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Layout planning of logistics network for medical instruments based on third-party logistics

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Layout planning of logistics network for medical instrument based on third-party logistics

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Acknowledgement

Time flies.The study life in WMU is going to an end. During this period, I have learned a lot.

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Life is a long way to go, and thousands of wards end into thanks.

ABSTRACT

Nowadays, there are more and more domestic medical instrument enterprises for different kinds of scale, but the mode of management and operation is very backward, especially in the aspect of medical instrument logistics. In the mode of separate operation and decentralized traditional management, there must exist many issues, such as uneven warehouse management level, chaos transport links, high distribution cost, unsound information system and so on, in the medical equipment circulation industry. As there are few domestic research in medical equipment logistics and there are a few urgent issues in medical equipment logistics as well, this thesis puts forward the distribution network planning of medical equipment logistics based on third-party logistics.

The purpose of this paper is to build a new mode of medical instrument logistics through the introduction of the third-party logistics, so as to solve the high cost of these disadvantages caused by the logistics distribution and expensive medical services expenses, which at last provides strong support for vigorous development of medical instrument industry.

First, this paper constructed the medical instrument logistics distribution network based on third party. On the basis of comprehensive analysis of the present situation of logistics development of medical equipment at home and abroad, the existing problems and the necessity of optimization, etc, combining the characteristics of medical equipment logistics, it builds a medical instrument logistics distribution network based on third party.

Second, this paper conducted node layout planning study to medical instrument logistics distribution network. Combined with the characteristics of the medical equipment logistics, the logistics distribution center's location planning problems are analyzed. It puts forward a planning model of the location of medical instrument distribution center, and designed a double simulated annealing algorithm for this model. The calculation examples show that, using double simulated annealing algorithm and the location planning model is an effective method to solve the problem of medical instrument distribution network node layout planning.

In this paper, we research into node layout of logistics network, which comprehensively analyzes and solves the problems of planning issues of medical instrument logistics and distribution. This paper puts forward a new logistics mode for medical instrument, and has significance of reference to the future development of medical instrument logistics.

By Xu Kewei (International transport & logistics)

Directed by Prof, Hu Meifen

KEYWORDS: medical instrument, logistics distribution network, dynamic routing planning

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1 Introduction

1.1 Research Background

The industry of medical instrument, as high-tech industry, has the characteristics of intensive knowledge, intensive funds and multi-discipline, involving medicine, machinery and electronics, information technology and material science and others. At present, the domestic development of medical instrument industry has surprised the world. Known from the relevant logistics channels, from January to September of 2013, the import and export trade volume of our medical instrument amounts to $24.901 billion with a year on year growth of 13.83%, among which exports occupy $14.017 billion with a year on year growth of 9.27%; imports $10.884 billion with a year on year growth of 20.28%; surplus $3.133 billion with a year on year fall of 17.11%. Though the industry has a limited proportion in our national economy, but being an important branch industry, it has been gradually and stably rising with its proportion of GDP increasing from 0.24% of 2007 to 0.29 of 2011.

Though there still exists a big gap between China and the developed countries in the development of the industry. However, influenced by the rigid demand of global market of this industry, the demand of domestic market presents significant growth. It is predicted that our export trade of medical instruments will still maintain the growth rate of more than 10% and import and export volume will exceed $33 billion.

With the development of medical instrument industry in China, the current domestic medical market has formed two patterns: 1) the high-end medical equipment market monopolized by the developed countries, such as CT, MRI (magnetic resonance imaging), which is due to the lack of the domestic advanced technology and talents; 2) a large number of medical instrument enterprises in China producing traditional medical equipment parts with low technical content. According to some relevant and reliable statistical data, in 2010, there are 14337 medical device production enterprises, of which 4015 enterprises are of Class I; 7906 of Class II; 2416 of Class III. 1863 enterprises are of national and provincial key regulatory ones.

By the end of 2012, the national medical equipment production enterprise had increased to more than 16 thousand with 3% state-owned enterprises, 37%

foreign joint ventures and 60% private enterprises accounted, among which more than 200 enterprises have over 100 million output value; less than 20 have more than one billion output value. And the majority of enterprises are foreign owned, joint ventures.

The three regions, the Pearl River Delta, Yangtze River Delta and Bohai bay, as the three major industry gathering area of Chinese medical instrument industry, have gathered a large number of talents in science and technology in the local with a collection of cutting-edge technology and clinical medicine technology, enjoying the local policy advantage. The sum of the total output value and sales accounts for more than 80% of the national total.

As people attach great importance to the life and health and the degree of aging society has been deepened, health care and therapy has become a focus in modern society. How to properly deal with the health problems of general population, especially the health problems of the elderly is the key. The rapid development of the domestic medical equipment industry has brought better medical care for people. This is of course a good thing. But the use of medical instruments also increases the cost of medical service institutions, thus increasing the treatment costs. "Expensive to see a doctor expensive, difficult to see a doctor" has become a social problem. The high cost of medical care is a social problem. How to reduce the cost of medical service is problem to be solved.

1.2 The Research Review at Home and Abroad

1.2.1 The Research Review of Logistics Node Layout

The enriched and improved theoretical system of logistics planning, especially the planning and researches for logistics network, has a key role in the vigorous development of the logistics industry. Here is a brief review on the present theoretical research situation of the layout planning of logistics network nodes:

English professor Martin Christophe first clarified in 2000 the importance of logistics nodes planning based on the logistics strategic planning and management. He believes that the planning of logistics network is very important to the management supply chain. American D.J.Bowersox studied in 2002 the problems in the design and integration of logistics network planning. Olive.Fisher in 2002 divided nodes into three types: the distribution of production, transportation and consumption, according to different functions. Adopting the four stage method, combined with two aspects of network planning and joint planning, he studied the location and the determination of scale. Klose A, in 2005, performed a comprehensive analysis of the research method for the design of logistics network. In particular, the location model and mixed integer linear programming are analyzed. AliAmiri, in 2006, summarized the theory and method of logistics center location. Japanese scholars emphasize the concept of sustainable development. They conducted researches on constructing modern logistics network system from circular society angle

Although domestic logistics industry does not develop as early as that of America and Japan, but government departments in most cities have deeply been impressed with the economic outlook and environmental advantages of logistics planning. Domestic experts and scholars began to research into the logistics development planning in line with Chinese conditions on the basis of summarizing the world advanced logistics technology and experience,

Wang Zhitai (2001) systematically analyzed the logistics node function and put forward the construction of modern logistics network with the logistics base, logistics center and distribution center as the main body.

Cheng Guoquan (2004) believed that the rationalization of logistics network and node is the core of high-efficient logistics. He focused on the introduction of modern logistics network and the optimization method of logistics network, from the basic characteristics of modern logistics, and emphasized the optimization of logistics network and the design of logistics facilities.

Xu Jie &Ju Songdong (2005) pointed out that the logistics network can be divided into three parts: logistics network, logistics infrastructure network and logistics information network according to the operation mode

Lang Fengping (2006) first analyzed the rational planning of regional logistics system, application of fuzzy evaluation method and analytic hierarchy process. He conducted the planning research on the northeast economic regional logistics network and the logistics network of Russian border trade, determining the evaluation system of regional logistics network.

Peng Benhong (2009) presented a spatial hierarchy theory of regional logistics network and studied the structure of logistics network of Jiangxi Province with multivariate statistical model

1.2.2 Status of Medical Logistics Development

In foreign countries, the use of medical devices can be realized by a logistics process between medical equipment in the medical center and medical institutions in the medical logistics field. Any specific logistics link will directly affect the total cost of medical logistics, because medical logistics is a complex system of the logistics chain with cost factor of each link interacting. According to reliable statistical data related, one dollar spent, the costs delivered to the end user will be more than $0.7~1 in the procurement of medical supplies. In the hospital, he integrated logistics process with demand as the core must be established and then straighten out the security link by designing the medical material logistics system design of the hospital, eliminating non value added activities. For the outside of medical institutions, long-term strategic cooperation partnership with other suppliers needs to be established in order to realize the optimization of inventory management. At the same time, an alliance between the various medical institutions to get the scale economy and the resource allocation optimized in order to reduce logistics cost. With the development of computer technology, the whole logistics process of medical instrument is optimized by use of computer. The computerized management and scientific planning should be adopted to the location of medical instrument distribution center, the forecasting of logistics demand for medical quantity, the optimization of vehicle scheduling in transportation, and the whole medical resource optimization management

The medical instrument industry, as an emerging industry, starts late and lag behind compared with developed countries. In addition, there is less the domestic study on the logistics field of medical instrument, which is attributed to the fact that the medical instrument industry in China is still in the initial stage with no more perfect and systematic logistics access mechanism.

1.3 Existing problems

The medical instrument industry, as an emerging industry in our country, started late, lagging behind compared with developed countries. In addition, there is not so many domestic researches on the logistics field of medical instruments. This is attributed to the medical instrument industry in China is still in the initial stage of development with no more perfect logistics system access mechanism.

Presently, the circulation pattern of medical instrument is too complex. Purchase and sale system consists of a number of manufacturers, more distributors, multistage area. All medical instrument business entities have their own warehouse and logistics distribution services (Whether it is rented or self built). Take Town Weijiatun, Jizhou City in Hebei Province for example. Almost each household is engaged in the production and sales of medical instruments. But every enterprise has independent sales and product transportation with simple production process and low added value. Scaled industry structure having not formed restricts the further development and expansion of enterprises, and it Is also not conducive to the further development of medical industry. In addition, since Town Weijiatun has been incorporated into the New District of Binhui, Hengshui City, it lies In the key areas of wetland in Hengshui Lake, influenced by adverse development constraints, such as various venues, personnel, policy environment, and the overall strength of the industry is weakened.

