Information Systems and e-Business Management
https://doi.org/10.1007/s10257-018-00393-5

ORIGINAL ARTICLE

Business service network node optimization and resource integration based on the construction of logistics information systems

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Received: 9 November 2018 / Revised: 10 December 2018 / Accepted: 26 December 2018

Abstract
With the rapid development of rural retail enterprises, China's chain retail enterprises attach increasing importance to integration management of the supermarket and the production base, but business logistics service network need to improve the way of integration optimization. How to integrate nodes between supermarket and commercial logistics distribution centre and production base is of great significance to the development of China's commercial enterprises. In this paper, the author only selected the nodes of logistics distribution centre, supermarket chains, production base and other commercial service network for simple optimization analysis. When analysing the logistics distribution centre of retail supermarket, the paper studies the location selection modelling; When analysing the distribution routes from the production and planting base to the distribution centre, the paper studies the optimization of transportation routes according to TSP model; In the study of how to optimize the nodes of business outlets from distribution centre to supermarket stores, VRP model was adopted to analyse the paper. The supply chain process of commercial service network can be optimized by the construction of logistics information systems, information management of processing and distribution, and distribution route. Based on the relationship between commercial logistics operation cost and inventory, this paper proposes the establishment of inventory management decision support system. Through the rapid exchange of information between the distribution centre and the store, the inventory safety of the store can be guaranteed, while the product stock of the store can be reduced as much as possible, thus reducing the total cost of the operation of the supermarket. Through such nodes integrated optimization analysis, can achieve the intensive development of business logistics service network.

Keywords Integrated node · Business logistics network · Optimization of distribution routes · VRP problem · Logistics information systems

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Published online: 12 January 2019

Abbreviations

3PLS	Third party logistics service
NP	Non-deterministic polynomial
COM	Component object model
DCOM	Distributed COM

1 Introduction

Accelerating the construction of urban–rural integrated trade service network is an urgent problem in coordinating urban and rural development. At the same time, dominated by large supermarket chains in the modern commodity supply chain is forming. Business logistics service is an important link directly linked to the consumer in, is the process of the goods delivered to the consignee from logistics nodes. Supermarket logistics distribution process mainly includes: sourcing from suppliers or production base and gathering goods collection work; according to different requirements, each store goods in distribution centre will need selected distribution operations; considering the distribution quality and volume of goods, make full use of the load and displacement of the vehicle fittings, truck goods and determination of distribution path.

Business service networks is to focus on logistics, information flow and cash flow for the integration of flow-through nodes, so scientific and reasonable distribution network integration optimization study is very important. Logistics distribution centre layout and site selection whether is reasonable or not, the function of logistics distribution centre of exert a great influence and comprehensive benefits. Logistics distribution is an important link in service network which is directly connected with supermarkets; it is the process of goods from distribution centre node to service network. On distribution route optimization problem domestic and foreign scholars have done a lot of research, and established a relevant mathematical model and algorithm. However, with the rapid development of modern information technology, the simple model and algorithm only Combined with computer technology, can provide higher efficiency of decision-making support for modern logistics management.

With the rapid development of network, management information system based on Web has become the primary trend in corporation nowadays. The modern logistics information system and the application of logistics network information will be conducive to the dynamic integration of logistics network resources. The informatization of logistics network is the inevitable development of logistics network. The analysis of the components of logistics information system mainly refers to the networking of logistics information resources, communication and computer. On the one hand, logistics information resources should be integrated within the scope of logistics network, on the other hand, the arrival of the information age provides logistics enterprises to cross the boundaries of enterprises and explore information channels to integrate logistics resources outside the supply chain, the realization of logistics network information system becomes a new research hotspot of business management.

Monios studied and analysed the quality-based functional method, the fuzzy cluster theory and group decision theory are also used, such a site selection model can comprehensively consider the site selection needs of the distribution centre from the perspective of 3PLS and customers, and it also reflects the characteristics of fuzzy and group strategic decision making in decision-making process (Monios 2015). Wang reviewed the state-of-the-art of VRP problem, studies three VRP variant problem which are most common and urgent to address for distribution companies in reality, and proposed meta-heuristics to solve the problem (Wang et al. 2015a).

The research results of some foreign scholars on logistics organization show that logistics organizations should operate in coordination and integration. Such as Yang and Zhao's research has shown that how do suppliers and customers integrate in the logistics outsourcing relationship, scholars have come up with a new method of innovation, this method is affected by environmental uncertainty in logistics outsourcing relations (Yang and Zhao 2016). The research of foreign scholars on task coordination of logistics network mainly focuses on VRP (the Vehicle Routing Problem), VSP (the Vehicle Scheduling Problem) and MTSP (the Multiple Traveling Salesman Problem), etc. More than 700 papers were mentioned in Baldacci and Bodin's review (Baldacci et al. 2006). For VRP problems with capacity constraints or time window problems or no dwell time, a three—subscript vehicle flow equation is proposed by Imai to solve the problem (Imai et al. 2006). Based on an adapted version of an existing comprehensive taxonomy, Braekers classify 277 articles and analyse the trends in the VRP literature (Braekers et al. 2016). After the above research, scholars have to deepen and expand the method constantly, make its application in VRP problems widely. Neil studied the distribution channels of crops, he thinks that the contract between the distribution nodes in the channel can reduce the irrelevant cost, and increase the profits of the cooperative units, so as to realize win–win (Cameron 2006). Kotzab and Telloer proposed a retail in-store logistics model, and used the model analyzed 200 dairy grocery store logistics process in Austria, the investigation result shows the main problem of storage link, clearly pointed out the logistics is the key factor that affect the success of the retail store (Kotzab and Telloer 2005). Application of ant algorithm to solve VRPTW is the new direction of recent studies, because of its parallelism and distribution; it is especially suitable for large-scale heuristic search.

