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Function and design of simulation system for the workload distribution among storage blocks in a container terminal yard

Dongyuan REN

SHANGHAI MARITIME UNIVERSITY

WORLD MARITIME UNIVERSITY

Shanghai, China

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By

Ren Dongyuan

China

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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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Supervised by

Professor Sha Mei

Shanghai Maritime University

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Thesis writing is coming to finish. In the process of writing in this period, I got a lot of help from supervisor and friends. I would like to express my gratitude to all those who helped me during the writing of this thesis.

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Once again thanks to the group of professors participate in the paper review and reply and all those who helped me during the writing of this thesis!

ABSTRACT

Nowadays with the container terminal throughput concussion continuous, the effective use of existing resources is a great challenge for port enterprises. Storage blocks allocation method can improve the port production efficiency. The main purpose of developing the simulation system for the workload distribution among storage blocks in a container terminal yard is to simulate the production activities in reality through the system. The main function is to accurately reproduce the situation of workload distribution among storage blocks, and on this basis, improve the utilization rate of resources.

In this paper, according to the factors of container terminal yard business process and the influence of terminal production efficiency, analyzes existing port plan of workload distribution among storage blocks, designs the distribution model under the control of the double factors of block region and a variety of distribution rules.

Firstly, divide different areas according to the actual needs of production. Then set rules to different region. And according to the actual production condition of port, establish the mathematical model for workload distribution among storage blocks. Make sure work flow of the system.

Then, establish database reference model according to the relational mathematical model and the actual needs of production. Model includes the existing data, import data by users and the data calculated by simulation .Establish a database using access. According to the database model analyze the data logic process of relationship of internal simulation system, then use PowerBuilder9.0 to design this system.

This paper establishes optimization model and the simulation system, verifies its feasibility through the actual operation, and generally applicable to China other container terminals. This research can improve the production of port service quality and enhance the yard operation efficiency. Through the study, this paper establishes the distribution model of workload distribution among storage blocks in container terminal yard, verifies the practicability of the model, uses real data do the simulation and get the result of workload distribution among storage blocks.

This paper analyzes existing problems of existing distribution scheme, and prospects based on this study. Also, this paper provides a useful reference to enhance utilization ratio of port resources and block allocation scheme.

KEYWORDS: workload distribution, region value, stacking rules, simulation system

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Chapter 1 Introduction

1.1 The research background and significance

1.1.1 Background

With the deepening of China's foreign trade, container transportation with its characteristics of high efficiency and cost-effective, plays a more and more important role in the field of transportation. Container transport began in the early twentieth Century in England, after the continuous improvement, the advantage is more and more recognized by people.

During 1986-2006, the average annual growth rate of mainland China's container port throughput close to 30%, in 2007 the total throughput of national ports (excluding Hong Kong and Taiwan port) reaches 113000000 TEU. The global financial crisis outbreak in the second half of 2008, this figure reached 128000000 TEU with the growth rate of 13%. In 2009, affected by the financial crisis, the total throughput of the ten major ports from January to November fell to 89630000 TEU. The global economic recovered in 2010,China shipping market has rebounded slightly, the container throughput of major ports in China in the first three quarters once again broken billion, up to 108000000 TEU. In 2011, the first time the national port cargo throughput has exceeded 10 billion ton, and container throughput reached 164000000 TEU, ranking first in the world. In 2012, throughput of China's container port reached 177470000 TEU, growth of 8.43% over the previous year. In the first 9 months in 2013, China's port container throughput of 141000000 TEU, grow 7.5% compared to the same period.

With the increasing of container throughput year by year, it brings enormous pressure to the port. The port is an important node in import and export trade, port handling and transportation is the most complex part in the whole supply chain, also creates the most value in the chain. Under the difficult circumstances of infrastructure expansion, how to effectively use the existing resources, provide better service for inland transport, become the problem of port enterprises that urgently need to solve.

1.1.2Research significance

Nowadays with the container terminal throughput concussion continuous, the effective use of existing resources is a great challenge for port enterprises. Workload distribution among storage blocks method can improve the port production efficiency. Loading and unloading operations of port enterprises is a complicated system, various factors in the system of mutual influences and constraints, including any part problems are likely to make the whole system paralysis. Therefore, as one of the important links in the port enterprises production activities-- workload distribution among storage blocks, need a whole concept so as to reach the workload distribution among storage blocks results in different constraint conditions.

The main purpose of developing the simulation system for the workload distribution among storage blocks in a container terminal yard is to simulate the production activities in reality through the system. The main function is to accurately reproduce the situation of workload distribution among storage blocks, and on this basis, improves the utilization rate of resources.

The purpose of the study is to consider the container yard service ability as the direction, with the yard block as the research object, designs a simulation system for the port, in order to provide a scientific way to solve the problem of workload distribution among storage blocks in container terminal yard.

Although scholars in each country have conducted in-depth research on the container yard, Studies on the workload distribution among storage blocks rules are still less. This paper at first simulates import block information and container volumes, then distributes workload among storage blocks according to the initial data and the stacking rules, then discusses for the different situations according to meet the requirements separately, finally get the suitable scheme of workload distribution among storage blocks.

1.2 Research content and the technical route

1.2.1 Research content

After a lot of port related literature and the large container terminal field research, knows the container terminal enterprises business model and the system demand, this paper mainly studies on workload distribution among storage blocks by various rules based on different region division.

Firstly, this paper set up a workload distribution among storage blocks model, defines distribution algorithm of single rules, distribution algorithm of various combinations of rules, algorithm of according to the step workload. And build the algorithm flow charts and the relational tables, lays the foundation for the next step in the development of procedures.

Secondly, based on the previous work, this paper designs and develops a general simulation system of workload distribution among storage blocks based on various rules and various region division ways in the container yard. Generalization means in the simulation system, fully considerate various distribution rules and various container types in different container terminals. Generates the container yard layout based on user (terminals) characteristics through the self selection by user (terminals). According to different actual situations, set different parameters to meet the needs of data. Divides the region, and then chooses the rules according to the existing ships and block data. Finally, calculates workload distribution among storage blocks based on the conditions set before, gets the quantity for each step processing business with properties.

Finally, gets the simulation results based on simulation system, then comprehensive analyzes characteristics during a period of time, different choices of rules and different setting of regions characteristics in the workload distribution among storage blocks.

1.2.2Technical route

The technique route shown in Figure 1-1 of the above research content:

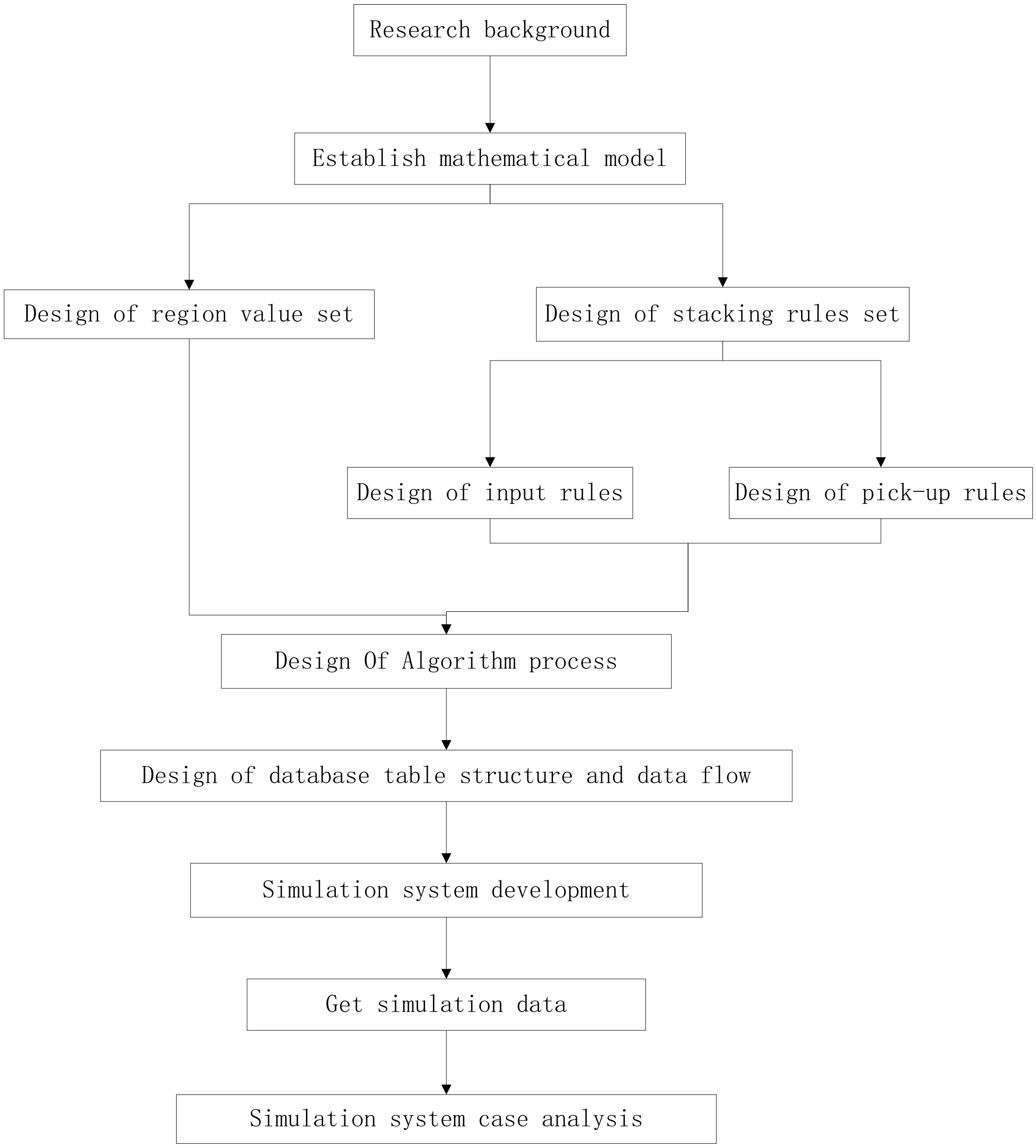


Figure 1-1 Technical map

1.3 Research methods

1. Technology method

By extensive reading of related references and studying the content, they provide reference for the technical ideas.

2. Actual study

The simulation system must be a system approximates to the real production situation. In order to make the simulation system distort, the container terminal business process and operation way must be understood to provide practical basis for establishing model for simulation system for the workload distribution among storage blocks in a container terminal yard.

3. Data acquisition

Collecting the real data is used as the basis for case analysis of the simulation system.

Chapter 2 Literature review

2.1 Review of research in related fields in western countries

2.1.1 Aspects of container terminal business process

With the increase of import and export business in China, as well as the deepening of modern logistics and supply chain management concept, the development of the port is facing a new environment. Consider the port as an important part of the supply chain, the competition of port has changed from regional evolution to the worldwide competition. While the development of container transport and enlargement in vessel size, the competition of container hub port becomes the focus of the competition of port. The information management of container port has become a trend. Based on the establishment and perfect of the container port management information system, container port adjusts some parameters and compares multi programs. Then the port get a program that can increase port efficiency, achieve scientific management and decision for port operation. Container port in order to win in the new round of competition, port enterprises need to constantly improve their operational efficiency.

Foreign scholars make simulation study on automated container terminal. Mark B. Duinkerken and Jaap A. Ottjes (2000) first make a relevant description on overall model of Simulation, including the shore crane, gantry crane, ship and container and horizontal transport layout. After do related research on the design plan and control the order distribution, automatic guide vehicle allocation and container crane loading sequence , finally match the actual model to simulation model, and the test is according to the actual case of Rotterdam port. It can be found that the result matches the conclusion [1].

Sonke Hartmanna (2004) studies the optimization of the generation of scene simulation and container terminal logistics. He proposes a method to reproduce the container terminal scene, the data of the scene includes arriving vessels, feeder vessels, train and truck delivery together with the list of container, crane and container attributes (size, weight, etc.). He uses algorithm to calculate these data, get the optimization model of berth and quay crane scheduling plan. The goal is to develop a capable of reproducing realistic scene simulation system, and get optimize simulation through the algorithm [2].

Luca Maria Gambardella, Gianluca Bontempi, Eric Taillard, DavideRomanengo, Guido Raso, Pietro Piermar (1998) study about policy and forecast of the intermodal container terminal. They realize the decision support method for a day and a long-term integrated simulation, prediction and planning development in multimodal container terminal [3].

2.1.2 Aspects of block allocation in container terminals

Mohammad Bazzazia, Nima Safaeib, Nikbakhsh Javadian (2009) proposes the research solve the container terminal storage space allocation problem by using genetic algorithm. They first define the related equipment, and then propose the model on the basis of the definition. Finally the simulation experiment use genetic algorithms to solve the problem of storge space allocation [4].

Mingzhu Yu, Xiangtong Qi (2013) design distribution among storage blocks model for inner container terminal, the purpose is to improve container port operation efficiency of the modern automatic container port. They design heuristic algorithm in the model, include three models: non-isolation model, isolation model and multi period model to solve the distribution among storage blocks problem. Finally, they get solution for the algorithm by simulation experiment and verify the feasibility of the three models [5].

Kap Hwan Kim, Hong Bae Kim (1999) propose a separate block allocation model, mainly to study how to distribute important container, and they use mathematical model of Lagrange relaxation technique, to solve the problem of how to use small minimization of the yard resources reasonably in the minimum number of loading and unloading. And use the data to test the rationality of the model [6].

Chuqian Zhang, Jiyin Liu, Yat-wah Wan, Katta G. Murty, Richard J. Linn(2003) propose distribution model of container terminals, they give full consideration to the complexity of container port work, includes the shore crane, gantry crane, yard channel and so on, and use rolling plan method to establish the model. Finally the simulation result is tested by Hong Kong port. They solve the bottleneck problem in the operation of port effectively [7].

2.2 Review of research in related fields in China

2.2.1 Aspects of container terminal business process

Sha Mei (2003) studies on the design of modeling and simulation technology of container terminals, she uses discrete system simulation to the design of process system of container terminal. Combines the traditional loading and unloading process with advanced computer simulation, provides decision support for the designation of container port project [8].

Yu Meng, Wang Shaomei, Xiao Feng (2007) study on simulation of container handling system based on the flexsim. Use flexsim to establish the model of container terminal handling operation simulation. Use its core mechanism -- the task sequence driving device model, finally achieve 3D dynamic simulation of loading and unloading process [9].

Zhou Qiang (2007) studies container terminal road traffic simulation. He establishes the process model to realize logistics functions of ships loading and unloading, and containers collecting and dispatching in container terminal based on the theory of discrete event dynamic system. Through the analysis of the structure of the port road network, he establishes the road as the basic unit of the terminal network model and cross intersection safety mode. Then, he puts up a compound model of traffic simulation and analysis, combins the process model and traffic net model by computer simulation method [10].

Sha Mei (2008) studies the EEAP of container terminal logistics operation system simulation model based on DEDS. Then she builds basic model of simulation system entities, events, activities and process 4 elements and refines its complicated relationship. The simulation model and system based on the basic elements can provide decision support for the operation of container terminal logistics. Finally she verifies the effectiveness of the proposed method [11].

