Research on Assessment of Farm Product Cold Chain Quality and Safety Based on Intuitionistic Triangular Fuzzy TOPSIS

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Keywords: Technique for Order Preference by Similarity to Ideal Solution（TOPSIS）, intuitionistic triangular fuzzy ,farm product cold chain ,assessment of quality and safety.

Abstract. The aim of this paper is to compare the safety and quality among farm product cold chain companies. Equipment and facility, logistics environment, personnel quality and process are used to establish the comprehensive index system. Then, because of the uncertainty and fuzziness, a risk prioritization model of farm product cold chain quality and safety based on intuitionistic triangular fuzzy TOPSIS was constructed. A case example was presented to demonstrate the practicality of proposed approach.

1. Introduction

Nowadays people pay more attention to food freshness and greenness, especially for those fresh farm products. However, whether the quality of farm products can be guaranteed remains a problem. Some nationwide serious safety accidents generated extensive hazard. As a result, consumers do not trust those similar industries. Based on these considerations as above, we need to set goals focused on sorts of quality safety evaluation for cold chain logistics enterprises, which is useful for us to play its guiding roles and significance both in theory and practice.

Over the years, theoretical research of farm product logistics is mainly about the content of farm product cold chain quality safety control, relationships between food safety and logistics, etc, which can form the basis of deeper research in the future. Currently, the cold chain logistics industry has developed rapidly and many new enterprises entered the market, however, low safety of cold chain logistics not only poses a serious threat to customers but also brings a great loss to the national economy. However, there are only a few theories about cold chain logistics at present, and we found that cold chain could play an important role both in farm product safety and the area of farm products safety control when we studied cold chain logistics.

According to the study of references, we have established the quality safety evaluation model by analyzing the influencing factors of cold chain logistics of farm products. This model can be used to compare the quality and safety of different cold chain logistics enterprises and sort efficiently, so as to find out those enterprises exist security risks and improve them.

2. Organization of the Text

2.1 TOPSIS Analysis of Cold Chain Logistics of Farm Products

2.1.1 TOPSOS Method

The concept of intuitionistic fuzzy sets was proposed by the Bulgarian scholar Atanassov in 1986.Because of the introduction of non-membership degree, a new parameter, which can describe fuzzy concept, intuitionistic fuzzy sets can deal with the uncertainty and fuzziness more flexibly.

Definition 1 : assuming $\tilde{a}$ is a fuzzy number on the real number set $\tilde{a} = ([\underline{a}, a, \overline{a}], \mu_{\tilde{a}}, \upsilon_{\tilde{a}})$, so its membership function is

$$\omega_{\tilde{a}}(x) = \begin{cases} \frac{x - \underline{a}}{a - \underline{a}} \mu_{\tilde{a}}, \underline{a} \le x < a; \\ \frac{\overline{a} - x}{\overline{a} - a} \mu_{\tilde{a}}, a \le x \le \overline{a}; \\ 0, else \end{cases} \quad (1)$$

and its non-membership function is

$$u_{\tilde{a}}(x) = \begin{cases} \frac{a - x + \upsilon_{\tilde{a}}(x - \underline{a})}{a - \overline{a}}, \underline{a} \le x < a; \\ \frac{x - a + \upsilon_{\tilde{a}}(\overline{a} - x)}{\overline{a} - a}, a \le x \le \overline{a}; \\ 0, else \end{cases} \quad (2)$$

Among them, the maximum membership degree is $\mu_{\tilde{a}}$, the minimum membership degree is $\upsilon_{\tilde{a}}$, and $0 \le \mu_{\tilde{a}} \le 1$, $0 \le \upsilon_{\tilde{a}} \le 1$, $\mu_{\tilde{a}} + \upsilon_{\tilde{a}} \le 1$, $a, b, c \in R$, so $\tilde{a} = ([\underline{a}, a, \overline{a}], \mu_{\tilde{a}}, \upsilon_{\tilde{a}})$ is called intuitionistic triangular fuzzy numbers. Non-membership function indicates that decision makers don not think it belongs to the extent of $[\underline{a}, a, \overline{a}]$. In particular cases, $\omega_{\tilde{a}} = 1$, $u_{\tilde{a}} = 0$, $\tilde{a}$ is a traditional intuitionistic triangular fuzzy number.

