Research Article

Determining and Weighting the Inhibitory Risks of the Development of the Supply Chain of Tomato Products in Bushehr

Mohammad Chavoshi [a*], Seyed Alireza Radmanesh [b]

[a] M.Sc, marketing management, university of Tehran, Tehran, Iran.
[b] PHD, industrial management, Allameh Tabataba'i university, Iran.

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Abstract: The agricultural products supply chain has a significant role in the formation and integration of businesses and economic activities of the agricultural sector and food security. The tomato crop in Bushehr faces different challenges reducing the pace of the chain operation of this crop. Thus, the purpose of the study was to determine and weigh the inhibitory risks of tomato crop supply chain development in Bushehr. The designed questionnaire was given to 30 Bushehr Agriculture Jihad Organization experts to collect data and to perform pairwise comparisons of supply chain risk criteria of the tomato crop, and fuzzy analytic hierarchy process (FAHP) was used to weight and prioritize the criteria. The findings indicated that from among the six main criteria, the highest weight was related to environmental risks (0.354) and the lowest to social-service risks (0.029). Additionally, economic, policy-making, technical-infrastructure, and education-extension risks have relative weights of 0.214, 0.145, 0.133, and 0.125, respectively. Thus, planning and investing in improving environmental and economic conditions like market regulation and facilitating the payment of agricultural loans can increase the stability of the tomato supply chain.

Keywords: Fuzzy Analytic Hierarchy Process (FAHP), Tomato crop, Supply chain, Inhibitory risks, weighting, Relative priority

1. Introduction

Nowadays, one of the main human problems is meeting nutritional needs, so that food security and quality improvement have turned into important goals of governments. Here, the production of agricultural products has attracted great attention (Tsolakis, 2014). Agriculture is one of the key sectors in the economy of any country with a significant role in its economic-political independence. The existence of abundant natural resources and special climatic conditions have made Iran a land of four seasons, providing the conditions required to make this sector the core of the country's economy. One of the largest problems of the agricultural sector in the country is the farmers' unawareness of the balanced planting of agricultural products according to the demand, thedisruption of which leads to the abundance of a product and a significant reduction in its price in one year and harming farmers on the one hand and increases the price and people's dissatisfaction by reducing other products on the other. Management weakness in the supply chain of agricultural products and the entry of intermediaries in this field can be considered as the main problem of this sector of the country's economy. This necessitates examining supply chain models in the agricultural sector, and especially the production and distribution of agricultural products.

The food supply chain is of great significance because of the growing population of the world. The significant point is that one-third of the world's annual food production is wasted and gets out of reach (FAO, 2011). With the waste of food products, the resources used in their production and distribution along the food supply chain (like fuel, water, fertilizers) are wasted and end in negative effects on profits, natural resources, ecosystems, and human health(Gobel et al., 2015). The environmental effect is more prevalent in developing countries like Iran because of their inefficient methods during the cultivation, processing, packaging, and transportation stages of the food supply chain.

2. Literature review

Nowadays, despite the significance of the agricultural sector in economic development and social welfare in the country, having a traditional structure in business management has removed this sector from its main state. Supply chain management is a key factor in creating and maintaining a competitive advantage of farmers' products in the market. Challenges and problems like competitors with low-cost products, fluctuating prices of agricultural products, rising consumer expectations, poor economic conditions of producers, and the existence of intermediaries as nodes connecting a farmer with the city lead to paying special attention to the supply chain of agricultural products (Miri et al., 2017).

In definition, an agricultural supply chain refers to the activities from production to distribution that bring agricultural and horticultural products from farms to the food table. What distinguishes the agricultural supply chain from other supply chains is the significance of the factors like food quality and safety and variables associated with climatic conditions (Tsolakis et al. 2014). Because of the farmers' lack of information about crop demand and lack of proper planning for harvest time, about 30% of all crops are spoiled every year.

By examining risk management in supply chain management, Zand hesami and Savoji (2012) showed that the most important supply chain risks are, respectively, environmental, financial resources, strategy, information and communication technology, equipment, and technology.

Houqing (2013) used the SCOR method to identify supply chain risks and then evaluated the risks and which one has the greatest effect on the supply chain using fuzzy analytic hierarchy process (FAHP) and finally using selection theory presented a model for controlling identified risks.

Yanyan and Zheng (2017) divided risks and hurdles of the agricultural supply chain into internal threats from farmers, processing companies, brokers, customers, and other members of the supply chain like information risks, logistics risks, credit risks among supply chain links, and external threats affected by the natural environment and government policies.