Therefore, under the traditional management mode of independent operation, decentralization, there must have many problems of medical instrument in circulation industry: too many transportation links; low management level of storage; imperfect information system, etc. At the same time, medical instrument being a special health commodity, It is difficult to perform effective medical product tracking and monitoring in the whole process of circulation. Meanwhile, a potential possibility is provided for the products of overdue equipment and poor quality to enter the normal circulation channel. In addition, the high costs of logistics caused by product backlog has seriously increased the production cost of enterprises, increased the burden on patients and social overall medical expenditure, which Is not conducive for the government to effectively respond to the public safety crisis, such as natural disasters and the like, directly affecting the government’s scientific decision-making and macro management.

1.4 The Research Significance and the Technical Route

1.4.1 The Research Significance

The paper aims at a reasonable, effective logistics mode to replace the traditional circulation mode of existing medical instruments in order to be more economical and efficient for the logistics distribution of medical instruments. The significance of planning and constructing the logistics mode are as follows:

1. Banning middle circulation process (dealers and agents) of medical instrument to reduce the total cost of medical instrument;

2. Rationally planning medical instrument logistics network to reduce the

transportation cost and improve the efficiency of transportation.

3. Reducing the cost of medical service and solving “difficult and expensive seeing a doctor” to a certain degree;

4. The medical instrument enterprises focusing on developing more high-end medical products to promote rapid development of medical instrument industry.

1.4.2 Technical Route

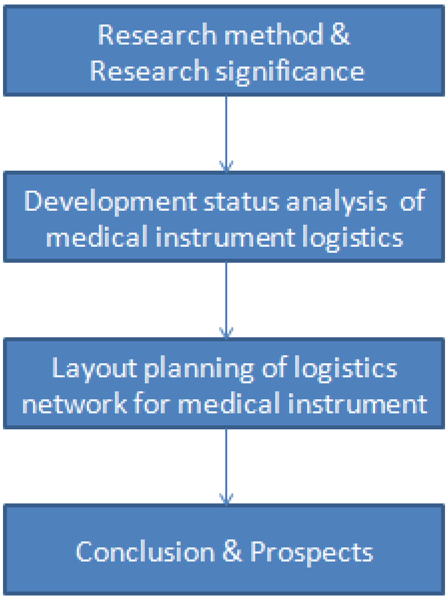

Figure 1-1 Technical route

2 Analysis about development situation of medical instrument logistics

2.1 Medical instrument

2.1.1 Definition

The regulations on the supervision and administration of medical instruments (2000) shows the definition of medical instrument, that's instruments, materials or other items used in the human body by combination or alone, including the needed software. Its effect on human body on surface and in vivo is not obtained by means of pharmacology, immunology or metabolism, but may have the means to participate in, and play a supplementary role. It's used to achieve the following intended purposes:

(1)Prevention, diagnosis, treatment, care and ease of diseases;

(2)Diagnosis, treatment, care, relief and compensation of injury or disability;

(3)Study, replacement and adjustment of anatomical or physiological process;

(4)Control of pregnancy.

As we can see from the above definition, to determine whether a product belongs to medical instrument ,it must have a combination of the following four points: the first is judged by the expected purpose of the product use; the second is from the way that the product act on human body; the third is the difference between with drugs; the fourth is to define with the objective, scope and requirements of the legal regulation, and product attribute.

2.1.2 Classification

(1) According to the regulations on the supervision and administration of medical instruments, they are divided into three categories according to the safety:

The first type refers to medical instrument that its security and effectiveness can be ensured through a routine administration;

The second refers to medical instrument that its security and effectiveness shall be controlled;

The third refers to the implantable medical instrument used to sustain life, it must be carried out strict control in safe and effective ways, to avoid dangerous for the human body.

(2) According to the main technical features and applications, medical instruments can be divided into:

Conventional instrument;

Auxiliary instrument;

Diagnostic instrument;

Therapeutic instrument;

Experimental and scientific educational instrument.

(3) According to the structure features, they are divided into active and passive medical instruments.

Active instruments work by outside power or other energy. The use form of active medical instruments include ionizing radiation; energy treatment; diagnostic monitoring; conveying fluid; laboratory and other active auxiliary equipments, etc.

The use form of passive medical instruments including disposable sterile instruments; repeated use of surgical instruments; implanted devices; changes in blood and body fluids apparatus; liquid transportation and save equipment; contraception and family planning devices; disinfection cleaning equipment; medical dressings; surgical instruments and other passive contact or passive auxiliary instruments, etc.

(4) According to the classification of international standards, medical instruments can be divided into 12 major categories:

Radiation instruments: including X-ray, ultrasound imaging, isotopes in vivo imaging, linear accelerator, MRI and other diagnosis and treatment instruments. Such as X-ray equipment, X-ray computed tomography (CT) camera and its accessories.

Disabled auxiliary instruments: this kind of instruments is used to relieve, compensation, offset the inconvenience taken by disability and damage. They are divided into special and general kinds, such as crutches, wheelchairs, prosthesis, hearing AIDS, etc.

Dental instruments: this kind includes instruments for diagnosis, prevention, care, treatment or remission in mouth, led surface and dental diseases, such as dental surgical instruments, impression materials, and dental amalgam.

Eye and optical instruments: this equipment is used in the diagnosis, prevention, treatment; relieve eye diseases such as myopia, amblyopic, cataract and visual impairment. Instrument such as tonometer, accessories such as lenses, etc.

Reusable instruments: many surgical medical devices are able to use again after cleaning and sterilization, such as hemostat, retractor, scalpel, forceps, and other accessories.

IVD instruments: include instruments for virtual examination of pediments of human body to determine the physiological or pathological status, such as blood glucose monitor, bilirubin tester.

Passive implantable instruments: this equipment include instruments other than active implantable devices and embedded more than 30 d devices. Such as heart valve, orthopedic prosthesis.

Disposable medical instruments: as the name implies, this kind of instruments only allow to use once, and need to be recycled after use, such as intravenous infusion, medical bandage accessories, etc.

Hospital hardware instruments: such devices belong to the regular hospital instruments; they are not used for diagnosis and treatment, such as sterilizer, patients conveying instruments.

Mechanical and electrical medical instruments: the diagnosis and treatment of such devices relying on the effect of electricity, and is a kind of active medical instruments, such as electroencephalogram, electrocardiogram machine, hemodialysis monitor, etc.

Anesthesia and respiratory instruments: this kind of instruments are used in the supplication, regulation, supervision, distribution, transportation, medical breathing and anesthetic of gas and steam, to supply and/or control breathing and/or anesthesia. Such as anesthesia workbench, breath circulation machine.

Active implantable instruments: this kind includes instruments that rely on energy rather than directly produced by the human body or gravity energy, insert the human body in whole or in part by surgery or medicine means. Such as pacemakers, implantable infusion pumps.

(5) According to the technology content of medical instruments, they can be divided into high-end medical instruments and conventional medical instruments.

A high-end medical instrument refers to expensive medical devices that condense the content of cutting-edge science and technology, such as CT machine, MRI machine. Conventional medical instruments involved in the scope of more extensive, has common characteristics like low technical content, mainly labor-intensive production and operation, such as medical equipment, rehabilitation supplies, medical supplies, medical dressings and oral material, etc.

2.1.3 Features

(1) Specificity

By the last section of the classification of medical instruments, we can see, there are many kinds of medical instruments; this also explains the function subdivision of medical instruments. The more meticulous of the division, the single of the function of the product. Therefore, medical instrument products have a strong specificity.

(2) Security

Medical instruments are high-end tools used in the diagnosis and treatment of patients; we must pay attention to its safety during using. Only reasonable and safe use can ensure the health and safety of patients or equipment users, and ensure the effect of it for disease. Therefore, most medical instrument production enterprises attached safety instructions in the packaging of medical instruments, inform the safe and effective way of use.

(3) Complexity

Medical instruments are high-end products of integrating multiple technologies. With advances in science and technology, functions and structures of them will be more and more complex; the users also need detailed instructions to use the products rationally and effectively.

2.2 Present situation of medical instruments' circulation pattern

2.2.1 The traditional circulation pattern

Because the domestic medical instrument industry started relatively late, and combined with the slow development of domestic logistics industry, domestic medical instrument has been the traditional logistics mode of operation pattern, that is, from manufacturers to medical institutions in the process of logistics has a lot of logistics links, correspondent system is used in the intermediate process, including the total agents, dealers and distributors. As shown in figure 2-1 for the current circulation pattern of most medical instrument enterprises inland. Among them, the manufacturers include multinational and domestic medical instrument enterprise. Before selling medical products, these manufacturers first look for distributors in the market, dealers are responsible for finding the regional agents, then the regional agents look for vendors at the provincial level, until city, county, each distributor is responsible for medical instrument distribution of hospitals in his own range.

