Research on Joint Distribution Route Optimization of Cold-chain Logistics for Fresh Agricultural Products

Xuewen Yang¹, Zhiguo Zhang¹*, and You Wu²

¹School of Logistics, Chengdu University of Information Technology, Chengdu, China
²Academy of Marxism, Chengdu University of Technology, Chengdu, China

*Corresponding author email: zgzhang@cuit.edu.cn

Abstract. In order to meet the development speed of cold-chain logistics, it is essential to enhance the efficiency of cold chain logistics, reduce the damage of fresh agricultural products, as well as guarantee the final transportation effect of all kinds of agricultural products. In view of the application of the Internet of things and the transportation principle of low temperature logistics, then the pattern of joint distribution is adopted, and the fixed cost, the transportation cost of distribution vehicles, the damage cost of fresh agricultural products and the operation cost of IOT are considered comprehensively. Under the basic setting of sufficient assumptions, the total cost to be lowest is taken as the objective function to construct a mathematical model to enhance the actual operation of cold-chain logistics in a scientific way.

Keywords: IOT; Fresh Agricultural Products; Joint Distribution.

1. Introduction
The logistics of agricultural products is one important link in China's agriculture-related work. So as to reduce the perishability of agricultural products and maintain freshness from producing area to consumers, cold-chain logistics becomes the main component of agricultural product logistics. Various agricultural products enter the market through different sales channels, which accelerates the people's quantity demand of cold-chain logistics. But since it is high in cost and agricultural products is small in profit space, current low temperature logistics is still distributed in traditional method. In general, fixed vehicles separately distribute the agricultural products in the specific storage temperature zone. As a result, many distribution vehicles distribute agricultural products in different areas at the same time, and logistics cost increases but the logistics efficiency is still low. Such low-efficiency distribution not only greatly wastes the logistics resources, the simultaneous distribution of many cold-chain vehicles also aggravates the urban traffic congestion and environmental pollution.

With the constant update of internet technology, joint distribution mode gradually shows its advantage in distribution cost and efficient. Since the joint distribution needs to integrate resources at the end of the logistics distribution, all resources are optimized as a whole, and the overall distribution expenses of logistics enterprises are further reduced. As a result, the end distribution efficiency is improved and the traffic pressure, environmental pollution, etc. Caused due to independent distribution of each logistics company are alleviated.
2. Construction of Mode

2.1. Problem Description
Based on the wide application of the system network, the information among each logistics transport center not only achieves the interchanges, but also promptly updates, creating good environment for joint distribution. It issues researched are established on the basis of known demand quantity of each demand point and the known total ability of yard. After the order of cold-chain logistics transport vehicle is distributed, under the background of the original yard, each order of logistics center is reconstructed at first to guarantee the mathematical model aiming at the minimum total cost is established in consideration of the shortest time under the premise of meeting the demands of each user.

2.2. Condition Assumption
In actual condition, cold-chain logistics is very complex in distribution and there are many external influencing factors. The change of one condition would influence the whole result. In order to facilitate the construction and solving of model, the realistic issues are abstracted and simplified and the model is assumed as follows:

- All distribution vehicles start from their respective distribution centers, and return to the original distribution centers after distribution to wait the next distribution;
- This model adopts the route issue mode of pure distribution vehicles. In order to guarantee the distribution vehicles can arrive at the customer points on schedule as far as possible, new order tasks wouldn't be assigned to distribution vehicles in halfway, namely the order wouldn't have any change during the distribution process;
- All cold chain trucks used in the distribution link have the same loading capacity, vehicle condition and in-vehicle equipment, and the sum of demand quantity of all customers doesn't exceed the maximum loading capacity of such distribution vehicle in the service route of distribution vehicle;
- Various types of fresh agricultural products are allowed on the distribution vehicle;
- Assuming in the distribution process, the temperature in cold-chain distribution carriage can reach the low-temperature status required by various fresh agricultural product requirements. For the convenience of research, the decay hypothesis of fresh agricultural product is concerned to the distribution time, and the impact of other factors on the quality of fresh agricultural products isn't considered;

