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Extendsim-based research on transport process optimization of emergency Cold-chain Logistics

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EXTENDSIM-BASED RESEARCH ON TRANSPORT PROCESS OPTIMIZATION OF EMERGENCY COLD-CHAIN LOGISTICS

By

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A research paper submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

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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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Abstracts

Title of Research paper: **ExtendSim-Based Research on Transport Process Optimization of Emergency Cold-Chain Logistics**

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The thesis is a comprehensive comparison study of a special and critical logistics form - the transport process of the emergency relief materials cold-chain, which is developed by ExtendSim to implement dynamic simulation, comparing the results obtained by traditional methods of transport with those achieved through the application of transport process optimization theory onto emergency cold-chain.

A brief look is taken at present transport means of evaluating both timeliness and efficacy in the emergency cold chain logistics field, which are examined to assess a range of social feedbacks on such logistics form. The development of this traditional transport process and their inherent limitations and ExtendSim are investigated. With highly compliments on the present optimized transport process in time saving, precise temperature control and good environmental performance of post-disaster relief materials, and this thesis challenges the feasibility of the present transport means by thorough transit-related process analysis creating a better optimized transport process for vaccines or the other emergency biological pharmaceutical products.

Additionally, an application on emergency vaccine cold-chain transport after the Wenchuan Earthquake in China proves that the optimized transport organization now being appropriate for adopting the transport process optimization theory by ExtendSim. The results were collated and estimated for more extensive succour activities, in relation to natural disasters or the other emergency public events.

The concluding chapters examine the results of the transport process by ExtendSim, and discuss the potential use of ExtendSim for both simulating and as a means of tackling un-occurred transport problems in our life. A number of recommendations are made concerning the need for further investigation in the subject.

KEYWORDS: Transport Process Optimization, Emergency Cold-Chain Logistics, ExtendSim, Simulation, Vaccine, the Wenchuan Earthquake

Table of Contents

List of Tables

List of Figures

List of Abbreviation

BMK	Benchmarking
CCA	Cold Chain Association
CCGD	Canadian Council of Grocery Distributors
CCQI	Cold Chain Quality Index
CFIG	Canadian Independent Retailers Association
CTA	Canadian truck Alliance
DHS	Department of Homeland Security
DMAIC Model	Define Measure Analyse Improve Control Model
ECRS Analysis	Eliminate Combine Rearrange Simplify Analysis
ESIA Analysis	Eliminate Simplify Integrate Automate Analysis
ETC	Electronic Toll Collection
EU	European Union
FEMA	Federal Emergency Management Agency
GCCA	Global Cold Chain Alliance
HACCP	Hazard Analysis and Critical Control Point
IACSC	International Association for Cold Storage Construction
IARW	International Association of Refrigerated Warehouses
IRTF	International Refrigerated Transportation Association
NGO	Non-Government Organization
PPP	Product Process Package
PTSP	Perishables and Temperature Sensitive Products
SDCA Cycle	Standardization Do Check Action Cycle
TRRF	Refrigeration Research Foundation
TTT	Time Temperature Tolerance
WFLO	World Food Logistics Organization

Chapter 1. Introduction

1.1 Background

Due to the geographical position and the tectonic section of China, the geological disasters occur frequently, which trigger severe and widespread devastation. More exactly, the mainland of China lies between Eurasian seismic belt and the central Pacific seismic belt, undergoing strong compression of the continental plates, e.g. the Pacific Plate, the Indian Plate and the Philippine Sea Plate, so that the distribution of seismic fault belts are very serried widely separated. China, that is to say, is under 33 per cent of the global continental earthquake by 7 per cent of the world’s land area which can be said the country with the most continental earthquake. (Liu J. , 2008, pp. 122-129) Unsurprisingly, the transport of relief materials struggled with a series problems, such as, the emergency supplies cannot arrive at afflicted area in time; some biological pharmaceutical emergency products (i.e. vaccine and plasma) may delivery without efficacy due to unqualified temperature control technology.

On May 12, 2008, a deadly earthquake happened in Sichuan Province of China that measured at 8.0 M_s[1] and 8.3 M_w[2] which is known as the 2008 Sichuan Earthquake, the Great Sichuan Earthquake or *the Wenchuan Earthquake*. The epicentre was lo-

[1] The Surface Wave Magnitude Scale is based on measurements in Rayleigh surface waves that travel primarily along the uppermost layers of the earth, which is currently used in People's Republic of China as a national standard (GB 17740-1999) for categorising earthquakes.

[2] The Moment Magnitude Scale is based on the seismic moment of the earthquake, which is equal to the rigidity of the Earth multiplied by the average amount of slip on the fault and the size of the area that slipped.

cated at Yingxiu Town in Wenchuan County, also being felt nearby countries and as far away as both Beijing and Shang. As of September 25, 2008, the official statistics statement updated[3] that there already were 69,227 people confirmed dead, including 68,636 in Sichuan province, and 374,176 injured, with 17,923 listed as missing in such earthquake, which led to direct economic losses of 8,451 billion Yuan at least. (Wikipedia, the Free Encyclopedia, 2008) As a consequence, our country and people had to bear a great number of losses on physical and philosophical because of the deadliest earthquake we have never seen in this century, relating to social stability and national security which has great negative impact on development of social economy.

Where is a great earthquake, there is an epidemic. Without considering about such aspects that building collapse, traffic congestion, communication interrupt and so on so forth; the conditions like continuous raining after earthquake and heat wave and sultry weather of epicentre, which offered a warm bed for bacteria growth. In the case of the Wenchuan Earthquake, millions of victims lost their homes instead of living in limited temporary rooms, such as, temps and shelters. There is no doubt that is must trigger a series of health problems owning to the various extremely abominable living conditions - shortage of cleaning drinking water because of the destroyed city drain system; propagation of mosquitoes and flies since the spoiled suite sewage system; congestion of traffic as continuous aftershocks or even landslides and mudslides in the mountain area; and the victims must be badly in need of provisions. Additionally, the dead bodies piled up like a mountain to rot in the muggy weather which contaminated water-source, nourished bacteria, and poisoned people. This above is a seriously vicious cycle for the affected area. (Xin, 2008, pp. E01,E04)

[3] This is the latest data added up by the end of 25th Sept, 2008, from a Chinese website: http://news.sina.com.cn/c/2008-09-25/183514499939s.shtml

In order to complete the post-disaster reconstruction, the government should keep doing anti-epidemic works as the prerequisite. After the Wenchuan Earthquake, the outbreak of post-disaster epidemics became increasingly proliferated. To prevent from that, Beichuan County had been blocked out by force for several times. (Liu Z. , 2008, pp. A20,A21) Things like the injured rescue, health epidemic prevention, post-disaster reestablishment, prolificacy regeneration, and public order rehabilitation, are crying for emergency materials that are also pressed for the emergency logistics system in action. The emergency cold-chain logistics is the vital part of the emergency logistics system, which provides stable and reliable guarantee like quality and prompt warranty of delivery for those required succour with low-temperature conservation. Also, this emergency cold-chain logistics, as a kind of special and specialized emergency logistics, is able to satisfy the rigorous request of temperature control as to vaccines and the other biological pharmaceutical products. In a word, the emergency cold-chain logistics is playing an increasingly important role in goods and materials supporting after disasters (Xu & Huang, 2010, pp. 88-90).

Whether the public health events such as SARS, bird flu, and HINI influenza or the natural disasters such as the Wenchuan Earthquake and the Chongqing Landslide all made such a huge loss of life and property that needed large amounts of relief supplies emergently (Li K. , 2010, pp. 44-46). The concept of emergency materials means to cope with the transport process of necessary security materials in emergency response to events, such as, serious natural disasters, sudden public health incidents, public security incidents and military conflicts (Cao, 2010, p. 73). In a brief, it is can be called emergency materials that are used to address the emergency public events. Among them, these emergency materials can be divided into 13 classes as usage; they are protection equipment, life assistance, life support, rescue carrier, temporary accommodation, pollution clean-up, power fuel and engineering equipment, tools, lighting equipment, communications and broadcasting, transportation, and engineering materials. (National Development and Reform Commission, 2010) Among that the biological pharmaceutical products like vaccine and plasma, as the most special supporting emergency materials, are needed indeed and required thorough consideration about timeliness-based on delivery and high quality of temperature control during transport.

Nowadays, it is clear that both the social stability and economic development relied increasingly on safety guarantee system, compelling the social focus to the incomplete emergency cold-chain logistics system (Xiao, 2009, pp. 18-19). In practise, the emergency cold-chain logistics is an extremely complex and relatively opened system which is badly in need of timeliness delivery and high-qualified temperature control transport, so that the growth and development of emergency cold-chain logistics system is always suffering setbacks. Owning to be influenced by various internal and external factors, the effect of the entire system would be uncertainty once changed one link of this specialized chain. This is why that we need simulate such transport process by simulation tools to verify or even do further decision-making. With the growth and development of emergency cold-chain and logistics simulation technology in the world, however, this paper focus on researching the vaccines transport process and simulation.

ExtendSim is the one of the simulation tools from the above scenarios, which is widely adopted in simulating current transport process for emergency cold-chain logistics. Apparent benefits from ExtendSim contributed a great cost-saving for carriers, such as the bunkers consumption in transport and the absorption for extra-expenditure of cold-chain technology. Moreover, using ExtendSim software to build and simulate the real system operation model based on economy, timeliness and technicality, is more suitable for simulation and research on complex dynamic stochastic system. Developers can use the embedded compiling language (MODL[4]) to create model, also can reuse those off-the-shelf modelling module; while for someone who do not proficient in programming languages (VB, C++, FORTRAN, etc.) and simulation languages (GPSS、SIMSCRIPT、SLAM、SIMAN, etc.), ExtendSim is so convenient that easily to get started. It is worthy to mention that the user terminals are interface with developing tools, with flexible functions like automatically generating the customized report charts and compatibly integrating with other applications. (Qin, 2008, pp. 5-6) As one of the outstanding design software for dynamic simulation system, the practicability of ExtendSim goes far beyond the Excel and its plug-in simulated effects. For instance, developers may construct a simulation model using geographic representation in a visual way, which is able to improve modelling efficiency greatly and reduce modelling difficulty. As a result of that, ExtendSim became increasingly popular in transport process simulation.

Significantly, every details of running the model can be seen clearly by using ExtendSim, including the production of vaccine, the various means of transport and its links, or even the solution of time distribution for each time. As to optimized-related problems of emergency cold-chain transport under earthquake, the most solutions are belong to mathematical modelling method, according to factors like cost-saving and time saving. It is a standard analytical model to get the optimum solution, though the case in this paper is emergent and uncertain, changing with the subjective and objective factors. This is why this paper had chosen ExtendSim to solve such dynamic stochastic system problems.

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[4] MODL is similar to C language.

However, when the government and non-governmental organizations (NGOs) advocated substantially for earthquake relief work, criticisms and concerns about the traditional transport process arouse across the related affairs of emergency cold-chain logistics. More and more people complained and questioned the traditional transit means for the increasing bullwhip effect regarding longer transit time. In traditional transport process, the relief supplies are transported to one destination and another sub-destination in a serial connection way. What's more, the connection between various transit means by different type of carries is not good enough. Consequently, we should figure out flexible way to tackle such problems as soon as possible, because citizens' lives and property are not a game.

Fortunately, there are a series of advanced logistics theory lies on emergency cold-chain, which can make the traditional transport process better. As so long as these improvement methods can be applied in practical, we may achieve an optimized transport process as a part of current rescue and relief work. Despite this theoretical optimization, the actual contribution from the optimized transport process is considerable. The optimized transport process of post-earthquake succour adopts multimodal or combined transport instead of traditional direct transport, which is able to relieve the acute obstruction of disaster-related information caused by bullwhip effect; updating transport and its plugin equipment to reach the professional cold-chain requirement, which is obliged to control post-disaster materials under a certain range of temperature. Nevertheless, certain technical barriers are still to be addressed.

The application of the optimized transport process on emergency cold-chain logistics are highlights teamwork between government and associated NGOs; it is worthy thinking over the truth of optimized transport process in today's emergency cold-chain logistics concerning all the related parties and issues. From all the perspectives mentioned above, this paper intends to convince readers that the rescue and relief effect by using the optimized transport process is really much better than the traditional way for emergency cold-chain logistics. *Is this just a transient fashion or a successful way here to stay?*

1.2 Objectives of Study

The first of this paper is to *investigate* current and potential impacts and concerns brought by the optimized transport process instead of the traditional transport process of emergency cold-chain logistics through the whole rescue and relief work after disasters. The second objective of the paper is to *determine* the advantages of the optimized transport process subject to several correlative factors. The third objective of the paper is to *prove* the assumption through an application to a case of the Wenchuan Earthquake.

1.3 Methodology

The purpose of this paper to analyse and assess the sustainability of the optimized transport process compared with the traditional way for emergency cold-chain in an overall perspective. To achieve the mentioned goal, the paper will first analyse transit-related logistics factors of emergency cold-chain based on timeliness of delivery and high-qualified temperature control of transport. Meanwhile, the application of the optimized transport process of emergency cold-chain improved by the advanced logistics theory will be estimated representing the rescue and relief effect which is largely better than traditional way. Second, a comprehensive comparison with both two transit methods is simulated by ExtendSim to adopt the special and specialized succour work, i.e., the result of time and capacity factors on emergency cold-chain materials. To make this approach more legible, we will simply use a case study of the Wenchuan Earthquake watching the tendency and changing of time and capacity factors when transporting in different way. Third, based on the model, the result of such factors for each transit process on the Wenchuan Case are applied to compare with ExtendSim, appraising whether the optimized transport process if feasible and sustainable.

1.4 Outline of the Paper

Chapter 2, literature review, means to overview relevant theses and market reports or comments on the transport process of emergency cold-chain logistics. Several re-searches emphasize influences of transport process across the whole rescue and relief work. Chapter 3, analyse on the process of emergency cold-chain transport in China, the transit-related logistics methods and policy will be presented and analysed for corresponding current situations and future growth and development tendency. Chapter 4, the research on process of emergency vaccine cold-chain transport based on ExtendSim with a case of the Wenchuan Earthquake, the two different transport process models simulated by ExtendSim is to determine the sustainability and flexi-bility of emergency cold-chain transport for rescue and relief work. As the same time an application to the Wenchuan Earthquake is applied to appraise the sustainability and flexibility of the optimized transport process compared with the traditional transport process. Chapter 5, suggestion and Chapter 6, conclusion, after given some practical and efficient recommendations for the growth and development of the emergency cold-chain transport process, the summary of findings, implications and limitations of this research will be presented.

Chapter 2. Literature Review

2.1 Introduction

As stated in the previous chapter, the relief materials for emergency cold-chain like vaccine are badly in need when a massive epidemic outbreaks. This is the main reason that why the process of emergency cold-chain transport raised the increasing attention from social emergency cold-chain system. From the sake of emergency cold-chain logistics, both timeliness and high-qualified temperature control technology during transport on the basic of delivery are always the theme of operation. With the frequent occurrence epidemic, the optimized process of emergency cold-chain transport seems an effective way to relieve such situation. Furthermore, the application of certain advanced logistics theory may improve the traditional transport process with a case of the Wenchuan Earthquake which is able to prove that the optimized transport process is better on rescue and relief work. Consequently, as a special form of logistics, emergency cold-chain logistics plays a decisive role for the effective control of major accidents, sudden disasters, and thus its study have significant theoretical value and practical significance, which becoming a hot topic of research. (Zheng, Li, & Wang, 2009, pp. 65-67)

In this chapter, we will first review the fundamental knowledge like concepts and characteristics, the growth and developments, and the status at home and abroad of the emergency logistics, cold-chain logistics, and the emergency vaccine cold-chain logistics. At the same time, both timeliness and efficacy factors in logistics will be observed. Finally, the domestic and international application of ExtendSim will be studied, comparing with the other simulation platforms.

2.2 Emergency Cold-Chain Logistics Development Status

2.2.1 Emergency Logistics

2.2.1.1 Basic Concepts of Emergency Logistics in Foreign Countries

Until now, the concept of emergency logistics has no unified definition at home and abroad, the representative one is proposed by the special issue Transportation Research Part E, edited by Jiuh-Biing Sheu in 2007: the emergency logistics is a process for planning, management and control of information flow and distribution flow, service flow from the starting point to the destination point which influenced by the emergency situation. (Sheu, 2007, pp. 655-772)

2.2.1.2 Growth and Development of Emergency Logistics in Foreign Countries

Initially, the American scholars began to research the emergency logistics linked closely with military activities, which is more advanced than other countries now. After the Second World War, some American scholars (i.e., Rupperthal, Roland G, Gaviggia John and Max Herrmann) stated their own opinions on supplies and logistics in the war. However, in the aspect of responding the natural disasters, the research on emergency logistics originated in the year of 1971; in 1979, President Carter reassembled all kinds of disaster management departments, established the Federal Emergency Management Agency (FEMA), which became one part of the

U.S. Department of Homeland Security (DHS) on March 1st, 2003. (FEMA, 2010)

Furthermore, in the aspect of the characteristics of emergency logistics, D. Kemball-Cook and R. Stephenson addressed the need for logistics management in transport of relief materials to improve transport efficiency. (Kemball-Cook & Stephenson, 1984, pp. 111-121) A part of that, foreign scholars are always integrated the supplies of emergency logistics with emergency management to study. It was followed by the concept of emergency logistics, originated by an American scholar J.L.Wybo in 1998; in his research, a decision support system for forest fire protection and fighting has been stated in details (Wybo, 1998, pp. 127-131). Suleyman Tufekci and William A.Wallace, the experts of emergency logistics, argued that management is fundamentally a complicated optimization problem; under the constraints of emergency resource, we must solve the problem of resource utilization (Tufekci & Wallace, 1998, pp. 399-420).

Then, the emergency logistics has already become a mature system, especially on transport process and materials allocation. For example, Philip T. Evers researched the impacts of total logistics costs compared with both emergency transhipments and order splitting (Philip, 1999, pp. 119-141); while S.M. Hong-Minh et al researched the application of simulation methods for emergency logistics in supply chain. (Hong-Minh, Disney, & Naim, 2000, pp. 788-816) Gradually, the core framework of emergency logistics has been given by Jiuh-Biing Sheu that emergency logistics system consists of emergency material demand forecast, emergency logistics network planning and design, emergency materials distribution problem and rapid response of emergency materials distribution. (Sheu, 2005, pp. 459-460) The mentioned above are all laid the foundation for further research.

Generally speaking, the research on emergency logistics abroad already well-skilled, efficient emergency response system may explain the efforts from foreign scholars in this regard. In the developed countries, the government set up a special government agency which is responsible for national emergency logistics management, and established a relatively perfect management system for emergency logistics.

2.2.1.3 Basic Concepts of Emergency Logistics in China

He Mingke pointed out that the emergency logistics means to go on logistics operations caused by some rapid-onset factors, including both supply and demand (He, 2003, pp. 18-19). Besides, Gao Dongye et al indicated that the emergency logistics is one of the special logistics operations (Gao & Liu, 2003, pp. 22-23).

On the basis of that, Ou Zhongwen et al and Lei Ling summarised and developed the concept of emergency logistics, respectively. As a special kind of logistics operations, the emergency logistics pursues to maximize the benefits and minimize the disaster losses, which is aiming to supply materials for sudden natural disasters and public health incidents (Ou, Wang, Wei, Lu, & Liang, 2004, pp. 164-167); whereas, another argument is that the emergency logistics is a special kind of logistics operations dealing with a series emergent response in supplies of materials, staff and funds, for the great epidemics, the serious natural disasters, military conflicts and so on so forth (Lei, 2004, pp. 122-123).

Accordingly, Han Jingchou et al stated the concept of emergency logistics system and its basic model, believing that the emergency logistics system is a special kind of logistics systems based on the construction of supply chain between the government and enterprises (Han, Zhan, Xu, & Li, 2005, pp. 92-94).

In the People's Republic of China National, Standard Logistics Terminology (GB / T18354 - 2006), the emergency logistics is defined as a good pre-arranged planning for emergencies that may arise, which can be rapidly implemented as a logistics activity (Ministry of Communications of the People's Republic of China, 2005).

2.2.1.4 Growth and Development of Emergency Logistics in China

At present, the emergency logistics in China is still in his infancy; there are so many shortcomings in the aspects of the construction of public health facilities and logistics infrastructure, and the emergent storage during the national conflicts. Research on emergency logistics was taken in serious gradually, until 2003 with the outbreak of SARS. On the one hand, the study is around the storage of relief materials, the funds for disaster relief and effective management, which are confined to the traditional logistics level with localization and isolation. However, the natural disaster relief logistics is a system problem in modern logistics, which studied the disaster relief supplies, storage, transportation and distribution as a whole is studied. On the other hand, from 2003, domestic experts and scholars had started from such point of view to study with putting forward the concept of emergency logistics and researching emergency logistics management in perspective of system engineering.

