RESEARCH ON LOGISTICS LOCATION OPTIMIZATION MODEL BASED ON TIME DIMENSIONS

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Abstract: The classical logistics facility location models seldom lay emphasis on time, which is a critical issue for a company to gain its competitive advantage nowadays. Some scholars study maximal covering location problem based on time-satisfaction, but most of them have not taken the consumption of time cost into account. This paper presents a new location model which incorporates time cost compared with previous approaches of time satisfaction. The model is initially developed based on the integer programming, whose objective function is subject to the maximization of total satisfaction and the minimization of total cost. Finally, it makes precise analysis taking the case of a regional network layout optimization. The computational result proves the feasibility and value of this model in its practical application.

1 INTRODUCTION

The competition advantage in Modern logistics is focused on how to access to consumption with the fastest speed, the shortest distance and lowest cost under the premise of the satisfaction of individual customer needs by distribution channels. So logistics siting problem in logistic distribution centre is an important part of the entire product supply chain optimization.

The economic globalization and international competition augment the frequency of location decisions because of shortened product life cycles. On the other hand, the decisions on the siting problem have a growing impact on competitiveness of enterprises. With the progress of information technology and developing of logistics and supply chain management in recent years, making location decisions has become a corporate capacity trained for business and part of changing tactical decisions. Sometimes it is usually structured to support the organization's daily scientific decision-making. Therefore, the academics and managers pay close attention to how to solve the location problem by analysing, classifying, modelling and calculating (Bo et al, 2008).

Nowadays, time is on the cutting edge. Time will become the next competitive resource advantages. Time-based competition can be a strategic tool to gain success in many industries, especially in logistics industry. Especially in delivery of perishable goods and emergency services, time is even more obvious. For the pursuit of zero-time response to customer demand, siting problem of various service facilities cannot be an overlooked factor. The conventional location models of logistics facilities have a time constraint or use time as the main target elements, but it is still too simplified to define time. Usually enterprises look on time of customers demand from its own perspective, not from the customer itself. It did not fully reflect the importance and differentiation of time required by people in the 21st century.

Based on the background herebefore, time is even more obvious. Therefore, time effect should be fully taken into account in the location decision-making process of logistics distribution centre as the key factors. Thus, this paper introduces time into location model of logistics distribution centre. We propose time is not considered in isolation and shortening the time without condition is not scientific. It should define and model time from the perspective of the customer. In this model, we consider not only maximizing total time satisfaction, but also minimizing total cost of time. The time satisfaction mentioned in this article means the customer satisfaction of responding to the needs of the time required. The time cost is the cost consumed by logistics services for customers in order to satisfy their needs.
2 LITERATURE OVERVIEW

With the growing attention on logistics industry, more and more enterprises are starting to focus on logistics facilities location problem. Logistics facility Location is a very old and classic problem, developing of the foreign research can be divided into three stages with different focus (Brandeau and Chui, 1989).

① Fragmented Research Stage

This stage was from 1909 to 1960. It focused on solving a variety of practical problems in production and daily life. The mainly representatives was the German economist Alfred weber. He considered a single warehouse location problem is to determine the location, so that total transportation distance is the shortest between warehouse and customers. Hotelling proposed location of two competing suppliers in a straight line and built related models in 1929. Then Smithies, Stevens studied this problem in more depth. Regional economist Isard also analysed the choice of industrial location from the perspective of land use, input and output.

② Systemic Research Stage

Hakimi went into more theoretical issues of research on the site in 1964. For selecting for the network location of one or more facilities, he considers it should make the total distance or the distance between facilities minimum. Since then, the location problem was introduced into a broader area. After that, the location problem of Production centre, the transport hub and substation was researched in succession.

③ Uncertainty Research Stage

So far into the 80s of last century, along with great changes in the market, the static and deterministic location model cannot meet the development of location method. Louveaux, Mirchandani, Weaver, Church and other scholars let the transport time and demands as random variables on the issue of uncertainty median. Berman and Odoni, Berman and Leblanc let the time or transportation costs as uncertain system variables to study the traffic problem in random networks (Owen and Daskin, 1998).