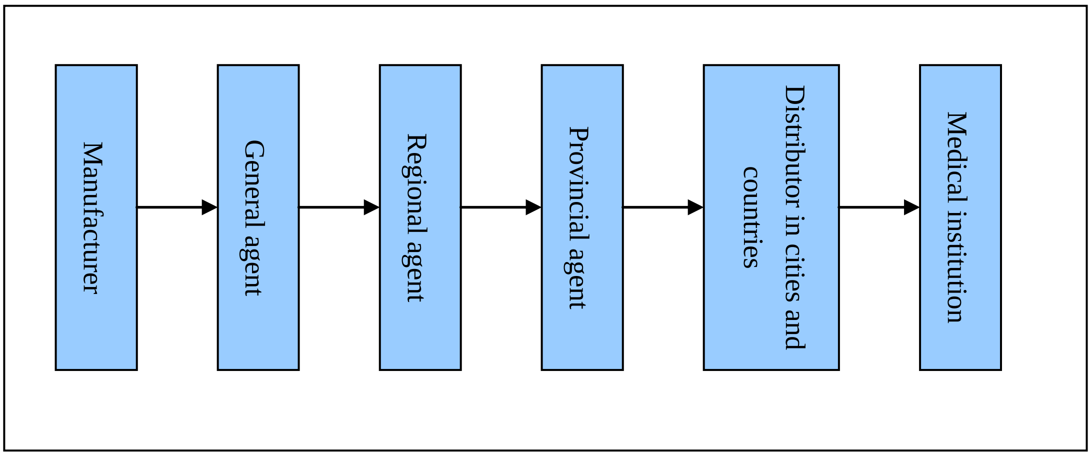

Figure 2-1Traditional circulation mode of medical instrument

The traditional mode has some problems:

(1)Too many intermediate links increase the cost of medical instrument distribution, make originally highly cost medical instruments combines more logistics cost, that lead the final patients to bear very high hospitalization costs. Moreover, as an intermediate role, distributions and agents reap big profits, finally come at the expense of the patient's medical expenses;

(2) Because the manufacturers deliver medical instrument business to the agent or distributor, product sales channels are under the control of the dealer. This weakens the medical instrument manufacturers' control of the market, also likely to lead to product technology cannot be promoted;

(3) Traditional logistics mode involved too much intermediate links and relevant agents, dealers and distributors. The companies’ scale is not the same as the needed regulation, and is fragmented at the same time, increasing the difficulty of supervision;

(4) Domestic logistics professionals is very lack, most medical instrument companies are not to be full-time employees, this makes the too much logistics transportation more difficult to control, increase the difficulty of quality tracking and regulation.

(5) In traditional management mode, medical instruments of circulation industry has disadvantage of independent operation and decentralization, lead to the emergence of many problems, such as uneven of inventory control management, information system is not sound, distribution cost on the high side, confusion of transportation, etc. Second, as a special commodity, medical instrument products will lead to low quality and outdated products into the circulation channels in the process of circulation. It will seriously affect the normal medical instrument product circulation order, damage the fundamental interests of

patients and medical institution. Again, a large backlog of medical instrument products results from inventory mismanagement, increase the cost of the production enterprises, seriously affected the enterprise's operation and management, and bring heavy economic burden to social medical institutions and consumers, also affect the implementation of the government logistics policy.

2.2.2 The middle circulation mode——logistics platform mode

Although most medical instrument companies still use the traditional circulation mode, logistics platform mode between the traditional circulation mode and third party logistics has gradually been adopted by some of the medical device manufacturing enterprise. Model of logistics platform, known as the middle model, establish large-scale logistics warehouse in each sales region to direct hospital medical instrument distribution specially. This model replace the ordinary medical instrument company's control of the warehouse management largely reduced the number of medical instrument company, making medical instrument product logistics distribution regulation simpler. It only needs to monitor logistics Platform Company, save a large amount of regulatory costs. This kind of logistics mode, while reduce logistics cost, also raised the level of logistics distribution service for the customer. As shown in figure 2-2 is model for logistics platform.

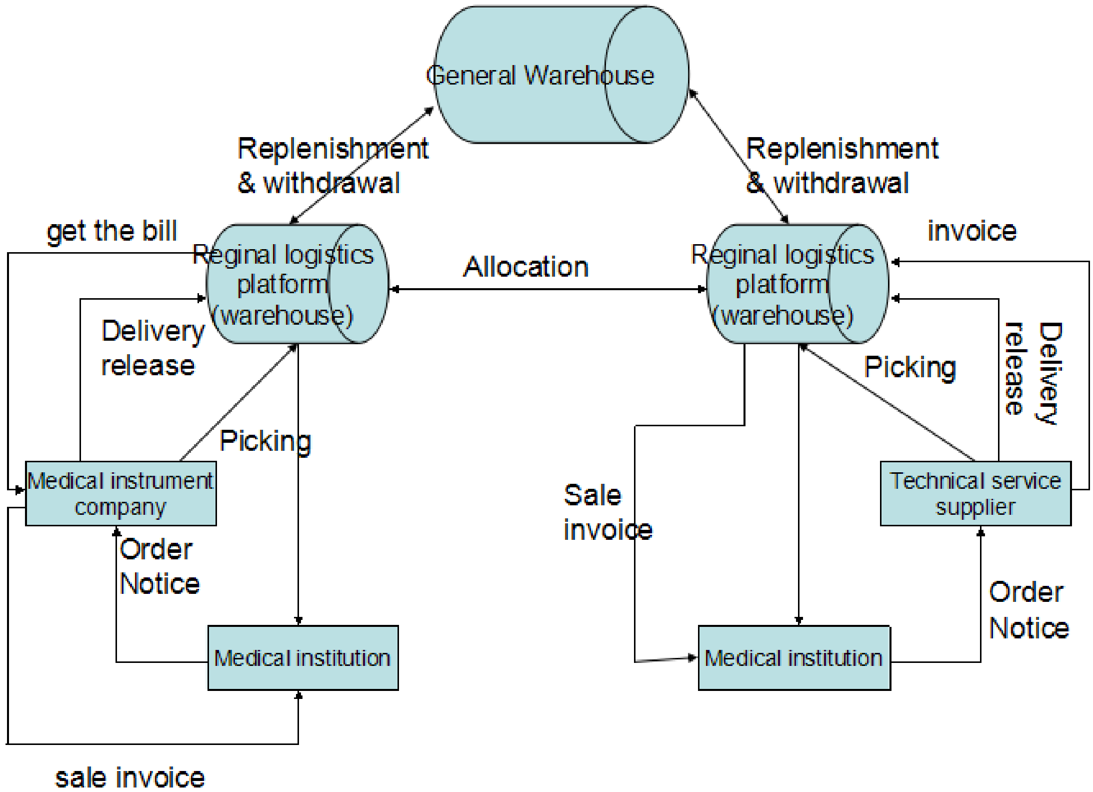

Figure 2-2 logistics platform mode of medical instrument

However, this logistics mode is only known as the middle platform, there are some problems such as the lack of profession of company business in logistics platform. Most logistics platform companies just replaced the original distributor or agent to manage the large warehouse area. They help manufacturers to hoard goods; do not bear the transport or distribution function. It cannot fundamentally improve the management level. Logistics platform companies help manufacturer sales representatives to achieve sales target, but are also just as a large warehouse, specific transportation and distribution still need medical instruments companies to operate.

2.3 Characteristics of medical logistics

(1) Particularity

As special goods relates to life and health, special material for medical institutions and the necessary equipment in the process of diagnosis and treatment, medical instruments' circulation pattern also has particularity. The supply chain demand terminal of medical instruments is very single, just medical institutions, few other within the scope of the circulation in society. Medical instruments have corresponding requirement for temperature and humidity in the product transportation, storage, etc, and most common products don’t have these requirements.

(2) Complexity

The particularity and complexity of medical instruments product itself, make it high demanded in the process of transportation and distribution. With the vigorous development of the domestic medical instrument industry, its product category is unceasingly subdividing; its logistics business mode has changed from few varieties and large quantities to multiple varieties and small batch. The market needs of the business fluctuate at any time, put forward higher requirements for medical instrument logistics, its process is also becoming more and more complex.

(3) Economy

Due to the cost of medical instrument distribution center to provide services mainly comes from logistics cost in the process of circulation. Therefore, to enhance the level of logistics operation and reduce distribution costs can make the enterprise improve the quality of service and in profit at the same time, and also reduce medical health care costs.

(4) Diversity

Based on the classification of medical instruments, we can see a wide range of it, from large high-tech medical instruments, medical auxiliary equipments, and medical consumables dressings to family health care supplies. They have different purposes. Based on the characteristics of medical instrument products, we need to gradually improve its logistics mode of many varieties and small batch.

(5) Strict regulatory

Medical instrument products relate to human life and health. Its particularity request every product registers certification. At the same time, medical instrument manufacturers and logistics enterprises need to get the corresponding licensing qualification with legal effect. It is different from other ordinary commodity production, management and distribution.

In addition, different from ordinary products, when medical instrument products pass into circulation channels, their batch numbers, quality and expiration date should be strictly tracked, and records should be timely updated.

Table 2-1 Medical instrument products compared with common products on regulatory requirements

Process link	Compared projects	Medical instrument products	Common products

Order review	Registration certificate verification for the ordering products	Must	Do not need
	License qualification audit for the production supply and business enterprise	Must	Generally do not need
Transport	Preservation conditions of transport	Some products need	do not need
Incoming inspection	Check for packaging	Need; Especially the sterilization packaging	Need
	Check for the label content	Detailed	Simple
	Batch records for purchases	Must	Generally do not need
	Check for validity	Must	Partly need
Warehouse keeper	Requirement for storage conditions	Need	Partly need
Outbound review	Batch records for outbound products	Must	Generally do not need
	Validity inspection for outbound products		
Distribution	Distribute combination requirements for outbound products	High; According to the need of surgery or hospital	Lower
Information processing	Record files for stocks	Complex	Simple
	Record files for sales	Complex; Set up patients' records	Simple
	Traceability requirements for product quality	High	Very low
	Feedback for product quality	Strict	Common

2.4 Adaptive analysis of medical instrument logistics mode based on the third-party

2.4.1 Advantages and developing situation of third-party logistics

(1) Advantages of third-party logistics

In order to gain more profit, enterprises must concentrate the limited manpower and material resources on the core business, all other business need to release more or less effort, or outsourcing. Through outsourcing logistics business not be so core to a third party, can make the production and management enterprises have more time and energy to pursue their core business' competition in the market place.