Diying (2018) used several scientific approaches to examine the supply chain of fresh agricultural products in production and processing units, retail and wholesale stores in Jiangxi City as the four main links of this supply chain and examined their effect on the entire supply chain model while identifying the main problems.

Nakandala et al. (2016) claimed that given the perishable nature of fresh agricultural products, the supply chain of these products will face a wide range of risks. The study offered a general cost model using a genetic algorithm.

Min J. et al. (2019) use fuzzy hierarchical analysis to examine the risks of weakening the supply chain of fresh agricultural products in China and presented six criteria - production risk, demand risk, supply risk, cooperation risk, logistics risk, and environmental risk -and suggested a model for evaluating the existing risks.

Rohit Sharma et al. (2020) presented the risks that affect the agricultural supply chain and examined these risks using the Fuzzy Linguistic Quantifier Order Weighted Aggregation (FLQ-OWA) model. Their results indicated that regardless of the type and size of production and processing units, supply risks, demand risks, financial risks, logistics and infrastructure risks, managerial risks, political and legal risks, environmental and biological risks significantly affect the agricultural supply chain.

Hierarchical analysis

The process of hierarchical analysis, which is one of the best-known decision-making techniques, was first invented by Thomas. L Saaty, an Iraqi researcher, in 1980. This approach is used for decision-making according to qualitative criteria. In this approach, by relying on the mathematical foundations of matrices, one can prioritize criteria by proposing different criteria. Moreover, one can use the views of various people to make decisions and use this method to process the opinions of experts. As the process of hierarchical analysis is very compatible with the thinking way and mental processes of humans and its algorithm is based on mathematical logic, it has great efficiency and solving many decision problems (Meixner, 2009).

AHP enables combining qualitative and quantitative criteria simultaneously. This process uses binary comparisons of variables and decision criteria. Pairwise comparisons allow the decision-maker to focus on comparing only two criteria, regardless of any external effect or nuisance. Furthermore, it brings about valuable information on the problem examined and enhances the rationale for the decision-making process. This process is based on pairwise comparisons with facilities to ease judgments and calculations. This method is dedicated to mental differences based on the significance of each criterion and numerical values and identifies the most important criteria. In other words, the priority of the criteria in this process is determined. Moreover, one can make the problem hierarchically as equations and consider various quantitative and qualitative criteria by using this model (Chadwick, 1971).

Despite the simplicity and prevalence of AHP among decision-makers, there are some criticisms to this approach, among which the inability to calculate, data uncertainty, and also the uncertainty of the criteria weight can be stated. AHP is based on expert knowledge but cannot truly represent human thought and knowledge (Zhi-Ping Fan et al. 2004).

In the AHP decision environment, the input information and the relationship between criteria and indices is not clear and the expert judgments are stated as definite numbers, yet in some pairwise comparisons, this comparison cannot be expressed as a definite number. In most cases, the decision-maker cannot accurately score various options according to a specific criterion. To deal with the disadvantages of AHP, the researchers used fuzzy logic principles that could deal with the ambiguity of the binary comparison process. The scholars stated that by integrating AHP and fuzzy, Fuzzy Analytic Hierarchy Process, we can solve the AHP problem (Zhi-Ping Fan et al. 2004). Using fuzzy theory allows the decision-maker to make decisions despite the incomplete information, which is not accessible and is expressed qualitatively, as well as criteria that cannot be measured together. Yong Chang (1996) introduced a model that was a combination of AHP and fuzzy theory, known as the fuzzy hierarchical analysis method. As this method is very compatible with the way of thinking and mental processes of human beings whose algorithm is based on mathematical logic, it has high efficiency and is considered as a new method in decision making today (Zhi-Ping Fan et al. 2004).

