Assessment and Risk Mitigation of Arabica Ijen Coffee Supply Chains

by Saptya Prawitasari

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ABSTRACT
Risk management plays an important role in managing supply chains. Agricultural commodities different from manufactured products because agricultural products have unique properties, perishable, their shapes and sizes are very varied, seasonal, the business scale is generally small and Kamba, so agricultural supply chains are also different from supply chains of manufactured products. The problem in Arabica Ijen coffee agroindustry is the availability of raw material supply, diverse quality and not following with processor qualifications. So, it is vulnerable to the risk of loss for the culprit. The purpose of this study is to determine the factors that influence quality risk and determine the risk mitigation of Ijen Arabica coffee. Risk assessment of Arabica Ijen coffee supply chain quality uses Fuzzy FMEA (Failure Mode Effect Analysis) method, to identify the cause of the problem by considering the occurrence criteria (O), severity (S), and detection (D). Data is collected from interviews with expert respondents/experts from farmers, cooperatives, agro-industries, researchers and academics, who have been involved for at least ten years in the coffee agro-industry. The results of the analysis show that a structural model to identify and prioritize risks, by identifying six factors and 20 sub-factors. This study reveals that farmers' knowledge and skills in terms of cultivation techniques are the main risks that relative importance inherent in the Ijen Arabica coffee supply chain and thus require attention. Mitigation efforts that can be taken are improvements to cultivation that focus on the management of pests and diseases of coffee plants or technical education and training are others alternative to reduce this risk. Factors that prevent farmers from accessing and implementing training must be considered so that the provision of knowledge and skills can be carried out effectively.
Keywords: *risk, mitigation, coffee, Arabica Ijen*

1. INTRODUCTION

Arabica Ijen is coffee produced from plantations around Ijen. The Mount Ijen region has good characteristics for Arabica coffee plants and has ownership as a producer of Arabica coffee since the 18th century known in the world market by the name of Java Coffe. Arabica coffee plantations with elevations between 1,000 to 1,400 meters above sea level, entisol and inceptisol volcanic soils are considered ideal by coffee experts to plant Arabica coffee which can bring out the distinctive taste of Ijen Arabica Coffee. This distinctive taste makes Ijen Arabica Coffee get a geographical indication certificate from the Indonesian Ministry of Law and Human Rights with number IG.00.2013.000001 on September 10, 2013, as Ijen Raung Java Coffee [1].

The supply chain that requires a lot of processes, ranging from material suppliers, production, customer demand, transportation, warehousing, distribution, so it requires high assistance in its management. At each process in the supply chain, risks occur [2].

The Ijen Arabica coffee business is currently developing, but faces various problems related to the low product, low productivity, comparing prices between farmers and agro-industries and increasing information on the need for inter-coffee needs in the supply chain. These problems can cause problems with the supply of raw materials, prices, and supplies for farmers, traders and coffee agro-industries that can support the competitiveness of Ijen Arabica coffee. Therefore, it is necessary to anticipate and mitigate efforts to reduce these risks.

Risk is the uncertainty of future events, in other words, risks are those that occur both internally and externally that are negative towards the achievement of organizational goals in the future [3]. Risk also determines as an impact of environmental and financial processes that are issued [4]. To avoid and reduce the impacts arising from risks there needs to be a mitigation scenario prepared based on the risk specifications associated with the Ijen Arabica coffee supply chain.

The concept of Supply Chain Risk Management, in this study was adopted from the definition given by Ho et al. [5] based on a study they have done from journal articles in the field of supply chain risk management. They define supply chain risk management as "collaborative efforts between organizations that use quantitative and qualitative risk management methods to identify, evaluate, mitigate, and monitor unexpected and micro-level events or conditions that may have a detrimental impact on each part of the supply chain". The purpose of supply chain risk management is to control, monitor and evaluate supply chain risk by optimizing actions to prevent disruption and recover quickly. Supply chain risk management also has a large influence on the stability of dynamic cooperation among supply chain partners and is thus very important for the overall performance of supply chain operations [6]. Giannakis and Papadopoulos [7] stated that the process of risk management in the supply chain includes several things, namely: risk identification, risk assessment and priority setting, risk management actions, and risk monitoring.

