Research of Food Supply Chain Safety Evaluation based on Fuzzy Analytic Hierarchy Process

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Keywords: Food Supply Chain, Fuzzy Analytic Hierarchy Process, Safety Evaluation.

Abstract: Aiming at the food supply chain safety evaluation, this paper adopts a fuzzy hierarchy analysis method to build a risk identification model of the food supply chain from strengthening five aspects: quality and safety risk control, logistics safety risk control, cooperative safety risk control, market safety risk control and environmental safety risk control. According to the calculation results of the model, the specific risk factors affecting the safety of the food supply chain are analyzed. It is of specific reference value to study food quality risk management based on the food supply chain level, take scientific measures to reduce food quality and safety risks caused by various factors, and strengthen food safety risk prevention and control ability.

1 INTRODUCTION

Food safety risks always exist judging from the emerging food safety problems, which will gradually become the focus of social attention (Shaw and Shaw,2019). With improving people's living standards in modern times, the requirements and standards for healthier food are also increasing. Food raw materials feature variety, different places of origin, seasonality, perishability, and there are many factors such as physical, chemical, and biological factors that may threaten food safety (Beulens et al. 2005). Thus, it is challenging to guarantee food safety only by controlling one link in food operation. As an essential part of food safety research, researchers at home and abroad have studied the food safety evaluation system from the perspective of food safety management technology, consumer behaviour, and overall food safety evaluation and other aspects (Dani and Deep, 2010; Spink, 2019).

For the safety risk management of the food supply chain, Fares and Rouviere (2010) adopted the corresponding mechanism of food safety system as the research object. From the food safety system and mechanism perspective, identify and classify food safety risk factors. Government departments play a role in food safety research and management. This management method reduces the possibility of security risks in the supply chain. Wolfe and Lee (2003) pointed out that it is necessary to find the primary person responsible for food safety when conducting food safety management. Finding out the person responsible for the accident is of great significance to the effective development of the research. By finding the person in charge, we can deal with safety accidents in a targeted way. Secondly, he believes that a traceable food safety supervision and management system should be established so that the root cause of the problem can be found when the problem occurs. The supply chain can reduce the possibility of food safety events and establish an excellent company's external image. Ahi and Searcy (2013) established a supply chain network model, focusing on the three central subjects of the food supply chain, food retailers and food distributors. The food safety risk management decision is divided into multi-level, and the food safety risk is reduced through multi-level decision-making. If the model shows convergence when calculating the data, the model is in equilibrium, and the safety risk is low.

When Hallikas and four other researchers (2004) conducted supply chain management, he focused on key supply chain network management and non-basic supply chain network management methods. This research method is more in-depth and practical. Carry out in-depth supply chain management. It is found that the more members in the supply chain, the more

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Huang, Y.
Research of Food Supply Chain Safety Evaluation based on Fuzzy Analytic Hierarchy Process.
DOI: 10.5220/0011304400003437
In *Proceedings of the 1st International Conference on Public Management and Big Data Analysis (PMBDA 2021)*, pages 113-118
ISBN: 978-989-758-589-0

risk-prone the supply chain is, and the non-primary supply chain network management method can manage the supply chain more effectively. Ray (2021) took the perishable goods supply chain as the research object and established the optimization model of the perishable goods supply chain. The model improves the expected profit of decision-makers under the uncertainty of demand and price and manages the supply chain to achieve the expected effect of risk management. A case study is carried out to compare the operation effects of the basic single strategic scheme and the multi decision combination scheme.

A single approach is not enough to provide solutions in all risk scenarios. Combining various methods is the most effective and best goal of risk management. Dharmalingam and the other four experts (2021) the effective operation of the supply chain depends not only on the solid competitiveness of each node enterprise but also on the harmonious, cooperative relationship and coordinated development with other cooperative enterprises in the supply chain. Therefore, facing the risks arising from the supply chain, it is necessary for each enterprise to carry out sufficient supervision and management and need to manage together with other enterprises. Therefore, supply chain risk needs to be managed in the whole supply chain. In many traditional risk management models, few people pay attention to the importance of internal risk management culture. The author believes that the risk of the whole supply chain should be managed by introducing a revolutionary supply chain risk management process and emphasizes the importance of the company's risk management strategy - the embedded risk management culture. Shi (2020) believes that we must build a new logistics and emergency supply chain system to strengthen supply chain management. The supply chain is quickly interrupted or inefficient without a sound logistics system. The emergence and use of intelligent logistics will avoid various problems in traditional logistics, and intelligent logistics will be more efficient, intelligent, fast, border and flexible. The emergency supply chain shows more agile characteristics, collaboration, accuracy and green, which align with the current supply chain demand (Liang and Yang, 2020). The popularity of COVID-19 has strengthened the requirements of food supply chain management. In this environment, the food supply chain management must first establish an information network platform to facilitate all enterprises in the food supply chain. Be able to timely understand the information of the whole supply chain and make timely adjustments to yourself. Understand the real-time unsalable products of the enterprise in the production process, integrate the source of products according to the real-time demand of the market, and allocate products among various markets. Secondly, build an intelligent supply chain connecting buyers, sellers and logistics, and build a three-dimensional distribution system to ensure the smooth transportation and supply balance of products in all markets.