3. Methods

The study was non-experimental in terms of the extent and degree of control of variables and descriptive in terms of data collection and was a field study and a survey in terms of generalizability of the results. The main tool for data collection was a questionnaire provided to some professors and experts before the survey to determine the validity and make the necessary corrections, and their corrective and supplementary opinions were counted and applied, and the validity of the questionnaire was confirmed. After determining the criteria, the designed questionnaire was given to 30 Bushehr Agriculture Jihad Organization experts for pairwise comparisons, and the following steps were carried out to specify the weight of the criteria using fuzzy hierarchical analysis:

1. Determining verbal expressions for pairwise comparisons of the criteria in question using Table 1
2. Using triangular fuzzy numbers to form a pairwise comparison matrix: In the study, the triangular fuzzy numbers presented in Table 1 were used to show the result of even comparisons in AHP to avoid ambiguity because of uncertainty in decision making in all stages. A triangular fuzzy number is shown by $\tilde{A}$ = (1 + m + u) has the following membership function where the m is the maximum degree of the membership function and μ and l,respectively, the upper and lower limit. A triangular fuzzy number with three components (M, L, U) and a membership function μ(X) is given in Figure 1. Figure 2 is the triangular membership function for linguistic values (Sun, 2010).

$$\mu(x)=\begin{cases} (x-l)/(m-l)\ , & x\epsilon[l,m] \\ (u-x)/(u-m), & x\epsilon[m,u] \\ 0\ , & \text{otherwise} \end{cases}$$

$$\tilde{A} = \begin{pmatrix} 1 & \dots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \dots & 1 \end{pmatrix}$$

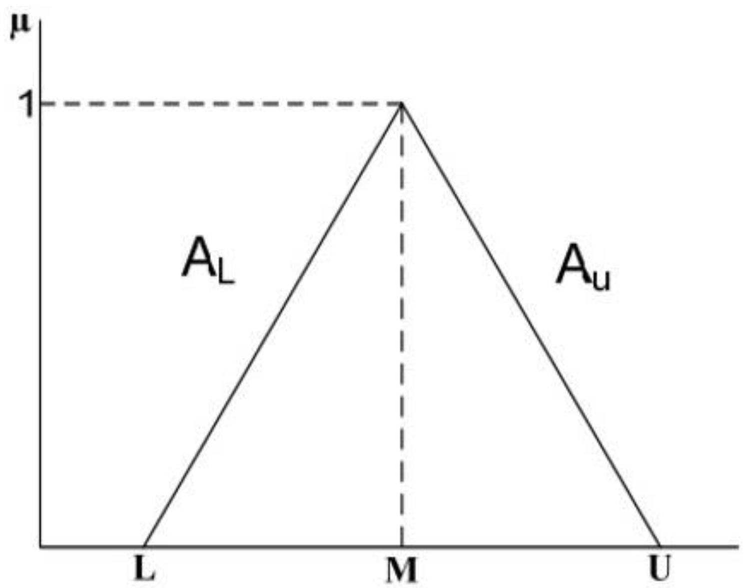

Figure 1. Triangular fuzzy number with three components

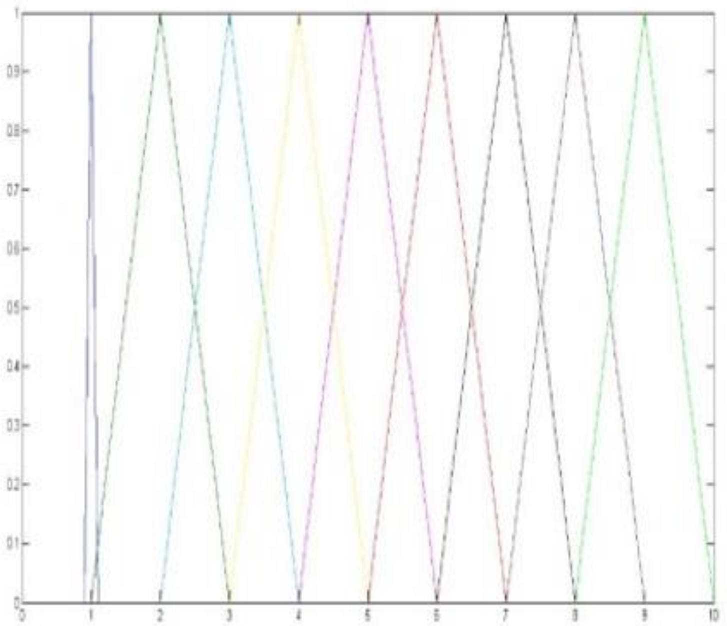

Figure 2. Triangular membership function for linguistic values

1. Using Fuzzy Geometric Mean (Sun, 2010)

   $\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \otimes \tilde{a}_{in})^{1/n}$