Sha Mei (2008) studies for generality abstract methodology of general simulation modeling for container terminal logistics operation system, and establishes human corresponding rule based on the discrete event dynamic systems; in accordance with the rules abstracts the basic elements of human common to logic elements and solid elements, then she designs the corresponding standard refer to systematically describe common abstract. Finally she uses Yangshan Port case to test the system [12].

Ceng Qingcheng, Zhang Qian (2009) study simulation optimization model and algorithm of container berth allocation interference management. They put forward the berth allocation interference management model, and tested by the examples [13].

Zhou Pengfei, Xiao Meizhen (2011) work for a simulation system of container shipping service. They put forward the system simulation through the container ship service system. Then they test a specific example based on arena simulation platform, and use software to achieve fitting of the simulation and statistical analysis. Finally they get the influences of the key parameters of processing method in the simulation system of container terminal simulation modeling [14].

Qin Tianbao (2011) studies the simulation of the road planning of container terminal yard. He uses Flexsim simulation software to establish a 3D virtual reality simulation model of a large planning container terminal yard in China. Then he determines the reasonable width of trunk road and the system structure, composition and process model are given. Through the simulation experiment, judge the rationality of road design and put forward the improvement proposal [15].

2.2.2 Aspects of block allocation in container terminals

Li Haoyuan, Wang Dingwei (2008) use the method of the discrete event system simulation modeling, they solve the container block planning problem of container yard based on the genetic algorithm of simulation. And the introduction of the solving process is based on the calculation method of parallel cluster MPI message passing standard. And through the analysis of simulation results, this method obtains the container terminal yard block planning problem better solutions [16].

Yan Wei, Xie Chen, Chang Daofang (2009) use the way of objective programming build a yard allocation model of export container rolling plan for the yard allocation problem of export containers in container terminals. The goal of the model is to reduce the block to berth horizontal transportation distance and balance the amount of work within the yard, improves the efficiency and reduce the cost of shipping requirements. Use the hybrid algorithm of parallel genetic algorithm and heuristic algorithm, to optimize the export container yard allocation model, and prove its effectiveness and practicability [17].

Tao Jinghui and Wang Min (2009) establish the mathematical model of import and export container mixed reactor. The model is divided into two stages, the first stage is to solve the workload balance optimization problem, the second stage is to solve the group case balance optimization problem, and then use the heuristic algorithm to solve the model. And the model and algorithm are tested by using the actual data of Shenzhen Shekou Container Terminals. The results show that the model and algorithm has been greatly improved efficiency than the existing port stacking strategy [18].

Zhao Ning, Mi Weijian, Deng Zhong (2010) propose import container dynamic selection ideas and methods based on the" decentralized and centralized" floor shunt storage principle. After summarize the different container terminal, get a lot of valuable experience foundation from different scheduling staff, they establish a model of ship unloading approach automatically. And the example shows the rationality. Its rationality, balance and dynamic can greatly improve the site operation efficiency, so as to eliminate the bottleneck of ship unloading operations, achieve the organic combination of each link, to maximize the mechanical capability, improve the overall efficiency of container terminal handling operations [19].

Wang Zhiming, Fu Yunqing (2010) establish the allocation model which set the pack-up container time as constraints according to the actual situation of Chongqing port, minimize the turnover rate of container yard block as the target. And the model is proposed for the solution based on genetic algorithm. The model makes whole optimization for a ship or a batch of container, and considers the effect of subsequent containers distribution [20].

Fan Lingfang, Chen Lu (2011) put forward optimization algorithm to the export container in the yard in the stack of two stage allocation. The first stage allocates the bay to the export containers. The second stage allocates specific bay to each export container based on first stage. The first stage of the algorithm uses a mixed integer programming model for modeling and solving the problem, the second stage using heuristic algorithm based on hybrid stack position allocation solution. The two stage algorithm provides a systematic solution for the export containers allocation problem in the yard, increase the operation scheduling efficiency of subsequent export container yard [21].

Wang Xiaobian (2011) establishes minimize the number of yard crane model under different block length. She gets the number of gantry cranes under different block length. According to the different ratio of gantry crane and bridge crane, she uses the port simulation software Flexsim CT establishes 8 kinds of simulation model for different numbers of loading and unloading machines under the different block length, then studies the effect of 8 blocks length of different terminal handling efficiency, gets the block length under maximum efficiency of the bridge crane [22].

Feng Meiling, Yue Wenying, Sun Junqing (2011) establish the mixed integer model of stacking containers apart between front yard and behind yard and between import and export containers. The buffer forms are used by front and back yard, accelerate the spread of loading and unloading and improve the utilization of yard space. Finally, they use the optimization software lingo solve the example, achieve an overall balance of the truck running effectively reduce the distance and gantry crane in the box interval operation amount [23].

Cui Dongfang and Liang Chengji (2013) propose a hybrid storage strategy for storing principles of container terminal yard. They make sure the import / export containers can be mixed put in the same block while avoiding excessive concentration. On the basis of the plan they build the mixed integer mathematical model of the rolling based on the balance in the blocks interval operation of mixed storage mode, and use Cplex to solve the model. Finally they achieve the optimal proportion of space allocation scheme of each phase of input container and import and export container Bay relationship in hybrid stack mode [24].

Zheng Hongxing, Wang Xiaowei, Dong, Zhou Tingyang (2013) study container block assignment problem for hybrid stack mode. They establish a multi-objective integer programming model for blocks work balance based on the rolling plan in order to improve the utilization of yard space resource. And they use simulated annealing algorithm to solve the model. The equilibrium quantity of work between yard blocks achieves optimal allocation of container yard block space resources [25].

Hao Jumin, Ji Zhuo Shang et al (2000) put forward the concept of mixing order yard operation. Based on the graph search techniques and pattern recognition theory, they establish a stochastic condition of mixed operation sequence yard bay operation model [26].

Li Yanli (2010) in her master's thesis analyzes throughput capacity, loading and unloading equipment configuration, loading and unloading point, the effect of terminal handling technology to the yard layout, and combines the system simulation theory and genetic algorithm theory, sets the optimization throughput capacity of the largest and yard transport efficiency as the research object, establishes the mathematical evaluation of container yard layout model [27].

2.3 summarize the research situation

Overall, research in western countries on the simulation start earlier and develop to a diversification trend. The simulation technology has infiltrated all areas. Especially in recent years, research on simulation technology in port areas showing a blowout type development. Research results are various. But there are still some problems to be improved:

Firstly, in the side of container storage strategy, the depth of research of Chinese scholars is deeper than scholars in western countries, this mainly related with China situation. China's main port is located in the eastern coastal shoreline, it has dense population and high rate of land utilization, port enterprises need fully consider stacking strategies to reasonable planning yard area. Therefore, the related data is not enough when doing research on other countries.

Secondly, there are still many shortcomings in the existing research on stacking rules. Scholars mainly set allocation scheme based on algorithm model, but few definitions are given by various scholars about clear stacking rule, this also provides certain difficulties for future study. Besides, development and design of simulation system for the port enterprise of container terminal is even less.

Chapter 3 Analysis of key factors of the workload distribution among storage blocks

3.1 Container yard overview

Container yard is an important part of the port, it is not only a place for loading and unloading ships store container, but also the place to the owner to transfer container. As a buffer zone of import and export container storage, container terminal yard is also a kind of "channel".

3.1.1 Container terminal layout

In order to have a better introduce about the importance of container terminal operation in container yard, we first do a brief introduction about the basic composition of the container terminal.

There is a high degree of standardization of layout of the container terminal, mainly consists of the berths, container yard, crossing, and other facilities. Berth is the facility for loading and unloading container ship stop in the port. In general, 1700 meters of the shoreline can be allocated 5-6 berths. The front of the port width must meet the requirements for handling machinery and transportation machinery sites on the quay at work. Container yard is the largest area in container terminal. Based on the statistical data of the gate, port achieves the statistics of berth import container, and can be more effective for the container terminal management. Other facilities include lighting, electric tower facilities, control center and entering the gate etc.

3.1.2 Introduction of container yard

Container yard, some places also called station. For the export of sea containers, container yard is the role at first set up all container of export customer in somewhere (no matter whether after clearance), after the port time, then loads them together (at this time must have clearance).Container yard's main business is for the container loading and unloading, transportation, packing, devanning, transceiver, handover, storage, handling, and the supply of goods. In addition, there are other works as container repairing, flushing, fumigation and relevant measure etc. The type of the container yard is divided into the marshalling yard, container yard and empty container yard.

Container marshalling yard

Container marshalling yard refers to the front in the container terminal, to speed up the loading and unloading of ships and temporary stacking site of containers. Its role is: when before the container arrives to the port, make a plan to stack export containers neatly which have the order according to the stowage requirements, temporarily stacks import container in front of the port when the ship is unloading, to speed up the work of loading and unloading of ships.

Container yard

Container yard is the place of loading container, transferring container and stacking. Some countries do not distinguish front yard and rear yard of container yard, collectively refers to as the yard. Container yard is part of container handling zone. Container yard is the place that delivery FCL based on transfer mode of "field to field" container transportation (The handover is in fact finishes the container handling zone "gate").

Empty container yard

Empty container yard is the place refers to the special for the collection, storage, stacking empty or transfer. It is designed for container loading and unloading area or transfer station yard which is insufficient. The yard is not for heavy boxes or cargoes. It can be separate operated, also can be additionally arranged by outside of container handling zone. In some countries, the management of the empty container yard should apply to the Shipping Conference statement.

3.1.3 Container yard loading and unloading process

Now the container terminal operation is very advanced, with advanced equipment and sophisticated computer management system, finishes the operation for customers more conveniently and efficiently. Through the three parts: berth planning, yard arrangement and gate management, it finishes the whole process of goods entering or leaving the port.

1. Ship to port

A. Confirm the computer system

Shipping companies provide monthly shipment forecast arrangement to the port.

Port will summary each shipment forecast for the table of monthly forecast of shipping date summary.

Port defines terminal operating system according to the monthly forecast of shipping date table.

The ship company provides the latest receiving container time, voyage, port of discharge and ship data to port.

Port updates and confirms the computer system according to the shipping company request.

B. Arranging berth

1) The shipping company or agent to port forecast time of arrival and volume of containers loaded and unloaded.

2) Port according to the time of arrival, volume of containers loaded and unloaded, arrange loading and unloading machinery and berth.

3) Provide the berth arrangement diagram to site operation staff.

4) Inform the shipping company or agent berths arrange results.

5) Make berthing schedule based on the result of the berth arrangement, provide to the customs, frontier defense, pilot, or other related units.

2. Containers come in the yard

1) Port control tower to arrange the position of the container put in the yard, and notices the container information to the yard.

2) Yard workers determine tools of the container loading and unloading, and arrange the tools and equipment in place.

3) Yard works inform drivers and conductors do preparations, and arrange the auxiliary hanger.

4) Truck drivers put containers onto the specified position of the yard according to the instruction.

5) Gantry crane drivers lift and place the container to the specified location.

6) Yard workers handover completion confirmation with truck drivers.

3. The trailers get in and out of port

Get in the port:

1) Haul freight external trailer empty frame into the yard for the owner.

2) Drivers receive note paper of container position information in CMS.

3) Trailers extract containers in the specified position of the yard.

4) Trailers accept inspection, pay by credit card in the gate, then get out of gate.

Get out of the port

1) External trailers carrying container get through the gate into the terminal after inspection.

2) Trailer drivers receive note paper of container position information in CMS.

3) Drivers stack containers to the specified position according to note information.

4) Give note paper documents to gate switching operation, and collect delivery receipt.

5) Trailers get out of gate.

3.2 Stacking rules of containers in the block

3.2.1 Introduction of main stacking rules of containers in the block

Stacking rules of containers in the block directly affect the amount of stacking containers, also affects the amount of exacting containers. Stacking rules include mixed stacking and stacking separately, mixed stacking does not distinguish between import and export container block, is a relatively saves space of the stacking. Stacking separately makes a difference between import and export container, get better efficiency of ship handling, it also more favored by domestic large port.

In this paper, the main selected four kinds of stacking methods of stacking, they are the lowest utilization of block rule, block closest to the berth rule, cargo owner specifies block rule and port of destination specifies block rule. Four kinds of rules can be used single, also can use by combination according to different region settings.

Cargo owner specifies block rule is stacking container based on specify by user, then finish stacking work and get workload distribution among storage blocks result.

Port of destination specifies block rule is stacking container based on specify by port of destination, then finish stacking work and get workload distribution among storage blocks result.

The lowest utilization of block rule is at first arrange the utilization of the blocks from small to large, then do the stacking work to the block of lowest utilization, all the works are finished as this way and get workload distribution among storage blocks result.

Block closest to the berth rule is at first arrange the distance from the blocks to the berth from small to large, then do the stacking work to the block closest to the berth, all the works are finished as this way and get workload distribution among storage blocks result.

3.2.2 Factors affecting the selection of stacking rules

Factors affecting the stacking rules of container yard also include port throughput. In addition, the layout of container area is key factor of is stacking rules selection. Each container port layout of the yard is almost the same, but also has the difference. Block layout, selection of design of block, block attribute, size also affect the stacking rules. Finally, setting and selection of region value will also determine selection of stacking rules. These factors will affect the simulation result.

Chapter 4 Logical relationship design of simulation system for the workload distribution among storage blocks in a container terminal yard

4.1 system process design

4.1.1 Process of generating block data

Process of generating block data is shown in figure 4-1:

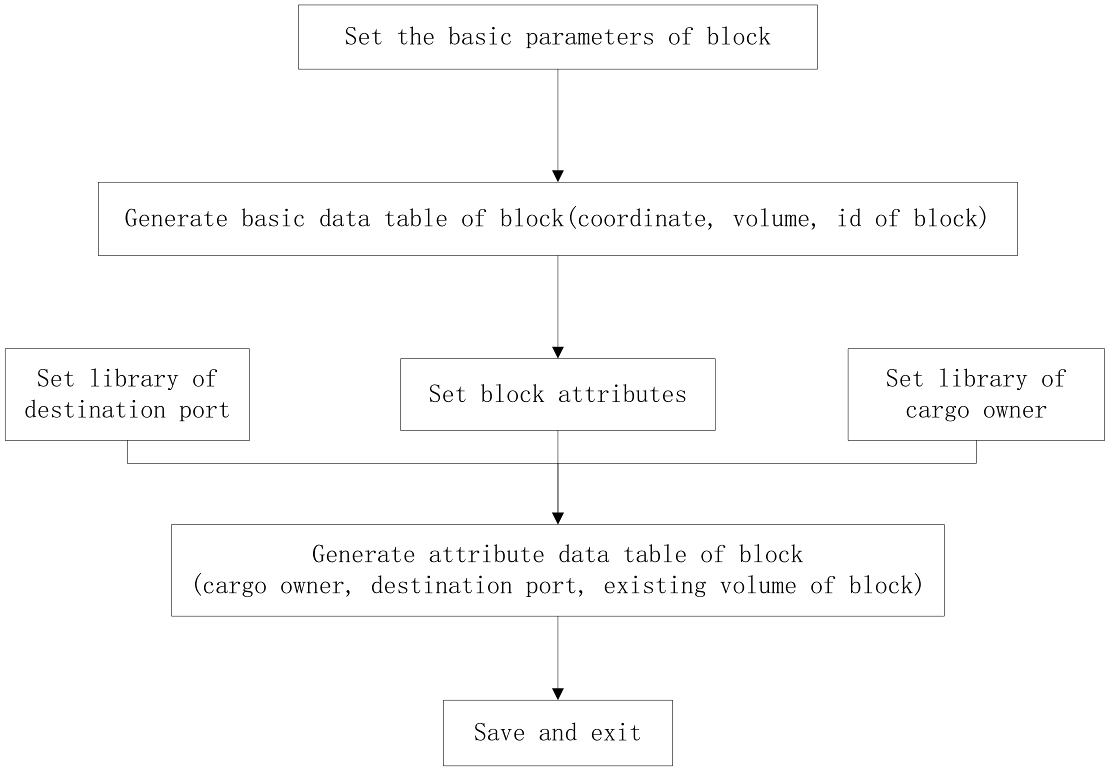


Figure 4-1 Process of generating block data

First of all, set block basic information includes the number of block rows and columns, length and width values and the basic parameters of block district space. Then set block attributes (cargo owners, ports of destination). Finally, according to these parameters generates the initial block data table.