Modern logistic as a rapidly developing high-tech industry, combined with a large number of advanced information technology, has been widely read and researched in electronic information technology, communication technology, network technology and other neighborhood, among which, GPS, GIS, and ITS technology has been used by many logistics enterprises. The third party logistics enterprises as professional enterprise in logistics and warehousing, its content and level of science and technology in terms of logistics technology and logistics equipment has larger scale and stronger strength than other non-professional companies.

As a logistics mediation platform, the third party logistics enterprise can continuously integrate and improve enterprise's supply chain, enhance the competitiveness, improve the quality of customer service. It is the enterprise focus on their core business without having to worry too much about the operation and management of logistics that ensure the production enterprise's competitive position in the market.

(2) Current development status of third-party logistics

Enterprise scaled: at present, the development of the third party logistics enterprise is very fast, many large state-owned, private or foreign enterprises, all integrate the capital and business channels, and even merge small and medium-sized logistics enterprises to expand their own scale effect. In addition, many of the third party logistics enterprise also spent a lot of cost in the construction of their own transportation team, transport types includes motor transport, maritime transport and air transport; and build large warehouse and distribution centers in large areas at the same time.

Information networked: with the rapid development of information technology, the Internet can connect both upstream and downstream in the supply and demand sides with the third party logistics enterprise on the information platform. A large number of high-end information technology, especially the introduction of large data and the Internet, and the use of radio frequency identification technology (RFID), location tracking technology (GPS), geographic information system (GIS), bring strong support to the further development and research of the logistics information network.

Logistics intelligent: intelligent, as the name implies, is to use software technology to develop logistics intelligent software for decision support. It is an application of a higher level based on logistics informatization. The decision-making management problems in logistics system need to be solved by intelligent software tools. For example, the determination of warehouse site selection, inventory levels, and the choice of transport path, requires modeling and algorithm design to implement accordingly.

2.4.2 Introduction of third-party logistics

Based on the above summary of the disadvantages of two kinds of logistics mode, a third party logistics was introduced in the application and regulatory in the medical instrument industry. First of all, the introduction of the third party logistics, change the logistics mode into flat structure, replacing the original traditional circulation mode of vertical structure, effectively solve the problem of too much intermediate links in circulation process and enhance the manufacturer’s control to the market; Second, compared with normal medical instrument companies or logistics platform enterprises, third party logistics enterprises are more professional. They have a more comprehensive and professional services in warehouse management, transportation, distribution, information management, case records, etc, Again, by outsourcing its logistics to the third party logistics enterprise, the medical instrument manufacturers can put money and effort to focus on core business. It accelerates the vigorous development of the medical instrument industry.

2.4.3 Claim to third-party logistics of medical instrument products

According to the technical content, medical instruments can be divided into high-end medical instruments and conventional medical instruments. high-end medical instruments refers to large medical instruments that condense the content of cutting-edge science and technology, such as CT machine and the MRI machine. Conventional medical instruments involved in the scope of more extensive. They have low technical content and labor-intensive production and operation mainly in common, such as diagnostic instruments, rehabilitation supplies, medical supplies, medical dressings and oral materials, etc.

Because domestic scientific and technological level is backward, China's high-end medical instrument market is monopolized by the developed countries. Most high-end medical instruments rely on imports. The circulation pattern is direct sales pattern that hospitals order and domestic dealers directly delivery. Therefore, this paper studies on medical instruments exclusive of high-end medical instruments.

Medical instrument products studied in this paper refer to conventional medical instruments. The range of conventional medical instruments is very wide, including diagnostic instruments, rehabilitation supplies, medical supplies, medical dressings and oral materials, etc.

Research shows that the development of third party logistics in China is still in the initial stage. There are many deficiencies, especially the lack of logistics professionals, ordinary employees lack professional knowledge of the storage and transportation of different industry products. And the logistics industry does not reach the designated position in practitioners' qualification admittance and skill training. Logistics enterprises are in urgent need of inter-disciplinary talents. Therefore, large third-party logistics enterprises of specific industry like medical instruments are still lacking. Additionally, because medical instrument product itself has special requirements in transportation, distribution, storage, sorting, packaging, reverse recovery, archives management and information processing, there is no real third party logistics company in medical instrument industry.

In order to meet the special requirements of medical instrument logistics as well as the effective regulation, third-party logistics must set strict demands on access standards, including enterprise's scale of land use, economic scale, transportation and storage conditions, inventory levels, personnel qualification, quality control and supervision and management ability, etc. This requires the third party logistics to plan and design reasonably in location of distribution networks, the optimal path planning, inventory level control, transportation equipment configuration, etc, and at the same time, establish a unified national medical instrument production, distribution and sales information system, so as to fully manage all medical instrument products.

3 Research in logistics distribution network for medical instrument

3.1 Function of distribution network for medical instrument

In the past few years, traditional logistics mode with too many intermediate links of dealers or agents was used in domestic logistics mode of general medical instrument. At present, the logistics platform mode is used in this industry, but it has a few demerits, such as unprofessional distribution with single function of warehousing. No matter which mode of current medical instrument logistics, traditional or platform, they both increase the costs of transportation and inventory, cause nonstandard phenomenon in the supply and demand link, at the same time damaging the interests of patients and medical institutions. So they both owe to improve.

Although the phenomenon of outsourcing logistics business has emerged, from manufacturing enterprises of medical instrument to third-party logistics enterprises, the phenomenon is not universal and the operation process is not enough mature or sound. Recent existing issue in outsourcing logistics business to third-party is that it dose not fundamentally resolve the strategic target of cost reduction of transportation, inventory and distribution. The manufacturing enterprises just outsource this business to third-party in order to focus on their core business.

To cure the above problems, this thesis proposes to construct logistics network of medical instrument with low cost, high efficiency and informatization. The research method is to optimize the logistics network layout and supply chain, consequently enhancing competitiveness of enterprises and booming the whole medical instrument industry.

Logistics distribution mode of medical instrument based on third party is shown in the following figure.

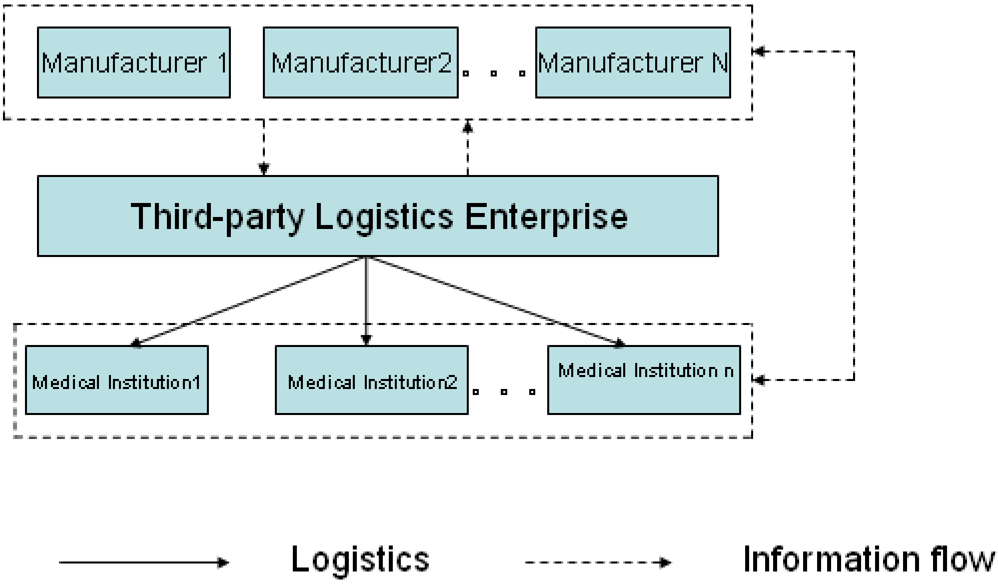

Figure3-1 Logistics distribution mode of medical instrument based on third party

3.2 Logistics distribution network planning for medical instrument

3.2.1 Network topology

As the scope of distribution for medical instrument is relatively wide, this thesis sets the distribution network mode as a multi-level network. Taking cost factor into consideration, the network is divided into two level, level-1 and level-2, of which, level-2 is closer to medical institutions, so as to solve level-1's incapability to deliver in time because of long transportation distance. So level-1 is to deliver products to level-2 or a few medical institutions near it.

