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A Study on Cost Allocation Model and Application of Beijing Fresh Products

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Abstract. This paper introduces the co-distribution model into the distribution of fresh products in Beijing, and studies the problem of cost sharing among them. Based on the research on the basic theory, the paper establishes the cost sharing model of Beijing fresh products, and uses the Nash negotiation method to solve the model. Finally, three typical fresh products distribution enterprises in Beijing were selected, and the feasibility of the model was verified by calculating the cost of co-distribution under different cooperation schemes.

Keywords: Joint distribution, Fresh products, Cost-sharing, Nash negotiation method.

1. Introduction

In recent years, the increasing demand for fresh products logistics and the rapid development of modern logistics information technology have provided requirements and conditions for the application of the common distribution model of fresh products. Joint distribution refers to the distribution activities jointly implemented by many enterprises. It is an important way to achieve the scale of distribution economy, reduce enterprise operating costs, and save enterprise resources. It is also a powerful means to improve the transportation environment and realize social resource sharing and effective use. Fresh products distribution enterprises cooperate to carry out joint distribution, can quickly integrate the fresh logistics resources of enterprises, generate additional benefits from cooperation, and improve the viability of enterprises. But at present our country still lacks the relevant experience to implement the joint distribution, the enterprise also does not combine the joint distribution theory with the practice. According to the present situation and demand of fresh distribution, establishing a scientific and reasonable cost sharing mechanism is a necessary condition for the development of fresh and common distribution mode.

2. Research Status of Fresh Product Logistics

The research on fresh product logistics abroad has been relatively rich. As early as 1901, the American scholar John Crowe analyzed the composition of the distribution cost of fresh products and its influencing factors, and opened up the way for the study of fresh product distribution logistics [1]. In 1932, Kelake.weierde began the design of the fresh product logistics model through the detailed division of fresh agricultural products in the flow process, and analyzed the relationship between input and output under different modes [2]. In 1998, Salin.V proposed that fresh agricultural products should be guaranteed the quality and safety of fresh products during storage and transportation, and corresponding protection measures should be adopted during the distribution process [3]. In 2009, Rui M.S Crus, Margaridda et al. established a distribution consumption model for agricultural products and studied the impact of changes in cold chain temperature on the quality of fresh products [4]. And in recent years, relevant scholars have begun to try to apply the common distribution model and the fresh product distribution model. In 2004, Teoder, Gabriel, etc. proposed the concept of joint distribution [5]. In 2008, Matopoulos studied the MTGD logistics service model, which is a multi-temperature common distribution system, providing effective solutions for fresh products of different properties [6].

Although China's fresh product logistics industry has not developed for a long time, experts and scholars are enthusiastic about the field of fresh product logistics. In 2004, Li Yanfeng proposed that the logistics of fresh agricultural products based on third parties should be the future development direction by studying the logistics model of fresh agricultural products in China. And in 2009, Yang Guanghua proposed that cold chain transportation is an effective way to reduce the loss of fresh products in the road, and related studies have been conducted on the application of cold chain. In 2013, Yuanqing believed that China's fresh cold chain logistics lacks relevant standards and put forward relevant suggestions for promoting the standardization of fresh product cold chain logistics. And in the face of the problems found in the distribution of urban fresh products in China, scholars began to turn the focus of research to the optimization direction of the problem. In 2013, Hou Yan designed a common distribution model suitable for frozen food companies in Henan Province through the study of existing common distribution modes, and used the satisfaction equation method to share the cost of common distribution.

3. Construction of Cost Allocation Model for Common Distribution of Fresh Products

3.1 Definition of Research Subjects

The joint distribution alliance of Beijing fresh products is established on the basis of the common distribution model. The enterprises participating in the joint distribution alliance are the enterprises engaged in fresh cold chain distribution in Beijing, that is, the model is based on fresh products distribution enterprises.

3.2 Setting of Model Parameters

In order to facilitate the analysis of the cost sharing of the main body of the game, the following variables are given, as shown in Table 1.

Table 1. Model Variables and Meaning

variable	significance
y_i	cost-sharing of I participating co-distribution enterprises
$C(N)$	Total operating cost of the joint distribution alliance when carrying out joint distribution business
c_i	I Operating costs when enterprises do not cooperate to complete distribution operations alone
k_1	fuel consumption factor for distribution vehicles
k_2	Operating cost factor during distribution
m	Refrigeration consumption factor for refrigeration vehicles
l_N, t_N	Total distance of joint distribution alliance delivery process and total time of refrigerated truck operation
l_i, t_i	I Overall distance of individual distribution process for enterprises and time of operation of refrigerated vehicles.

3.3 Model Construction

(1) Definition of the Alliance for Joint Distribution of Fresh Products

The Fresh Products Joint Distribution Alliance refers to the collection of all participating companies involved in the joint distribution of fresh products, denoted as N ={1, 2, ..., N}, Any of the non-empty subsets S⊂N ,corresponds to a real-valued function V(S), satisfying the following conditions:

$$\begin{cases} V(\emptyset) = 0 \\ V(S_1 \cup S_2) \geq V(S_1) + V(S_2)\ (S_1 \cap S_2 = \emptyset) \end{cases} \quad (1)$$

Called [N, V] for N participating corporate cooperation countermeasures, V is the characteristic function of the countermeasure, and $V(S)$ is called the return value of the cooperative alliance S. The feature function actually states that the benefits that can be produced under different cooperation modes are more than those under non-cooperation modes; Cooperation not only does not harm the interests of the individual, but also brings about the increase of benefits for the individual and the whole. Therefore, the mode of cooperation is the best choice for all partners.

