

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

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Abstract

A fuzzy random model of Combined Location Routing and Inventory Problem (CLRIP) has been presented with continuous review inventory policy in B2C distribution environment for the first time. Demands of customers and distribution centers are uncertain and have been assumed to be fuzzy random variables. To solve the model, first the expected value of fuzzy random variable and the possibilistic mean value have been used to convert the fuzzy random variables to crisp ones. A mythology has been designed for solving determined model. A numerical example has demonstrated the effectiveness of the model and algorithm.

Keywords: *B2C distribution system optimization; Combined Location Routing and Inventory Problem; continuous review inventory; fuzzy random; possibilistic mean value*

1. Introduction

Distribution is an important guarantee for the rapid development of E-commerce and the last one kilometer link of customer service. It is also one of the bottlenecks in the development of E-commerce. How to provide efficient, fast and low-cost distribution services has become a pressing matter of the moment in E-commerce enterprise. Therefore, B2C E-commerce businesses put increasing emphasis on logistics and distribution system optimization in order to cope with the fierce competition in the market, and provide customers with more convenient and excellent service. Some of the stronger large-scale B2C enterprises have invested heavily in building its own distribution system to enhance their core competitiveness. B2C enterprises to build logistics distribution system have three levels of decision-making: strategic, tactical and operational. In the system design phase, location and other strategic decisions play an important role. Once the system frame is determined, the focus can be shifted to tactical and operational 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 [1]. For example, if the number of distribution centers increases, distribution center location costs and inventory costs will ascend, and distribution costs will decrease due to the distance reduced. Conversely, the number of distribution centers declines, location costs and inventory costs will decrease, and distribution costs will rise due to

distance increased. Therefore, we should fully consider combined location routing and inventory problem (CLRIP) in order to achieve the total logistics system cost savings.

In recent years, with the continuous improvement of the level of modeling and the computation ability, and the emergence of new algorithm, research focus of logistics distribution system optimization which has shifted to the integrated optimization which combined two levels of decision from location decisions, inventory control and vehicle route planning, 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 S. C. Liu. S. C. Liu and S. B. Lee constructed multi-depot LRP model taking inventory control decisions into consideration, and designed a two-phase heuristic method to solve this problem [1]. S.C.Liu and C.C.Lin then further defined CLRIP concept, because of the two-phase heuristic algorithm in work [1] was easy to fall into local optima, designed a hybrid heuristic combining tabu search with simulated annealing algorithm to improve the initial solution phase in the second stage [2]. Based on studies of S.C. Liu, G. B. Cui and Y. J. Li established single-stage and multi-depot CLRIP model with single period and fuzzy demand, used the mean area measure method to defuzzification, thus determined the optimal order quantity, and designed a two-stage algorithm to solve this problem [3]. A. A. Javid and N. Azad considered CLRIP with capacity constrained distribution center and with random demand, designed a two-phase hybrid heuristic algorithm based on tabu search and simulated annealing [4]. M. H. Wu and X. Yang fully considered the characteristics of timeliness, built multi-objective CLRIP model with stochastic demand to consider the time factor and designed two layers particle swarm optimization algorithm to solve [5].

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, hydraulic 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. O. Dey and D. Chakraborty studied periodic review inventory system with fuzzy random demand [6], and then developed this problem with fuzzy random demand and variable lead-time [7]. L. Li considered order model under VMI environment with a fuzzy random demand and fuzzy random time arrival rate [8]. A. A. Taleizadeh and S. T. A. Niaki set up an integer nonlinear programming inventory model with fuzzy random lost-sale and backordered quantities [9]. J. P. Xu and F. Yan firstly introduced fuzzy random time windows into the study of vehicle routing problem (VRP) [10]. S. G. J. Naini and M. M. Paydar paid much attention to multiple traveling salesman fuzzy random linear programming problem with fuzzy random travel distance [11].

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 bi-level distribution system will be discussed. The rest of the paper has been organized as follows: in Section 2, the model with fuzzy random variables has been proposed and converted to deterministic. Section 3 provides solution methodology where a two-stage hybrid heuristic method bases on TS has been designed. A numerical example has been given in section 4 and finally the conclusion has been drawn in Section 5.

