Analysis of Influencing Factors of Cold Chain Logistics Cost of Dairy Products

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Abstract: Alongside the gradual improvement of the market position of dairy cold chain logistics, the cold chain transportation technology used in the logistics industry has also been taken to a whole-new level. There exists a fundamental contradiction between the rigorous requirements of dairy products for temperature control and the low level of development of cold chain logistics, and this contradiction is one of the reasons for the high costs of dairy cold chain logistics. To address this contradiction, we established an indicator system of factors influencing the costs of dairy cold chain logistics from three dimensions of dairy product characteristics, transportation process and cold chain logistics market, and invited managers from dairy companies and transportation professors from relevant universities to probe into the corresponding weights and to pin down the appropriate scores for indicators at all levels. Then we harnessed the AHP method to calculate the important weights for indicators at all levels, and eventually put forward the optimal solution for cutting the costs of cold chain logistics through weight difference analysis.

1. Introduction

As the summation of all expenditures incurred in the logistics activities, the logistics cost is the basis underlying logistics management and optimization. How to cut logistics costs has been a long-time pursuit of the logistics sector, and it is no exaggeration to call the history of logistics management a struggling history of cost-cutting. As a matter of fact, against the backdrop of the increasingly fierce competition in the market, how to maximize the business profits has become the biggest concern for all entrepreneurs.

As a pivotal part of the supply chain for perishable goods, cold chain transport prevents dairy products from getting stale or spoiled and protects them from influencing factors such as temperature, humidity, light or specific contaminants, thereby keeping dairy products fresh. Hence, the application and promotion of cold chain in the logistics industry is inevitably necessary, yet the spread and development of cold chain logistics have been stalled by many constraints. Cold chain logistics is holding ever-mounting sway in the market of low-temperature dairy products due to its much-hailed merits of keeping freshness and nutrition, avoiding spoilage, extending the shelf life

and thus expanding the sales area of dairy products. If the costs of cold chain logistics are higher than the losses of agricultural products transported without cold chain, the producers or merchants would be most likely to go for other transport options, such as transporting goods in special times or by ways other than the cold chain. Therefore, it is of paramount importance to optimize and cut the costs of cold chain logistics. By elucidating the composition of cold chain logistics cost and its influencing factors, this paper aims to uncover the deep-seated causes of the persistently high logistics costs by examining those key influencing factors and eventually to propose possible cost optimizations to the respective links of cold chain logistics.

2. Influencing Factors of Cold Chain Logistics Costs of Dairy Products

2.1. Product Characteristics

2.1.1. Product Types and Characteristics

There are many varieties of dairy products, including liquid milk, condensed milk, cheese, milk powder, milk fat, etc. Different types of dairy products have distinctly different temperature requirements in their transportation.

2.1.2. Storage, Transportation and Delivery

According to the temperature requirements of transportation[1], dairy products can be roughly divided into three categories: 1) room-temperature liquid milk, which can be stored and transported at room temperature; 2) pasteurized milk, which must be transported under refrigerated conditions; and 3) ice cream products, which must be transported under frozen conditions.

2.1.3 High Costs of Cold Chain Logistics

The diverse temperature requirements of different dairy products is reflected in the different transport vehicles for difference purposes. The low cost of dairy products is in stark contrast to the expensive cold chain equipment, which in turn push up the logistics costs.

2.2. Influencing Factors of Cold Chain Transport

2.2.1. Transport Choice

Dairy products are perishable and have a short shelf life. While ordinary means of transport will cause dairy products to rot, and stink, the cold chain logistics can increase the transportation efficiency of dairy products and minimize the risk of their deterioration.

2.2.2. Transport Route

China is a country with a vast territory. While consumers of dairy products are mostly concentrated in urban areas, dairy farms tend to be located in the distant grassland areas. As a result, dairy products must be transported over a long distance and in large quantities. Building a full-supply-chain and highly efficient cold chain logistics information system[2] undergirded by a whole-new model would certainly help bring down the costs of cold chain logistics.

2.2.3. Transport Cost

Cold chain logistics technology is still in its infancy in China. In order to ensure the quality and freshness of low-temperature goods, special equipment must be used throughout the supply chain,

which encompasses production, distribution, transportation, storage, sales and the final delivery to end customers. That's why the cold chain logistics is more expensive than other types of logistics.

