A Fuzzy Random CLRIP Model of B2C E-commerce Distribution System

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Abstract. A mixed 0-1 integer programming model of Combined Location Routing and Inventory Problem (CLRIP) with fuzzy random demand has been proposed in B2C E-commerce distribution environment. Demands of customers and distribution centers have been assumed to be fuzzy random variables.

Keywords: E-commerce; distribution; CLRIP; fuzzy random

1 Introduction

B2C enterprises to build logistics distribution system have three levels of decision-making: strategic, tactical and operational level. In the system design phase, location and other strategic layer decisions play an important role. Once the system frame is determined, the focus can be shifted to tactical and operational level decisions, such as inventory control and vehicle route planning. In previous literature, most of the different levels of decision-making are considered separately. However, the decisions for solving these three levels are interrelated to one another. Therefore, we should fully consider combined location routing and inventory problem (CLRIP) in order to achieve the total logistics system cost savings [1].

In recent years, research focus of distribution system optimization which has shifted to the integrated optimization which combined two levels of decision, such as location-inventory problem (LIP), location-routing problem (LRP) and Inventory-routing problem (IRP). At present, due to the complexity of CLRIP, there are few studies on CLRIP. It is generally thought that one of the earliest studies of CLRIP was done by Liu, S.C. (2003) [1]. Liu, S.C. and Lee, S.B. constructed multi-depot location-routing problem (LRP) model taking inventory control decisions into consideration, and designed a two-phase heuristic method to solve this problem. Liu, S.C. and Lin, C.C. then further defined CLRIP concept, designed a hybrid heuristic combining tabu search with simulated annealing algorithm to improve the initial solution phase in the second stage [2]. Javid, A. A. and Azad, N. considered CLRIP
with capacity constrained distribution center and with random demand [3]. Wang, C. F. and Shuai, B. proposed maintenance spare parts CLRIP model with lateral transshipment on the basis of inventory sharing between deferent depot [4].

The above-mentioned documents discussed CLRIP on the assumption that customer demand is determined or random or fuzzy, but in the practice of enterprise distribution, customer demands are often in the coexistence of random and fuzzy, that is fuzzy randomness. Currently, further research is done to deal the problem of fuzzy random variable in construction engineering, Supply Chain Management, etc. In recent years, there have been some scholars began to study the problem of fuzzy randomness in the field of logistics [5-7].

In summary, the above literatures all researched single-level decision-making such as inventory or transportation. There is little research on CLRIP with fuzzy random demand. Especially, few researchers studied the CLRIP model and algorithm with fuzzy random variable. In this paper, a CLRIP model with fuzzy random demand of B2C distribution system will be discussed.

2 Problem Description and Assumption

The goal of our CLRIP model is to optimize the B2C E-commerce distribution system in VMI environment, which consists of a single vendor, multiple distribution centers (DC) and a number of potential customers, the network structure shown in Figure 1. In this bi-level distribution network, the first level is from supplier to DCs and the second level network is from DCs to potential customers. We assume that the location and number of each candidate DC and customer is determined, customer demand is fuzzy random. DC maintains a certain inventory, and its inventory decision given by supplier. Because the supplier usually has a certain production cycle and generally uses the regular order model, this paper uses the continuous review inventory strategy, and touring distribution methods to provide distribution services for customers. We need to determine the number and location of DCs, vehicle routing for its allocated customers, optimal order quantity and the reorder point of each open DC.

Our important assumptions are as follows: The distribution good of DC is single commodity. Select the optimal number and location from the candidate DCs, and the location cost of each DC in unit time is known. Each customer can be served by only one vehicle. Each route has only one vehicle to service customers, and vehicles’...
capacities are the same. The total demands of customers on each route can’t exceed the capacity of the vehicle. Each route starts from a DC and ends at the same DC. Customers demand is independent and uncertain in unit time, which is considered as fuzzy random variables. Each DC follows \((Q_j, r_j)\) continuous review inventory policy.