2. Calculating the fuzzy weight of each element (Sun, 2010).

   $\tilde{w}_i = \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1}$

3. Using the best non-fuzzy performance (BNP) method

   BNPi = (li + mi + ui) / 3

4. Calculating the degree of matrix inconsistency: The comparisons made in this approach are subjective and AHP tolerates some inconsistency. The comparisons must be repeated if the consistency ratio (CR) does not reach the desired level. CR is calculated as follows:

$$CR = \frac{CI}{RI}$$

The Consistency Index (CI) shows the degree of deviation from the consistency, calculated based on the following equation:

$$CI = \frac{\lambda max - n}{n-1}$$

In the formula above, n is the size of the pairwise comparison matrix, λ_{max} the maximum value of the comparison matrix, and RI is the random index, or the index of randomly generated weights, which can be extracted from the relevant table (Alavi, 2014). If CR obtained is less than 0.1, the comparisons made are acceptable; otherwise, the comparisons have to be done again with more information that is more accurate.

Pairwise comparisons in the study were carried out using Table 1 by Bushehr Agriculture Jihad Organization experts. After collecting the questionnaires filled out by the experts, along with the matrix of pairwise comparisons and specifying the degree of preference of each individual, the relevant information was extracted and the first data processing was performed in Excel. Then, using MATLAB software to calculate the coefficients of each matrix of pairwise comparisons for each of the experts in the study.

4. Results

The purpose of the study was to determine the inhibitory risks of tomato crop supply chain development in Bushehr using a questionnaire and to determine the weights related to each of the criteria using the FAHP model.

As Table 2 shows, in this study, 6 main criteria and 25 sub-criteria were considered as risks to the development of the tomato supply chain based on the purpose of the problem. Then the selected criteria were sent to Bushehr Agriculture Jihad Organization experts for pairwise comparisons. Ultimately, the weight of each criterion was analyzed by the fuzzy hierarchical analysis method based on the significance of the criteria against each other in relation to the desired goal. The inconsistency rate in the study was 0.082, which is less than the acceptable level of 0.1 and thus suitable. According to the findings of the fuzzy hierarchical analysis, the environmental risk (C6) with a value of (0.354) had the highest relative weight. Other criteria and their relative weights are given in Table 3. Moreover, pairwise comparisons results of the sub-criteria are given in Table 4.

5. Discussion and Conclusion

Nowadays, given the significance of food supply to the growing population of the world, the production and development of the supply chain of agricultural products have received more attention than before. Inattention to any of the threats to this supply chain can lead to serious challenges to the global food supply community. Hence, the study decided to use FAHP to deal with the relative significance of each of the risks in the supply chain of tomato crop as one of the important crops. To this end, first, using library studies, the identified risks of the supply chain of tomato crop as a crop were extracted, and then the final modifications were made by experts. Then, each of the risks stated was compared through pairwise comparisons by Bushehr Agriculture Jihad Organization experts, and their relative weight in preventing the development of tomato crop supply chain in Bushehr was calculated using FAHP.

Among the risks of the tomato supply chain, the highest weight was related to the risk of environmental conditions (0.354), showing the significance of this criterion. Among the sub-criteria of this criterion, the highest relative weight was related to "scarcity of agricultural water resources and decline of groundwater aquifers" (sc23) with a value of 0.431, proving the serious threat of tomato cultivation and production in Bushehr because of low water crisis and drought in recent years as a result of improper use of water resources and digging unlicensed wells. The sub-criteria "soil quality reduction" (sc24) and "high nitrate content of tomato crop because of excessive use of pesticides" (sc25), respectively, with relative weights 0.323 and 0.245affect the supply chain of tomato products.

The next criterion with the highest relative weight among the main criteria was the economic risk with 0.214 relative weights. Additionally, among the economic risk sub-criteria, the highest weight was related to "the high cost of product storage in regional cold storages" (sc17) with a relative weight (0.418), which can be due to the importance of cold storage in tomato storage for gradual tomato supply off-season at a reasonable price in Bushehr.

The highest relative significance in the policymaking risk (C3) was for the sub-criterion "inefficient planning of the production system and regulation of the tomato product market" (sc12) with a relative weight of 0.380, and the highest relative significance in the technical-infrastructure risk criterion (C1) was "the lack of storage houses and proper storage of the product" (sc5) with a relative weight of 0.314.

Additionally, education-extension risk (C5) with a relative weight of 0.125 and social-service risk (C2) with a relative weight of 0.029 was the least important relative to other risks threatening the supply chain of tomato products from according to the experts in the study.