Nevertheless, the development of the natural disaster emergency logistics is relatively fast in our country. More than that, the other related areas, i.e., the construction of emergency logistics centre, the supply, storage, transportation and distribution of relief materials, the dispatch of vehicles, the transport process selection of emergency relief materials, the support of information system, and even the management of professional emergency logisticians, already get some achievements. Most researchers insist that we should construct the emergency logistics system through establishing the emergency logistics command centre.

In China, most researches focus on the microscopic emergent materials management. Zeng Wenqi thought that the emergent materials management has many problems on purchasing, warehousing, and transporting (Zeng, 2004, pp. 53-55). Among that, Guo Ruipeng researched on the problem of decision and optimization of emergent materials under certain circumstances (Kong, 2006). At the end of 2006, the first professional emergency logistics organization has been established in China, authorized by both the State-owned Assets Supervision and Administration Commission of the State Council, and the Ministry of Civil Affairs of the People's Republic of China.

Dong Yuhong and Yan Hua put forward the requirements and processes of emergency materials management, describing each part of emergency logistics information system and its main functions, but the purchasing, warehousing, transporting and distributing of emergency materials (Dong, Yan, Yan, Ou, & Liu, 2007, pp. 17-19); in contrast, Zhao Duling took his attention on storage and distribution of emergent materials for cities based on city emergency management model and emergency management network model, orientated to the great hazard sources of cities (Zhao, 2007, pp. 27-29).

Recent years, researches on the emergency logistics management have already stepped into a positive cycle depending on teamwork and system development. A guidebook called Emergency Logistics Research Guide was formulated and released by the Emergency Logistics Professional Committee of China's Logistics and Procurement Federation. More than that, the China Society of Logistics took the China Emergency Logistics Current Situation and the other five related topics into the annual research plan, in 2007. The government and enterprises gradually began to recognize that the important role of emergency logistics.

2.2.2 Emergency Cold-Chain Logistics

2.2.2.1 Basic Concepts of Cold Chain in Foreign Countries

Cold chain was originated in the 19^{th} Century, establishing and developing with the progress of science and technology during the age of freezer invention; it is a logistics phenomenon based on refrigeration technology, transporting in low temperature by the means of refrigeration technique. This concept was first brought by Albert Barrier (an American scholar) and J.A.Ruddich (a British scholar) successively, in 1984. Now in the developed countries, cold-chain for fresh-keeping technology has reached the advanced level.

However, during the period of the Second World War, the cold chain system was destroyed in Europe and the United States, especially in the food-related field. Now, Europe and the United States form a complete cold chain system through a quickly recovery after war. The food-related cold chain is the most important part of cold chain, which is based on the food safety theory and supply chain theory for development.

2.2.2.2 Growth and Development of Cold Chain in Foreign Countries

The Global Cold Chain Alliance (GCCA), launched in 2007, is a platform for communication, networking and education for each link of the cold chain. (Global Cold Chain Alliance, 2007). The GCCA will be the recognized authority in forging a universally strong cold chain where every product retains quality and safety through each link with its four core partners, i.e., the International Association of Refrigerated Warehouses (IARW), the World Food Logistics Organization (WFLO), the International Refrigerated Transportation Association (IRTF), and the International Association for Cold Storage Construction (IACSC).

Among them, the WFLO was founded in 1943 as the Refrigeration Research Foundation (TRRF), aiming to improve the refrigeration technology, personnel training, and the communication for food during its handling and storage, and safe, efficient and reliable movement of food to the people of the world (Global Cold Chain Alliance, 1943). In 1959, the United States Pearce Parker Company and American Aerospace Bureau jointed to develop the aerospace food formed the Hazard Analysis and Critical Control Point (HACCP) Food Safety Management system, which is a scientific and practical quality control system for food safety prevention in all over the world (Mortimore, 2001, pp. 209–215).

With the development of supply chain theory, M. Den Ouden et al first put forward the concept of food supply chain in 1996; they thought that the food supply chain management for organizing the agricultural products, food production and sales, is an integrated operation mode to reduce food and other agricultural products logistics cost, improve quality, food security and logistics service level (Ouden, Dijkhuizen, Huirne, & Zuurbier, 1996, pp. 277-290).

From the perspective of government macro-control, the Danish scholar Eva Roth and Harald Rosenthal did a detailed study on cold chain for fish exports from the developing countries to the European Union (EU) - the government supervision departments should be at what position of the chain that can get best effect, with giving four kinds of models to compare and analyse (Roth & Rosenthal, 2006, pp. 599-605). Canadian scholar Simon Jol, Alex Kassianenko proposed that the cold chain should also include the Canadian truck Alliance (CTA), the Canadian Independent Retailers Association (CFIG) and the Canadian Council of Grocery Distributors (CCGD). They thought that only added such governmental background organizations, the HACCP-based cold chain would be guarantee from production to final consumers without weakness, so that the entire cold chain can integrate operation smoothly (Jol, Kassianenko, Wszol, & Oggel, 2007, pp. 713-715).

Apart from the food cold chain, the pharmaceutical products cold chain is the one that cannot be ignored. In Japan, researches on transport, management and technology of medical cold supply chain system has begun to take shape and become more and more mature - the upstream commodity supplier and distributor can realize information sharing; the bar code technology in pharmaceutical logistics industry already has such a wide range of applications, that the logistics centre may realize standardization; plus, the high automation degree for storage and sorting equipment, and the convenient and powerful warehouse management operations to ensure the cold medicines logistics operation efficient and costs saving at the same time.

In America, the Cold Chain Association (CCA) is a non-profit organization, founded in 2003, with the aim of synchronizing the cool supply chain in order to improve the quality of Perishables and Temperature Sensitive Products (PTSP) and thus prolong their shelf life and reduce wastage (Cold Chain Association, 2003). In 2008, the CCA issued a Cold Chain Quality Index (CCQI), covers the medical cold chain logistics and each inside industry, to test the enterprise's reliability, quality and proficiency on transport, handling and storage of perishable goods. Besides, there is an American pharmaceutical company, using RFID electronic label applied on its supply chain and evaluating the practical usefulness.

In addition, most of the countries established the cold chain association in order to lay the foundation for certification the whole perishable goods supply chain. As a bridge bonding government and the enterprises, those associations play an important role in improving industry management process. The medical cold chain logistics is a branch of the logistics industry, especially to meet people’s needs in disease prevention, diagnosis and treatment under the entity cold medicines chain from the producer to the user, including its production, transportation, storage, usage and other links. The foreign advanced experiences and methods provide a good example of China’s pharmaceutical cold chain logistics and even the related policy, which can be learned to get good effect on pharmaceutical cold chain in our country.

2.2.2.3 Basic Concepts of Cold Chain in China

China's cold chain was originated in 1950s with doing meat export business. In 1982, China promulgated the The Food Hygiene Law of the People's Republic of China (for trial implementation), promoted the development of cold chain in some extent (The Standing Committee of the National People's Congress, 1982). The next two decades, with some food processing industry as the forerunner, China built her own products cold chain system, including quick-frozen food enterprises, meat processing enterprises, ice cream and dairy enterprises and large fast food chain enterprises.

Generally speaking, however, China basically did not establish a real sense of cold chain system, food transportation and distribution remains from food production enterprises operating directly, without outsourcing. These transport enterprises have gradually began to do business in refrigerated transport services, which also needs to improve in terms of service quality.

Furthermore, each link of cold chain will need to integrate as well. Information technology in a certain range has been applied, whereas most manufacturers were still in the half manual processing and half automation level. It can be proved that the future use of information technology to improve the operation efficiency has great space to develop. Food production enterprises are the headstream of cold chain whilst the biggest point of interruption of cold chain is between the farm and the wholesale market, transporting fruit and vegetable. In practice, it seems that the fresh fruits and vegetables are usually failed precooling treatment; and the transport process is usually not refrigeration during cold chain transport.

2.2.2.4 Growth and Development of Cold Chain in China

As core links of cold chain, cold storage and distribution facilities have so many problems during its growth and development. In the first place, a large number of cold storage facilities are from other uses buildings' conversion, which is almost unqualified. Moreover, cold chain management level need to be improved, food processing of cold chain is not reasonable. As the the last link chain that consumer-oriented food cold chain, the storage capacity of supermarket stores is limited because of the lack of storage area and stocking area, which means that the cold chain distribution centre has very large space to develop.

In China, domestic scholars mainly focus on researching cold chain process and cold storage equipment. Li Baoren established a model integrated the gross of cold chain logistics facilities and equipment (especially the cold chain transport vehicles) with structure configuration by using optimization and statistics theory, giving a case as application (Li B. , 2001, pp. 30-32). However, Wang Zilin argued that the hardware facilities was insufficient with shortage of the overall planning and integration from downstream to upstream of cold chain, through his analysis on the current development status of China's cold chain logistics (Wang Z. , 2005, pp. 18-20). Then, Bao Changsheng insisted that the cold chain logistics operation should include the demand forecast, facility location, cold chain logistics facilities and equipment management, cold chain logistics centre and transportation management, customer and order management, information management, cold chain logistics cost control, cold chain logistics quality control, etc. (Bao, 2006, pp. 147-148). After a systematic analysis on the refrigerator car, Lu Gang thought that our country was in great demand for refrigerator car, which would continue to increase; the direction of future development should pay attention to energy consumption, noise and environmental pollution (Lu, 2005, pp. 56-58). Li Wanqiu researched on the cold chain logistics management to point out that the selection of cold chain logistics centre location should be considered about customers, supply chain management, city development, road traffic planning, government investment policy, environmental factors and so on so forth (Li W. , 2006, pp. 108-109).

2.2.3 Cold Chain

2.2.3.1 Basic Concepts of Emergency Cold-Chain Logistics

Emergency cold chain logistics is a vital component of the emergency logistics system, playing a decisive role in society at home and abroad. The need for low temperature preservation of emergent materials provides a stable and reliable quality assurance and timely and effective support and distribution in response to incidents.

First, the rescue and relief work is crying for the pharmaceutical products transported by emergency cold-chain. When the sudden public events happened, in particular the natural disasters, often accompanies with casualties. In order to rescue the injured, a large number of surgical operation needs must be urgently transported, such as vaccine and plasma. Take the Wenchuan Earthquake as an example, vaccine and plasma were dispatched from everywhere in order to support disaster area, rescuing the injured as an unplaced role.

Second, the construction of social health and security cannot leave the emergency cold-chain away. The emergency cold-chain vaccine always has crucial impacts on disease prevention and control, when epidemic outbreaks to threat the whole social public security. There is an example can prove that, in 2009, the H1N1 influenza can be prevented and controlled successfully mainly relied dispatch of influenza vaccine, which powerful ensure the national stability and effective epidemic control.

Third, the well-operated emergency cold-chain may enhance the public confidence in the region to some extent. We can imagine that when we have to face with a large outbreak of disasters, if the government have the ability to organize emergency cold chain logistics like food safety to ensure victims' healthy diet, as far as possible to improve the life quality of victims, this would maximize the encouragement, enhance the self-confidence and natural morale of victims, and guarantee the market price stability or even the social security. In addition, in the social security incidents, such as the 2009 Xinjiang Incidents, emergency cold chain logistics played an important role in maintaining social stability and keeping the supply in the market.

2.2.3.2 Growth and Development of Emergency Cold-Chain Logistics

Compared to common logistics form, the emergency vaccine cold-chain logistics is not belong to a medical cold chain part but belong to an emergency logistics part, which has a strict requirement on both time and temperature factors. The current cold chain service mainly for two major categories of products under the freezing temperature zone and the cooling temperature zone, including biomedical products such as vaccine and plasma, which can be processed and transported under low temperature condition from -3℃ to -15℃ according to different species (Liu Y. , 2004). However, the Shanxi Vaccine Event exposed the safety issue for the circulation of vaccine cold chain (Zhang, 2011, pp. 49-51).

Once again, the two core points of emergency cold chain logistics are urgent and cold. This special logistics form applied to the perishable biological pharmaceutical products from the production and processing factory to store, transport and serve on the hospital and epidemic prevention station, aiming to ensure the quality of products and reduce the response layers of them. Compared with the common emergency logistics form, the products of emergency cold chain have characteristics and high quality requirements for time and temperature. Medical products like vaccine for post-disaster are required to maintain the constant low temperature transport and the particularly timeliness at the same time.

2.3 Transport Process Optimization

2.3.1 Process Optimization

Process means to a series interrelated procedures to create value for objects, especially for customers. For instance, the traditional management process is a complex operation with low efficiency, which hides under the tedious organisation, leading to endless complaints from customers. This is so-called the Cask Effect, which is also known as the Barrel Effect. In order to address such problems these objects faced with, the reciprocal process must be reformed in essence from the aspects such as quality, costs, speed and service.

Process optimization is not only to do right things, but also how to do these right things. This is a kind of strategies kept superiority through continuous development, improvement and optimization. In the design and implementation procedures of process, the initial process needs to keep refine to get the optimum effect. The way is so-called process optimization, which is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. In addition, process optimization is also one of the major quantitative tools in industrial decision making. When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints. (Wikipedia, the Free Encyclopedia, 2011)

The optimization of process, whether the entire operation or its certain part, are all for the purpose of improving quality and efficiency of work, reducing costs, consumption, environmental pollution and labour intensity, and ensuring production security by links reduction, orders transformation, equipment update and materials replacement. When it is difficulty in equipment update and materials replacement, the optimization of process mainly depends on process reform instead of process re-design, including dismissing the unnecessary links and content, combining with those necessary ones, rearranging the procedures rationally, and simplifying all the necessary links.

At present, there are five basic methods to optimize process - Benchmarking (BMK), Define Measure Analyse Improve Control Model (DMAIC Model), Eliminate Simplify Integrate Automate Analysis (ESIA Analysis), Eliminate Combine Rearrange Simplify Analysis (ECRS Analysis), and Standardization Do Check Action Cycle (SDCA Cycle) (Li, Xu, & Peng, 2008, pp. 175-203).

2.3.2 Logistics Process

Logistics can be realised by logistics activities, which form logistics process. The logistics process is an economic procedure to create utility for time and space. Although the logistics process has much in common compared with other type of process, it is necessary to define it in the business process optimization theory field: logistics process means to a series logical and relevant logistics activities which are aiming to fulfil certain objective (or, task) in ordered sets (Li G. , 2005).

The logistics process consists of input, output, conduct, control, and feedback. Input is the objective to conduct, including materials, requirements, tools and equipment, and orders. Output is conduct or its results, including information, product and service. In terms of the conduct results, conduct (or, reform) can be divided into shape reform, place reform and information reform. Shape reform is the transformation from materials and semi-finished products to higher value-added products or service like manufacturing and processing; place reform is materials and other products movement from one place to another place and storage during their movement, such as the link of transport; information reform is the transfer from input data to valued outputs like information processing of cargo handling. Control is aiming at organization construction, implementation, technology and equipment. Feedback is for maintaining certain output property to modify the conduct (or, reform).

In general, a well-operated process should have effective control and feedback based on the data collected from outputs, such as, products' reliability and delivery accuracy. The transport process can be seen as a logistics operation comprises processing, handling, transportation and distribution. (Xie & Han, 2004, pp. 16-18)

2.3.3 Transport Process Optimization

Logistics process optimization is objective-based on reforming logistics process, through thorough analysis to get valuable results. It is a systematic optimization from designing and optimizing each link and its functions, to realise better objectives than initial one. For transport process optimization, better means to more timeliness and higher efficacy of emergency cold-chain products like vaccine transport process. Therefore, re-design the transport process of emergency vaccine cold-chain needs optimize time and quality factors of vaccine transport as object, to achieve more effective transport process through thorough analysis on the traditional transport process of emergency vaccine cold-chain. It follows that the reform of transport process is a systematic improvement instead of deny as a whole, to get a more effective transport process based on time and quality.

2.4 Transport Process of Emergency Cold-Chain Based on ExtendSim

2.4.1 Practical Application of ExtendSim

2.4.1.1 Practical Application of ExtendSim in Foreign Countries

Imagine That, Inc. generated Extend software platform in 1988. With nearly two decades development, Extend is widely used in every field in the world, such as logistics/supply chain, discrete/consecutive manufactory, transport, environment protection, and even military. For instance, in the logistics/supply chain field, M. Elisa Cunha made further research on the hierarchical model and its extensibility applying Extend-based n-tiers supply chain; they though that the METRIC Model made a great contribution theoretically and practically on supply chain modelling and warehousing management; they also stated that the simulation failure rate may increase with the growth of module numbers and found the relation between the non-cycled n-tier supply chain and the model adaptation (Cunha, 2005).

2.4.1.2 Practical Application of ExtendSim in China

Until 2005, Extend became to be used in China. As a very good kind of simulation software with most users spread in various global industries, we can use the ExtendSim simulation software to model vaccine emergency cold chain transportation process, find and solve the problem. However, the ExtendSim-based researches of cold chain logistics emergency all have few applications; especially applying to simulate transport process under emergency cold-chain constrains.

Shi Wangying argued that todays' researches are used to focus on a single transport link to study instead of the whole logistics transport organization, leading to systematic weakness for coordination and integration among transit network, transport and different types of cargo. Secondly, system simulation is generally fixed structure, i.e., a number of nodes and transit line fixed. When the actual transport routes simulated in the models, the exceed resources of transport lines will be wasted, bringing out a big limitation. Finally, the current logistics transport organization performance evaluation is obtained by the fixed data in database, according to various performance indicators. While the actual value of time, cost and quality of service is not fixed, if only using the fixed data calculation results and ignore reality, accuracy will drop. (Shi, 2008, pp. 85-90)

In transport industry, Chen Chong et al designed a dynamic simulation system for the dispatch of open-air mine trucks, proposing a new way to simulate and model the trucks dispatch (Chen, Zhang, Wang, Xu, & Wang, 2007, pp. 914-917). Wang Zhi-min et al built Extend model for materials handling system, utilizing the random experiments to get the fulfil time, queuing length of each service link, waiting time and use ratio, in order to provide foundation of assessing system protect ability and formulating scientific allocation scheme (Wang, Li, Chen, Gao, & Liu , 2007, pp. 1366-1369).

2.4.2 Comparison with Other Simulation Platforms

At present, there is so much simulation software in the market except ExtendSim, such as, Arena, Promodel, Flexsim, EM-plant, Witness, Enterprise Dynamics, SimulS, GPSS/H, Powersim, etc. Compared with them, ExtendSim models can be easily modified and extended which can make a dream come true that the boss can become a professor using ExtendSim to simulate (Jagstam & Klingstam, 2002, pp. 1940-1944).

João Weinholtz et al introduced the simulate application on allocation and the integration of simulation and optimization, comparing with the other six software from A level to D level to get a conclusion that ExtendSim is better than the others (Weinholtz, Loureiro, Cardeira, & Sousa, 2004, pp. 73-78). Table 2.1 describes the comparison in detail with Arena, Automod, Promodel, Simple++, Taylor and Witness from Level A (the best level) to Level D (the worst level).

Table 2-1 Comparison of simulation software tools

Index / Software	Operation-ally level	Adaptation for process	Continuity Process	Visualiza-tion degree	Cost
Arena	D	A	C	A	C
Automod	C	A	C	A	D
Promodel	B	B	D	B	D
Simple++	C	C	D	C	E
Taylor	B	C	D	B	B
Witness	C	A	C	B	D
ExtendSim	B	B	A	B	A

Source: (Weinholtz, Loureiro, Cardeira, & Sousa, 2004). *Automatic Creation of Simulation Models for Flow Assembly*. Proceedings sixth Portuguese conference on automatic control (CONTROLO 2004), University of Algarve, Faro, Portugal.

We can see from Table 2.1 that ExtendSim is better than the others, especially on the aspects of operationally level and continuity process. Concerning the stated above, we can use ExtendSim as the main simulation tools to develop the dynamic simulation system for logistics transport organization, by calculating the performance index to search the optimal path, to achieve the entire logistics transport process optimization. Qiao Wenshan, Huang Yindi argued that the existing cargo loading models are based on expected utility theory, which is a purely abstract decision mode. We can use the ExtendSim analogy strategies to introduce actual loading model and make it more understandable for users. (Qiao & Huang, 2010, pp. 76-79)

2.5 Summary

In this chapter, we reviewed relevant researches from two aspects, namely, emergency cold-chain logistics development status, and the process of emergency cold-chain transport based on ExtendSim. From an objective perspective, the emergency materials cold-chain is mainly considering about the process from transport to distribute. Theoretically, the emergency cold-chain logistics is a special logistics operation, which contains the actual materials transport process from supplies to demand under an economic condition. However, in order to respond the sudden public events, the emergency cold-chain focuses on how to solve the obstacle of time and space, satisfying the needs as soon as possible. Therefore, this thesis places emphasis on the transportation and distribution process from supplies to demand after incidents, including the period of peak hour in depressed area but the stage of production and storage.