In comparison, there is still no comprehensive and unified evaluation of regional food safety. This study seriously studies the management of food quality risk and carries out a scientific evaluation from the food supply chain and food safety perspective. The fuzzy analytic hierarchy process is adopted to research the food supply chain safety evaluation to provide a scientific reference for further food safety research.

2 INTRODUCTION OF THE FUZZY ANALYTICAL HIERARCHY PROCESS

The fuzzy analytic hierarchy process is a systematic analysis method that combines qualitative and quantitative analysis and analyzes based on the fuzzy number or fuzzy judgment matrix (Nehme,2019). The traditional analytic hierarchy process has certain limitations on testing the judgment matrix, while the fuzzy analytic hierarchy process overcomes this defect. It is a more effective comprehensive evaluation method of which the specific analysis steps are as follows.

2.1 Fuzzy Hierarchical Structure Model

First, all factors are divided into three layers and arranged into the target layer, criterion layer, and index layer from high to low, respectively, to establish the fuzzy hierarchy model of this study, as shown in Fig. 1 (Bakhtari et al. 2021).

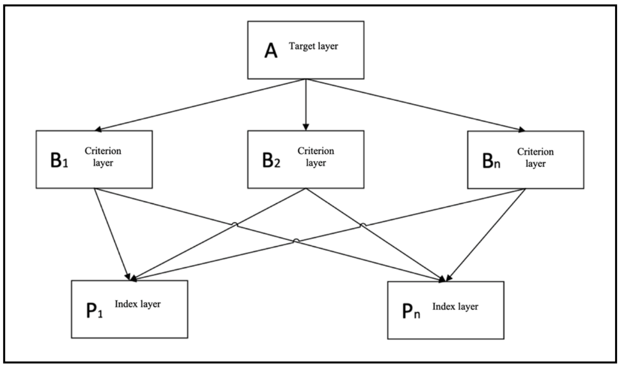

Figure 1: Fuzzy hierarchical structure model.

2.2 Fuzzy Complementary Matrix

Compare the relative importance of relevant elements between the upper layer element B and the current layer element C to create a fuzzy complementary matrix R, which is:

$$R_{B-C}=\begin{bmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & r_{n3} & \cdots & r_{nn} \end{bmatrix}$$

where $r_{ii}=0.5,(i=1,2,\cdots,n)$; $r_{ji}=1-r_{ij},(i,j=1,2,\cdots,n)$.

2.3 Hierarchical Single Sorting

The importance of the factors on the current layer is sorted, and the weight is determined according to the calculation of the fuzzy complementarity matrix (Li and Xu,2021). That is, the single hierarchical sorting is formed. The weight formula is:

$$w_i=\frac{1}{n}-\frac{1}{2a}+\frac{1}{na}\sum\nolimits_{k=1}^{n} r_{ik},(i,k=1,2,\cdots,n)$$

where n is the order of R, and $a=\frac{(n-1)}{2}$.

2.4 Hierarchical Total Sorting

The hierarchical total sorting can be obtained by calculating the weighted sum of the results of hierarchical single sorting from top to bottom. The importance vector of the element n_k on layer K to the elements on layer k-1 is: $w_k^{k-1}=(w_{k-n_1},w_{k-n_2},\cdots,w_{k-n_{k-1}})^T$ .The synthetic importance vector of the elements on the k-th layer to the total target is: $w_k^{1}=w^{k}_{k\text{-}1}\times w_k^{k\text{-}1}$. The weight matrix of index factor layer of the n-layer low-order structure is:

$$w_k^{1}=\prod_{2}^{i=n} w^{1}_{i}=w_n^{n-1}w_{n-1}^{n-2}w_{n-2}^{n-3}\cdots w_2^{3}w_1^{2}.$$

2.5 Determine the Index Factor Set

Assign initial values to each index ≤ factor in the above evaluation index system, and the index factor set after dimensionless treatment is: $X=(X_1,X_2,X_3\cdots X_n)^T$.