The existing literatures mainly consider the location problem of logistics from the perspective of minimizing the cost and the time, but research on location model of logistics facilities and distribution considered by satisfying customer needs is not too much. Logistic is a typical service industry, customer satisfaction must be put in the first place. At the same time, it is an important factor to determine customer satisfaction. The aim of introducing the concept of time satisfaction to location model of logistics distribution centre is to ensure location of services and facilities is consistent with strategic goals and business objectives and the expectations of customers, but few studies take into account the cost of time caused by satisfying customer needs when time satisfaction is considered in the model.

3 OPTIMIZATION MODEL TO LOGISTICS LOCATION

PROBLEM

This siting model is formulated to solve location problem of logistics distribution centre, so as to maximize a range of benefits. In this model, we employ the Ma Yun-feng TSBMCLP model to calculate the time satisfaction and establish the frame of the time cost. We formulated model as an integer programming under the goal of maximizing the total satisfaction of customers and minimizing the total cost to the service facility’s response time, which builds respectively from the points of cost and benefit (Daskin, 1995). The above-mentioned model is given as follows:

3.1 Notations

$I_{ij}$ The shortest waiting time accepted by customers between the service demand point $i$ and the primary service point $j$.
$c_{ij}$ Transportation cost per unit between service demand point $i$ and the primary service point $j$. It is proportional to the shortest distance between two points.
$L_i$ Acceptable maximum waiting time between primary service demand point $i$ and secondary (and lower class) service points when customers feel very satisfied.
$U_i$ The shortest waiting time between service demand point $i$ and secondary (and lower class) services point when customers feel very dissatisfied. $L_i \leq U_i$.
$c_i$ Field processing costs per unit in primary service point $j$ when customers feel satisfied, including the cost of cargo handling, sorting and etc.
$h_i$ Demand of service demand point $i$.
$P$ Number of primary service points.
The ratio of the time and cost, it completes conversion of time and cost. Its value depends on specific situation. For example, if the enterprise is more concerned about customer satisfaction and weaken the concern of cost, \( \lambda \) will be a smaller value.

\( f(t_i) \) The satisfaction level of response time between the secondary (and lower class) service point \( i \) and primary service point \( j \).

The curves of time satisfaction function is of a variety of situations, many functions can be used to represent the satisfaction of time (Yun-feng et al., 2006). In this paper, we use linear function of time-satisfaction, for all \( f(t_i) \in [0,1] \).

\[ \begin{align*}
\text{If} & \quad t_i < L_i, \quad f(t_i) = 1; \quad \text{if} \quad t_i > U_i, \quad f(t_i) = 0; \quad \text{if} \quad t_i \in [L_i,U_i], \quad f(t_i) = \frac{U_i - t_i}{U_i - L_i}.
\end{align*} \]

3.2 Formulation of the Model

In a network \( G(V,A) \), \( V \) is a vertex set, \( |V| = n \), \( A \) is an edge set \( i \in I, \ j \in J \). We define \( I \in V \) is total subscript set for the set of service demand points and \( J \in V \) is total subscript set for the set of primary service points, \( I \cup J = V \). The model can be formulated as follows:

\[ \begin{align*}
\text{Max } z &= \sum_{i \in I} \sum_{j \in J} c_{ij} Y_{ij} - \lambda \sum_{i \in I} \sum_{j \in J} c_{ij} Y_{ij} - \lambda \sum_{i \in I} \sum_{j \in J} h_{ij} Y_{ij} \\
\text{s.t.} & \quad \sum_{j \in J} X_{ij} = 1 \quad \forall i \in I \tag{2} \\
& \quad \sum_{i \in I} X_{ij} = p \tag{3} \\
& \quad Y_{ij} - X_{ij} \leq 0 \quad \forall i \in I, \ \forall j \in J \tag{4} \\
& \quad X_{ij} = 0,1 \quad \forall j \in J \tag{5} \\
& \quad Y_{ij} = 0,1 \quad \forall i \in I, \ \forall j \in J \tag{6} \\
& \lambda \geq 0 \quad \lambda \in N \tag{7}
\end{align*} \]

The objective function is to maximize actual satisfaction of services demand, while ensure the minimum cost of time. A weight is given to \( \lambda \) relative to the preference of the logistics enterprises. Constraints (2) ensure every demand point is serviced by the only one service point (this service point can provide the best time satisfaction). Constraints (3) ensure number of service point is \( P \). Constraints (4) limit the satisfaction of demand points by establishment of service stations (if service station is not established, the service satisfaction of it is zero). Constraints (5) and (6) are the 0-1 Constraint.