In term of simulating the emergency cold-chain transport process by ExtendSim, many scholars pointed that it should be carefully examined subject to different benchmarks, normally, timeliness and efficacy related. Quantitative analysis is limited to transport costs with more considering victims' lives and property and social security. Generally, it is a very huge system taking all the related factors into consideration. The literature review has already provided some qualitative review on this logistics operation, in the next chapter, the current problems of traditional transport process and the four corresponsive improvement methods will be presented with detailed analysis, to help us get the optimized transport process.

Chapter 3. Analysis on Transport Process of Emergency Cold-Chain in China

3.1 Introduction

As widely accepted by main researches, the ExtendSim is effectively coping with simulation of the transport process of emergency cold-chain. But how to get optimized transport way shall not be a simply question. In this chapter, the problems of the traditional transport process and its improvement methods like the advanced logistics theory in emergency cold-chain will be listed out providing an overall time/effect analysis for further sustainability assessment.

3.2 Characteristics of Emergency Cold-Chain Logistics

3.2.1 Characteristics of Emergency Logistics

a) Suddenness. The emergency logistics was caused by sudden incident, so its most notable feature is the suddenness and unpredictability. There must be a most effective system to deal with series problems between urgent demands and materials supplies, instead of the normal one that we already had. Plus, due to the suddenness, a great amount of rescue materials must be timely delivered to the disaster-affected area. This can be so-called flow-imbalance of the emergency cold-chain logistics.

b) Uncertainty. We usually cannot exactly forecast the the duration, strength and coverage of the sudden events, leading to uncertainty about emergency cold-chain. For instance, at the beginning of the 2008 Snowstorm in southern China, the government cannot predict when the rail way and high way can be put into operation and how many the standard passengers are.

c) Uncommon. The emergency cold-chain logistics saved many between-links based on the principle Special Event Special Treat which seems very tight and tidy, and unlike other normal logistics activities. For example, when the 2008 Wenchuan Earthquake happened, the government took responses quickly to build the emergent command institution to ensure that the rescue materials can timely arrive at the exact direction.

d) Less-economics. One of the biggest characteristics of the emergency cold-chain logistics is urgent in some serious incidents, so the common economics principle of logistics is not being considered as a vital objective. Sometimes the emergency cold-chain logistics is becoming a pure consumption activity to some extent, with focusing on the efficiency.

e) Government and Market fixed-Participation. The crisis events bring a great negative influence on society and people’s life, which is crying for helping of the government and market together in a coordinated integration mechanism.

3.2.2 TTT and PPP Principle of Cold-Chain Logistics

The cold chain describes the techniques and procedures used to ensure that heat-sensitive biological products such as vaccines, sera, and antibiotics do not deteriorate in transit from the place where they are produced to the patients and others who ultimately receive them as part of a preventive or therapeutic regimen. Due to the cold-chain-related products are most food and medicines which requires constant low temperature as well as timeliness, the construction of cold-chain logistics should take all the involved aspects into account, such as production, transportation, economics and technology, this is to say - the cold-chain logistics is a high-tech cryogenic system engineering to ensure the security of perishable products from processing, storage, transportation and distribution. Every link may affect the whole chain, and each link and nodes need special refrigerated equipment and technology.

The cold chain is the ultimate link to product quality, depending on the time, temperature and tolerance during production, processing and packaging procedure, which is so-called the TTT and PPP principles. These two principles dominate control of quality and safety in chilled products: TTT (time-temperature-tolerance) and PPP (produce-process-package). In cold chain applications, temperature is the most important factor. Control of temperature is, therefore, essential. TTT factors maintain quality and safety during storage and offer guidance on how to deliver foods with long quality shelf life. TTT concepts refer to the relationship between storage temperature and storage life (Jordaan, 2006, pp. 13-15).

3.2.3 Characteristics of Emergency Cold-Chain Logistics

The emergency cold-chain can be said either the specialized emergency logistics or the cold-chain with emergent nature. Therefore, it has the advantages of both.

a) Professional and high requirements of equipment. The cold-chain equipment must keep a certain rang of low temperature, but also have high performance to run through the complex terrain under harsh environment like the post natural disasters.

b) High risks and government enforcement. Under the emergent situation, the various kinds of risk factors may lead to injured, equipment failures and materials damaged. Besides, the cold-chain market is still not so mature with high operating risks. In practice, therefore, the government sometimes has to order by force and pay the bills.

c) Huge investment and social benefits outstanding. With the high requirements of the equipment, the costs of purchase and use are inevitable increasing with time. According to research, the investment of emergency cold-chain equipment is 5 to 10 times or more, than the investment of common logistics. It is obviously that the emergency cold-chain has less economics but more social benefits for response to sudden public events.

3.3 Traditional Transport Process of Emergency Cold-Chain in China

3.3.1 Analysis on Traditional Transport Process of Emergency Cold-Chain in China

The two core elements of emergency cold chain are timeliness and quality. This special logistics operation applied to the perishable pharmaceutical products from product and process to transport and serve on the hospital and epidemic prevention station, aiming to ensure the quality of products and reduce the side effect when uses. Compared with the common emergency logistics operation, the products of emergency cold chain have characteristics and high quality requirements for time and temperature. Medical products like vaccine for post-disaster are required to maintain the constant low temperature transport and the particularly timeliness at the same time.

The pharmaceutical emergency cold-chain is a systemic engineering, which is also known as a long tediously supply chain, requiring low temperature control as a whole process. Therefore, in order to operate a successful emergency vaccine cold-chain, each link has to learn how to adjust each other and obey the unified operating standard. If there is one mistake, there would be failure.

For the characteristics of vaccine, the operation must to be done under a certain rang of temperature from vaccine production factory to epidemic station or even the inoculators. Among that, there are various refrigerated equipment can be used, such as, refrigerated trucks, refrigerated house, refrigerator, refrigerated containers and other refrigerate-related device. Different kinds of vaccine have different temperature requirements from -20℃ to 8℃. For instance, hepatitis a vaccine requires -20℃ to 8℃ whilst hepatitis b vaccine requires 2℃ to 8℃. According to that, we can build an emergency vaccine cold-chain mode shown as Figure 3.1, with an integration of materials flow and information flow at the same time. But due to the characteristics of emergency cold-chain, the capital flow cannot be discussed in this section.

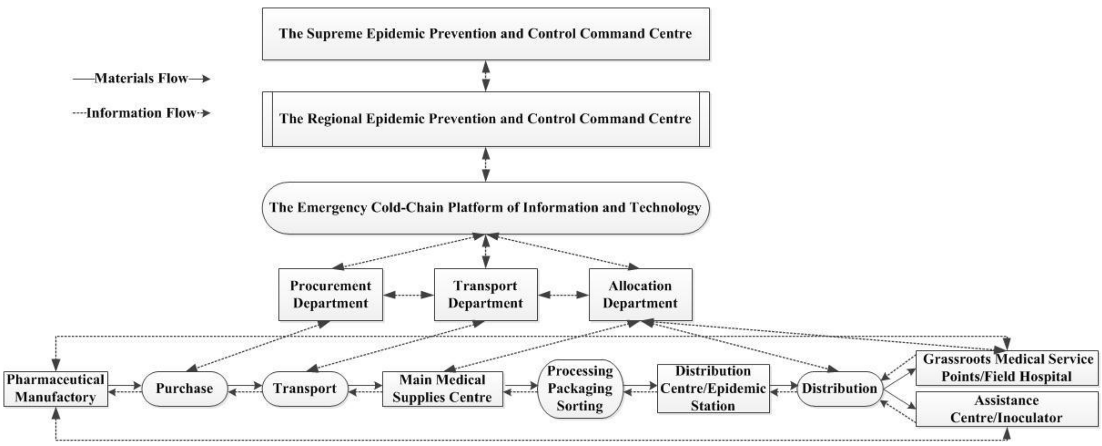

Figure 3-1 Traditional Transport Process of Emergency Vaccine Cold-Chain

Note: See clear version in Appendix I.

As we can see from Figure 3.1, the traditional transport process of emergency vaccine cold-chain can be divided into five parts as following:

a) Procurement. With the outbreaks of serious sudden events, the need of rescue materials is shape increasing. At the meanwhile, we must purchase in time because of the shortage of government emergent storage, and sometimes medical equipment and materials are not suitable for storage. The procurement comes from contracts and social donation. The procurement contract is signed by government with the high degrees of credit enterprises to get high quality and inexpensive materials timely when needed. The benefits of this approach are to avoid additional warehousing costs, but also to ensure the quality of disaster relief materials. The social donation is usually from the social enterprises which has the sense of social responsibility, in order to the return society. This donated materials form alleviates greatly in the relief pressure of demand and the national burden. The donated materials are variety with different classes of quality, so the government usually calls for donation to the disaster area to meet the urgently needs. The outbreak of epidemic is badly in need of major medical equipment and related drugs. Only to do good procurement, the relief will be supported substantially.

b) Transport. Emergency supplies have relatively high requirements for transport speed, usually based on the shortest time as a principle to choose transport pathways. Due to the less attention of cost, whether the transport time of emergency materials can be effective compressed or not becomes the key point. According to the value and quantity of materials and the transport requirements, we can choose a reasonable transport mode to realize the direct transport and combined transport. When the epidemic occurs, it can create an easy access to materials flow, with simplified relevant test procedures; and the implementation of the priority should be given to transport, putting civil emergency supplies and military materials to equal priority treatment which ensures smooth and efficient operation of emergency logistics. In addition, it is crucial important to take fully consideration to prediction and prevention at first, which is essential to ensure the safety service and avoid unnecessary losses.

c) Storage. Emergency materials storage is the most intuitionistic foundation and safeguard for implementing rescue, directly affecting the reaction rate and the ultimate result. For epidemic, the most important materials storage is the prevention and treatment of drugs, coming from different places with different ways. These disaster medicines and medical equipment disposed by the preliminary sorting, packaging and other work in the main medical supplies centre, to convenient transport and meet different needs. For China, a country with a large population, the sufficient number of vaccine reservation and enough vaccine production capacity has great significance for the prevention and control of epidemic.

d) Distribution. In term of the relationship between time and distance, the emergency distribution centre should be set up around the distressed-area, at which can be expanded with a convenient transport condition to handling and sorting quickly for relief supplies to meet the victims' needs in the first time by fastest speed and shortest time. Though epidemics always have great negative impact on our country, after SARS period, our emergency departments has already much mature than before, given full play to their role for prevention and control the disease spread effectively. Apart from that, in terms of organizational structure, the grassroots medical service point and the assistance centre turn the distribution centre into an information collection hub for emergent supply and demand. It can timely and exactly collect information about the shortage of supplies category and other information, according to the order of priority, quickly and accurately feedback to the emergency command centre, in order to better coordinate the balance of supply and demand.

e) The grassroots medical service point and assistance centre. The grassroots medical service point and assistance centre directly open to victims, as one kind of logistics node, based on First Urgent Last Less-Urgent, Highlight the Key Point Principle. For a limited availability of therapeutic drugs and vaccines, their supplies should adhere to the principle to support the high-risk groups at first place. For example, the first bunch of H1N1 vaccines (about 470 thousand pieces) arrived in Chongqing, prior to the high risk groups of vaccinated, such as the primary and middle school students, doctor and taxi drivers. Since they have to contact a large number of people with the most vulnerable to infection and spread of the virus, let them priority is to safeguard the city public service system and slow of further epidemic diffusion as maximum as possible.

To sum up, according to an epidemic, this set of emergency logistics system flow is in under the direction of the supreme epidemic prevention and control command centre which is directly on the regional command centre to issue instructions. This paper only shows one area prevention and control command centre as the object, in the actual command system, the highest command centre and the regional command centre and each different regional command centres are connected to each other through the same information platform system, realizing real-time information synchronization. Different regional command centre set up the purchase department, transport department and materials management department, as well as the emergency logistics information platform and technology platform for these departments to coordinate.

When epidemic out broke or spread, the command centres began to control and manage the departmental operations and sent the instruction message, at the same time the departments would implement the feedback information, and each departments would also implement two-way transmission of information for each other. In this paper, the core process of emergency cold-chain logistics system is the regional command centre. Most researchers put forward only one single emergency logistics command centre for all emergency coordination management for system construction, to some extent, it is in favour of developing fast decision-making but triggering many problems due to the large and complex system construction. Therefore, the graded process system by using a hierarchical management mode should implement to information update and synchronization step by step. Central command centre directly issued on each regional command centre, and each department of the regional command centre is on its duty keeping close contract with each other.

3.3.2 Problems of Traditional Transport Process of Emergency Cold-Chain in China

In the past few years, our country frequently suffered from the different types of natural disasters with varying degrees - the 1998 Great Flood, the 2003 SARS, the 2008 Snowstorm and the Wenchuan Earthquake, and the H1N1 flu epidemic. In a positive response to the disaster, the construction of emergency logistics system gradually turn to more effective application level from the conceptual level at the same time. Although the construction of emergency logistics system researches have made great progress, but in practice there are still some imperfections. At present, our country emergency cold chain logistics is a good perspective for development, but to deal with unexpected public events there is a certain gap, which can be performed in all aspects of the emergency cold-chain logistics:

a) Organization. There is no that much standardized and institutionalized organization for emergency cold-chain. The government control and social donation cannot be adjusted very well, leading to higher costs and lower efficiency than the other organization operation.

When disasters happened in the United States, facing with the potential significant casualties, the government declared to start the emergency plan. In this emergent situation, a special federal emergency management agency (Federal Emergency Management Agency, FEMA) is responsible for all the relief affairs, particularly the establishment of the distribution centre, which is duty on the unified storage management and related packaging.

In our country, however, with the outbreaks of the unexpected events, the government was usually took staffs from all kinds of governmental departments temporarily making up the event handling office. In terms of the establishment of different treatment organizations for different emergencies, it will make a great amount of investment due to the high maintenance costs, causing a huge waste of social resource. In contract, it might not unrealistic that the establishment of a permanent emergency treatment organization designed to handle sudden disaster events. At ordinary time, this organization can be seen as a general office of government, doing a good job of disaster relief materials reservation, relief programmes planning and disaster forecasting, etc. However, when disasters occur, this organization can be immediately separated into an independent agency, to respond to disasters. Overall, no matter what form of organization, the key is efficient and quick response to disasters.

b) Procurement. The rescue and relief work is pressed for time, so information about emergency cold-chain seems asymmetry which brings trouble in making scientific procurement programmes and ensuring its quality for products.

c) Storage. In the first place, the layout of the emergency cold-chain storage is unreasonable in our country. At present, only Shenyang, Tianjin, Heilongjiang, Hefei, Zhengzhou, Wuhan, Nanning, Chengdu, Xi'an, etc. established the central emergency reservation points. Such emergency warehouse is clearly insufficient which are most concentrated in the middle-east of China, so it is difficult to implement rapid response to major disasters in western. Secondly, our country emergency cold chain materials reservation is obviously insufficient.

At present, the management of relief supplies is carried out by different departments in our country - the civil affairs department is taking clothes, tents and other life relief in charge while health management department is responsible for food, medicine, and other food-related sectors. This relief supplies are stored separately with decentralized management, which is the result of the slow information transferring and difficulty scheduling for disaster relief. To solve this problem, we can reserve some-required relief materials in advance and establish an effective materials management department specialized in allocation materials.

d) Transport. China's current emergency cold-chain logistics is lack of professionals and professional equipment, leading to poor convergence of transport organization. Troops will be dispatched when sudden events occurs, this is far short of professional requirements. Emergency cold-chain logistics, as a new industry, is facing with the tough task which is requiring professionals responsible for. In general, the eastern is better than the western because of the developing degree of economics; cities are better than counties; and big cities are better than small ones.

e) Distribution. Throughout the development of emergency cold-chain logistics in our country, the materials distribution is operated by the government and relief forces with less efficiency caused a narrow range of distribution.

f) Information. The current information level of emergency cold-chain is low in our county, which is difficult to meet the special requirements of the emergent situation. It does not become a network linking suppliers, hospitals, epidemic stations, assistance centres, and other relevant departments, so that we cannot forecast demands and watch the temperature. In addition, the social donation can make the imbalance of supply and demand because of the information interruption. So strengthening the information construction is the key point to improve the level of emergency cold-chain logistics system.

3.4 Summary

In this chapter, apart from the mentioned above, the rest problems can be posted in the aspect of equipment shortage and facilities outdated, professionals insufficient and legislation weakness. But in this paper, we should mainly focus on the transport process sector of the emergency cold-chain logistics, which has more significance on coping with practical problems. Therefore, the transport process optimization by advanced logistics theory will be stated to help us get the reasonable optimized transport process for emergency cold-chain logistics.

Chapter 4. Application of Process Optimization Theory onto Traditional Emergency Cold-Chain Transport Process

4.1 Introduction

In this chapter, the first part is the overview of process optimization theory, which is mainly focus on the transport process optimization theoretically. Next, according the relevant problems of the traditional vaccine transport process of the emergency cold-chain logistics in China, the flexible and reasonable optimization solutions will be listed one by one. Finally, the optimized vaccine transport process will be compared with the traditional way to prove its superiority by simulating with ExtendSim.

4.2 Basic Concepts and Characteristics of Transport Process Optimization

4.2.1 Basic Concepts of Process Optimization

The thought of process optimization is stated initially by Michael Hammer, a famous America enterprise management master, the professor of Technology Institute, Massachusetts. Its basic idea is to rethink, renovation process, reforming the various traditional tasks to a more complete process, in order to be improved in cost, quality, service, speed, etc. (Michael & Bryan, 1999)

4.2.2 Characteristics of Transport Process Optimization

The transport process optimization means to be developed by demands, focusing on reforming the transport process with a throughout analyses - rebuild each factors among them and the between-links to get value-some. The optimized transport process is better than the traditional one instead of totally denied. To get a better transport process for emergency cold-chain logistics, the relevant policy, the advanced logistics theory or even the intelligent information technology can be used to optimize this traditional transport process to meet the requirements about time and quality of emergency vaccine cold-chain transport.

According to that, the characteristics of transport process optimization can be summarized as following:

a) the optimized process seems more simplify than the initial one because of process batching and compressing;
b) the vertical ranking system has been compressed due to the process compressing, which does not need to report and request layer upon layer;
c) the way of arrangement is various that almost every relevant procedures can work in more flexible way at the same time based on information conduct system;
d) the function of service is also various that considering about the environmental changes to change the way of service;
and e) the optimized transport process is far beyond the bound of each organization by teamwork.

4.2.3 Steps of Transport Process Optimization

In general, when facing with the time and quality problems of vaccine emergency cold-chain transport, the traditional transport process should be optimized by corresponding process optimization. Next, the steps of transport process optimization can be divided into five parts, shown as Figure 4.1.

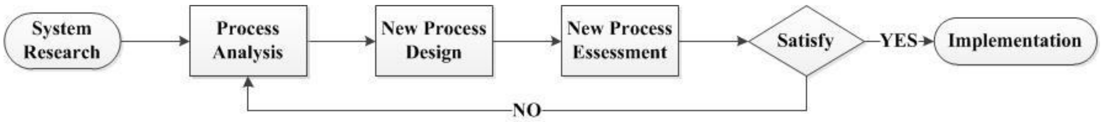

Figure 4-1 Steps of transport process optimization

As we can see from Figure 4.1, there are five steps for the process optimization: Step one, confirm the objective (time and quality of vaccine transport) of optimization after system research, in this paper is the transport process. Step two, analyse the transport process, to find the problems compared with the traditional one. Step three, apply certain methods, to optimize the initial transport process for such problems stated above. Step four, assess the optimized transport process, whether flexibility or not; and Step five, if yes, implement the optimized transport process into emergency vaccine cold-chain; if not, re-optimized the transport process using other methods.

4.3 Optimization for Traditional Transport Process of Emergency Cold-Chain

In the paper, we can use the policy-related, logistics-related and ITS(Intelligent Transport System)-related methods to optimize the traditional transport process for the emergency cold-chain logistics according to the five steps stated above, in order to get a more effective transport process taking timeliness and well-efficacy factors into priority account.

4.3.1 Policy-Related Methods

4.3.1.1 Build Green Pathway

When epidemic occurs, the government should build a green pathway to guarantee the smooth transport of relief materials, especially for vaccine. For emergency vaccine cold-chain, the relevant checking procedures can be simplified under the green pathway policy, no matter what transport modes will be used - by air, railway, by trucks, container trucks, etc. This method also provides the same priority to both military materials and emergency cold-chain vaccines.

In the traditional vaccine transport process, the government had to aggregate the troops urgently to take charge in vaccine transport by planes, trains, trucks or other different ways, without using the green pathway. Unlikely, if the government could build a green pathway for vaccine transport when the epidemic had occurred, there was a sequence of time-saving, such as clearance checking.