VectorX(V) $= (X_1(\mathrm{V}), X_2(\mathrm{V}), \ldots, X_n(\mathrm{V}))$represents the cost allocation after cooperating, Among them, $X_i(\mathrm{V})$ represents the cost allocated to the first joint distribution participating company. Cooperative countermeasures (allocation vectors) should satisfy the following theorems:

1) Unordered: How much is allocated is irrelevant to the number of the joint distribution company.

2) Total invariance: The sum of the costs shared by the participating companies of the common distribution is equal to the sum of the costs of the joint distribution alliance.

3) No contributors are not allocated: For a joint distribution participating enterprise I, all S, when $\mathrm{i} \in \mathrm{S} \subset \mathrm{I}$, and $\mathrm{V}(S) = \mathrm{V}(S - \{i\})$, $X_i(\mathrm{V}) = 0$ holds.

4) Meet the linear transformation: If N participating companies carry out two collaborations, the distribution of the two partnerships will have the same effect as the total one-time allocation.

(2) Construction of Cost Allocation Model

The cost shared in the cost sharing model refers to the total cost consumed by the joint distribution alliance of fresh products during the operation process. It mainly includes distribution transportation costs, vehicle refrigeration costs, and operating costs such as manpower and vehicle maintenance during operation. Therefore, the cost-sharing model of the Fresh Products Joint Distribution Alliance means that for N coalition members, there is an N-dimensional vector($\mathrm{y} = y_1, y_2, \ldots, y_n$)that satisfies:

$$\begin{cases} \sum_{i \in N} y_i = C(N) \\ y_i \leq \mathrm{c}_i \end{cases} \tag{2}$$

$$\begin{cases} C(N) = C_1 + C_2 \\ C_1 = (k)_1 + k_2 \times l_N + m \times t_N \\ C_2 = (k)_1 + k_2 \times l'_N + m \times t'_N \\ \mathrm{c}_i = (k)_1 + k_2 \times l_i + m \times t_i \end{cases} \tag{3}$$

In the above model, the n-dimensional vector ($\mathrm{y} = y_1, y_2, \ldots, y_n$) represents the final cost share of each member of the joint distribution alliance composed of N fresh cold chain logistics companies. y_i represents the cost share of the first participating company, an $C(N)$ represents the total cost incurred by N participating in the joint distribution operation(regardless of the fixed costs of the previous input, including distribution costs and fund-raising costs). c_i represents the cost of the first enterprise in the joint distribution alliance when it does not participate in the joint distribution operation alone, k_1 represents the fuel consumption factor of the distribution vehicle, and k_2 represents the operating cost factor of the distribution process. M represents the refrigeration consumption factor for refrigeration vehicles, l_N represents the total distance of the joint distribution alliance distribution process, and t_N represents the total time of the joint distribution alliance distribution process. l_N' indicates the total distance used for the joint distribution of the alliance collection process, l_i indicates the total distance of the I enterprise's individual distribution process, and t_i indicates the total time of the I enterprise's individual distribution process.

3.4 Model Solving Algorithm

Nash proposed the Nash negotiation method with the help of game theory analysis tools in 1950-1953, using axiomatic methods to solve cooperation problems. Nash negotiation method can be used to solve the problem of calculating the cost sharing of each participant in common distribution [12]. The applicable principles of the Nash negotiating method are shown in Table 2, and solutions that conform to these principles are unique.

Table 2. Principles of Nash Negotiations

Principle	Content
Metric irrelevance	The outcome of the negotiations is independent of the unit of measure used during the negotiations
Effectiveness of results	The result of the negotiation is a valid optimal solution
Irrelevance of irrelevant choices	The outcome of the negotiations is only relevant to the eventual adoption of a viable solution
Symmetry	The exchange of positions between the parties does not affect the final outcome

Using the Nash product method in the Nash negotiation principle to solve the above established distribution cost sharing model for fresh products, the solution of this model can be converted into the following linear programming problems:

$$max \prod_{i \in N}(c_i - y_i) \tag{4}$$

s. t.

$$\begin{cases} \sum_{i \in N} y_i - C(N) = 0 \\ \Delta c < y_i < c_i \end{cases} \tag{5}$$

The constraint condition $\sum_{i \in N} y_i - C(N) = 0$ indicates that the cost after the alliance is fully shared among all participating enterprises, which is in accordance with the principle of economic efficiency. Condition $\Delta c < y_i < c_i$, which means that the cost of any participation in the enterprise is less than the cost at the time of its separate distribution, but it is greater than the marginal cost incurred.