2. Description and Modeling about CLRIP with Fuzzy Random Variables

2.1 Problem Description and Assumption

The goal of our CLRIP model is to optimize the total cost of B2C E-commerce distribution system. There are a single vendor, multiple distribution centers and a number of potential customers in this system. The network structure of this distribution system is shown in Figure 1. In this bi-level distribution network, the first level is from supplier to distribution centers and the second level is from distribution centers to potential customers. We assume that the location and number of each candidate distribution center and customer is determined, customer and distribution center's demand is fuzzy random variable. Each distribution center maintains a certain inventory, uses the continuous review inventory policy and touring distribution methods. We need to determine the number and location of distribution centers, vehicle routing for its allocated customers, optimal order quantity and the reorder point of each open distribution center.

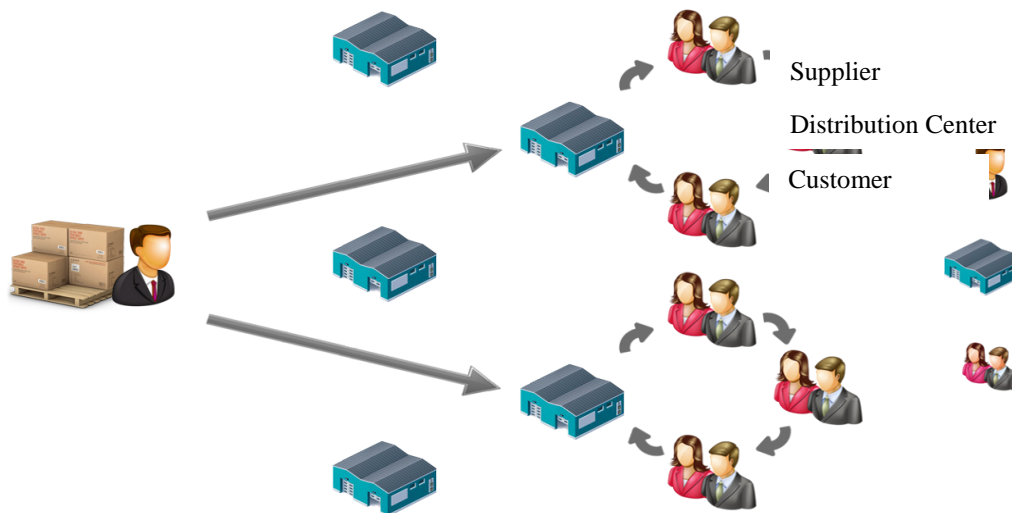


Figure 1. Network Structure of B2C E-Commerce Distribution System

Our important assumptions are as follows: This paper is dealing with single-product multi-distribution centers CLRIP. The number and location of candidate customer and Distribution Center are known, and the location cost of each Distribution Center is fixed and known. Each customer is served by only one route. Each route has exactly one vehicle to service customers, and each vehicle has the same capacities. Distribution centers are no facility restrict. The customers' demands of each route can't exceed the capacity of the vehicle. Each route begins from a Distribution Center and ends at the same one. Each Distribution Center follows (Q_j, r_j) continuous review inventory policy. Customers' demand is fuzzy random variables. For more results on fuzzy random variable, we refer readers to [6-8].

2.2. Parameters and Notations

- I set of customers, $I = \{i | i = 1, 2, \dots, n\}$
 J set of candidate Distribution Centers, $J = \{j | j = 1, 2, \dots, m\}$

K	set of vehicles, $K = \{k k = 1,2,\dots,l\}$
F_j	yearly opening and operating cost of Distribution Center j
C_1	unit commodity transportation cost from supplier to each Distribution Center
C_2	unit distance distribution cost from every Distribution Center to each customer
C_3	cost per order placed to the supplier by each Distribution Center
L	lead time
T	order time
dis_j	distance of the route j
C_q	delivery capacity of a vehicle
\tilde{D}_j	yearly fuzzy random demand of customers served by Distribution Center j
$\tilde{D}_{L,j}$	fuzzy random demand of customers served by Distribution Center j at lead time,
$\tilde{D}_{L,j} = \tilde{D}_j \times L$	
\tilde{d}_i	yearly fuzzy random demand of customer i
Q_j	order quantity of distribution center j
r_j	reorder point of distribution center j
H	inventory holding cost per unit commodity per year
S	backorder cost per unit commodity per cycle