4.1.2 Process of generating workload of each step

Process of generating workload of each step is shown in figure 4-2:

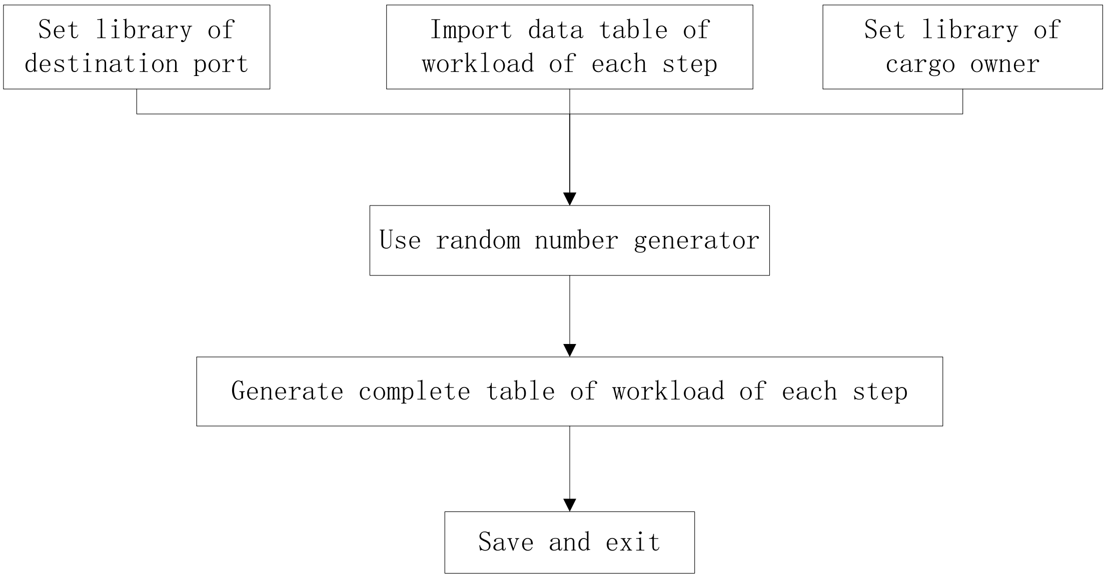


Figure 4-2 Process of generating workload of each step

First of all, user imports existing table of workload of each step, and then imports the port of destination and the cargo owner dictionary, according to the random number generator add container information to each step of the workload. Finally generate table of step workload.

4.1.3 Process of setting and selection of region value

The so-called regional value, refers to the value of dividing the blocks that participate in the distribution in different stages. Figure 4-3 as an example:

Figure 4-3 Set diagram of regional value

In the process of distribution among storage blocks, since not all of the container area should be distributed at the same time, this requires the division of region to ensure the work of distribution among storage blocks can be successful. In the diagram, the black part is the first region. When the division of part of block is finish and there also exists the containers for distributing, choose gray region as the second division region and so on. Until the workload distribution among storage block has been completed. In different regions, use can invoke different rules of distribution. Process shown as figure 4-4:

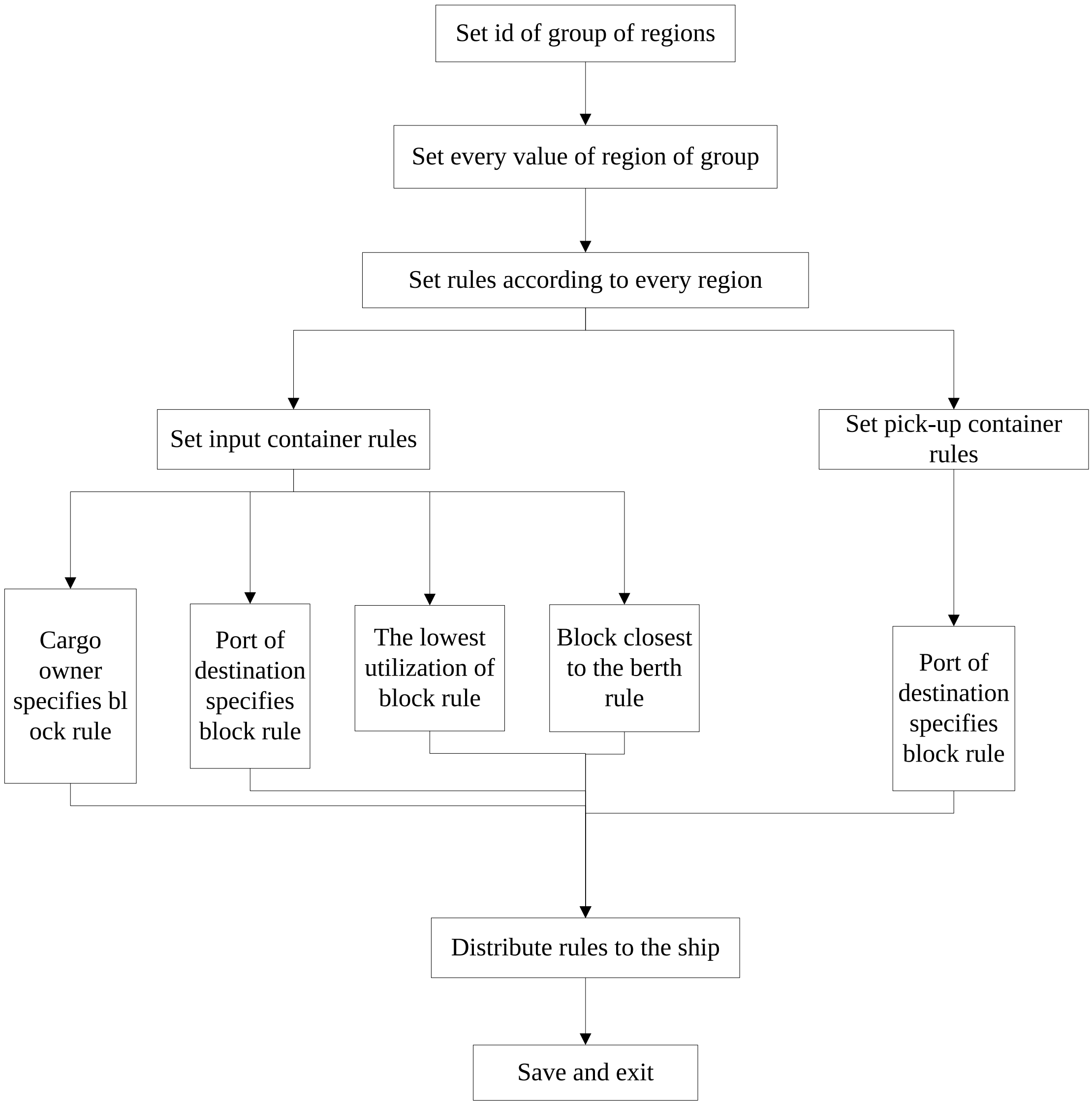


Figure 4-4 Process of set region value

In the region setting in the process, we must determine the regional range of each region. Then select rules according to each region data. The input container rule choice has four kinds: the lowest utilization of block rule, block closest to the berth rule, cargo owner specifies block rule and port of destination specifies block rule. The pick-up container rule choice has one kind: port of destination specifies block rule. After set the rules, save data and make the correlation between data.

4.1.4 Process of sorting business data

Sort data is to sort the data to appropriate format before the simulation process as it can be invoked convenient, the results of set rules are also shown in the data table. Process is shown as figure 4-5:

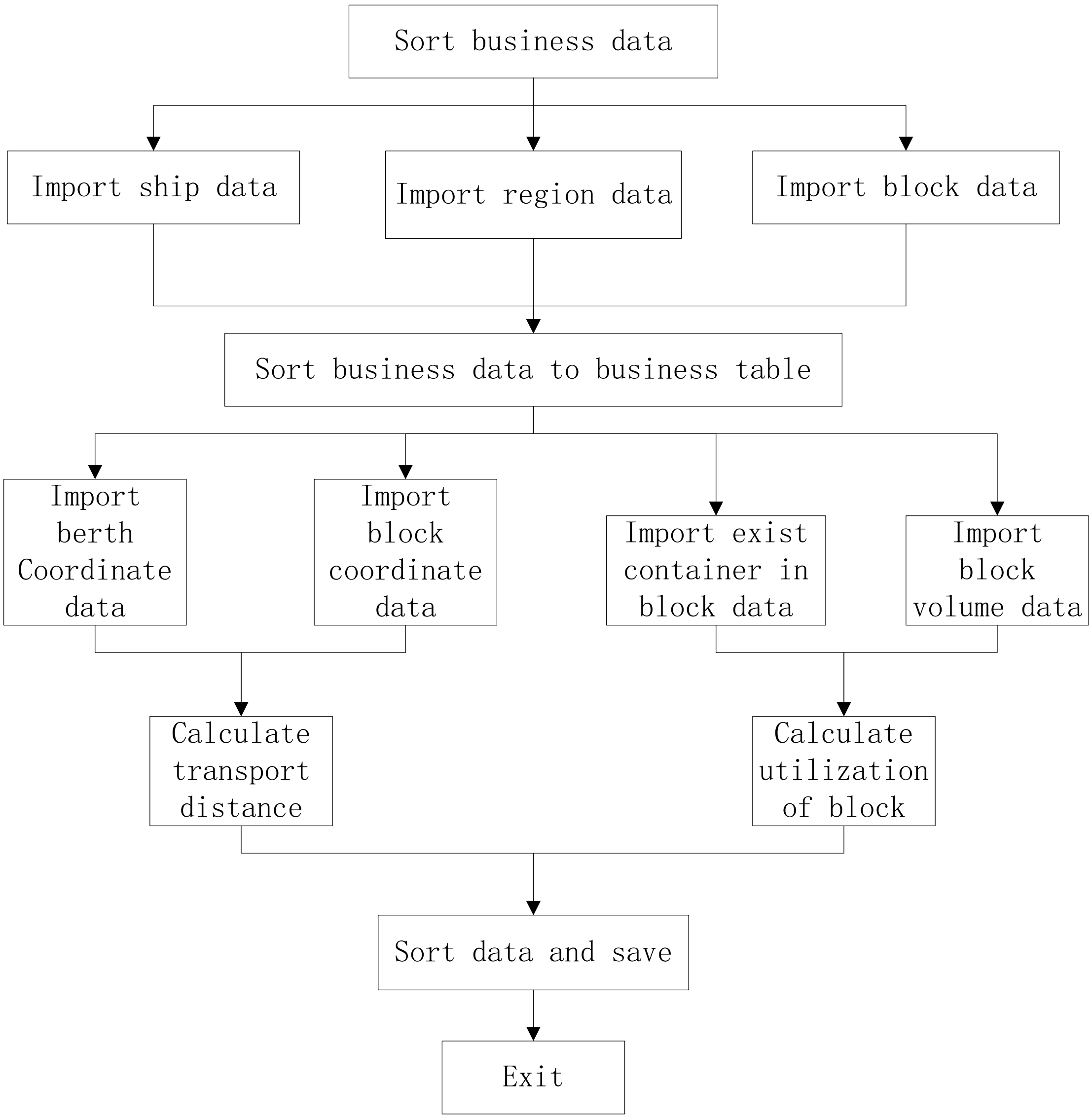


Figure 4-5 Process of sorting business data

First of all, we import the generated data of ship, block and region into business data table. Transport distance calculation is according to the block coordinate and berth coordinate, utilization is calculated on the basis of the existing container and total volume. After the data rearrange and save to the data in the table.

4.1.5 Process of simulation calculation

The simulation process is the core process of the whole process. We can get the final result of distribution among storage blocks according to the simulation based on the data before. Process is shown as figure 4-6:

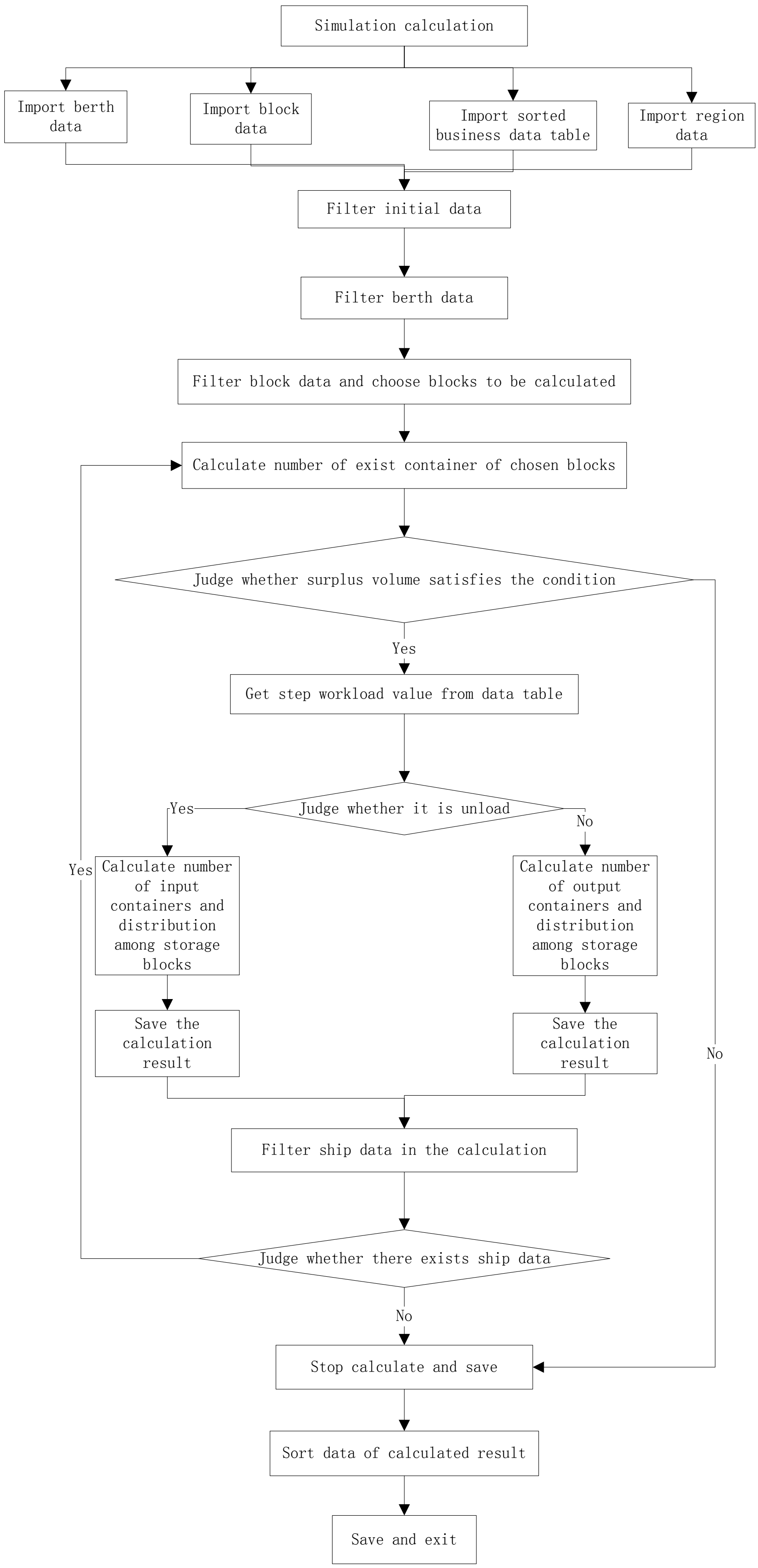


Figure 4-6 Process of simulation calculation

First of all, we select the sorted data, choose the data to participate the calculation in this moment, calculate whether the volume of blocks participate the distribution satisfies the satisfy distribution principle. The principle is shown as figure 4-7:

