A Model study of Logistics Distribution Location and Route Optimization Based on Progressive Coverage and Minimum Envelopment Clustering Model

Jianchao Yang
Business School, Sichuan University, Chengdu 610065, China

Abstract

In recent years, the progress of Internet of Things technology and modern information technology has led to the rapid rise of the modern logistics industry and has become an important promoting industry for ensuring the sustainable development of the national economy at a high starting point. The logistics industry holds enormous market potentials and extremely broad development prospects. Driven by the Internet of things and modern information technology, an integrated logistics system that combines modern management and science and technology is realized. The optimization of the logistics system facilitates to implement the optimal allocation of resources and form a favourable divergent effect to promote the national economic growth. In the logistics system, the location and route optimization of logistics distribution are the two most significant issues. For a long time, scholars have taken a single analysis approach to analyze these two problems, which makes it difficult for the logistics system to make favourable connections and to realize the ideal optimization result. For this reason, this paper analyzes the connotation of distribution center, discusses the discrete location method, and on the basis of this, proposes the improved progressive coverage and the minimum envelope clustering model to solve the route optimization of the logistics distribution location. The algorithm process of route optimization and node allocation rules are optimized by using the progressive coverage model, and the minimum envelope model is applied to improve the judging criteria based on the comprehensive consideration of the spatial distribution of nodes and the service time.

Keywords: Progressive Coverage, Minimum Envelope Clustering Model, Logistics Distribution, Site Selection and Route; Optimization Model.

1. RESEARCH BACKGROUND

1.1 Research Overview

With the progress of economic globalization, modern logistics emerges as the times require and becomes a major driving force for promoting global economic integration. At present, the development of science and technology and the increasingly intensified market competition environment have brought increasing attention to the modern logistics featured with advanced management techniques and management ideas. Nowadays, modern logistics has been widely applied in numerous fields such as production and service and has gradually become a key pillar industry that supports the growth of the national economy. Meanwhile, the increasing demand for logistics also greatly enlarges the inventory cost and transportation cost of modern logistics. As China’s development level in the logistics industry is still at a low level, the extensive business model leads to a number of problems in modern logistics, such as low utilization rate of warehousing sites, unreasonable layout planning of warehousing enterprises and uncoordinated functions. As a consequence, massive resources are idled and wasted, the economic growth and competitiveness of enterprises in China are seriously undermined, which has become an important issue urgently needed to be solved in the process of enterprise development at this stage (Dou and Li, 2017). For this purpose, it is highly necessary to reduce the logistics costs and improve the service level of logistics enterprises on the basis of elevating the management level and the delivery efficiency of modern logistics and maximizing the demand of customers. In the modern logistics system, distribution is the key link of the logistics enterprise services and holds self-evident importance, which includes both all the logistics activities and the warehousing and transportation process and also becomes an important discussion topic in the field of practice (Guo et al., 2017). However, for a long time, the problems of transportation and warehousing in the distribution chain have been independently researched. Consequently, it is difficult for the logistic system to achieve the overall optimal goal. As the complexity of the distribution system becomes higher and higher, the coupling of the
two major issues—transport and warehousing continuously improves. Therefore, when solving the practical problems, it is a must to comprehensively consider the two issues, eventually leading to the problems of site selection and route optimization of the logistics distribution, which is of vital significance for the overall optimization of logistics system resources (Dai et al., 2016).

1.2 Research Objective

This paper aims to optimize the site selection and the route of logistics distribution through the application of the improved progressive coverage and the minimum envelope clustering model, so as to solve the two problems long existing in the modern logistics system—transportation and warehousing, to efficiently utilize the resources of the modern logistics system, to improve the convergence and coordination of different functions, and to elevate the service level of modern logistics. In this way, the modern logistics industry can better promote China’s economic development. To this end, first, this article analyzes the related theory of the optimized site selection and route of logistics distribution, briefly introduces the concept of distribution center and its related theory of site selection, analyzes the present discrete location method, and puts forward the corresponding solution according to the vehicle routing problem. Secondly, time satisfaction is discussed, and the corresponding tabu search algorithm is proposed to address the problem. Thirdly, the study analyzes the travel time of vehicles in dynamic environment, combines the requirements of time window, introduces customer satisfaction degree into the construction of the LRP problem model, applies the decomposition method to resolve the problem, and then realizes site selection by means of the improved minimum envelope clustering model. Based on this, a two-layer nested hybrid genetic algorithm is proposed to solve the problem, and the tabu search algorithm is adopted to realize the local optimization of the solution process.

