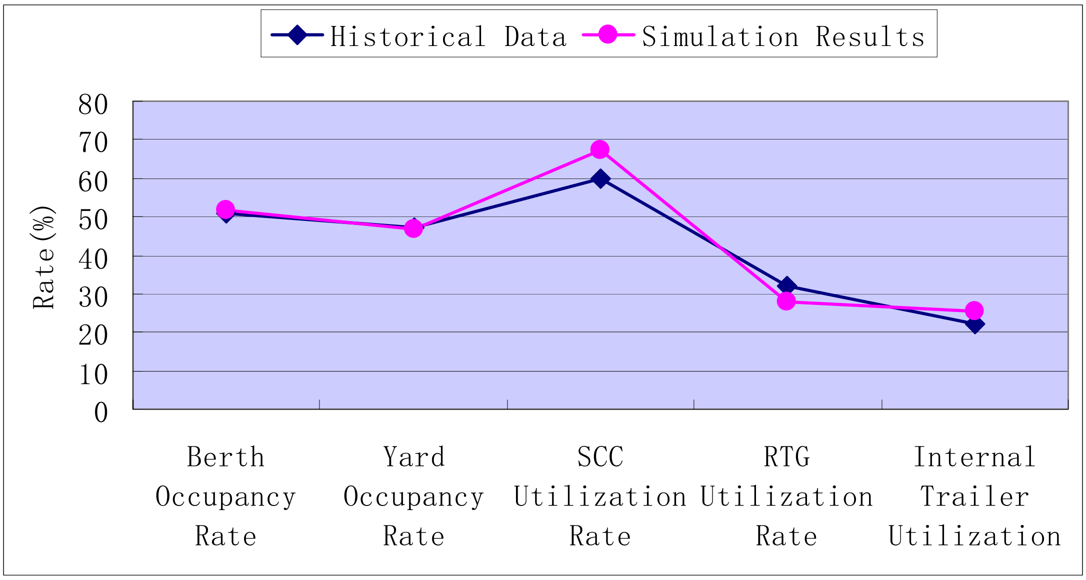

Figure 5-1 Comparison of historical data and simulation results

5.2 Application of Simulation Model

The simulation model could optimal facilities deployment and scheduling plan for whole inland container terminal with theses existing resources. And then reduce the total time of a ship stay in terminal and improve competitiveness for this terminal.

5.2.1 Machine Deployment Analysis

Operating mechanization of inland container terminal provided good condition for efficient handling in inland container terminal. In order to meet the needs of inland container terminal development, and to enhance capacity, the number of SCC, internal trailer and rubber typed gantry used in inland container terminal must be suitable. Therefore, it is very important to do a reasonable facility deployment for this inland container terminal.

Currently, there are 2 Rubber typed gantries, 1 SCC and 4 internal trailers working in this terminal. Different facilities deployment will bring different impacts on the average total time of a ship stay in terminal. Now, we will do the following simulations according three options.

(1) Keep the number of RTG and internal trailer and change the number of SCC;
(2) Keep the number of SCC and internal trailer and change the number of RTG;
(3) Keep the number of RTG and SCC and change the number of internal trailer.

Before take records of simulation results, preheat for 10 days, and the time for each simulation is 20 days. A series of figures which means arrival time of ships and working time of equipment are generated by computer randomly. The whole simulation contains five-time separate experiments, and the simulation results were shown in Figure 5 -2.

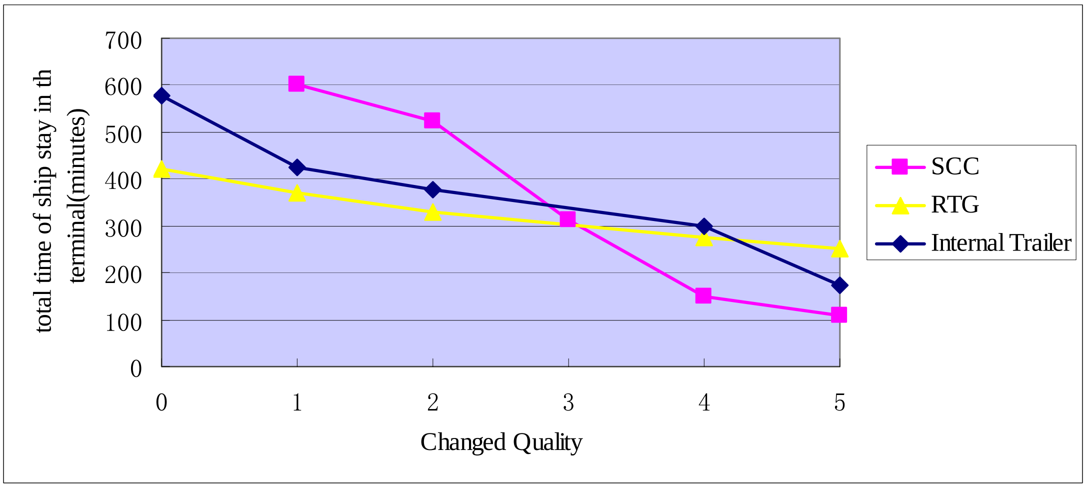

Figure 5-2 Total time of ship stay in the terminal under different equipment deployments

From the figure 5-2 shown above, change the number of SCC brought tremendous impact on the total time in terminal of ships. And internal trailer and RTG are in the next place.

For the current situation, increase the number of SCC from 1 to 2 can reduce the total time in terminal of ships obviously, which is about 150 minutes. And reduce the number of SCC is merely increase the total time in terminal of ships by a very short time. So deploy less RTG might be more economical for this inland container terminal.

Another deployment analysis is to keep the two SCC steadily and change the numbers of RTG and internal trailer. Here are the two simulation projects.

(1) Keep the number of RTG, and change the number of internal trailer;

(2) Keep the number of internal trailer, and change the number of RTG.

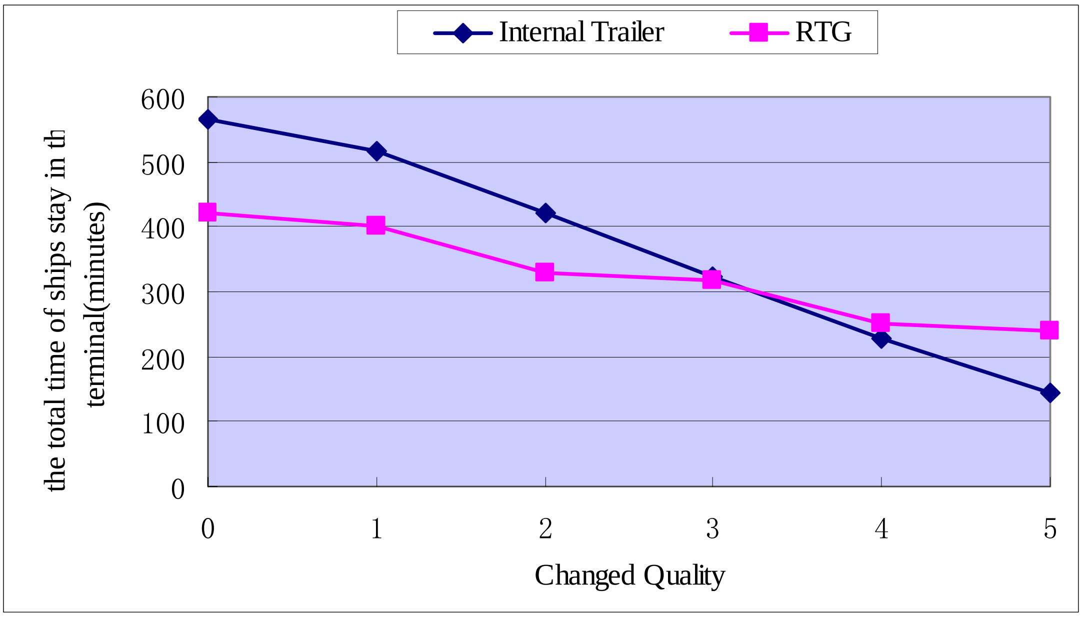

Figure 5-3 Total time in terminal of a ship when the number of SCC is fixed up and the number of RTG and internal trailer are keeping changing.

From the figure5-3, the number of RTG can be decreased properly because that it did not bring such heavier impact on the total time in terminal of ships. Meanwhile, this reduction can cover the cost which is invested in purchasing lots of SCC. Certainly, before making any decisions, we must do an analysis about cost and profits. For instance, we have to balance the money invested on purchase a new SCC and its operation cost, even the further maintenance fee with the profits get from increased cargo handling speed in details.

5.2.2 Scheduling Analysis

The so-called "operation routes" is refers to a transport working line which is consist of corresponding level transport machinery and yard operation facilities to a SCC. In traditional mode, people usually gives fixed deployment such as labor and operating machinery for each working line. Because that they thought that this deployment is more easily to doing equipment management and financial assessment. However, fixed operating machinery with a certain working line is easily cause waste of resources. For example, a working line is inefficient with some reasons now. That means on this working line, there are so many trailers in the queue waiting. Maybe at the same time, other working lines are lack of internal trailers and lead to operation pause.

Let's introduce a new mode of operation, which is installed a wireless terminal on internal trailer to indicate its specific tasks, and all of the internal trailers are commanded by control room. The control room response for harmonize the progress of each working line, and send instructions by the wireless terminal, then, commanders on shore and machinery drivers will follow the instructions for specific operations. This new mode releases the original limitations completely. Thus, when a trailer hauled boxes from the container yard to one of the working lines for shipment, after the trailer finished it, then, the trailer becoming a free trailer. At that time, we can deploy this trailer to support another discharging working line by hauled those discharged containers into yard, thereby it reducing the void distance which is generated by empty trailer traveled. Meanwhile, the utilization rate of trailers is increased and it also accelerated the linkage of operations.

Keep other parameters unchanged, doing simulation followed by the two projects below. Before take records of simulation results, preheat for 10 days, and the time for each simulation is 20 days. A series of figures which means arrival time of ships and working time of equipment are generated by computer randomly. The whole simulation contains five-time separate experiments, and the simulation results were shown in figure 5 -4 and figure 5-5.

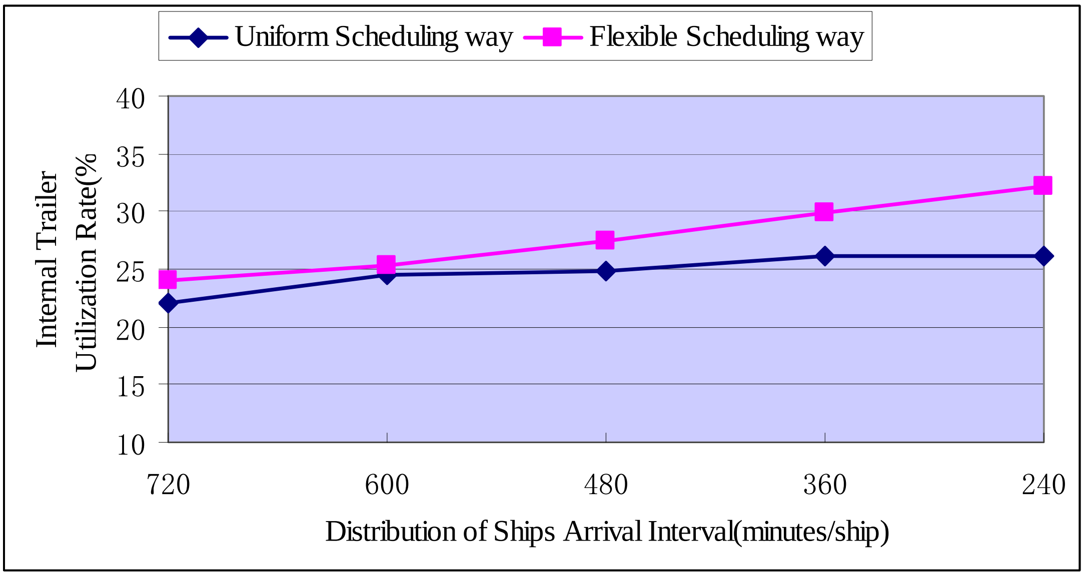

Figure 5-4 Internal trailer utilizations of two projects above under different ship arrival density