2.2.4. Transport Temperature

The logistics transportation from dairy farms and the ensuing circulation of dairy products must rely on cold chain logistics technology. The prosperity of low-temperature dairy products hinges largely on China's infrastructure provision and the technological strength of dairy companies. While dairy products have extremely strict temperature requirements[3], China's fledgling cold chain logistics system occasionally fails to keep dairy products at low temperature during production, storage, distribution, and sales. To solve this problem, professional cold chain transport equipment would be needed. China's developmental lag in the cold chain logistics indirectly pushes up the costs of cold chain logistics.

2.2.5. Transportation Management

On the one hand, the transportation of dairy products has extremely strict temperature control requirements. The management team must strengthen self-planning, manage the entire cold chain in a reasonable and effective manner and tighten its grip over temperature control throughout the cold chain[4]. On the other hand, efforts shall be taken to introduce state-of-the-art cold chain transportation and management solutions, to upgrade cold chain equipment, and to vigorously foster cold chain talents to improve the management efficiency.

2.2.6. Transport Risks

Compared with ordinary goods, dairy products are faced with higher risks associated with cold chain transport and therefore involve higher transport costs. To guarantee product quality, dairy companies are supposed to build a full-fledged cold chain[5]. To build an efficient cold chain, dairy companies must harness advanced refrigeration technology to minimize product spoilage and thus reduce losses.

2.3. Market-Related Influencing Factors

2.3.1. Market Competition

Despite the immense market size and its burgeoning development, the dairy cold chain logistics sector is constrained by its low degree of concentration, small fleet of refrigerated trucks and the scattering of refrigerated warehouses. There is no conglomerate in the market with sufficient strength for industrial consolidation, and therefore the competition in the dairy cold chain logistics sector is far from fierce.

2.3.2. Market Circulation

The third-party logistics of dairy cold chain lags far behind in development. The immature service network and information system are posing tremendous impact[6] on the quality and timeliness of dairy products in transit, and are also pushing up the costs of cold chain logistics and the losses of goods.

3. Using Analytic Hierarchy Process (AHP) to Examine Factors Influencing the Costs of Dairy Cold Chain Logistics

3.1. Fundamentals

AHP is to break down a complex and abstract multi-objective decision into indicators of different levels[7], on which basis the decision qualitatively and quantitatively breaks up into different hierarchical structures. The expert would assign values to indicators of the same level according to the corresponding importance scale, and then use the judgment matrix eigenvectors to calculate the weights for further analysis.

3.2. Analysis Process

(1) Establish a hierarchical model and determine the scale matrix

The factors influencing the costs of dairy cold chain logistics are divided into primary and secondary indicators according to their importance. The secondary indicators are shown in Figure 1. The scale matrix of influencing factors is shown in Table 1.
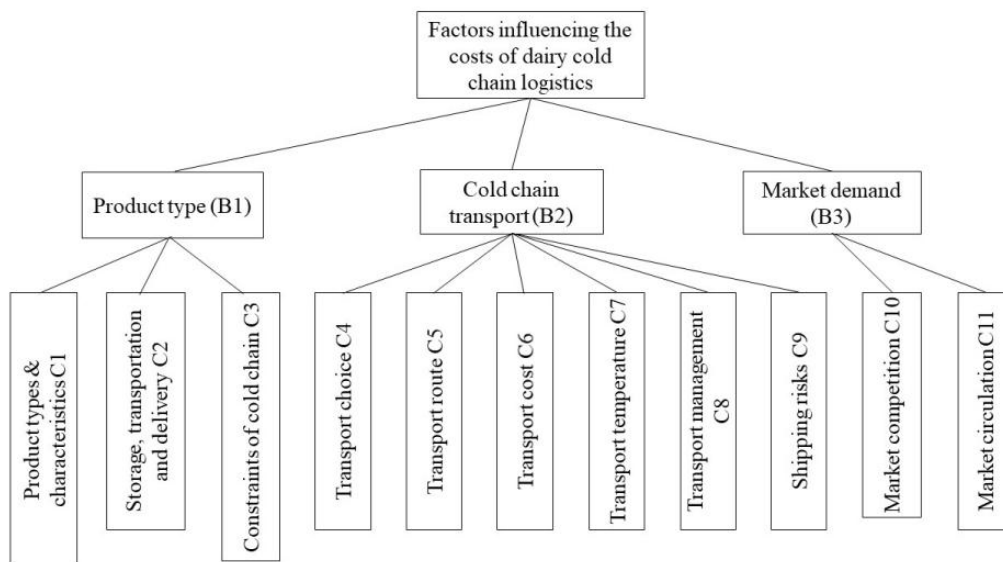

Figure 1: Hierarchical structure of factors influencing the costs of dairy cold chain logistics.