2. THEORETICAL ANALYSIS OF SITE SELECTION AND ROUTE OPTIMIZATION OF LOGISTICS DISTRIBUTION

2.1 Logistics Distribution Center and its Site Selection Theory

The logistics distribution center contains five layers of definition, including the hierarchical definition, the horizontal definition, the vertical definition, the system definition and the function definition. In light of the function difference and scale layer of the hierarchical definition, logistics distribution centers can be divided into distribution center, logistics park and logistics center. Logistics distribution centers in the horizontal definition are at the end of the logistics location, but has more perfect organization and more professional technology and equipment compared with traditional warehouses. In the vertical definition, the link at the end of the logistics directly face the customers. The system definition, located in the core of the logistics system, can significantly improve the operation level of the logistics system. The function definition realizes the final allocation of resources through the delivery and distribution (Xiang, 2016). Logistics centers are divided into basic functions and value-added functions. Specifically, basic functions comprise warehousing, sorting, distribution, processing, loading and unloading, and packaging, and value-added functions involve settlement, logistics systems, etc. The types of distribution center can be sorted by distribution object, logistics function and coverage area. The purpose of selecting the sites of a distribution center is to optimize the allocation of resources and maximize the overall optimization of the logistics distribution system (Yang et al., 2015). The objectives of site selection involve cost minimization, service optimization, potential maximization and evaluation integration, respectively, and the principles of site selection include adaptability, economical efficiency, coordination and perspectiveness.

2.2 Distribution Center Location Model

Distribution center location model applies mathematical methods and principles as well as qualitative and quantitative analysis methods to describe the actual problems under the constraint conditions such as optimization objective, location object and region and cost function, in order to determine the location, size and quantity of distribution nodes in the logistics system, reasonably plan the distribution network structure, achieve the objective of minimizing logistics costs and consequently provide reliable data support and basis for solving practical problems (Wang et al., 2015). The distribution center location model concerns discrete location model and
continuous location model, and analytical methods include mixed 0-1 integer programming, maximum coverage model and cluster analysis site selection model. The mixed 0-1 integer programming method is able to solve the problem of site layout problem in multiple distribution centers and takes into consideration the operation costs and construction fixed costs of distribution centers, and the formula is established as

$$\min Z = \sum_{g=1}^{k} \sum_{i=1}^{s} a_{gi} w_{gi} + \sum_{i=1}^{s} \sum_{j=1}^{c} c_{ij} x_{ij} + \sum_{i=1}^{s} F_{i} X_{i} + \sum_{g=1}^{k} \sum_{i=1}^{s} P_{gi} w_{gi}.$$  

(1)

The maximum coverage model can determine the service facilities where customer demand and time are known so as to solve the problem of site selection, which is a highly effective location model with the ability to achieve the location optimization of numerous distribution centers and satisfy customer demands as much as possible (Tang, 2014). The formula for satisfying the needs of the client at the maximum extent is $\max \sum_{j \in \lambda(i)} \sum_{i \in C} d_{ij} x_{ij}$, which can be solved by the heuristic algorithm. Clustering analysis can effectively address the transportation routing problem when there are several customer points in the region, and the demand and coordinate positions are known, and the region also contains the alternative set of distribution centers (Li, 2014).

2.3 Vehicle Routing Problem and its Solution

The related components in the vehicle routing problem mainly involve constraints, distribution centers, objective functions, transportation networks, vehicles and products. The types of vehicle routing problems are mainly divided into static VRP and dynamic VRP which contains basic and extended types. The solution to the vehicle routing problem of static VRP primarily concerns precision algorithm, classical heuristic algorithm and general heuristic algorithm, and the solution to the vehicle routing problem of dynamic VRP contains the above method, a-priori optimization and real-time optimization (Wang, 2016). The basic types of vehicle routing problems mainly include problems under the restriction of route length and load capacity, pick-up and delivery, time window, and return trip transportation (Zhao and Zhang, 2015). Figure 1 illustrates the basic types of vehicle routing problems.