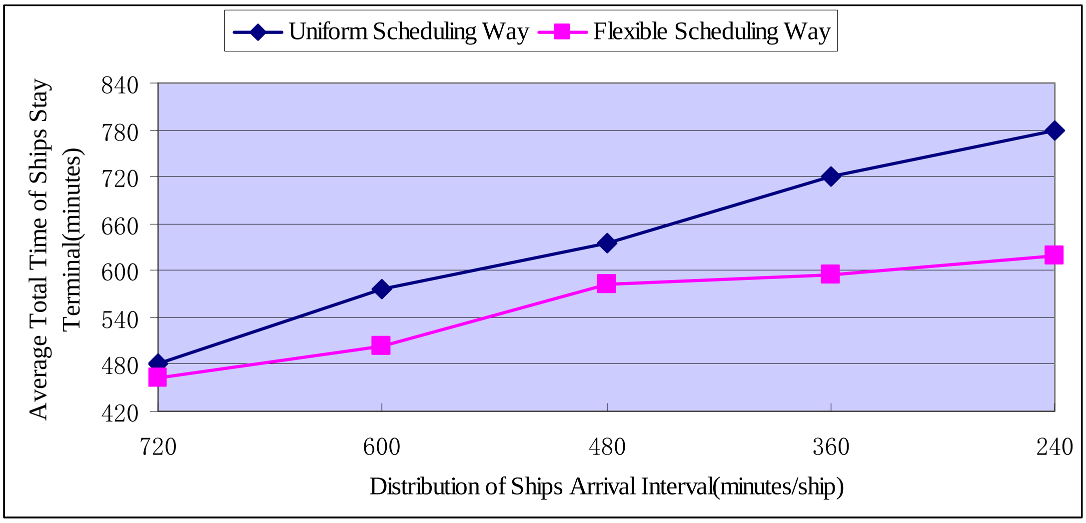

Figure 5-5 Average total time in terminal of ships for the two projects above under different ship arrival density

(1)Uniform Scheduling way

Under this scheduling way, the internal trailer and SCC always make a fixed arrangement which means that ratio of the number of internal trailer and the number of SCC is an integer.

(2)Flexible scheduling way

Under this scheduling way, during the simulation processes, the leisure internal trailer will be deployed to a working SCC to take part in the cargo handling automatically.

From the figure5-4 and figure 5-5, obviously, internal trailer utilization is more higher when we use flexible scheduling way, especially when ship arrival density keep increasing or with a high density of ships arrival, our ships spend relative shorter time in terminal than under the uniform scheduling way.

Chapter 6 Summary and Conclusion

6.1 Research Summary

This dissertation makes a relative complete research and lucubration on operational characteristics of inland container terminal and its scheduling situation, and combined with the basic theoretical principles of the object-oriented approach into practical application. On the basis of theoretical analysis, this paper finished a simulation of an inland container terminal logistics system by using professional simulation software which called EXTEND. It reveals some important internal relations between those elements within the inland container terminal logistics system. In the course of the study, we have done these following researches:

(1) To analyze the characteristics of discrete dynamic system in order to review the researches on the inland container terminal logistics system in some foreign countries and in domestic market, and to understand the different working processes and the attributes of the working environment by using object-oriented analysis to set up the modeling for the inland container terminal logistics system.

(2) Give an introduction about principles of select handling technology and the layout and operating characteristics of an inland container terminal, especially emphasis on the scheduling procedures and statistical indicators of an inland container terminal.

(3) After introducing some basic concept of the object-oriented method, combining with inland container terminal logistics system and its subsystems, also with the object-oriented modeling technology, simplified and decomposed the system.

(4) After introducing the specialty of the professional emulation software EXTEND, according to the specialty of inland container terminal operation and the emulational objective of the system and based on the actual operation data of the terminal, EXTEND was used to model and emulate the inland container terminal logistics system which has been reasonably simplified.

(5) The emulation modeling is using full size of the real container port to testify the reliability by analyzing whether the yard utilization and the outfit of the berth, SCC and the internal trailer is reasonable or not in order to point out the bottlenecks of the inland container port logistics system. Finally, this modeling provides the decision making function by using the analysis of equipped mechanism and equipment control of the inland container terminal.

According to the simulation result in chapter 5, we can get such research conclusions as:

(1) Using this model to evaluate the performance of inland container terminal logistics system is reliable.

(2) Changed the number of SCC brought tremendous impact on the total time in terminal of ships. And internal trailer and RTG are in the next place. And for the current situation, deploy less RTG might be more economical for this inland container terminal.

(3) The number of RTG can be decreased properly because that it did not bring such heavier impact on the total time in terminal of ships. Meanwhile, this reduction can cover the cost which is invested in purchasing lots of SCC. But we must do an analysis about cost and profits in details before making any decisions.

(4) Internal trailer utilization is much higher when we use flexible scheduling way, especially when ship arrival density keeps increasing or with a high density of ships arrival.

In the course of the study, according to the characteristics of this research problem, based on a careful analysis of all the previous research work, the paper put toward some suggestions for improvement which include those following points:

(1) Expand the use of object-oriented methods to establish inland container terminal logistics system model, solve a previous problem which is lack of description for both of the inland container terminal logistics system level and relationships among lots of elements.

(2) Take berth, SCC, RTG, especially the management of the yard and trailers, which are ignored in some other similar studies in a part of inland container terminal logistics system simulation model. This model considering mutual checks among every factor, lead to the reduction of the simulation error and the reliability of simulation results has been increased.

6.2 Outlook

Although some improvement has been gained in the field of emulation application of inland container terminal logistics system, due to the limited time, the complexity of practical application, the lack of familiarity of professional emulation software EXTEND and the superficial theoretical basis of the research objective, there exists many deficiencies in this paper which need further research in the future.

(1) The structure of this model which is based on object-oriented is not rigorous enough. In further research, we should try to overcome such vices as lack of effective method for both analysis and validation.

(2) The further research should pay attention on scheduling condition when gantry working on the yard and optimal assort with the gantry and external trailer. And the impacts of terminal traffic also have to be taken into account.

(3) Take an ulterior collection for the relevant data of inland container terminal. Such as maintenance rate of related machinery, the ship distribution and so on, try to make the model more realistic.

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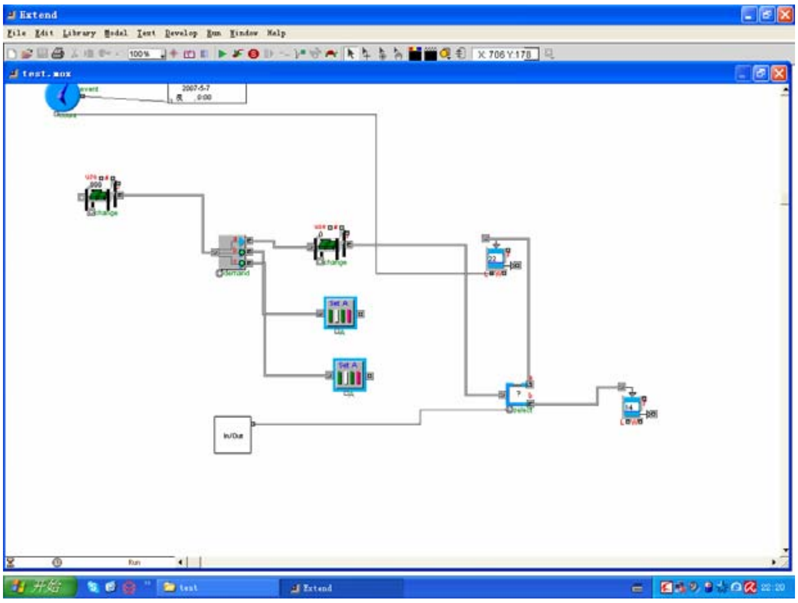
Appendices

The inland container terminal logistics simulation model implement by EXTEND.

(Screenshots from computer, 36 images in total)



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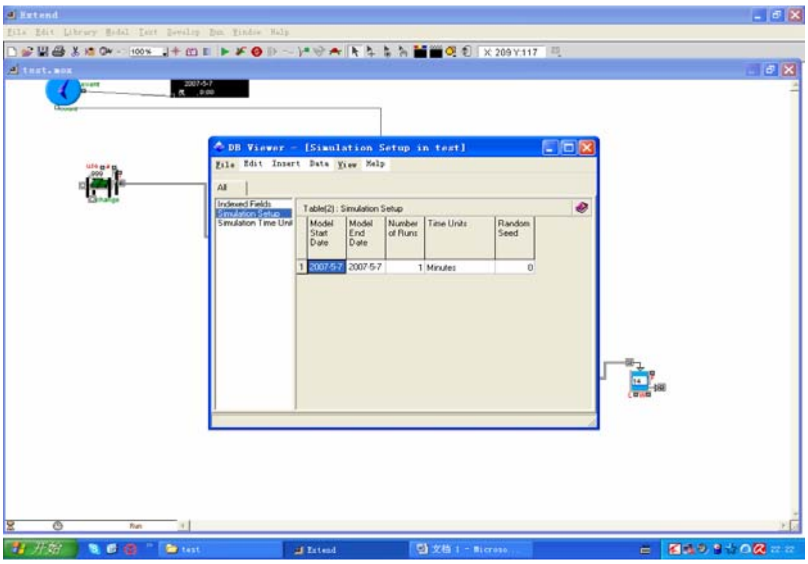
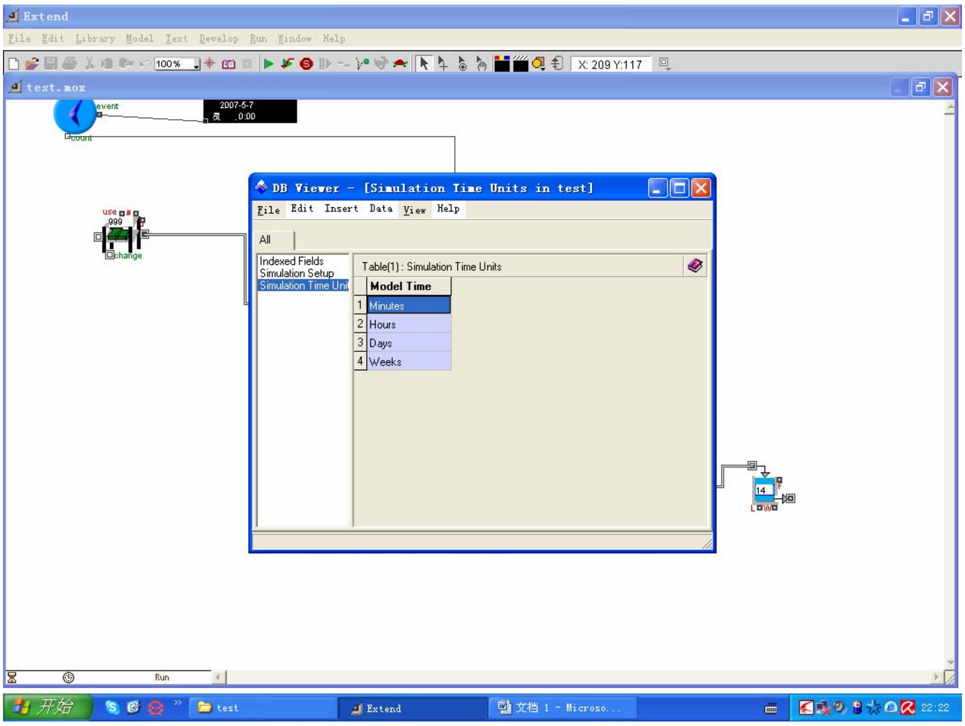


