Modeling and Optimizing for the Regional Logistics Distribution Systems of Drinking Water Companies Based on the Random Service System Theory

Jia-jing Zhou, Wen-hao Liu, Zhao-yun Zhang, Jiang-ying Zhang, Dong-yang Xin, Yao-yao Wei*

School of Management, University of South China, Hengyang, China.
Email: 24359048@qq.com

Abstract. Due to the complex service mechanism and the random market requirements, lots of factors influence the regional logistics distribution processes of the drinking water companies. It's hard for those companies to optimize their logistics distribution systems only by using the traditional decision methods. Thus, this paper puts forward an idea so as to optimize the regional logistic distribution system and to establish the logistics information support system based on the theory of Random Service System (RSS). Furthermore, the regional logistics distribution system of "NongFu Spring (Zhejiang)" is taken as a concrete example. Through modeling and simulating of their distribution system, the major factors cause the resource-wasting and the transportation costs can be found and the optimized system is designed.

Keywords: Regional logistics, distribution, theory of random service system (RSS).

1 Introduction

As one of the top 10 emerging industries in China, the government strongly advocates the development of the logistics industry as well as implements the policies to promote the progress in enterprises' logistics. With the increase in per capita consumption and the improvement on the logistics system, the demand for drinks grows as well, together with a higher requirement for the regional logistics distribution system in drinks enterprises and more frequent interactions among manufacturers. In this context, the development of the enterprise ushered in the opportunity. Therefore, it is a priority to find a way to reduce waste of resources and costs in regional logistics distribution.

As e-commerce develops and per capita consumption rises, the issues on regional distribution of drinking water are becoming prominent gradually nowadays, which arouse a good deal of experts' attention on the problems of regional logistics distribution for drinking water and its related industries. Thus remarkable achievements have been acquired. Based on the study of the distribution mode of Nongfu Spring in Yibin, Qiang Yu and Ping Li [1] put forward 3 optimal distribution modes, namely the self-built distribution center, the common distribution and the third party full-time delivery. The optimal solution is determined on a case-by-case basis. And the best regional logistics distribution solution for reducing transportation costs and coping with issues for miscellaneous distribution was acquired. Starting from the warehouse performance in the logistics distribution network, Erhan Kutanoglu et al. [2] proposed applying genetic algorithm to study the dynamic distribution network structure, through the analog simulation as well as the evaluation on service capabilities and service time of the warehouse to predict the uncertain factors with regard to customers' demands as well as time to place the order so as to confirm service and off-service time for various distribution warehouses in the logistics distribution network and to achieve the optimal goal for the whole network. In accordance with the characteristics of food logistics and supply chains, Linxing Hu [3] mainly analyzed the current situation of logistics of the leading enterprise in the food industry, Hangzhou Wahaha Group Co., Ltd., in the Hangzhou Area market. Through the key transportation issue in food logistics and supply chains, combining the outsourcing strategy of the third party, the marketing mode and the logistics process of Wahaha was improved and the operating efficiency together with management abilities was enhanced. In the meantime, the optimal model of regional logistics distribution was built, the main route was clarified, and the distribution network was optimized according to enterprise's production and demand status at present, thus the expense for low efficient logistics was

reduced, and the transportation efficiency was enhanced. Tian Li [4] took Yanjing Brewery as an example in her study. Furthermore, the research focused on major drinking producers' business models: the intensive operation and the small regional operation. A detailed introduction of drinking business distribution was made and finally the analysis came to the conclusion: A good logistics management information system has a huge impact on the logistics distribution system. What makes distribution system valuable is that it monitors and tests each link by making use of the function of business operating, planning and predicting of the logistics management system and then the problem could be found out and measures could be put forward. Wei Xu [5] applied the data calculation method in the paper *Analysis on the Regional Logistics Network for Drinking Enterprises and Selection on the Logistics Distribution Model* to scientifically and effectively reduce logistics costs.

It seems that all experts have made a wide range of research on regional logistics distribution and provided methods to optimize distribution. However, most of their plans are introduced based on theoretical knowledge without any practice.

