

# Study on Location of Fresh Food Distribution Center with Demand Influenced by the Freshness

Jian Zhang\*, Shaochuan Fu  
 School of Economics and Management  
 Beijing Jiaotong University, Beijing, China, 100044  
 \*EMAIL: zhangjian556@126.com

**Abstract:** This paper mainly focuses on the fresh food and assumes that its demand is influenced by the freshness. It's a new assumption that is more practical and closer to customers' purchase psychology. Based on the assumption, the paper establishes a location model of fresh food distribution center. We use a heuristic algorithm—ADD for the model to obtain the initial solution, and then the initial solution is improved by neighborhood search exchange algorithm to get the optimal solution. Finally, the paper verifies the effectiveness of the model through a case. This study contributes to optimize the fresh food cold-chain distribution system so as to improve the logistics efficiency.

**Keywords:** Fresh food, Freshness, Distribution center, Location

## I. Introduction

Fresh food is characteristic of its perishability and short shelf life, so it must be stored in low temperature environment when transported. But Li Jiaxi[1] pointed out the freshness of fresh food would decrease with transportation distance increasing even in low temperature environment.

For the problem of locating fresh food distribution centers, the studies existing mainly classified fresh food as perishable goods. They were more concerned about the rotting rate. And from the standpoint of rotting rate, they established models of minimizing the sum of transportation cost and loss cost. Xie Xiaoliang[2] established a location model of perishable agricultural products distribution center. Zhu Chuanhua[3] made a study of perishable inventory-distribution model with demands in accord with lifecycle changes. Obviously there is a common shortcoming of these studies: By classifying fresh food as perishable goods, they all ignore the effect the freshness has on the demand. The effect of freshness-losing contains that of perishability, while the latter can't contain the former. Therefore, the freshness variable should be taken into the location model to make it more practical.

Based on the above analysis, this paper establishes a location model of fresh food distribution center with demand influenced by freshness, which is closer to customers'

purchase psychology. It provides a new method for engineering the fresh food distribution system.

## II. The Location Model of Fresh Food Distribution Center with Demand Influenced by Freshness

### Problem description

There are  $i$  demand nodes for fresh food in one distribution region. The demand for each node has been given. Distribution centers send fresh food to demand nodes according to the given demand at each node. Because the freshness is influenced by the transportation distance, it will decrease when the fresh food is transported to the demand nodes. Meanwhile, the given demand at node  $i$  will decline as the freshness decreases. The problem is that: Choose some demand nodes as distribution centers to send fresh food to the other demand nodes. Find the optimal combination of demand nodes as distribution centers, to make the profit of each distribution largest.

### Model assumptions

- (i) Each demand node can be satisfied by only one distribution center. The distribution amount for each distribution center is uncapacitated.
- (ii) For the given speed, freshness-losing is relevant to transportation distance. The freshness-losing per unit distance is  $\theta$ .
- (iv) The relation between demand and freshness is that: demand declines by  $\beta$  percent when the freshness decreases by one percent.
- (iv) The freshness of fresh food is 1 when it is to leave the distribution center.
- (v) The remaining fresh food than can't sell has no salvage value.

### Model parameters

$c$ : cost per unit fresh food before distribution

$p$ : price per unit fresh food

$h_i$ : demand at node  $i$

$d_{ij}$ : distance from demand  $i$  to distribution center  $j$

$f_j$  : fixed locating cost at node  $j$  shared by each distribution

$\alpha$ : cost per unit distance per unit fresh food

$\beta$ : the percent demand declines by when freshness decreases by one percent

$\theta$ : freshness-losing per unit distance

$$X_j = \begin{cases} 1 & \text{if we locate distribution center at node } j \\ 0 & \text{if not} \end{cases}$$

$$Y_{ij} = \begin{cases} 1 & \text{if demand at node } i \text{ are satisfied by distribution center } j \\ 0 & \text{if not} \end{cases}$$

### Model analysis and establishment

According to the assumption, the freshness at node  $i$  after the fresh food is transported from distribution center  $j$  is:

$$\phi_i = (1 - \theta)^{d_{ij}Y_{ij}} \quad (1)$$

Influenced by the freshness, the corrected value of demand at node  $i$  is:

$$Q_i = h_i - (1 - \phi_i)\beta h_i = [1 - (1 - \phi_i)\beta]h_i \quad (2)$$

(i) The revenue of each distribution is:

$$I = \sum_i pQ_i = p \sum_i Q_i = p \sum_i [1 - (1 - \phi_i)\beta]h_i \quad (3)$$