A good management decision in managing risks must begin with understanding and prioritizing the risks experienced by all members of the supply chain through identification. Identification of the source of risk, making decision-makers aware of the phenomenon that causes uncertainty [8]. Risk assessment requires the loyalty and accuracy of the entire supply chain [9]. FMEA is a powerful and effective analytical tool and has been widely used to assess the relative importance of risks, identify the causes and potential effects of risks and examine the potential correlations between identified risks [7]. FMEA was first applied to aerospace industry research in the mid-1960s which focused on safety issues such as improving safety, preventing defects and increasing customer satisfaction [10]. In its development, FMEA is also used in risk assessment in various industries [11]. In the FMEA process, all potential failures are evaluated in three dimensions of risk: (occurrence), severity and detectability. Then the Risk Priority Number (RPN) is calculated for each potential failure. A higher RPN score implies a greater risk [12].

In previous studies FMEA implementation for supply chain risk assessment has been widely carried out both industry and agricultural supply chains [2],[7],[12-15]. Jaya et al. [2] examines the most influential risk factors and determines their mitigation in the Gayo coffee supply chain using the Fuzzy AHP approach. Raab et al. [16] developed a study for risk categorization, systematization, identification, and evaluation of failures in the context of implementing a proactive risk management system in the global value-added chain for fruits and vegetables. In their research, FMEA is used to identify product-specific risk categories, assess risks (based on supplier country, company and process steps) and to rank potential hazards using a risk priority number then a mitigation strategy is tested. Anin et al. [13] also conducted a study evaluating pineapple supply chain networks in Ghana using the Pareto analytical model with FMEA. This approach is applied to identify risks, analyse risks and then classify based on the level of impact on operational activities. Mitigation strategies are then developed to deal with risks. They found that lack of good planting material, availability of skilled labour, fluctuations in electricity, pre-cooling facilities and ineffective cold chains were the main risks faced by most pineapple supply chain actors in Ghana. However, each commodity supply chain has different risks and risk factors. Therefore, it is necessary to identify risks in the coffee supply chain.

Liu et al. [11] state that the FMEA method has shortcomings, based on the summary of various risk measurement models from various articles. One of FMEA's weaknesses is that it does not consider the relative importance of the three risk dimensions, these three risk factors are considered to have the same importance. Different combinations of the three risk dimensions can also produce identical RPN values, for example, LOO (RPN_1 = 10 (S) x 5 (O) x 2 (D), RPN_2 = 1Qx2x5) which can lead to the conclusion that priorities for corrective actions are applied to two the risk component is the same [17]. Although the risk implications of the two events may be different due to different levels of severity and failure. The example shows that FMEA is not strong enough in the priority mode of failure. Therefore, an important role in the critical analysis is the proper assessment of the weight of risk factors because they can influence the failure mode ranking [15].

Some authors propose an alternative method to increase the significance of the RPN, which is to combine the traditional FMEA Method with Multi-Criteria Decision Making (MCDM). Chang et al. [18] have applied grey theory to FMEA to improve product reliability and process stability during the product design and process planning stages. Braglia et al. [19] presented a fuzzy technique for Order Preference with Similarity to the Ideal Solution (TOPSIS) approach to prioritizing failures in failure modes, effects and criticality analysis (FMECA). Seyed-Hosseini et al. [20] propose an alternative multi-attribute decision-making approach called the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to reprioritize failure modes in the FMEA system for corrective action. Liu et al. [21] used the extended VIKOR method under a fuzzy environment to give priority to the FMEA method. The Analytic Hierarchy Process (AHP) combined with FMEA was applied in several cases [2],[22-25]. In a further development, Slamet et al. [15] in its publication applied the fuzzy ANP approach with FMEA for risk assessment in the coffee supply chain. This study proposes using this method to assess the risk of the Arabica Ijen coffee supply chain.

2. METHOD

Research framework: The research methodology consists of several sequential phases to assess coffee supply chain risk based on processes within the supply chain risk management framework.

The first phase is the identification of supply chain risk, which is the basis of risk management to recognize future uncertainty. This phase identifies potential problems according to all members of the supply chain [8]. This study, integrating risk assessment for identification, fuzzy ANP to identify and determine the relative importance of coffee supply chain risk factors.