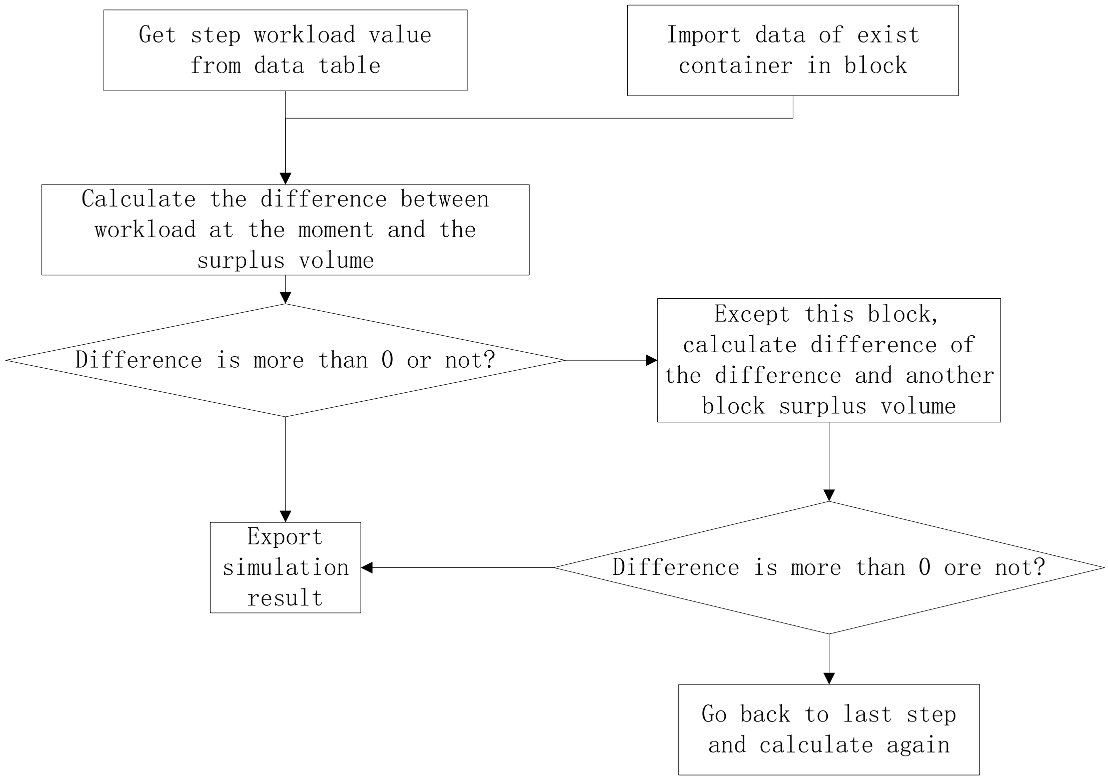


Figure 4-7 Satisfy distribution principle

The satisfy distribution principle is mainly two kinds of situation of judging whether meet the requirements: first, in the step container workload volume is greater than the selected block difference value, distribute directly. Second, in the step of container volume is less than the selected block difference volume, after the block distribution is completed, the remaining containers find other blocks to do the next assignment, until all the containers complete distribution. Process is shown as figure 4-8:

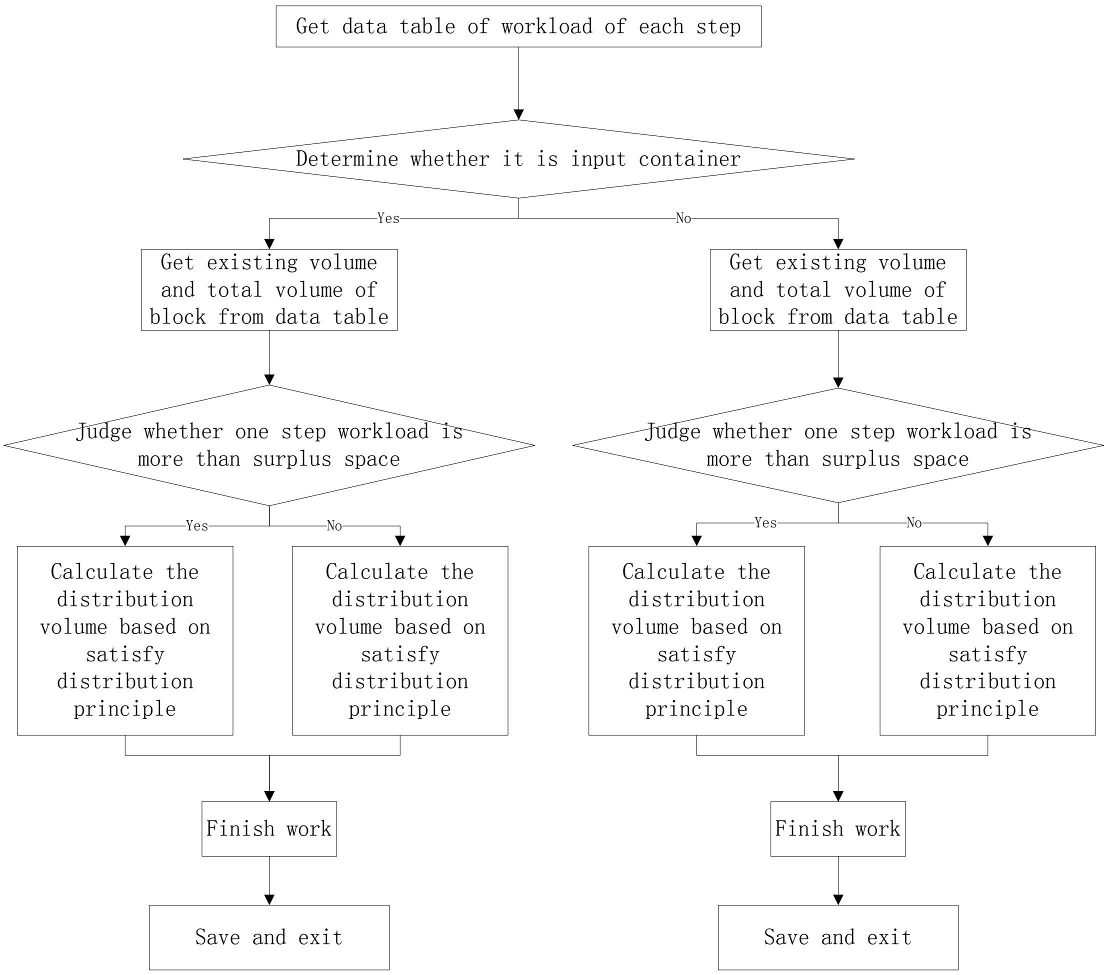


Figure 4-8 Process of ship input and output container

The process judges the step workload value participates in the distribution, judge whether the block suit for input and pick-up requirements, distribute containers according to satisfy distribution principle until the end of the work.

Finally, the progress saves calculation results to final result table, complete simulation process.

4.2 Analysis of system data flow

The simulation system for the workload distribution among storage blocks in a container terminal yard includes a complex database system. At the same time, there is a complex data flow and data corresponding relation. The relation is shown as figure 4-9:

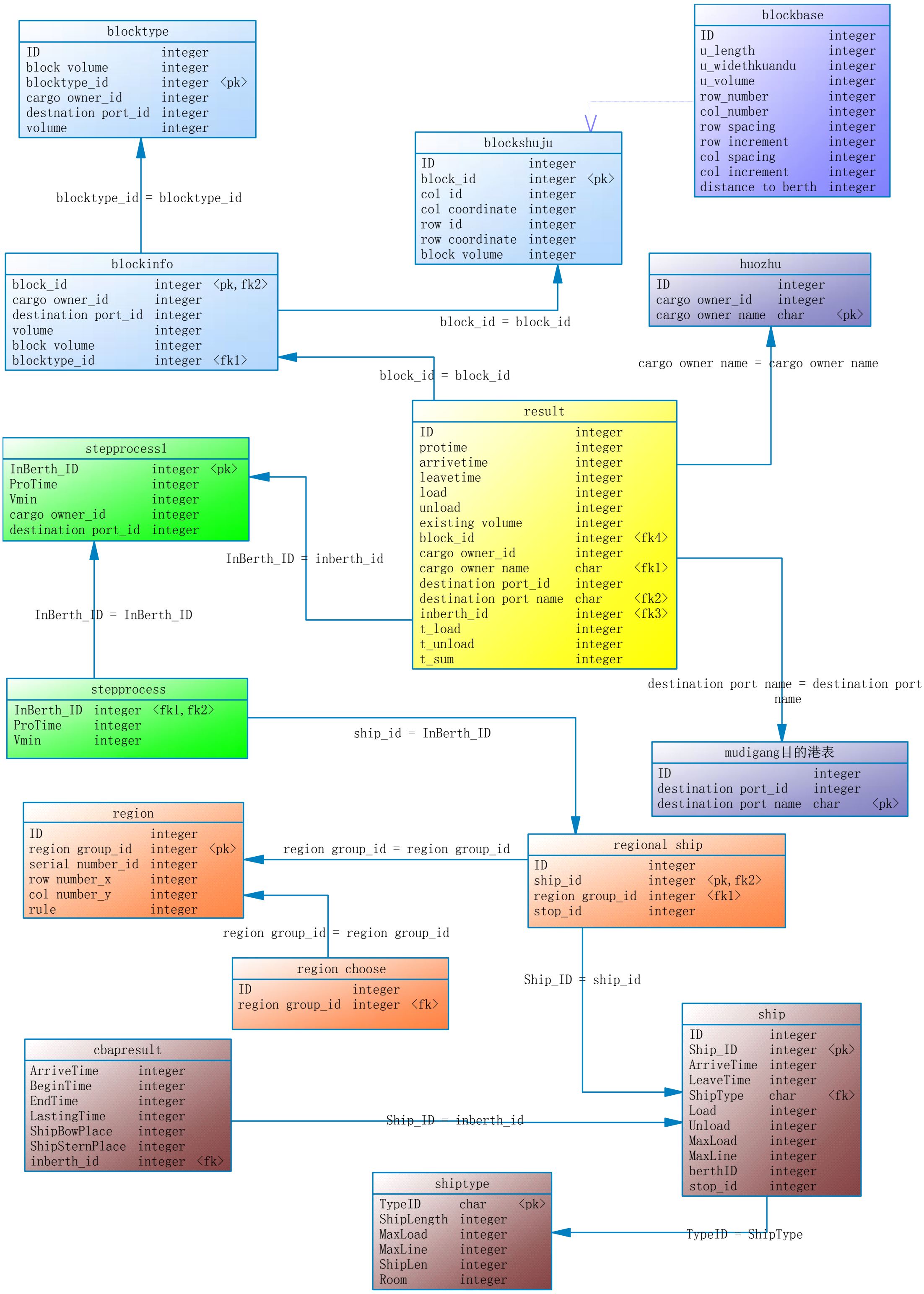


Figure 4-9 diagram data relationship

4.3 Design of database and dictionary

4.3.1 List of tables

List of tables is an index of the tables. It is shown in table 4-1:

Table4-1 List of tables

Name	Code
blockbase	blockbase
blockinfo	blockinfo
blockshuju	blockshuju
blocktype	blocktype
cargo owner	huozhu
cbapresult	cbapresult
destination port	mudigang
region	area
region choose	areachoose
regional ship	areaship
result	result
ship	ship
shiptype	shiptype
stepprocess	stepprocess
stepprocess1	stepprocess1

4.3.2 List of table columns

List of table columns is the dictionary of all elements. It is shown in table 4-2:

Table 4-2 List of table columns

Name	Code
ID	ID
block volume	danweixiangliang
blocktype_id	blocktype_id
cargo owner_id	huozhu_id
destnation port_id	mudigang_id
volume	xiangliang
ID	ID
block_id	block_id
col id	liehao
col coordinate	liezuobiao
row id	hanghao
row coordinate	hangzuobiao
block volume	danweixiangliang
block_id	block_id
cargo owner_id	huozhu_id
destination port_id	mudigang_id

volume	xiangliang
block volume	danweixiangliang
blocktype_id	blocktype_id
ID	ID
u_length	u_changdu
u_widethkuandu	u_kuandu
u_volume	u_xiangshuliang
row_number	row_shuliang
col_number	col_shuliang
row spacing	hangjianju
row increment	hangzengliang
col spacing	liejianju
col increment	liezengliang
distance to berth	libojuli
ID	ID
region group_id	yuzu_id
serial number_id	xuhao_id
row number_x	hangshuliang_x
col number_y	lieshuliang_y
rule	guize
ID	ID
region group_id	yuzu_id
ID	ID
ship_id	ship_id
region group_id	yuzu_id
stop_id	tingbo_id
ArriveTime	ArriveTime
BeginTime	BeginTime
EndTime	EndTime
LastingTime	LastingTime
ShipBowPlace	ShipBowPlace
ShipSternPlace	ShipSternPlace
inberth_id	inberth_id
ID	ID
cargo owner_id	huozhu_id
cargo owner name	huozhuming
ID	ID
destination port_id	mudigang_id
destination port name	mudigangming
ID	ID
Ship_ID	Ship_ID

ArriveTime	ArriveTime
LeaveTime	LeaveTime
ShipType	ShipType
Load	Load
Unload	Unload
MaxLoad	MaxLoad
MaxLine	MaxLine
berthID	berthID
stop_id	tingbo_id
TypeID	TypeID
ShipLength	ShipLength
MaxLoad	MaxLoad
MaxLine	MaxLine
ShipLen	ShipLen
Room	Room
InBerth_ID	InBerth_ID
ProTime	ProTime
Vmin	Vmin
InBerth_ID	InBerth_ID
ProTime	ProTime
Vmin	Vmin
cargo owner_id	huozhu_id
destination port_id	mudigang_id
ID	ID
protime	protime
arrivetime	arrivetime
leavetime	leavetime
load	load
unload	unload
existing volume	yiyouxiangliang
block_id	block_id
cargo owner_id	huozhu_id
cargo owner name	huozhuming
destination port_id	mudigang_id
destination port name	mudigangming
inberth_id	inberth_id
t_load	t_load
t_unload	t_unload
t_sum	t_sum

4.3.3 List of references

Reference is the relation between tables, is the connection based on primary keys of the table and foreign keys of other tables (or primary).List of reference is the structure index between all tables. It is shown in table 4-3:

Table 4-3 List of references

Name	Code	Parent Table	Child Table
Reference_1	Reference_1	blocktype	blockinfo
Reference_3	Reference_3	stepprocess1	stepprocess
Reference_4	Reference_4	cargo owner	result
Reference_5	Reference_5	destination port	result
Reference_6	Reference_6	stepprocess1	result
Reference_7	Reference_7	blockinfo	result
Reference_9	Reference_9	region	regional ship
Reference_10	Reference_10	region	region choose
Reference_11	Reference_11	shiptype	ship
Reference_13	Reference_13	ship	cbapresult
Reference_14	Reference_14	ship	regional ship
Reference_15	Reference_15	blockshuju	blockinfo
Reference_16	Reference_16	regional ship	stepprocess

4.3.4 List of columns

List of columns is the specific information in each column of each table in the database, including name, code and foreign keys.