Decision variable is seen as follows:

\[ \begin{align*}
X_{ij} &= \begin{cases} 
0 & \text{not set up a service at point } j, \forall j \in J \\
1 & \text{set up a service at point } j, \forall j \in J \\
0 & \text{customers at point } i \text{ do not accept} \end{cases} \\
Y_{ij} &= \begin{cases} 
1 & \text{customers at point } i \text{ accept the service from point } j, \forall i \in I, \forall j \in J \\
0 & \text{the service from point } j, \forall i \in I, \forall j \in J \\
0 \text{ customers at point } i \text{ do not accept} \end{cases}
\end{align*} \]

3.3 Solving the Model

The specific target of this model is to maximize total satisfaction of secondary (and lower class) service points covered by primary service points, while reducing the cost of it. The relevant algorithm is proposed to solve the problem. With the introduction of time satisfaction function, location model will be more flexible and effective (Gen-gui and Yan-fei, 2008). At the same time, it will increase the complexity of the algorithm. According to adjusting classical algorithm of current location model, the time-based location model can be solved. The greedy algorithm, Ant colony algorithm, genetic algorithm, tabu search algorithm, artificial neural networks method and simulated annealing method can be adjusted to solve such problems. Linear programming software can also be used for solving of Small-scale problems, such as lindo and lingo (Yong, 2008).

4 APPLICATION TO A CASE STUDY

4.1 The Case

In order to verify the feasibility of modeling, we apply this model to solve and optimize an actual location problem. Company A is a large private express delivery companies. It forces on customer-oriented strategy, which pays close attention to customer service and level of customer satisfaction. A has three primary services points in East China (respectively in Shanghai, Wuxi, Hangzhou) and twenty-four secondary service points. Its annual throughput of 591,000 tons is also the forefront of all regions. According to the above analysis, there is an obvious and typical site layout problem in the region of East China. We number twenty-seven service points, and the defined number and Throughputs of twenty-seven service points in East China are given in Table 1:

<table>
<thead>
<tr>
<th>Service Point</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai</td>
<td>100,000</td>
</tr>
<tr>
<td>Wuxi</td>
<td>80,000</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>120,000</td>
</tr>
<tr>
<td>Company A</td>
<td>591,000</td>
</tr>
</tbody>
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</table>
### 4.2 Solving of Case

#### ① Numbering

In the given network $G(V, A)$, $|V| = n = 27$. Shanghai, Hangzhou, Wuxi are three original primary service points among them, so their current handling capacity ranks first in major cities in East China. After considering the fixed costs of set up a new primary service point, carrying capacity of cities and distribution of airports, we assume Shanghai, Hangzhou and Wuxi are candidate primary service points. $X_j$ is set as follows:

$X_1$: Primary service point in Shanghai;
$X_2$: Primary service point in Hangzhou;
$X_3$: Primary service point in Wuxi;

Actually, A Company has realized two location problems: ① the layout of three primary service points mentioned above is not suitable; ② the scope of their distribution is not unreasonable because the relatively distance between them is short. Therefore, we reduce number of primary service points. We assume $p = 2$.

#### ② Time-satisfaction Function $f(t_{ij})$

If $V$ is the average speed and $S_{ij}$ is the distance between two service points, $t_{ij} = \frac{S_{ij}}{V}$. The time can be figured out by the linear distance between two service points. $S_{ij}$ is showed in Table 2:

<table>
<thead>
<tr>
<th>Distance $S_{ij}$</th>
<th>Shanghai $X_1$</th>
<th>Hangzhou $X_2$</th>
<th>Wuxi $X_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>km</td>
<td>120.3</td>
<td>188.7</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 2: The distance between primary service point i and secondary service point j.
Table 2: The distance between primary service point \(i\) and secondary service point \(j\) (cont.).