In recent years, the development of information communication technologies such as the Internet of things and big data has provided great convenience for the research on the optimization of service network and resource integration (Mikalef et al. 2018). Ilie-Zudor et al. (2015), Orgaz et al. (2015), Kirci (2016), Huang et al. (2017) and Guo et al. (2017) have studied the optimization of big data and logistics service network. Schwind et al. (2009) studied combinatorial intra-enterprise exchange for logistics services. Scholars demonstrate that by using the ComEx mechanism, the total cost of transportation of our logistics company can be reduced by up to 14%. Lin studied the impact of technological innovation capabilities on supply chain integration. The results support the theorized relationships indicating that the level of partnership quality and supply chain integration is positively influenced by socialization mechanisms and technological innovation capabilities (Lin 2014). Haak and Weinhardt (2014) described the optimization process in Service

Value Networks, an extensive elaboration on different optimization techniques that allow for a computational efficient service selection and a broad analytical and simulation-based evaluation of these techniques. Koppenhagen et al. designed a supply network artifact for data, process, and people integration. Their results show that the proposed design reduces mental effort of supply management professionals and significantly increases efficiency when performing typical supply network tasks such as supplier qualification (Koppenhagen et al. 2016). Chern et al. assessed the efficiency of supply chain scheduling algorithms using data envelopment analysis. Results showed that the DEA model proposed can be used to assess the efficiency of a real-world operation with undesirable outputs/inputs, such as inventory and delayed demands (Chern et al. 2016).

2 Methodology

Scientific and reasonable node optimization can not only save the enterprise operating expenses in the future, what is more important for the customers to provide high quality and efficient logistics services. Thus the location problem of distribution node in the study of the entire logistics system occupies very important position, the research questions mainly belong to the supermarket chains management strategy layer.

The so-called multiple distribution centre location is in some known alternative site choose a certain number of places to set up the distribution centre, make the minimum total cost of the supermarket logistics network, including basic investment cost, variable cost and fixed cost.

2.1 The principle of integration of distribution nodes

The location selection of the distribution centre of a commercial enterprise refers to the decision-making process of selecting one or more locations as the distribution centre within the range of multiple regional nodes available for selection. If the site selection is not reasonable, it will have a great negative effect and suffer losses. Therefore, after considering the influencing factors of distribution centre, supermarket should according to certain principles, with the system point of view, and comprehensive analysis from various aspects.

The main principles of node integration in logistics distribution centres are as follows: economy, coordination and the overall situation, among them, economy is a priority. The cost of maintaining the operation of the distribution centre can be divided into investment cost and labour cost, therefore, it is necessary to calculate the possible cost of the distribution centre scientifically, so as to minimize the cost of building the logistics distribution centre. Coordination means that the construction of distribution centre should be coordinated with the surrounding environment; it is in harmony with the development level of culture and custom in the areas concerned, it is in harmony with the regional distribution of supply and demand of logistics resources. The overall principle is to point to the logistics distribution centre location for strategic comprehensive observation, this should take into account both immediate needs and long-term development needs.

2.2 Supermarket chains distribution centre location model

Supermarket chains distribution centre location is a comprehensive decision problem involving a lot of influence factors, usually distribution centre main consideration when making location decisions are: the natural environment factors; business environment; infrastructure factors; logistics cost factors.

2.2.1 Fundamental assumption

The collection will take place at a location of choice, and select a certain number of candidate locations from which to use as distribution centers, in order to minimize the total cost of the established logistics distribution center and the distribution system formed by the retail supermarkets. Among them, the total cost including the construction or loan the one-time investment of logistics distribution center and devices, variable cost distribution center, distribution center fixed management cost and transport cost, etc. In the multi-step logistics distribution center location modeling, it is also required to integrate the distribution from the production base to the distribution center, it involves two levels of transport, that is, the distribution from the production and planting base to the logistics distribution center, and from the logistics distribution center to the business service networks, this diagram describes a common distribution pattern in a distribution center as shown in Fig. 1.

Therefore, the following hypothesis should be made to establish the location model of distribution centre:

(a) The cost of transporting goods in supermarkets is measured by weight; therefore, consideration should be given to the origin distribution of products from the production and planting base.
(b) The production capacity of the production plant base can meet the demand of the business service networks for the goods sold.
(c) Enterprises can only select the new distribution centre location within a given candidate address.
(d) The products of the base to be delivered can be delivered at one time.

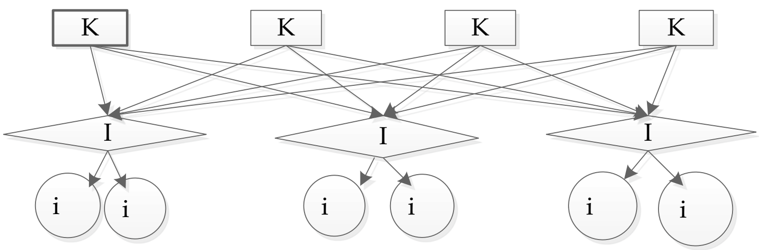


Fig. 1 Distribution centre distribution mode

2.2.2 Construction of logistics distribution centre location model

The purpose of location optimization of logistics distribution centre is to make the operation efficiency of logistics system higher, lower total cost. That should be taken into account in the logistics distribution centre location model set up several distribution centre, distribution centre should choose where each distribution centre which supermarket distribution, etc., are related to the distribution system of service quality and cost. Number of logistics distribution centre, the service level is high, but the cost is large; Logistics centre location and allocation is not reasonable, also can reduce the service level and increase the cost. Logistics distribution centre location problem belongs to the minimum cost problem, namely solving the sum of transportation cost, operating cost is the smallest optimization problem. In general the target function:

Total cost function = fixed cost + transportation cost + variable cost.