2.3. Decision Variables

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

$$g \neq h, g, h = 1, 2, \dots, n + m, k = 1, 2, \dots, l$$

$$y_j = \begin{cases} 1, & \text{if DC } j \text{ is opened} \\ 0, & \text{otherwise} \end{cases} \quad j = 1, 2, \dots, m$$

$$z_{ij} = \begin{cases} 1, & \text{if customer } i \text{ is assigned to DC } j \\ 0, & \text{otherwise} \end{cases} \quad i = 1, 2, \dots, n, j = 1, 2, \dots, m$$

Note $x = (x_{111}, x_{112}, \dots, x_{n+m, n+m, l})^T$, $y = (y_1, y_2, \dots, y_m)^T$, $r = (r_1, r_2, \dots, r_m)^T$,
 $Q = (Q_1, Q_2, \dots, Q_m)^T$.

2.4. Optimization Model of CLRIP

Before developing the optimization model of CLRIP, three relevant costs are stated as follows. Location cost C_L is the annual opening and operating cost of all opened

Distribution Centers. It can be given by $C_L = \sum_{j=1}^m F_j y_j$. Inventory cost C_I consists of

ordering cost, holding cost and backorder cost. C_I is given as follows

$$C_I = \sum_{j=1}^m \left\{ \frac{\tilde{D}_j}{Q_j} C_3 + H \left(\frac{Q_j}{2} + r_j - \tilde{D}_{L,j} \right) + S \frac{\tilde{D}_j}{Q_j} \overline{M} (\tilde{D}_{L,j} - r_j)^+ \right\} y_j.$$

Transportation cost C_T contains transportation cost from supplier to each opened distribution center and distribution cost from each opened distribution center to customers. C_T is as follows

$C_T = \sum_{j=1}^m \tilde{D}_j C_1 y_j + \sum_{j=1}^m \frac{\tilde{D}_j}{Q_j} dis_j C_2 y_j$. Thus the model of CLRIP with fuzzy random demand can be given as follows.

$$\min \tilde{C}(Q, R, x, y) = \sum_{j=1}^m F_j y_j + \sum_{j=1}^m \tilde{D}_j C_1 y_j + \sum_{j=1}^m \frac{\tilde{D}_j}{Q_j} dis_j C_2 y_j + \sum_{j=1}^m \left\{ \frac{\tilde{D}_j}{Q_j} C_3 + H \left(\frac{Q_j}{2} + r_j - L \tilde{D}_j \right) + S \frac{\tilde{D}_j}{Q_j} \overline{M}(\tilde{D}_{L,j} - r_j)^+ \right\} y_j \quad (1)$$

s.t.

$$\sum_{g=1}^{n+m} \sum_{k=1}^l x_{ghk} = 1, h = 1, 2, \dots, n \quad (2)$$

$$\sum_{g=1}^{n+m} \sum_{i=1}^n \tilde{d}_i x_{gik} \leq C_q, k = 1, 2, \dots, l \quad (3)$$

$$\sum_{g=1}^m \sum_{h=1}^m x_{ghk} \leq 1, k = 1, 2, \dots, l \quad (4)$$

$$\sum_{g,h=1}^{n+m} x_{ghk} - \sum_{h,g=1}^{n+m} x_{h g k} = 0, k = 1, 2, \dots, l \quad (5)$$

$$y_j \geq z_{ij}, i = 1, 2, \dots, n, j = 1, 2, \dots, m \quad (6)$$

$$\tilde{D}_j - \sum_{i=1}^n \tilde{d}_i z_{ij} = 0, j = 1, 2, \dots, m \quad (7)$$

$$x_{ghk} \in \{0,1\}, g \neq h, g, h = 1, 2, \dots, n+m, k = 1, 2, \dots, l \quad (8)$$

$$y_j \in \{0,1\}, j = 1, 2, \dots, m \quad (9)$$

$$z_{ij} \in \{0,1\}, i = 1, 2, \dots, n, j = 1, 2, \dots, m \quad (10)$$

Formula (1) is the objective function to ensure that the total cost including location cost, inventory cost and transportation cost is the minimum. Constraint (2) indicates that each customer is in only one distribution route. Constraint (3) is the vehicle's delivery capacity constraint. Constraint (4) guarantees exactly one distribution center in each route. Constraint (5) makes sure that the distribution route still circular, if a vehicle enters a customer or distribution center node then it must leave from the same node. Constraint (6) implies that only the selected distribution center provides service for customers. Constraint (7) states that each distribution center's demand is the total demand of the customers allocated to it. Constraints (8), (9), (10) are 0-1 decision variables.