Image 2



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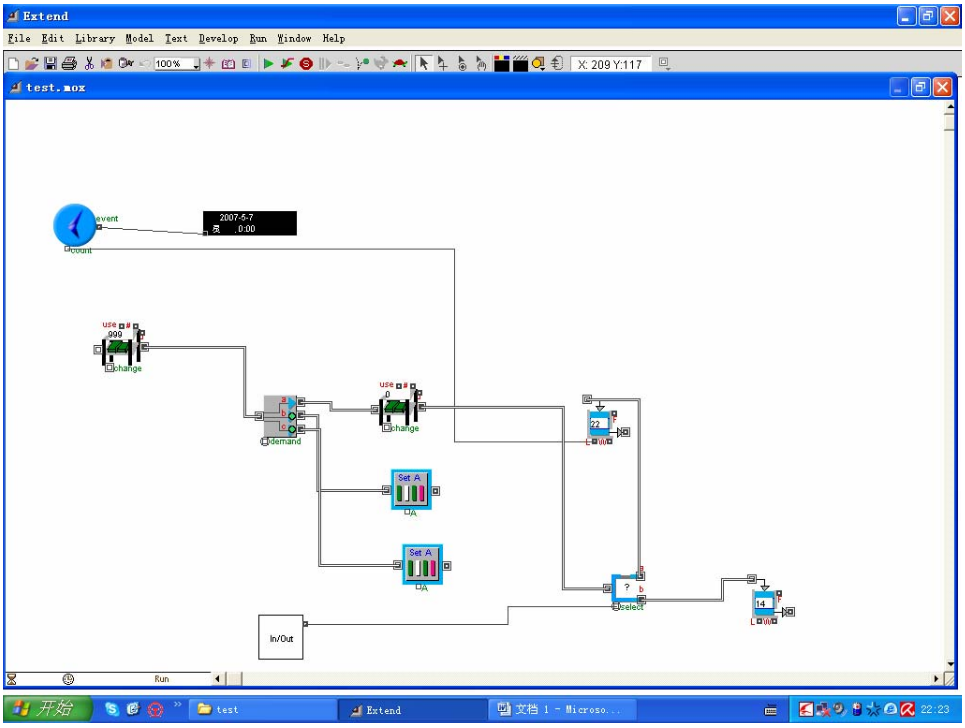

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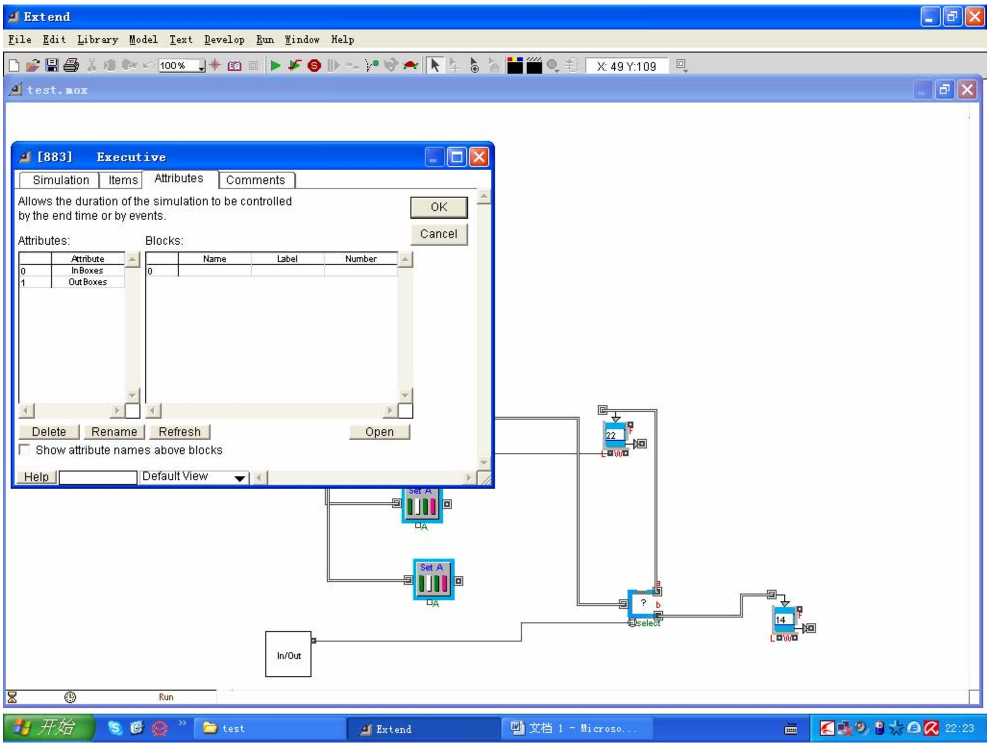

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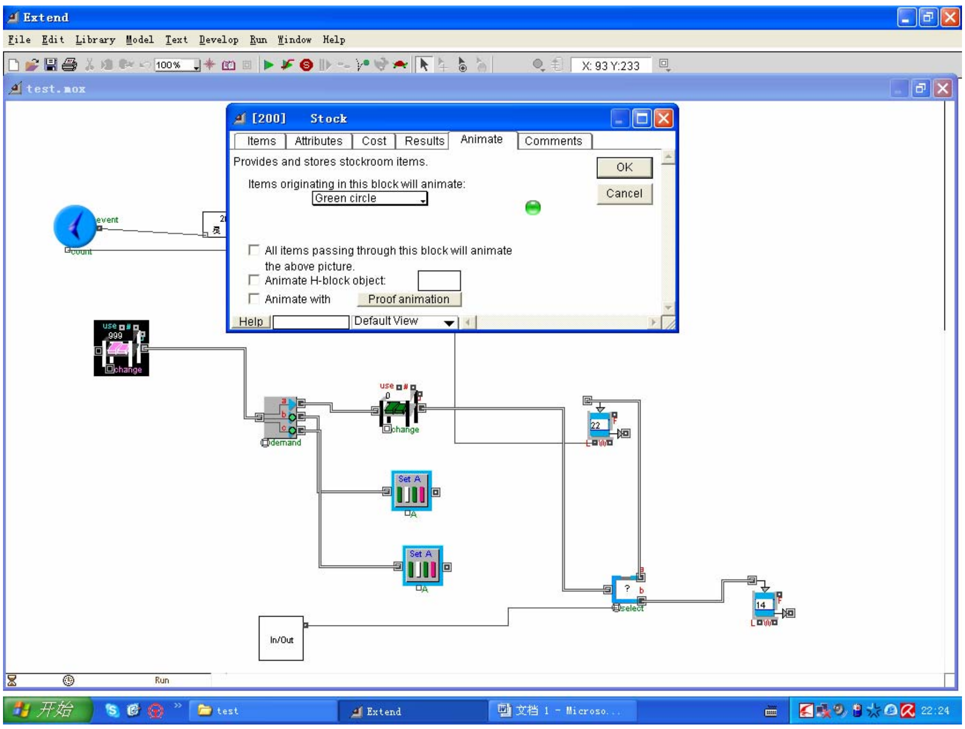

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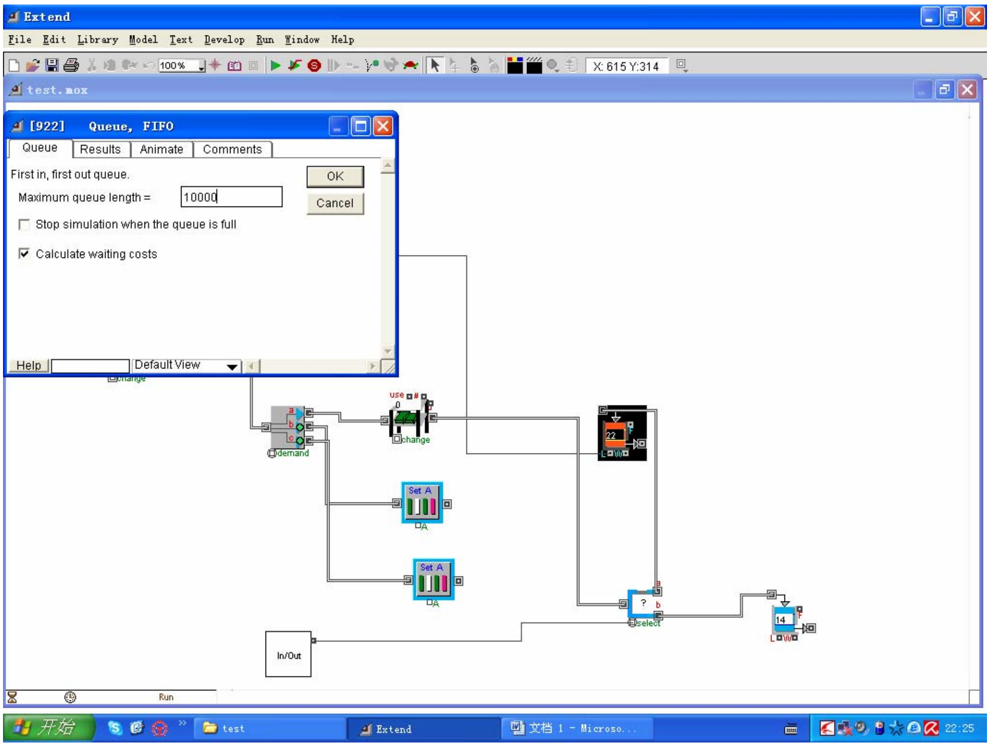

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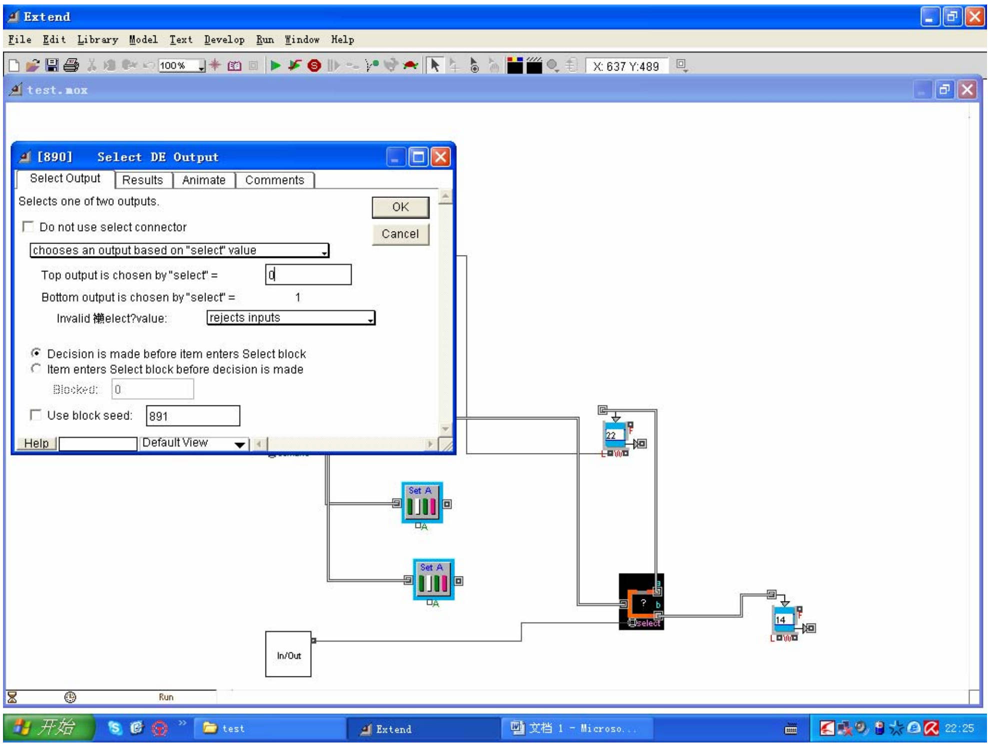