The second phase includes risk assessment using FMEA. All risks identified in the first phase are assessed in terms of the likelihood of their occurrence and the impacts or consequences that may result. Then proceed with the calculation of RPN based on three dimensions of risk.

The third phase of the RPN is calculated by weighting the risk factors obtained from the fuzzy ANP which gives a weighted RPN. The multiplication of these components enables the prioritization of risk factors to determine management actions that are deemed most appropriate to the coffee supply chain situation.

Data is collected based on in-depth interviews with expert respondents/experts representing members of the supply chain and come from farmers, traders, agro-industries, researchers, academics with qualifications that have been in the minimum 10 years in the coffee agro-industry. In this study, expert farmers were selected from the Farming Group 3 of Selencak Hamlet, Sukorejo Village, Sumber Wringin District, representing wholesale and retail supply chain managers at Sumber Wringin, researchers from the Coffee and Cacao Research Center and academics from the university. The questionnaire consists of two parts, the first part contains questions related to supply chain risks and the second part contains questions for risk assessment. An ANP survey was then conducted aiming to evaluate the comparison of perceived criteria for supply chain risk factors. Risk assessment is then measured according to supply chain risk criteria using FMEA.

Fuzzy logic is a logic that has a value of blurring or blurring (Fuzyness) between right and wrong. The purpose of the Fuzzy approach is to equate a notion of a set and problem to accommodate the type of obscurity in some problems in decision making. Fuzzy Analytical Network Process: ANP introduced by Saaty in 1996, is a generalization of AHP [26]. The AHP model assumes a simple hierarchical relationship between decision levels. The ANP method allows for more complex interaction dependencies within clusters (internal dependencies) and between clusters (external dependencies) through the development of super matrix [27-28]. ANP uses the same method as AHP, which uses a fundamental comparison scale (1-9) to assess the preferences of decision-makers, except in the case of fuzzy representations, Triangular Fuzzy Numbers (TFN) is used [29]. The Fuzzy Set Theory (FST) was introduced by Zadeh to deal with uncertainties in the human valuation process because of inaccuracy and obscurity. Decision-makers usually measure uncertain events and objects using unclear language, such as 'equal', 'sufficient', 'very', 'very strong', 'absolute' and 'significant level'. FST allows them to solve the problem of ambiguity involved in the process of linguistic assessment of data [30].

In this study, it is proposed to combine FST concepts with the ANP Method. Fuzzy ANP has been recognized as a well-accepted technique for adequately addressing the limitations of conventional ANP in the decision-making process [31-33]. The fuzzy set is then determined by the membership function which will assign each membership level object which ranges between 0 and 1 [28]. Fuzzy triangle numbers (M) as shown in Fig. 2, defined as (1, m, u), where ls m su. Parameter 1 represents the smallest possible value; parameter m represents the most promising value and parameter u represents the largest value that represents a fuzzy event. The TFN membership function can be defined as follows:

	0	x< 1	
	(x-l)/(m-1)	l<x<m.	(1)
μ(xlrYi) =	(μ-x)/(μ-m)	m<x<μ	
	0	x>μ	

Fuzzy numbers can be given by the left and right that are appropriate for each level of membership:

$M = [M^{t(y)}, M^r(y)] = [1 + (m - u)Y, u + (m - u)Y]$

$y \in [0,1]$ (2)

Where l (y) and r (y) represent the left and right sides of the fuzzy number, respectively. Definitions and detailed discussion of arithmetic operations on fuzzy triangles can be found in Kahraman et al. [34]. Furthermore, in designing the relative importance scale to construct a pairwise comparison/evaluation matrix, TFN was used to improve the classical nine-point scaling design. Fuzzy linguistic scale regarding relative importance to measure relative weight [35].

