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Fuzzy TOPSIS-Based Supply Chain Optimization of Fresh Agricultural Products

* Shi Haoran, **Liu Kejian, ***Peng Haihua,****Yao Yang

*School of Energy and Power Engineering, Xihua University of Shi Hao-ran,Peng Haihua and Yao Yang
P.R.China, Chengdu, 610039,(624473792@qq.com)
** School of Computer and Software Engineering, Xihua University of Liu Kejian
P.R.China, Chengdu, 610039, (liukejian@gmail.com)

Abstract

Because of the complexity of fresh agricultural products, the supply chain is also in the form of diversity. Based on the analysis of existing supply chains of fresh agricultural products (FAPs), an optimization of the basic ones was undertaken in the paper, which gave priority to losses and benefits of FAPs among all the chosen elements such as safety, reliability and distance. What is more, the optimal sequence of existing FAP supply chains was obtained in a way that attaching equal importance to loss control and benefit maximization. Finally, the conclusion was analyzed.

Key words

fresh agricultural products, supply chain network optimization, TOPSIS, expert evaluation methods, loss

1. Introduction

Loss is a serious problem for fresh agricultural products, especially fresh agricultural products in China, so people take a lot of measures to reduce the loss of fresh agricultural products. But because of the special nature of fresh agricultural products, the loss has not been a good solution.

Chinese government vigorously promotes the "agricultural super docking", hoping to shorten the existing supply chain of fresh agricultural products in order to reduce the flow of links to reduce losses and increase efficiency. But to reduce the loss, improve efficiency is not only to shorten the supply chain will be able to achieve the purpose.

Many experts and scholars also hope that through the network of fresh agricultural products supply chain to find ways to reduce the loss and improve the efficiency of agricultural products. Because of the complexity of fresh agricultural products and the diversity of people's demands, in a long time, the fresh agricultural products supply chain will be in a certain range to a variety of structures exist. We study the existing main fresh agricultural products supply chain, seeking the least loss, the best efficiency of the supply chain, and to optimize the results.

2. Research Foundation

2.1 Research into the existing network of FAP supply chain

Researchers in developed countries have fully studied on FAP supply chain. As a compassion, the corresponding studies in China remain immature due to historical reasons and realities. Specifically, as a result of the laggard agricultural industry, most of Chinese agricultural products rest on traditional small-scale peasant economy. Moreover, different domestic FAP supply chains that are complicated, poorly-informationalized and ill-served by high-caliber staff can neither simply draw experience from foreign counterparts nor have any single one gain predominance. This dilemma of development leads to coexistence of diversified FAP supply chains in the country.

Most of suggestions and strategies in written documents unanimously involve the government's overall planning and rational division of labor in relation to FAP supply chain management [1-4]. This type of phenomenon arises when there are overlapping of functions and vague accountability between Ministry of Agriculture, Ministry of Industry and Commerce, and Quality Inspection Departments. With a description of the consumption characteristics of Chinese FAPs as well as SWOT analysis, Han Song (2007) [5] summarized the necessities of managing FAP supply chain and provided a corresponding game matrix. Li Zehua (2002)[6] suggested to imitate experience of Japan and other developed countries by introducing the auction mechanism into the wholesale fresh agricultural product market in China. As late adopters of FAP supply chain management, Chinese researchers largely focus on qualitative studies rather than quantitative ones. In this connection, there are a few core issues well worth follow-up research, including inventory replenishment strategies, coordination mechanism, profit distribution mechanism, and supplier selection.

Single crop approaches are used for establishment of most existing models of FAP supply chain, because different species of crops require different models of supply chain management due to characteristic variety. However, such models are mainly dominated by planning, management and optimization. For example, the linear planning model is frequently used in Ferrer and Widodo's documents [7-11]. Kazaz (2004), Darby-Dowman et al. (2000) conducted research on the basis of dynamic planning and mixed integer programming [12-14]. Apart from them, other research methods such as nonlinear planning, multi-objective programming, strategy analysis, and genetic algorithm undergo full application [15-17].

2.2 FAP supply chains

The loss of FAPs occurs at the start of harvest, or even earlier in case of FAP spoilage due to untimely harvest. Given this, ideally, FAPs are supposed to be picked up for immediate consumption upon ripeness. However, it is always a figment of imagination. The avoidance of the resultant FAP loss cannot be achieved in spite of technological development and traffic improvement. In this regard, the paper intended to start from research into the existing domestic FAP supply chains to optimize the selection among them, allowing for loss control and benefit maximization.

First, all modes of existing FAP supply chains from manufacturing to consumption should be ascertained for analysis, so that loss control can be done on this basis.