<table>
<thead>
<tr>
<th>Distance (S_{ij})</th>
<th>Shanghai (X_1)</th>
<th>Hangzhou (X_2)</th>
<th>Wuxi (X_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suzhou Wuzhong</td>
<td>79.3</td>
<td>144.8</td>
<td>45.7</td>
</tr>
<tr>
<td>Nantong Yongxing</td>
<td>115.8</td>
<td>237.6</td>
<td>127.7</td>
</tr>
<tr>
<td>Wuxi Shuofang</td>
<td>112.1</td>
<td>170.2</td>
<td>13.4</td>
</tr>
<tr>
<td>Jindong</td>
<td>298.8</td>
<td>133.5</td>
<td>326.2</td>
</tr>
<tr>
<td>Yiwu Heye Tang</td>
<td>256.3</td>
<td>93.5</td>
<td>261.3</td>
</tr>
<tr>
<td>Huangyan</td>
<td>233.4</td>
<td>70.5</td>
<td>248.5</td>
</tr>
<tr>
<td>Keqiao</td>
<td>184.6</td>
<td>38.5</td>
<td>211.3</td>
</tr>
<tr>
<td>Zhujul</td>
<td>217.4</td>
<td>55.3</td>
<td>241.5</td>
</tr>
<tr>
<td>Shaoxing Donghu</td>
<td>201.2</td>
<td>47.6</td>
<td>225.8</td>
</tr>
<tr>
<td>Xiaoshan</td>
<td>165.8</td>
<td>17.5</td>
<td>187.7</td>
</tr>
<tr>
<td>Xiacheng</td>
<td>167.4</td>
<td>25.0</td>
<td>183.2</td>
</tr>
<tr>
<td>Changzhou HengshanBridge</td>
<td>142.0</td>
<td>188.2</td>
<td>28.1</td>
</tr>
<tr>
<td>Nanjing Guanghua</td>
<td>271.6</td>
<td>248.4</td>
<td>158.5</td>
</tr>
<tr>
<td>Zhenjiang Danyang</td>
<td>197.7</td>
<td>228.5</td>
<td>82.7</td>
</tr>
<tr>
<td>Huaian Wangying</td>
<td>356.4</td>
<td>423.4</td>
<td>271.6</td>
</tr>
</tbody>
</table>

Data is measured by Google Maps

3. The Cost

The value of cost parameters \(c_j\) and \(c_y\) is given by the actual data analysis. \(c_j = 34.3\) and \(c_y = 35.4\).

We assume customers can accept service provided by primary service points and secondary service points in East China. So the time-satisfaction is not zero. According to customer-focused strategic analysis of private express delivery companies, we give same weight to time and cost. \(\lambda = 0.014\).

4.3 Illustrative Results and Analysis

We solve this model based on the branch and bound algorithms and lingo software. The lingo result showed as follows:

1. \(\text{Max } z = 36.234\)
2. The site selection resulting of primary service point is A transit output is \(X_1, X_2, X_3\). The final selection is Hangzhou and Wuxi. Shanghai is changed into secondary service point. The specific service scope is showed in Figure 1.

5 CONCLUSIONS

This paper discusses location model of logistics distribution and service centre based on time dimensions. The main value added of this study is the development of the new location model, in which, both time satisfaction and time cost are taken into account. We formulated the model as an integer programming under the goal of maximizing the total satisfaction and minimizing the total cost. According to analysing the optimized layout of regional networks which is solved by this model, we confirm the model has usage value for the location problem of logistics facility. Nevertheless, a more research is needed to develop the model. The following step of this research could be to replace a part or all of relevant expressions about transportation cost with time cost accurately in objective function or constraints. At the same time, more factors need to be considered in this model so as to reflect actual situation.
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