The variable cost here refers to the management cost incurred by the logistics distribution center when transporting goods. Many models treat variable cost as a linear function, which is inconsistent with the actual situation; this cannot describe the actual cost of a logistics distribution center, therefore, the calculated optimization scheme is not in accordance with the actual best case. Especially the production base of fresh agricultural products distribution characteristics of small batch, batches, variable costs more than a linear function. Therefore, when considering the variable cost, a parameter λ should be introduced, at this point, the variable cost is $\sum_{k=1}^{L}\sum_{i=1}^{M}\mu_i x_{ki}^{\lambda}$, in accordance with the actual situation of fresh agricultural products distribution, Based on reference (Huang et al. 2015), the parameter of variable cost can be adopted as follows: $\lambda=0.5$. Solving this kind of equation problem often has the property of NP problem, solving such equations is not suitable for applying linear models, function models of equations are often expressed in discrete form. Therefore, should establish a model for fresh agricultural products distribution center, it's a nonlinear mixed 0–1 programming function:

$$\min z=\sum_{i=1}^{M} f_i y_i+\sum_{i=1}^{M}\sum_{j=1}^{N} c_{ij} x_{ij}+\sum_{k=1}^{L}\sum_{i=1}^{M} c_{ki} x_{ki}+\sum_{k=1}^{L}\sum_{i=1}^{M} y_i u_i x_{ki}^{\lambda} \tag{1}$$

$$\text{s.t.} \sum_{i=1}^{M} \mathrm{x_{ij}} \geq \mathrm{a_j} \quad (\mathrm{j}=1,2,\ldots,\mathrm{N}) \tag{2}$$

$$\sum_{k=1}^{L} \mathrm{x_{ki}} \leq \mathrm{b_i\, y_i} \quad (\mathrm{j}=1,2,\ldots,\mathrm{N}) \tag{3}$$

$$\sum_{i=1}^{M} Y_i \leq 0 \tag{4}$$

$$\sum_{j=1}^{N} \mathrm{x_{ij}}=\sum_{k=1}^{L} \mathrm{x_{ki}} \quad (\mathrm{i}=1,2,\ldots,\mathrm{M}) \tag{5}$$

$$\sum_{i=1}^{M} x_{ki} \leq c_k \quad (k = 1, 2, \dots, L) \tag{6}$$

$$Y_i = 0 \; or \; 1, \; (i = 1, 2, \dots M) \tag{7}$$

$$X_{ij} \geq 0, \; X_{ki} \geq 0 \; (i = 1, 2, \dots, M; j = 1, 2, \dots, N; k = 1, 2, \dots, L) \tag{8}$$

The meaning of the symbol: i—Logistics distribution center; j—Chain supermarket; k—Production and planting base. Y_i—Whether the distribution center is chosen to be built, if you build it, it's going to be 1; otherwise it's going to be 0; f_i—Fixed cost of operation of logistics distribution center i, Units: ten thousand Yuan; c_{ij}—From the distribution center i to the supermarket j transport unit price, Units: thousand Yuan; x_{ij}—The amount of transportation from the logistics distribution center i to the chain supermarket j. Units: ton; c_{ki}—From production and planting base k to logistics distribution center i delivery costs, Units: thousand Yuan; x_{ki}—Transportation from supplier k to logistics distribution center i; u_i—Circulation unit price of logistics distribution center i, Units: thousand Yuan; a_j—Demand for business service networks j, Units: ton; b_i—The capacity of logistics distribution center i, c_k—Supply quantity of k in production plant base, Units: ton. M—The number of logistics distribution centers available for selection; N—The number of supermarket chains; L—Number of production and planting bases; O—The maximum number of logistics distribution centers that can be built.

The constraint condition of function (2) shows that the logistics distribution center can meet the distribution requirements of chain supermarket; The constraint condition of function (3) indicates that the quantity of goods transported into logistics distribution center i is less than the capacity of the warehouse; The constraint condition of the function (4) shows that the number of logistics distribution centers i that can be selected cannot be greater than the maximum number of O; The constraint condition of function (5) indicates that the number of goods in and out of logistics distribution center i should be equal; The constraint condition of the function (6) shows that the quantity of goods transported from the production planting base k to the logistics distribution center i is smaller than its production quantity.

3 Results and discussion

From the perspective of the supply chain of supermarket goods, its distribution system including from each set of cargo transportation to distribution center and distribution center for further processing after packaging transported to each supermarket stores, the supermarket goods transport distribution is indispensable to the whole supply chain. But in addition to increasing the cost of transportation for the goods itself, distribution unable to increase the value of the product, therefore, supermarket chains enterprises must to reduce transport distance of goods as much as possible in order to reduce costs. Supermarket goods from production base set after the goods to delivery to the distribution center, generally in accordance with the principle of shortest path, the supermarket has more options for transport routes.

3.1 The principle of business service networks distribution network optimization

3.1.1 Principle of minimum cost

From the distribution center to distribution location path, selection of transport costs increase with the rising of scale distribution path selection, in other words, the scale of distribution route choice, the greater the number, the more the greater the amount of product in transit, accordingly the more investment in the transportation cost. On the other hand, the supermarket will be able to shorten the delivery distance, reducing distribution costs.

The operating fee of distribution path selection, the upkeep fee of in the library, the consignee or consignor processing and distribution of route choice according to the points are ladder shape, the higher the stronghold of the number, the more cost. The total cost curve of logistics is a concave function, that is, to a certain number of points, the total cost of logistics will be along with the increase in traffic and presented down trend, but beyond certain equilibrium, the total cost of logistics will be raised as the extension of transport time.

3.1.2 The principle of simplifying the process

To reduce or eliminate unnecessary process, this is one of the most effective ways to improve the productivity of enterprises and to reduce consumption, when designing distribution path, supermarket should as far as possible in order to direct the finish, and change with the decrease of the intermediate links for the guidelines, so that supermarket can minimize the goods loading and unloading, handling, to ensure the quality of its appearance and damage. On the plan, the supermarket should design a variety of solutions, based on the principle of decision-making optimization, through analysis and comparison, choose the best solution.

3.2 From the production base to the distribution centre of transportation route optimization

In the freight practice of logistics distribution business, there are some different restrictions, this makes the logistics delivery problem more complex, Such as: how transportation tools can be used, each have their own transport capacity and bearing capacity limit; Some or all of the locations opening hours are limited; For vehicle capacity restrictions or other factors, requirements to deliver the goods again, The driver's meals and rest time is also considering range. In practice, it is often an effective way to solve problems by adopting a simple and easy way.

Example 1 Logistics distribution centers need to acquire agricultural products from production and planting bases located in several different locations, then the goods are transported to the logistics distribution center, every production and planting base will have a certain number of products to be shipped every day (See Fig. 2 below). Here, each truck carries 10,000 kg of cargo, and only once a day. The problem with making decisions: How many Lorries does the commercial company need, how to arrange the base order of freight truck transportation products?