Mode 1: self-producing self-sale. As the most primitive FAP supply chain, this mode requires producers to cultivate and harvest crops as demanded and to consume them by themselves. In this mode, FAPs are technically not commodities by nature, without any circulation. This shortest supply chain is supposed to be the optimal approach to loss reduction. However, FAPs supplied this way still waste significantly. The reason is that agricultural products are cultivated and collected in batches at the same time when the harvest time is limited. Such over-supply may result in product loss in the form of food deterioration or preparation for the next season's cultivation. This mode is still applied to the vast rural areas in the country.

Mode 2: Agricultural surpluses that arise from further development of productivity allow farmers to engage themselves in other fields of work. Based on it, people begin to barter goods in the market, and the FAP supply chain extends out of producers accordingly. The structure of the supply chain becomes: manufacturer - consumer. Over the course of thousands of years' civilized society, this supply chain mode remains active in the vast villages and towns and even in some large cities.

Mode 3: Along with commercial expansion, trade between manufacturers and consumers is done through a middleman as an intermediate character. Therefore, the structure of the supply chain becomes: manufacturer - middleman - consumer.

Mode 4: As the market expands and flourishes, the type of sellers is divided into two subtypes: wholesaler and retailer. Therefore, the structure of the supply chain becomes: manufacturer - wholesaler & retailer - consumer. This mode is still frequently-used in most county fairs.

Mode 5: linking farmers to supermarket chains: This mode occurs when the said modes are less and less adaptable to the day. The structure of the supply chain changes into: manufacturer - supermarket - consumer. As a result, the supply chain length is shortened to some extent, and the supply chain structure is optimized in a way that reducing circulation costs and product loss.

Mode 6: direct selling. This is the marketing and selling of products directly to consumers away from a fixed retail location. The concept of "consumer" therein is differentiated from the one in Mode 2, because it comprises groups with large, fixed demands for consumption instead of individual consumers of stochastic and unpredictable demands. Hotels, canteens, restaurants and factories are all such consumers. Make to order and manufacturing on demand can be achieved to certain degree.

Mode 7: e-commerce. With a surge in electronic technologies, the Internet and logistics as well, the on-line selling business model is used for marketing and selling of a part of FAPs, where buyers directly place orders that specify the ranges and numbers for sellers to manufacture and distribute. This mode is still at its preliminary stage due to FAP vulnerability and logistic cost, and often suitable to expensive FAPs. Nevertheless, it is predictable that this mode will gain further development and expansion if logistic service is improved.

Mode 8: garden harvest: This mode allows consumers to collect FAPs directly in manufacturer's garden or farmland with permission. It is rarely seen in most areas in China, but has been popularized in developed countries and developed domestic localities. On the one hand, demands for fresh and safe products are met; on the other hand, the desire for country life is satisfied.

The above eight modes have different merits and demerits, and partly coexist for a certain duration in certain areas. They together realize the distribution of FAPs to consumers. Along with further development of productivity and the improvement of living standards, some changes may happen to supply chain modes, with which a few modes may disappear and some new modes appear.

Theoretically, product loss occurs to all the eight modes, albeit in different magnitudes. The complete avoidance of FAP loss is impossible to achieve so far. Given this, the paper practically optimizes the selection of existing supply chains with regard to loss control.

2.3TOPSIS-based model

The technique for order preference by similarity to ideal solution (TOPSIS) is a multi-attribute decision making (MADM) technique for ranking and selection of a number of externally determined alternatives through distances from the positive ideal solution and the negative ideal solution. It was first introduced by Hwang and Yoon (1981) to data analysis technologies, and was also used to address objective, realistic problems arising from related issues under fuzzy environments (Muralidhar et al., 2013[18]; Ataei, et al., 2008[19]; Zeki and Rifat, 2012[20]. Sun (2010)[21] employed the fuzzy AHP and fuzzy TOPSIS to assess different notebook manufacturers, and concluded that fuzzy TOPSIS can provide a more accurate, effective and systematic decision-support tool. Yu et al. (2011) [22] proposed a fuzzy-TOPSIS-based evaluation model to rank the conditions of B2C e-commerce. With the method of fuzzy TOPSIS, Zouggari and Benyoucef (2012) [23] distributed orders among select suppliers. In addition to the said fields, TOPSIS is widely applied to some other fields.

Supposing that the alternatives set of a multi-attribute decision-making issue is $X=\{x_1, x_2,\cdots x_m\}$, and that the attribute vector of corresponding evaluation indices is $Y=\{y_1, y_2,\cdots y_n\}$. Therefore, each alternative $x_i(i=1, 2,\cdots m)$ in X has n attributes that constitute the vector $Y_i=\{y_{1i}, y_{2i},\cdots y_{ni}\}$ as a single point in n-dimensional space which denotes the sole representative alternative x_i .