No studies have been carried out so far on the risks threatening the development of the tomato crop supply chain; thus, the study can be useful in identifying and weighting the main risks of the tomato crop supply chain in planning and prioritizing the future actions of trustees and the relevant organizations. Furthermore, it is recommended that the present study be conducted on other important agricultural products separately and other multivariate decision models be used to compare the results and efficiency of the models to identify other risks of the agricultural supply chain.

Table 1. Verbal expressions for pairwise comparisons to express the degree of importance

Fuzzy number scale	Code (Numerical rating)	Linguistic variable
(1,1,1)	1	Equal preferred
(3,2,1)	2	Equally to moderately
(4,3,2)	3	Moderately preferred
(5,4,3)	4	Moderately to Strongly
(6,5,4)	5	Strongly preferred
(7,6,5)	6	Strongly to very strongly
(8,7,6)	7	Very strongly preferred
(9,8,7)	8	Very strong to extremely
(10,9,8)	9	Extremely preferred

Table 2. Introduction of criteria and sub-criteria for inhibitory risks of tomato supply chain development

Risk criteria	Risk sub-criteria
Technical-infrastructure (c1)	Inconsistency of tomato cultivation method with production objectives like an edible, seed, and industrial (sc1)
	Inconsistency of old age of tomato producers with modern production methods (sc2)
	Inconsistency of tomato cultivars with the needs of tomato processing industries (sc3)
	Limited cultivation of tomatoes for industrial use (sc4)
	Lack of proper product storage and storage (sc5)
	Low skills and technical knowledge of agricultural workers (sc6)
	High tomato crop waste in various stages from production to consumption (sc7)
Social Services (c2)	Reduction of cooperation and collaboration between farmers (sc8)
	Interventions and non-adherence to the privacy of tomato cultivation lands by the people (sc9)
	The inappropriate transportation system in terms of quality and price of services (sc10)
Policymaking (c3)	Lack of tomato processing plants in the region due to lack of conditions (sc11)
	Inefficient planning of the production system and regulation of the tomato product market (sc12)
	Ignorance of the lack of tomato grading and packaging units by the relevant authorities (sc13)
	Lack of monitoring system to prevent the entry of non-professionals and profiteers into the circle of producers and exporters of tomato products to prevent the destruction of the history of tomato production in the province (sc14)
Economic (c4)	The collateral problem for receiving the facility (sc15)
	Late allocation of bank facilities (sc16)
	High costs of product storage costs in regional refrigerators (sc17)
	Inconsistency between devices in facilitating border and customs affairs for exporting tomato products to other countries (sc18)
Education-extension (c5)	Lack of special information system for agricultural products (input prices, market situation, and product exports) (sc19)
	The inability of the farmers to use information systems to know the price of inputs and market situation (sc20)
	The inefficiency of research and promotion system in transmitting findings to producers (sc21)
	Decrease in farmers' profits and incomes due to lack of innovation (sc22)
Environmental (c6)	Lack of agricultural water resources and decline of groundwater aquifers (sc23)
	Decreased soil quality (sc24)
	The high nitrate content of tomato crop with excessive use of pesticides (sc25)

Table 3. Summary of the prioritization of key risk criteria according to fuzzy weights

Risk criteria	C1	C2	C3	C4	C5	C6
Fuzzy weights	0.133	0.029	0.145	0.214	0.125	0.354
Relative priorities	IV	VI	III	II	V	I

Table 4. The summary of prioritization of risk sub-criteria based on fuzzy relative weights

Main risk criteria	Risk sub-criteria	Relative fuzzy weights	Relative priority / significance
Technical-infrastructure (c1)	Sc1	0.073	VII
	Sc2	0.101	VI
	Sc3	0.133	III
	Sc4	0.112	V
	Sc5	0.314	I

	Sc6	0.125	IV
	Sc7	0.142	II
Social Services (c2)	Sc8	0.245	III
	Sc9	0.323	II
	Sc10	0.431	I
Policymaking (c3)	Sc11	0.262	II
	Sc12	0.380	I
	Sc13	0.243	III
	Sc14	0.114	IV
Economic (c4)	Sc15	0.242	II
	Sc16	0.171	III
	Sc17	0.418	I
	Sc18	0.167	IV
Education-extension (c5)	Sc19	0.158	III
	Sc20	0.107	IV
	Sc21	0.220	II
	Sc22	0.513	I
Environmental (c6)	Sc23	0.431	I
	Sc24	0.323	II
	Sc25	0.245	III

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