3. Solution Methodologies

3.1 Deterministic Equivalent

Because of the complexity of the fuzzy random problem, we need to convert the fuzzy random model to be deterministic. For the convenience of calculation, in formula (1), let A be the certain costs that independent fuzzy random variables, thus

$$A = \sum_{j=1}^m \left[F_j + H \left(\frac{Q_j}{2} + r_j \right) \right] y_j \quad (11)$$

$$\tilde{C}(Q, r, x, y) = A + \sum_{j=1}^m \tilde{D}_j \left\{ \frac{C_3}{Q_j} - HL + \frac{S}{Q_j} \bar{M}(\tilde{D}_{L,j} - r_j)^+ + C_1 + \frac{C_2 \text{dis}_j}{Q_j} \right\} y_j \quad (12)$$

3.1.1 Determination of Expected Shortage: In the reality of B2C E-commerce distribution, if customers' demands exceed the reorder point in distribution center j during the lead time, then shortage occurs. Due to the reorder point lying between $\underline{D}_{L,j}$ and $\bar{D}_{L,j}$, in order to determine the expectation amount of shortage, we need to consider two cases [7].

Case 1: When $\underline{D}_{L,j} \leq r_j \leq D_{L,j}$, the possibilistic mean values [6] of the expected amount of shortage as follows:

$$\bar{M}(\tilde{D}_{L,j} - r_j)^+ = \int_0^1 \alpha(D_{L,j}^+)_{\alpha} d\alpha + \int_{L(r_j)}^1 \alpha(D_{L,j}^-)_{\alpha} d\alpha - r_j \left(1 - \frac{1}{2} L^2(r_j) \right)$$

Case 2: When $D_{L,j} \leq r_j \leq \bar{D}_{L,j}$, the possibilistic mean values [6] of the expected amount of shortage as follows:

$$\bar{M}(\tilde{D}_{L,j} - r_j)^+ = \int_0^{R(r_j)} \alpha(D_{L,j}^+)_{\alpha} d\alpha = \int_0^{R(r_j)} \alpha(D_{L,j}^+)_{\alpha} d\alpha - \frac{1}{2} r_j R^2(r_j)$$

3.1.2 Determination of the Other Costs Expectations: Due to $\tilde{C}(Q, r, x, y)$ is fuzzy random variables, its expectation is a unique fuzzy number. We will use possibilistic mean values to defuzzify [6-7]. Thus, fuzzy random variable $\tilde{C}(Q, r, x, y)$ can be transformed to deterministic one. The possibilistic mean values of $\tilde{C}(Q, r, x, y)$ is as follows:

$$\begin{aligned} \bar{M}(Q, r, x, y) &= \int_0^1 \alpha(E(C_{\alpha}^-) + E(C_{\alpha}^+)) d\alpha \\ &= \int_0^1 \alpha \left\{ \sum_{f=1}^F \left[A + \sum_{j=1}^m (D_{jf,\alpha}^- + D_{jf,\alpha}^+) \left(\frac{C_3}{Q_j} - HL + \frac{S}{Q_j} \bar{M}(\tilde{D}_{L,j} - r_j)^+ + C_1 + \frac{C_2 \text{dis}_j}{Q_j} \right) y_j \right] p_f \right\} d\alpha \\ &= A + \sum_{j=1}^m G_j \left(\frac{C_3}{Q_j} - HL + \frac{S}{Q_j} \bar{M}(\tilde{D}_{L,j} - r_j)^+ + C_1 + \frac{C_2 \text{dis}_j}{Q_j} \right) y_j \end{aligned}$$

$$\text{Where, } G_j = \sum_{f=1}^F \left[\frac{1}{6} (D_{jf}^- + \bar{D}_{jf}^-) + \frac{2}{3} D_{jf}^- \right] p_f \circ$$

3.1.3 Deterministic Equivalent Object Function of CLRIP Model: Through the above transformation, deterministic equivalent object function in two cases as follows.