For instance, the refrigerated trucks can be equipped with Electronic Toll Collection (ETC) cards during vaccine transport without speed-related constrains on the highway. We can suppose that one truck needs 120 seconds to pass the manual checking station under the common clearance checking procedure, whilst 50 seconds using ETC card through green pathway (p.s., these two ways are all including the average queuing time which is the same as each other); besides, the distance from place *m* to place *n* is 300 kilometres, which has one enter checking station and one exit checking station. In addition, the average speed is 60 km/h per truck whilst 100 km/h per truck without the speed constrain to go on the green pathway. Figure 4.2 shows the simulation model built by ExtendSim:

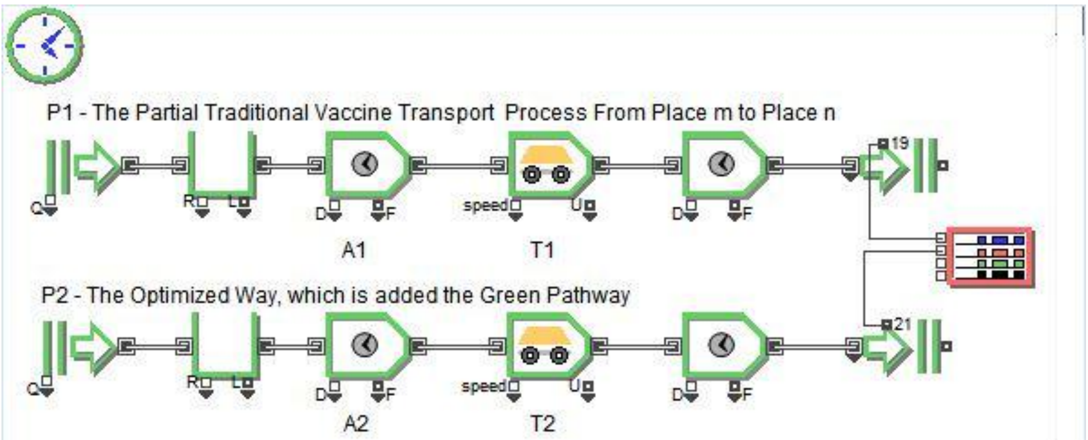

Figure 4-2 Partial vaccine transport process model and its optimized model (P1&P2)

Source: Own simulation

Note: The detailed module set of attributes can be seen in Appendix II -1.

According to the simulation model from Figure 4.2, the number of the arrived trucks from place *m* to place *n* per working day (24 hours) can be calculated as following, shown as Table 4.1:

Table 4-1 Results of running the transport model simulated by ExtendSim

Results	Working hours	Trucks arrived (N)
P1	24	19
P2	24	21

Source: Own calculation based on ExtendSim

It can be seen clearly from Table 4.1 that in the same working hours, the optimized transport process can achieve 21 trucks arrived at place *n* which is bigger than 19 trucks transported under the traditional way, that is to say that more trucks arrived means more vaccine supplied for distressed-area for victims.

4.3.1.2 First Urgent Last Less-Urgent, Highlight the Key Point Principle

The grassroots medical service point and assistance centre directly open to victims, as one kind of logistics node, based on First Urgent Last Less-Urgent, Highlight the Key Point Principle. For a limited availability of therapeutic drugs and vaccine or serum, their supplies should adhere to the principle to support the high-risk groups at first place.

For example, the first bunch of H1N1 vaccines (about 470 thousand pieces) arrived in Chongqing, prior to the high risk groups of vaccinated, such as the primary and middle school students, doctor and taxi drivers. Since they have to contact a large number of people with the most vulnerable to infection and spread of the virus, let them priority is to safeguard the city public service system and slow of further epidemic diffusion as maximum as possible. This priority model can be simulated as Figure 4.3:

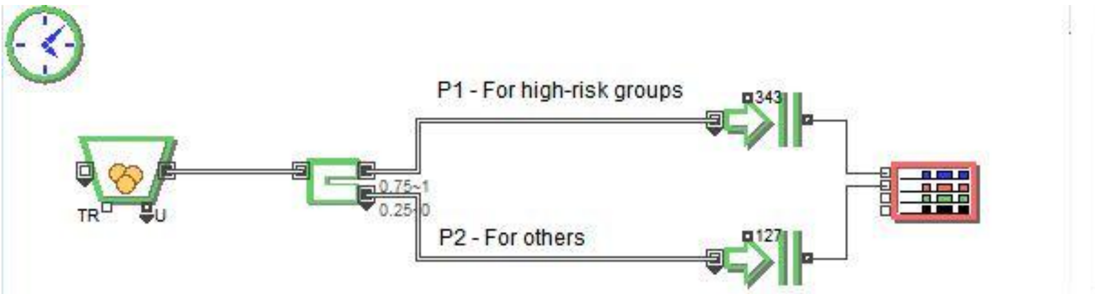

Figure 4-3 Priority model for both high-risk groups and others

Beside, this priority property can be performed by the Selection Item Out Module which is shown as Figure 4.4:

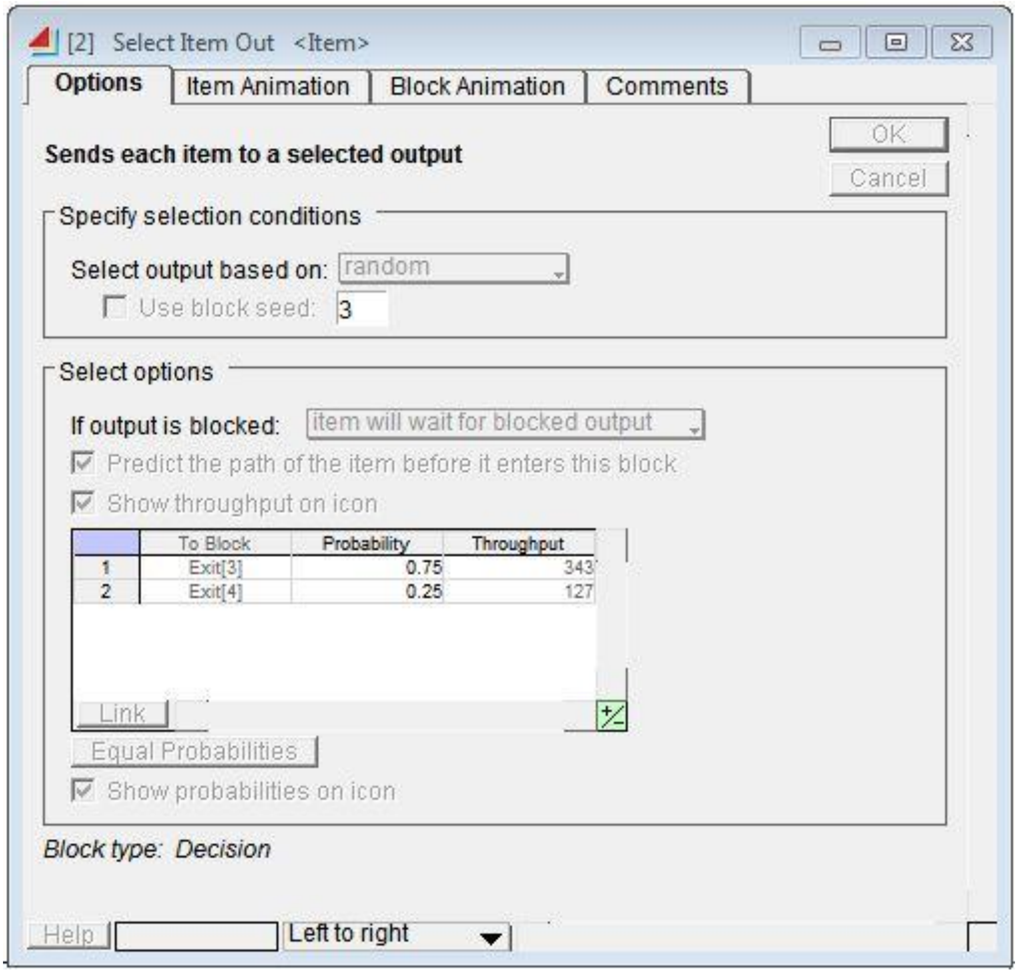

Figure 4-4 Module attribute of priority

From Figure 4.4, the vaccine output can be set based on connector priority with 75 per cent for high-risk vaccinated groups and 25 per cent for the rest in optimized transport process, which is able to get more effective rescue and relief effect (343 > 127 vaccine throughputs) by control the epidemic from the initials.

4.3.1.3 Improve Alarm-Action System

In general, it would be some signs before the outbreaks of epidemic. For instance, at the beginning of SARS, there was an unexpected increasing for the price of white vinegar and radix isatidis in Shenzhen; another example is H1N1, we can monitor the number of visiting patients in main hospitals in certain area per day and per week, to forecast and estimate. If there is a huge increasing, this area might be the highlight place to prevent and control by government, particular as to the vaccine. So in the emergency cold-chain system, the information platform can be designed with such alarm-action mechanism.

4.3.1.4 Establish Assessment System

Whether the links and between-links need to operate or not, it can be decided by establishing the assessment system. Through assessment, we can figure out the weakness link or between-link in the whole emergency cold-chain. It can help us correct mistakes in time to increase the effective.

4.3.2 Logistics-Related Methods

4.3.2.1 Select Reasonable Modes and Tools

Before transport, we may fully take the transport environment into consideration. In order to ensure the safety delivery of relief materials and prevent from inevitable losses, we must do a good prediction and prevention work in priority. The special cold-chain transport tools are very insufficient, especially for emergent vaccine. So we should adjust these tools reasonably to relieve the pressure for limited number of transport tools, doing our best to rescue and relief in right time with right effect arrived at the assistance centres and the grassroots medical service points.

For instance, we can suppose that there are 1000 kilometres away from place i to place *j*, place *k* is between them which is 600 kilometres from place *i*. Place *i* and *k* can be seen as the vaccine supplies, while place *j* is their destination. In the traditional transport process, the vaccine would be transported by refrigerated train from place *i* to place *k* then arrived at place *j* in a straight line with 300 km/h. However, due to the time and quality factors of vaccine and the long transport distance, the optimized transport way should transport vaccine by refrigerated plane from place *i* to place *j* directly with 1000km/h, and at the same time, it should use refrigerated trucks from place *k* to place *j* with 100 km/h. Finally, we should also suppose that the vaccine should have 1 hour to load on the refrigerated train at place *k*. Figure 4.5 shows the models both traditional and optimized transport process.

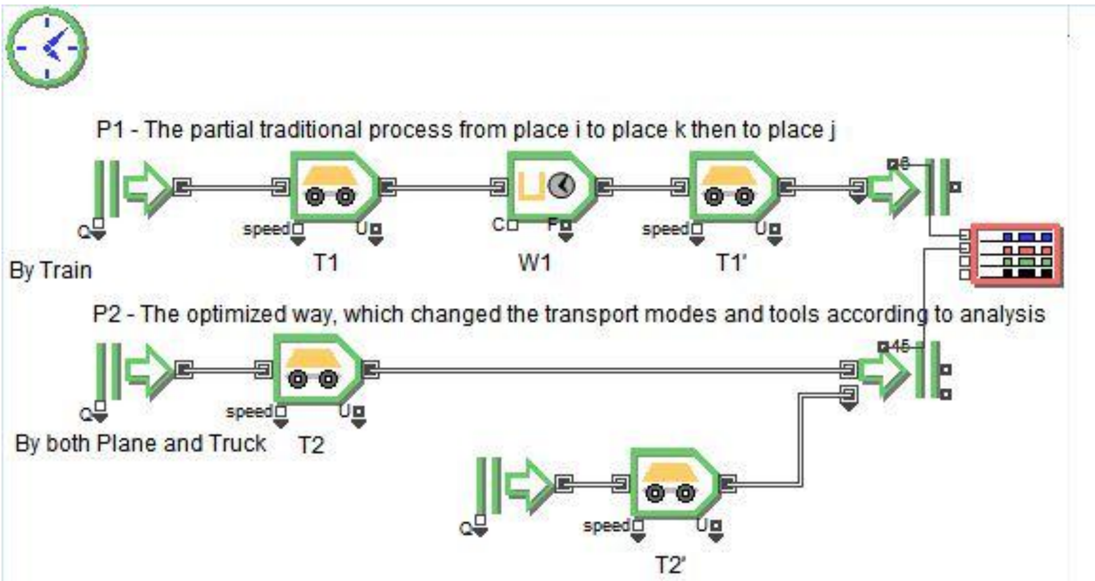

Figure 4-5 Partial vaccine transport process model and its optimized model (P1&P2)

Source: Own simulation

Note: The detailed module set of attributes can be seen in Appendix II-2.

According to the simulated model from Figure 4.5, the supply volume of vaccine can be calculated by the number of arrived transport tools times the vaccine capacity per transport tool, from place *i* to place *j* through place *k* per working day (24 hours). Table 4.3 shows the results of that:

Table 4-2 Results of running the transport model simulated by ExtendSim

<table>
<tr><th>Results</th><th>Working hours</th><th>Tools arrived (N)</th><th>Vaccine capacity per tool (unit)</th><th colspan="2">Total transport volume (unit)</th></tr>
<tr><td>P1</td><td>24</td><td>6</td><td>10000</td><td colspan="2">60,000</td></tr>
<tr><td rowspan="2">P2</td><td rowspan="2">24</td><td>24</td><td>2500</td><td>60,000</td><td rowspan="2">68,400</td></tr>
<tr><td>21</td><td>400</td><td>8,200</td></tr>
</table>

Source: Own calculation based on ExtendSim

It can be seen clearly from Table 4.3 that in the same working hours (24h), place *j* can get 68,400 units vaccine which is transport by the total number of 45 tools includes refrigerated planes and refrigerated trucks in the optimized transport process, while the total volume of vaccine in traditional way is just 60,000 units which is much less than the optimized way. It is obvious that the optimized transport process exhibits higher performance for vaccine transport.

4.3.2.2 Direct Transport and Combined Transport

With the outbreaks of epidemic, the needs of vaccine are increasingly growth. The government must responsible for timely procurement because of the shortage of vaccine and the unsuited-reserved factor of vaccine. For vaccine, transport needs high speed with shortest pathway and time but less considering about the cost savings. Plus, the special requirement of cold-chain for temperature control. We should choice the direct transport and combined transport in right way.

4.3.3 ITS(Intelligent Transport System)-Related Methods

The government can develop the Intelligent Transport System (ITS) and add Geographic Information System (GIS) and Radio Frequency Identification (RFID) technology to realise information sharing, which is able to solve the problem of information delay and bullwhip effect. This ITS-based information sharing system can overcome the uncertainty, imbalance and separation of the information. It can be performed like the third sharing party and the sharing centre to build the emergency cold-chain database pool, including all kinds of data like supply and demand, and storage, transportation and distribution.

For instance, through the integrated application of RFID technology, GIS technology, modern communication technology, map matching technology and computer network technology, the ITS can achieve the real-time vehicle monitoring scheduling system to track control of the transport tools. In terms of vaccine transport, the RFID label will be posted on the vaccine storage boxes and vehicles; whilst the RFID receiving transmitting device will be installed at some checking station in transport line like post, pier, warehouse, station, wharf, airport and other key places. When the RFID receiving transmitting device received the information from the RFID label, this information and its surrounding situation will be sent to the communication satellite by General Packet Radio Service (GPRS), and re-sent to transport dispatching centre with writing in database. This can accelerate the transport speed of vaccine, and improve the efficiency and accuracy of sorting and distribution by reducing manual work and transport costs.

4.4 Summary

In this chapter, we learned the characteristics of the emergency cold-chain logistics by analysing the vital factors of both the emergency logistics and the cold-chain logistics. It is the basis upon finding the problems of the traditional transport process of emergency cold-chain logistics. Next, according to the thinking of process optimization, we can make the traditional transport process better based on certain methods, including the three aspects of policy, logistics and information.

Based on these three methods, in the next chapter, we will simulate each transport process by ExtendSim, to prove that the optimized one is really more effective than the traditional one through process optimization theory, along with taking the Wenchuan Earthquake case as an example to support the view of this paper.

Chapter 5. Research on Transport Process of Emergency Vaccine Cold-Chain Logistics Based on ExtendSim with a Case of Wenchuan Earthquake

5.1 Introduction

After identifying all the optimized-related methods in transport process, the transport process of emergency cold-chain logistics analysis is based on time and quality comparison from supply to demand. In this chapter, the traditional transport process and the optimized transport model will be built and simulated by ExtendSim with a case of the Wenchuan Earthquake - an application on vaccine emergent cold-chain transport process.

5.2 Description of the Transport Process of Emergency Vaccine Cold-Chain Logistics with the Wenchuan Earthquake Case

5.2.1 Simulation Hypothesis

In the case of the Wenchuan Earthquake, we suppose that the destroyed highway and railway can be fixed after disaster which seems the main pass path for the emergency vaccine cold-chain transport, except the poor communication and illegal profits pursuit by someone. The vaccine emergent cold-chain transport is based on refrigerated technology to realise low temperature transport in emergent response. Due to the less economics of emergency cold-chain logistics, we do not consider much about cost savings. To facilitate the study of transport process, some hypothesis will be listed before modelling: a) Do not take cost savings into consider; b) Ignore the emptied-redelivery for transport tools like refrigerated trucks, etc.; and, c) Except the waiting time at epidemic centre and its sub-class centre, other duration caused by waiting included in the operation time.

5.2.2 Modelling Idea Diagram

According to the hypothesis, the transport process can be seen as a discrete event system. Figure 5.1 shows the diagram of modelling idea.

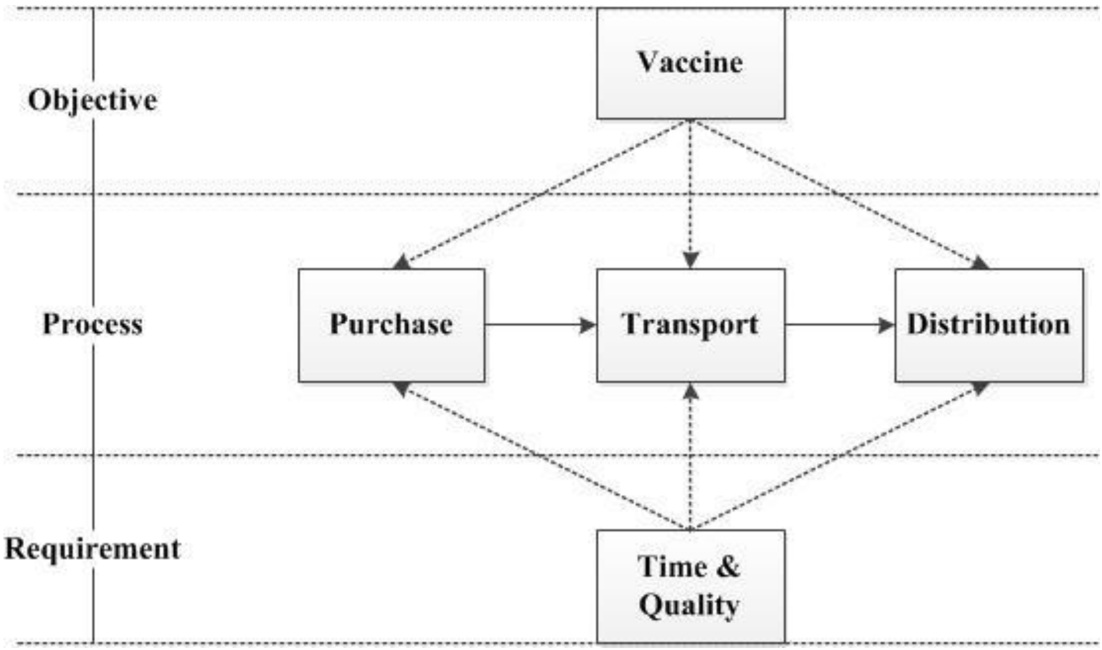

Figure 5-1 Diagram of Modelling Idea

Figure 5.1 shows us the diagram of modelling idea about vaccine transport process during transport and distribution procedures concerning time and quality factors.

5.2.3 Actual Activity into Abstract

Then we need to make the hierarchical system for vaccine transport process in abstract, shown as Figure 5.2.