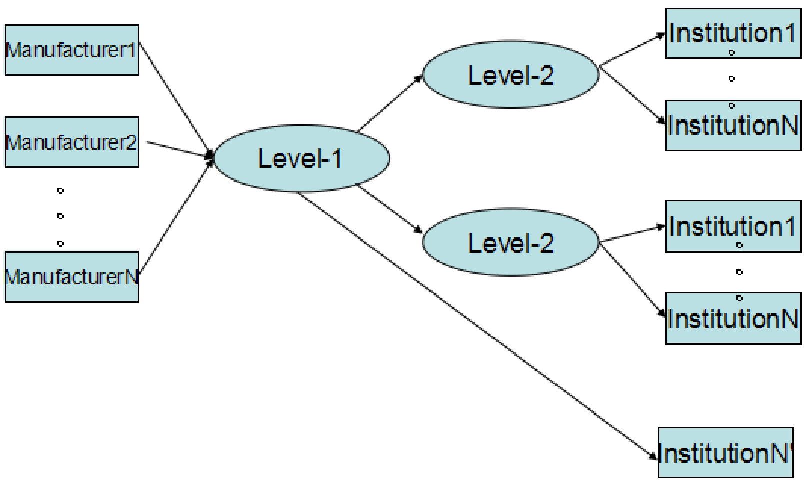

Figure3-2 Topology of logistics network for medical instrument

From the figure3-2, we can see a series of characters for the distribution network mode:

(1).Allocation and distribution of medical instrument through the construction of level-1 is able to generate scale economy effect and reduce distribution cost effectively.

(2).As to some medical institutions closer to level-1, its product demand can be directly delivered by level-1. While many other medical institutions' demand can be satisfied by level-2, because most of institutions are closer to level-2 and the second is able to improve service level for clients.

(3).As shown in the figure 3-2, the distribution network mode is able to adapt to wide-range distribution and large-scale logistics system.

3.2.2 Network elements

The logistics distribution network for medical instrument is a comprehensive network concentrating on logistics facility, logistics information and capital flow, shown in the following figure.

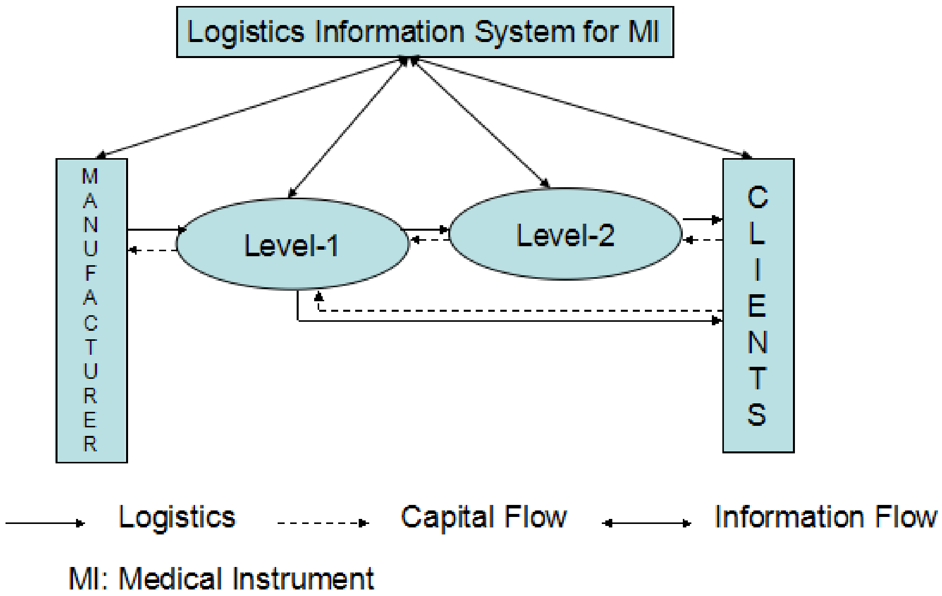

Figure3-3 Logistics distribution network concentrating on logistics, capital flow and information flow

From figure3-2 and figure3-3, we can see the network elements consist of medical instrument manufacturers, level-1, level-2 and medical institutions. The distribution process is as follows: After completing production, medical instrument go into level-1 from manufacturer for storage, then workers in the center begin to sort out, package and prepare to transport medical instrument to level-2; At last, medical instrument are carried from level-2 to various medical institutions according to different demands. As to some large-scale medical institutions or institutions closer to level-1, medical instrument can be directly delivered by level-1.

(1)Manufacturers

The manufacturers are referred to the medical instrument suppliers who produce and manage conventional medical instrument. These manufacturers outsource the logistics business to third-party logistics enterprises, selling products and transporting them to different regions through third-party.

(2)Level-1

Level-1 plays a transitional role in the circulation process of medical instrument. In the first place, level-1 boosts the development of scale economies. In the second place, the characters of medical instrument, such as different kinds, wide-range demand and various demand conditions, ask for allocation and package for products from different manufacturers, at last transporting products to level-2. Level-1 is often set in the center of one large region, for example, provincial capital city.

(3)Level-2

Taking into consideration many medical institutions' large distribution range, long route, only constructing level-1 is not enough, which often cause issues, such as incapability to complete business volume in time, so that lowering service level and increasing transportation cost. It is required to construct level-2 on the basis of level-1. Level-2 is often set in a prefecture-level city or planned in the actual local situation of business volume.

(4)Medical institution

Medical institutions are the demander of medical instrument, which is the terminal node of logistics distribution network. Medical institutions are referred to various kinds of hospitals or clinics, also including retail stores selling family medical apparatus.

This thesis focuses on the logistics distribution network planning from manufacturers to medical institutions.

3.3 Layout planning of logistics distribution network nodes for medical instrument

The planning model of network nodes layout is described as follows: Pick up p locations as level-1 from m alternative nodes; and pick up p' locations as level-2 from n alternative nodes. Level-1 offers products and service to level-2 and a few clients in the service range; while level-2 only offer service to clients. This model is aimed to minimize total costs (including construction costs, variable costs and operation costs), under the condition of ensuring clients' demand and service quality.

3.3.1 Model hypothesis

(1) Every medical institution can receive service from only one level-1 or level-2;

(2) Every second-level distribution can receive service from only one level-1;

(3) level-2 can satisfy all the medical institutions' demands;

(4) level-1 can satisfy all the demands from level-2 and medical institutions.

3.3.2 Mark description

$I = \{1,2,...,m\}$: Collection of alternatives for level-1;

$I^{'} = \{1,2,...,n\}$: Collection of alternatives for level-2;

$I^{''} = \{1,2,...,k\}$: Collection of alternatives for manufacturers;

J: Collection of medical institutions receiving service from level-1;

$J^{'}$: Collection of medical institutions receiving service from level-2;

C_{ij}: each unit-distance transport rate for per unit medical instrument, from one node to the next node, such as, from one logistics/distribution center to one medical institution, or, from one manufacturer to one logistics center;

l_{ij}^{0}: transport mileage from level-1 i to level-2 j;

l_{ij}^{1}: transport mileage from level-1 i to medical institution j within the range of service;

l_{ij}^{2}: transport mileage from level-2 i to medical institution j;

l_{ij}^{3}: transport mileage from manufacturer i to level-1 j;

G_i: Construction cost for constructing level-1 i;

$G_i^{'}$: Construction cost for constructing level-2i;

B_i: Variable cost for constructing level-1 i;

$B_i^{'}$: Variable cost for constructing level-2 i;

$H_{ij}^{'}$: Annual supply volume from manufacturer i to level-1 j;

H_i: Annual distribution volume for level-2 i;

q_j: Annual demand volume for medical institution j;

γ_i: Inventory capacity for level-1 i;

$\gamma_i^{'}$: Inventory capacity for level-2 i;

p: Optional address number for level-1;

$p^{'}$: Optional address number for level-2;

s^1: standard of transport distance for level-1; if the distance from one medical institution to nearby level-1 is within the standard, it is considered to reach timely traffic level, otherwise, fail to reach;

s^2: standard of transport distance for level-2; if the distance from one medical institution to nearby level-2 is within the standard, it is considered to reach timely traffic level, otherwise, fail to reach;

ρ: Service level for logistics/distribution center;

ω: Service quality evaluation weights for logistics/distribution center;

$$Z_i = \begin{cases} 1, construct \\ 0, otherwise \end{cases}, for level 1$$

$$Z_i^{'} = \begin{cases} 1, construct \\ 0, otherwise \end{cases}, for level 2$$

$$y_{ij}^1 = \begin{cases} 1, select to distribute \\ 0, otherwise \end{cases} for level 1$$

$$y_{ij}^2 = \begin{cases} 1, select to distribute \\ 0, otherwise \end{cases} for level 2$$

$$Z_{ij}^{1} = \begin{cases} 1, if l_{ij}^{1} > s^{1} \\ 0, otherwise \end{cases}$$

$$Z_{ij}^{2} = \begin{cases} 1, if l_{ij}^{2} > s^{2} \\ 0, otherwise \end{cases}$$

3.3.3 Model building

In this model, the most important which should be considered is expense cost, including construction cost, transport cost and variable cost; the second important considered is service level, exactly, timely delivery capacity. If clients is within the standard of timely delivery capacity, it is indicated that the clients can receive service in time, otherwise, they cannot. By the way, the more timely the delivery service, the higher the distribution cost.

Therefore, the model is in fact game between reducing total expense cost and improving service level.

The construction cost for level-1 is $\sum_{i \in \mathrm{I}} G_i Z_i$; the construction cost for second-level distribution center is $\sum_{i \in \mathrm{I}'} G_i' Z_i'$; so the total construction cost is $\sum_{i \in \mathrm{I}} G_i Z_i + \sum_{i \in \mathrm{I}'} G_i' Z_i'$.