Table 1: Scale matrix of factors influencing the costs of dairy cold chain logistics.

Scale	Definition
1	The comparison of two elements finds two elements are equally important
3	The comparison of two elements finds the former is obviously important than the latter
5	The comparison of two elements finds the former is way more important than the latter
2、4	The comparison of two elements finds the importance of former element falls between the corresponding values
Reciprocal	The comparison of two elements finds the latter is more important than the former (refer to the above definition)

(2) Construct the judgment matrix

The judgment matrix is obtained by comparing objectives of the same level in pairs. The judgment matrix in this paper was obtained by consulting relevant experts (see Tables 2 to 5), and has the following characteristics:

$$a_{ij} = \frac{1}{a_{ij}} \qquad (1)$$

Table 2: Judgments on primary indicators relative to the overall objective.

	Expert s1			Expert s2			Expert s3			Expert s4		
	Ua	Ub	Uc	Ua	Ub	Uc	Ua	Ub	Uc	Ua	Ub	Uc
Ua	1	4	5	1	3	3	1	3	3	1	3	3
Ub	1/4	1	2	1/3	1	1	1/3	1	2	1/3	1	1
Uc	1/5	1/2	1	1/3	1	1	1/3	1/2	1	1/3	1	1
	λ_{max}=3.0246,CR=0.024			λmax=3,CR=0			λmax=3.0536, CR=0.052			λ_{max}=3,CR=0		

Table 3: Judgments on secondary indicators relative to product type factors.

	Expert s1			Expert s2			Expert s3			Expert s4		
	Ua	Ub	Uc	Ua	Ub	Uc	Ua	Ub	Uc	Ua	Ub	Uc
Ua	1	2	1	1	3	1/2	1	3	2	1	1/2	1/3
Ub	1/2	1	1/2	1/3	1	1/4	1/3	1	1/2	2	1	1/2
Uc	1	2	1	2	4	1	1/2	2	1	3	2	1
	λ_{max}=3,CR=0			λ_{max}=3.018,CR=0.018			λ_{max}3.0092, CR=0.009			λ_{max}3.0092, CR=0.009		

Table 4: Judgments on secondary indicators relative to cold chain transport factors.

	Expert s1						Expert s2					
	B1	B2	B3	B4	B5	B6	B1	B2	B3	B4	B5	B6
B1	1	1/3	1/5	1/3	1/4	1/2	1	2	1	3	2	1/3
B2	3	1	1/3	2	1/2	2	1/2	1	1/2	2	1	1/2
B3	5	3	1	3	1/2	2	1	2	1	3	2	1/3
B4	3	1/2	1/3	1	1/2	2	1/3	1/2	1/3	1	1/2	1/5
B5	4	2	2	2	1	3	1/2	1	1/2	2	1	1/3
B6	2	1/2	1/2	1/2	1/3	1	3	2	3	5	3	1
	λ_{max}=6.2633,CR=0.042						λ_{max}=6.1318,CR=0.02					
	Expert s3						Expert s4					
B1	1	2	3	4	2	1/2	1	1	1/2	1/4	1/2	1/3
B2	1/2	1	1	2	1	1/3	1	1	1/2	1/4	1/2	1/3
B3	1/2	1	1	2	1	1/3	2	2	1	1/2	1	1/2
B4	1/4	1/2	1/2	1	1/2	1/6	4	4	2	1	2	1
B5	1/2	1	1	2	1	1/3	2	2	1	1/2	1	1/2

B6	2	3	3	6	3	1	3	3	2	1	2	1
	λ_{max}=6.0955,CR=0.015						λ_{max}=6.0138,CR=0.002					

Table 5: Judgments on secondary indicators relative to market demand factors.