Case 1: When $\underline{D}_{L,j} \leq r_j \leq D_{L,j}$, deterministic equivalent object function is given by

$$\begin{aligned} \bar{M}(Q, r, x, y) = & A + \sum_{j=1}^m G_j \left(\frac{C_3}{Q_j} - HL + C_1 + \frac{C_2 \text{dis}_j}{Q_j} \right) y_j \\ & + \sum_{j=1}^m G_j \frac{S}{Q_j} \left(\int_0^1 \alpha(D_{L,j}^+) \alpha d\alpha + \int_{L(r_j)}^1 \alpha(D_{L,j}^-) \alpha d\alpha - r_j \left(1 - \frac{1}{2} L^2(r_j) \right) \right) y_j \end{aligned} \quad (13)$$

Case 2: When $D_{L,j} \leq r_j \leq \bar{D}_{L,j}$, deterministic equivalent object function is given by

$$\bar{M}(Q, r, x, y) = A + \sum_{j=1}^m G_j \left(\frac{C_3}{Q_j} - HL + \frac{S}{Q_j} \left(\int_0^{R(r_j)} \alpha(D_{L,j}^+) \alpha d\alpha - \frac{1}{2} r_j R^2(r_j) \right) + C_1 + \frac{C_2 \text{dis}_j}{Q_j} \right) y_j \quad (14)$$

3.1.4 Deterministic Equivalent Forms of Constraints with Fuzzy Random Variables:

Because there are fuzzy random variables in constraints (3) and (7), we need to transform them into deterministic. According to the work of Liu B [12], we can use fuzzy random expectation to convert them. Therefore, the deterministic equivalent form of constraint (3) can be given by

$$\sum_{g=1}^{n+m} \sum_{i=1}^n \sum_{f=1}^F \frac{1}{4} (\underline{d}_{if} + 2d_{if} + \bar{d}_{if}) p_f x_{gik} \leq C_q, k = 1, 2, \dots, l \quad (15)$$

Likewise, the deterministic equivalent form of constraint (7) can be given by

$$\sum_{f=1}^F \frac{1}{4} (\underline{D}_{if} + 2D_{if} + \bar{D}_{if}) p_f - \sum_{i=1}^n \sum_{f=1}^F \frac{1}{4} (\underline{d}_{if} + 2d_{if} + \bar{d}_{if}) p_f z_{ij} = 0, j = 1, 2, \dots, m \quad (16)$$

3.2 Determination of the Optimal Values of Q_j and r_j

There are four decision variables in the determined model, such as Q_j , r_j , x and y . Firstly, we determine the optimal values of Q_j and r_j , then to find the optimal values of x and y through designing a two-stage heuristic method. Separately calculate the optimal values of Q_j and r_j in the two cases as 3.1.3 description.

Case 1: When $\underline{D}_{L,j} \leq r_j \leq D_{L,j}$, for r_j , $\frac{\partial^2 \bar{M}}{\partial r_j^2} \geq 0$, then object function has minimum

value. Let $\frac{\partial \bar{M}}{\partial r_j} = H - \frac{G_j S}{Q_j} \left(1 - \frac{1}{2} L^2(r_j) \right) = 0$, thus we have $L^2(r_j) = 2 \left(1 - \frac{Q_j H}{G_j S} \right)$, then

$$r_j^* = (D_{L,j} - \underline{D}_{L,j}) \sqrt{2 \left(1 - \frac{Q_j H}{G_j S} \right)} + \underline{D}_{L,j} = L(D_j - \underline{D}_j) \sqrt{2 \left(1 - \frac{Q_j H}{G_j S} \right)} + L \underline{D}_j \quad (17)$$

Since $L(r_j) = \frac{r_j - \underline{D}_{L,j}}{D_{L,j} - \underline{D}_{L,j}}$, then we get $0 \leq L^2(r_j) \leq 1$, thus we

have $\frac{G_j S}{2H} \leq Q_j \leq \frac{G_j S}{H}$.