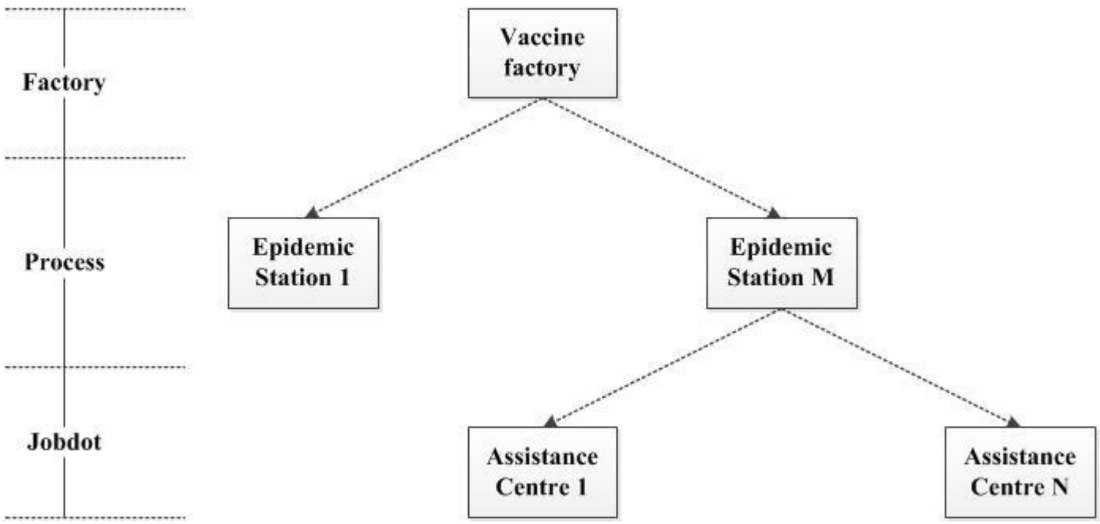

Figure 5-2 Hierarchical system of vaccine transport process

Figure 5.2 shows us the hierarchical system of vaccine transport process in three parts, factory, process and jobdot. Factory is responsible for the supply and demand of vaccine in emergent cold-chain, linking with other processes. Process in this case can be understood both transportation and distribution for vaccine. Vaccine can be transported in different suitable ways by different reasonable modes. Jobdot, to some extent, can be added some constrains under time and quality factor lies on the emergency cold-chain logistics.

5.3 ExtendSim-Based on Modelling and Simulation of the Transport Process of Emergency Vaccine Cold-Chain

5.3.1 The Simulation Module

Under the hypothesis the above, we can choose suitable modules to build the vaccine transport process simulation model easily. The simulation module can be divided into three parts: the general control module, the basic unit module and the public sub module.

5.3.1.1 The General Control Module

The general control module is in the up level as whole for running the simulation model, which is responsible for arrangement such as, at what time the event will happen, and guarantee the activities fulfilment successfully before the next event happens. In ExtendSim, the general control module is the Executive module, which can be used to set up the vaccine transport database per day.

5.3.1.2 The Basic Unit Module

The basic unit module is used for describing the relationship between actual objectives and events.

a) The vaccine production module is the foundation of the entire system model, mirroring the supply situation of vaccine. We can choose the Resource Item module to represent the situation of vaccine production. It can satisfy the needs of vaccine in a certain quantity per certain time units. On the other hand, the transport tools module is also can be simulated by the Resource Item module with building the resource item pool, which can realise the automatic dispatch of the airplanes, trucks, trains or other kinds of transport tools with refrigeration technology.

b) The logistics activities module consists of Activity module, Delay module and Batch and Unbatch module, and Transport module. The Activity module and Delay module are utilized together to simulate the sorting, packaging and processing activities for vaccine in the epidemic station and the assistance centre; the Transport module are used for simulating the transport process from vaccine manufactory to epidemic station by air, truck or train under cold-chai, and the distribution process from epidemic station to assistance centre. Besides, the Batch module and Unbatch module can simulate the handling activities at vaccine factory, epidemic station and its sub-station. Through input setting up the different proportion between vaccine volume and transport-related tools number, we can show the transport capacity clearly. In addition, due to the delay property of Activity module and Delay module means the transferring and processing time for vaccine which is variable, we can use Input Random Data module to simulate by input different mathematic distribution.

c) The pathway selection module is made up by Select Item In/Combine module and Select Item Out module, which can select the suitable pathway under certain conditions. For example, the Select Item Out module can choose one out point from different points, while Select Item In module reverses; the Combine module can combine the different pathway into one point. They are all used to simulate the vaccine in or out factory, epidemic station and its sub-station.

d) The buffering module can directly use the Queue module, which can be coordinated with FIFO module. It can simulate the phenomena that first getting in vaccine first service and first getting out when queuing outsides epidemic station and its sub-station. Based on the Queue module, we can use Decision module to make the decision that whether the logistics activities begins or not.

5.3.1.3 The Public Sub Module

The public sub module is used for inputting parameter, generating variables, getting simulation results report, and collecting statistics.

The Input Random Number module is to simulate the vaccine waiting time by giving the random distribution. Apart from that, the Timer module, Mean & Variance module and Mean & Variance State module can combine to get the average time of vaccine transport, and the mean and variance in certain confidence interval after times simulation.

The model is usually data-related empty which would be some deviation if we have stated to collect data at the very beginning of simulation. So we can use a period time before running the model by simulating the running time as a preheating period. It can be realised by using Clearing Statistics module and Program module.

5.3.2 Transport Process Model for Emergency Vaccine Cold-Chain

5.3.2.1 The Wenchuan Earthquake Case Description

Beichuan County was repeatedly closed by force after Wenchuan earthquake, with being guarded day and night. There were more than 600 polices around Mianyang, in addition to hold special permits and epidemic prevention, public security personnel and vehicles, forbidden and other personnel in and out of Beichuan county. People, who went into the county epidemic prevention (i.e., public security officers and engineering rescue vehicles and personnel), must take one permitted time to consciously accept the police check, health sector disinfection treatment. Where undocumented enters, no matter the vehicle and personnel are seen as against the law. The Table 5.2 and Table 5.3 overview the needs for emergent reservation of standing vaccine products:

Table 5-1 Earthquake disaster scene with the medical point of drugs, emergency drugs demand for reserves (2,000 copies per week's volume)

Standing vaccine products (unit)	
Name of the drug	Inventory
Tetanus antitoxin (1500IU/Unit)	3,500
Botulinum antitoxin	1,000
Encephalitis virus vaccine	1,000
Haemorrhagic fever with renal syndrome vaccine	1,000
JE vaccine	1,000
Meningococcal polysaccharide vaccine	1,000
Oral cholera vaccine	1,000
Rabies vaccine for human	1,000

Source: data from http://www.moh.gov.cn General Office of Ministry of Health issued the "5.12" Wenchuan earthquake relief emergency medical treatment inform the relevant standards

Table 5-2 Earthquake relief medicines reference configuration with a field hospital, emergency drug storage needs (1,000 copies per week's volume).

Standing vaccine products (unit)	
Name of the drug	Inventory
Tetanus antitoxin (1500IU/Unit)	3,500

Botulinum antitoxin	1,000
Encephalitis virus vaccine	1,000
Haemorrhagic fever with renal syndrome vaccine	1,000
JE vaccine	1,000
Meningococcal polysaccharide vaccine	1,000
Oral cholera vaccine	1,000
Rabies vaccine for human	1,000

Source: data from http://www.moh.gov.cn General Office of Ministry of Health issued the "5.12" Wenchuan earthquake relief emergency medical treatment inform the relevant standards

From the above charts, it can be seen that after the earthquake, epidemic, sometimes accompanied by the disaster and plagued far more harm than the disaster itself. Well the disease prevention and control is in death see-saw, brucellosis, fever, malaria, dengue fever, enteritis, general, dysentery, cholera, the plague of tetanus, etc. This may be an easy job to put victims just run away from the line of life and death once again to fire death. This requires the rescue units as far as possible to ensure that victims' diet health safety of drinking water, to control vectors density and make the dead bodies clear at the same time, which can effectively prevent the occurrence spread and prevalence of certain infectious diseases. According to the local situation, the government should give priority to develop the vaccination work for typhoid, hepatitis a, hepatitis b, and measles, which is necessary to carry out cholera vaccination. Epidemic prevention vaccine as a special biological pharmaceutical products category of emergency supplies, with strict requirement to the temperature control during transport, should be immediately transported to the distressed-area epidemic station after the earthquake.

5.3.2.2 Traditional Transport Process Model for Emergency Vaccine Cold-Chain

In the Wenchuan Earthquake Case, Beichuan (county - X - Assistance Centre), Mianyang (city - A - Epidemic Station) has a great need of vaccine due to the out-breaks of epidemic. There were three vaccine production manufactories from three different cities - Xi'an (city - B - Vaccine Manufactory), Chengdu (city - C - Vaccine Manufactory) and Chongqing (city - D - Vaccine Manufactory) - to provide vaccine for Beichuan and its surroundings. Such traditional transport process of emergency vaccine cold-chain is shown as Figure 5.3:

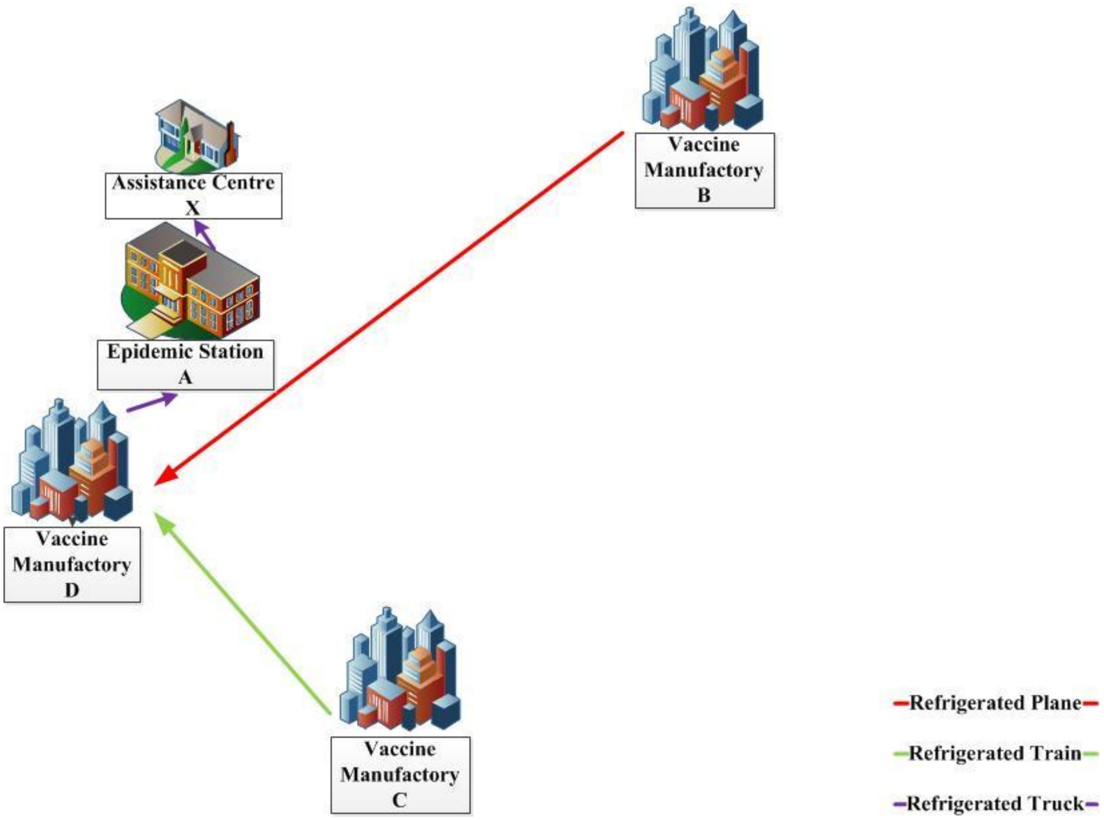

Figure 5-3 Beichuan, Mianyang traditional transport process for emergency vaccine cold-chain

It can be seen from Figure 5.3 that the construction of the traditional transport process is in series by the influence of traditional distribution. Vaccine from B and C were all transported to D in the first place. Then, it can be dispatched together, to A. In B, the vaccine was transported by refrigerated plane, while C was refrigerated train. Arrived at D, vaccine would be handling and transported again by Average Principle, i.e., when one car vaccine arrived, handling to take half to stay half to prepare to leave. The rest in outside D was combined with next half one together and transported to X.

This is a straight line transport process, leading to a huge waste of time and interruption between-link. But the biggest defect is less considering about practice to make decisions, using Average Principle. It has a great negative impact on epidemic station of A, such as overcapacity and supply delay to assistance centre of X, which has side effect on efficacy of vaccine. Figure 5.4 shows us the process of simulation model:

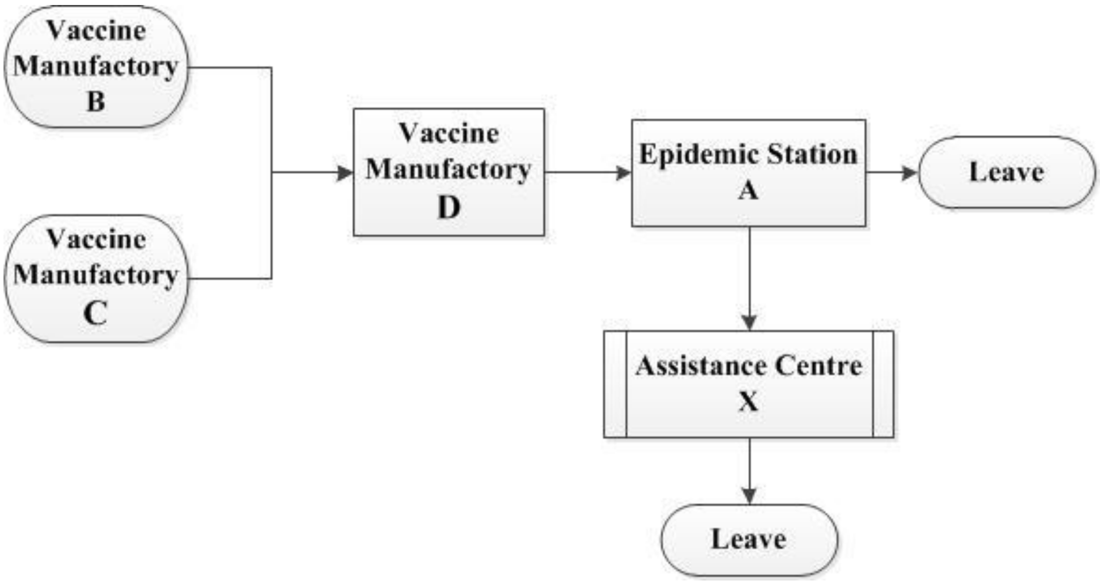

Figure 5-4 Beichuan, Mianyang traditional transport process model for emergency vaccine cold-chain

According to Figure 5.3 and Figure 5.4, the relevant data about vaccine transport is shown as Table 5.4:

Table 5-3 Transport modes and tools selection about Beichuan, Mianyang emergent vaccine cold-chain transport

Transport Time (minute)	Refrigerated plane	Refrigerated train	Refrigerated car	Miles (kilometre)
B-D	60			700
C-D		210		300
D-A			120	150
A-X			50	60
Unit Capacity (Box)	2,000	10,000	400	

Source: Own simulation

5.3.2.3 Optimized Transport Process Model for Emergency Vaccine Cold-Chain

The optimized transport process model for emergency vaccine cold-chain was improved by the process optimization methods, to reform the traditional straight line. Considering about the problems that vaccine transport faced in a distressed area, the optimized transport process applied direct transport and combined transport, built the green pathway for vaccine transport to relieve such problems, and obeyed the First Urgent Last Less-Urgent, Highlight the Key Point Principle to solve the priority. After that, we can get Figure 5.5 as follow:

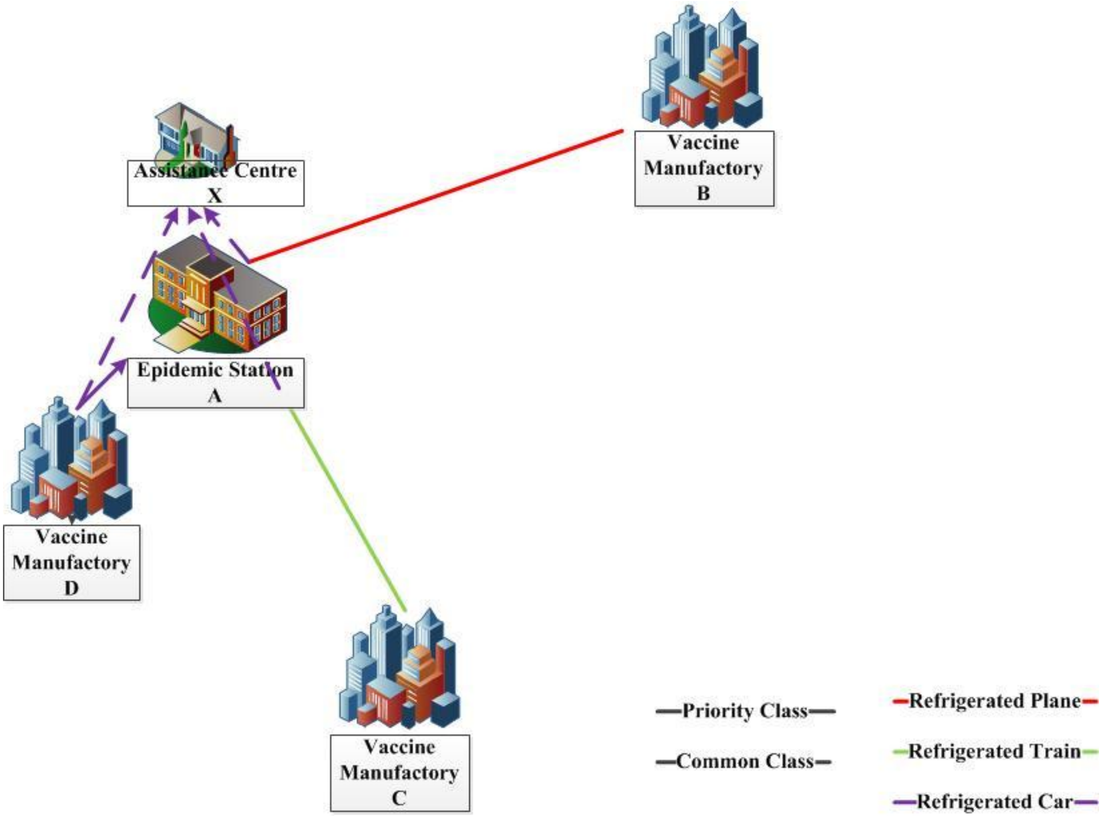

Figure 5-5 Beichuan, Mianyang traditional transport process for emergency vaccine cold-chain

It can be seen from Figure 5.5 that the optimized transport process is in parallel, taking limitation of transport tools into account, applying direct and combined transport, building the green pathway, and making a decision that A is the priority transported area.

B-(A)-X, due to the distance from B to A is longer than the other two distances (C to A and D to A), about 700 km, which has smaller destroy after earthquake in the air route. So the refrigerated plane can be used to transport vaccine instead of refrigerated trucks.

Vaccine will be loaded in B's airport after cold storage and transported to A's airport, dressing up to continue transport to A's epidemic station. In this decision, if the vaccine supply of A's epidemic station is over its management ability, the excessive vaccine will be transported to X's assistance centre by refrigerated truck. Among that, we should pay attention to the problem of batch arrived, which is namely that when the vaccine is transported by refrigerated aircraft transferred to refrigerated vehicle, each batch of vaccine unloaded from aircraft needs more refrigerated van to simultaneously transport. One refrigerated airplane volume often equals five refrigerated van to bear.

C-(A)-X, due to the distance from C to A is long with 300 km, it can use long distance transport tools for vaccine transport like both the refrigerated container truck and the refrigerated train. The vaccine transport can be packaged in the form of refrigerated container under an easy access named the green pathway which can simplify vaccine checking procedures and perform the priority transport treatment same as military supplies. This guarantees the smooth and efficient operation of emergency cold-chain logistics.

Also, such transport form realizes the connection between refrigerated container truck and refrigerated train; bring convenient loading and unloading methods for vaccine transport. Vaccine will be transported from C's vaccine production unit (vaccine manufactory) by the local train station, and by refrigerated container truck directly in A's train station after unloaded to A' epidemic station. In this decision, vaccine should be transported in right amount timely to X's assistance centre.

DA / DX, due to the distance from D to A is short with 150 km, it can use short distance transport tools for vaccine transport like the single transport mode by refrigerated vehicle - road transport. In the first place, compared to X's assistance centre, A's epidemic station has a large qualities of vaccine supplies and reservation itself. Second, as the remote mountain area, county X is always poor post-earthquake traffic situation, though it is also more serious epidemic region.

Therefore, few part of vaccine from D's vaccine production unit will be transported to A's epidemic station, the most rest part is not through city A to X's assistance centre directly. Such direct transport can reduce the risk of temperature changes for vaccine between different transport modes from different places, to minimize handling workload and guarantee vaccine with its initial efficacy. Eventually, vaccine will be transported to X's assistance centre, such as the various temporary medical relief on-site and the field hospital, in time to injection.