Definition 2 : assuming $\tilde{a} = ([\underline{a}, a, \overline{a}], \mu_{\tilde{a}}, \upsilon_{\tilde{a}})$ and $\tilde{b} = ([\underline{b}, b, \overline{b}], \mu_{\tilde{b}}, \upsilon_{\tilde{b}})$ are two intuitionistic triangular fuzzy numbers, so the distance between $\tilde{a}$ and $\tilde{b}$ is

$$D(\tilde{a}, \tilde{b}) = \frac{\lambda}{4}\left|(\underline{a} + 2a + \overline{a})\mu_{\tilde{a}} - (\underline{b} + 2b + \overline{b})\mu_{\tilde{b}}\right| + \frac{1-\lambda}{4}\left|(\underline{a} + 2a + \overline{a})(1 - \upsilon_{\tilde{a}}) - (\underline{b} + 2b + \overline{b})(1 - \upsilon_{\tilde{b}})\right| \quad (3)$$

2.1.2 Cold Chain Logistics Evaluation Index System

Based on the characteristics of farm products, aiming at the characteristics of cold chain logistics, this paper establishes a comprehensive index system of farm products logistics, as shown in the following Table 1.

Table 1 Cold Chain Logistics Safety Evaluation Index System

Overall Layer	Dimension Layer	Index Layer
Cold Chain Logistics Quality Safety Index S	Logistics Operation Environment E	Temperature E1
		Humidity E2
		Cleanliness E3
	Installation Facility F	Refrigerator car use rate F1
		Cold storage capacityF2
		Cold storage utilization ratio F3
		Temperature control facilities advanced F4
	Operation Process P	Cold chain transport cargo damage rate P1
		Precooling preservation rate P2
		Cold chain link flexibility P3
	Staff Quality Q	Professional occupancy Q1
		Health knowledge training rate Q2
		Staff skills training Q3

2.2 Cold Chain Logistics Quality and Safety Evaluation Model of Farm Products

2.2.1 Set Up Triangular Intuitionistic Fuzzy Matrix

Fuzzy index for evaluating the safety of cold chain logistics can be quantified as triangular intuitionistic fuzzy numbers and formed matrix according to experts and the measurement of relevant data. For example, the triangular intuitionistic fuzzy matrix of multiple enterprises in logistics operation environment as shown in the following Table 2:

Table 2 Triangular intuitionistic fuzzy matrix

E_1	E_2	E_3
$([\underline{a}_{11}, a_{11}, \overline{a}_{11}], \mu_{\tilde{a}_{11}}, \upsilon_{\tilde{a}_{11}})$	$([\underline{a}_{12}, a_{12}, \overline{a}_{12}], \mu_{\tilde{a}_{12}}, \upsilon_{\tilde{a}_{12}})$	$([\underline{a}_{13}, a_{13}, \overline{a}_{13}], \mu_{\tilde{a}_{13}}, \upsilon_{\tilde{a}_{13}})$
$([\underline{a}_{21}, a_{21}, \overline{a}_{21}], \mu_{\tilde{a}_{21}}, \upsilon_{\tilde{a}_{21}})$	$([\underline{a}_{22}, a_{22}, \overline{a}_{22}], \mu_{\tilde{a}_{22}}, \upsilon_{\tilde{a}_{22}})$	$([\underline{a}_{23}, a_{23}, \overline{a}_{23}], \mu_{\tilde{a}_{23}}, \upsilon_{\tilde{a}_{23}})$
$([\underline{a}_{31}, a_{31}, \overline{a}_{31}], \mu_{\tilde{a}_{31}}, \upsilon_{\tilde{a}_{31}})$	$([\underline{a}_{32}, a_{32}, \overline{a}_{32}], \mu_{\tilde{a}_{32}}, \upsilon_{\tilde{a}_{32}})$	$([\underline{a}_{33}, a_{33}, \overline{a}_{33}], \mu_{\tilde{a}_{33}}, \upsilon_{\tilde{a}_{33}})$
...	...	...
$([\underline{a}_{n1}, a_{n1}, \overline{a}_{n1}], \mu_{\tilde{a}_{n1}}, \upsilon_{\tilde{a}_{n1}})$	$([\underline{a}_{n2}, a_{n2}, \overline{a}_{n2}], \mu_{\tilde{a}_{n2}}, \upsilon_{\tilde{a}_{n2}})$	$([\underline{a}_{n3}, a_{n3}, \overline{a}_{n3}], \mu_{\tilde{a}_{n3}}, \upsilon_{\tilde{a}_{n3}})$