The aforementioned models will be effective to the idealized systems with a good definition and structure. And the model could be built based on deductive reasoning. However, the service mechanism and service demand are so complicate, and the random factors have a great impact on service efficiency, the traditional decision-making method usually is hard to make a dynamic characterization of the system. It can't provide a persistent real-time analysis to the real system, which makes it hard to gain a satisfying strategy in a short time. As to the optimization problem of this kind of logistics system, the decision which is made based on the simulation technology will be able to offer us a valid theory and tool support.

Logistics distribution system is a typical random social service (RSS) system driven by random events, and it is a dynamic system whose system state will change by leaps and bounds, its internal state changes are random, the same internal state can transform to a variety of state transitions. Due to the universal applicability of the RSS system in society, a great many scholars did surveys on the RSS theory and put forward a series of optimizing solutions by the RSS theory: Jiangnan Wang and Xujie Jia [6] studied the optimizing and arranging issue of the eye disease bed via M/M/C and M/G/K models in the RSS theory to enable the time that patients spend in the system to be the shortest. Budgaga, W., Malensek, M. et al. [7] supported the discrete type of RSS through statistics and study. Booker, M. T., O'Connell, R. J. [8] brought in the discrete type of RSS to carry out the simulation when studying the improvement on the quality. Furian, N., O'Sullivan, M., Walker, C., Vossner, S., Neubacher, D. [9] utilized the discrete events of the hierarchical control structure to build the model, focusing more on system behavior, controlling strategies and dispatching processes of the model as well as their structural expression in the conceptual model. Chandra V., Huang Z., Kumar R. [10] mentioned the communication method controlled and synthesized by the assembly line through using the control theory of the discrete even system. Most social service systems can be described by RSS, same as the potable water distribution system Drinking water production and distribution service random demand (bottled water arrival at distribution center random will be formed as the crowded queuing phenomenon), and the service capability of the logistics system and the system state affected by changed requirements has strong randomness. At present, RSS simulation technology is based on the object-oriented visual modeling method, and gradually masters the statistical rule of state changes in the system, quickly putting the elements in the real system, relations internal hips, layouts, operation processes, and uncertain factors into the simulation model. As RSS theory-based simulation software, Flexsim has a powerful visual modeling and analysis function, it can quickly create a real 3D virtual simulation model of the logistics system to achieve the optimal allocation responding to the system through the analysis on the operation data as well as the parameter calculation of the model. The Research of Optimization on the Operating Process of the Distribution Center for the Cold-chain Logistics Center from X. Zhu, R. Zhang, F. Chu, Z. He, J. Li [11] is carried out on the basis of Flexsim. The technology can effectively save time for decision-making and for resources costs, quickly and efficiently getting accurate system state data and offering the analog simulation and decision-making support for reconstructing the layout, process design and optimization procedure of the logistics distribution systems of drinking water enterprises.

This research is based on the RSS theory. According to this theory, a simulate optimization method of the logistics distribution systems of drinking water enterprises is put forward. Nongfu Spring Co., Ltd. was taken as an example. The system structure and the service characteristics of this company were observed and researched, and then a simulation model by analyzing their system was set up. Afterwards, the simulation process based on the acquired real data was performed. Finally, the system performance was

improved through continuous dynamic analysis and optimization towards the system according to the quantized data stemmed from the simulation.

The paper is organized as follows. Section 2 presents the modeling principle that based on the analysis and optimization of the Random Service System theory. Section 3 presents a description of how the research was carried out to include research design, measurement of population among others. Section 4 gives an example of the regional logistics distribution system of "NongFu Spring (Zhejiang)" based on RSS. Finally, the paper is concluded in Section 5.