2.3. Parameter Setting
To facilitate the description of the model, we make the following settings for the parameters that will be used:
Table 1. Model symbol and parameter meaning

| Model symbol | parameter meaning |
|--------------|-------------------|
| N = \{i, j | i, j = 1,2, ..., N\} | Customers accepting distribution |
| K = \{1,2, ..., M\} | Distribution vehicles |
| α₁ | Energy consumption cost of cold chain distribution vehicle per unit time |
| Pᵣ | The price of fresh produce |
| qᵢj | Order quantity of fresh agricultural product r ordered by the jᵗʰ customer |
| β₁ | Cargo loss rate per unit time of fresh agricultural products during transportation |
| θ₁ | Penalty coefficient for delivery vehicles earlier than the time requested by customers |
| θ₂ | Penalty coefficient for delivery vehicles later than the time requested by customers |
| tᵢj | The time point which the transportation vehicle reaches the designated customer |
| ET | Opening time of customer time window |
| LT | Closing time of customer time window |
| Γ | Complexity level of the use of IOT of things technology |
| Cₑ | Unit maintenance cost in the process of IoT technology distribution |
| Cᵢ | Unit cost of RFID tags |
| δ | RFID label usage |
| μ | Delivery distance per unit of delivery vehicle (yuan/km) |
| dᵢj | Driving distance of the kᵗʰ cold chain distribution vehicle from site I to site j |

2.4. Cost Analysis

2.4.1. Energy costs. In the transportation course of cold chain logistics, in order to ensure the freshness of products, the compartment of the cold chain logistics vehicle must be kept at a low temperature directly. Therefore, there will be a lot of energy consumption in transport process. The specific announcement is as follows:

\[
C₁ = \sum_{k=1}^{K} \sum_{j=1}^{N} X_{i,j}^k α₁ (t_{j}^k - t_{j-1}^k)
\]

2.4.2. Cargo damage cost. With the extension of the delivery time, the temperature or humidity in the transport vehicle will change accordingly, which will lead to a decline in the quality of Agricultural produces. For ease of modeling, only the cargo damage rate is related to time. The specific announcement is as follows:

\[
C₂ = \sum_{k=1}^{K} \sum_{j=1}^{N} \sum_{r=1}^{R} Pᵣqᵢr X_{i,j}^k β₁ (t_{j}^k - t_{j-1}^k)
\]

2.4.3. Penalty costs for time. In the distribution process, there will be some uncontrollable external factors that affect the arrival time of the distribution vehicle. Therefore, setting a time window to allow the distribution vehicle to arrive within the specified time range will not incur time penalty costs. But earlier or later than the time required by the customer will affect the customer's satisfaction and will incur time penalty costs. The specific announcement is as follows:
2.4.4. IOT Costs. The Internet of Things technology is currently widely used to improve distribution efficiency during delivery. The IOT technology cost referred to in this article mainly comes from the use and maintenance of RFID technology in the distribution process. The specific announcement is as follows:

\[
C_4 = \gamma(C_w+C_B\delta)q_{jr}
\]

2.4.5. Transportation Cost. In the transportation process of cold chain distribution vehicles, each delivery will incur fuel consumption, maintenance and other costs. This article sets the transportation cost to be related to the unit distance transportation cost and the actual driving distance. The specific announcement is as follows:

\[
C_5 = \sum_{k=1}^{K} \sum_{i=1}^{N} \sum_{j=1}^{N} \mu d_{ij}^k X_{ij}^k
\]