4. Case Analysis

In this paper, three fresh products distribution enterprises A, B and C in Beijing are selected to form a joint distribution alliance for fresh products, and 10 supermarkets, fresh shops and catering enterprises that all three distribution enterprises have distribution business contacts are selected as the distribution destinations. Calculate the fresh cold chain distribution cost before and after the application of the common distribution mode. When the distribution business between the three fresh distribution enterprises and the 10 distribution destinations remains unchanged, the calculation results are compared and analyzed.

4.1 Data Processing

Through research and calculation, the optimal distribution mileage and delivery time in each distribution situation are obtained, as shown in Table 3:

Table 3. Distribution time and duration of the company's cooperation

Cooperation	Distribution miles/km	Distribution times/min
A	93	309
B	101	323
C	110	340
AB	174	658
AC	187	680
BC	197	698
ABC	214	905

The cost of distribution costs only covers the three main aspects of distribution vehicle driving costs, in-transit refrigeration costs, and distribution operation costs. In the calculation, the average daily distribution volume of each company is used as the benchmark, and the single day distribution operation is used as the reference period. The cost calculation formula is:

Distribution cost = Vehicle driving cost + Vehicle in transit refrigeration cost + Distribution operation cost.

According to the investigation, the vehicle engine is a diesel engine. The fuel consumption during the driving process is 0.15 L/km. The current diesel market price is about 6 yuan/L, and the refrigeration cost for refrigerated vehicles is 4 yuan/hour. The average speed is 35 km/h. About; The unloading time of fresh products occurring at each distribution point is recorded as 15 min; Distribution operating costs and distribution mileage are roughly proportional, and the operating cost coefficient in the distribution process is 0.4 yuan/km. The aggregate time for each temporary storage area is 30 min. The results are obtained from the formula, as shown in table 4.

Table 4. Distribution costs of the company's cooperation

Cooperation	A	B	C	AB	AC	BC	ABC
Cost/yuan	141.5	152.8	167	270.1	288.4	302.6	336.7

From the above table, we can know:

$\Delta c(A) = c(ABC) - c(BC) = 336.7 - 302.6 = 34.1$yuan

$\Delta c(B) = c(ABC) - c(AC) = 336.7 - 288.4 = 48.3$yuan

$\Delta c(C) = c(ABC) - c(AB) = 336.7 - 270.1 = 66.6$yuan

4.2 Model Solving

Based on the data obtained from the above calculations, using the established cost sharing model, the Nash negotiation method is used to calculate the cost apportionment of the three participating enterprises.$Y = \{y_A, y_B, y_C\}$ represents the cost to be shared by the three companies participating in the joint distribution, transforming the solution of the model into the following linear programming problems:

$$\max(141.5 - y_A)(152.8 - y_B)(167 - y_C)$$

s.t.

$$34.1 < y_A < 141.5$$
$$48.3 < y_B < 152.8$$
$$66.6 < y_C < 167$$
$$y_A + y_B + y_C = 336.7$$

Using lingo software to solve the linear programming problem, solved y_A= 100(yuan), y_B= 111.3(yuan), y_C= 125.4(yuan).

In order to reflect the changes in costs after the use of joint distribution by the three ABC companies more intuitively, a comparative map of the cost changes before and after the adoption of the common distribution model by the three ABC companies is drawn based on the information in table 4, as shown in figure 1.

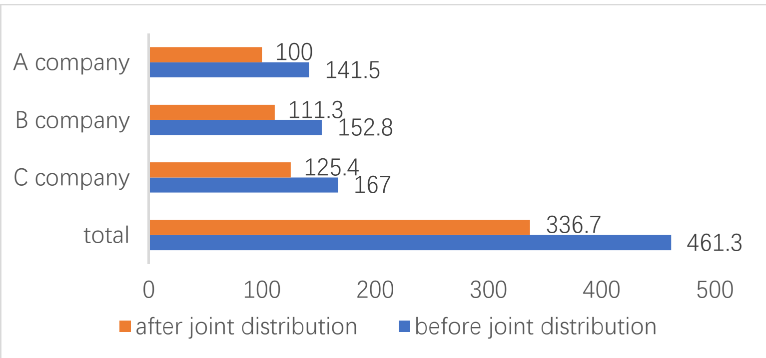

Figure 1. Cost comparison before and after ABC common distribution

Therefore, after the three fresh distribution companies adopt a common distribution model, the share of the cost of the single distribution of bicycles is 100 yuan for A enterprise, 111.3 yuan for B enterprise, and 125.4 yuan for C enterprise. Using this method to share the cost, compared with the three fresh distribution enterprises that carry out distribution alone, A enterprise 141.5 yuan, B enterprise 152.8 yuan, C enterprise 167 yuan, costs saving about 30 %.

5. Conclusion

Based on the problem of high cost of fresh product distribution enterprises, this paper puts forward the concept of joint distribution, establishes the cost sharing model of Beijing fresh product distribution, uses Nash negotiation method to solve the cost sharing problem, and finally combines the data of three distribution centers in Beijing to carry out empirical research. Empirical results show that the distribution cost of the joint distribution system is significantly reduced after the joint distribution model is adopted, which satisfies the objectives established by the joint distribution system, and proves that the cost sharing mechanism is scientific and reasonable.

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