2.6 Calculation of the Evaluation Set

If the evaluation set of the target layer to be determined is Y, then: $Y=(w_n^1)^T\times X=\sum_{i=1}^{n} w_i x_i$.

3 FUZZY ANALYTIC HIERARCHY PROCESS RESULTS

By reading a large number of relevant literature on supply chain risk, based on the expert survey method, and through detailed index sorting and screening, the following 20 secondary risk elements are finally determined: (1) five secondary indexes of quality risk: the use of pesticides, hormones, food additives, and other chemicals; poor hygienic environment in food production, processing, and sales; improper food storage; imperfect food safety supervision mechanism; imperfect enterprise food quality management system (Fung, Guo and Wang,2021); (2) three secondary indexes of logistics risk: damage in the process of food circulation; mixed transportation of food and other commodities; delayed arrival of food; (3) five secondary indexes of cooperation risk: information asymmetry; unreasonable distribution of interests; distrust among enterprises; inconsistent strategic objectives; corporate culture differences; (4) five secondary indexes of market risk: market demand uncertainty; insufficient product supply; food price fluctuation; industry competition risk; changes in economic policies; (5) two secondary indexes of environmental risk: natural environment risk; economic environment risk.

To determine ratios to construct a relevant judgment matrix of indexes on each layer, comparisons between each factor on the same layer and a particular factor on the higher layer are carried out by referring to a large number of relevant research literature and using the expert assignment scaling method. MATLAB software is used to calculate the judgment matrices (Regattieri, Gamberi and Manzini, 2007). Results are shown in Table I below.

Table 1: Criterion Layer F Judgment Matrix.

F	F1	F2	F3	F4	F5	W
F1[a]	1.00	3.00	2.00	1.00	.50	0.2255
F2[b]	0.33	1.00	1.00	0.33	0.33	0.0936
F3[c]	0.50	1.00	1.00	0.50	0.50	0.1194
F4[d]	1.00	3.00	2.00	1.00	3.00	0.3227
F5[e]	2.00	3.00	2.00	0.33	1.00	0.2388

a. F1 is for quality risk; b. F2 logistics risk; c. F3 cooperation risk; d. F4 market risk; e. F5 environmental risk.

Table 2: Supply Chain Quality Risk F1 Judgment Matrix.

F1	F11	F12	F13	F14	F15	W
F11[a]	1.00	0.50	2.00	2.00	0.50	0.1815
F12[b]	2.00	1.00	3.00	2.00	1.00	0.2984
F13[c]	0.50	0.33	1.00	1.00	0.33	0.1018
F14[d]	0.50	0.50	1.00	1.00	0.50	0.1198
F15[e]	2.00	1.00	3.00	2.00	1.00	0.2984

a. F11 is for the use of pesticides, hormones, food additives, and other chemicals; b. F12 poor hygienic environment in food production, processing, and sales; c. F13 refers to improper food storage; d. F14 imperfect food safety supervision mechanism; e. F15 imperfect food quality management system.

Table 3: Supply Chain Logistics Risk F2 Judgment Matrix.

F2	F21	F22	F23	W
F21[a]	1.00	1.00	2.00	0.416
F22[b]	1.00	1.00	1.00	0.3275
F23[c]	0.50	1.00	1.00	0.2599

a. F21 is for the damage during food circulation; b. F22 mixed transportation of food and other commodities; c. F23 delayed arrival of food.

Table 4: Supply Chain Cooperation Risk F3 Judgment Matrix.

F3	F31	F32	F33	F34	F35	W
F31[a]	1.00	0.33	0.50	0.50	0.50	0.0943
F32[b]	3.00	1.00	2.00	2.00	2.00	0.3368
F33[c]	2.00	0.50	1.00	3.00	1.00	0.2222
F34[d]	2.00	0.50	0.33	1.00	0.50	0.1244
F35[e]	3.00	0.50	1.00	2.00	1.00	0.2222

a. F31 refers to information asymmetry; b. F32 unreasonable benefit distribution; c. F33 distrust among enterprises; d. F34 inconsistent strategic objectives; e.F35 corporate cultural differences.

Table 5: Supply Chain Market Risk F4 Judgment Matrix.