2   Principle: Based on the Analysis and Optimization of the Random Service System Theory (RSS)

Based on the theory of Random Service System (RSS), simulation and optimization principles of regional logistics distribution in drinking water enterprises include the following steps:
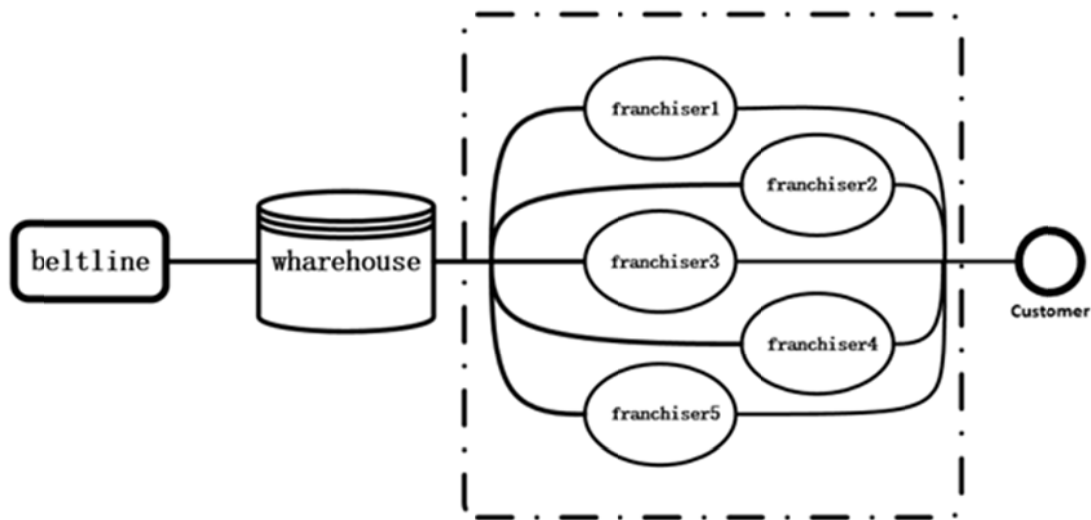
2.1   Modeling

Figure 1. Abstract model of regional logistics distribution system.

2.2   Model Introduction

The model is based on the regional logistics distribution system of the NongFu Spring in Hangzhou, Zhejiang province, focusing on its downstream distribution system, and the abstract model is shown in figure 1. The structure of regional logistics distribution is composed of entity and temporary entity flow. Entities including permanent entity and temporary and permanent entity -- all the stay in the system entities (e.g., manufacturers, franchisers, etc.), a temporary entity is to stay in the system during the simulation, the simulation end leaving entity (e.g., NongFu Spring). The inflow, outflow and service process of the entity constitute temporary entity flow. Second, the regional logistics distribution scene and customer demand should be analyzed and defined, and the probability distribution of order arrival time interval (or order arrival rate) should be calculated according to market demand information. Third, the service efficiency of the regional logistics distribution system should be defined. The corresponding restricted conditions of regional logistics distribution are set up, such as the system capacity, number of franchisers, service type and service time (service rate).

2.3   Simulation, Analysis and Optimization

After the simulation model runs to the specified time, the simulation data is stable such as distribution efficiency and random service performance. Through the analysis of stable data, the bottleneck of the regional logistics distribution system is found, and the model is optimized to solve the problems and improve the efficiency of distribution.

2.4   Repeated Simulation and Analysis Optimization

According to the simulation of the steady state of quantized data, the dynamic analysis of the system was carried out, the main bottleneck of system performance was found, and then the corresponding optimization strategy was put forward on the system layout as well as the service rules. The new bottleneck was found continuously, and a new optimization strategy was put forward, to form the continuous system optimization method of "finding the bottleneck - optimization and improvement", and ultimately to gain solutions on the efficient regional distribution system.

3   Research Method for the Project

Research design: the simulation method is applied in the test, the operating process for the model in the distribution system of the Hangzhou Area was simulated through the field investigation of one Nongfu Spring factory in Jiande half month ago, the regional division of five districts in Hangzhou (Gongsu District, Downtown District, Uptown District, Jianggan District and Binjiang District) was carried out, the car speed, distribution efficiency, and distribution process were simulated according to current delivery rates and route settings of the logistics system acquired through the field investigation in one Nongfu Spring factory. Meanwhile, some materials and documents regarding Nongfu Spring had been found, and the average production efficiency in the production line of Nongfu Spring was learned, base on which the production efficiency for the Nongfu Spring factory in Jiande over the past three years was roughly estimated. The practical situation on logistics as well as warehousing for the Nongfu Spring factory in Jiande could be simply simulated. Furthermore, the issues found out in the on-going distribution system through analyzing the simulation, the distribution system could be improved through the solution of issues. All the data are obtained in this way.

