Research on Distribution Route of Electricity Supplier Logistics Based on the Customer's Hidden Cost

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ABSTRACT: The rise of e-commerce makes green logistics increasingly important role. Combined with the characteristics of logistics distribution under the new e-commerce, the distribution route choice model was established. Based on lowering the total distribution cost and shortening delivery time, the paper proposes the idea to improve customer satisfaction. In calculating the total cost of the process, while taking the vehicle start-up cost and vehicle cost into account, the concept of hidden cost was proposed, that is a kind of penalty cost due to customer dissatisfaction. In solving the model, determine the weight of each objective function by maximizing deviations, transfer the multi-objective functions into a single objective function which is relatively simple. Finally, take use of specific examples to drawn weights.

1 GENERAL INSTRUCTIONS

With the rapid development of communication and network technology, e-commerce has become very active in new commodity trading patterns, which greatly promoted the development of logistics industry in China[1-4]. However, in recent years, promotional activities in large scales that electricity enterprises planned put forward higher request to logistics enterprises, such as highly anticipated online shopping festival in November 11, 2015, Alibaba group sales in 91.2 billion yuan, Suning Tesco open platform sales up 358% from a year earlier, the sales of Vipshop reached up to 1.038 billion yuan. The accumulation of a large number of orders in a short time sharply increased the pressure of logistics distribution, which undoubtedly brings new opportunities and challenges to logistics.

Distribution route choice is the crucial link in logistics system, it is of great practical significance in reducing costs, improving service quality, maximizing benefit efficiency, optimizing resource allocation and enhancing urban comprehensive competitiveness. And previous scholars conducted related research for such problem[5-8]. Reference [7] on the premise of the use of the vehicle to minimize number to establish the minimum distribution costs as the objective function of optimization model, and a tabu search algorithm is designed. Model in Reference [8] took the value of time and quality of time as key consideration, and proposed hybrid genetic algorithm based on tabu search solution to logistics and distribution route optimization under the e-commerce environment. To meet customer demand as the prerequisite condition, the establishment of model in Reference [9] took distribution costs minimized as the objective function, time, space and quality as constraint, then designed a tabu search algorithm. It is easy to see from the previous research, in the process of traditional model build, simply from the perspective of explicit cost when calculating distribution costs as the breakthrough point, ignoring the hidden cost the customer satisfaction may increase. However, when the logistics companies through large-scale development to meet the quantity requirements, the quality of service will indirectly affect its effectiveness. In addition, the traditional model considering the human factors too much for the weight of each objective function, while weakening the objective conditions of route choice problem, which influenced distribution service effect, and need to be analyzed and solute in depth.

Therefore, this paper combined the characteristics of logistics distribution for the new e-commerce model, established distribution route choice model considering the penalty cost that customers bring, and took use of maximizing deviations to weaken the influence of subjective factors in solving the objective function weights.
2 ELECTRICITY SUPPLIER LOGISTICS
ROUTE CHOICE MODEL

2.1 Problem description and the assumptions of the model

Due to the difference between e-commerce distribution and traditional distribution lies, the former pays more attention to rapid response to meet the command of providing customers with personalized and value-added services in the increasingly competitive environment \cite{10-11}. Distribution route selection and vehicle scheduling is the core of the logistics distribution system, how to solve the problems in the logistics distribution existing in the e-commerce mode and reflect the optimization of advanced management concept, as well as how to find an equilibrium among reducing logistics costs, shortening delivery time, and improving customer satisfaction, are the problems what this paper want to solve.

In response to these new features extending in the traditional distribution, the basic idea of logistics distribution route choice model can be described as, a logistics distribution system has a unique distribution center, in which there are a number of transport vehicles. These vehicles are starting from the distribution center for cargo delivery to customers located in different places, the vehicle must be returned to the distribution center after the completion of the distribution task. Among them, the relationship between the vehicle and the customers for a one-to-many relationship, namely a car service multiple clients, and a customer can be serviced only once by one car. There is a certain constraint on the demand of customer for commodity quantity and service time allowed. In the case of satisfy the constraint conditions, to seek for the routes that meet the need of lowest distribution costs, largest time efficiency and highest customer satisfaction.

In order to establish the model more strictly, this paper will make the following assumptions:

1. The logistics distribution system has a unique distribution center, in which there are a number of transport vehicles. These vehicles are starting from the distribution center and returning back after the distribution finished.

2. In the same car allows the loading of the different types of goods.

3. The commodity quantity from the customers demand does not exceed the maximum load of the distribution vehicle.

4. The weight and volume of all the vehicles must be certain and it does not allow overloading.

5. One delivery place can be distributed only once by one car and one car can distribute goods to multiple locations.

(6) The customers' delivery location, commodity quantity, the ranges of delivery time and the distance between each customer point are known previously.