The ideal solution x^* is made up virtually as the optimal alternative in X . Any of its attributes is likely to be optimal in the decision matrix. The negative ideal solution x^0 is the worst possible alternative, and any of its attributes is likely to be the poorest in the decision matrix. With TOPSIS, the distance of each alternative x_i that belongs to X from x^* and x^0 is measured. The chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. All alternatives in X are ranked according to their calculated geometric distances.

3 model establishment

3.1 relative definitions

Definition 1: In the domain of discourse X, the fuzzy set $\tilde{a}$ is decided by the membership function $\mu_{\tilde{a}}(x)$ that belongs to X. Element x exists in X. Real numbers fall in the interval of $[0,1]$. The membership function $\mu_{\tilde{a}}(x)$ reflects the degree of membership of x in $\tilde{a}$ (Zadeh, 1965) 。Triangular fuzzy numbers used in the research are represented by a triplet (a_1, a_2, a_3) 。

Definition 2：： $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ are a pair of triangular fuzzy numbers. According to publications by Wang and Lee (2009)[24], the distance measurement function $(\tilde{a}, \tilde{b})$ can be given as

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \tag{1}$$

Definition 3: $\tilde{a}$ is a triangular fuzzy number, and $\tilde{a}_\alpha$ is defined as

$$\tilde{a}_\alpha = [(a_2 - a_1)\alpha + a_1, a_3 - (a_3 - a_2)\alpha] \tag{2}$$

Definition 4: $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ are pair of triangular fuzzy numbers. The division of $\tilde{a} = (a_1, a_2, a_3)$ by $\tilde{b} = (b_1, b_2, b_3)$ is defined as

$$\frac{\tilde{a}_\alpha}{\tilde{b}_\alpha} = [\frac{(a_2 - a_1)\alpha + a_1}{-(b_3 - b_2)\alpha + b_3}, \frac{-(a_3 - a_2)\alpha + a_3}{(b_2 - b_1)\alpha + b_1}] \tag{3}$$

When $\alpha = 0$, $\frac{\tilde{a}_0}{\tilde{b}_0} = [\frac{a_1}{b_3}, \frac{a_3}{b_1}]$

When $\alpha = 1$, $\frac{\tilde{a}_1}{\tilde{b}_1} = [\frac{(a_2 - a_1) + a_1}{-(b_3 - b_2) + b_3}, \frac{-(a_3 - a_2) + a_3}{(b_2 - b_1) + b_1}]$ (4)

$$\frac{\tilde{a}_1}{\tilde{b}_1} = [\frac{a_2}{b_2}, \frac{a_2}{b_2}]$$

Therefore, the estimated value set of $\tilde{a}/\tilde{b}$ is obtained as $\frac{\tilde{a}}{\tilde{b}} = [\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}]$ 。

Definition 5: Supposing that $\tilde{a}=(a_1,a_2,a_3)$ and $\tilde{b}=(b_1,b_2,b_3)$ are real numbers, and that the distance between them $d(\tilde{a},\tilde{b})$ uses Euclidean distance。

Below are basic operations on the triangular fuzzy numbers:

The estimated value by multiplication is $\tilde{a}\otimes\tilde{b}=(a_1\times b_1,a_2\times b_2,a_3\times b_3)$ 。

The estimated value by addition is $\tilde{a}\oplus\tilde{b}=(a_1+b_1,a_2+b_2,a_3+b_3)$

3.2 fuzzy membership function

During the process of computation, a weight represents the subjective expert evaluation on an element through survey and research, and reflects the level of importance for the element. Linguistic terminologies can be divided in several levels: very low (VL), Low (L), Intermediate (M), High (H) and Very high (VH). Supposing that all these terminologies can be displaced with triangular fuzzy numbers which fall in the interval of [0,1]. According to some documents (Yang and Hung, 2007) [25] ， every level corresponds to an evenly distributed membership function at an interval of 0.30 or 0.25. Based on the above hypothesis, the corresponding conversion table of fuzzy membership functions can be obtained as shown in Table 1.