4   Example

Through the field research, production of a product line in Nongfu Spring is 72000 boxes of bottled water a day, the average warehouse reserve is 16000 boxes of bottled water. According to the condition of logistic regional distribution, the corporation's distribution system needs improvement. The corporation adopted the "manufacturer-storage-franchiser-marketing" system, one manufacturer with 5 franchisers. The initial data of related production and sales and some constraint conditions of environment include:

(1)   The interval time fits the Normal Distribution, and the average production time is 1.2 seconds and the standard deviation is 10 (seconds);
(2)   The Maximum inventory is 160000 boxes of bottled water;
(3)   The manufacturer accepts the orders from franchisers, which corresponds to the Discrete Uniform Distribution
(4)   All the sale orders of 5 franchisers fits the Normal Distribution with 13.29-second average time and 2-second standard deviation, 24.08-second average time and 4-second standard deviation, 17.28-second average time and 4-second standard deviation, 12.34-second average time and 2-second standard deviation, 6.17-second average time and 2.5-second standard deviation.
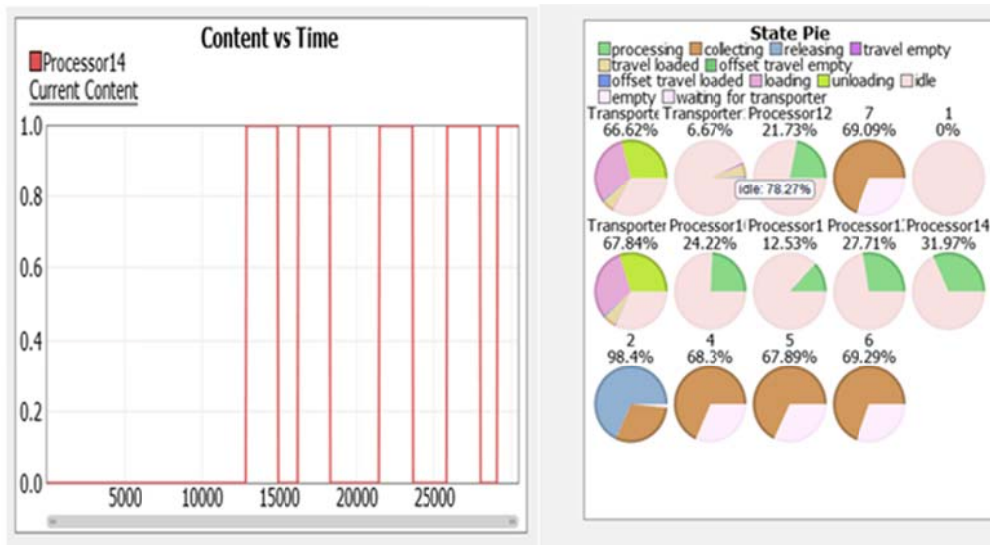
Figure 2. The screenshot of simulation data before optimizing.

After about 50000 seconds of simulation, the product of the Nongfu Spring's production line has been sold out, the manufacturer achieves zero stock. As shown in the Figure 2, when the "franchisers 10, 11, 12, 13" sold out, the lead time from placing the order to the delivery of the order is too long, and the time spans are different between 1000 (seconds), 5000 (seconds) or 2000 (seconds) and so on, it will be a greater chance for the franchiser to have losses due to the long-term inefficient inventory. In addition, the transportation rate of "the transportation facilities of 6, 7, 10" is too slow, merely reaching 6.67%. The time for loading and unloading is about 70%, whose efficiency is low.