Image 8

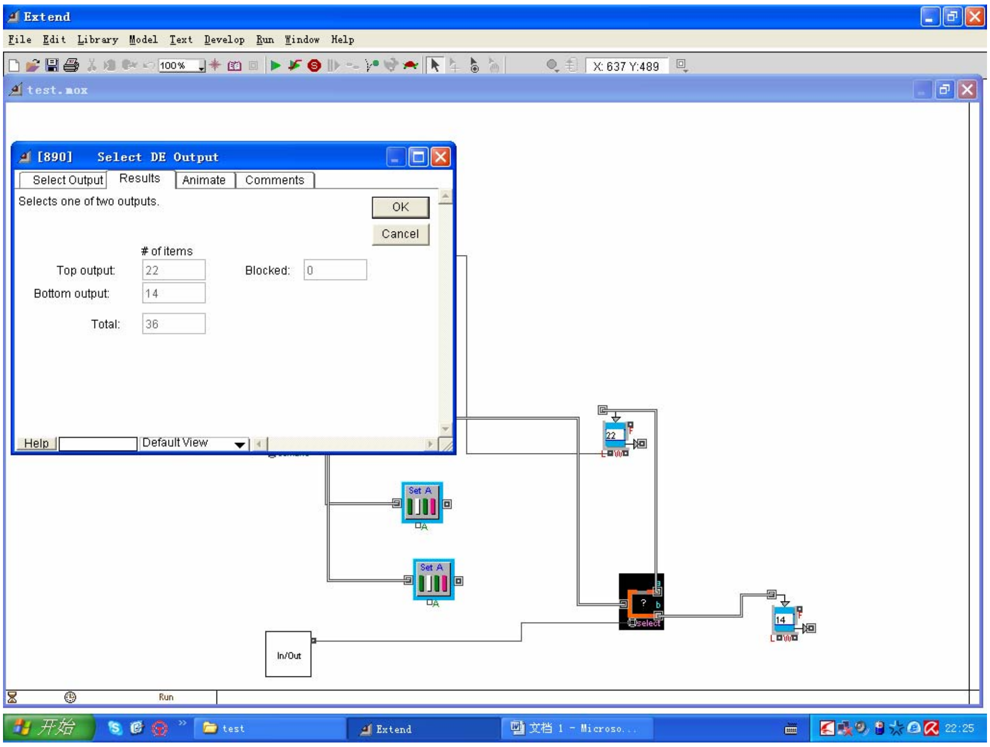


Image 9

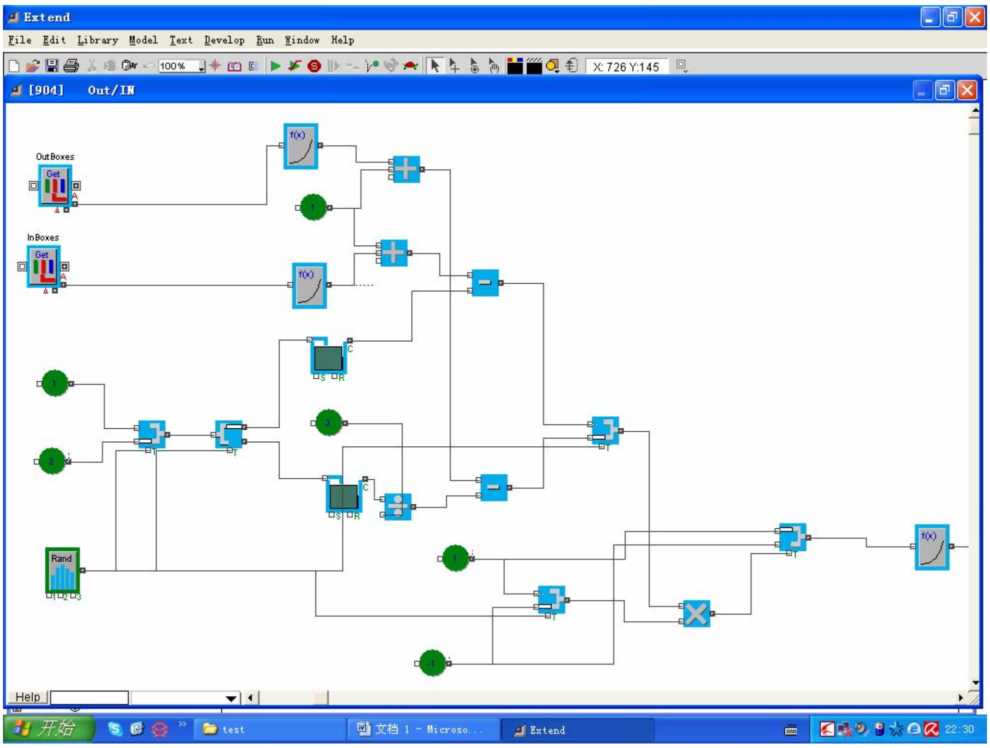


Image 10

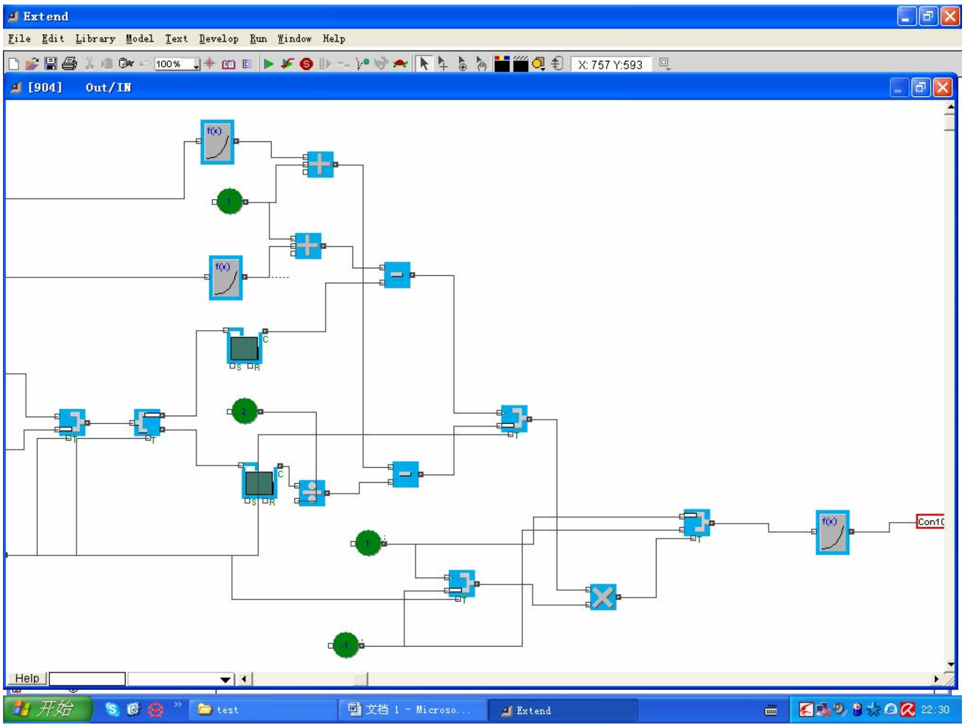
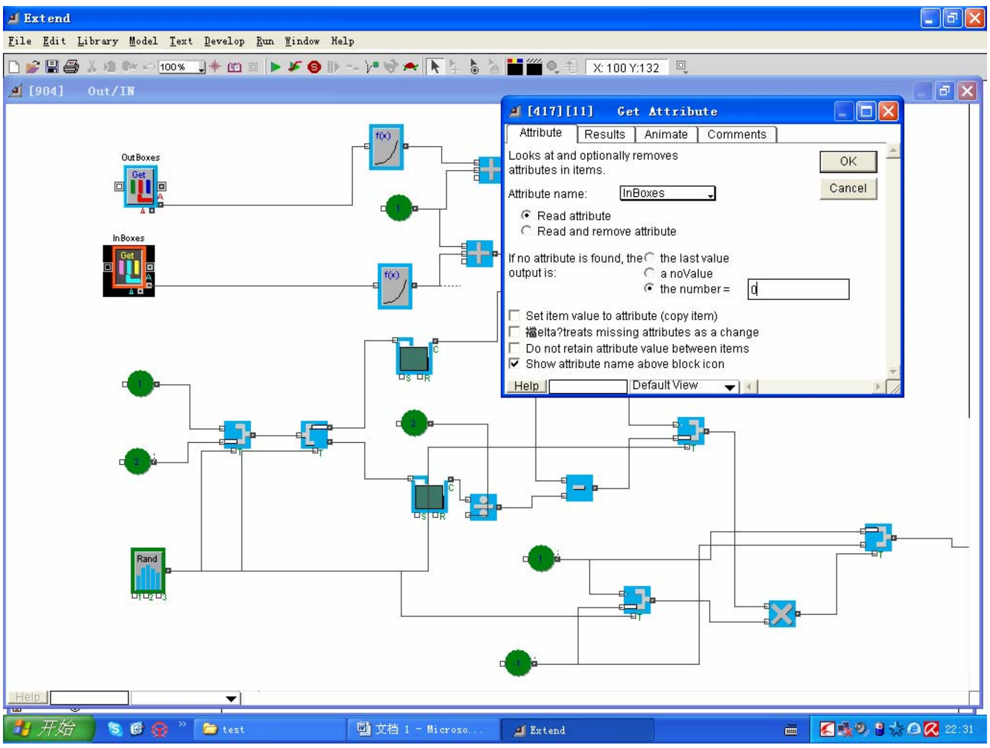


Image 11



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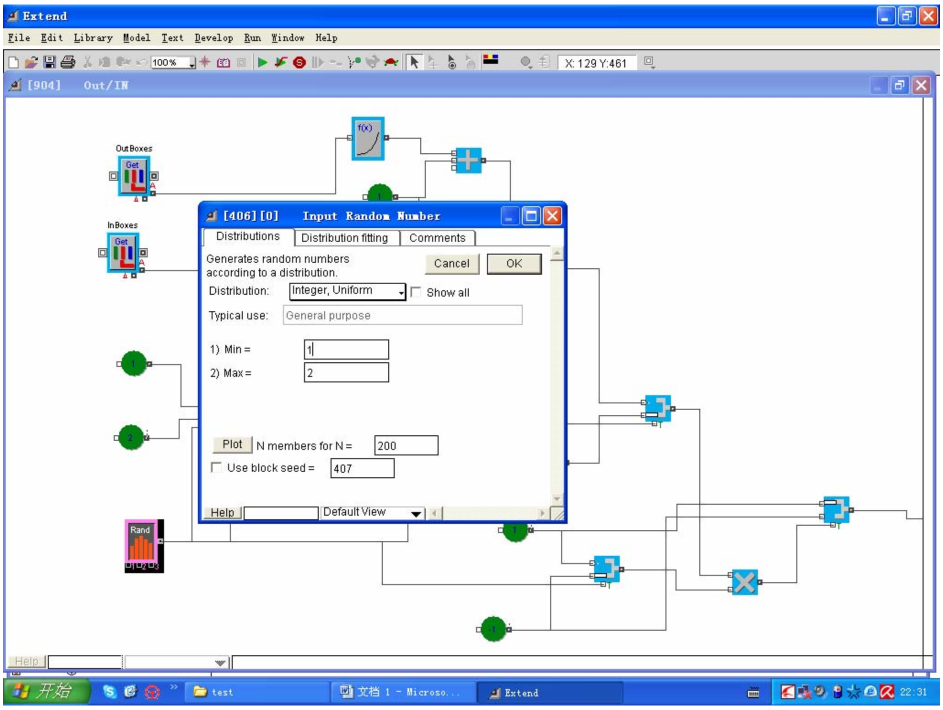

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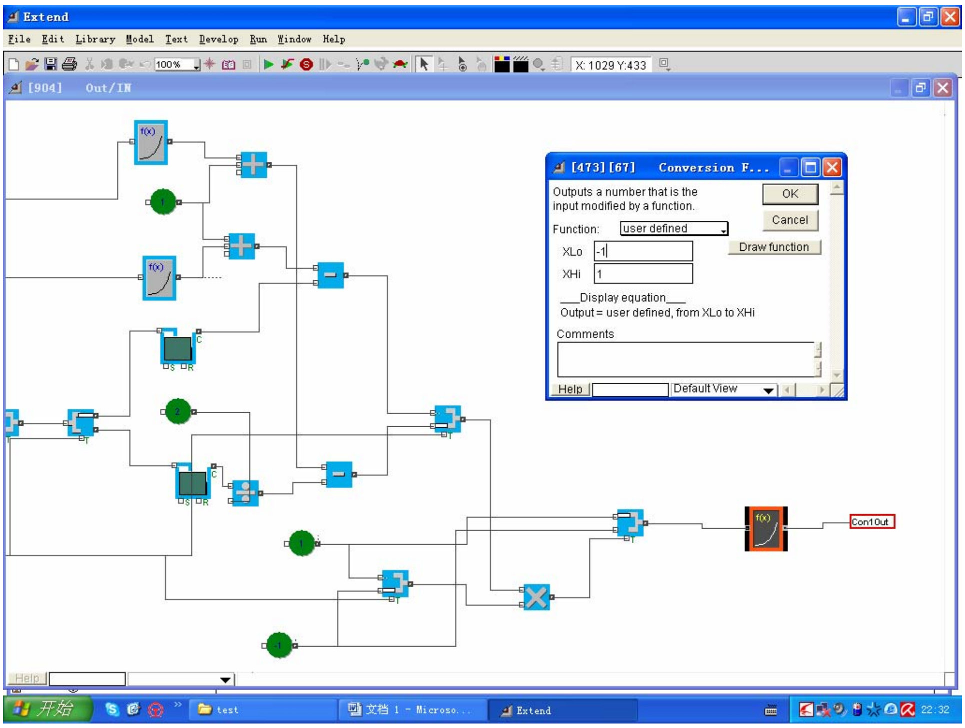