To sum up the optimized vaccine transport process of emergency cold-chain, it used advanced transport process optimization theory lies on both emergency and cold-chain logistics as well as policy and information fields. It is a more complex transport process than the traditional emergency vaccine cold-chain transport process which can overcome the problems of the traditional way, such as the bullwhip effect of vaccine supply and demand information from production units to destination like epidemic station and assistance centre, the oversupply for epidemic and the shortage for assistance centre, the difficulty of temperature control between the links of various transport tools and the weak timeliness for vaccine transport from different transport modes like the connection between refrigerated train and refrigerated container truck.

In summary, the optimized vaccine transport process model can be built and shown as Figure 5.6:

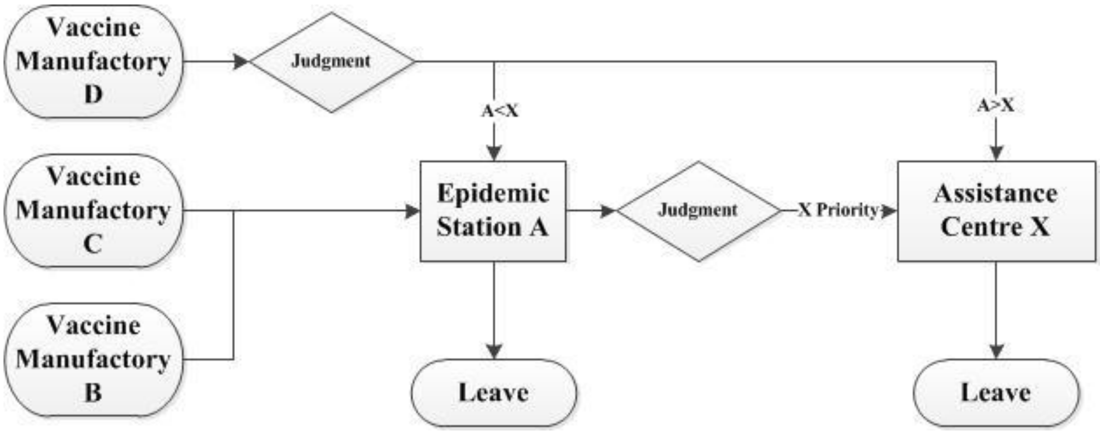

Figure 5-6 Beichuan, Mianyang traditional transport process model for emergency vaccine cold-chain

According to Figure 5.5 and Figure 5.6, the relevant data about vaccine transport is shown as Table 5.5:

Table 5-4 Transport modes and tools selection about Beichuan, Mianyang emergent vaccine cold-chain transport

Transport Time (minute)	Refrigerated plane	Refrigerated train	Refrigerated car		Miles (kilometre)
			car	Container car	
B-(A)-X	90		50	-	1000+60
C-(A)-X		210		50	300
D-A			120	-	150
D-X			130	-	160
Unit Capacity (Box)	2,000	10,000	400	500	

Source: Own simulation

5.3.3 ExtendSim-Based on Transport Process Model Simulation for Emergency Vaccine Cold-Chain

5.3.3.1 Simulation of Traditional Transport Process Model for Emergency Vaccine Cold-Chain

Figure 5.7 shows us the ExtendSim-based traditional process simulation model of emergency vaccine cold-chain as following, which is according to Figure 5.4.

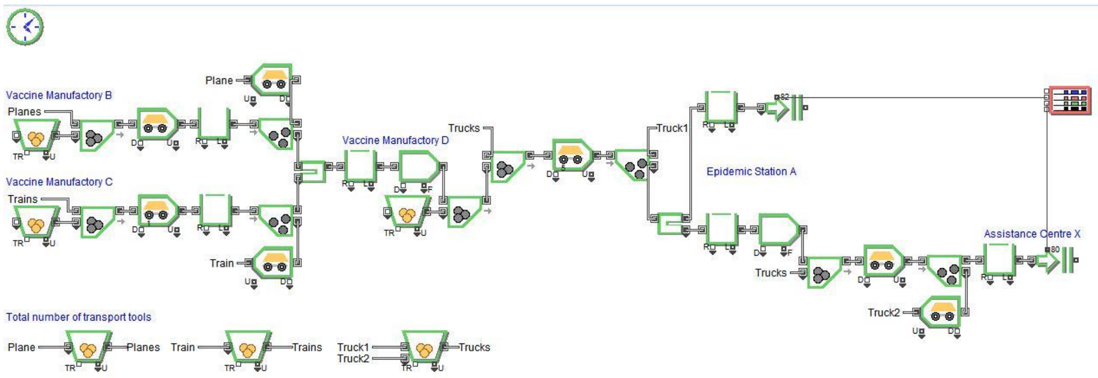

Figure 5-7 ExtendSim-based traditional transport process simulation model of emergency vaccine cold-chain

Note: See clear model process and module set in Appendix III - 1.

Based on Figure 5.7, the simulation period of this case is supposed as 1 day (only daytime), i.e., 480 minutes. Due to the practice of limitation of transport tools, supposing 3 planes, 3 trains and 50 cars. In addition, capacity of different transport tools is all setting up to x per hundred boxes. Finally, other data can be found from Table 5.6 as following:

Table 5-5 Instruction book to traditional vaccine transport process

Place	Initials (100 boxes)	Next	Queue capacity	Trigger condition	Tools	Unit capacity (100 boxes)	Transport time (min)	Transport capacity	Queue capacity	Combined time (min)
B	1000	D	500	D is available	plane	20	60	2	unlimited	20
C	1000				train	100	210	1	1	
D	500	A	500	handling	car	4	120	unlimited	500 (100 boxes)	-
A	-	X	250	handling	car	4	50	unlimited	500 (100 boxes)	20
		leave	-	-	-	-	-	-	-	-
X	-	leave	-	-	-	-	-	-	-	-

Source: Own Simulation.

Note: In Table 5.6, trigger condition means to at what time vaccine can leave from one place to another place, and queue capacity means to the maximum vaccine volume or transport tools number, including the handling vaccine.

5.3.3.2 Simulation of Optimized Transport Process Model for Emergency Vaccine Cold-Chain

Figure 5.8 shows us the ExtendSim-based optimized process simulation model of emergency vaccine cold-chain as following, which is according to Figure 5.6.

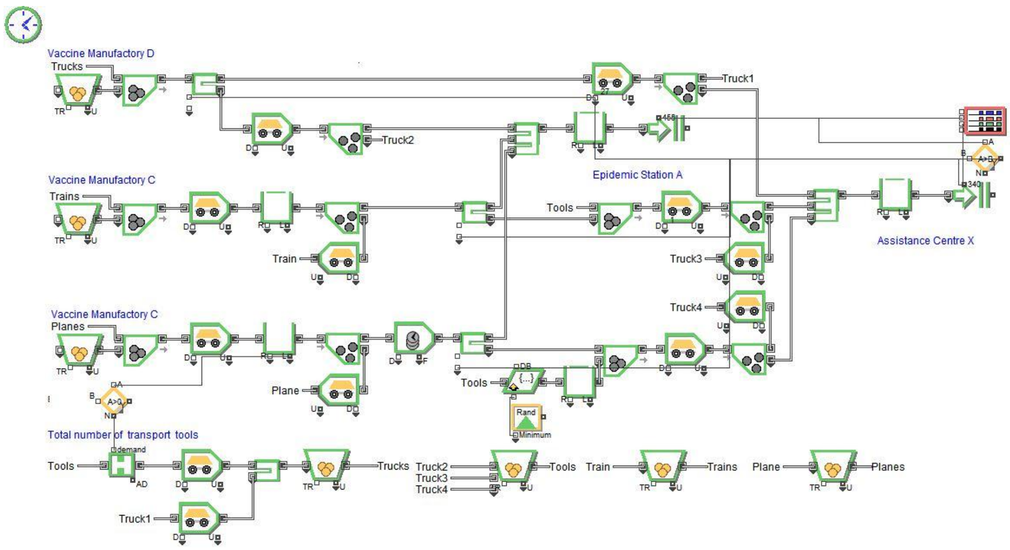

Figure 5-8 ExtendSim-based optimized process simulation model of emergency vaccine cold-chain

Note: See clear model process See clear model process and module set in Appendix III – 2.

Based on Figure 5.8, the simulation period of this case is supposed as 1 day (only at daytime), i.e., 480 minutes. Due to the practice of limitation of transport tools, supposing 3 planes, 3 trains and 50 cars. Capacity of different transport tools is all setting up to x per hundred boxes. Besides, at A, vaccine begins to transport by trucks in batch if needed and priority to less supplied between A and X. Finally, other data can be found from Table 5.7 as following:

Table 5-6 Instruction book to optimized vaccine transport process

Place	Initials (100 boxes)	Next	Queue capacity	Trigger condition	Tools	Unit capacity (100 boxes)	Transport time (min)	Transport capacity	Queue capacity	Combined time (min)
D	500	A	1000	less vaccine	car	4	120	Unlimited	Unlimited	-
		X	250	less vaccine	car	4	130	Unlimited	Unlimited	-
C	1000	A	1000	A is available	train	100	150	1	1	-
B	1000				plane	20	90	2	Unlimited	20
A	-	X	250	Handling	container	5	50	Unlimited	Unlimited	-
					truck	4				
X	-	leave	-	-	-	-	-	-	-	-

Source: Own Simulation.

Note: In Table 5.6, trigger condition means to at what time vaccine can leave from one place to an-other place, and queue capacity means to the maximum vaccine volume or transport tools number, including the handling vaccine.

5.3.4 The Analysis of the Simulation Results

In terms of the transport process optimization of emergency vaccine cold chain, this simulation can be interpreted as different transport modes and tools under the coordination of the entire transport process. In order to inspect the vaccine transport process optimization and its accessibility, this paper use various channels to collect the following data in ExtendSim simulation model, taking the Wenchuan Earthquake as a case, carrying out relief and rescue work for disease in city A, and studying the transport process optimization and simulation of emergency vaccine cold-chain. After running these two models above, the results can be captured as screenshots which means to the emergent vaccine supplies per day - the detailed results are shown from the Figure 5.7 (the traditional transport process) and the Figure 5.8 (the optimized transport process), which represent the actual vaccine supplied volume for A's epidemic station with green line and X's assistance centre with red line:

5.3.4.1 The Result of Traditional Transport Process Model for Emergency Vaccine Cold-Chain

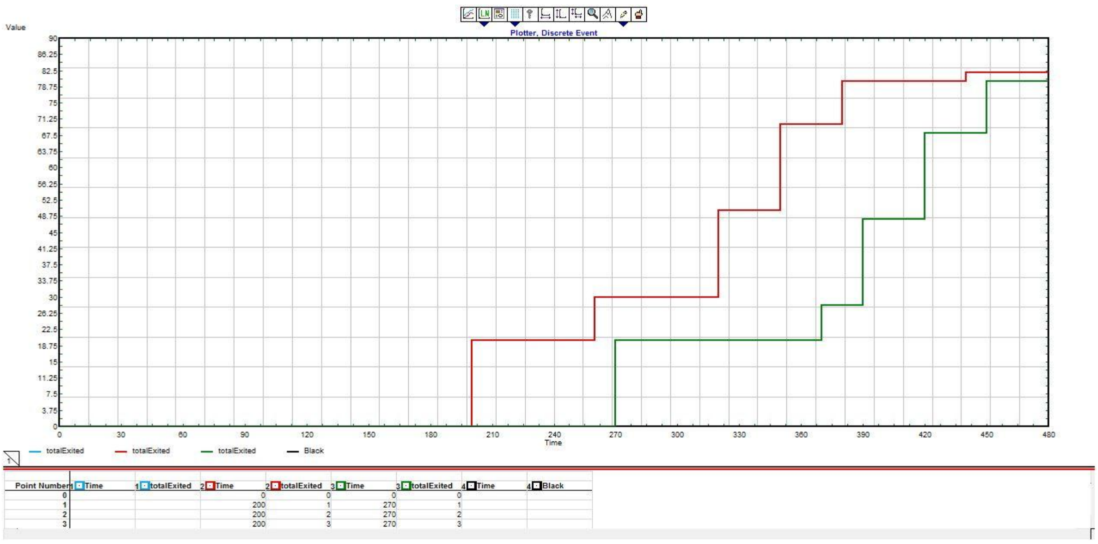

Figure 5-9 Result of Traditional Vaccine Transport Process Model

Note: See clear result information in Appendix IV - 1.

5.3.4.2 The Result of Optimized Transport Process Model for Emergency Vaccine Cold-Chain

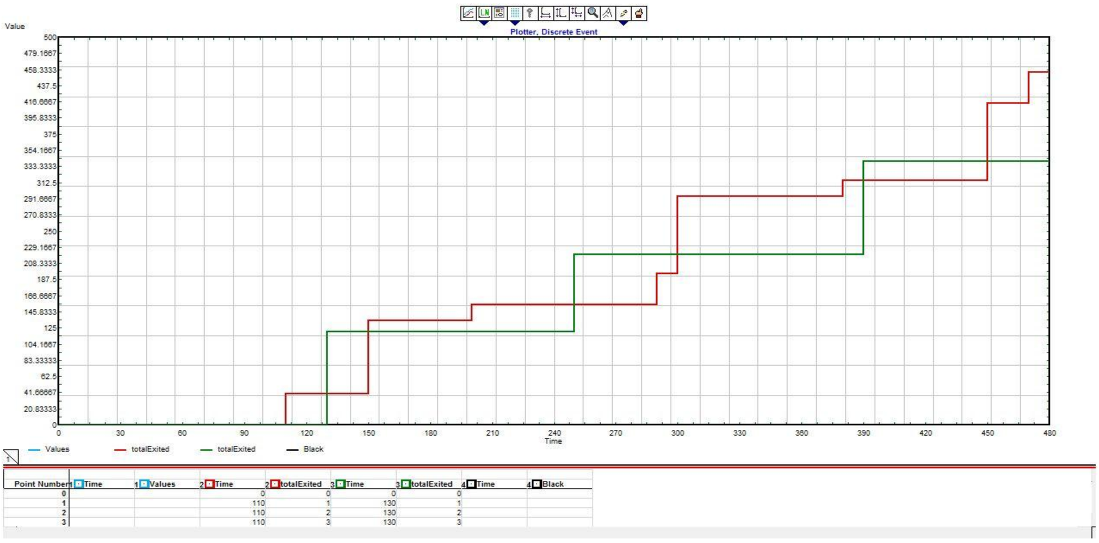

Figure 5-10 Result of Optimized Vaccine Transport Process Model

Note: See clear result information in Appendix IV - 2.

From Figure 5.9 and Figure 5.10 we can see that the abscissa represents the time axis, with the ordinate represents vaccine supplies (100 boxes); the red curve represents the vaccine volume A's epidemic station supplied, while the green curve represents X's assistance centre. Apparently, the optimized vaccine transport process is better than the traditional way after one working day simulation. The vaccine supplied for A's epidemic station is 8,200 boxes whilst X's assistance centre is 8,000 boxes at the same time under the traditional vaccine transport process of emergency cold-chain. On the other hand, A's epidemic station has 45,500 boxes vaccine volume whilst X' assistance centre has 34,000 boxes. The results can be analysed as follows:

Focus on the Figure 5.9, the simulation result of the optimized vaccine transport process of emergency cold-chain, we can see A’s epidemic station received vaccine volume is always greater than X’s assistance centre. However, the vaccine supplied level for X’s assistance centre is showing hysteresis.

At about 200 minute, the first batch of vaccine supply arrived at A’s epidemic station, that is to say - before this period of time, emergent vaccine has been transported on the road. Obviously, this is because of the tandem structural limitations about the traditional vaccine transport cold-chain, which leads to poor performance of vaccine transport efficiency. Similarly, at about 270 minute X’s assistance centre got its first batch of vaccine supply. This is because of the average principle originates from the traditional vaccine transport process, namely, regardless of actual disaster situation as well as the control limitation of A’s epidemic station on total vaccine volume, the tandem structure blinds to unload all boxes of vaccine when arrived at A’s epidemic station, and stored half volume of vaccine at epidemic station while the rest was into vacant time, waiting for the next batch of vaccine delivery and transporting to X’s assistance centre together or reserving for injection preparation. During the waiting time, this may weaken the vaccine efficacy because of the improper temperature control; even harm the health of inoculation. Overall, such kind of inefficient and insecurity transport process is likely to seriously affect the distressed-areas with one disaster after another.

On the other hand, it is clear from the Figure 5.10 that both A’s epidemic station and X’s assistance centre got sufficient vaccine supply which is almost 40 times of the traditional vaccine transport process simulation. This is because of the parallel network structure.

In optimized vaccine transport process simulation result, the vaccine supplied for A's epidemic station at about 100 minutes and X's assistance centre at about 120 minute, respectively. This is mainly because of the time saving from the direct transport between D's vaccine manufactory and X's assistance centre, the transfer from refrigerated train to refrigerated container truck under the green pathway, and the batch arrived principle for refrigerated trucks after vaccine reaches A's airplane. In other word, the optimized vaccine transport process avoids jams in the limited space and complex operational problems and ensures the strict requirements of vaccine temperature control at the same time. Apart from that, the vaccine supplied for X's assistance centre can always catch up with A's epidemic station without any hysteresis phenomenon. In addition, there are five points of interactions which represent dynamic balance status of vaccine supplied between A's epidemic station and X's assistance centre. This hints that the optimized vaccine transport process has good transport ability and capacity, which is able to realise the hysteresis phenomenon that one place has shortage of vaccine but another is oversupplied. After information decision-making, when the vaccine supplied for A's epidemic station is greater than X's assistance centre, the vaccine from D's vaccine manufactory will be transport directly to X's assistant centre without passing A's epidemic station. For B and C's vaccine manufactories, vaccine may not pass A's epidemic station too, to realise dynamic balance of vaccine supplied for both A and X areas with the great efficacy. Overall, the optimized vaccine transport process of emergency cold-chain has more actual significant compared with the traditional one with better efficient for relief and rescue work.

5.4 Summary

In this chapter, we firstly establish model for assessing the feasibility and sustainability of transport process for emergency vaccine cold-chain. First of all, the area B in the edge of Wenchuan Earthquake affected range, which has less impacts compared with other distressed-areas, the production capacity of its vaccine manufactory can work well, so there is no such urgent needs for vaccine in local area but trying its best to supply city A which is in heavy destroyed. However, the long distance has strict temperature control requirements for vaccine transport without suitable for large quantities of vaccine transport. Due to the aircrafts can quickly respond to epidemic emergent vaccine needs as long distance transport mode, it is not necessary to worry about declining vaccine efficacy with a large volume of vaccine to transport under high-quality of temperature control. Secondly, city C has been in the earthquake affected range, but suffered minor without terrible epidemic disaster. So C's vaccine manufactory could bear the responsibility to provide emergent vaccine for city A. Although city C has no epidemic, the earthquake damaged roads. As result of that, large quantities of emergent vaccine have to be transported by rail with an extremely strict requirement for rail. So the government should immediately take various relief and rescue measures for the distressed-areas, such as building the green pathway between city C to county A as an easy access with simplifying security sector procedures, so that the vaccine can be transported in an unobstructed way. Once again, city D is very close to the epicentre, the magnitude of the disaster is not optimistic. So vaccine from its manufactory is not only for the epidemic victims at county A, but also for its local victims. But city D has a better traffic situation than county A after the earthquake, so the remaining part of the vaccine production is to support city A and its surrounding county.

In this way, through the timely information feedback from A's epidemic station and X's assistance centre after decisions can determine either the rest of the vaccine is transported directly to city A or county X. Accordingly, vaccine from B and C's manufactories arrived at city A also needs the same decision to determine stay or left. However, city A as the epicentre in heavy endemic areas can be said as a distribution centre, the traffic condition and the information feedback ability are all stronger than county X. Although county X is located far away from downtown with heavy epidemic situation, it still needs to rely on A's epidemic station to dispatch and make decision, connecting vaccine transport process as a parallel network structure. Overall, by using a case study from the Wenchuan Earthquake, we find that the optimized transport process by process optimization methods is really more effective than the traditional one, particularly on time and quality factors.

Chapter 6. Conclusion

6.1 Main Findings

The innovation of this paper lies in the two combinations of emergency cold chain logistics and transport processes, as well as the research on the application of simulation software in ExtendSim. In the domestic and foreign related studies, the relief and rescue supplies almost solely focused on achieving emergency rapid efficacy response, while transport temperature control with strict requirements of the special materials (i.e., vaccine) of the cold chain transport paid very little attention. For cold chain, the better development is belong to perishable fresh food cold chain transport research, while the research for vaccine and other perishable biological medicinal products cold chain transport is received far less attention, which also has great significance for reality.

Today, the government is facing great pressure from increasing epidemic and its losses for people and property correspondingly. In this paper, we learned the previous theory of practice relating to both emergency logistics and disasters in the special nature of the vaccine cold chain transport, considering the breakout of epidemic after earthquake disasters under the cold chain from procurement to distribution within various transport factors (such as time, quality), for the emergent vaccine cold chain transport process optimization study.