List of columns of the table blockbase is shown in table 4-4:

Table 4-4 List of columns of the table blockbase

Name	Code
ID	ID
u_length	u_changdu
u_widethkuandu	u_kuandu
u_volume	u_xiangshuliang
row_number	row_shuliang
col_number	col_shuliang
row spacing	hangjianju
row increment	hangzengliang
col spacing	liejianju
col increment	liezengliang
distance to berth	libojuli

List of columns of the table blockinfo is shown in table 4-5:

Table 4-5 List of columns of the table blockinfo

Name	Code
block_id	block_id
cargo owner_id	huozhu_id
destination port_id	mudigang_id
volume	xiangliang
block volume	danweixiangliang
blocktype_id	blocktype_id

List of columns of the table blockshuju is shown in table 4-6:

Table 4-6 List of columns of the table blockshuju

Name	Code
ID	ID
block_id	block_id
col id	liehao
col coordinate	liezuobiao
row id	hanghao
row coordinate	hangzuobiao
block volume	danweixiangliang

List of columns of the table blocktype is shown in table 4-7:

Table 4-7 List of columns of the table blocktype

Name	Code
ID	ID
block volume	danweixiangliang
blocktype_id	blocktype_id
cargo owner_id	huozhu_id
destnation port_id	mudigang_id
volume	xiangliang

List of columns of the table cargo owner is shown in table 4-8:

Table 4-8 List of columns of the table cargo owner

Name	Code
ID	ID
cargo owner_id	huozhu_id
cargo owner name	huozhuming

List of columns of the table cbapresult is shown in table 4-9:

Table 4-9 List of columns of the table cbapresult

Name	Code
ArriveTime	ArriveTime
BeginTime	BeginTime
EndTime	EndTime
LastingTime	LastingTime
ShipBowPlace	ShipBowPlace
ShipSternPlace	ShipSternPlace
inberth_id	inberth_id

List of columns of the table destination port is shown in table 4-10:

Table 4-10 List of columns of the table destination port

Name	Code
ID	ID
destination port_id	mudigang_id
destination port name	mudigangming

List of columns of the table region is shown in table 4-11:

Table 4-11 List of columns of the table region

Name	Code
ID	ID
region group_id	yuzu_id
serial number_id	xuhao_id
row number_x	hangshuliang_x
col number_y	lieshuliang_y
rule	guize

List of columns of the table region choose is shown in table 4-12:

Table 4-12 List of columns of the table region choose

Name	Code
ID	ID
region group_id	yuzu_id

List of columns of the table regional ship is shown in table 4-13:

Table 4-13 List of columns of the table regional ship

Name	Code
ID	ID
ship_id	ship_id
region group_id	yuzu_id
stop_id	tingbo_id

List of columns of the table result is shown in table 4-14:

Table 4-14 List of columns of the table result

Name	Code
ID	ID
protime	protime
arrivetime	arrivetime
leavetime	leavetime
load	load
unload	unload
existing volume	yiyouxiangliang
block_id	block_id
cargo owner_id	huozhu_id
cargo owner name	huozhuming
destination port_id	mudigang_id
destination port name	mudigangming
inberth_id	inberth_id
t_load	t_load
t_unload	t_unload
t_sum	t_sum

List of columns of the table ship is shown in table 4-15:

Table 4-15 List of columns of the table ship

Name	Code
ID	ID
Ship_ID	Ship_ID
ArriveTime	ArriveTime
LeaveTime	LeaveTime
ShipType	ShipType
Load	Load
Unload	Unload
MaxLoad	MaxLoad
MaxLine	MaxLine
berthID	berthID
stop_id	tingbo_id

List of columns of the table shiptype is shown in table 4-16:

Table 4-16 List of columns of the table shiptype

Name	Code
TypeID	TypeID
ShipLength	ShipLength
MaxLoad	MaxLoad
MaxLine	MaxLine
ShipLen	ShipLen
Room	Room

List of columns of the table stepprocess is shown in table 4-17:

Table 4-17 List of columns of the table stepprocess

Name	Code
InBerth_ID	InBerth_ID
ProTime	ProTime
Vmin	Vmin

List of columns of the table stepprocess1 is shown in table 4-18:

Table 4-18 List of columns of the table stepprocess1

Name	Code
InBerth_ID	InBerth_ID
ProTime	ProTime
Vmin	Vmin
cargo owner_id	huozhu_id
destination port_id	mudigang_id

Chapter 5 Development and function design of simulation system for the workload distribution among storage blocks in a container terminal yard

5.1 User main interface design

The whole system includes the initial interface, a plurality of data input window, the output window, report window. It maintains a consistent style for the convenience of the user to quickly grasp the operating system.

1． The main window interface

In this system, the main window interface using Windows forms of Windows, the "window" is mainly composed of logo picture and program operation menu, the menu includes the following functions:

Set ship data consists of two parts, first part is importing ship data, it imports the initial data of the ship into the window, second part is importing step workload, then gets ready for the calculation of next step.

Set block data includes three parts, block parameter setting, block initial types setting, and the block data generation.

Set container parameters can set specific information on the block, regional value set is set specific regional value dialog box.

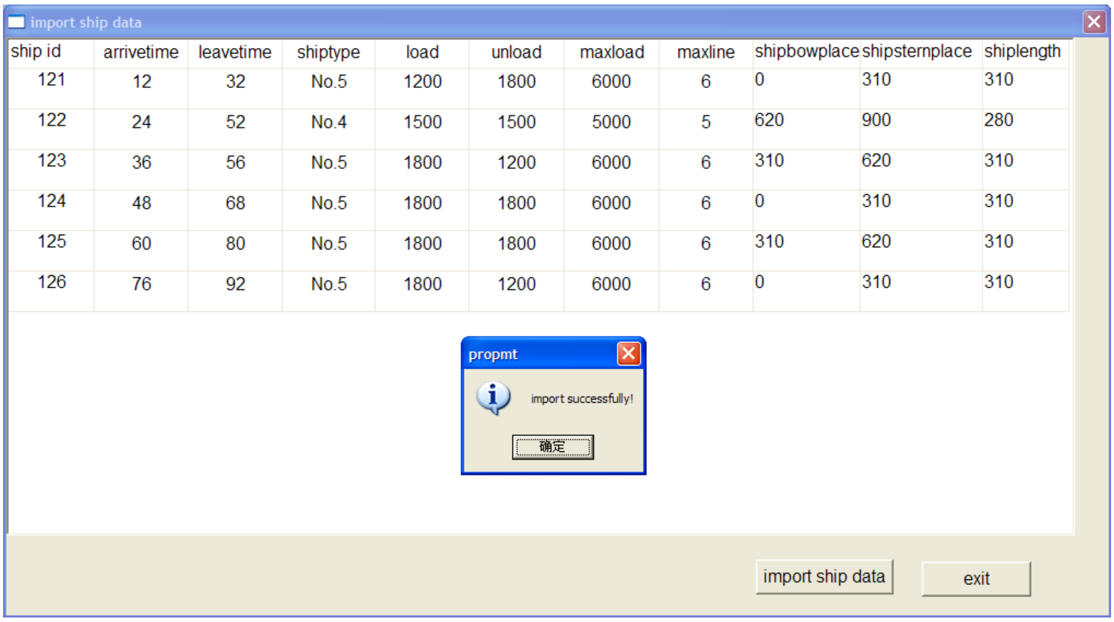
The calculation is simulation, is the core part of the progress.

Window is shown as figure 5-1:

Figure 5-1 main window

2. First step: set ship data

Click “set ship data” button, choose “import ship data” and “import step workload” two functions, they can import step workload and ship data. This is the first step of this system. Only introduce initial data can complete the following work. It is shown as figure 5-2:



ship id	arrivetime	leavetime	shiptype	load	unload	maxload	maxline	shipbowplace	shipsternplace	shiplength
121	12	32	No.5	1200	1800	6000	6	0	310	310
122	24	52	No.4	1500	1500	5000	5	620	900	280
123	36	56	No.5	1800	1200	6000	6	310	620	310
124	48	68	No.5	1800	1800	6000	6	0	310	310
125	60	80	No.5	1800	1800	6000	6	310	620	310
126	76	92	No.5	1800	1200	6000	6	0	310	310

Figure 5-2 window of importing ship data

“Import ship data” is to import data from access database to windows. Press "import ship data" button, if import successfully, we can see message box and save all the information and prepare for the calculation next step.

"Import step workload" button is to initialize for data information of every step. It is show as figure 5-3:

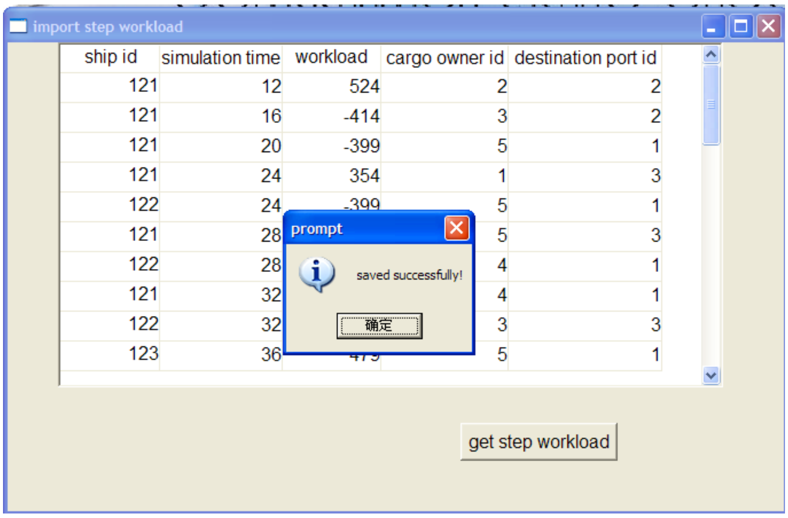


Figure 5-3 window of initializing step workload

In the existing database, the program only has three kinds of data when begins to run, the data are the number, the simulation time and the actual loading and unloading volume. So add the shipper and the port of destination information to each step of the workload according to the random number generator. This part is operated when click "get step workload" button and is operated by system automatic. And after generate these data, system will save the data, prepares or the following computation.

3. Step 2: Set block data

"Set block data" includes "set block parameter", "set initial block type" and "generate block data" three function.

"Set block parameter" is the window to input basic attribute of block. User can set different scope of block types include length, width, increment, block volume and number of blocks. User can get different initial block types based on different ways of setting. This step is to provide condition for the following step of generating basic block data. Window is shown as figure 5-4:

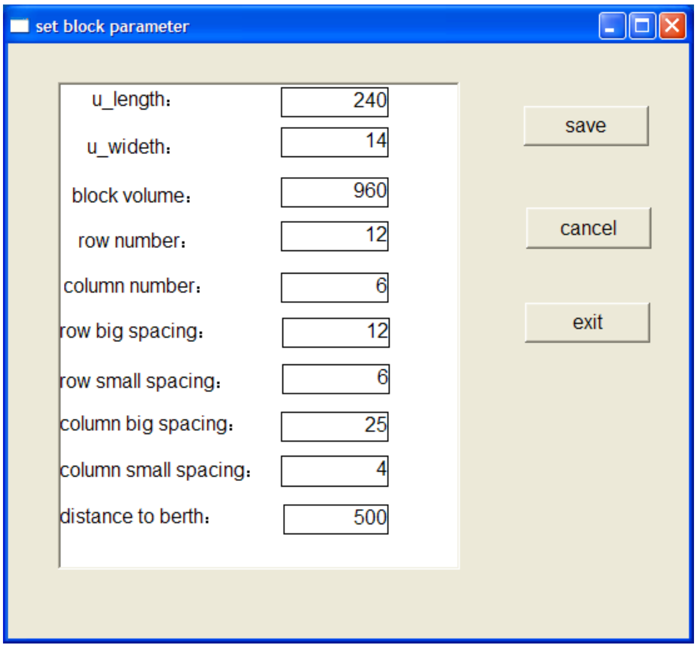


Figure 5-4 set block parameter

“Set initial blocktype” is to set types of block. Users can set different types of block form in the window, and these data can be called in importing block data process. After set the data, data can be saved into database. The window is shown as figure 5-5:

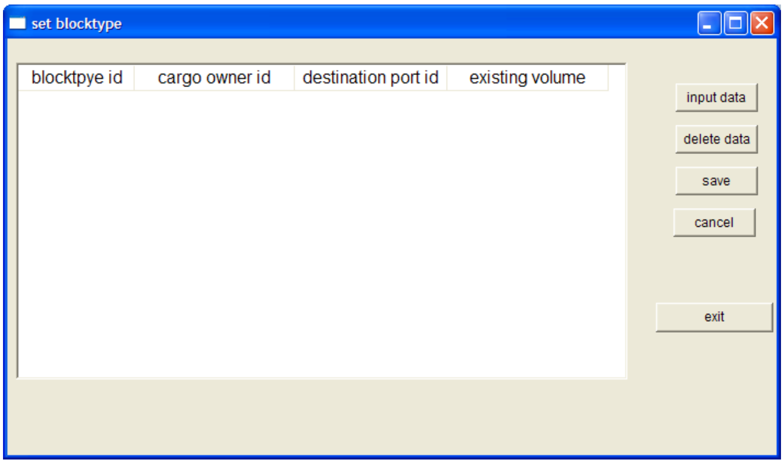


Figure 5-5 set initial block type

"Block data generation" window is the role of the previous data generation and associates with this window. Click on the "generate block data based on parameter" button to generate block data (the data in left window). Click one colum of data on the left window, the data associate to the right side of the window based on block number, get the block specific parameter information (probably more than one message).