3.2.1 A simple approximate solution to task assignment

A simple approximate solution to such problems is:

(a) First of all, the locations of all production and planting bases and logistics distribution centers should be clearly marked in Fig. 2.
(b) Secondly, draw a solid line from the logistics distribution center along a certain direction, the solid line on the right is shown in Fig. 2, and then rotate this solid line, until the solid line passes through the first planting site. If the total loading weight has not exceeded the truck's loading weight, and keep rotating the solid line until it passes through the second planting site; Stop turning the solid line if the total traffic exceeds the weight of the truck, In this way those ahead of the shipment are still below the capacity of the planting base can be set as a zone. According to the above method, the planting bases in this case can be divided into three areas.
(c) Finally, the delivery order should be arranged in each area according to the shortest route requirements. In this case, the TSP model can be used to solve the optimal delivery routes in each region.

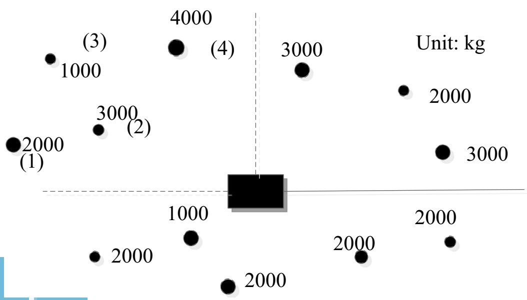
Therefore, three Lorries are required in this example, and the delivery task of each truck as shown in Fig. 2 (i.e., according to the dotted line and a solid line is divided into three parts).

3.2.2 TSP model was used to optimize the distribution route

Now, analyze the upper left region divided in Fig. 2, the TSP model can be used to study and optimize the freight routes in the distribution area:

The TSP model can be described as follows: According to an n vertex business service network given, requires finding a loop contains all the cost of the n vertices of minimum cost (Franceschettia et al. 2017). Each loop containing all n vertices in

Fig. 2 Task assignment



the service network can be regarded as a circuit. Because each circuit is a cycle with all vertices, you can think of any node as a starting point, this is a feature of the TSP problem.

(a) The mathematical expression of the TSP problem:

It has a connected graph H, the vertex set of the model is A, the distance between the vertices in the graph is:

$$\mathrm{c} = \{c_{ij}|i \geq 1,\ j \leq n,\ i,\ j \in N\};\ \min \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

Content:

$$\sum_{j=1}^{n} X_{ij} = 1, i = 1, 2, \ldots, n; \sum_{i=1}^{n} X_{ij} = 1, j = 1, 2, \ldots, n.$$

$$x_{ij} \in |0, 1|, i = 1, 2, \ldots, n; j = 1, 2, \ldots, n$$

$$x_{ij} = \begin{cases} 0, & \textit{there is no pathway from i to j} \\ 1, & \textit{there's a pathway from i to j} \end{cases}$$

When solving the TSP problem equation, if you want to find the exact optimal solution, the easiest way is to enumerate. For small problems, it is also a very effective method. But for the big problem, because the enumeration method list number is $(n-1)!$ Times, it is unimaginable.

At present, heuristic algorithms are mostly used to solve large-scale TSP model problems (Wang et al. 2015b). Heuristic algorithms are not only used for many complex TSP problems, it can also be used for small—and medium-sized vehicle routing problems. The lack of it is that the only guarantee a feasible solution and it is the result of a variety of different heuristic algorithm is not exactly the same. When using heuristic algorithm to solve is how to design the algorithm for solving the results had a greater influence on the precision of a factor. A simple algorithm to solve this problem is the nearest neighbor method.

Suppose the service network contains n nodes, the set of nodes is N, and set the truck to start from node 1, suppose the vehicle runs to the distribution node i, hypothesis:

$N_i = \{2, 3, \ldots, i-1,\ i+1, \ldots, n\}$, This formula represents the collection of all nodes from node 1 to node i.

S is the collection of all the nodes experienced by the journey before the truck runs to node i, the set satisfies: $S \subseteq N$.

Therefore, the point (i, s) can be regarded as a function variable describing the running state, the optimal numerical function $f_k(i, s)$ is set as the shortest distribution path, or collection of node starting from node 1 by k to node i shortest path, represents the path from node 1 through the S collection of k nodes to node i, therefore, the study can find the recursive relation of dynamic programming:

$$f_k(i,s) = \min[f_{k-1}(j, S\{j\}) + d_{ji}],\ i = 1,2,\dots,n,\ S \subseteq N_i,\ k = 1,2,\dots,n-1$$

The boundary condition is: $f_0(i,\phi) = d_{ij}$.

$P_k(i,s)$ Represents the optimal decision function, it starts at node 1 and passes through the S set of k intermediate nodes to reach the node immediately ahead of node i on the shortest path of node i.

(b) In Fig. 2, (1)–(4) the distance between the four production and planting bases is shown in Table 1 below:

It can be seen from the boundary conditions analyzed above:

$f_0(2,\phi) = d_{12} = 8$; $f_0(3,\phi) = d_{13} = 5$; $f_0(4,\phi) = d_{14} = 6$;

When $k=1$, the shortest path for the delivery vehicle to run from the production base 1 through a base to base i is:

$$f_1(2,\{3\}) = f_0(3,\phi) + d_{32} = 5 + 9 = 14\ f_1(2,\{4\}) = f_0(4,\phi) + d_{42} = 6 + 7 = 13$$

In the same way:

$$f_1(3,\{2\}) = 8 + 8 = 16; f_1(3,\{4\}) = 6 + 8 = 14;\ f_1(4,\{2\}) = 8 + 5 = 13; f_1(4,\{3\}) = 5 + 5 = 10.$$

When $k=2$, that is, the shortest path for a vehicle to travel from production base 1 through two production bases to base i is:

$$f_2(2,\{3,4\}) = \min[f_1(3,\{4\}) + d_{32}, f_1(4,\{3\} + d_{42}] = \min\ (14 + 9, 10 + 7) = 17;\ p_2(2,\{3,4\}) = 4$$

In a similar way:

$$f_2(3,\{2,4\}) = \min(13 + 8, 13 + 8) = 21;\ \ p_2(3,\{2,4\}) = 2\,or\,4.$$
$$f_2(4,\{2,3\}) = \min(14 + 5, 16 + 5) = 19;\ \ p_2(4,\{2,3\}) = 2.$$

When $k=3$, that is, the shortest path from the production base 1 to the base i by driving through the three production bases is:

$$f_3(1,\{2,3,4\}) = \min[f_2(2,\{3,4\}) + d_{21}, f_2(3,\{2,4\}) + d_{31},$$
$$f_2(4,\{2,3\}) + d_{41}] = \min[17 + 6, 21 + 7, 19 + 9] = 23,\ \ p_3(1,\{2,3,4\}) = 2.$$

Therefore, the optimal transportation route for delivery truck should be: 1–3–4–2–1, the shortest distance a truck can travel is 23 km.