Table.1. Conversion of Fuzzy Membership Functions

Level	sub-criteria level	membership function
Very low (VL)	1	(0.00,0.10,0.25)
Low (L)	2	(0.15,0.30,0.45)
Intermediate (M)	3	(0.35,0.50,0.65)
High (H)	4	(0.55,0.70,0.85)
Very high (VH)	5	(0.75,0.90,1.00)

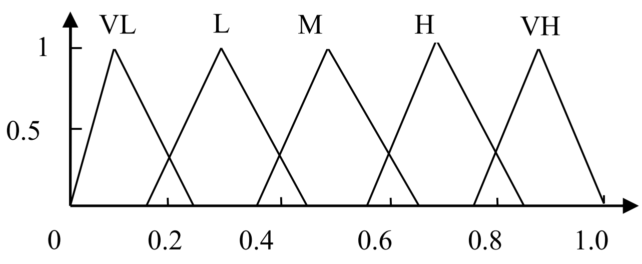

Fig.1. Fuzzy Triangular Membership Function

3.3 fuzzy-TOPSIS-based model

Here is a question to compare and evaluate fuzzy multi-criteria decision-makings (FMCDM) which is briefed as

$$
\begin{array}{cc}
 & \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\
\begin{array}{c} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} &
\begin{bmatrix}
\tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \cdots & \tilde{x}_{1n} \\
\tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \cdots & \tilde{x}_{2n} \\
\tilde{x}_{31} & \tilde{x}_{32} & \tilde{x}_{33} & \cdots & \tilde{x}_{3n} \\
\vdots & & & & \\
\tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \cdots & \tilde{x}_{mn}
\end{bmatrix}
\end{array}
\tag{5}
$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \cdots \tilde{w}_n]$$

Where $x_{ij}, i = 1, 2, \cdots, m; j = 1, 2, \cdots, n$ and $\tilde{w}_j, j = 1, 2, \cdots, n$ are triangular fuzzy numbers, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$, $\tilde{w}_j = (a_{j1}, b_{j2}, c_{j3})$ 。The normalized fuzzy decision-making matrix is $\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$, and the weighed fuzzy normalized decision-making matrix is

$$
V = \begin{bmatrix}
\tilde{v}_{11} & \tilde{v}_{12} & \tilde{v}_{13} & \cdots & \tilde{v}_{1n} \\
\tilde{v}_{21} & \tilde{v}_{22} & \tilde{v}_{23} & \cdots & \tilde{v}_{2n} \\
\tilde{v}_{31} & \tilde{v}_{32} & \tilde{v}_{33} & \cdots & \tilde{v}_{3n} \\
\vdots & & & & \\
\tilde{v}_{m1} & \tilde{v}_{m1} & \tilde{v}_{m1} & \cdots & \tilde{v}_{m1}
\end{bmatrix}
= \begin{bmatrix}
\tilde{w}_1\tilde{r}_{11} & \tilde{w}_2\tilde{r}_{12} & \tilde{w}_3\tilde{r}_{13} & \cdots & \tilde{w}_n\tilde{r}_{1n} \\
\tilde{w}_1\tilde{r}_{21} & \tilde{w}_2\tilde{r}_{22} & \tilde{w}_3\tilde{r}_{23} & \cdots & \tilde{w}_n\tilde{r}_{2n} \\
\tilde{w}_1\tilde{r}_{31} & \tilde{w}_2\tilde{r}_{32} & \tilde{w}_3\tilde{r}_{33} & \cdots & \tilde{w}_n\tilde{r}_{3n} \\
\vdots & & & & \\
\tilde{w}_1\tilde{r}_{m1} & \tilde{w}_2\tilde{r}_{m2} & \tilde{w}_3\tilde{r}_{m3} & \cdots & \tilde{w}_n\tilde{r}_{mn}
\end{bmatrix}
\tag{6}
$$

Based on the aforementioned fuzzy theory, the paper proposed the procedure or step of fuzzy TOPSIS.

Step 1：select out $x_{ij}, i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n$

Step 2：establish the weighted normalized fuzzy decision-making matrix V

Step 3：define the positive ideal solution (A^+) and the negative ideal solution (A^-)

$$A^{+} = \left\{ \tilde{v}_1^{+}, \tilde{v}_2^{+}, \ldots, \tilde{v}_n^{+} \right\}$$
$$= \left\{ (\max_i \tilde{v}_{ij} \middle| i = 1, 2, \ldots, m), j = 1, 2, \ldots, n \right\}.$$

$$A^{-} = \left\{ \tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots, \tilde{v}_n^{-} \right\}$$
$$= \left\{ (\min_i \tilde{v}_{ij} \middle| i = 1, 2, \ldots, m), j = 1, 2, \ldots, n \right\}.$$

Step 4: compute the distance of elements in (A^{+}) and (A^{-}) with the following formula:

$$d_i^{+} = \frac{1}{n} \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{+}), i = 1, 2, \ldots, m \qquad d_i^{-} = \frac{1}{n} \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-}), i = 1, 2, \ldots, m$$

Step 5：Compute the similarities of the ideal solution $CC_i = \dfrac{d_i^{-}}{d_i^{+} + d_i^{-}}$