The variable cost for logistics/distribution center, mainly including management cost, is $\sum_{i \in \mathrm{I}} B_i Z_i + \sum_{i \in \mathrm{I}'} B_i' Z_i'$; the transport cost mainly consists of four parts: the first part is the transport cost from manufacturers to level-1, exactly, $\sum_{i \in I''} \sum_{j \in I} Z_j C_{ij} H_{ij}' l_{ij}^3$; the second part is the transport cost from level-1 to medical institutions (level-2 not included), exactly, $\sum_{j \in J} \sum_{i \in I} Z_i C_{ij} y_{ij}^1 q_j l_{ij}^1$; the third part is the transport cost from level-1 to level-2, exactly, $\sum_{i \in \mathrm{I}} \sum_{j \in I'} Z_i Z_j' H_j C_{ij} l_{ij}^0$; the forth part is the transport cost from level-2 to medical institutions, exactly, $\sum_{j \in J'} \sum_{i \in I'} Z_i' C_{ij} q_j y_{ij}^2 l_{ij}^2$.

So the total transport cost is:

$$\sum_{i \in I''} \sum_{j \in I} Z_j C_{ij} H_{ij}' I_{ij}^3 + \sum_{j \in J} \sum_{i \in I} Z_i C_{ij} y_{ij}^1 q_j l_{ij}^1 + \sum_{i \in I} \sum_{j \in I'} Z_i Z_j' H_j C_{ij} l_{ij}^0 + \sum_{j \in J'} \sum_{i \in I'} Z_i' C_{ij} q_j y_{ij}^2 l_{ij}^2 .$$

The service level can be formulated by the demand of medical institutions who cannot receive timely delivery service, exactly, $\sum_{i\in I}\sum_{j\in J} Z_i Z_{ij}^1 q_j + \sum_{i\in I^{'}}\sum_{j\in J^{'}} Z_i^{'} Z_{ij}^2 q_j$. So the service level is $\rho = \sum_{i\in I}\sum_{j\in J} Z_i Z_{ij}^1 q_j + \sum_{i\in I^{'}}\sum_{j\in J^{'}} Z_i^{'} Z_{ij}^2 q_j$, in which the smaller the numerical value, the higher the service level.

In conclusion, the model of layout planning of logistics distribution network node is as follows:

$$
\begin{aligned}
\min\ f =& \sum_{i\in I} G_i Z_i + \sum_{i\in I^{'}} G_i^{'} Z_i^{'} + \sum_{i\in I} B_i Z_i + \sum_{i\in I^{'}} B_i^{'} Z_i^{'} \\
&+ \sum_{i\in I^{''}}\sum_{j\in I} Z_j C_{ij} H_{ij}^{'} I_{ij}^3 + \sum_{j\in J}\sum_{i\in I} Z_i C_{ij} y_{ij}^1 q_j l_{ij}^1 + \sum_{i\in I}\sum_{j\in I^{'}} Z_i Z_j^{'} H_j C_{ij} l_{ij}^0 + \sum_{j\in J^{'}}\sum_{i\in I^{'}} Z_i^{'} C_{ij} q_j y_{ij}^2 l_{ij}^2 \\
&+ \omega\left[\sum_{i\in I}\sum_{j\in J} Z_i Z_{ij}^1 q_j + \sum_{i\in I^{'}}\sum_{j\in J^{'}} Z_i^{'} Z_{ij}^2 q_j\right]
\end{aligned}
\qquad (3\text{-}1)
$$

$$\text{s.t. } H_i \le \gamma_i^{'}, i \in I^{'} \qquad (3\text{-}2)$$

$$H_i = \sum_{j\in J^{'}} q_j y_{ij}^2, i \in I^{'} \qquad (3\text{-}3)$$

$$\sum_{j\in I^{'}} H_j Z_j^{'} + \sum_{j\in J} q_j \le \sum_{i\in I} Z_i \gamma_i \qquad (3\text{-}4)$$

$$\sum_{i\in I^{'}} y_{ij}^2 = 1, j \in J^{'} \qquad (3\text{-}5)$$

$$(1 - Z_i)\sum_{j\in J} y_{ij}^1 = 0, i \in I \qquad (3\text{-}6)$$

$$(1 - Z_i^{'})\sum_{j\in J^{'}} y_{ij}^2 = 0, i \in I^{'} \qquad (3\text{-}7)$$

$$1 \le \sum_{i\in I} Z_i \le p \qquad (3\text{-}8)$$

$$1 \le \sum_{i\in I^{'}} Z_i^{'} \le p^{'} \qquad (3\text{-}9)$$

$$Z_i, Z_i^{'} \in \{0,1\} \qquad (3\text{-}10)$$

$$y_{ij}^1, y_{ij}^2 \in \{0,1\} \qquad (3\text{-}11)$$

$$Z_{ij}^1, Z_{ij}^2 \in \{0,1\} \qquad (3\text{-}12)$$

3.3.4 Model instruction

The special of this model is to maximize the service level in addition to minimize the total cost. In fact, it is game between the expense cost and service level. The expense cost consists of construction cost, variable cost for logistics/distribution center and transport cost; the service level is represented by standard of transport distance, exactly, S^1 、 S^2, described above.

The objective function (3-1) is to maximize the service level in addition to minimize the total cost (including construction cost, variable cost and transport cost);

The constraint condition (3-2) is to ensure that the inventory level of level-2 can satisfy clients' demand;

The constraint condition (3-3) is to show that the demand of level-2 equal to the demand of all the medical institutions which the second-level offers service;

The constraint condition (3-4) is to ensure that the inventory level of level-1 can satisfy the demand of its clients and level-2, that's to say, promising not to out of stock;

The constraint condition (3-5) is to ensure that every client can receive service from only one level-2;

The constraint condition (3-6) and (3-7) is to ensure that level-1 and level-2, who have clients' demand, must be both constructed.

The constraint condition (3-8)is to ensure the number of level-1 must not be more than p;

The constraint condition (3-9) is to ensure the number of level-2 must not be more than p';

The constraint condition (3-10), (3-11) and (3-12) is the value range of decision variables.

3.4 Solution of bi-layer simulated annealing algorithm

3.4.1 Introduction of simulated annealing (SA) algorithm

In 1953, N.Metropolis put forward simulated annealing (SA) algorithm, however, it did not have a great influence until 1982, when Kirkpatrick introduced the idea of SA into the field of combinatorial optimization. Kirkpatrick put forward stochastic searching optimization based on MonteCarlo Simulated, by which he tried to solve problems of combinatorial optimization. That's to say, just in 1982 did SA come to be popular.

Simulated annealing (SA) algorithm is a similarity principle based between general combinatorial optimization and physically annealing process of solid substance. In the annealing process of solid substance, firstly, the solid substance should be heated to enough high temperature; in the heating process, particulars inside the solid substance present disordered state and internal energy increases; if the speed of temperature drop is slow enough, the solid substance will form the most stable state, that's to say, it is the optimal solution of combinatorial optimization.

(1)Metropolis norm

$$p=\begin{cases}1, E(x_{new})<E(x_{old})\\ \exp(\dfrac{E(x_{new})-E(x_{old})}{T}), E(x_{new})\geq E(x_{old})\end{cases} \qquad (3\text{-}13)$$

$E(x_{old})$ indicates heat energy in the old state;

$E(x_{new})$ indicates heat energy in the new state;

p indicates probability of acceptance transferring from old state to new state.

(2)Similarity comparison between physical annealing and simulated annealing

Table 3-1 Similarity comparison between physical annealing and simulated annealing

Simulated annealing algorithm	Physical annealing
Solution	Particle state
Optimal solution	Lowest energy state
Initial temperature	Melting process
Metropolis sampling process	Isothermal process
Controls parameter's decline	Cooling
Objective function	Energy

(3)Algorithm elements

① State space: State space consists of a series of feasible encoding solution set.

② State-generating function: namely focal function, transferring from old solution to new solution.

③ State-transferring probability: Probability of transition from one feasible state to another;

④ Cooling schedule: namely cooling schedule, from high-temperature state to low-temperature state;

(4)Operating steps

From figure 3-4, we can see the operating steps are as follows:

Step1: Algorithm Initialization: Set initial temperature T (usually 10000 degree), and set initial solution state S, and also set iterations L in each temperature condition;

Step2: In k=1,…,L, repeat operating steps from 3 to 5;

Step3:Generate new solution, and calculate the formula $\Delta f = f(S^{'}) - f(S)$, among which, $f(S)$ is fitness function;

Step4: If $\Delta f < 0$, then accept $S^{'}$ as new solution, otherwise, decide whether to accept it or not according to Metropolis norm;

Step5: When meeting the termination conditions, output present optimal solution, and at the same time, the algorithm terminates and the program ends; otherwise, transfer to step2.