Table 1 The distance table between planting bases

Distance	1	2	3	4
1	–	8	5	6
2	6	–	8	5
3	7	9	–	5
4	9	7	8	–

3.3 Optimization of distribution routes from distribution centres to chain supermarket

The distribution path from logistics distribution center to business service networks belongs to multi-loop distribution; the optimal distribution route can be obtained according to the VRP model.

3.3.1 Conditions for VRP problems

(a) General conditions: Now let's say distribution center have *m* of the same trucks in a common place, it needs to deliver goods to *n* supermarkets, supermarket chains are $v_1, v_2, \ldots, v_n$
(b) The model considers that the number of trucks needed is *N*, and put the trucks in the middle of a loop, at the same time, there is the vehicle route sequence and scheduling in the loop, finally, the total cost *C* of logistics distribution is minimized.
(c) Restrictive condition:

$N \leq C$; Every order has to be completed; each truck has to return to its original location after completing its mission; do not exceed the capacity limit of the delivery vehicle; special delivery problems should also take into account the impact of time window constraints; restrictions on transportation regulations

3.3.2 Use saving algorithm for VRP problem

The saving algorithm is a very famous heuristic algorithm used to solve VRP model, it is often used to solve VRP problem in the case of uncertainty of delivery truck (the number of delivery truck is a decision variable in VRP problem), this algorithm can be used for both directed and undirected problems (Mohammed et al. 2017). The calculation method is shown in the Fig. 3(1) below, here, *P* represents the address of the logistics distribution center, *A* and *B* represents the address of the supermarket chain, the mileage between nodes is *a*, *b* and *c*. The simplest way of transport is to use two trucks to deliver goods to supermarkets *A* and *B*, in this case, the delivery results are shown in Fig. 3(2) below, the mileage of the truck is $2a+2b$ (assuming no direction). However, suppose a truck is used for itinerant delivery as shown in Fig. 3(3), the mileage of the delivery vehicle

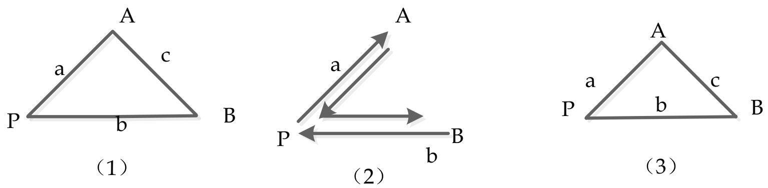


Fig. 3 The choice of distribution center and distribution lines

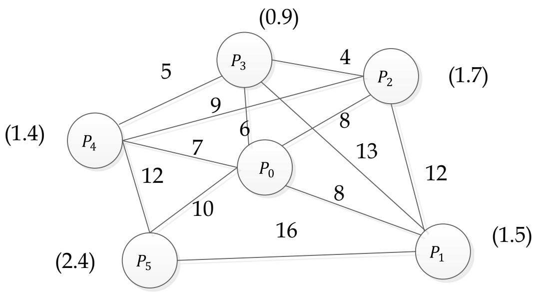


Fig. 4 Distribution center and supermarket stores

Table 2 Distribution vehicle shortest mileage matrix table

	p_0					
p_1	8	p_1				
p_2	8	12	p_2			
p_3	6	13	4	p_3		
p_4	7	15	9	5	p_4	
p_5	10	16	18	16	12	p_5

is $a+b+c$, suppose there is no accident on the way, it can save the mileage of a truck: $(2a+2b)-(a+b+c) = a+b-c>0$, so it's also called the "travel saving method".

In daily business practice, a large number of supermarkets need to deliver goods, therefore, the first step is to calculate the shortest distance between two locations including the distribution center, and then figured out the mileage savings for each of the two supermarkets, each distribution node is connected in turn according to the size of mileage saving, finally, the transportation route is planned (Ricardo and Arturo 2015).

If the logistics distribution center p_0 is responsible for 5 supermarket p_i goods distribution, the distance between its distribution service network distribution center and chain supermarket and the mutual distance between each business service networks is shown in Fig. 4. The figure in brackets is the number of orders (unit: tons) ordered by the supermarket, the number on the line is the distance between two nodes, the logistics distribution center has 2 ton trucks and 4 ton trucks for dispatch, the optimal distribution scheme can be found below.

(a) First step: the shortest distance between nodes is required; Follow the distance between the logistics distribution centre and each chain supermarket as shown in Fig. 4, and the distance between the supermarket chains, the study can find the matrix table with the shortest mileage of the delivery vehicle, see Table 2 below.
(b) Second step: In the shortest mileage matrix table, the travel saved between each chain supermarket can be found, see Table 3 below.
(c) Third step: Arrange the saved miles in order of size, see Table 4 below.
(d) Fourth step: Arrange the list according to the saved route order, and reassemble the road map of the truck.

Table 3 Distribution route to save mileage matrix

	p_0					
p_1	8	p_1				
p_2	8	4	p_2			
p_3	6	1	10	p_3		
p_4	7	0	6	8	p_4	
p_5	10	2	0	0	5	p_5

Table 4 Save the driving distance

Order	1	2	3	4	5	6	7	8	9	10
Route	P_2P_3	P_3P_4	P_2P_4	P_4P_5	P_1P_2	P_1P_5	P_1P_3	P_2P_5	P_3P_5	P_1P_4
Save mileage	10	8	6	5	4	2	1	0	0	0

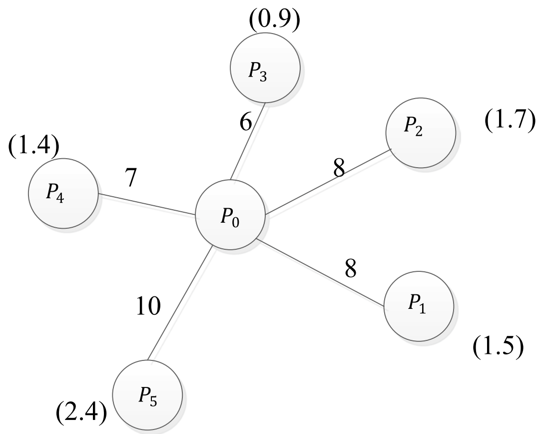


Fig. 5 Initial solution

The initial solution: See Fig. 5 below, delivery from the logistics distribution center p_0 to each chain supermarket. There are five routes, the total mileage is 78 km, four trucks with a load of 2 tons and a 4 tons truck are required.