And for Q_j , $\frac{\partial^2 \bar{M}}{\partial Q_j^2} \geq 0$, which means $\bar{M}(Q, r, x, y)$ has minimum value of Q_j , we get

$$Q_j = \sqrt{\frac{2G_j}{H} \left[C_3 + C_2 dis_j + S \left(\frac{1}{6} L(\bar{D}_j - \underline{D}_j) + \frac{1}{6} (L\underline{D}_j + 5r_j) \left(\frac{r_j - L\underline{D}_j}{L\underline{D}_j - L\underline{D}_j} \right)^2 - r_j \right) \right]} \quad (18)$$

Case2: When $D_{L,j} \leq r_j \leq \bar{D}_{L,j}$, in the same way, we have $R^2(r_j) = \frac{2Q_j H}{G_j S}$,

$$0 \leq Q_j \leq \frac{G_j S}{2H}.$$

$$r_j^* = \bar{D}_{L,j} - (\bar{D}_{L,j} - D_{L,j}) \sqrt{\frac{2Q_j H}{G_j S}} = L\bar{D}_j - L(\bar{D}_j - D_j) \sqrt{\frac{2Q_j H}{G_j S}} \quad (19)$$

$$Q_j = \sqrt{\frac{G_j}{3H} (C_3 + S) (3L\bar{D}_j - 2L\underline{D}_j - r_j) \left(\frac{L\bar{D}_j - r_j}{L\bar{D}_j - L\underline{D}_j} \right)^2} \quad (20)$$

In the above two cases, the iterative algorithm has been used to solve the optimal values of Q_j and r_j . The solving procedure is as follows:

Step1: $Q_j^o = \frac{G_j S}{2H}$ as the initial solution substituted in r_j^* and solved for r_j^1 .

Step2: r_j^1 substituted in Q_j^* and solved for Q_j^1 .

Step3: Q_j^1 substituted in r_j^* and solved for r_j^2 .

Step4: Repeat Step 2-Step 3, until the value of Q_j^i and r_j^i is no longer a greater change.

The above iterative algorithm is solved for Q_j and r_j in two cases, and substituted in Formula (13) and (14) separately.

3.3 Heuristic Method

This paper used a two-stage hybrid heuristic method in the work of [13] to solve the deterministic CLRIP model. The algorithm can be decomposed into two stages. Firstly, an initial solution is obtained through randomly assigned customers to each Distribution Center and vehicle. Then, the solution is iteratively improved based on Tabu Search (TS). We improve the initial solution in location-allocation stage at first, and continue to make improvements in the inventory-routing stage. The heuristic algorithm will stop when the termination criterion is matched. Finally, the heuristic algorithm is separately run in above two cases, and the smaller value of two cases is the best solution.

4. Computational Experiments

A company of B2C E-Commerce has 4 Distribution Centers and 8 customers in its distribution system. Each Distribution Center reviews the inventory continuously and reorders at r_j . The following parameters are given as follows: $C_1=3$, $C_2=2$, $C_3=18$, $L=10$ days = $1/36$ year, $C_q=500$, $H=2$, $S=3$.

Parameters of Distribution Centers and customers are shown in Table 1 and Table 2.

Table 1. Parameters of Distribution Centers

Distribution Center j	1	2	3	4
Coordinate	(12,23)	(15,65)	(42,78)	(58,90)
F_j	520	490	610	530

Table 2. Parameters of Customers

Customer i	1	2	3	4
Coordinate	(10,39)	(67,21)	(58,76)	(86,93)
$\tilde{d}_{i1} (p_1=0.5)$	1080,2160,2880	1080,2880,3960	1080,2880,3240	1440,2160,2880
$\tilde{d}_{i2} (p_2=0.3)$	720,1080,1440	720,1440,1800	720,1440,1800	720,1440,1800
$\tilde{d}_{i3} (p_3=0.2)$	360,720,1080	360,1080,1440	360,720,1440	360,720,1080
Customer i	5	6	7	8
Coordinate	(64,48)	(32,23)	(25,57)	(54,72)
$\tilde{d}_{i1} (p_1=0.5)$	1080,2160,2880	1800,2520,3240	1080,2520,3240	720,1800,2160
$\tilde{d}_{i2} (p_2=0.3)$	720,1440,2520	1080,1800,2160	720,1440,1800	360,1080,1440
$\tilde{d}_{i3} (p_3=0.2)$	360,1080,1440	720,1440,1800	360,1080,1440	360,720,1080

By using the two-stage hybrid heuristic method in the work of [13], Matlab7.1 is used to develop the algorithm procedure. In order to evaluate our model and algorithm, we separately run the procedure 10 times, and record the 10 groups of best solutions when the initial solution is different [14]. Results are reported in Table 3. Where, J_j denotes Distribution Center j , I_i denotes customer i , for example, distribution route $J_2=\{I_8, I_1, I_2\}$ denotes that distribution sequence is J_2, I_8, I_1, I_2 and J_2 .