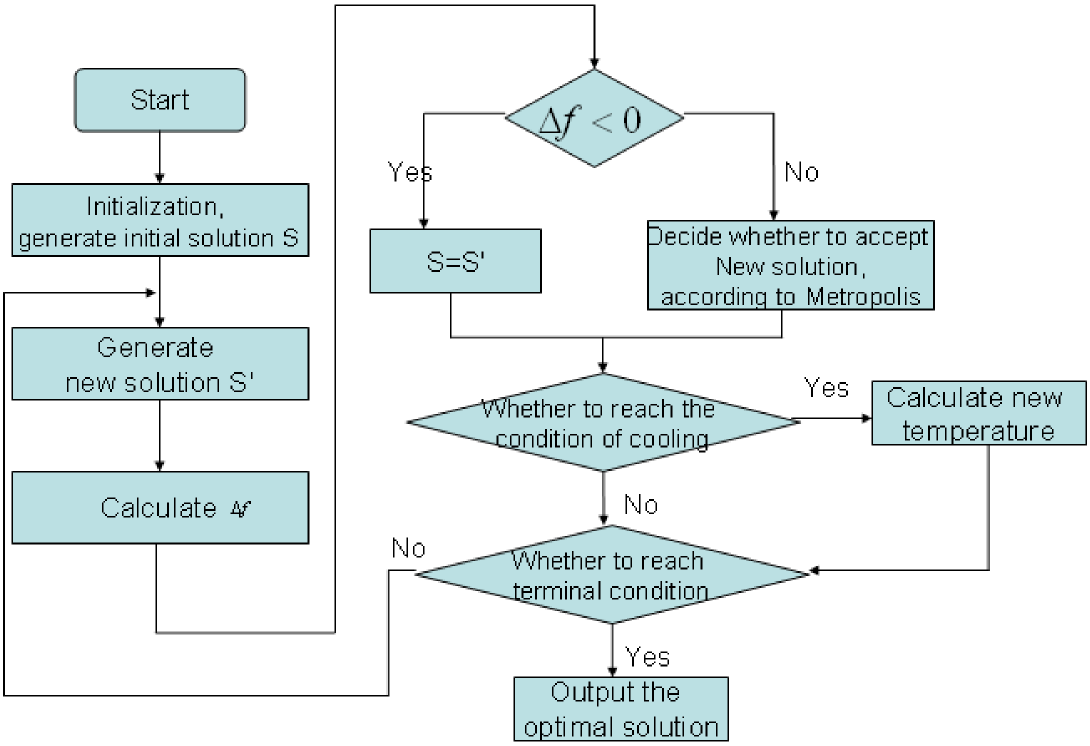

Figure3-4 Flow chart of simulated annealing algorithm

3.4.2 Algorithm design of bi-layer simulated annealing (SA)

Node layout of distribution network center is a typical NP problem, so using traditional approximate algorithm or probability algorithm not only need long operation time and large amount of time, but also have poor versatility. Thus we use bi-layer simulated annealing algorithm to solve the model. We consider the distribution network as a whole, in which, the outer layer is for location selection and the inner layer is to optimize allocation of clients for distribution center on the basis of outer layer's layout.

(1) Elements design of bi-layer simulated annealing algorithm

① Focal functions

For outer layer:

In the algorithm design, we use binary 0-1 to encode for level-1 and level-2, for example, "1001" represents selecting the first and the forth nodes from four alternative nodes to build level-1.

The focal function of level-1: Exchange selected nodes with unselected ones, for example, as above, exchange the first and the second node values with the third and the forth ones, get "0110".

The focal function of level-2: There are two kinds of operations: 1. Exchange selected nodes with unselected ones, for example, |01|1 can be exchanged into |10|1; 2.Exchange 0 to 1 for selected nodes, for example, 1|0|0 can be exchanged into 1|1|0. Select one of methods to implement the algorithm.

For inner layer:

The focal function of inner layer aims at the variable y_{ij}^2, which is used to allocate clients for level-2. The operations are as follows: Exchange y_{ij}^2 with $y_{i^{'}j}^2$, in which $j \in J^{'}$ and i, $i^{'}$ belong to selected level-2.

② Cooling rules

The cooling rule is $T_{i+1} = \alpha T_i$, in which, T_i is the ith iteration temperature and α is damping coefficient.

③ Termination rules

The termination condition is to drop to terminal temperature t_1, which means the algorithm has reached the lowest temperature.

(2) Concrete steps of bi-layer simulated annealing algorithm

For outer layer:

Step 1: Set Control coefficients, such as initial temperature T_0, damping coefficient α and terminal temperature t_1 and set iteration time U of current temperature and remaining time L of optimal objective value; Set $u = 0$, $l = 0$, randomly generate a initial solution S and set it current optimal solution $\bar{S} = S$;

Step 2: Operate focal function of outer layer, receive new solution S', and order $u = u + 1$;

Step 3: Operate focal function of inner layer, receive objective value $f_{(S')}$;

Step 4: If $f_{(S')} < f_{(\bar{S})}$, order $\bar{S} = S$, $S = S'$, turn to Step 6, or $l = l + 1$;

Step 5: If $f_{(S')} < f_{(S)}$, order $S = S'$, or, randomly generate a value ρ from interval $(0,1)$; if $\rho < \exp(-(f_{(S')} - f_{(S)})/T_i)$, order $S = S'$, or reject this solution.

Step 6: According to cooling rules, if $u \geq U$ or $l \geq L$, then $T_{i+1} = \alpha T_i$, $u = 0$, $l = 0$, and turn to Step 7, or, return to Step 2;

Step 7: If the terminal condition is satisfied, output the optimal solution $\bar{S}$, or, return to Step 2.

For inner layer:

Step 1: Set S' as initial solution and optimal solution of inner layer optimization algorithm, so as to build initial solution R, and also initiate control coefficient(e.g. set initial temperature T_0'), and set remaining time L' of optimal solution and iteration time U', order $l' = 0$, u'=0, and current optimal solution $\bar{R} = R$;

Step 2: Operate the focal function of inner layer, and receive new inner solution R', $u' = u' + 1$;

Step 3: If $f_{(R')} < f_{(\bar{R})}$, $R = R'$; or, randomly generate a value ρ from interval $(0,1)$; if $\rho < \exp(-(f_{(R')} - f_{(R)})/T_i)$, order $R = R'$, or reject this solution;

Step 4: According to cooling rules, if $u' \geq U'$ or $l' \geq L'$, then $T_{i+1}' = \alpha T_i'$, $u' = 0$, $l' = 0$, turn to Step 5, or return to Step 2;

Step 5: Terminate the algorithm, and return $f_{(\bar{R})}$ to the optimal algorithm of outer layer, or return to Step 2.

The following figure 3-5 is the flow chart of bi-layer simulated annealing algorithm.

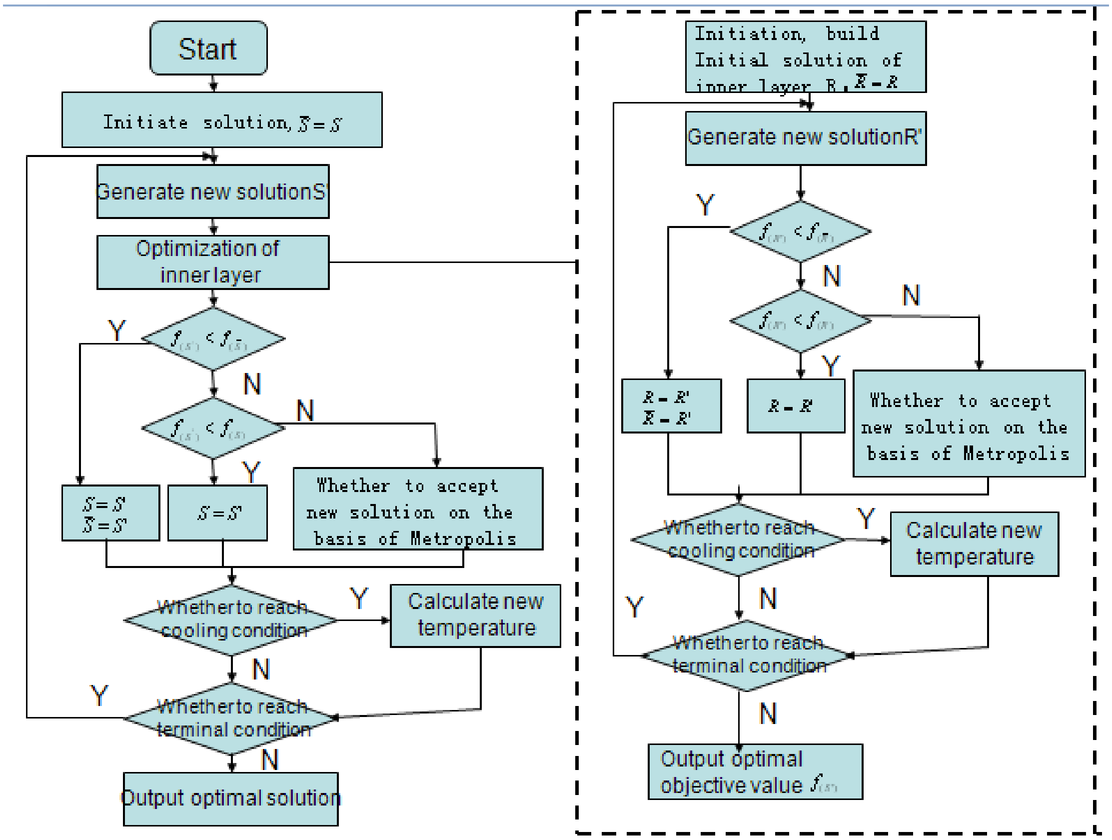

Figure3-5 Flow chart of bi-layer simulated annealing algorithm

3.5 Analysis of examples

Assume one third-party logistics enterprise for medical instrument is in urgent need to enlarge scale of market sales, and prepare to build its logistics distribution network in certain area. Now there are 5 manufacturers represented as (G1,G2,G3,G4,G5) to supply medical instrument, and there are 5 alternative selections for level-1s and 12 alternatives for level-2s. In addition, level-1s need to offer service for 15 clients and level-2s need to offer service for 45 clients. However, according to relative rules, it is allowed to build 1 level-1 and no more than 3 level-2s. The object of this distribution network is to minimize the total cost in the context of timely delivery and good-quality service.

Between logistics/distribution center i and client j, per unit distance transport rate is $C_{ij} = 3$ yuan/km for per unit medical instrument. From the title, the number of level-2 is no more than 3, exactly, $p' = 3$. In addition, standard of transport distance for level-1 is $s^1 = 45$ km; while standard for level-2 is $s^1 = 45$ km. Some other initial data is shown from table 3-2 to table 3-9.