(7) Regardless of the transport network in the vehicle flow restrictions.

2.2 Construction of the model

When select the distribution route under ecommerce mode, based on three objectives of reducing total logistics costs, shortening delivery times and increasing customer satisfaction, the model of distribution route choice problem with multi-objective programming function is to set up.

The decision variables of the model are as follows:

\[
x_{i,j,k} = \begin{cases} 
1, & \text{vehicle } k \text{ from } i \text{ to } j \\ 
0, & \text{otherwise} 
\end{cases}
\]

\[
y_{i,k} = \begin{cases} 
1, & \text{customer } i \text{ serviced by vehicle } k \\ 
0, & \text{otherwise} 
\end{cases}
\]

2.2.1 Total distribution cost

When the objective function is the pursuit of the lowest total distribution cost, considering the total cost mainly consists of two parts, namely transportation cost and penalty cost\cite{12-14}, which are respectively calculated by the equation (1) and (2), where the transportation cost include vehicle start-up cost and running cost, while penalty cost is related to customer satisfaction.

\[
TC = c_1 \sum_k \sum_i \sum_j d_{ij} x_{i,j,k} + c_2 \sum_k \sum_j x_{i,j,k} \lambda 
\]

\[
PC = \sum_i \frac{\lambda}{F_i(t_i)} 
\]

where \(E\) represents the set of customer distribution node, namely \(E=\{e\}\), it means distribution center when \(e=0\). \(i\) and \(j\) are any two customers, namely \(\forall i \in E, \forall j \in E\). \(K=\{k\}\).TC represents total transportation cost. \(c_i\) is transportation cost of unit distance. \(d_{ij}\) is the distance between customer \(i\) and the next customer \(j\). \(c_2\) is vehicle start-up cost. \(PC\) represents penalty cost, the additional expenditure caused by customer dissatisfaction. \(\lambda\) is penalty coefficient. \(F_i(t_i)\) represents satisfaction function.

2.2.2 Total delivery time

When the objective function is the pursuit of the shortest total delivery time so that efficiency is maximized, considering the total delivery time consists of the time that distribution vehicle need to
a customer and service time for the customer. The
time that distribution vehicle need to a customer is
given by equation (3) and service time for the
customer can be obtained by measuring.

\[ T_j = \alpha \times T_i + \beta \times ST_i + \gamma \times DT_i \quad \forall i \in E, \forall j \in E, \forall k \in K \]  

(3)

where \( T_j \) is the time that distribution vehicle arriving to the customer \( j \). \( T_i \) is the beginning time that distribution vehicle serves customer \( i \). \( ST_i \) represents service time for customer \( i \). \( DT_i \) is the travel time of distribution vehicle from customer \( i \) to \( j \).

2.2.3 Customer satisfaction

When the objective function for the pursuit of the
highest customer satisfaction, the satisfaction
function is defined as follows.

\[ F_i(t_i) = \begin{cases} 
\left( \frac{t_i - E_i}{e_i - E_i} \right)^{\alpha}, & E_i < t_i < e_i \\
1, & e_i \leq t_i \leq l_i \\
\left( \frac{L_i - t_i}{L_i - l_i} \right)^{\beta}, & l_i < t_i < L_i \\
0, & \text{otherwise}
\end{cases} \]  

(4)

where \( t_i \) is the beginning time of service for
customer \( i \), the lower and upper limit of fuzzy time
windows of customer \( i \) are respectively \( E_i \) and \( L_i \).
\( \alpha \) and \( \beta \) are customer sensitive coefficients of
time. When a customer get the distribution service in
desired service period \([e_i, t_i]\), its satisfaction reaches
up to 1, otherwise, satisfaction with the gap between
the actual service time and the desired time increases
lower.

Based on the above analysis, a multi-objective
programming function for distribution route
selection model is set up as follows.

The objective functions:

\[ \begin{align*}
\min f_1 &= TC + PC \\
\min f_2 &= \sum_i T_i + \sum_i ST_i \\
\max f_3 &= \sum_i \alpha F_i(t_i)
\end{align*} \]  

(5) (6) (7)

where \( \alpha \) represents weight of satisfaction function.