In conclusion, emergency cold chain through the integration of a large number of domestic and international logistics and transport ideas, to ensure the emergency vaccine cold chain transport efficiency, enhance the speciality and reliability of the related operations and improve emergent response capacity of cold chain transport while using ExtendSim simulation software to establish a complete set of transport process simulation system from the vaccine production unit to the county epidemic prevention station. It proves that through using the advanced process optimization theory onto the traditional transport process of emergency vaccine cold-chain, the optimized transport process over comes the under-level of time and quality factors for emergency cold-chain transport, which is the more efficient way for emergency vaccine cold-chain transport.

6.2 Future Research Areas

Emergency cold chain transport process is very complex, this article does not consider the cost factor to the vaccine cold chain transportation emergency flow impact, because of the time and some other restrictions, the scheme also has many deficiencies, emergency materials reservation is the most intuitive and direct field, which carries out emergency relief, relocates foundation and guarantees emergency logistics system, affecting the reaction speed and the final results directly.

China is such big country with a numerous population, for post-earthquake epidemics, sufficient numbers of vaccine reservation or enough vaccine production capacity for prevention and control of epidemic has great significance. In terms of geographical position and time & quality factors for emergency distribution centre, it is suitable to set up in the disaster area surrounding which has transport more convenient location, and its space can be expanded, so that it can provide convenient conditions for emergency materials handling and also can quickly sorting of relief and rescue supplies in the first time to meet the distressed-area's needs. The key among that are the fastest speed and the shortest time.

However, this paper considers more about the emergency response mechanism after starting materials distribution and transportation, while production, inventory and other front links are considered not that prominent for emergent properties without being focused on. As a result of that, the vaccine transport has both speed and temperature control, which are needed to substantial cost of output as support. But in this paper, in order to maximize the meet the distressed-area's emergent vaccine demand, this did not make the cost constraints into account in the period.

Based on this thesis, it will be two main research directions for future research areas in my opinion. Future work directions for research can be adopted econometric models and methods with existing data to carry out empirical analysis to get a more accurate emergency vaccine cold-chain. Emergency cold-chain research in China is not mature, so it may be more difficult. At a later time, I will continue to study and research, taking vaccine cold chain logistics transport emergency supplies production, inventory and other front links and cost constraints into account, and the scope of the study will continue to be focused on.

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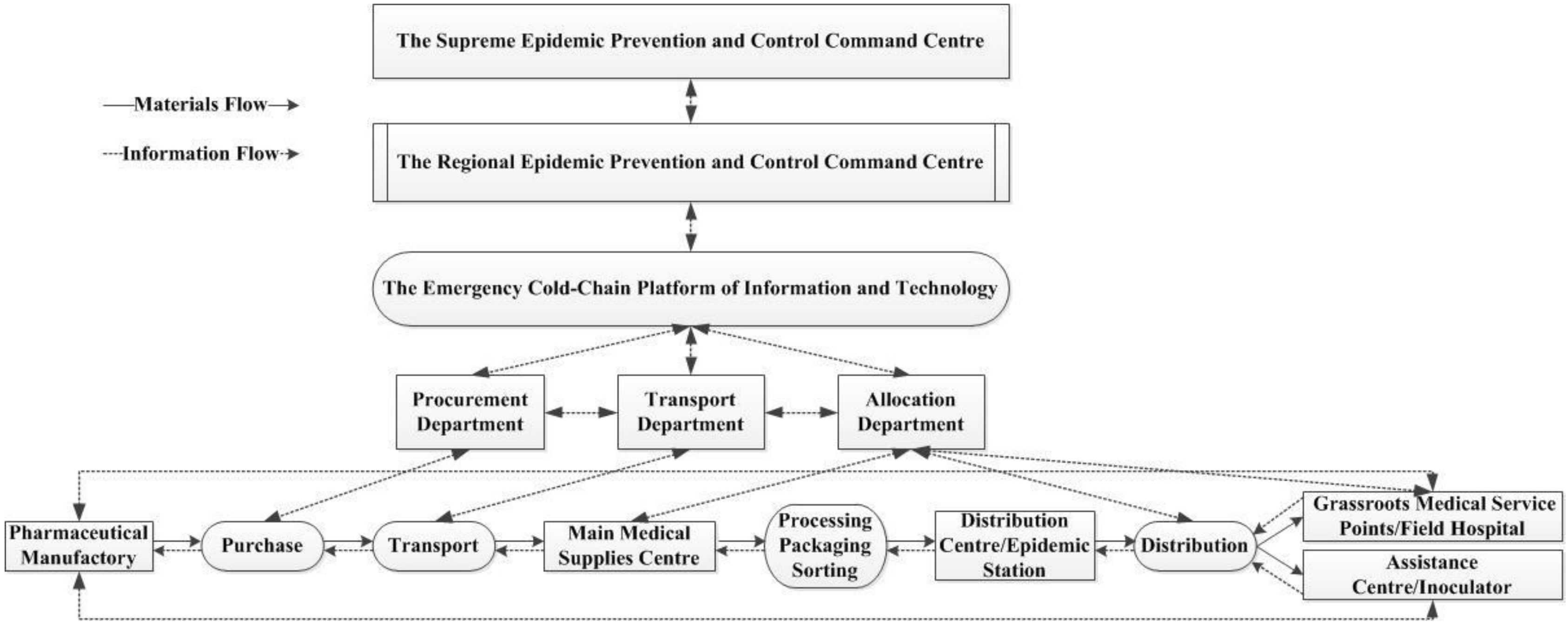
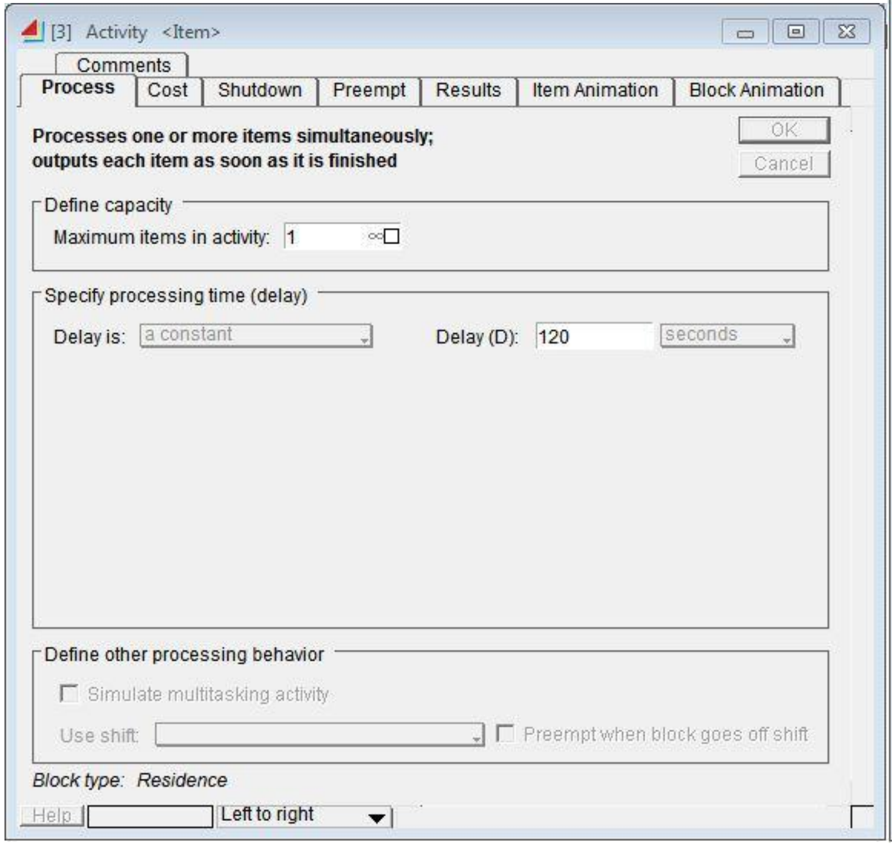
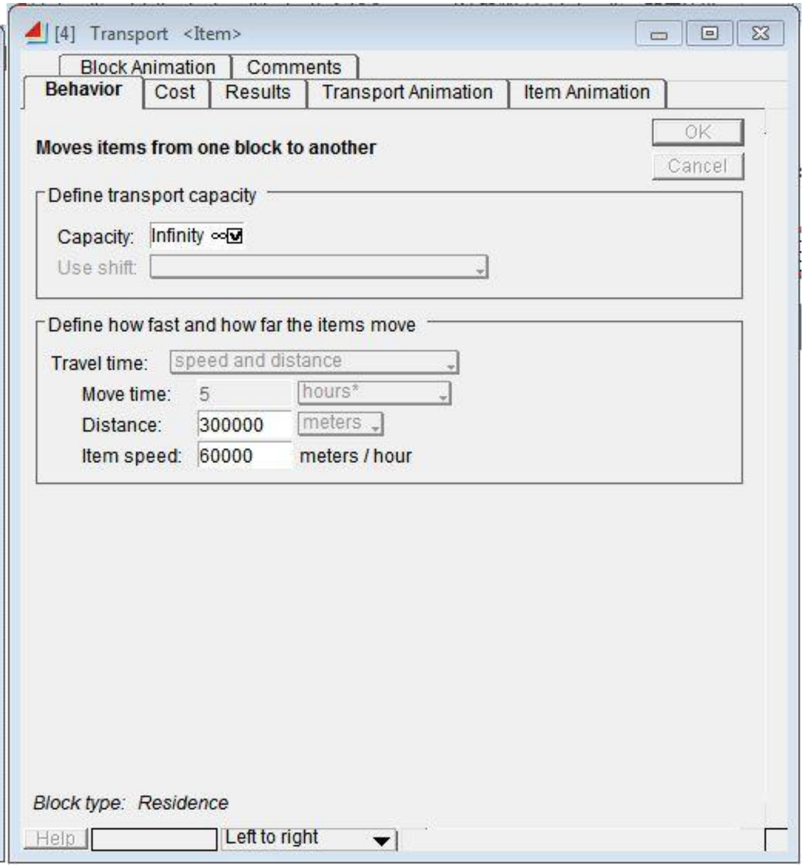
Appendices

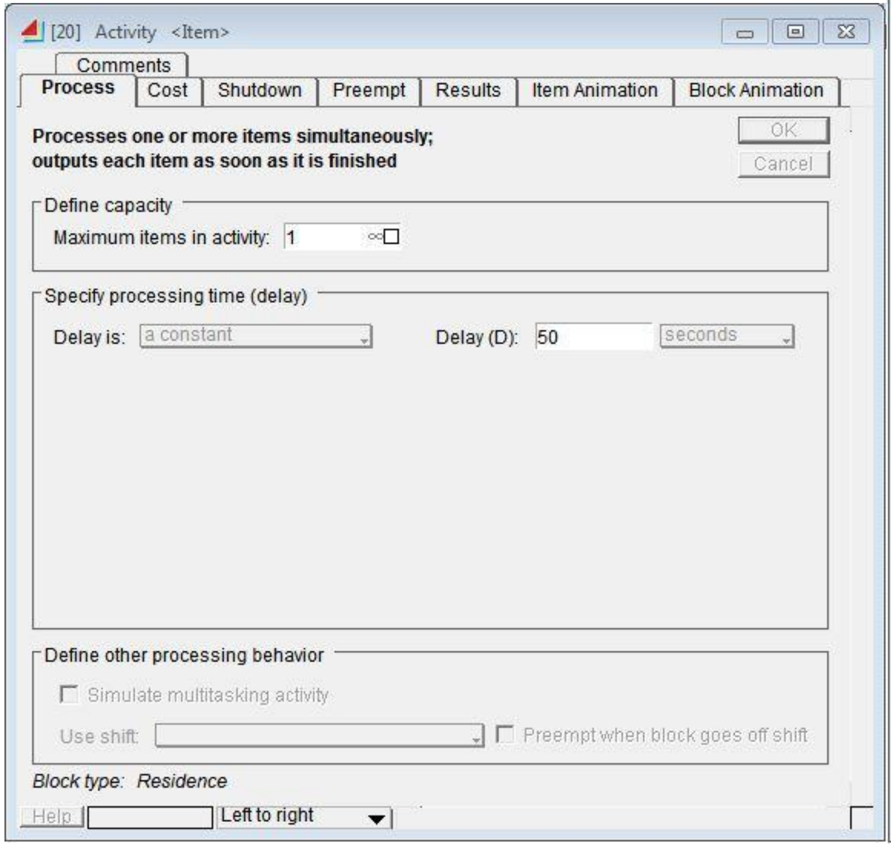
Appendix I Traditional Transport Process of Emergency Vaccine Cold-Chain

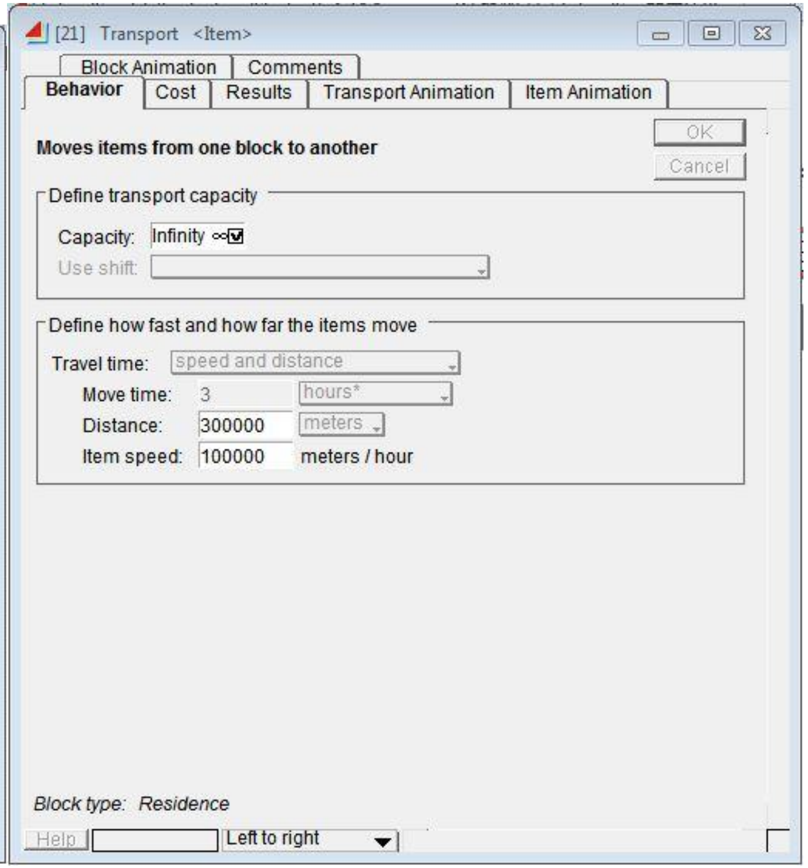


Appendix II - 1 The detailed module set of attributes for A1, T1, A2, T2.

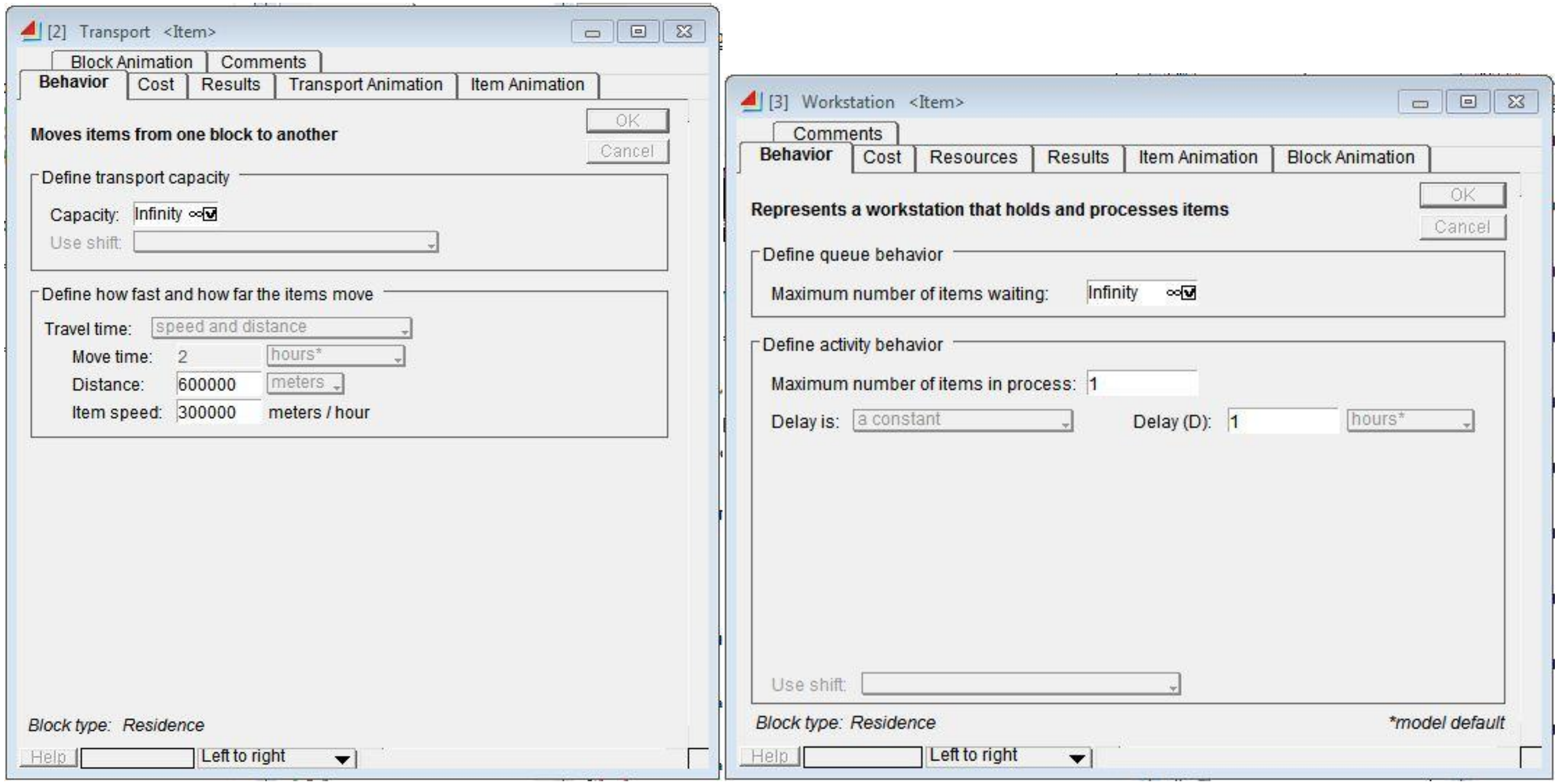


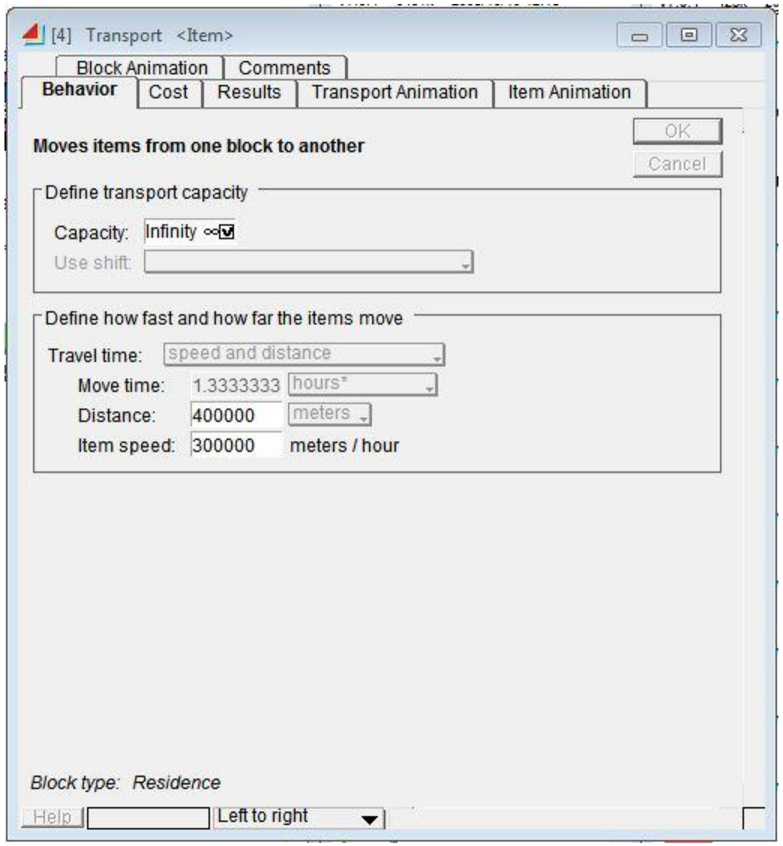


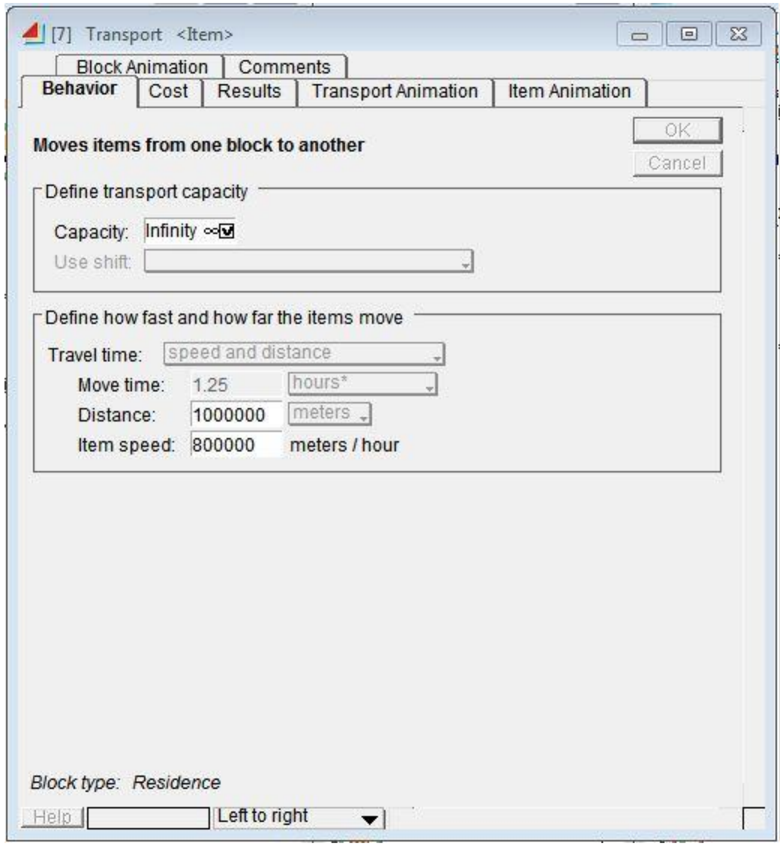

[20] Activity <Item>
Comments
Process
Cost
Shutdown
Preempt
Results
Item Animation
Block Animation
OK
Cancel
Processes one or more items simultaneously; outputs each item as soon as it is finished
Define capacity
Maximum items in activity: 1
Specify processing time (delay)
Delay is: a constant
Delay (D): 50
seconds
Define other processing behavior
Simulate multitasking activity
Use shift:
Preempt when block goes off shift
Block type: Residence
Help
Left to right