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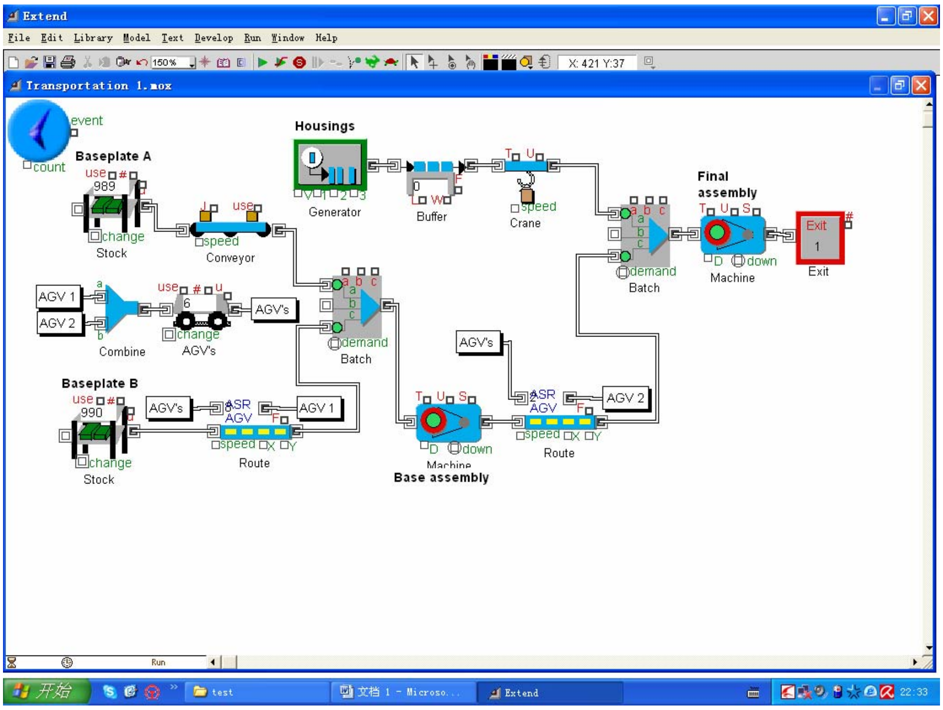

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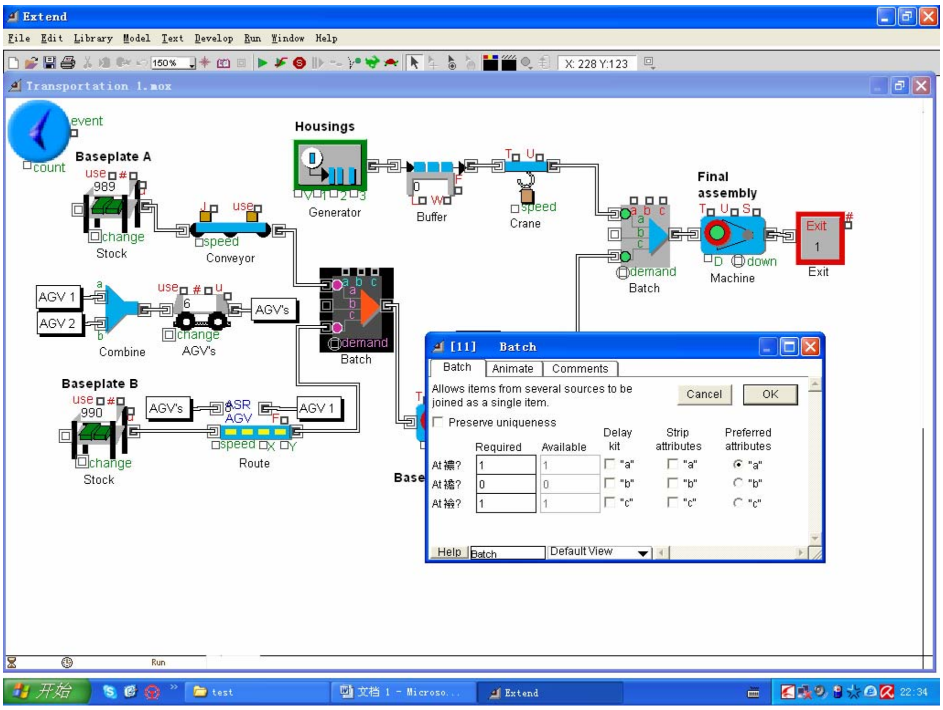

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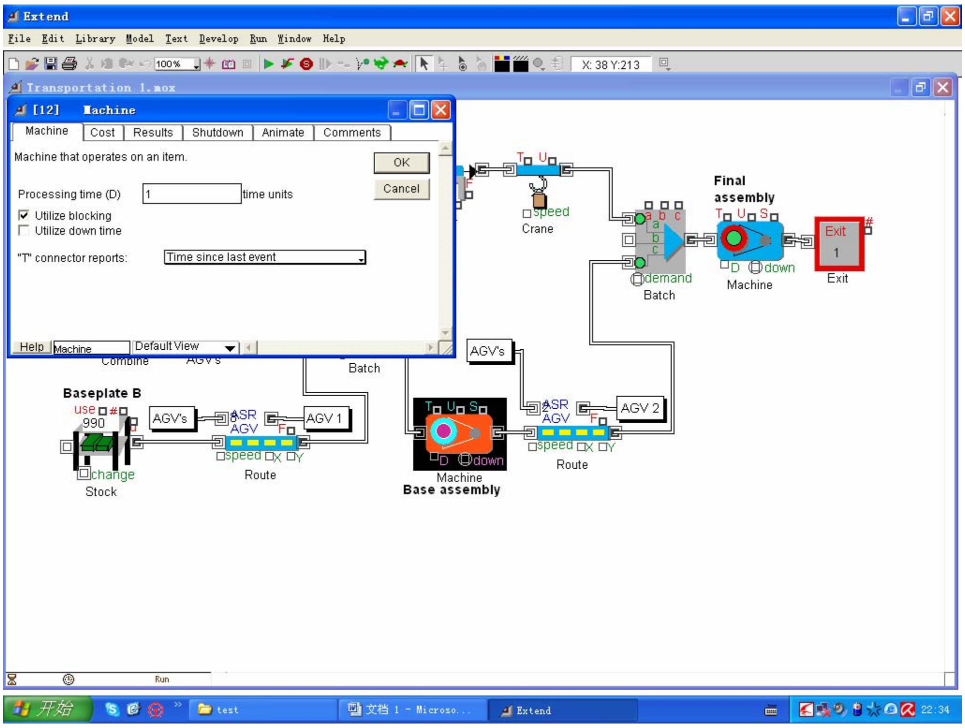

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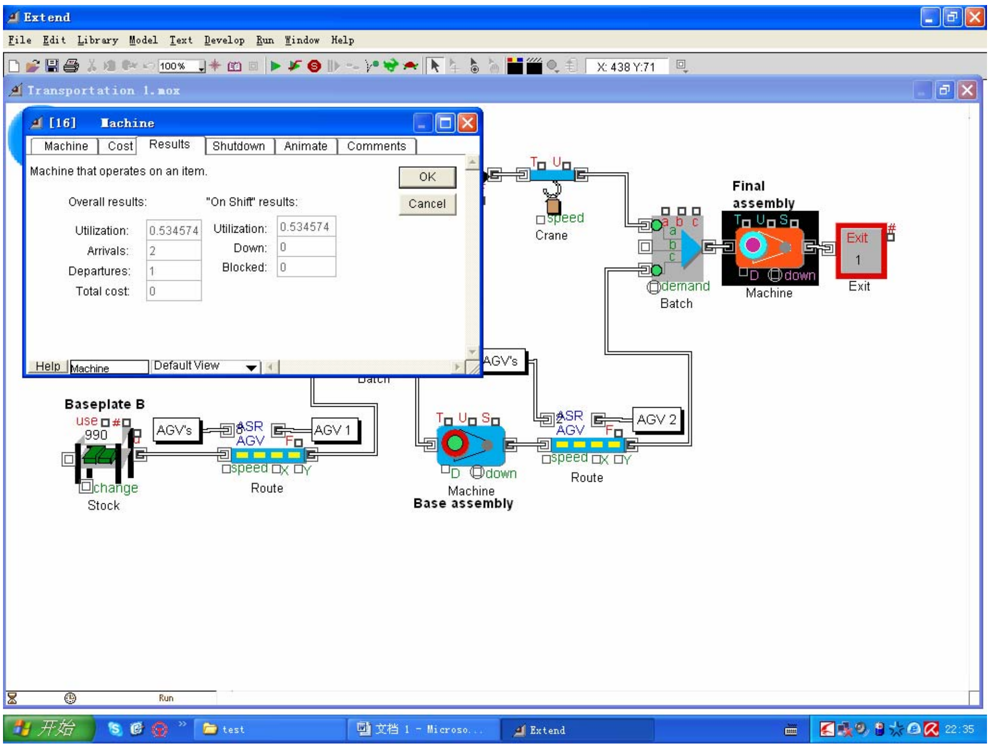

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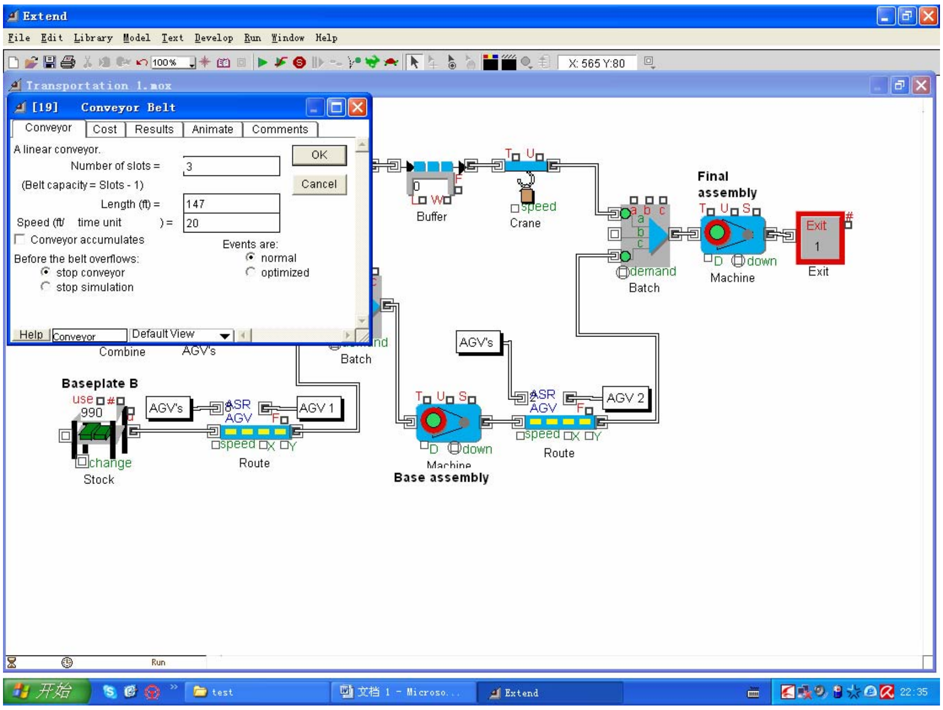