Table 3. Initial Solution and Best Solution

Initial solution			Best solution		
Opened Distribution Center	Distribution routs	Total cost	Opened Distribution Center	Distribution routs	Total cost
J_1, J_2, J_3	$J_1=\{I_1, I_2, I_3\}, J_2=\{I_4, I_5, I_6\}, J_3=\{I_7, I_8\}$	130937.25	J_1, J_3, J_4	$J_1=\{I_1, I_7, I_5\}, J_3=\{I_4, I_8, I_6\}, J_4=\{I_2, I_3\}$	105259.24
J_1, J_2, J_4	$J_1=\{I_1, I_2, I_3\}, J_2=\{I_7, I_8\}, J_4=\{I_4, I_5, I_6\}$	135274.56	J_2, J_3, J_4	$J_2=\{I_3, I_8, I_2\}, J_3=\{I_6, I_4, I_1\}, J_4=\{I_5, I_7\}$	105732.61
J_1, J_2, J_3	$J_1=\{I_7, I_8\}, J_2=\{I_1, I_2, I_3\}, J_3=\{I_4, I_5, I_6\}$	112825.70	J_1, J_3, J_4	$J_1=\{I_1, I_4, I_6\}, J_3=\{I_5, I_3, I_7\}, J_4=\{I_8, I_2\}$	105413.31
J_2, J_3, J_4	$J_2=\{I_1, I_2, I_3\}, J_3=\{I_4, I_5, I_6\}, J_4=\{I_7, I_8\}$	133518.27	J_1, J_3, J_4	$J_1=\{I_3, I_7, I_5\}, J_3=\{I_1, I_4, I_6\}, J_4=\{I_2, I_8\}$	105705.40
J_1, J_3, J_4	$J_1=\{I_1, I_2, I_3\}, J_3=\{I_7, I_8\}, J_4=\{I_4, I_5, I_6\}$	140251.02	J_1, J_2, J_3	$J_1=\{I_1, I_7, I_6\}, J_2=\{I_4, I_2, I_5\}, J_3=\{I_3, I_8\}$	105260.28
J_1, J_2, J_3	$J_1=\{I_7, I_8\}, J_2=\{I_1, I_2, I_3\}, J_3=\{I_4, I_5, I_6\}$	135258.86	J_1, J_3, J_4	$J_1=\{I_7, I_2, I_5\}, J_3=\{I_4, I_6\}, J_4=\{I_8, I_1, I_3\}$	105465.93
J_2, J_3, J_4	$J_2=\{I_1, I_2\}, J_3=\{I_3, I_4, I_5\}, J_4=\{I_6, I_7, I_8\}$	122514.18	J_1, J_2, J_4	$J_1=\{I_1, I_3\}, J_2=\{I_2, I_4, I_8\}, J_4=\{I_6, I_7, I_5\}$	105356.44
J_1, J_3, J_4	$J_1=\{I_1, I_2\}, J_3=\{I_6, I_7, I_8\}, J_4=\{I_3, I_4, I_5\}$	128165.16	J_1, J_3, J_4	$J_1=\{I_2, I_4, I_5\}, J_3=\{I_7, I_8, I_6\}, J_4=\{I_2, I_3\}$	105361.39
J_1, J_2, J_4	$J_1=\{I_1, I_2, I_3\}, J_2=\{I_4, I_5, I_6\}, J_4=\{I_7, I_8\}$	135864.90	J_2, J_3, J_4	$J_2=\{I_2, I_1, I_6\}, J_3=\{I_3, I_4\}, J_4=\{I_8, I_5, I_7\}$	105634.81
J_2, J_3, J_4	$J_2=\{I_7, I_8\}, J_3=\{I_4, I_5, I_6\}, J_4=\{I_1, I_2, I_3\}$	126924.36	J_1, J_3, J_4	$J_1=\{I_8, I_1, I_5\}, J_3=\{I_4, I_7\}, J_4=\{I_2, I_6, I_3\}$	105058.20

As shown in Table 3, by using our heuristic algorithm, the best solution of total cost is much closed when different initial solution is given. The relative deviation between maximum (105732.61) and minimum (105058.20) is only 0.64%, which stated that the heuristic algorithm is effective.