(ii) The original cost of each distribution is:

$$C_1 = \sum_i c h_i = c \sum_i h_i \quad (4)$$

(iv) The fixed cost shared by each distribution is:

$$C_2 = \sum_j f_j X_j \quad (5)$$

(iv) The transportation cost of each distribution is

$$C_3 = \alpha \sum_i \sum_j h_i d_{ij} Y_{ij} \quad (6)$$

Based on the above analysis, we can calculate the profit of each distribution:

$$P = I - C_1 - C_2 - C_3 \quad (7)$$

Therefore, the location of fresh food distribution centers can be formulated as follows:

Max:  $P = I - C_1 - C_2 - C_3$

$$= p \sum_i [1 - (1 - \phi_i)\beta]h_i - c \sum_i h_i - \sum_j f_j X_j - \alpha \sum_i \sum_j h_i d_{ij} Y_{ij} \quad (8)$$

$$\text{s.t. } \sum_j Y_{ij} = 1 \quad \forall i \quad (9)$$

$$Y_{ij} \leq X_j \quad \forall i, j \quad (10)$$

$$X_j = 0, 1 \quad \forall j \quad (11)$$

$$Y_{ij} = 0, 1 \quad \forall i, j \quad (12)$$

The objective function (8) maximizes the profit of each distribution. Constraint (9) requires each demand node  $i$  to be satisfied by exactly one distribution center  $j$ . Constraint (10) states that demands at node  $i$  can only be satisfied by

distribution center  $j$  ( $Y_{ij} = 1$ ) if demand node  $j$  is chosen as distribution center ( $X_j = 1$ ). Constraint (11) and (12) are the standard integrality conditions.

### III. Model Solving

This location problem is NP-complete. So we need to construct effective heuristic algorithms to solve it. Here, we use the ADD heuristic algorithm to obtain the initial solution. And then we improve it using the neighborhood search exchange algorithm to get it much closer to the optimal solution.

#### Obtaining the initial solution using ADD algorithm

The procedures of the ADD algorithm are as follows:

Step1: Choose one demand node as a distribution center, which makes the profit largest when it satisfies all the demands of the remaining nodes.

Step2: Given the first distribution center according to step1, add another one node to it to make it a new combination. If the new combination can not increase the profit when the nodes in it satisfy all the remaining demands, stop and output the initial solution. Otherwise, go to step3.

Step3: Of all the nodes that make the profit increase when they are added to the former combination, choose the one which increases the profit most. Put the chosen node into the former combination.

Step4: Assign the remaining nodes to the chosen distribution centers according to the principle of shortest distance. Then compute the profit and go to step2.

#### Improving the initial solution using neighborhood search exchange algorithm.

The initial solution obtained by ADD algorithm is usually not optimal. So we improve it using the neighborhood search exchange algorithm to make it much closer to the optimal solution. The procedures of neighborhood search exchange algorithm are as follows:

Step1: For any node of the initial solution, choose one which is closest to it to replace the node. Keep the other nodes of the solution unchanged and compute the profit of the new solution.

Step2: If the profit increases, go to step3. Otherwise, go to step4.

Step3: Replace the current node with the chosen one. And then reassign the demand nodes to the distribution centers.

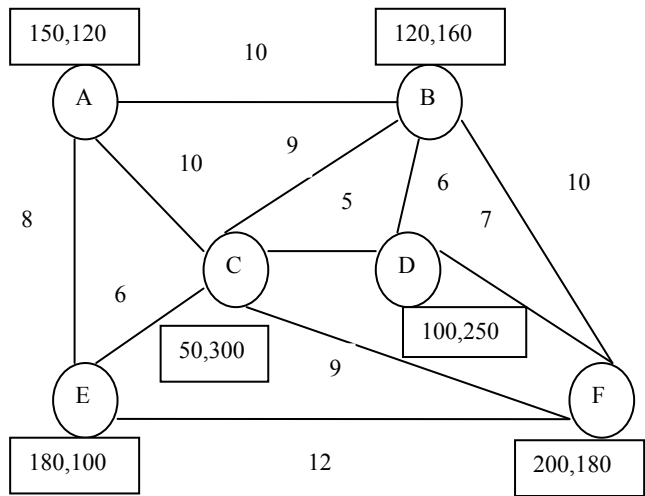
Step4: If all the nodes of the solution have been considered for removal, stop and output the optimal solution. Otherwise, turn to the next node and go to step2.

### IV. Numerical Example and Sensitivity Analysis

Now we have an example to verify the effectiveness of the

model. The network in Figure 1 shows the distributed situation of demand nodes in one region.

Figure I. The distributed situation of demand nodes in one region.



There are 6 demand nodes in the region, A-F. The distances between any two nodes are marked next to the lines between them. There are two numbers in each box next to the demand node. The first number presents the demand of the node and the second presents the fixed cost shared by each distribution. The problem is to find the optimal location of distribution centers in the fresh food distribution region, where  $\alpha=0.01$ ,  $\beta=2$ ,  $\theta=0.005$ ,  $c=5$ ,  $p=8$ .