At the same time, if there is an Excel data file, the file can be directly linked to the window. Also the data can be put into the window according to the specific needs. The window is shown as figure 5-6:

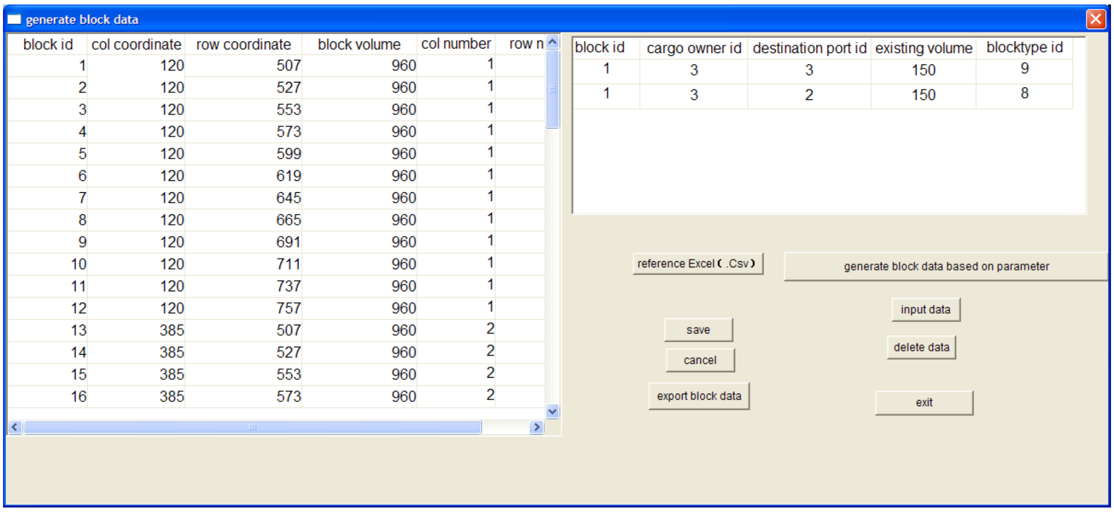


Figure 5-6 window of block data generation

4. Step 3: Container parameter set

"Set container parameter" window, is shown as figure 5-7:

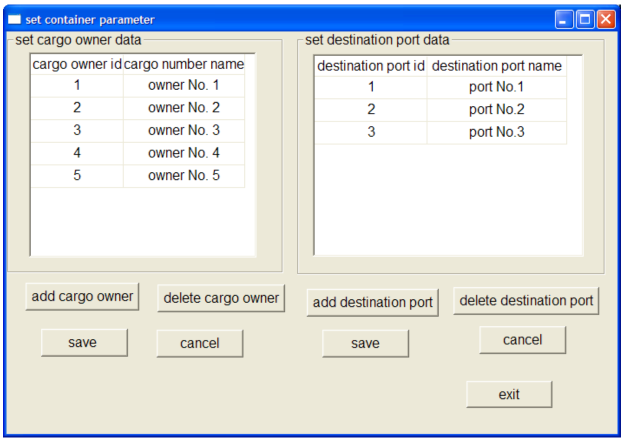


Figure 5-7 window of set container parameter

This form has imported the existing data of cargo owner and the port of destination, and also can modify the existing parameter.

The most important significance of this window is for each part of the system, exists container type information. Container information set in this window can be directly affects the distribution result. For example, in the process of calculation will call cargo owner id and destination port id in the algorithm, and link the owner information and destination information to the window according to the id.

5. Step 4: Set region value and rules

User can associate ship data with region value data, choose allocation space to allocating block. Set region value window is shown as figure 5-8:

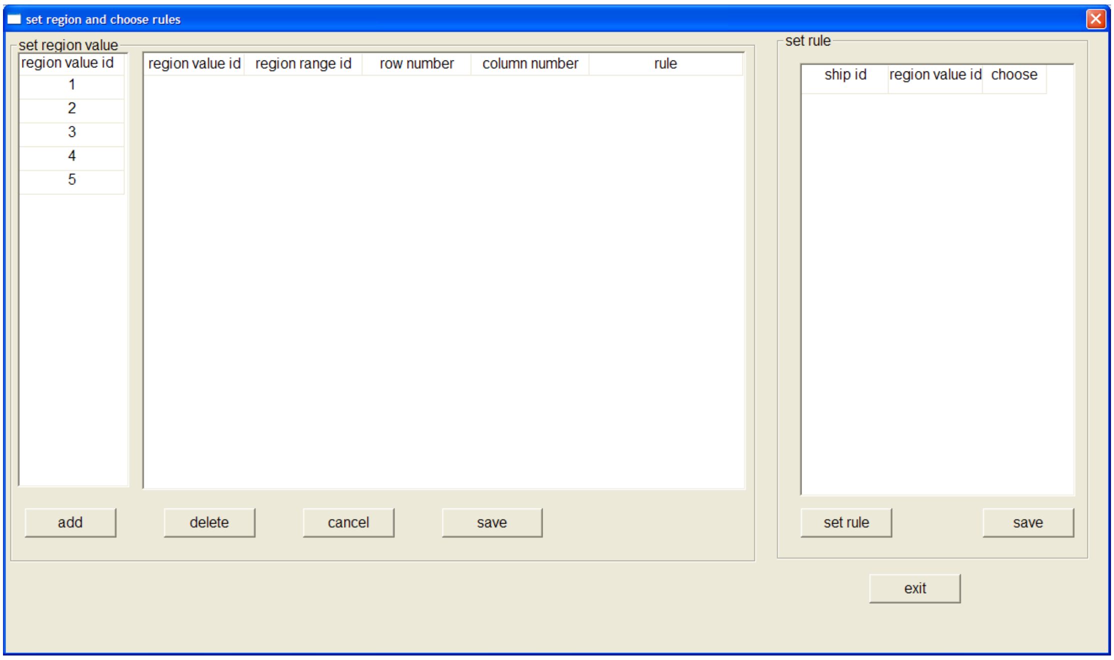


Figure 5-8 set region value

After open the window, press “set rule” button to set rule. The window is shown s figure 5-9:

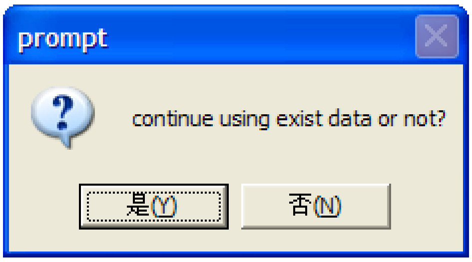


Figure 5-9 notice of set rule

Press “Y” option, user can choose exist data to calculate directly, press “N” can rename the data. Rename the name is shown as figure 5-10:

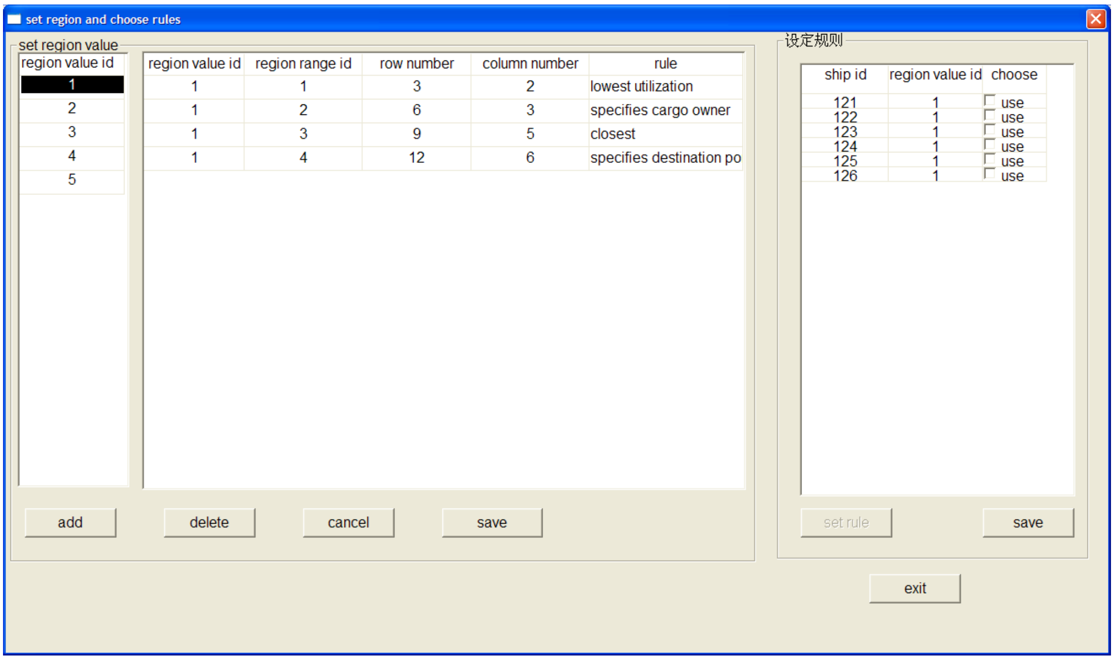


Figure 5-10 reset region value

This window has two basic functions:

1) Update region group value data

In the two data windows in this window, user can set region group value data. Set add a new region value as an example. First press a region group value in the left data window, then press "add" button, add a new empty column in middle data window. Then user inputs "region value id", "region range id", "row number", "column number", and chooses a rule in the four existing rules. Press "save" button, save the new data to database. The operation of pressing "delete" button is as the same.

2) Set rule

When user does not need to change regional value data, ship data can associate with regional value data. For example, user selects region value numbers for regional group 1, then click on the column of "use" box to choose ship in the right side of the window, whenever click once, "ship id" and "regional value id" obtains allocation. When the allocation is complete, click the "save" button to save the data into the database. The data window filters ship data which has been allocated, the user can allocate again according to the needs of the region value id, until the right data window has no data. At this time, all the values and rules of data are assigned to all ship data participate in the allocation.

6. Step 5: simulation calculation

Press “simulation calculation” button to calculate, and save result to the data window upside. The window includes two parts: block data reduction and simulation calculation. The windows are shown as 5-11 and 5-12:

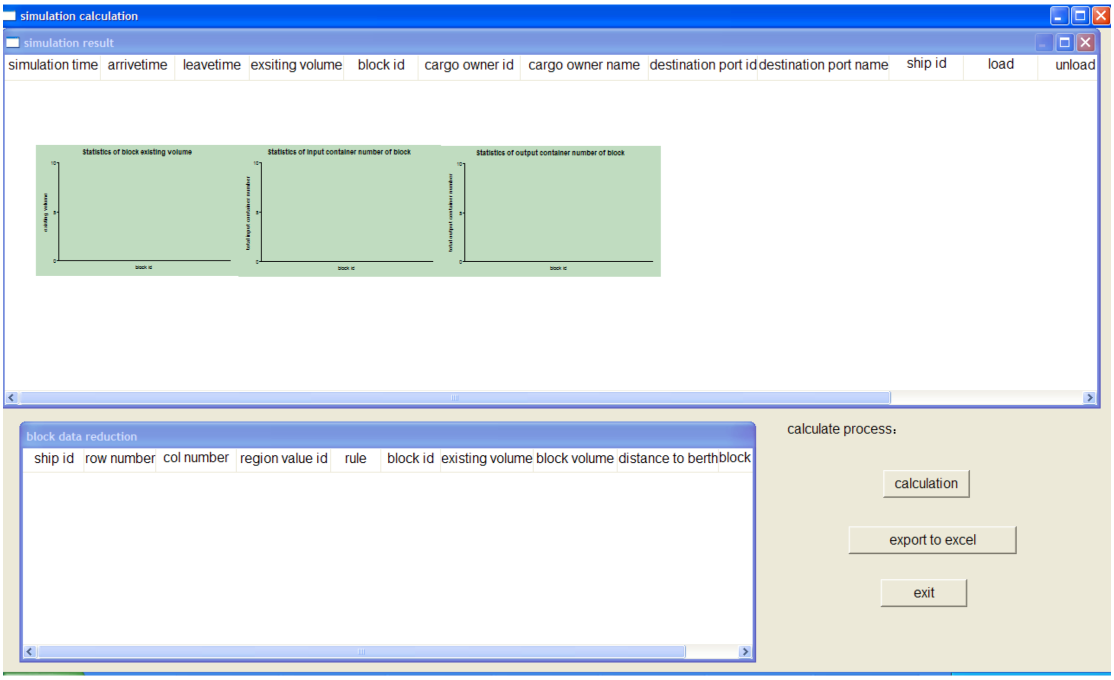


Figure 5-11 window of simulation calculation

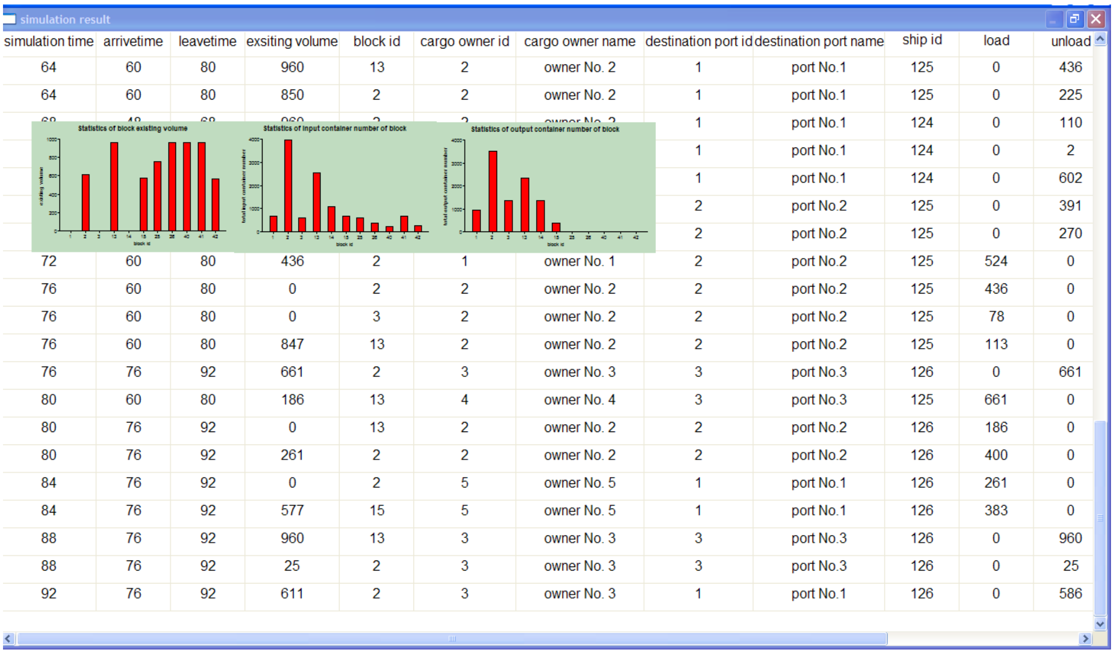
block data reduction

ship id	row number	col number	region value id	rule	block id	existing volume	block volume	distance to berth	block utilization
121	1	1	1	2	1	0	960	542	0
121	2	1	1	2	2	611	960	562	0
121	3	1	1	2	3	0	960	588	0
121	3	2	1	2	15	577	960	783	0
121	2	2	1	2	14	0	960	757	0
121	1	2	1	2	13	960	960	737	0

Figure 5-12 window of block data reduction

In this window, at first, window retrieves all the data which participating the calculation, and sets them to the window to prepare for calculating. Distance to berth and utilization of block data are achieved by calculating, and refreshing based on time until simulation is finished.