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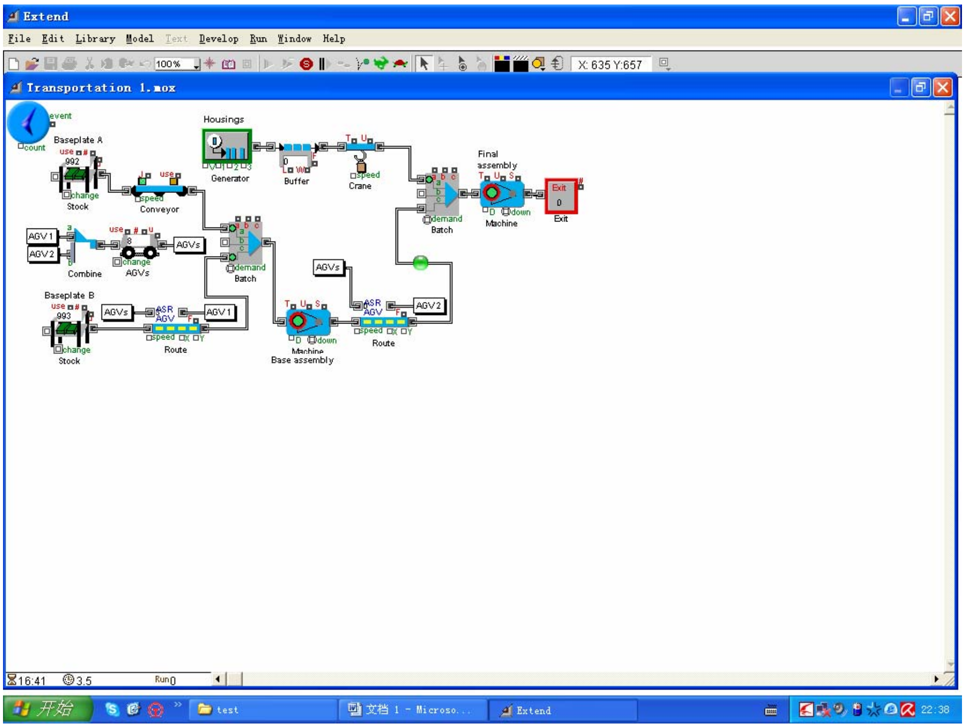

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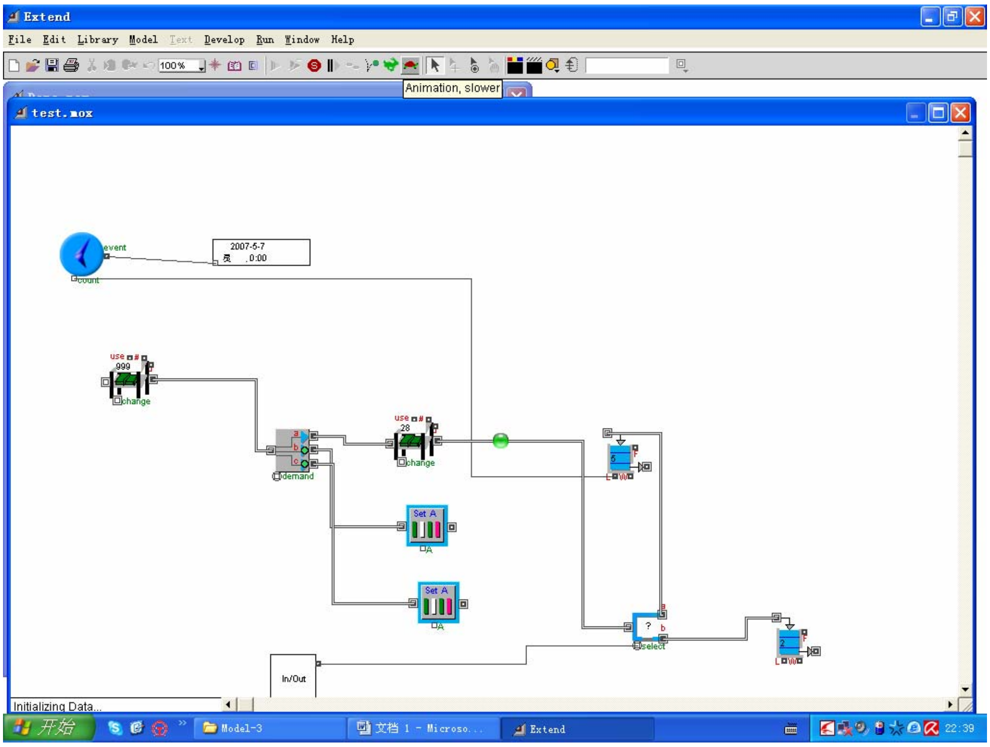

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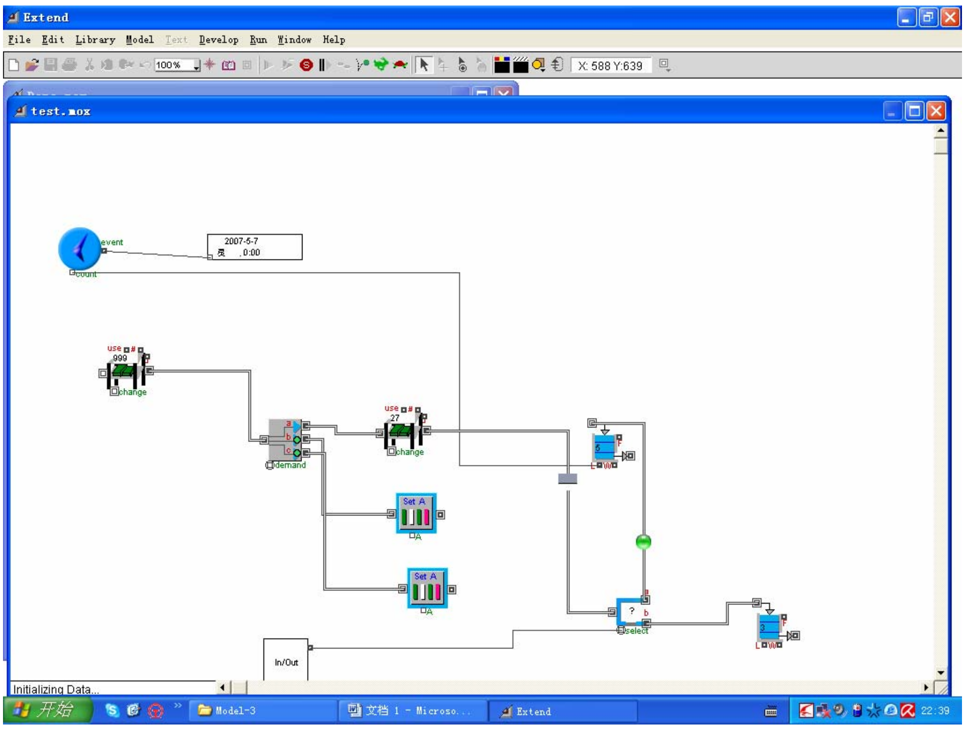

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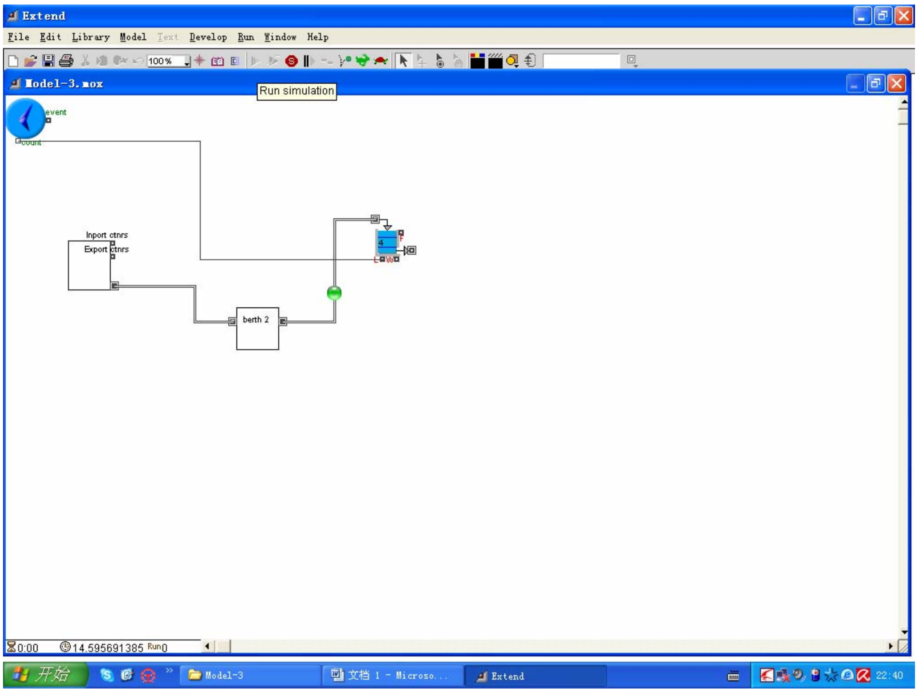

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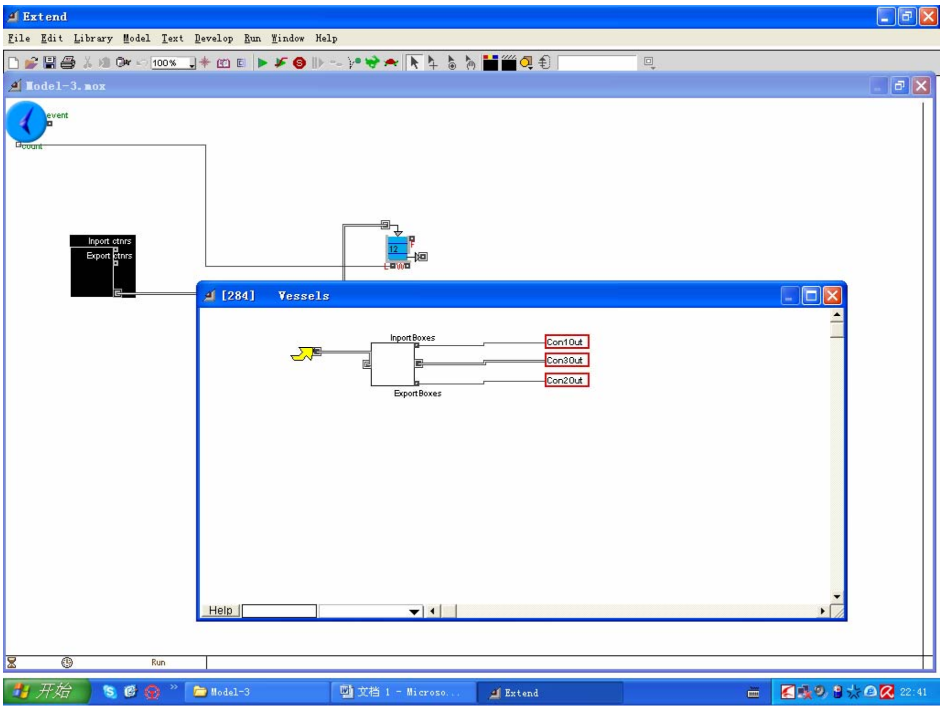

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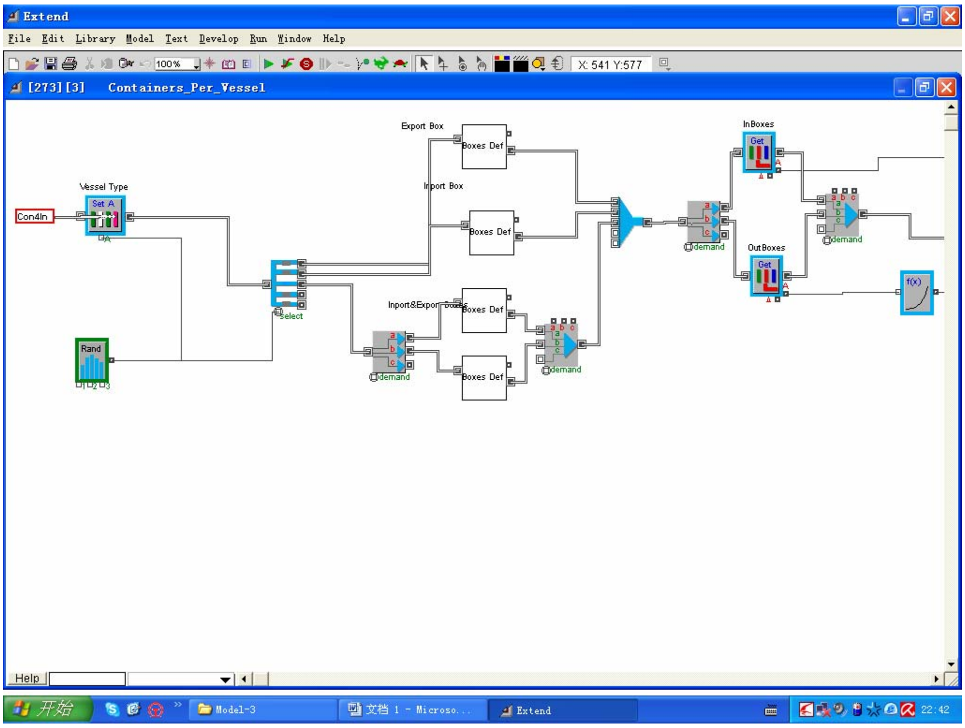