Step 6：Rank the alternatives in descending order by CC_i

4 Optimal selection of FAP supply chains with regard to loss control

4.1Selection of FAP supply chain indices

There are plenty of elements in relation to loss control from the perspective of the entire supply chain, such as product variety, harvest time, transportation means, transportation duration, turnover times, package, handling, and temperature & climate. Based on the said eight supply chain structures, the paper endeavored to list such elements in levels and categories for optimization. Figure 2 is the specific levels and categories of optimization indices. By referring to a large amount of information and practical investigation as well, the paper proposed nine reference indices as shown in Table 2, where SC_1-SC_9 denoted nine sub criteria, and A_1-A_8 represents eight different FAP supply chains.

In the FAP supply chain, as it is difficult to define the said criteria, we referred to the concept of fuzzy mathematics to uniformly define these criteria in ascending order. To facilitate computation, we assumed that the nine sub criteria were selected between [0-10]. The subjectivity and fuzziness of such definition will not affect the feasibility of the data and methods adopted herein, because our work is to compare several supply chains by a single mean and under the same criteria, which is much less interfered by the systemic error arising from such fuzziness and subjectivity.

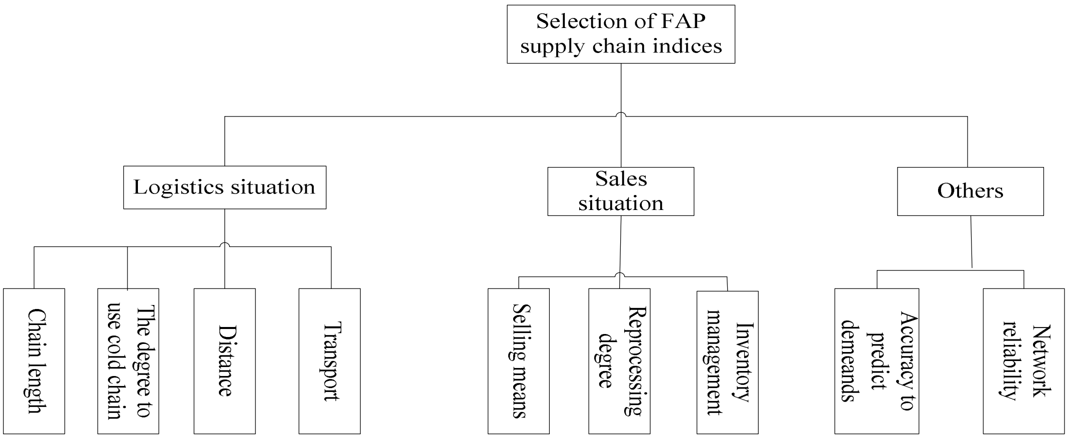

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Fig.2. Indices of FAP Supply Chains with Regard to Loss Control

Table.2. Conversion of Fuzzy Membership Functions

SC_1	SC_2	SC_3	SC_4	SC_5	SC_5	SC_6	SC_6	SC_7	SC_7	SC_8	SC_9
0	0	0	10	10	0	8	6	10	0	0	10
2	0	1	6	7	2	7	5	7	0	1	6
4	2	4	6	6	4	6	5	7	2	4	6
6	2	5	7	5	4	2	5	5	2	5	7
4	5	3	8	9	6	6	7	8	5	3	8
2	2	2	6	10	2	6	9	9	2	2	6
4	4	3	7	10	7	5	8	9	4	3	7
1	2	1	6	9	0	8	7	7	2	1	6

The level of importance for each sub criterion has already been provided as VL、L、M、H、and VH. The paper then invited seven experts to evaluate these supply chains. Table 3 is the evaluation table provided by E_1, E_2, E_3, E_4, E_5, E_6, E_7.

Table.3. Weights Determined by Seven Experts

No.	element	E_1	E_2	E_3	E_4	E_5	E_6	E_7
SC_1	Chain length	M	L	M	VL	M	M	H
SC_2	The degree to use cold chain	VH	VH	VL	L	VH	VL	VH
SC_3	Distance	L	M	VL	M	VH	H	M
SC_4	Transportation condition	VH	M	VL	VH	L	VH	VL
SC_5	Selling means	VH	VH	VH	L	M	VL	L
SC_6	Reprocessing degree	VL	H	VL	M	VL	L	L
SC_7	Inventory management	VH	H	VL	VL	VL	VL	L
SC_8	Accuracy to predict demands	M	VL	VL	VL	VL	VL	M

SC_9	Network reliability	M	L	M	VL	M	M	H

4.2 optimal computation of FAP supply chains with regard to loss control

The fuzzy variables in the above matrix can be converted to fuzzy triangular membership functions. For the next steps, the average value that each element obtained was calculated. Below is the deduction of the mean standard weight.