We need to eliminate the influence of different physical dimensions on decision results, so as to normalize triangular intuitionistic fuzzy decision matrix , as is shown in Formula (4).

$$\tilde{r} = \left(\left[\frac{\underline{a}_{nE_j}}{\overline{a}_{nE_j}}, \frac{a_{nE_j}}{\overline{a}_{nE_j}}, \frac{\overline{a}_{nE_j}}{\overline{a}_{nE_j}}\right], \mu_{\tilde{a}_{nE_j}}, \upsilon_{\tilde{a}_{nE_j}}\right) \quad n = (1,2,3...),\ j = (1,2,3) \tag{4}$$

As the important degree of each index in the evaluation system is different, we need to calculate the weight of each index. This paper adopts the intuitionistic fuzzy entropy method to calculate the objective weight of index, which can make the evaluation results more scientific and accord with the characteristics of index.

As for intuitionistic triangular fuzzy numbers $\tilde{a} = ([\underline{a}, a, \overline{a}], \mu_{\tilde{a}}, \upsilon_{\tilde{a}})$, we say that $\pi_{\tilde{a}}(x) = 1 - \mu_{\tilde{a}}(x) - \upsilon_{\tilde{a}}(x)$ is the hesitation degree of x about $\tilde{a}$,and $f_{\tilde{a}}(x) = 1 - |\mu_{\tilde{a}}(x) - \upsilon_{\tilde{a}}(x)|$ is the fuzzy degree of x about $\tilde{a}$ .The intuitionistic fuzzy entropy of definition index E is

$$U(E_j) = \frac{1}{n}\sum_{i=1}^{n}\sqrt{\frac{\pi_{iE_j}^2(x) + f_{iE_j}^2(x)}{2}} \quad j = 1,2,3; i = 1,2,3...n$$

The bigger the fuzzy entropy $U(E_j)$, the higher degree of uncertainty and ambiguity of E_{ij} ,and the weight of the index should be smaller. So the weight of the index E_j is

$$\omega_j = \frac{1 - U(E_j)}{\sum_{j=1}^{4}(1 - U(E_j))}, \ j = 1,2,3 \tag{5}$$

So $\tilde{g} = \omega_j \tilde{r} = ([\omega_j \underline{r}, \omega_j r, \omega_j \overline{r}], \mu_{\tilde{r}}, \upsilon_{\tilde{r}})$

After processing, the fuzzy triangular matrix is shown in Table 3

Table 3 Specification weighted triangular fuzzy matrix

E_1	E_2	E_3
$([\underline{g}_{11}, g_{11}, \overline{g}_{11}], \mu_{\tilde{g}_{11}}, \upsilon_{\tilde{g}_{11}})$	$([\underline{g}_{12}, g_{12}, \overline{g}_{12}], \mu_{\tilde{g}_{12}}, \upsilon_{\tilde{g}_{12}})$	$([\underline{g}_{13}, g_{13}, \overline{g}_{13}], \mu_{\tilde{g}_{13}}, \upsilon_{\tilde{g}_{13}})$
$([\underline{g}_{21}, g_{21}, \overline{g}_{21}], \mu_{\tilde{g}_{21}}, \upsilon_{\tilde{g}_{21}})$	$([\underline{g}_{22}, g_{22}, \overline{g}_{22}], \mu_{\tilde{g}_{22}}, \upsilon_{\tilde{g}_{22}})$	$([\underline{g}_{23}, g_{23}, \overline{g}_{23}], \mu_{\tilde{g}_{23}}, \upsilon_{\tilde{g}_{23}})$
$([\underline{g}_{31}, g_{31}, \overline{g}_{31}], \mu_{\tilde{g}_{31}}, \upsilon_{\tilde{g}_{31}})$	$([\underline{g}_{32}, g_{32}, \overline{g}_{32}], \mu_{\tilde{g}_{32}}, \upsilon_{\tilde{g}_{32}})$	$([\underline{g}_{33}, g_{33}, \overline{g}_{33}], \mu_{\tilde{g}_{33}}, \upsilon_{\tilde{g}_{33}})$
...	...	...
$([\underline{g}_{n1}, g_{n1}, \overline{g}_{n1}], \mu_{\tilde{g}_{n1}}, \upsilon_{\tilde{g}_{n1}})$	$([\underline{g}_{n2}, g_{n2}, \overline{g}_{n2}], \mu_{\tilde{g}_{n2}}, \upsilon_{\tilde{g}_{n2}})$	$([\underline{g}_{n3}, g_{n3}, \overline{g}_{n3}], \mu_{\tilde{g}_{n3}}, \upsilon_{\tilde{g}_{n3}})$