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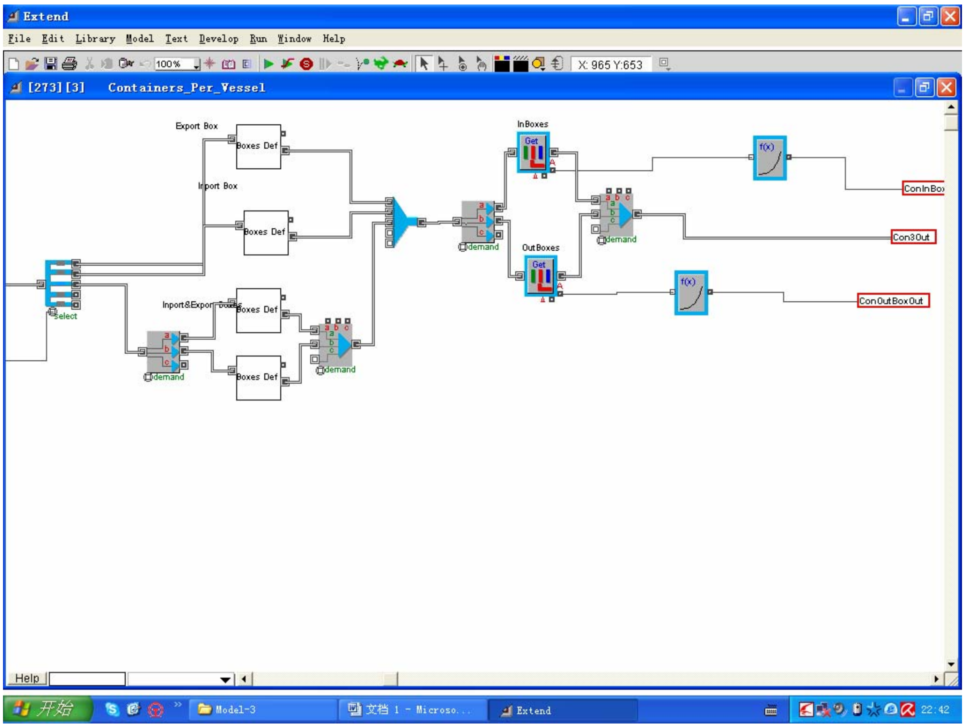

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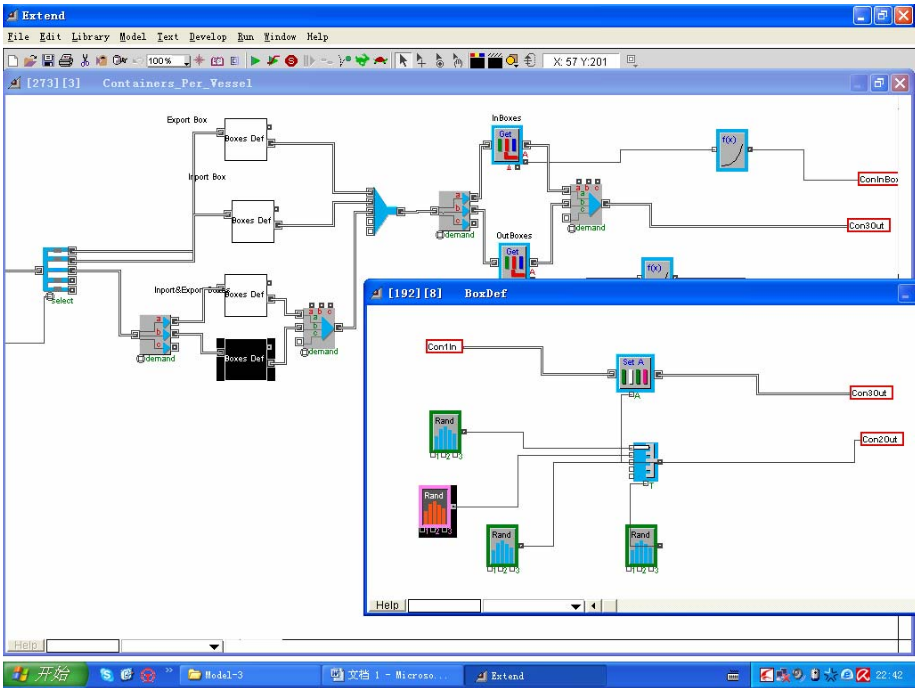

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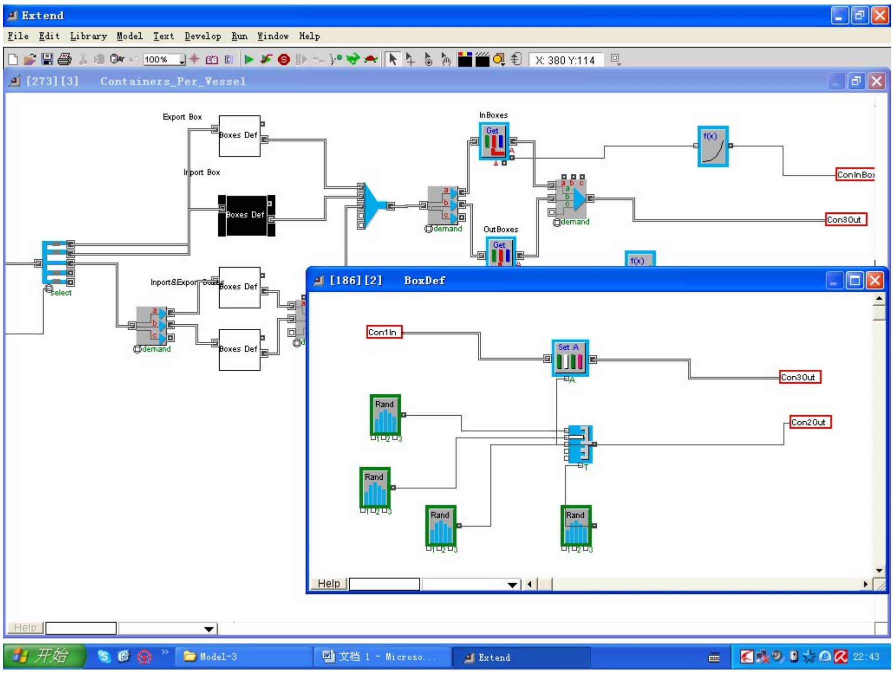

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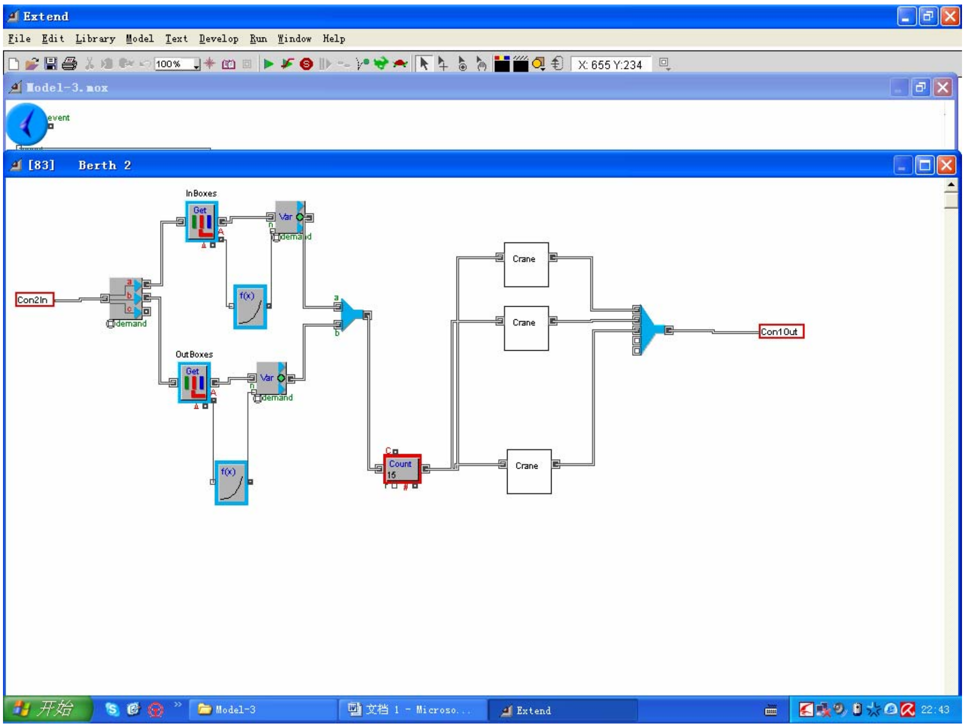

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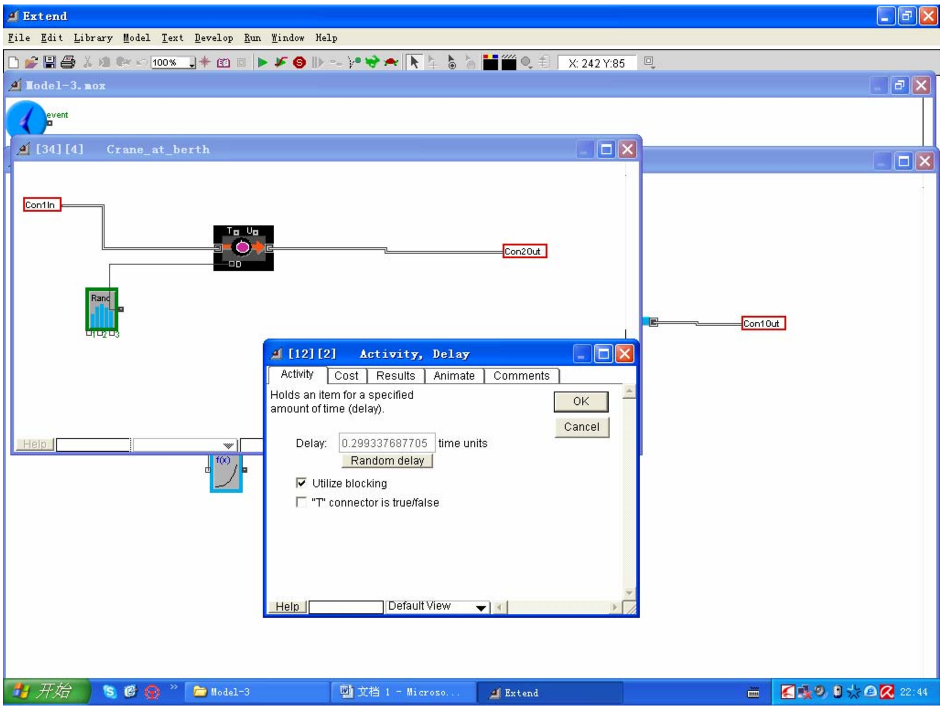