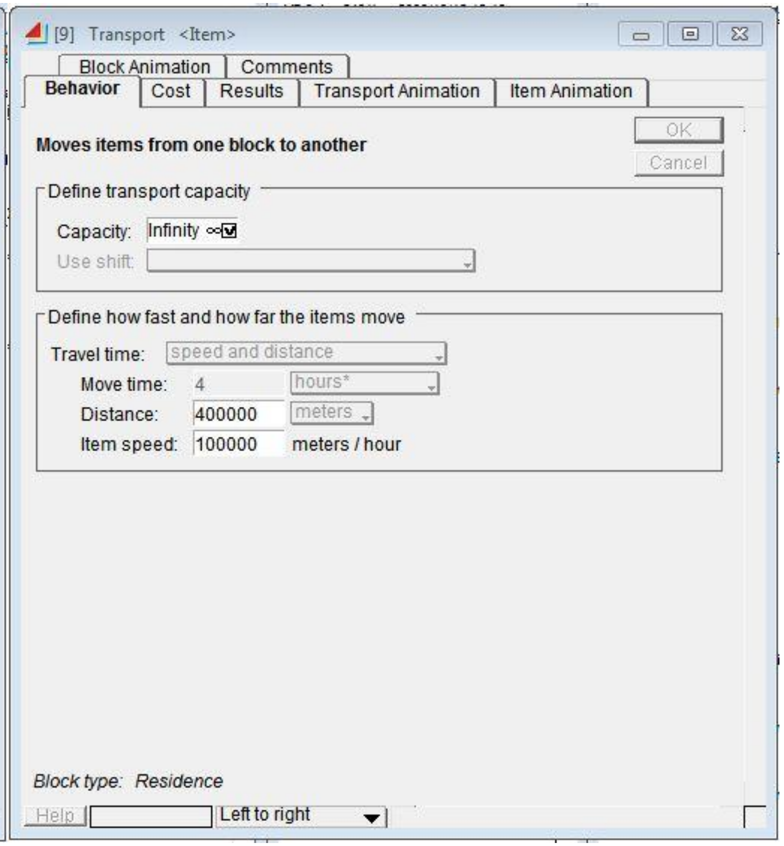

[21] Transport <Item>
Block Animation
Comments
Behavior
Cost
Results
Transport Animation
Item Animation
OK
Cancel
Moves items from one block to another
Define transport capacity
Capacity: Infinity
Use shift:
Define how fast and how far the items move
Travel time: speed and distance
Move time: 3
hours*
Distance: 300000
meters
Item speed: 100000
meters / hour
Block type: Residence
Help
Left to right

Appendix II - 2 The detailed module set of attributes for T1, W1, T1', T2, T2'.

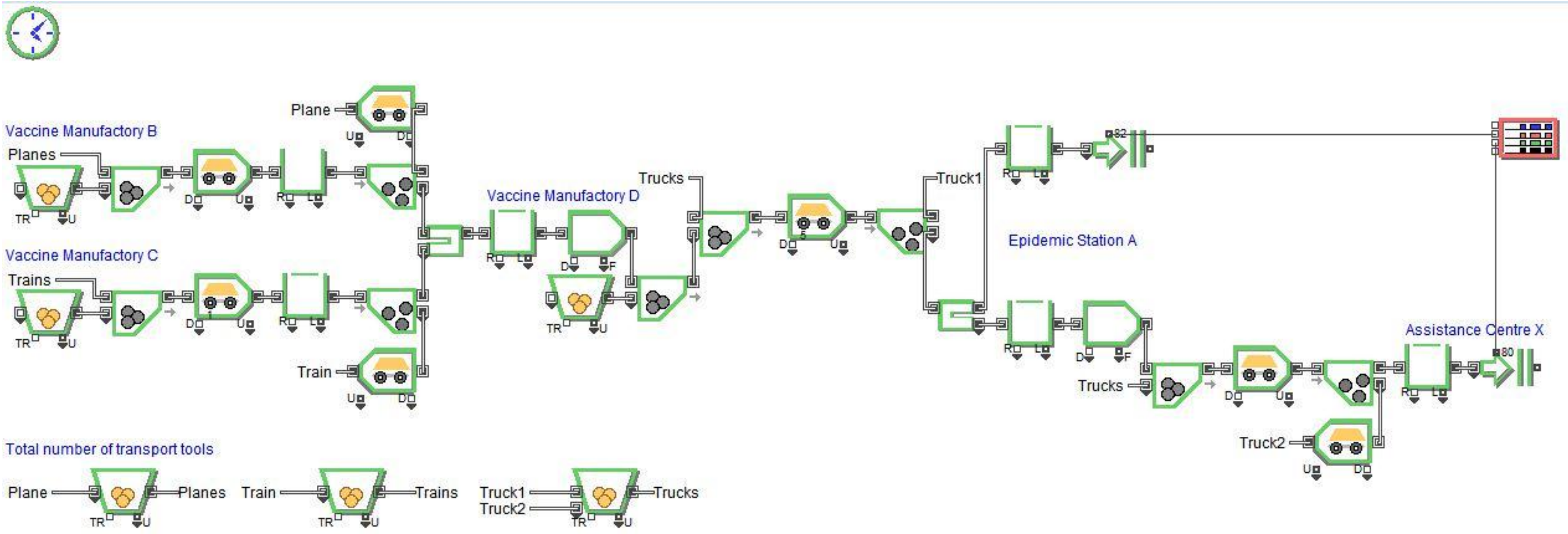



[4] Transport <Item>
Block Animation
Comments
Behavior
Cost
Results
Transport Animation
Item Animation
OK
Cancel
Moves items from one block to another
Define transport capacity
Capacity: Infinity ∞
Use shift:
Define how fast and how far the items move
Travel time: speed and distance
Move time: 1.3333333 hours*
Distance: 400000 meters
Item speed: 300000 meters / hour
Block type: Residence
Help
Left to right

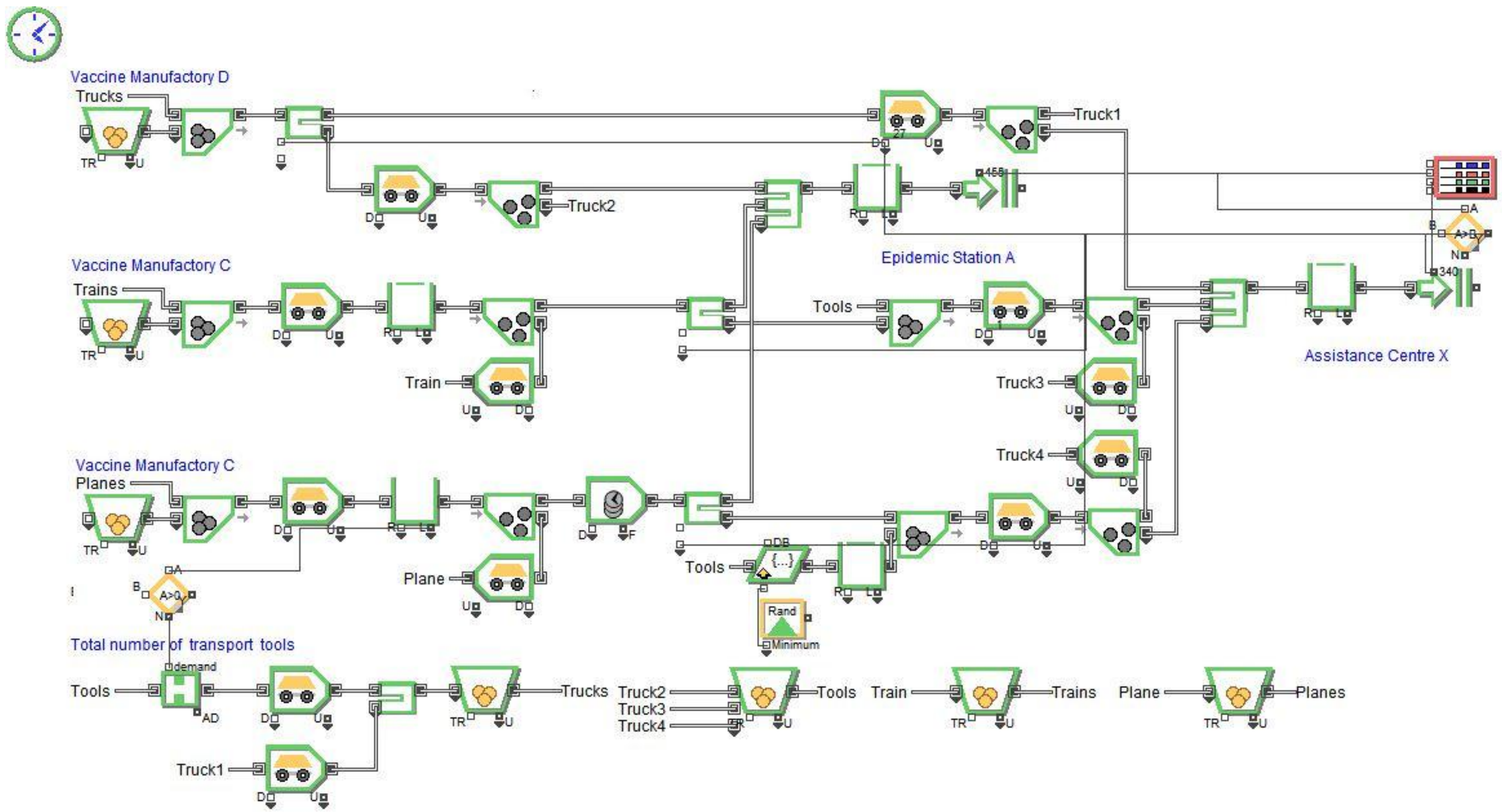

[7] Transport <Item>
Block Animation
Comments
Behavior
Cost
Results
Transport Animation
Item Animation
OK
Cancel
Moves items from one block to another
Define transport capacity
Capacity: Infinity ∞
Use shift:
Define how fast and how far the items move
Travel time: speed and distance
Move time: 1.25 hours*
Distance: 1000000 meters
Item speed: 800000 meters / hour
Block type: Residence
Help
Left to right


[9] Transport <Item>
Block Animation
Comments
Behavior
Cost
Results
Transport Animation
Item Animation
OK
Cancel
Moves items from one block to another
Define transport capacity
Capacity: Infinity ∞
Use shift:
Define how fast and how far the items move
Travel time: speed and distance
Move time: 4 hours*
Distance: 400000 meters
Item speed: 100000 meters / hour
Block type: Residence
Help
Left to right

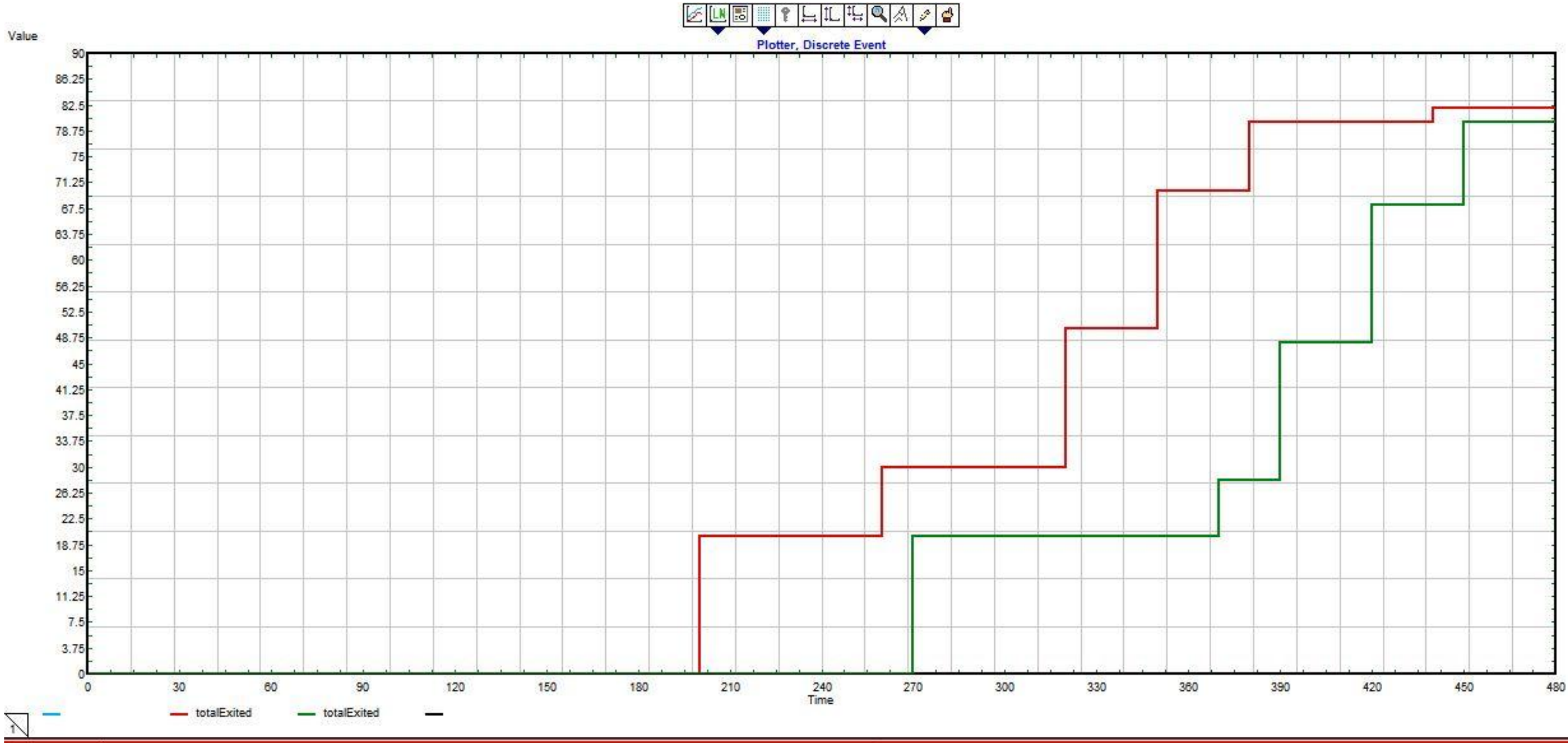
Appendix III - 1 ExtendSim-based traditional vaccine transport process simulation model



Appendix III - 2 ExtendSim-based optimized vaccine transport process simulation model

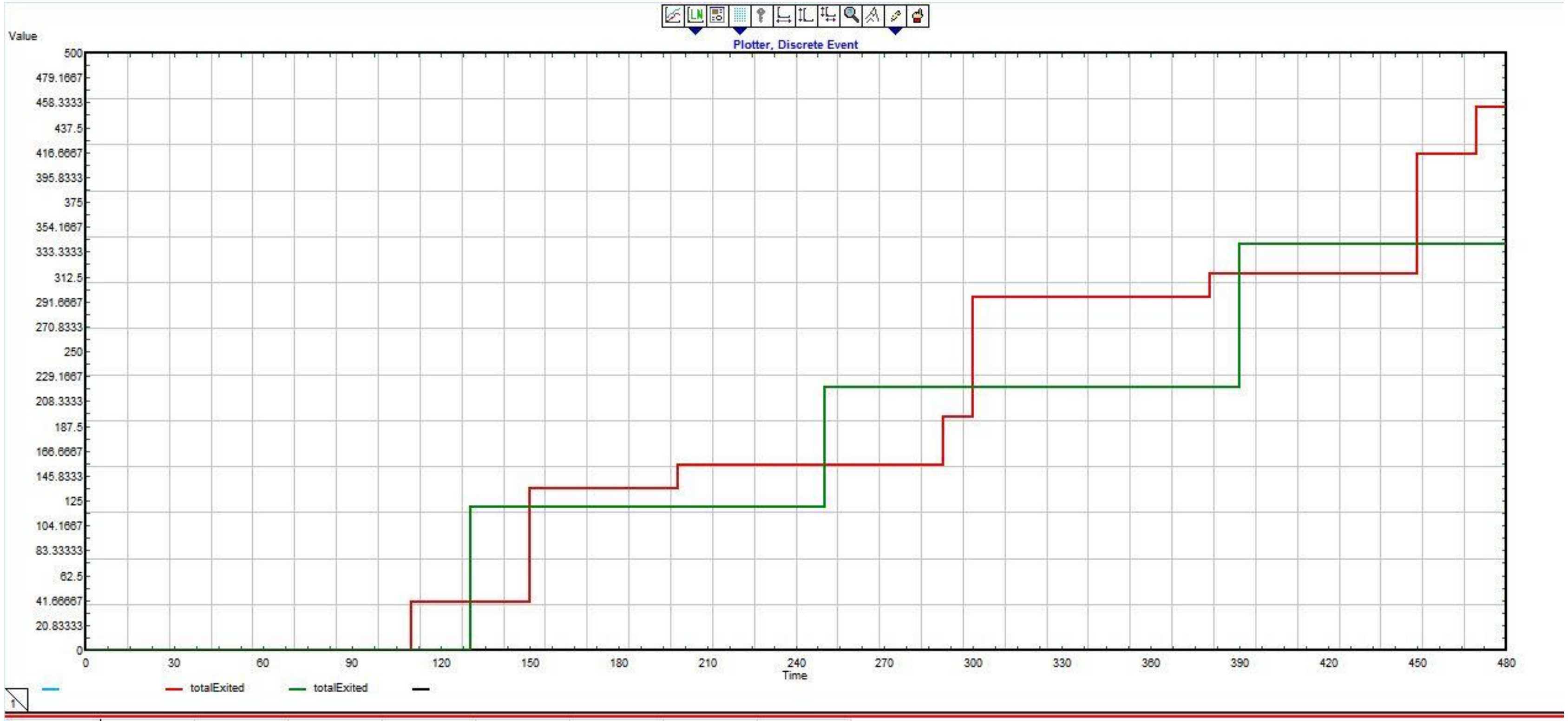


Appendix IV - 1 Result of Traditional Vaccine Transport Process Model



Point Number	1	1	2 Time	2 totalExited	3 Time	3 totalExited	4	4
80			380	80	450	80		
81			440	81	480	80		
82			440	82				
83			480	82				

Appendix IV - 2 Result of Traditional Vaccine Transport Process Model



Point Number	1	1	2 Time	2 totalExited	3 Time	3 totalExited	4	4
453			470	453				
454			470	454				
455			470	455				
456			480	455				