Secondary solution: Connect $P_2-\mathrm{P}_3$, $P_3-\mathrm{P}_4$, in order according to the saved running distance size (as shown in Fig. 6 below), there are three delivery routes at this time, the total distance traveled is 60 km, it requires one truck with a load of 2 tons and two trucks with a load of 4 tons. This is shown in the figure below, in the optimized distribution route *I*, the load weight is 4 tons and the mileage is 24 km.

Third solution: Sort by how many trips are saved, the adjacent nodes p_4-p_5 and p_1-p_2 in the figure are in the distribution route *I* that can be connected to the secondary solution, however, it is constrained by the load capacity of the delivery vehicle and the mileage of each trip, distribution route *I* can no longer add chain supermarket, so you can't connect p_4-p_5 to p_1-p_2 anymore, but connect the p_1-p_5, finally, it is combined into distribution route *II* (as shown in Fig. 7

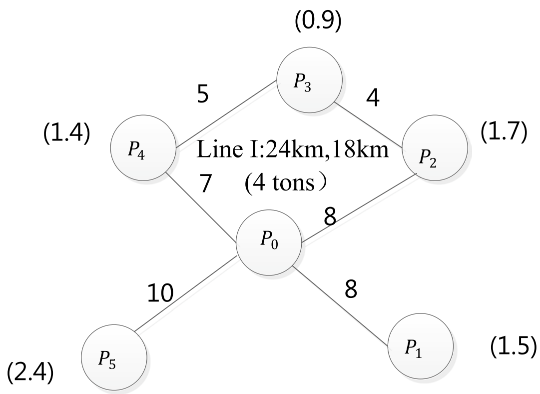


Fig. 6 The second solution

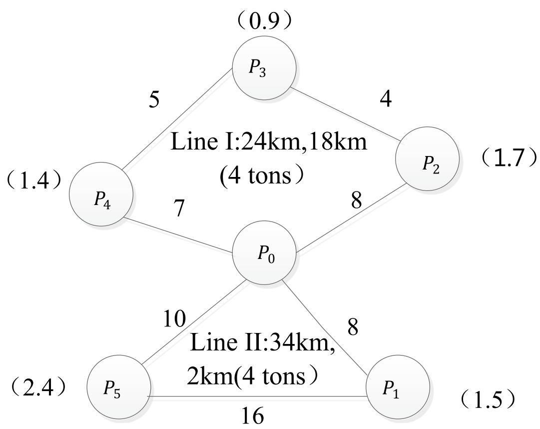


Fig. 7 The third solution

below). The weight on the route is 3.9 tons, and the mileage is 34 km. There are two optimized distribution routes, the total mileage is 58 km, the delivery vehicle here requires 0 trucks with a load of 2 tons, and two 4-ton trucks.

Distribution lines I: $p_0 - p_2 - p_3 - p_4 - p_0$, Traffic: $Q_1 = q_2 + q_3 + q_4 = 1.7 + 0.9 + 1.4 = 4\ tons$.

Arrange the delivery of a 4 ton truck, distribution center save mileage SA = 10 + 8 = 18 km.

Distribution line II: $p_0 - p_5 - p_1 - p_0$, Traffic: $Q_2 = q_5 + q_1 = 2.4 + 1.5 < 4$ tons.

Arranging a truck with a load of 4 tons can save the distance $SB = 2$ km.

Compared to the original individual vehicle delivery, the total mileage of the delivery truck is: $\Delta S = SA + SB = 20$ km.

Table 5 Production plant base to distribution centre unit freight and production capacity

Production plant base	The candidate locations					
	w_1(yuan)	w_2(yuan)	w_3(yuan)	w_4(yuan)	w_5(yuan)	Production capacity
F_1	7	7	8	12	11	40
F_2	14	12	9	6	8	50

Table 6 The unit freight from the distribution centre to the supermarket and the demand

The candidate locations	The supermarket							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
w_1 (yuan)	5	11	3	8	5	10	11	11
w_2 (yuan)	14	16	8	9	4	7	4	4
w_3 (yuan)	10	11	3	5	2	5	9	5
w_4 (yuan)	15	13	9	6	7	2	10	2
w_5 (yuan)	9	7	3	2	6	5	12	8
Demand	10	10	10	15	5	15	10	5

3.4 Numerical calculating results

3.4.1 Analysis of examples

The freight from the production base to the distribution centre and distribution centres to chain supermarket See Tables 5 and 6 below.

For example, a commercial enterprise has 2 production bases in China. According to statistics and pretest analysis, its users are roughly distributed in 8 regions, preliminary plan has 5 distribution centers waiting for the candidate locations: w_1, w_2, w_3, w_4, w_5. It is known that the unit variable fee V_{hj} of the centre of distribution respectively is 75 Yuan, 80 Yuan, 75 Yuan, 80 Yuan and 70 Yuan, the fixed expenses respectively are 1000 Yuan, 1120 Yuan, 1080 Yuan, 1000 Yuan and 1100 Yuan (These values are the fees F_j that are discounted to each day of the payback period). The production capacity of each production base and the specific data of unit freight from the production base to the distribution centre and from the distribution centre to the supermarket are shown in Tables 5 and 6. Paper assumes that: $\theta = 0.5$, $\rho_1 = 0.9$, $\rho_2 = 0.1$ (Freight unit is Yuan/t).

(a) When building multiple distribution centers

According to Tables 5 and 6 and the above calculation steps, the initial solution can be obtained.