The constraint:

\[ \sum_j q_{i,j} y_{i,j} \leq Q \quad \forall h \in H, \forall k \in K \]  

(8)

where \( H \) is the set of distribution goods, \( H = \{ h \} \).
\( q_{i,j} \) is the quantity of goods \( h \) that customer \( i \)
demands. \( Q \) represents the maximum load of Given
type vehicle \( k \).

\[ \sum_j b_{i,j} y_{i,j} \leq B_k \quad \forall h \in H, \forall k \in K \]  

(9)

where \( b_{i,j} \) is the volume of goods \( h \) that customer \( i \)
requires. \( B_k \) represents the maximum load volume
of Given type vehicle \( k \).

\[ F_i(t_i) \geq \theta \quad \forall i \in E \]  

(10)

where \( \theta \) is the set minimum value of customer
satisfaction.

\[ \max(T_i, U_i(\theta)) \leq t_i \leq L_i(\theta) \quad \forall i \in E \]  

(11)

where \([U_i(\theta), L_i(\theta)]\) represents service time window
based on the lowest customer satisfaction.

\[ \sum_i y_{i,j} = 1 \quad \forall i \in E \]  

(12)

\[ \sum_j x_{j,k} = y_{i,k} \quad \forall j \in E, \forall k \in K \]  

(13)

\[ \sum_j x_{j,k} = y_{i,k} \quad \forall i \in E, \forall k \in K \]  

(14)

Under the mode of e-commerce, the model of
logistics distribution route choice seeks for three
goals that explained by equation (5) - (7).

In the above constraints, equation (8) represents
quantity constraint, the total quantity distributed by
same vehicle shall not exceed the maximum load of
vehicle. Equation (9) represents space constraint, the
total volume distributed by same vehicle shall not
exceed the maximum load volume of vehicle.
Equation (10) represents satisfaction constraint,
customer satisfaction is not less than the set
minimum value. Equation (11) represents the constraint on the beginning service time of the vehicles for the customer under a certain satisfaction where \( U_i(\theta) = 1 - \theta^{\frac{1}{\alpha}} e_i + \left[ 1 - \theta^{\frac{1}{\alpha}} \right]^* E_i \) and  
\( L_i(\theta) = \theta^{\frac{1}{\beta}} I_i + \left( 1 - \theta^{\frac{1}{\beta}} \right)^* L_i \). Equation (12) represents each distribution task must be completed, and it only can be performed by one vehicle. Equation (13) and (14) represents each customer will be serviced by one vehicle and only once.

3 MODEL SOLUTION AND EXAMPLE ANALYSIS

3.1 Model solution

3.1.1 Determine weights of multi-objective function

In the process of logistics distribution route selection which under the mode of e-commerce, in order to solve the model of multi-objective programming more easily, the multi-objective function can be transformed into a single objective function, then to solve a single objective function. In solving process, the method gives different weights to the objective function, which reflects the various index proportion in the decision, make the equilibrium among the three more accurate.

Suppose given m schemes and n factors when selecting the best route, \( V \) represents the prospect value of the m-th scheme on the n-th factor. About the prospect decision matrix, the deviation among decision scheme \( a_i \) and all the other decision-making schemes is

\[
L = \sum_{i=1}^{m} \sum_{j=1}^{n} d(V_i, V_j)w_j \tag{15}
\]

where \( d(V_i, V_j) = \sqrt{(V_i - V_j)^2} \).

According to the idea of maximizing deviations, weight should make the sum of the total deviation on all decision schemes maximized under all kinds of rules as:

\[
\text{max } Z = \sum_{j=1}^{m} \sum_{k=1}^{n} \sum_{j=1}^{n} d(V_i, V_j)w_j \tag{16}
\]

\[
\begin{cases}
\sum_{j=1}^{n} w_j = 1, w_j \geq 0 \\
w \in H
\end{cases}
\]

To solve the model (16), then optimal weights can be obtained \( w^* = (w^*_1, w^*_2, \ldots, w^*_n) \).

To analyze the model, the target layer of the decision is to select the best route, and the index layer is the three factors correspondingly, which are distribution cost \( c_1 \), delivery time \( c_2 \) as well as customer satisfaction \( c_3 \), then the optimal solution of their corresponding weights are \( w^* = (w^*_1, w^*_2, w^*_3) \).

3.1.2 Mathematical model of single objective function

In order to achieve the transformation between multi-objective function and single objective function, the idea of maximizing deviations can be used to determine the weights of three objective function of the above model. This paper argues that in a reasonable range, the index score of a scheme is much different from that of the rest, the greater the contribution degree of the score for this index is illustrated with reference value. Compared with AHP used in reference [7], it weakens the influence of human factors in the decision.

In the research of logistics distribution route selection which under the mode of e-commerce, mathematical model is established by applying the multi-objective programming function in this paper, three objective functions respectively are lowest total distribution cost \( f_1 \), shortest delivery time and highest customer satisfaction \( f_2 \). When the corresponding weights \( w_1, w_2 \) and \( w_3 \) of the objective function is known, the objective function (equation (5) to (7)) of this model can be changed to the following form:

\[
\text{min } w_1 f_1 + w_2 f_2 + w_3 (-f_3) \tag{17}
\]

In this case, the original model of multi-objective function is converted into a relatively simple single objective function.