Finally, get simulation result, part of the window is shown as figure 5-13:



simulation time	arrivetime	leavetime	exsiting volume	block id	cargo owner id	cargo owner name	destination port id	destination port name	ship id	load	unload
64	60	80	960	13	2	owner No. 2	1	port No.1	125	0	436
64	60	80	850	2	2	owner No. 2	1	port No.1	125	0	225
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	port No.1	124	0	110
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	port No.1	124	0	2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	port No.1	124	0	602
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	port No.2	125	0	391
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	port No.2	125	0	270
72	60	80	436	2	1	owner No. 1	2	port No.2	125	524	0
76	60	80	0	2	2	owner No. 2	2	port No.2	125	436	0
76	60	80	0	3	2	owner No. 2	2	port No.2	125	78	0
76	60	80	847	13	2	owner No. 2	2	port No.2	125	113	0
76	76	92	661	2	3	owner No. 3	3	port No.3	126	0	661
80	60	80	186	13	4	owner No. 4	3	port No.3	125	661	0
80	76	92	0	13	2	owner No. 2	2	port No.2	126	186	0
80	76	92	261	2	2	owner No. 2	2	port No.2	126	400	0
84	76	92	0	2	5	owner No. 5	1	port No.1	126	261	0
84	76	92	577	15	5	owner No. 5	1	port No.1	126	383	0
88	76	92	960	13	3	owner No. 3	3	port No.3	126	0	960
88	76	92	25	2	3	owner No. 3	3	port No.3	126	0	25
92	76	92	611	2	3	owner No. 3	1	port No.1	126	0	586

Figure 5-13 simulation result

Call plugins for block data, add the chart statistics function. Statistical data is divided into three parts:

First, statistics on the existing container volume after simulation the, this is the most direct and most important data for the statistical results.

Second, statistics on the input container number, statistics on input container work of each step.

Third, statistics on the output container number, statistics on output container work of each step.

Users can directly analyze the results according to histogram. At this point, simulation is over.

5.2 Case analysis

5.2.1Background introduction

In this chapter, we take the four stage of the Ningbo port container terminal as an example, and the case is solved by the system.

Gangji container terminal is Ningbo port group and the Mediterranean and EVA two ship company joint venture to build a container terminal, with

1700 meters coastline length, 5 berths, 20 loading bridges, 52 sets of gantry cranes in container terminal. The development of today, the port throughput can reach 360-380 million TEU, the water depth in good condition (17 meters), advanced equipment, good service, has attracted major shipping companies to berth.

Ningbo port four yard distribution of original distribution diagram as shown in figure 5-14. The dark blue area is empty container storage area, which belongs to the stacker work area, lake blue belongs to the warehouse area, big red area (0E, 0F) is a storage area of dangerous goods container.

Figure 5-14 map of four stage of the Ningbo port container terminal

The yellow areas in the images are as the block region involved in the calculation of the system. The basic data in the box area, including the block capacity, the row coordinate, the column coordinate, these data are from the real port data. The attribute data in the block, each block includes a five random to the owner, a three port of destination data. These data are automatically generated by simulation system. Relevant basic data as shown in table 5-1, the attribute data as shown in figure 5-15:

Table 5-1 part of block relevant data

Block id	Column coordinate	row coordinate	block capacity	Column number	Row number
1	120	507	960	1	1
2	120	527	960	1	2
3	120	553	960	1	3
4	120	573	960	1	4
5	120	599	960	1	5
6	120	619	960	1	6
7	120	645	960	1	7
8	120	665	960	1	8
9	120	691	960	1	9
10	120	711	960	1	10
11	120	737	960	1	11
12	120	757	960	1	12

block id	cargo owner id	destination port id	existing volume	blocktype id
7	2	3	150	6
7	1	1	150	1
7	2	2	150	5
7	3	2	150	8
7	3	1	150	7

Figure 5-15 block attribute data

5.2.2 Set basic simulation data

Obtains the initial ship data values according to the simulation system of container terminal resources allocation, includes ship basic data and the step workload, show in table 5-2, 5-3:

Table 5-2 ship basic data

Ship id	Arrive time	Leave time	Ship type	Load	Unload	Max load	Work line
121	12	32	5 号	1200	1800	6000	6
122	24	52	4 号	1500	1500	5000	5
123	36	56	5 号	1800	1200	6000	6
124	48	68	5 号	1800	1800	6000	6
125	60	80	5 号	1800	1800	6000	6
126	76	92	5 号	1800	1200	6000	6

Table 5-3 step workload

Ship id	Step protime	Step workload	Cargo owner id	Destination port id
121	12	524	2	2
121	16	-414	3	2
121	20	-399	5	1
121	24	354	1	3
121	28	985	5	1
121	32	714	5	3
122	24	-399	4	1
122	28	551	4	1
122	32	489	3	3
122	36	489	5	1
122	40	-304	1	2
122	44	-410	1	3
122	48	-304	2	2
122	52	-551	3	3
123	36	479	2	3
123	40	-479	2	2
123	44	-719	1	1
123	48	-586	3	1
123	52	661	3	2
123	56	410	2	3
124	48	657	2	1
124	52	-479	5	2
124	56	-921	3	2
124	60	586	4	2
124	64	485	3	3
124	68	714	3	3
125	60	-921	2	1
125	64	661	2	1
125	68	661	4	2
125	72	-524	1	2
125	76	-627	3	3
125	80	-661	2	2
126	76	661	2	2
126	80	-586	4	3
126	84	-644	5	1
126	88	985	3	3
126	92	586	3	1

In step workload table, destination and cargo owner id are generated by simulation system randomly. It is convenient for simulation calculation. According to the result in table 5-3, every step in simulation system is 4 hours, simulation time is 80 hours. 6 ships join the calculation in total.

Get every ship stop coordinate according to container terminal berth planning and optimization simulation system. The data are shown in table 5-4:

Table 5-4 berth allocation

Ship id	Arrive time	Begin time	End time	Last time	Ship bow place	Ship stern place	Ship length
121	12	12	34	22	0	310	310
122	24	24	52	28	620	900	280
123	36	36	59	23	310	620	310
124	48	48	74	26	0	310	310
125	60	60	87	27	310	620	310
126	76	76	110	34	0	310	310

5.2.3 A plurality of regional value division and rule setting simulation analysis

According to statistical analysis, different demands can choose different rule choices and region settings. Also user can use multiple rules combine with region value set to workload distribution among storage blocks. Since user can choose hundreds of allocating ways, in this paper, use fixed region value(first region 3 rows and 2 columns, second region 6 rows and 3 columns, third region 9 rows and 5 columns, forth region 12 rows and 6 columns) and choose different rules in every region to calculate. Use multiple rules combine with region value set to calculate is shown as follows:

1) Case 1: first region uses closest to berth rule + second region uses block lowest utilization rule + third region uses specify cargo owner rule + forth region uses specify destination port rule. The statistical result is shown as figure 5-16:

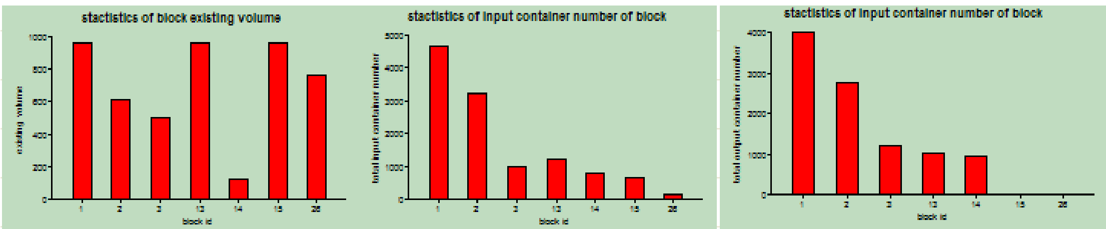


Figure5-16 statistical analysis in case 1

2) Case 2: first region uses block lowest utilization rule + second region uses closest to berth rule + third region uses specify cargo owner rule + forth region uses specify destination port rule. The statistical result is shown as figure 5-17:

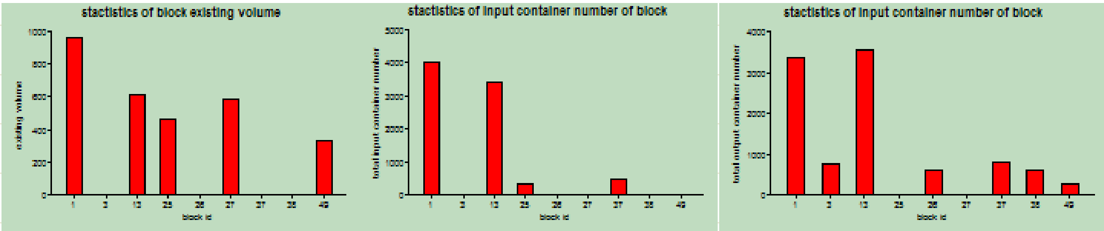


Figure 5-17 statistical analysis in case 2

3) Case 3: first region uses specify cargo owner rule + second region uses block lowest utilization rule + third region uses closest to berth rule + forth region uses specify destination port rule . The statistical result is shown as figure 5-18:

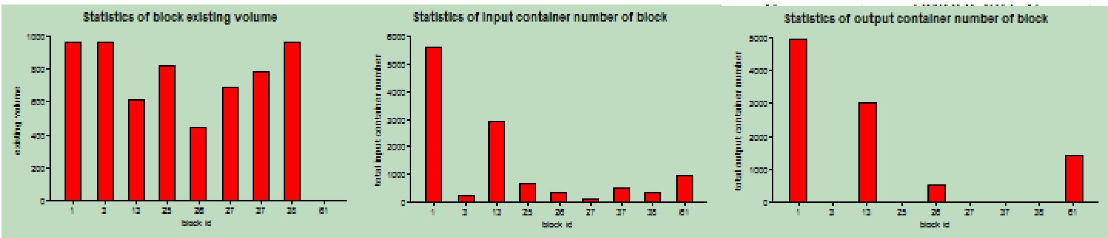


Figure 5-18 statistical analysis in case 3

4) Case 4: first region uses closest to berth rule + second region uses specify destination port rule + third region uses specify cargo owner rule + forth region uses block lowest utilization rule. The statistical result is shown as figure 5-19:

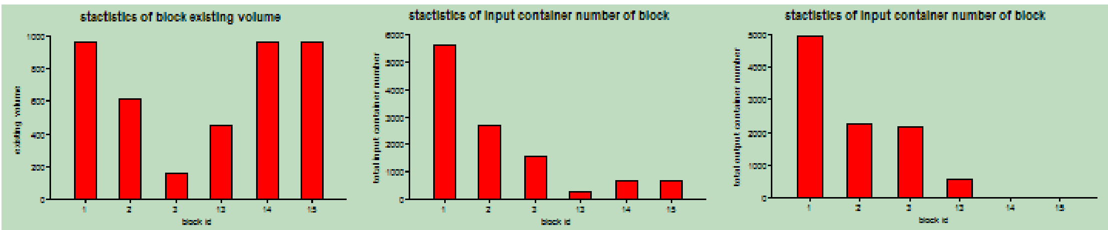


Figure 5-19 statistical analysis in case 4

5) Case 5: first region uses block lowest utilization rule + second region uses specify cargo owner rule+ third region uses closest to berth rule+ forth region uses specify destination port rule. The statistical result is shown as figure 5-20:

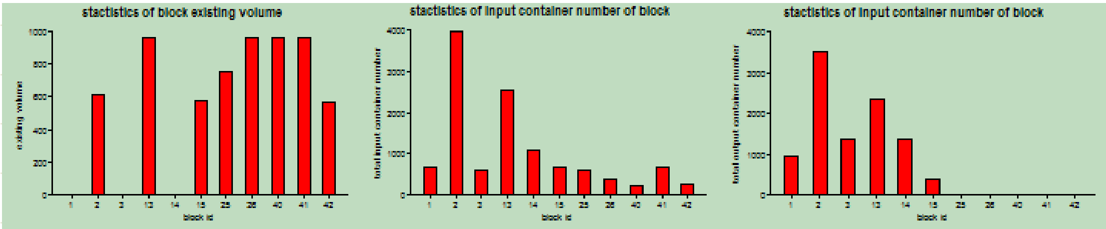


Figure 5-20 statistical analysis in case 5

From the several histograms chart above, can sum up the following characteristics:

Consider the region value division and ship berthing location, block 1 in most cases is the key area in input container operation in distribution among storage blocks, only case 5 special.

The distribution plan in scheme one and four can reduce the selection in distribution among storage blocks process, reduce the number of blocks involved in distribution. The common point of two kinds of distribution is use closest to berth rule in the first region. This kind of distribution can effectively reduce the use of block.

According to the histogram of scheme two shows, workload in container operation mainly concentrated in the first block and thirteenth block (two blocks are laterally adjacent). This distribution method can effectively reduce the call of gantry crane and improve the utilization rate and efficiency of gantry crane.

Case 5 results compared with several previous cases, calls more blocks and input workloads are average. Multi blocks selection can improve the yard utilization.

Chapter 6 Conclusion and Prospect

6.1 Research conclusion

In this paper, the author obtains a large number of domestic container terminal yard business process by reading literature, and designs simulation system for the workload distribution among storage blocks in a container terminal yard according to the container yard business process , the main conclusions of the study are as follows:

About setting region value in distribution among storage blocks, various operation modes are different in the distribution among storage blocks according to the actual operation of container terminal. As well as the specific circumstances of the yard, chooses a single regional value to set rules is not reasonable. The implementation is not realistic in the actual operation. Therefore, in this paper, according to the actual operating situation, capable of setting a plurality of region value, according to the different methods of setting region value can get multiple distribution among storage blocks results.

About setting stacking rules, chooses a single stacking rule is not reasonable according to the actual operation of container terminal and the region value partition method. The implementation is not realistic in the actual operation. Therefore, in this paper, according to the actual operating situation, with double factors control mode, at first set region value, then according to value setting multiple stacking rules, considers a multiple stacking strategy combination respectively, and tests the four stage of the Ningbo port container terminal as an example, analyzes its validity and rationality.

About design and implementation of simulation system for the workload distribution among storage blocks in a container terminal yard, this paper designs the data structure clearly, establishes a perfect database system. There is no bug appears in the running process of the system and the system shows stability.

6.2 Research prospect

The space can be expanded in this paper is relatively large. In general, they can be studied from the following aspects:

On the simulation system for the workload distribution among storage blocks in a container terminal yard, when the initial block attribute setup is completed, you can use a visual way to reflect the block initial results, and adjust the corresponding numerical constantly according to the calculation. The achievement of the visual input, need to use other software such as MapX associates with PowerBuilder, but considers the problems of time and technical level, the simulation system in this paper can not achieve this function.

Container terminal, crossing and berth import volume have detail data records. Because of the time, the system does not design crossing model, process only designs berth model. According to the existing rules and region setting, user can continue set crossing model, and can consider in parallel implementation of crossing model and berth model to further improve the model.

This paper establishes the division of region value. Although we set rules of input container carefully, we still have the space to expand. About the pick-up rules, this paper only consider the rule of specifying destination port, there is also further consider space.

About further research direction, distribution among storage blocks result in this paper can put forward very good reference and basic data. On this basis, studies are as follows: the model of gantry crane scheduling, block road congestion degree research and so on.