![Figure 1. Schematic diagram of the basic type of vehicle routing problem](image)

In addition, the extended types also include the vehicle routing problems of demand splitting, open type, multi-vehicle and multi-route. The optimization algorithms of the vehicle routing problem mainly incorporate heuristic algorithm and precise algorithm. The heuristic algorithms also cover classical heuristic algorithm and general heuristic algorithm that is mainly applied in solving this problem. The dynamic vehicle routing problems mainly concern DVRP, and the solution methods are a-priori two-stage optimization method and real-time re-
optimization method. The location route optimization problem is also called LRP problem. The solution to this type of problem is through precise algorithm and heuristic algorithm (Ma and Ding, 2014).

3. LOCATION OPTIMIZATION MODEL OF REVERSE LOGISTICS DISTRIBUTION IN A STATIC ENVIRONMENT

3.1 Time Satisfaction Function

Due to customers’ different time experience, different customer satisfaction degrees are produced in the process of accepting the product or services, which is called time satisfaction. Time satisfaction function can truly reflect the mathematical relationship expressed by customers’ time satisfaction degree and service waiting time, which is a non-increasing function of distance or time. Common continuous-time satisfaction functions mainly include linear time satisfaction function, concave-convex time satisfaction function and cosine time distribution satisfaction function (Chen and Li, 2015).

3.2 Solution Algorithm

In terms of the site selection problem of the reverse logistics distribution in a static environment, the LRP problem can be solved by using decomposition method. Specifically, the LRP problem is decomposed into two sub-problems that can be connected with intrinsic relations, and the location of the logistics distribution center and the customer base that requires services are determined by the progressive coverage model, thereby obtaining the logistics distribution optimization routes of different customer groups (Sun, 2014). The solution to the second sub-problem is conducted on basis of solving the first sub-problem. Next, the solutions to the two sub-problems are combined to find out the best goal solution of the overall network optimization problem. The design of the problem can be completed by the tabu search algorithm and complemented by Matlab software programming.

4. LOCATION OPTIMIZATION MODEL OF LOGISTICS DISTRIBUTION WITH TIME WINDOWS IN A DYNAMIC ENVIRONMENT

4.1 Analysis on Time Window Problem

In the previous LRP research, time window constraints were seldom considered, which, however, must be considered in a dynamic environment. Time window problems are divided into soft time window, hard time window and mixed time window. The hard time window means that the delivery service must be completed within a specified time period, and the customer may refuse the service beyond the time period. The soft time window refers to that customers can accept the service deviated from the scheduled time, but needs to be punished based on the degree of inconvenience. In addition, the issue of mixed-time window is also considered in some cases (Yi and Luo, 2016).

4.2 Vehicle Travel Time and Customer Satisfaction

In a dynamic environment, vehicle travel time is likely to be prolonged due to traffic congestion, accidents and the like, and the length of vehicle travel time is directly related to customer satisfaction. For this reason, fuzzy functions of vehicle time can be applied to construct the customer satisfaction degree model that is established based on soft-time windows and hard-time windows. Customer satisfaction can be maximized only if the delivery services are provided within customers’ expected time. Customer satisfaction drops as the gap between expected time and service time is enlarged. Customer satisfaction drops to zero when service time exceeds the tolerable time of customers (Qin, 2014).

4.3 Solution Algorithm

The LRP problem in a dynamic environment should be solved by the decomposition method where the LRP problem is decomposed into two sub-problems that are connected and inter-linked. Facilities location of the LRP
problem is conducted by means of the cluster location model, which means to determine the location of the distribution center and its customer service groups and to solve the distribution route of different customer groups. Afterwards, the solution to the second sub-problem is completed on the basis of the solution to the first sub-problem. The solutions of the two sub-problems are combined to solve the corresponding best target solution to the overall network optimization problem. The solution to this problem can be carried out by hybrid genetic algorithm and complemented by Matlab software programming.

5. CONCLUSION

In summary, the site selection and route optimization of logistics distribution have always been an urgent need for the modern logistics system to solve. In terms of this problem, this paper proposes the solution of the improved progressive coverage and minimum envelope clustering, introduces the concept of time satisfaction, customer satisfaction and time window in the solution according to the logistics distribution route in a dynamic environment, and accordingly designs the corresponding solution algorithm. Practice has proved that the application of the improved progressive coverage and the minimum envelope clustering model can effectively solve the problem of the site selection and route of logistics distribution, achieve the optimal planning objective of the site selection and route of logistics distribution, and holds an extremely high value in the modern logistics system.

REFERENCES