It's clear that the bottleneck of the logistic regional distribution system is the insufficient information feedback, the inefficient transport and the nonstandard loading and unloading process.
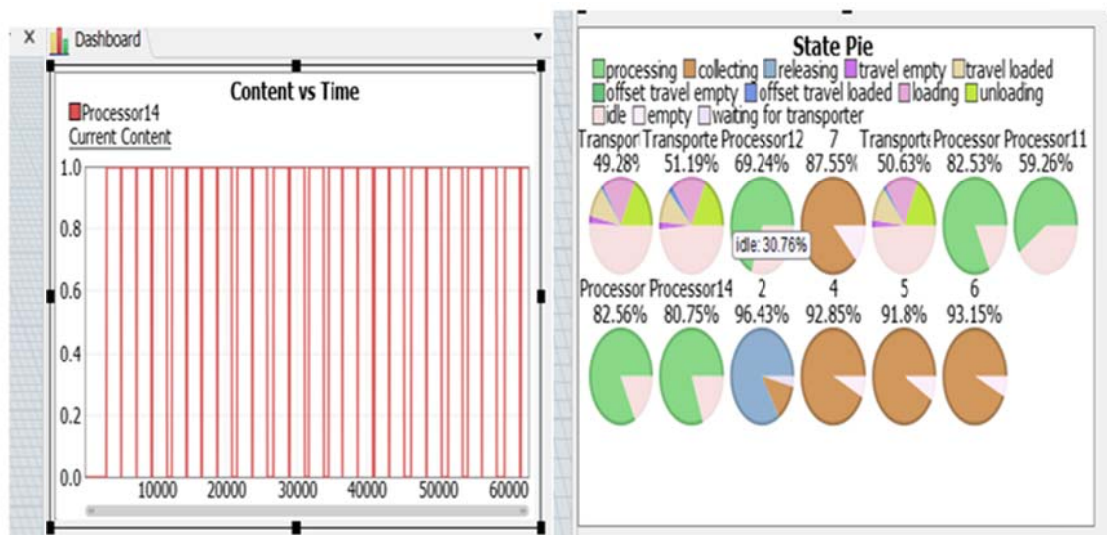

Figure 3. The screenshot of simulation data after optimizing.

Therefore, the company should improve the speed of transportation and the efficiency for loading and unloading, furthermore, the company should build an information feedback system, changing the transport's mode, using the DijKstra's Shortest Path Algorithm for regional distribution, optimizing the process of loading and unloading, and rationally using transport resource, setting safety stock for

franchisers when the inventory is lower than 120 boxes of bottled water, placing the order to manufacturer and prioritizing distribution to reduce the distribution's out-of-stock costs.

Table 1. The relevant annotations of the main entity names

Entity Names	System Elements	Relevant Annotations
Source2	The beltline of NongFu Spring manufacturer	The output of NongFu Spring beltline
1	Warehouse	Warehousing the spring water
2	Storage Area	Storage the ready to transport goods
Transporter6 Transporter7 Transporter10	Trucks	Transport cargo
3,4,5,6,7	Franchiser Warehouse	Save the entrance goods
Processor10 Processor11 Processor12 Processor13 Processor14	Franchiser	Sales of goods

The statistical data of same time (50000 seconds) shows that: firstly, it is obvious that the franchisers' lead time is shorter. Franchisers are able to supplement in time after the sales of orders are finished, and the cargo can arrive instantly, which greatly reduces franchisers' stockout costs. Secondly, transport machine' average rate of transportation is able to reach 30% or so; the efficiency of loading, unloading and carrying can reach 50% on average.

Therefore, it means that optimizing the regional logistics distribution system is effective (Figure 3). Through modifying the service mode for part of system entities and building the information feedback system, NongFu Spring's total reaction time would increase greatly and the regional logistics distribution system and resource utilization would improve significantly.

5   Conclusion

Based on the RSS theory, the NongFu Spring, in Hangzhou, Zhejiang province was taken as an example, and the drinking water regional logistics distribution was modelled, simulated and optimized. The optimizing function of this method to the regional logistics distribution system was verified as well in this study. Firstly, the service model based on the RSS theory identifies the actual layout of regional logistics distribution system and the characteristics of random service. In addition, by exploring the influence of main factors on regional logistics distribution, we modelled and obtained the statistical operation data, analyzing and finding the bottleneck, to optimize the regional logistics distribution system. Finally, the solution of simulation and optimization can reduce the logistics distribution cost and improve the efficiency of logistics distribution, expanding the market share, increasing the profit of drinking water companies and improving the customer satisfaction.

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