### 3 Modeling about CLRIP with fuzzy random variables

#### 3.1 Notations and Decision variables

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I)</td>
<td>Set of customers, ( I = {i\mid i = 1, 2, \cdots, n} )</td>
</tr>
<tr>
<td>(J)</td>
<td>Set of candidate DCs, ( J = {j\mid j = 1, 2, \cdots, m} )</td>
</tr>
<tr>
<td>(K)</td>
<td>Set of vehicles, ( K = {k\mid k = 1, 2, \cdots, l} )</td>
</tr>
<tr>
<td>(F_j)</td>
<td>Annual opening and operating cost of DC (j)</td>
</tr>
<tr>
<td>(C_1)</td>
<td>Unit commodity transportation cost from supplier to each DC</td>
</tr>
<tr>
<td>(C_2)</td>
<td>Unit distance transportation cost from every DC to each customer</td>
</tr>
<tr>
<td>(C_3)</td>
<td>Cost per order placed to the supplier by each DC</td>
</tr>
<tr>
<td>(L)</td>
<td>Lead time of each DC</td>
</tr>
<tr>
<td>(T)</td>
<td>Time between reviews</td>
</tr>
<tr>
<td>(dis_{jk})</td>
<td>Distribution distance of DC (j)</td>
</tr>
<tr>
<td>(d_{gh})</td>
<td>Distance from node (g) to node (h)</td>
</tr>
<tr>
<td>(C_d)</td>
<td>Delivery capacity of a vehicle</td>
</tr>
<tr>
<td>(\tilde{D}_j)</td>
<td>Annual fuzzy random demand of customers served by DC (j)</td>
</tr>
<tr>
<td>(\tilde{D}_{L,j})</td>
<td>Fuzzy random demand of customers served by DC (j) at lead time, (\tilde{D}_{L,j} = \tilde{D}_j \times L)</td>
</tr>
<tr>
<td>(\tilde{d}_j)</td>
<td>Yearly fuzzy random demand of customer (i)</td>
</tr>
<tr>
<td>(Q_j)</td>
<td>Order quantity of DC (j)</td>
</tr>
<tr>
<td>(r_j)</td>
<td>Reorder point of DC (j)</td>
</tr>
<tr>
<td>(C_h)</td>
<td>Inventory holding cost per unit commodity per year</td>
</tr>
<tr>
<td>(C_s)</td>
<td>Backorder cost per unit commodity</td>
</tr>
</tbody>
</table>

\[
x_{ghk} = \begin{cases} 1, & \text{if vehicle } k \text{ is from node } g \text{ to node } h \text{ } \\
0, & \text{otherwise} 
\end{cases}
\]

\[
y_j = \begin{cases} 1, & \text{if Distribution on Center } j \text{ is opened } \\
0, & \text{otherwise} 
\end{cases}
\]
\[ z_{ij} = \begin{cases} 1, & \text{if customer } i \text{ is assigned to center } j \\ 0, & \text{otherwise} \end{cases} \]

\[ i = 1, 2, \cdots, n, \quad j = 1, 2, \cdots, m \]

Note \( x = (x_{11}, x_{12}, \cdots, x_{n,n})^{T}, \quad y = (y_1, y_2, \cdots, y_m)^{T}, \quad r = (r_1, r_2, \cdots, r_m)^{T} \).

### 3.2 Model of CLRIP with Fuzzy Random Variable

In the CLRIP of B2C E-commerce distribution system, the total costs consist of the location cost, inventory cost and transportation cost. Location cost is the annual opening and operating cost of all opened DCs, it can be given by \( \sum_{j=1}^{m} m_j n_i \).

Inventory cost consists of ordering cost, holding cost and backorder cost, it is given as follows:

\[
\sum_{j=1}^{m} \left( \frac{\bar{D}_j}{Q_j} C_s + C_h \left( \frac{Q_j}{2} + r_j - \frac{\bar{D}_j}{L_{j,i}} \right) + C_r \frac{\bar{D}_j}{Q_j} \frac{M}{D_{L,j} - R_j} \right) y_j .
\]

Transportation cost contains transportation cost from supplier to each opened DC and distribution cost from each opened DC to customers, it is as follows:

\[
\sum_{j=1}^{m} \frac{\bar{D}_j}{Q_j} C_j y_j + \sum_{j=1}^{m} \frac{\bar{D}_j}{Q_j} \text{dis} \cdot C_z y_j .
\]

According to the description and analysis above, the optimization model of CLRIP with fuzzy random demand can be formulated as follows.

\[
\min C(Q, R, x, y) = \sum_{j=1}^{m} F_j y_j + \sum_{j=1}^{m} \frac{\bar{D}_j}{Q_j} C_j y_j + \sum_{j=1}^{m} \frac{\bar{D}_j}{Q_j} \text{dis} \cdot C_z y_j + \sum_{j=1}^{m} \left[ \frac{\bar{D}_j}{Q_j} C_s + C_h \left( \frac{Q_j}{2} + r_j - \frac{\bar{D}_j}{L_{j,i}} \right) + C_r \frac{\bar{D}_j}{Q_j} \frac{M}{D_{L,j} - R_j} \right] y_j \quad (2)
\]

s.t.

\[
\sum_{j=1}^{n} \sum_{k=1}^{m} x_{p,j,k} = 1, h = 1, 2, \cdots, n \tag{3}
\]

\[
\sum_{j=1}^{n} \sum_{k=1}^{m} d_{j,k} x_{j,k} \leq C_q k = 1, 2, \cdots, l \tag{4}
\]

\[
\sum_{j=1}^{n} \sum_{k=1}^{m} x_{j,k} \leq k = 1, 2, \cdots, l \tag{5}
\]
Formula (2) is the objective function to ensure that the total cost including DC opening and operating cost, inventory cost and transportation cost is the minimum. Constraint (3) guarantees that each customer has only one vehicle for its service, which is each customer in only one distribution route. Constraint (4) ensures that the customer's total demand of each distribution route cannot exceed the service capacity of the vehicle. Constraint (5) makes sure that each vehicle began at most one DC. Constraint (6) guarantees the continuity of the distribution, if a vehicle enters a customer or DC node then it must leave from that node. Constraint (7) indicates that only the selected DC provides service for customers. Constraint (8) implies that the demand of each DC is the total demand of the customers allocated to it. Constraints (9), (10), (11) are 0-1 decision variables.

References