W_1=(0.41,0.56,0.71),

W_2=(0.64,0.79,0.94),

W_3=(0.52,0.67,0.82),

W_4=(0.46,0.61,0.76),

W_5=(0.49,0.64,0.79),

W_6=(0.55,0.70,0.85),

W_7=(0.35,0.50,0.65),

W_8=(0.52,0.67,0.82),

W_9=(0.41,0.56,0.71).

The initial decision-making matrix is determined by experts through watch websites. The normalized decision-making matrix is derived from original data in Table 4.

The range for "the larger, the better" $$r_{ij} = \frac{\left[x_{ij} - \min\left\{x_{ij}\right\}\right]}{\left[\max\left\{x_{ij}\right\} - \min\left\{x_{ij}\right\}\right]} \tag{7}$$

The range for "the smaller, the better" $$r_{ij} = \frac{\left[\max\left\{x_{ij}\right\} - x_{ij}\right]}{\left[\max\left\{x_{ij}\right\} - \min\left\{x_{ij}\right\}\right]} \tag{8}$$

Table. 4. TOPSIS-based Normalized Decision-making Matrix

No.	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9
A_1	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.67	1.00
A_2	0.67	0.00	0.80	0.60	0.70	0.29	0.88	0.56	0.70
A_3	0.33	0.40	0.20	0.60	0.60	0.57	0.75	0.56	0.70
A_4	0.00	0.40	0.00	0.70	0.50	0.57	0.25	0.56	0.50
A_5	0.33	1.00	0.40	0.80	0.90	0.86	0.75	0.78	0.80
A_6	0.67	0.40	0.60	0.60	1.00	0.29	0.75	1.00	0.90
A_7	0.33	0.80	0.40	0.70	1.00	1.00	0.63	0.89	0.90
A_8	0.83	0.40	0.80	0.60	0.90	0.00	1.00	0.78	0.70

Till now, the research result shows that SC_1 、SC_3、SC_4、belong to the type of “the smaller, the better”, and the rest of elements are the type of “the larger, the better”. Table 5 shows the normalized decision-making matrix with the use of fuzzy language.

Table.5. Fuzzy-variable-based Normalized Decision-making Matrix

No.	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9
A_1	VH	VL	VH	VH	VH	VL	VH	H	VH
A_2	H	VL	VH	H	H	L	VH	M	H
A_3	L	M	L	H	H	M	H	M	H
A_4	VL	M	VL	H	M	M	VL	M	M
A_5	L	VH	M	VH	VH	VH	H	H	H
A_6	H	M	M	H	VH	L	H	VH	VH
A_7	L	VH	L	H	VH	VL	H	VH	VH
A_8	VH	M	VH	H	VH	VL	VH	H	H

Table.6. Fuzzy Decision-making Matrix

No.	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9
A_1	0.75, 0.90, 1.00	0.00 0.15 0.25	0.75, 0.90, 1.00	0.75, 0.90, 1.00	0.75, 0.90, 1.00	0.00 0.15 0.25	0.75, 0.90, 1.00	0.55, 0.70, 0.85	0.75, 0.90, 1.00
A_2	0.55 0.70 0.85	0.00 0.15 0.25	0.75, 0.90, 1.00	0.55, 0.7, 0.80	0.55, 0.70, 0.85	0.15 0.30 0.45	0.75, 0.90, 1.00	0.35, 0.50, 0.65	0.55, 0.70, 0.85
A3	0.15 0.30 0.45	0.35, 0.50, 0.65	0.15, 0.30, 0.45	0.55, 0.70, 0.85	0.55, 0.70, 0.85	0.35, 0.50, 0.65	0.55, 0.70, 0.85	0.35, 0.50, 0.65	0.55, 0.70, 0.85
A_4	0.00 0.15 0.25	0.35, 0.50, 0.65	0.00, 0.15, 0.25	0.55, 0.70, 0.85	0.35, 0.50, 0.65	0.35, 0.50, 0.65	0.15 0.30 0.45	0.35, 0.50, 0.65	0.35, 0.50, 0.65
A_5	0.15 0.30 0.45	0.75, 0.90, 1.00	0.35, 0.50, 0.65	0.75, 0.90, 1.00	0.75, 0.90, 1.00	0.75, 0.90, 1.00	0.55, 0.70, 0.85	0.55, 0.70, 0.85	0.55, 0.70, 0.85
A_6	0.55 0.70 0.85	0.35, 0.50, 0.65	0.35, 0.50, 0.65	0.55, 0.70, 0.85	0.75, 0.90, 1.00	0.15 0.30 0.45	0.55, 0.70, 0.85	0.75, 0.90, 1.00	0.75, 0.90, 1.00
A_7	0.15 0.30 0.45	0.75, 0.90, 1.00	0.15, 0.30, 0.45	0.55, 0.70, 0.85	0.75, 0.90, 1.00	0.15 0.30 0.45	0.55, 0.70, 0.85	0.75, 0.90, 1.00	0.75, 0.90, 1.00
A_8	0.75 0.90 1.00	0.35, 0.50, 0.65	0.75, 0.90, 1.00	0.55, 0.70, 0.85	0.75, 0.90, 1.00	0.15 0.30 0.45	0.75, 0.90, 1.00	0.55, 0.70, 0.85	0.55, 0.70, 0.85