Note: the letter w_{j} in () is the distribution center used, and the number in [] is the initial solution to the transportation problem by using the minimum element method.

From Table 7, the calculated results can obtain the new pass-through quantity Z_j^0 in each delivery, w_1 is 25t, w_2 is 10t, w_3 is 30t, w_4 is 5t, w_5 is 20t, then the transport cost is:

$$
\begin{aligned}
Y_{F_0} &= \sum_{h=1}^{q}\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{r}(A_{hij}+B_{hjk})X_{hijk}^0 \\
&= 12*10+18*5+10*10+10*5 \\
&+11*10+15*5+10*15 \\
&+8*15+8*15=935\ (\text{Yuan})
\end{aligned}
$$

Variable fee of distribution center (takes $\theta = 0.5$) is:

$$
\begin{aligned}
V_{F_0} &= \sum_{h=1}^{q}\sum_{j=1}^{m}V_{hj}\left(Z_{hj}^0\right)^{\theta} = 75*\sqrt{25}+80*\sqrt{10}+75*\sqrt{30}+80*\sqrt{5}+70*\sqrt{20} \\
&= 1546.91\ (\text{Yuan})
\end{aligned}
$$

So the total freight and variable costs are: $C_{F_0}=Y_{F_0}+V_{F_0}=2481.91(\text{Yuan})$.

The total cost for: $F_0(X)=0.9*2481.91+0.1*(1000+1120+1080+1000+1100) = 2763.719\,(\text{Yuan})$.

Similarly, the optimal solution is obtained after three operations. Among them, the throughput of each distribution center: w_1 is 30t, w_2 is 10t, w_3 is 0t, w_4 is 30t, w_5 is 20t, w_3 is 0t indicates that there is no need to build the distribution center w_3. Therefore, the total freight and variable costs are:

$$
C_{F_3}=Y_{F_3}+V_{F_3}=1672.1\ (\text{Yuan})
$$

The total cost for:

(b) New construction of a single distribution centre

$F_3(X)=0.9*1672.1+0.1*(1000+1120+1000+1100)=1936.89\ (\text{Yuan})$

New construction of single distribution center is a special case of new construction of multiple distribution centers. Due to the limited number of candidate distribution centers, the comparison method can be applied.

When distribution center w_1 is selected, its transportation cost is:

$$
\begin{aligned}
Y_1 &= \sum_{hijk}(A_{hij}+B_{hjk})X_{hijk}^0 = 7*40+14*50+5*10 \\
&+11*10+3*10+8*15+5*5+15*10 \\
&+11*10+11*5=1630\ (\text{Yuan})
\end{aligned}
$$

Variable costs are: $V_1=\sum_{h=1}^{q}\sum_{j=1}^{m}V_{hj}(Z_{hj}^0)^{\theta}=75*\sqrt{40+50}=711.75\ (\text{Yuan})$.

So the total cost of distribution center w_1 is: $F_1(x)=0.9*(1630+711.75)$ $+0.1*1000=2207.75\,(\text{Yuan})$.

In a similar way,

Table 7 Minimum freight from production base to supermarket

Production plant base	The supermarket							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
F_1	(w_1)	(w_1)	(w_1)	(w_5)	(w_3)	(w_3)	(w_2)	(w_2)
	12 (Ilie-Zudor et al. 2015)	18 (Imai et al. 2006)	10 (Ilie-Zudor et al. 2015)	13	10 (Imai et al. 2006)	13	11 (Ilie-Zudor et al. 2015)	11
F_2	(w_5)	(w_5)	(w_5)	(w_5)	(w_3)	(w_4)	(w_4)	(w_4)
	17	15 (Imai et al. 2006)	11	10 (Schwind et al. 2009)	11	8 (Schwind et al. 2009)	16	8 (Schwind et al. 2009)

Y_2=1580 (Yuan), V_2=758.95 (Yuan), $F_2(x)=0.9*(1580+758.95)+0.1*1120=$ 2217.055 (Yuan),

Y_3=1285 (Yuan), V_3=711.512 (Yuan), $F_3=0.9*(1285+711.512)+0.1*1080=$ 1904.86 (Yuan),

Y_4=1415 (Yuan), V_4=758.945 (Yuan), F_4=2056.55 (Yuan),

Y_5=1325 (Yuan), V_5=664 (Yuan), F_5=1900.07 (Yuan).

By comparing the total cost of the above five distribution centers, it can be seen that the minimum total cost of the distribution center w_5 is 1900.07 Yuan, so choose new construction distribution center w_5.

3.4.2 Model evaluation

The discrete model not only takes into account the transportation cost, but also the fixed cost (including capital cost and fixed economic cost) of distribution center construction and the variable cost caused by operation and management, which is less limited in practical application. From this model, researchers can evaluate the total cost of the circulation process (the sum of freight and distribution fixed fees and management fees). This model can not only calculate the number of optimal distribution centers, but also know the number of pass-through of selected distribution centers (to know the scale of the distribution center). According to the variable cost of distribution center, mass purchase can be adopted. Although the model belongs to the nonlinear mixed integer 0–1 programming, the calculation is simple, this paper deals only with the transportation problem of balance of supply and demand using partial differential to find the minimum value and the addition rule in multi-objective decision analysis, and using computer technology can greatly simplify the solution process. When $\sum_{j=1}^{m} S_j \geq 2$, it can be applied to multiple distribution center locations. In particular, when $\sum_{j=1}^{m} S_j=1$, it can be applied as a single distribution center location model, and the optimal solution can be obtained by using comparative method. Finally, because it belongs to discrete model, it can make up for the insufficiency of continuous model.

The disadvantage of this model is that the parameter θ of the logistics distribution center can be determined more accurately when there is sufficient actual data. Otherwise, it needs to be assumed; the benefits and efficiency of the distribution center are not reflected, weight coefficients are not easy to determine, the cost function can be improved, although it can be determined on the basis of experience and sufficient actual Numbers.