2.2.2 Calculate Positive and Negative Ideal Solution

$$\tilde{g}_{E_j}^{+} = \left(\left[\max_{1\le i\le N} \overline{g}_{iE_j}, \max_{1\le i\le N} g_{iE_j}, \max_{1\le i\le N} \underline{g}_{iE_j}\right]; \max_{1\le i\le N} \mu_{iE_j}, \max_{1\le i\le N} \upsilon_{iE_j}\right) = \left(\left[\underline{g}_{E_j}^{+}, g_{E_j}^{+}, \overline{g}_{E_j}^{+}\right]; \ \mu_{\tilde{g}_{E_j}}, \upsilon_{\tilde{g}_{E_j}}\right) \tag{6}$$

$$\tilde{g}_{E_j}^{-} = \left(\left[\min_{1\le i\le N} \overline{g}_{iE_j}, \min_{1\le i\le N} g_{iE_j}, \min_{1\le i\le N} \underline{g}_{iE_j}\right]; \min_{1\le i\le N} \mu_{iE_j}, \min_{1\le i\le N} \upsilon_{iE_j}\right) = \left(\left[\underline{g}_{E_j}^{-}, g_{E_j}^{-}, \overline{g}_{E_j}^{-}\right]; \ \mu_{\tilde{g}_{E_j}}, \upsilon_{\tilde{g}_{E_j}}\right) \tag{7}$$

2.2.3 Calculate the Distance between Positive and Negative Ideal Route

Assuming the safety evaluation state of different enterprises is $x_i (i = 1,2,3,..., N)$, so the distance between the positive and negative ideal route is:

$$D_i^+(x_i, x^+) = \sum_{j=1}^{n} \frac{1}{8}\left[\left|\left(\underline{g}_{iE_j} + 2g_{iE_j} + \overline{g}_{iE_j}\right)\mu_{\tilde{g}_{iE_j}} - \left(\underline{g}_j^+ + 2g_j^+ + \overline{g}_j^+\right)\mu_{\tilde{g}_{iE_j}}\right| + \left|\left(\underline{g}_{iE_j} + 2g_{iE_j} + \overline{g}_{iE_j}\right)\right.\right.$$
$$\left.\left.\left(1-\upsilon_{iE_j}\right) - \left(\underline{g}_j^+ + 2g_j^+ + \overline{g}_j^+\right)\left(1-\upsilon_{\tilde{g}_{iE_j}}\right)\right|\right] \quad (8)$$

$$D_i^-\left(x_i, x^-\right) = \sum_{j=1}^{n} \frac{1}{8}\left[\left|\left(\underline{g}_{iE_j} + 2g_{iE_j} + \overline{g}_{iE_j}\right)\mu_{\tilde{g}_{iE_j}} - \left(\underline{g}_j^- + 2g_j^- + \overline{g}_j^-\right)\mu_{\tilde{g}_{iE_j}}\right| + \left|\left(\underline{g}_{iE_j} + 2g_{iE_j} + \overline{g}_{iE_j}\right)\right.\right.$$
$$\left.\left.\left(1-\upsilon_{\tilde{g}_{iE_j}}\right) - \left(\underline{g}_j^- + 2g_j^- + \overline{g}_j^-\right)\left(1-\upsilon_{\tilde{g}_{iE_j}}\right)\right|\right] \quad (9)$$

Obviously, the smaller $D_i^+\left(x_i, x^+\right)$ is, the more closer to the positive ideal security state is, and the bigger $D_i^-\left(x_i, x^-\right)$ is, the better the security state is.

2.3 Analysis of Farm Products Cold Chain Logistics Quality and Safety Evaluation

According to the distance from the above models, we can calculate the relative proximity is

$$\rho_i = \frac{D_i^-}{D_i^+ + D_i^-}, (i = 1,2,3,..., N) \quad (10)$$

Obviously, the larger $\rho_i \in [0,1]$, the better corresponding scheme is. Thus, we can determine the priority of quality and safety according to the order of $\rho_i \in [0,1]$ from large to small. Besides, we can compare the rank of different enterprises in the indicator E in terms of their safety quality state. In the same way, other indicators can also be calculated for comparative sorting.