Table 3-2 Construction cost for level-1 (Unit: yuan)

No.	S1	S2	S3	S4	S5
Construction cost	3000000	3200000	2500000	3500000	4000000

Table 3-3 Variable cost for level-1 (Unit: yuan)

No.	S1	S2	S3	S4	S5
Variable cost	300000	320000	250000	350000	400000

Table 3-4 Demand of clients from level-1 (Unit: box)

No.	C1	C2	C3	C4	C5	C6	C7	C8
Demand	150	116	152	164	101	183	180	169
No.	C9	C10	C11	C12	C13	C14	C15	
Demand	146	108	182	119	144	101	130	

Table 3-5 Distance from client to level-1 (Unit: km)

	C1	C2	C3	C4	C5	C6	C7	C8
S1	29	33	26	46	29	20	29	58
S2	59	27	52	56	45	32	39	51
S3	54	22	22	52	29	58	47	20
S4	20	32	58	53	44	24	57	33
S5	39	33	32	45	30	43	37	41
	C9	C10	C11	C12	C13	C14	C15	
S1	49	28	49	48	22	52	29	
S2	37	54	44	28	50	56	58	
S3	23	49	22	51	38	53	32	
S4	59	36	22	26	57	54	51	
S5	41	32	45	28	20	51	55	

Table 3-6 Construction cost for level-2 (Unit: yuan)

No.	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8
Construction cost	700000	600000	550000	400000	250000	460000	500000	450000
No.	SS9	SS10	SS11	SS12				
Construction	800000	600000	430000	650000				

cost								

Table 3-7 Variable cost for level-2 (Unit: yuan)

No.	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8
Variable cost	70000	60000	55000	40000	25000	46000	50000	45000
No.	SS9	SS10	SS11	SS12				
Variable cost	80000	60000	43000	65000				

Table 3-8 Demand of Clients from level-2 (Unit: box)

No.	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8
Demand	127	136	101	188	186	125	156	115
No.	CC9	CC10	CC11	CC12	CC13	CC14	CC15	CC16
Demand	159	133	165	186	156	198	179	115
No.	CC17	CC18	CC19	CC20	CC21	CC22	CC23	CC24
Demand	183	119	163	166	177	137	144	148
No.	CC25	CC26	CC27	CC28	CC29	CC30	CC31	CC32
Demand	160	117	100	179	151	121	110	115
No.	CC33	CC34	CC35	CC36	CC37	CC38	CC39	CC40
Demand	140	140	105	194	114	138	131	116
No.	CC41	CC42	CC43	CC44	CC45			
Demand	189	132	173	141	139			

Table 3-9 Distance from manufacturers to level-1 (Unit: km)

	S1	S2	S3	S4	S5
G1	230	235	238	236	207
G2	239	235	201	211	207
G3	224	208	239	200	217
G4	205	224	230	211	221
G5	212	207	231	232	228

Table 3-10 Distance from client to level-2 (Unit: km)

	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9
SS1	77	55	36	50	36	64	61	75	70
SS2	41	65	30	67	52	47	64	60	60
SS3	60	51	74	43	65	38	49	42	65
SS4	54	45	39	51	74	37	50	73	34
SS5	74	39	44	76	43	39	62	55	51
SS6	68	39	63	64	42	51	71	66	48
SS7	52	64	44	40	73	72	48	51	38
SS8	30	45	53	71	41	54	51	78	71

SS9	71	57	33	61	70	70	59	33	71
SS10	52	37	79	36	75	53	58	57	52
SS11	60	64	59	40	41	52	65	44	77
SS12	69	48	51	60	41	52	55	72	37
	CC10	CC11	CC12	CC13	CC14	CC15	CC16	CC17	CC18
SS1	35	32	77	33	77	43	55	76	52
SS2	52	67	68	39	39	48	38	58	69
SS3	53	77	63	48	35	30	56	62	44
SS4	30	44	36	43	58	74	62	68	41
SS5	63	42	34	68	78	73	30	35	75
SS6	66	76	30	45	31	42	71	30	30
SS7	44	36	44	61	73	58	70	57	59
SS8	43	77	70	79	31	37	64	30	57
SS9	65	65	79	55	55	59	53	52	62
SS10	69	72	30	77	39	46	34	39	45
SS11	79	40	70	71	65	62	71	69	41
SS12	53	52	61	75	42	73	39	60	50
	CC19	CC20	CC21	CC22	CC23	CC24	CC25	CC26	CC27
SS1	51	60	31	78	66	52	34	48	68
SS2	65	43	69	65	77	46	61	69	44
SS3	60	41	79	69	62	49	52	69	38
SS4	44	65	35	41	67	74	33	49	64
SS5	72	57	61	39	47	68	48	42	43
SS6	35	77	36	43	74	74	42	47	52
SS7	44	46	45	65	47	52	76	78	72
SS8	34	65	36	78	32	69	61	53	74
SS9	49	77	41	61	65	36	73	48	65
SS10	46	59	49	57	77	33	62	68	67
SS11	77	74	36	72	37	48	69	48	78
SS12	71	67	42	70	50	48	51	75	50
	CC28	CC29	CC30	CC31	CC32	CC33	CC34	CC35	CC36
SS1	66	50	42	67	74	61	71	52	79
SS2	62	51	65	79	60	68	36	32	33
SS3	64	77	66	73	36	32	72	78	32
SS4	30	74	66	54	38	35	41	30	66
SS5	62	64	61	75	74	72	33	57	70
SS6	77	45	79	31	78	38	46	76	43
SS7	60	71	37	61	60	31	58	74	65
SS8	69	78	40	77	48	45	36	60	44
SS9	30	45	70	32	41	70	73	64	34
SS10	69	79	32	44	52	41	46	76	73
SS11	62	52	56	63	62	59	54	52	33

SS12	38	30	39	59	42	76	51	38	67
	CC37	CC38	CC39	CC40	CC41	CC42	CC43	CC44	CC45
SS1	56	54	52	58	60	71	39	65	65
SS2	76	51	71	77	61	41	55	70	70
SS3	48	47	71	45	38	79	40	40	55
SS4	61	75	57	43	50	43	58	68	55
SS5	38	38	34	33	65	41	78	73	67
SS6	69	49	44	46	51	56	53	70	41
SS7	48	78	60	44	40	58	70	67	77
SS8	68	33	39	50	59	71	51	75	34
SS9	47	45	66	31	71	44	42	52	57
SS10	68	36	57	44	74	42	61	62	75
SS11	37	35	37	40	74	42	48	30	73
SS12	37	38	76	58	78	57	51	79	61

According to principles of bi-layer simulated annealing algorithm, set initial temperature T_0 200000 degree, and select cooling rules of drop in proportion, exactly, $T_{i+1} = T_i * \alpha$, in which, T_i is the temperature in the i[th] iteration and its ratio value $\alpha = 0.95$. The terminal temperature $t_1 = 50$, and the quality evaluation weight of distribution service is $\omega = 5$. In the process of operation, receive initial solution by the method of random allocation.

For random searching algorithm, each operation result may get different final solution. So we operate 4 times and record final solution respectively for 4 different times, in order to verify the rationality and effectiveness of the model and algorithm proposed above. From table 3-11, we can see that compared with initial solution, the total solutions in 4 different operation all save the cost from 9.22% to 17.24%, which strongly proves rationality of above optimization model and algorithm.

Table 3-11 Initial solution and corresponding final solution

No.	Initial solution	Final solution	Gap (%)	Selection for level-1	Selection for level-2
1	11884933	10789717	9.22	S3	SS5
2	12202008	10634901	12.84	S1	SS5
3	12174465	10634901	12.65	S1	SS5
4	12850246	10634901	17.24	S1	SS5

4 Summary and prospect

4.1 Summary

Currently, there are more and more medical instrument enterprises in different scale, but their management is backward, especially in terms of medical instrument logistics. In the mode of separate operation and decentralized traditional management, there must exist many issues, such as uneven warehouse management level, chaos transport links, high distribution cost, unsound information system and so on, in the medical equipment circulation industry.

First, this paper constructed the medical instrument logistics distribution network based on third party. On the basis of comprehensive analysis of the present situation of logistics development of medical equipment at home and abroad, the existing problems and the necessity of optimization, etc, combining the characteristics of medical equipment logistics, it builds a medical instrument logistics distribution network based on third party.

Second, this paper conducted node layout planning study to medical instrument logistics distribution network. Combined with the characteristics of the medical equipment logistics, the logistics distribution center's location planning problems are analyzed. It puts forward a planning model of the location of medical instrument distribution center, and designed a double simulated annealing algorithm for this model. The calculation examples show that, using double simulated annealing algorithm and the location planning model is an effective method to solve the problem of medical instrument distribution network node layout planning.

In this paper, I research into node layout of logistics network, which comprehensively analyze and solve the problems of planning issues of medical instrument logistics and distribution. This paper puts forward a new logistics mode for medical instrument, and has significance of reference to the future development of medical instrument logistics.

4.2 Prospect

(1) As to the research content of layout planning of network nodes, the object and constraint conditions in the model are somewhat simple, only taking into

consideration minimal cost and maximal service quality, without some other factors, such as ecological environment, energy consumption and traffic condition. I hope, in the process of late research, the model of layout planning can be designed more practically.

(2) The algorithm of bi-layer simulated annealing algorithm is not the best suitable method for the math model, which should be verified later.

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