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Appendix

Appendix A Designing of simulation system main calculation code design

```
long i,ll_a_rowcount,a_i,k,ll_b_rowcount,ll_juli,ll_minjuli,ll_min_k,ll_xiangqu_rowcount
string ls_filter
il_s_rowcount = dw_stepprocess.rowcount()
ll_b_rowcount = dw_tankarea.rowcount()
if ll_b_rowcount <= 0 then
    messagebox("prompt","no block data")
    return
end if
dw_stepprocess.setsort("protime a,inberth_id a")
dw_stepprocess.sort()
dw_xiangquzhengli.setsort("yuzuxuhao a,hanghao a,liehao a")
dw_xiangquzhengli.sort()
for i = 1 to il_s_rowcount
select blocktype_id into :il_blocktype_id from blocktype where ship_id = :il_inberth_id;
select yuzu_id into :il_yuzu_id from areaship where ship_id = :il_inberth_id;
select arrivetime into :il_arrivetime from ship where ship_id = :il_inberth_id;
select leavetime into :il_leavetime from ship where ship_id = :il_inberth_id;
dw_area.retrieve(il_yuzu_id)
ll_a_rowcount = dw_area.rowcount()
    if ll_a_rowcount = 0 then
        messagebox("prompt"," region value is not complete, please try after set it")
        return
    end if
select ShipBowPlace into :il_ShipBowPlace from cbapresult where inberth_id
= :il_inberth_id;
select ShipSternPlace into :il_ShipSternPlace from cbapresult where inberth_id
```

```
= :il_inberth_id;
    for k = 1 to ll_b_rowcount
        il_liezuobiao = dw_tankarea.getitemnumber(k,"liezuobiao")
        il_hangzuobiao = dw_tankarea.getitemnumber(k,"hangzuobiao")
        ll_juli = abs((il_ShipSternPlace - il_ShipBowPlace)/2 - il_hangzuobiao) +
il_liezuobiao
        if ll_minjuli = 0 then
            ll_minjuli = ll_juli
            ll_min_k = k
        end if
        if ll_juli < ll_minjuli then
            ll_minjuli = ll_juli
            ll_min_k = k
        end if
    next
    il_hanghao = dw_tankarea.getitemnumber(ll_min_k,"hanghao")
    il_liehao = dw_tankarea.getitemnumber(ll_min_k,"liehao")
    il_bianjieliehao = dw_tankarea.getitemnumber(ll_b_rowcount,"liehao")
    il_bianjiehanghao = dw_tankarea.getitemnumber(ll_b_rowcount,"hanghao")
    ls_filter = "shipid = " + string(il_inberth_id)
    dw_xiangquzhengli.setfilter(ls_filter)
    dw_xiangquzhengli.filter()
    ll_xiangqu_rowcount = dw_xiangquzhengli.rowcount()
    if ll_xiangqu_rowcount <= 0 then
        if wf_xiangquzhengli(il_inberth_id) = 1 then
            messagebox("prompt","please set again")
            return
        end if
    end if
    if il_vmin > 0 then
        wf_zhuangxiangguize()
    else
        il_vmin = abs(il_vmin)
        wf_tixiangguize()
```

```
    end if
next
messagebox("prompt"," finish calculate")
```

Appendix B Designing of simulation system rule set code

```
long ll_xuhao,ll_xiangzheng_rowcount,i,ll_guize,ll_xiangquid,ll_shaixuan_rowcount
long j,ll_huozhuid,ll_mudigangid,ll_blocktypeid,ll_blockinfo_blockid,ll_libojuli
long ll_mudigang_count,ll_danweixiangliang,ll_yiyouxiangliang,ll_xiangliangcha
long ll_huozhu_count,ll_find_xiangquid,ll_xiangquliyong,ll_shipid
long ll_arg[],ll_unload,ll_row,ll_newrowcount
string ls_filter

ll_xiangzheng_rowcount = dw_xiangquzhengli.rowcount()
ll_xuhao = dw_xiangquzhengli.getitemnumber(ll_xiangzheng_rowcount,"yuzuxuhao")
do until i>= ll_xuhao or il_vmin <= 0
    i++
    ls_filter = "yuzuxuhao = " + string(i)
    dw_xiangquzhengli.setfilter(ls_filter)
    dw_xiangquzhengli.filter()
    ll_shaixuan_rowcount = dw_xiangquzhengli.rowcount()
    do until j >= ll_shaixuan_rowcount or il_vmin <= 0
        j++
        ll_xiangquid = dw_xiangquzhengli.getitemnumber(j,"xiangquid")
        ll_guize = dw_xiangquzhengli.getitemnumber(i,"guize")
        if ll_guize = 1 then
            dw_xiangquzhengli.setsort("libojuli a")
            dw_xiangquzhengli.sort()
            ll_xiangquid = dw_xiangquzhengli.getitemnumber(j,"xiangquid")
        ll_danweixiangliang =
dw_xiangquzhengli.getitemnumber(j,"danweixiangliang")
            il_yiyouxiangliang =
dw_xiangquzhengli.getitemnumber(j,"yiyouxiangliang")
            ll_xiangliangcha = ll_danweixiangliang - il_yiyouxiangliang
            if ll_xiangliangcha > 0 then
                if ll_xiangliangcha >= il_vmin then
                    ll_unload = il_vmin
```

```
				il_yiyouxiangliang = il_vmin + il_yiyouxiangliang
				dw_blockinfo.insertrow(0)
				ll_row = dw_blockinfo.rowcount()
				dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
				dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
				dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
				dw_blockinfo.setitem(ll_row,"xiangliang",il_vmin)
				if dw_blockinfo.update() = 1 then
					commit ;
				end if
				il_vmin = 0
			else
				ll_unload = ll_xiangliangcha
				il_yiyouxiangliang = il_yiyouxiangliang + ll_xiangliangcha
				ll_row = dw_blockinfo.insertrow(0)
				dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
				dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
				dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
				dw_blockinfo.setitem(ll_row,"xiangliang",ll_unload)
				if dw_blockinfo.update() = 1 then
					commit ;
				end if
				il_vmin = il_vmin - ll_xiangliangcha
			end if
		end if
		if ll_xiangliangcha = 0 then
				ll_find_xiangquid = 1
			else
				ll_find_xiangquid = 0
			end if
end if
if ll_guize = 2 then
	dw_xiangquzhengli.setsort("xiangquliyong a")
	dw_xiangquzhengli.sort()
```

```
		ll_xiangquid = dw_xiangquzhengli.getitemnumber(j,"xiangquid")
		ll_danweixiangliang =
dw_xiangquzhengli.getitemnumber(j,"danweixiangliang")
		il_yiyouxiangliang =
dw_xiangquzhengli.getitemnumber(j,"yiyouxiangliang")
		ll_xiangliangcha = ll_danweixiangliang - il_yiyouxiangliang
		if ll_xiangliangcha >= 0 then
			if ll_xiangliangcha >= il_vmin then
				ll_unload = il_vmin
				il_yiyouxiangliang = il_vmin + il_yiyouxiangliang
				ll_row = dw_blockinfo.insertrow(0)
				dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
				dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
				dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
				dw_blockinfo.setitem(ll_row,"xiangliang",il_vmin)
				if dw_blockinfo.update() = 1 then
					commit ;
				end if
				il_vmin = 0
			else
				ll_unload = ll_xiangliangcha
				il_yiyouxiangliang = il_yiyouxiangliang + ll_xiangliangcha
				ll_row = dw_blockinfo.insertrow(0)
				dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
				dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
				dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
				dw_blockinfo.setitem(ll_row,"xiangliang",ll_xiangliangcha)
				if dw_blockinfo.update() = 1 then
					commit ;
				end if
				il_vmin = il_vmin - ll_xiangliangcha
			end if
		end if
		if ll_xiangliangcha = 0 then
```

```
                    ll_find_xiangquid = 1
                else
                    ll_find_xiangquid = 0
                end if
        end if
        if ll_guize = 3 then
            select count(mudigang_id) into :ll_mudigang_count from blockinfo where
mudigang_id = :il_mudigang_id and block_id = :ll_xiangquid;
            if ll_mudigang_count > 0 then
                ll_danweixiangliang =
dw_xiangquzhengli.getitemnumber(j,"danweixiangliang")
                il_yiyouxiangliang =
dw_xiangquzhengli.getitemnumber(j,"yiyouxiangliang")
                ll_xiangliangcha = ll_danweixiangliang - il_yiyouxiangliang
                if ll_xiangliangcha >= 0 then
                    if ll_xiangliangcha >= il_vmin then
                    ll_unload = il_vmin
                    il_yiyouxiangliang = il_vmin + il_yiyouxiangliang
                    ll_row = dw_blockinfo.insertrow(0)
                    dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                    dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                    dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
                    dw_blockinfo.setitem(ll_row,"xiangliang",il_vmin)
                    if dw_blockinfo.update() = 1 then
                        commit ;
                    end if
                    il_vmin = 0
                    else
                    ll_unload = ll_xiangliangcha
                    il_yiyouxiangliang = il_yiyouxiangliang + ll_xiangliangcha
                    ll_row = dw_blockinfo.insertrow(0)
                    dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                    dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                    dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
```

```
                    dw_blockinfo.setitem(ll_row,"xiangliang",ll_xiangliangcha)
                    if dw_blockinfo.update() = 1 then
                        commit ;
                    end if
                    il_vmin = il_vmin - ll_xiangliangcha
                    end if
                end if
                if ll_xiangliangcha = 0 then
                    ll_find_xiangquid = 1
                else
                    ll_find_xiangquid = 0
                end if
            else
                ll_find_xiangquid = 1
            end if
        end if
        if ll_guize = 4 then
                select count(huozhu_id) into :ll_huozhu_count from blockinfo where
huozhu_id = :il_huozhu_id and block_id = :ll_xiangquid;
            if ll_huozhu_count > 0 then
        ll_danweixiangliang =
dw_xiangquzhengli.getitemnumber(j,"danweixiangliang")
            il_yiyouxiangliang =
dw_xiangquzhengli.getitemnumber(j,"yiyouxiangliang")
                ll_xiangliangcha = ll_danweixiangliang - il_yiyouxiangliang
                if ll_xiangliangcha >= 0 then
                    if ll_xiangliangcha >= il_vmin then
                    ll_unload = il_vmin
                    il_yiyouxiangliang = il_vmin + il_yiyouxiangliang
                    ll_row = dw_blockinfo.insertrow(0)
                    dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                    dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                    dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
                    dw_blockinfo.setitem(ll_row,"xiangliang",il_vmin)
```

```
                if dw_blockinfo.update() = 1 then
                    commit ;
                end if
                il_vmin = 0
                else
                ll_unload = ll_xiangliangcha
                il_yiyouxiangliang = il_yiyouxiangliang + ll_xiangliangcha
                ll_row = dw_blockinfo.insertrow(0)
                dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
                dw_blockinfo.setitem(ll_row,"xiangliang",ll_xiangliangcha)
                if dw_blockinfo.update() = 1 then
                    commit ;
                end if
                il_vmin = il_vmin - ll_xiangliangcha
                end if
            end if
            if ll_xiangliangcha = 0 then
                ll_find_xiangquid = 1
            else
                ll_find_xiangquid = 0
            end if
        else
            ll_find_xiangquid = 1
        end if
    end if
select sum(xiangliang) into :il_yiyouxiangliang from blockinfo where block_id
= :ll_xiangquid;
   dw_xiangquzhengli.setitem(ll_newrowcount,"danweixiangliang",ll_danweixianglian
g)
    ll_arg[1] = ll_xiangquid
    ll_arg[2] = il_yiyouxiangliang
    ll_arg[3] = 0
```

```
		ll_arg[4] = ll_unload
		if ll_find_xiangquid = 0 then
			wf_result(ll_arg[])
		end if
	loop
loop
return 0

long ll_xuhao,ll_xiangzheng_rowcount,i,ll_guize,ll_xiangquid,ll_shaixuan_rowcount
long j,ll_huozhuid,ll_mudigangid,ll_blocktypeid,ll_blockinfo_blockid
long ll_mudigang_count,ll_danweixiangliang,ll_yiyouxiangliang,ll_yiyouxiang
long ll_huozhu_count,ll_find_xiangquid,ll_xiangliangcha
long ll_arg[],ll_load,ll_row
string ls_filter
ll_xiangzheng_rowcount = dw_xiangquzhengli.rowcount()
ll_xuhao = dw_xiangquzhengli.getitemnumber(ll_xiangzheng_rowcount,"yuzuxuhao")
do until i>= ll_xuhao or il_vmin <= 0
	i++
	ls_filter = "yuzuxuhao = " + string(i)
	dw_xiangquzhengli.setfilter(ls_filter)
	dw_xiangquzhengli.filter()
	ll_shaixuan_rowcount = dw_xiangquzhengli.rowcount()
	do until j >= ll_shaixuan_rowcount or il_vmin <= 0
		j++
		ll_xiangquid = dw_xiangquzhengli.getitemnumber(j,"xiangquid")
		ll_guize = 1
		select count(mudigang_id) into :ll_mudigang_count from blockinfo where
mudigang_id = :il_mudigang_id and block_id = :ll_xiangquid;
		if ll_mudigang_count > 0 then
		ll_danweixiangliang =
dw_xiangquzhengli.getitemnumber(j,"danweixiangliang")
			il_yiyouxiangliang =
dw_xiangquzhengli.getitemnumber(j,"yiyouxiangliang")
			ll_xiangliangcha = il_yiyouxiangliang
```

```
        if ll_xiangliangcha > 0 then
            if il_yiyouxiangliang >= il_vmin then
                ll_load = il_vmin
                il_yiyouxiangliang = il_yiyouxiangliang - il_vmin
                ll_row = dw_blockinfo.insertrow(0)
                dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
                dw_blockinfo.setitem(ll_row,"xiangliang", -il_vmin)
                if dw_blockinfo.update() = 1 then
                    commit ;
                end if
                il_vmin = 0
            else
                ll_load = il_yiyouxiangliang
                il_vmin = il_vmin - il_yiyouxiangliang
                ll_row = dw_blockinfo.insertrow(0)
                dw_blockinfo.setitem(ll_row,"block_id",ll_xiangquid)
                dw_blockinfo.setitem(ll_row,"huozhu_id",il_huozhu_id)
                dw_blockinfo.setitem(ll_row,"mudigang_id",il_mudigang_id)
                dw_blockinfo.setitem(ll_row,"xiangliang", -il_yiyouxiangliang)
                if dw_blockinfo.update() = 1 then
                    commit ;
                end if
            end if
        end if
            if ll_xiangliangcha = 0 then
                ll_find_xiangquid = 1
            else
                ll_find_xiangquid = 0
            end if
        else
            ll_find_xiangquid = 1
    end if
```

```
	select sum(xiangliang) into :il_yiyouxiangliang from blockinfo where block_id
= :ll_xiangquid;
			dw_xiangquzhengli.setitem(j,"yiyouxiangliang",il_yiyouxiangliang)
		ll_arg[1] = ll_xiangquid
		ll_arg[2] = il_yiyouxiangliang
		ll_arg[3] = ll_load
		ll_arg[4] = 0
		if ll_find_xiangquid = 0 then
			wf_result(ll_arg[])
		end if
		loop
	loop
	return 0
```