First, we use ADD algorithm to obtain the initial solution. Table I gives the distance matrix between any two nodes.

Table I. Distance matrix between demand nodes.

	A	B	C	D	E	F
A	0	10	10	15	8	19
B	10	0	9	6	15	10
C	10	9	0	5	6	9
D	15	6	5	0	11	7
E	8	15	6	11	0	12
F	9	10	9	7	12	0

The computations for choosing the first distribution center are shown as follows:

Table II. The computations for choosing the first distribution center

	A	B	C	D	E	F
Actual demand	718	729	741	736	735	729
Revenue	5747	5835	5932	5885	5870	5830
Original cost	4000	4000	4000	4000	4000	4000
Transportation cost	844	725	596	660	680	736
Shared cost	120	160	300	250	180	200
Profit	783	950	1036	975	1010	894

The last row of Table II gives the profit associated with satisfying all the demand nodes from the distribution center locating in the given column. We locate the first distribution center at the node with the largest profit. This node is C. And then we choose the second node, given that the first distribution center is located at node C. Proceed in this manner until the profit no longer increases when we try to add another distribution center. The computations and results are shown in Table III.

Table III. Summary of ADD heuristic iterations

Iterations	Add DC at	Profit
1	C	1036.00
2	A	1183.22
3	F	1038.38

As shown in Table III, we locate distribution centers at node C and node A. If we try to add another distribution center, we find node F is the best, but locating there decreases the profit from 1183.22 to 1038.38. Thus, the solution from the ADD algorithm is to locate distribution centers at nodes C and A. Distribution center A satisfies the demand at node E, and C satisfies B, D and F. The total profit is 1183.22.

Then, we use the neighborhood search exchange algorithm to improve the initial solution. Choose the replacement nodes for A and C according to the principle of shortest distance. The comparing procedure is shown in Table IV.

Table IV. Summary of neighborhood search exchange heuristic iterations

Remove	Replace with	Profit	Profit change
C	D	1348.78	165.56
A	E	1391.64	42.86
E	C	1190.12	-201.52

Table IV shows that replacing node C and node A with node D and node E will increase the profit. We make this change to obtain a new solution of locating distribution centers at nodes D and E. If we try to optimize the new solution with replacing node E with node C, the profit decreases from 1391.64 to 1190.12. So the final solution is to locate distribution centers at nodes D and E. Demand node A is satisfied by distribution center E, and B, C, F by D. The total profit is 1391.64.

For a further study, we take a sensitivity analysis as follows:

Table V Sensitivity analysis

$\theta$	Locate at	Profit	Profit change
0.005	D,E	1391.64	0
0.01	D,E	1118.63	-19.62%
0.02	A,D,E,F	1036.95	-7.30%

Table V shows the amount of distribution center increases as the freshness-losing rate increases. It means distribution centers need to be closer to the demand nodes with a higher freshness-losing rate. But the profit decreases, because the fixed cost shared by each distribution increases more.

V. Conclusions

This paper establishes a new model of locating fresh food distribution centers on basis of the assumption the freshness of fresh food influences the demand. Taking the freshness variable into it, the model is closer to customers' purchase psychology. The paper uses a heuristic algorithm-ADD to obtain the initial solution and improves it with the neighborhood search exchange algorithm. Finally, the paper verifies the effectiveness and practicability of the model through a case. It offers a scientific location method for engineering the fresh food distribution system.

## References

- [1] Li Jiaxi. Speciality of fresh food distribution center. China: Chinese Logistics and Purchasing, 2007, 7:57.
- [2] Xie Xiaoliang. Optimization of locating distribution centers for perishable agricultural products. China: Guangdong Agricultural Science, 2009, 5: 224-226.
- [3] Zhu Chuanhua. Perishable Inventory Model with Demands in Accord with Lifecycle Changes. China: Industrial Engineering Journal, 2006, 7:94-96.
- [4] Mark S.Daskin. Network and Discrete Location. 2006.
- [5] Weaver, J.R. and R.L. Church. A Median Facility Location Problem with Closest Facility Service: Department of Management Science and Statistics. 1983b:83-110.

## Background of Authors

**Zhang Jian.** Master of Beijing Jiaotong University. Mainly focusing on logistics management. Email: zhangjian556@126.com Ph: 86 152 1057 3138

**Fu Shaochuan.** Associate professor of Beijing Jiaotong University. Mainly engaging supply chain management, logistics system planning and etc. Email: fushaochuan@263.net Ph: 86 138 1084 6759.