5. Conclusions

In this paper, the fuzzy random integrated optimal model is developed in three levels with location, vehicle routing and inventory control in B2C E-Commerce distribution system to establish the minimization of the total cost of the system. The main contribution of this paper is to construct model of CLRIP in the fuzzy random condition that is much closer to the practice of B2C distribution. The distribution network studied in this paper only assumes that the demand of each Distribution Center and customer is FRV. But in fact, the lead time and serve time windows may also be FRV. Thus, in further research, CLRIP can be extended to multiple objectives problem with FRV which simultaneously considers fuzzy random demand and fuzzy random time.

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References

- [1] S. C. Liu and S. B. Lee, "A two-phase heuristic method for the multi-depot location routing problem taking inventory control decisions into consideration", *International Journal of Advanced Manufacturing Technology*, vol. 22, no.11-12, (2003), pp. 941-950.
- [2] S. C. Liu and C. C. Lin, "A heuristic method for the combined location routing and inventory problem", *International Journal of Advanced Manufacturing Technology*, vol. 26, no. 4, (2005), pp. 372-381.
- [3] G. B. Cui and Y. J. Li, "Combined location routing and inventory problem with fuzzy demand in logistics system", *Control and Decision*, vol. 22, no. 9, (2007), pp. 1000-1004.
- [4] A. A. Javid and N. Azad, "Incorporating location, routing and inventory decisions in supply chain network design", *Transportation Research Part E: Logistics and Transportation Review*, vol. 46, no. 5, (2010), pp.582-597.
- [5] H.W. Ma, X. Yang, L.D. Zhao and X.F. Cheng, "Research into integrated optimization for two-stage logistics distribution network under stochastic demand based on time", *Operations Research and Management Science*, vol. 21, no. 1, (2012), pp.40-47.
- [6] O Dey and D. Chakraborty, "Fuzzy periodic review system with fuzzy random variable demand", *European Journal of Operational Research*, vol. 198, no. 1, (2009), pp. 113-120.
- [7] L. Li, "Order quantity model for VMI under fuzzy random environment of supply and demand", *Statistics and Decision*, vol. 27, no. 7, (2011), pp. 58-61.
- [8] O Dey and D. Chakraborty, "A fuzzy random periodic review system with variable lead-time and negative crashing cost", *Applied Mathematical Modeling*, vol. 36, no. 12, (2012), pp. 6312-6322.
- [9] A. A. Taleizadeh, S.T. Niaki and R.G. Meibodi, "Replenish-up-to multi-chance-constraint inventory control system under fuzzy random lost-sale and backordered quantities", *Knowledge-Based Systems*, vol. 53, no. 11, (2013), pp. 147-156.
- [10] J. P. Xu, F. Yan and S. Li, "Vehicle routing optimization with soft time windows in a fuzzy random environment", *Transportation Research Part E*, vol. 47, no. 6, (2011), pp. 1075-1091.
- [11] S. G. Naini, M.M. Paydar, J. Jouzdani and M. Fathian, "Fuzzy stochastic linear programming-based approach for multiple departures single destination multiple travelling salesman problem", *International Journal of Operational Research*, vol. 17, no. 4, (2013), pp. 417-435.
- [12] B. D. Liu, R. Q. Zhao and G. Wang, "Uncertain Programming with applications", *Tsinghua University Press, Peking*, (2003).
- [13] D. H. Chen, D. Y. Chen, G. L. Sun and G. M. Liu, "Combined location routing and inventory problem of E-Commerce distribution system with fuzzy random demand", *International Journal of Hybrid Information Technology*, vol. 7, no. 5, (2014).

- [14] J. Qin, L. L. Ni and L. X. Miao, "Optimization model and combined simulated annealing algorithm for multi-level multi-commodity logistics network design", *Application Research of Computers*, vol. 27, no. 9, (2010), pp. 3348-3351.

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