2.4 Cases Analysis of Cold Chain Logistics of Farm Products

Assuming that there are three cold chain logistics enterprises of farm products $x_i \left(i = 1,2,3\right)$, due to the large number of indicators, so as to verify the validity of models and simplify the computing process in the meanwhile. We only illustrated three indicators of the operating environment $E_i\left(i = 1,2,3\right)$. According to experts' measurement, we can obtain the intuitionistic triangular fuzzy numbers of these three enterprises about three safety evaluation indicators of temperature, humidity and cleanliness, as shown in Table 4. The weights of three indexes are set to 0.4,0.3 and 0.3, after normalization and weighting, the intuitionistic triangular fuzzy numbers are shown in Table 5.

Table 4 Triangular fuzzy matrix

	E_1	E_2	E_3
x_1	([5.7,7.7,9.3],0.7,0.2)	([5,7,9];0.6,0.3)	([5.7,7,7.9];0.8,0.1)
x_2	([6.5,8.6,10],0.4,0.5)	([8,9,10],0.6,0.3)	([8.3,9.7,10],0.7,0.2)
x_3	([6.5,8.2,9.3],0.8,0.1)	([7,9,10],0.7,0.2)	([0,9,10],0.5,0.2)

Table 5 Weighted norm triangle fuzzy matrix

	E_1	E_2	E_3
x_1	([0.12,0.16,0.2],0.7,0.2)	([0.1,0.14,0.19];0.6,0.3)	([0.11,0.15,0.17];0.8,0.1)
x_2	([0.13,0.18,0.2],0.4,0.5)	([0.16,0.19,0.2],0.6,0.3)	([0.16,0.18,0.19],0.7,0.2)
x_3	([0.13,0.17,0.19],0.8,0.1)	([0.14,0.19,0.21],0.7,0.2)	([0.13,0.17,0.19],0.5,0.2)

According to Formula (6) and Formula (7), we can find the positive and negative ideal solutions $x^+ = \{([0.13,0.18,0.21];0.8,0.1),([0.16,0.19, 0.21];0.7,0.2),([,0.16,0.18,0.19];0.8,0.1)\}$

$x^- = \{([0.12,0.16,0.19];0.4,0.5),([0.1,0.14, 0.19];0.6,0.3),([,0.11,0.15,0.17];0.5,0.2)\}$

According to Formula (8) and Formula (9), the distance between the positive ideal solution and the negative ideal solution is (assuming λ is $\frac{1}{2}$) $D(x_1,x^+)=1.567$ $D(x_2,x^+)=1.113$ $D(x_3,x^+)=0.773$ $D(x_1,x^-)=0.782$ $D(x_2,x^-)=1.236$ $D(x_3,x^-)=1.578$

According to Formula (10), we can calculate the relative proximity between x_i and x^+ is $\rho_1=0.333$, $\rho_2=0.526$, $\rho_3=0.671$

So the degree of safety of these three farm products cold chain logistics enterprises about operating environment indicators is ranked as $x_3 > x_2 > x_1$.

That is to say, Enterprise 3 is best and has the higher degree of safety by comparison in terms of operating environment.

3. Summary

Aiming at farm products cold chain quality and safety evaluation problems, we are able to solve the problems efficiently of safety evaluation among enterprises, and find out a certain safety weak line in an enterprise in the process of comparative sorting by using TOPSIS theory of intuitionistic triangular fuzzy. In addition, we can also choose relatively higher safety level enterprises in the same industry as standards. Then calculate and compare using the above methods and rank among these enterprises in the end. So the TOPSISI method has a good effect. However, these conclusions drawn by TOPSOS method are relative conclusions, and how to quantify and evaluate the quality and safety of some farm products cold chain logistics enterprises is still a problem for us which needs to be studied further.

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Supported by the Philosophy and Social Sciences Program of Sichuan Province(No. SC15B071), Supported by the Program of the Visual Computing and Virtual Reality Key Laboratory of Sichuan Province(No.KJ201420),Supported by the Program of the Department of Education of Sichuan Province(No.14SB0022), Supported by the Sichuan provincial innovation and entrepreneurship students Training Program(201410636045, 201510636087).