F4	F41	F42	F43	F44	F45	W
F41[a]	1.00	1.00	1.00	0.50	1.00	0.1626
F42[b]	1.00	1.00	0.33	0.50	0.50	0.1134
F43[c]	1.00	3.00	1.00	3.00	2.00	0.3070
F44[d]	2.00	2.00	0.50	1.00	3.00	0.2673
F45[e]	1.00	2.00	0.50	0.33	1.00	0.1476

a. F41 refers to market demand uncertainty; b. F42 insufficient product supply; c. F43 food price fluctuation; d. F44 industrial competition risk; e. F45 changes in economic policies.

Table 6: Environmental Risk F5 Judgment Matrix.

F5	F51	F52	W
F51[a]	1.00	0.50	0.3333
F52[b]	2.00	1.00	0.6667

a. F51 is the natural environment risk; b. F52 is the economic environment risk.

Through the above judgment matrices, the index weight set vectors of the target layer and the criterion layer are obtained respectively, which are:

W_F=(0.2255,0.0936,0.1194,0.3227,0.2388);

W_{F1}=(0.1815,0.2984,0.1018,0.1198,0.2984);

W_{F2}=(0.4126,0.3275,0.2599);

W_{F3}=(0.0943,0.3368,0.2222,0.1244,0.2222);

W_{F4}=(0.1626,0.1134,0.3070,0.2673,0.1496);

W_{F5}=(0.3333,0.6667).

According to the index, weight set vectors of the target and criterion layers are combined with the evaluation matrices of the five criterion layers of quality risk, logistics risk, cooperation risk, market risk, and environmental risk (Wei and Song,2018). The fuzzy comprehensive evaluation can bring the data into the fuzzy analytic hierarchy process for fuzzy operation.Then, it can be obtained that W1= (0.1519, 0.1743, 0.2592, 0.2140, 0.2006); W2= (0.1804, 0.1840, 0.1740, 0.2493, 0.2124); W3= (0.1598, 0.1925, 0.2266, 0.2269, 0.2078); W4= (0.1616, 0.1770, 0.2728, 0.2019, 0.1865); W5= (0.1300, 0.2567, 0.2533, 0.1867, 0.1733). By recombining the W1, W2, W3, W4, and W5 as a criterion layer to evaluate the matrix R, the final fuzzy evaluation of this supply chain is:

$$\begin{aligned} W &= W_F \times R \\ &= (0.2255,0.0936,0.1194,0.3227,0.2388) \\ &\times \begin{bmatrix} 0.1519 & 0.1743 & 0.2592 & 0.2140 & 0.2006 \\ 0.1804 & 0.1840 & 0.1740 & 0.2493 & 0.2124 \\ 0.1598 & 0.1925 & 0.2266 & 0.2269 & 0.2078 \\ 0.1616 & 0.1770 & 0.2728 & 0.2019 & 0.1865 \\ 0.1300 & 0.2567 & 0.2533 & 0.1867 & 0.1733 \end{bmatrix} \\ &= (0.1534,0.1979,0.2503,0.2084,0.1915) \end{aligned}$$

Combine the final fuzzy evaluation results with the Likert five-level scale for further matrix multiplication. The final evaluation score of food supply chain risk is 2.5179, which shows that the overall quality safety of the food supply chain is at the medium level.

4 CONCLUSIONS

Food is a necessity of our life, and from the most primitive state of food to the subsequent transmission to consumers, any mistake in any link may cause quality and safety risks, which will directly affect people's life and health, so society has paid great attention to it for a long time. In order to better ensure food safety and make consumers feel at ease and enterprises operate comfortably, unilateral investigation of the reasons of enterprises or consumers often does not play a key role. Exploring and evaluating comprehensive factors has become an important issue. Scholars have less research on the safety risk of the food supply chain, and only analyze it from the internal and external or subjective and objective single level of the food supply chain, lack the combination of qualitative and quantitative analysis, and do not comprehensively analyze the deep-seated reasons affecting the safety risk of food supply chain from multiple angles. Aiming at this problem, this paper first comprehensively analyzes the safety risk from the perspective of the food supply chain, combined with the internal, external, subjective and objective aspects of food supply chain enterprises, and finds out the factors that affect the safety risk of food supply chain in essence.

To sum up, from the perspective of food supply chain supervision, this paper establishes a quantitative evaluation model based on a fuzzy analytic hierarchy process. It provides a quantitative evaluation tool for food supply chain safety supervision, which realizes the overall safety and practical evaluation of the food supply chain and provides decision support for refining the food supply chain safety evaluation (Yeung and Morris,2013). Although this paper accurately, scientifically, and timely reflects the food safety situation from the fundamental problems of food source and food consumption from the aspects of quality risk, logistics risk, cooperation risk, market risk, and environmental risk of the food supply chain, improvement is still needed for specific research.

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