		Expert s1		Expert s2	
		C1	C2	C1	C2
C1		1	1/3	1	1
C2		3	1	1	1
		λ_{max}=2,CR=0		λ_{max}=2,CR=0	
		Expert s3		Expert s4	
C1		1	1	1	1/2
C2		1	1	2	1
		λ_{max}=2,CR=0		λ_{max}=2,CR=0	

(3) Calculate the weight

Calculate the weights according to the existing judgment matrix. The equation is shown below:

$$W_i = (\prod a_{ij})^{1/n} \qquad (2)$$

$$W_i^0 = W_i / \sum W_i \qquad (3)$$

(4) Consistency test

Due to the complexity and abstraction of the objectives, the expert's judgment is susceptible to certain subjective factors, and a consistency test can avoid the lack of logic in some judgments. The equation for consistency test is:

$$CR=CI/RI \qquad (4)$$

$$CI = \frac{\lambda_{max} - n}{N - 1} \qquad (5)$$

If CR<0.1, the judgments are considered to be consistent, or else they are inconsistent and shall be adjusted. The CR values of respective judgment matrices are shown in Table 2 to Table 5. According to these tables, the CR values are all less than 0.1, suggesting that the consistency test has been passed.

(5) Calculate the final weights

The final weights are obtained based on the mean weights of the indicators at all levels, as shown in Table 6.

Table 6: Weights for factors influencing the costs of dairy cold chain logistics.

A	B/C	B1	B2	B3	W	Ranking
0.6192	C1	0.3700	0	0	0.2291	2
	C2	0.1956	0	0	0.1211	3
	C3	0.4538	0	0	0.2801	1
0.2122	C4	0	0.1356	0	0.0288	9
	C5	0	0.1154	0	0.0244	11
	C6	0	0.1776	0	0.0377	7
	C7	0	0.1329	0	0.0282	10
	C8	0	0.1663	0	0.0353	8
	C9	0	0.2721	0	0.0577	6
0.1685	C10	0	0	0.3958	0.0667	5
	C11	0	0	0.6042	0.1018	4

3.3. Interpretation of Results

It can be seen from Table 6 that there are different degrees of differences between factors influencing the costs of cold chain logistics. The weight analysis further revealed that product characteristics had the most significant impact on logistics costs, with the greatest impact coming from the various constraints of the cold chain transportation of dairy products, followed by product type, and finally the process of storage, transportation and delivery. Since dairy products are perishable and get sour and stinky easily, they must be stored, transported, processed and handled at low temperatures. This means that the investment of cold chain logistics companies in transportation equipment is higher than that of ordinary logistics companies. Moreover, there are a wide variety of dairy products, and different dairy products have different temperature requirements, meaning that a large refrigerated truck can only transport certain types of dairy products. This increases not only the transportation cost but the management cost as well. On top of that, the impact of market on the costs of dairy cold chain logistics is also worthy of our attention. In China, dairy products are basically transported on a large scale by refrigerated trucks, which without doubt entail higher transportation costs than ordinary trucks. Whilst it's impossible to cut the transportation costs, the market demand for dairy products would pose a markedly huge impact, yet the market demand is uncontrollable, in which case our overarching priority would be to improve the technological level of cold chain logistics and to build a full-fledged cold chain logistics system. The circulation and competition in the cold chain logistics market are also closely correlated with the logistics costs, yet the additional costs arising amid the transportation process would pose little influence. Also, we can cut the costs by narrowing the delivery range, devising the best delivery routes or reducing the supply of dairy products.

4. Conclusion

In the wake of the improvement of living standards and the shift in dietary patterns, people have never been so zealous for dairy products as they are now. Dairy companies must attach importance to the upgrade of their cold chain logistics technology. Presently, whilst there is immense room for the blossoming development of the dairy cold chain logistics market, factors influencing logistics costs are markedly unstable -- whether it is the characteristics of dairy products or the transport losses or the market demand, the impact varies to a large extent. By establishing a matrix model to analyze the corresponding weights, we have come to the conclusion that in order to cut the logistics costs and to minimize the losses in transit, the cold chain logistics sector must strengthen infrastructure construction and push for technology upgrade.

Acknowledgements

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