Put the optimal weight obtained from above into equation (17), a further form of single objective function of the model as follows:

\[
\text{min } w^*_1 f_1 + w^*_2 f_2 + w^*_3 (-f_3) \tag{18}
\]

Thus, the problem is simplified into obtain the minimum value of \( \text{min } w_1 f_1 + w_2 f_2 + w_3 (-f_3) \) under the constraints (8) to (14), the minimum value that corresponds to the plan is a non inferior solution to the model of logistics distribution route choice under e-commerce mode.

3.2 Example analysis

About the problem of logistics distribution route selection under the e-commerce mode, this paper selects total distribution cost, total delivery time and customer satisfaction to evaluate. There is distribution route choice in a logistics company, Evaluation Panel in accordance with the10 score system, and evaluation data for each indicators as shown in Table 1. Among the three indicators, total
distribution cost and total delivery time are the type of cost, while customer satisfaction is the type of benefit. The weight in the not entirely sure form are \( H = \{0.2 \leq w_i \leq 0.4, 0.3 \leq w_j \leq 0.5, 0.4 \leq w_k \leq 0.6, w_i + w_j + w_k = 1\} \) that given by corporate decision makers. Try to determine the weight of each indicator.

<table>
<thead>
<tr>
<th>( a_i ) (cost)</th>
<th>( a_j ) (time)</th>
<th>( a_k ) (satisfaction)</th>
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<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

* the first column represents each scheme, the first row represents each indicator, and the numbers represent scores.

According to equation (15), calculate the corresponding deviation of each score \( V_i \) and \( V_j \) which shown in Table 2.

<table>
<thead>
<tr>
<th>1</th>
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<th>3</th>
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<td>1</td>
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</tbody>
</table>

* the first column represents \( l_i \), the first row represents \( j \), and the others represent \( V_i - V_j \).

Based on maximizing deviations, construct optimization model from the equation (16) as follows:

\[
\text{max } Z = 5w_i + 6w_j + 6w_k
\]

s.t. \( 0.2 \leq w_i \leq 0.4 \)

\[
0.3 \leq w_j \leq 0.5
\]

\[
0.4 \leq w_k \leq 0.6
\]

\[
w_i + w_j + w_k = 1
\]  \( (19) \)

Take use of Matlab to solve (19), \( Z = 5.8 \) and \( w^* = (0.2, 0.35, 0.45) \) can be obtained. Put the calculated values \( w_i^* = 0.2 \), \( w_j^* = 0.35 \) and \( w_k^* = 0.45 \) into equation (18), the single objective function can be written as follows:

\[
\text{min } 0.2 * f_i + 0.35 * f_j + 0.45 * (-f_k)
\]  \( (20) \)

To solve the minimum value of \( 0.2 * f_i + 0.35 * f_j + 0.45 * (-f_k) \), and the minimum value that corresponds to the plan is non inferior solution to the model of logistics distribution route choice under e-commerce mode. Compared with the weight of single objective function using AHP method in reference [15], the result fully considers scores of contribution to the difference degree as well as the reference value, and weakens the influence of subjective factors in decision-making.

For the solution of the single objective function value, it can be obtained with heuristic algorithm.

CAI Wan-jun [18] used ant colony algorithm for the periodic vehicle routing problem, and two improvement measures are put forward, dimensional pheromones and local optimization based on scanning method are used to improve the performance of the algorithm. ZENG Zheng-yang [19] developed a multi-start variable neighborhood descent algorithm to solve a cumulative multi-depot vehicle routing problem efficiently. ZHANG J [20] used insertion heuristic hybrid genetic algorithm for vehicle routing selection based on customer satisfaction. Guo Z G [24] proposed a method based on genetic algorithm to get the best or the solution closed to the best, so that the cost is minimized. In view of the previous research in this aspect, this paper will not to argue again.

4 CONCLUSION

Combined with the characteristics of logistics distribution under the new e-commerce, the distribution route choice model was established. Based on lowering the total distribution cost and shortening delivery time, the paper proposes the idea to improve customer satisfaction at the same time. In calculating the total cost of the process, while taking the vehicle start-up cost and vehicle cost into account, the concept of hidden cost was proposed, that is a kind of penalty cost due to customer dissatisfaction. In solving the model, determine the weight of each objective function by maximizing deviations, transfer the multi-objective functions into a single objective function which is relatively simple. The optimal solution of the single objective function is obtained under a plurality of non-linear constraints, namely non-inferior solution of the original multi-objective decision-making function correspondingly. Based on the proposed theory, take use of the example analysis to calculate the corresponding weight value of indicators making abstract mathematical model specific.

REFERENCES