2.5. Modeling

Combining the above analysis, with the lowest cold chain logistics cost as the goal, the specific formula of the objective function of establishing the optimal model of the cold chain logistics common distribution path is:

\[
\min C = C_1 + C_2 + C_3 + C_4 + C_5
\]

\[
= \sum_{k=1}^{K} \sum_{j=1}^{N} X_{ij}^k a_1(\frac{t_j^k}{t_{j,j-1}^k}) + \sum_{j=1}^{N} \sum_{i=1}^{N} \sum_{r=1}^{R} p_{rjr} X_{ij}^k \beta_1(\frac{t_j^k}{t_{j,j-1}^k}) + \phi(t_j^k) + \gamma(C_w+C_B\delta)q_{jr} + \sum_{k=1}^{K} \sum_{i=1}^{N} \sum_{j=1}^{N} \mu d_{ij}^k X_{ij}^k
\]

According to the actual situation, in order to meet the optimization and solution of the objective function, it is necessary to constrain each decision variable, follow the conditions assumed by the model, and propose the following constraints:

\[
\sum_{k=1}^{K} X_{ij}^k = 1 \quad \forall j \in N
\]

\[
\sum_{k=1}^{K} q_{jr} X_{ij}^k \leq Q_k \quad \forall k \in K
\]

\[
\sum_{r=1}^{R} q_{jr} = Q_j \quad \forall j \in N
\]

\[
\sum_{i=1}^{N} X_{ij}^k = \sum_{i=1}^{N} X_{ji}^k \quad \forall j \in N, \forall k \in K
\]

\[
X_{ij}^k = \begin{cases} 
1 & \text{Distribution vehicle } k \text{ goes from customer } i \text{ to customer } j \\
0 & \text{Distribution vehicle } k \text{ does not go from customer } i \text{ to customer } j
\end{cases}
\]

3. Conclusion

Heavy demand of agricultural products on the market causes cold-chain logistics becomes more and more important. But cold-chain logistics require high capital investment due to the restriction of cost condition. As a result, the agricultural products have very low sales profit. The construction of
cold-chain logistics can't match with the sales quantity of agricultural products, So its development is hindered. Therefore it is urgent to solve the conflict between the investment cost of cold-chain logistics and the low profits of agricultural products. The highly-developed Internet of Things creates development condition for cold-chain logistics. The networking technology plus bar code and the RFID acquisition equipment are widely used to control and detect the key temperature and humidity of distribution vehicle and track the goods, which achieves the overall monitoring of agricultural products' cold-chain logistics through feedback of real-time data and greatly improves the distribution efficiency. Hence, the joint distribution mode is adopted for distribution of fresh agricultural product based on the Internet of Things, and the cost of cold-chain distribution vehicles generated in distribution process is analyzed one by one. The mathematical model is established to aim at the minimum total cost and the distribution route of cold-chain distribution vehicle is optimized. In the joint distribution mode, the vehicle of agricultural product transport in cold-chain logistics is used reasonably to reduce the road congestion and make the logistics distribution efficiency higher, further promoting the development of China's cold-chain logistics.

References
[1] Yijun Liu, Pin Peng. Analysis and Reference of Common Distribution Policy Measures and Development Models in Developed Countries[J]. Corporate Economics, 2015(3).
[2] Lu Sun, Yuanjun Zhao, Wenqi Sun, Zhengkai Liu. Study on supply chain strategy based on cost income model and multi-access edge computing under the background of the Internet of Things, Neural Computing and Applications,2019.
[3] Yang Jianliang, Hou Hanping. Research on real-time monitoring and optimization of cold chain logistics big data[J]. Science and Technology Management Research, 2017,37(6):198-203.
[4] Zhenlin Wei, Jianqing Sun. Discussion on urbun common distribution mode for small and medium-sized e-commerce enterprises[J]. Journal of Beijing Jiaotong University(Social Science Edition),2015,14(1):104-110.
[5] Chuanlei Wang, Jiao Chen, Yihuo Wan. Research on the Urban Common Distribution Model from the Perspective of Modern Scale Economy[J]. Journal of Xi’an University of Finance and Economics,2017, 30(3):82-87.
[6] L. X. Li, Y. Yang, G. Y. Qin. "Analyzing the Impact of Vehicle Speed on Distribution Cost for Cold Chain Logistics", 2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 2019.