3.5 Business service networks inventory management decision support logistics information system

3.5.1 The overall analysis of decision system

The traditional supermarket retail enterprise inventory management focuses on the optimization of the single product inventory cost, embarks from the storage costs and ordering costs to determine the economic order quantity and order point there is information transmission timeliness and accuracy of the outstanding problems, this makes the traditional inventory decision auxiliary decision-making effect is not satisfactory. Inventory decision support system is based on inventory management logistics information system; it makes full use of information technology, timely and accurately reflect the current inventory situation, the customer's demand, accurate management accounts, and cited a lot of mathematical model, to analysis all kinds of large amounts of data statistics and decision, provides information to decision makers with demand forecasting and demand analysis of the required information. Supermarket chains enterprise inventory management decision support logistics information system of main modules and their functions as follows:

(a) Model analysis and processing module. According to users service level analysis of the current inventory management and form a decision, which can be established based on the intelligent decision-making logistics information system of knowledge.
(b) Data information management module. Including inventory, outbound information, inventory information management, provide inventory reaction model.
(c) System management module. This module includes operations management, file management, storage administration, equipment management, and process management.
(d) The human–computer interaction module. The module using a variety of modern information technologies, friendly man–machine interface, and have the function of online help.
(e) Communication module. The module can realize inventory management logistics information system with supplier and other resource sharing and information exchange between the management systems, the electrons in decision-making coordination board have played a role in conflict resolution.

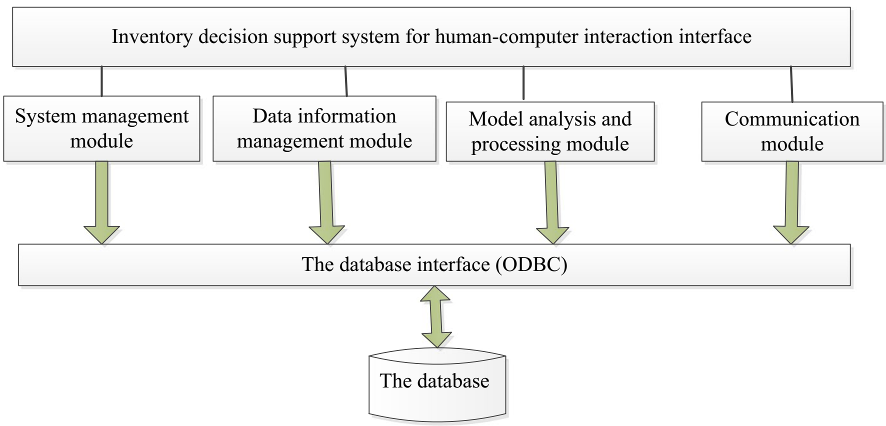


Fig. 8 General structure of business service network inventory decision support system

The overall structures of the inventory decision support logistics information system are shown in Fig. 8:

In the supermarket chains enterprise inventory decision support system, model base occupies the dominant position, other each subsystem according to the model and algorithms library data requirements. In the information system to provide the vendor information, goods and demand data, on the basis of system adopts the model and algorithm interactively with decision makers to make decision problem, thus greatly improve the degree of decision-making science, at the same time, on the premise of a certain decision rules, also can realize dynamic automation management of daily operation scheme.

3.5.2 The analysis of the model database management system

Model database management information system is mainly based on user calls by the analysis of the decision-making unit model, sent to the database management system call instruction about the model input parameters. Database management system according to the instructions, extract the corresponding data information from the database and passed to the model base management system, and in the model database management system to complete the tasks of decision analysis its analysis results can also be passed back to the stored in the database. As described above, the supermarket to live fresh product inventory replenishment strategy belongs to the category of multi-stage replenishment of inventory control. In fact the supermarket distribution network can be simplified as two levels of logistics information system, including distribution centers and retail stores.

3.5.3 The realization of the business service networks inventory management decision-making system

Supermarket chains enterprise inventory management decision support logistics information system has to be a network management information system; the transmission is a network of information transfer process and more sources of feedback, using WEB technology and COM/DCOM standard, in order to realize the information sharing between a cross-platform heterogeneous systems. System can use the client browser, WEB application server, database server; constitute an open system of three-tier client/server applications.

The decision support system of business service network needs to be built the community integration information service platform. The comprehensive information service platform is made up of such primary platforms as system, technology, data and network. Business service networks inventory management decision-making system using Microsoft Visual Studio.NET development platform, using Microsoft SQL Server as the database Server, and can support a variety of database connection. Considering the various types of database software application in current business, in order to make the system have a wide range of applicability, the system adopts ODBC database interface, it can with arbitrary ODBC driver database management system, does not need complex data conversion operation. At the same time, the business logistics service enterprises only need to change the system data source connection, another inventory system can be used for decision making.

4 Conclusion

In this paper, only logistics distribution center, supermarket business outlets, production and planting bases and other commercial service network nodes are selected for simple optimization analysis. Production base of fresh agricultural products in order to reach the goal of keeping fresh, for quick into consumer link, in circulation link, the less the better, because of the freshness and edible safety of fresh product is its value. But the dispersion of fresh products on the production and consumption in the circulation of inevitably to be one or more of the commodity distribution. With the development and application of information technology and automation equipment, the combination of multi-functional information platform and commercial outlets will provide better service of node integration.

Now the personage of course of study of business service network already had carried on thorough research, various optimization models are established, transportation costs usually assume that freight rate with the increase of transport is proportional to the distance, However, most of the freight is by changing with distance fixed part and not change with transport distance of variable parts; Model between logistics center and the other nodes in the path is usually assumed to straight line, actually so rarely. At present, there are few researches on the optimization information technology of the comprehensive distribution path of agricultural products in supermarkets based on the construction of logistics information systems; it is still at the stage of research and discussion on the mode of connecting urban commercial service network and rural commercial service network, it needs to be further studied by experts and scholars.

Acknowledgements The research presented in this paper was supported by Beijing Jiaotong University, China.

Authors' contributions Chao Yin is the main writer of this paper. He proposed the main idea, deduced the business logistics distribution network node integration, and analysed the result. Mingyu Zhang introduced the TSP algorithm in the distribution route optimization. Yihua Zhang showed that establish integrated information service system. Wenbing Wu gave some important suggestions for using modern heuristic algorithm is used to solve the path problem. All authors read and approved the final manuscript.

Funding The authors acknowledge the National Social Science Foundation of China (Grant: 15ZDA022), and Major project subject of NSFC: urban logistics management (Grant: 71390334).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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