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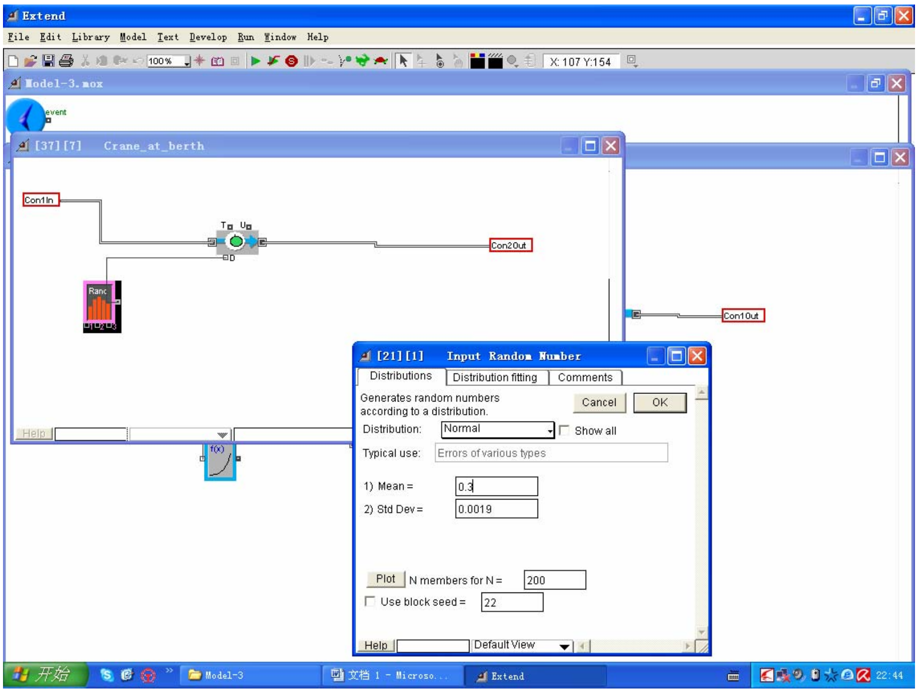

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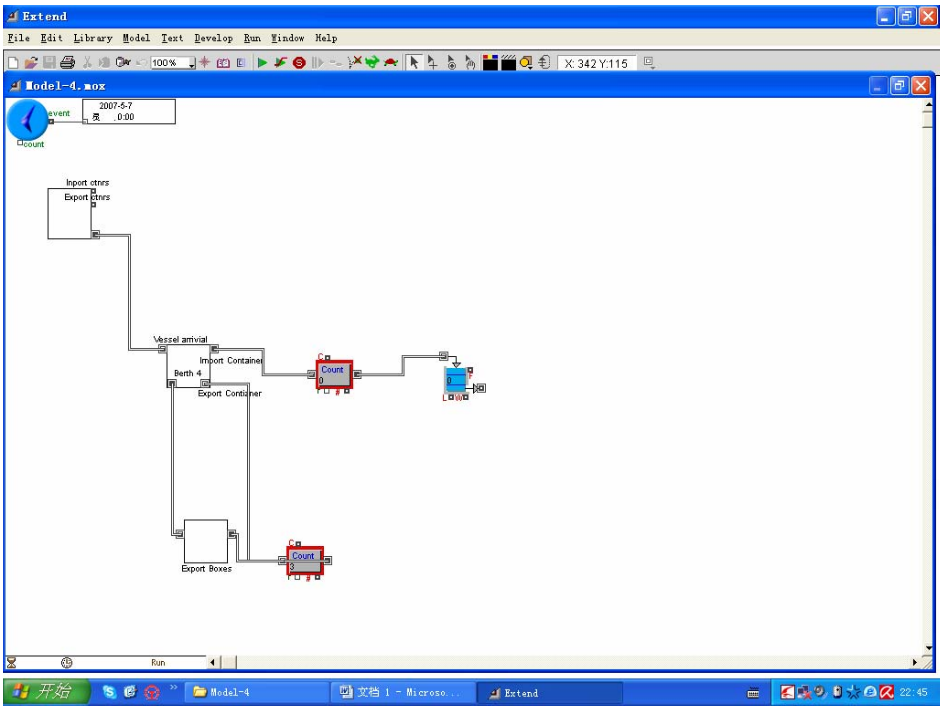

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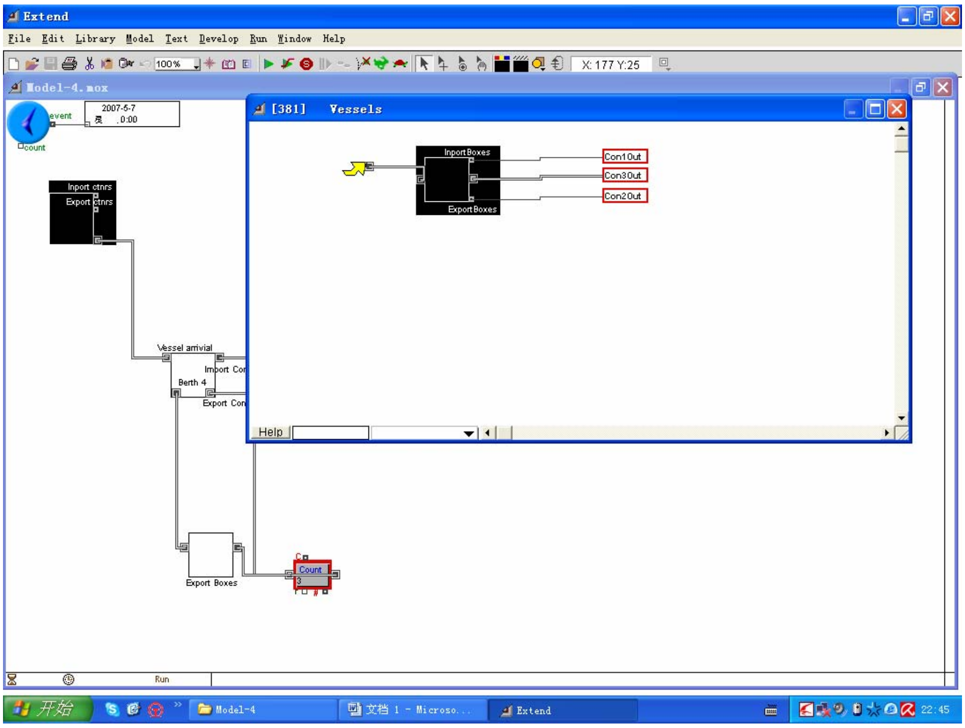

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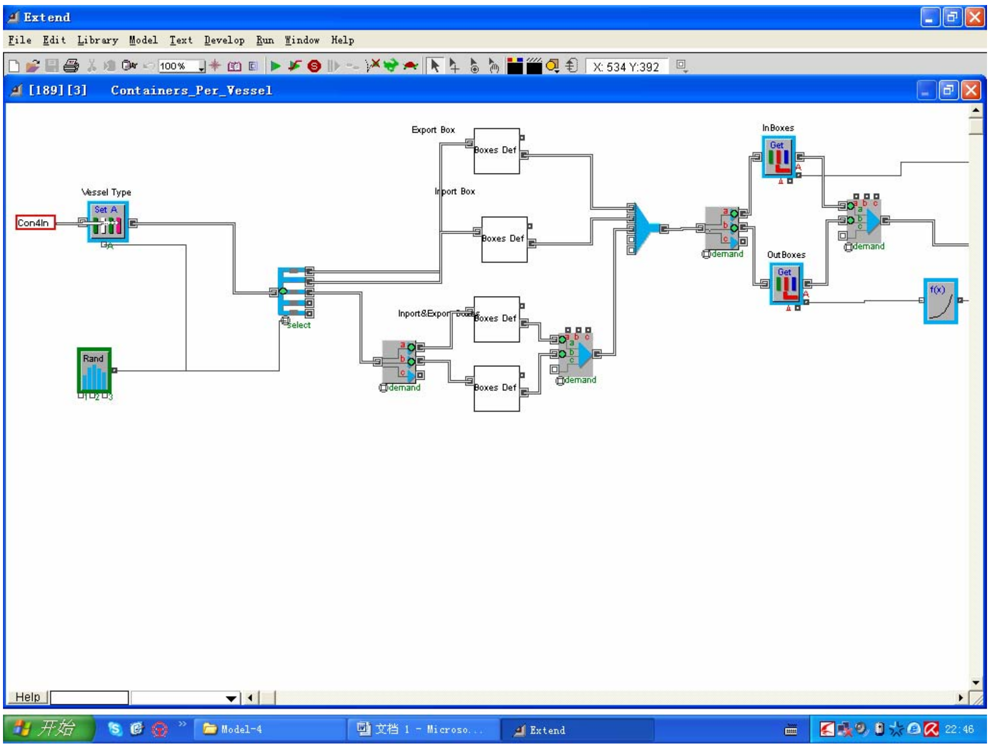

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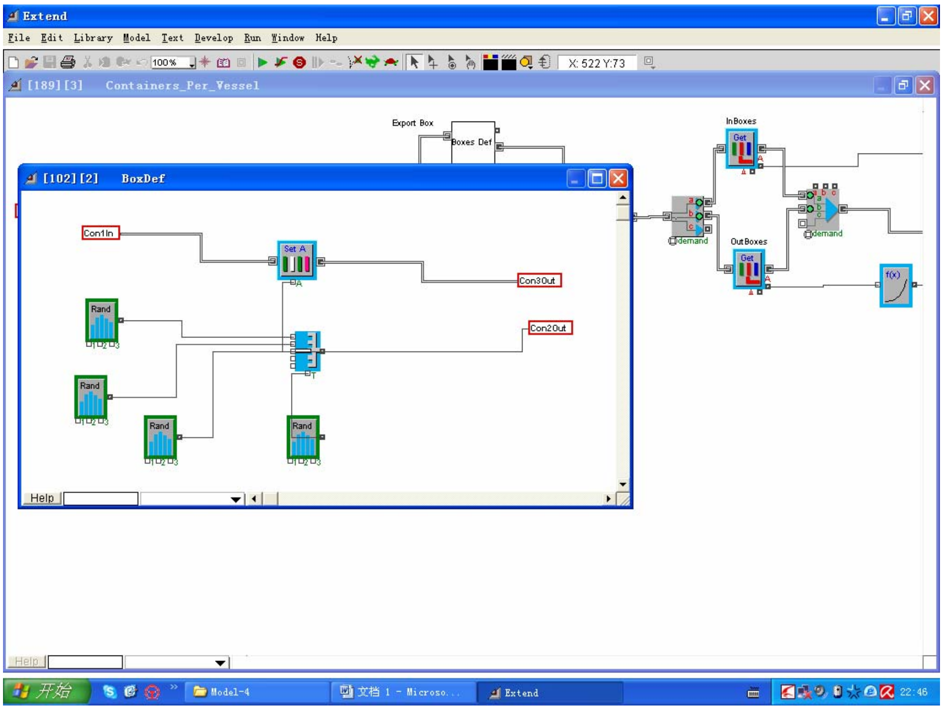

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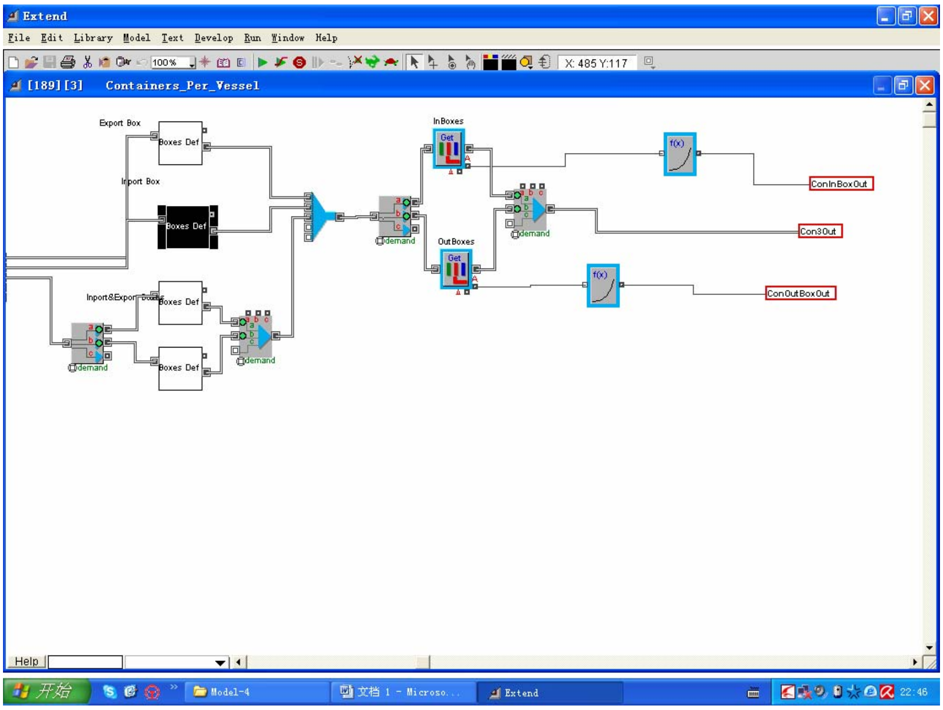

Image 36