As can be shown in Table 6, fuzzy variables are converted to corresponding fuzzy triangular membership functions, which can be used to deduct the fuzzy weighed decision-making matrix as shown in Table 7. Table 8 is the distance of A^{+} and A^{-} obtained through the CC_i method.

4.3Result analysis

According to the computation result, the scores of A_2、A_3、and A_4 are lower than 0.5, which means that product loss is serious with the use of these supply chains. Therefore, from the perspective of loss control, the preferable supply chains should be A_1、A_5、A_6、A_7、A_8 rather than A_2、A_3、A_4.

For a clearer view, the paper demonstrates the fuzzy TOPSIS analysis result in Figure 3 as follows.

Table.7. Fuzzy Weighed Decision-making Matrix

No.	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7	SC_8	SC_9
A_1	0.31 0.5 0.71	0.00, 0.12, 0.23	0.39, 0.60, 0.82	0.35, 0.55, 0.76	0.37, 0.58, 0.79	0.00, 0.11, 0.21	0.26, 0.45, 0.65	0.29, 0.47, 0.70	0.31, 0.50, 0.71
A_2	0.22, 0.39, 0.60	0.00, 0.12, 0.23	0.39, 0.60, 0.82	0.26, 0.43, 0.65	0.27, 0.45, 0.67	0.08, 0.21, 0.38	0.26, 0.45, 0.65	0.18, 0.34, 0.53	0.22, 0.39, 0.60
$A3$	0.06, 0.17, 0.32	0.22, 0.39, 0.61	0.08, 0.20, 0.37	0.26, 0.43, 0.65	0.27, 0.45, 0.67	0.19, 0.35, 0.55	0.19, 0.35, 0.55	0.18, 0.34, 0.53	0.22, 0.39, 0.60
A_4	0.00, 0.08, 0.18	0.22, 0.39, 0.61	0.00, 0.10, 0.21	0.26, 0.43, 0.65	0.17, 0.32, 0.52	0.19, 0.35, 0.55	0.00, 0.08, 0.16	0.18, 0.34, 0.53	0.14, 0.28, 0.46
A_5	0.06, 0.17, 0.32	0.48, 0.71, 0.94	0.18, 0.34, 0.53	0.35, 0.55, 0.76	0.37, 0.58, 0.79	0.41, 0.63, 0.85	0.19, 0.35, 0.55	0.29, 0.47, 0.70	0.22, 0.39, 0.60
A_6	0.22, 0.39, 0.60	0.22, 0.39, 0.61	0.18, 0.34, 0.53	0.26, 0.43, 0.65	0.37, 0.58, 0.79	0.08, 0.21, 0.38	0.19, 0.35, 0.55	0.39, 0.60, 0.82	0.31, 0.50, 0.71
A_7	0.06, 0.17, 0.32	0.48, 0.71, 0.94	0.08, 0.20, 0.37	0.26, 0.43, 0.65	0.37, 0.58, 0.79	0.00, 0.11, 0.21	0.26, 0.45, 0.65	0.39, 0.60, 0.82	0.31, 0.50, 0.71
A_8	0.31, 0.50, 0.71	0.22, 0.39, 0.61	0.39, 0.60, 0.82	0.26, 0.43, 0.65	0.37, 0.58, 0.79	0.00, 0.11, 0.21	0.26, 0.45, 0.65	0.29, 0.47, 0.70	0.22, 0.39, 0.60
A^+	0.31, 0.50, 0.71	0.48, 0.71, 0.94	0.39, 0.60, 0.82	0.35, 0.55, 0.76	0.37, 0.58, 0.79	0.41, 0.63, 0.85	0.26, 0.45, 0.65	0.39, 0.60, 0.82	0.31, 0.50, 0.71
A^-	0.00, 0.08, 0.18	0.00, 0.12, 0.23	0.00, 0.10, 0.21	0.26, 0.43, 0.65	0.17, 0.32, 0.52	0.00, 0.11, 0.21	0.00, 0.08, 0.16	0.18, 0.34, 0.53	0.14, 0.28, 0.46

The paper attempts to ascertain controllable influential factors of FAP loss, by specifying measurement indices and using the method of fuzzy TOPSIS to evaluate existing supply chains with these indices. The primary data are derived from practical survey result. Limited by the fuzziness and overlapping of supply chains, the initial data is merely qualitative and fuzzy. Then, fuzzy TOPSIS is employed to assess the loss control efficiency of FAP supply chains in a quantitative manner.

Table.8. Distance of A^{+} and A^{-}

No.	d_i^+	d_i^-	*CCi*	sequence
A_1	0.155689	0.164601	0.514	5
A_2	0.153441	0.144636	0.485	6
A_3	0.140687	0.105824	0.429	7
A_4	0.186685	0.076812	0.292	8
A_5	0.087473	0.18342	0.677	1
A_6	0.114633	0.141203	0.552	3
A_7	0.143846	0.161244	0.529	4
A_8	0.123435	0.169405	0.578	2

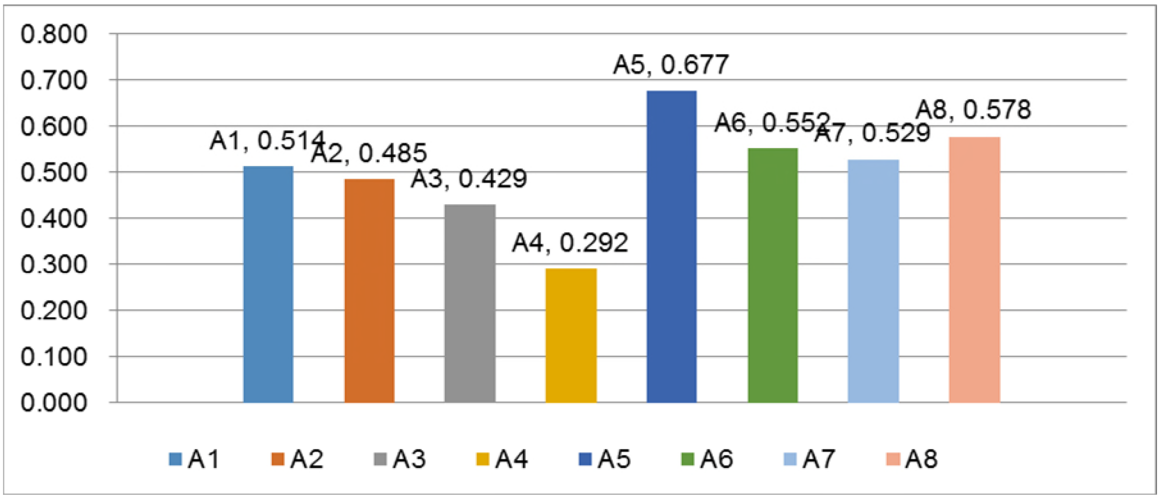

Fig.3. Evaluation Results of the Eight Supply Chains

According to empirical research result, there is a tremendous gap between ideal FAP supply chains (0.65) and unideal ones (0.22). This great difference reflects the necessity to choose better supply chains in order to control product loss.

Nine factors were used in the paper to evaluate FAP supply chains. According to the weight evaluated by 7 experts, the cold chain is the predominant factor (0.66,0.81,0.94). This means that a supply chain without cold chain transportation will cause phenomenal product loss. Fuzzy TOPSIS is used in the paper to optimize the selection of FAP supply chains, where different elements such as logistics, transportation, turnover times and sales are all taken into account. As a result, the optimization of FAP supply chains is improved.

Conclusion

Through optimization of the selection of FAP supply chains, we ascertain the following several factors to control FAP loss: (1) try to shorten the time span of FAP harvest, storage and transportation in supply chains; (2) previously, it was only after the manufacturing of FAP that sellers hunt for willing buyers, and make to order was rarely seen. As a consequence, the product loss magnifies when many FAPs ready for sale are in turn overstocked. (3) If there are excess inventories, the seller is able to adjust product prices promptly, so that selling them before they lost editable value. The influence of other factors on loss control is smaller than of the above three factors.

Although agriculture super docking mode of loss of control and benefit increase is of great advantage, but because of the characteristics of complexity and fresh agricultural products low output of fresh agricultural products demand, leading to several other high loss, low efficiency of fresh agricultural products will still in many areas exist for a long time.

With the improvement of productivity and social development, the factors that affect the supply chain of fresh agricultural products will change, the future electricity supplier model will become the main direction of the development of fresh agricultural products supply chain.

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