In this paper, we use the fuzzy ANP method which will determine the important weighting of the nks in the coffee supply chain. Important elements of the integration of ANP and fuzzy set theory are as follows:

a. Identify the coffee supply chain risk factors and sub-factors that will be used in the model.

b. Structuring of the ANP model (targets, risk factors, risk sub-factors)

Determine the local weighting of risk factors and sub-factors using a paired comparison matrix (assumption: there is no dependency between factors). In this step, it is necessary to collect fuzzy numbers into crisp values using the Extent Chang Analysis method. Compared to other approaches, this method is easier and has been widely accepted to calculate the weighting of fuzzy aggregate importance for the evaluation matrix in pairs of fuzzy inputs [36]. The details of Chang's area analysis method calculation [37] are: if the area analysis value for the i-th object is represented by, $m_{gi}^1, m_{gi}^2, m_{gi}^3$ ... where (i = 1,2,3,4, ... n) and all, m_{gi}^j (j = 1,2,3,4, ...) is TFN (j = 1, 2, 3, ..., m), then the appropriate fuzzy synthetic level is represented as:

$S_i = \sum_{i=1}^n M_{gi}^j \left[\sum_{i=1}^n \quad \sum_{r=1}^m \quad M_{gi}^j\right]$ (3)

The values for a particular matrix are then carried out to obtain

$$\sum_{j=1}^{m} M_{g1}^i$$

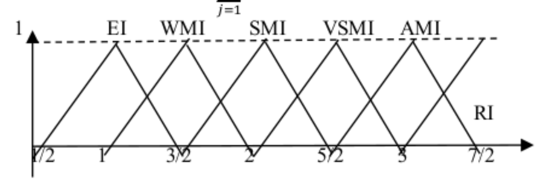

Figure 1 Representation of intersection between Ml and M2

$\sum_{i=1}^n \sum_{j=1}^m M_{gi} = \left(\sum_{j=1}^m L_j, \sum_{j=1}^m M_j, \sum_{j=1}^m \mu_{i_i}\right)$ (4)

And the Fuzzy addition operation of M_{gi}^j ; j = 1,2,3, … m Value are performed toobtain $[\sum_{i=1}^n \sum_{j=1}^m \sum_{g=1}^l \quad]$

$\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j = (\sum_{i=1}^n L_i, \sum_{i=1}^n M_i, \sum_{i=1}^n \mu_i)$ (5)

And then calculate the inverse of the vector in Equation Formula 6

$[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j] = \frac{1}{\sum_i^n u_i}, \frac{1}{\sum_i^n m_i}, \frac{1}{\sum_i^n l_i}$ (6)

Next, taking into account the minimum and maximum values for fuzzy numbers, the degree of probability for two fuzzy numbers M2 = (12, m., U2) .; ::, M1 = (11, m., U.) Represented

$v\,[M_2 \geq M_1] = \sup[\min((\mu_{M1})(X), (\mu_{M2})(Y))]$(7)

where $x, y \in R$ and $x > Y$ where X, y, R and X, Y

It is noted that, if x, Y and uMi (x) ≥ uMi (y) = 1, then V (M2 ≥ CM1), because M2 and M1 are two convex fuzzy numbers, it satisfies the properties mentioned as:

$$v(M_2 \geq M_1) = 1 \; if \; m_2 \geq m_1 \qquad (8)$$

$$v(M_2 \geq M_1) = 1 \; if \; m_2 \geq u_1 \qquad (9)$$

$$v(M_2 \geq M_1) = hgt\,(m_1 \cap m_2) \qquad (10)$$

$$= \mu\, M_2(d)$$

where, d is the highest intersection point D between μM, and μM, (Fig. 4) and subsequently, D is given as: (formula 3)

$$v\,(M_2 \geq M_1) = hgt\,(M_1 \cap M_2) \qquad (11)$$

$$= (i_1 - \mu_2) - (m_2 - \mu_2) - (m_1 - \mu_1)$$

We need both of values $v = (M_i \geq M_j)$ and $v = (M1 \geq M_2)$ to compare M_1 and M_2. Next, the level of probability for fuzzy convex numbers M_i (1 = 1, 2, 3, ..., m) calculated as:

$$v\,(M \geq M_1, M_2, M_3, \ldots, M_k)$$

$$v\,[(M \geq M_1)\; and\; (MM_2)\; and\; \ldots and\; (M \geq M_k)]$$

$$= \min v\,(M \geq M_i), i = 1,2,3, \ldots, k \qquad (12)$$

Assuming that fork $d(A) = \min v\,(S_i \geq S_2)$ d (A,) = min $v\,(S_i \geq S_2)$ = 1, 2, 3, …, n; however, the weight vector is given by:

$$W = \left(d\,(A_1), d\,(A_2)\right)^T \qquad (13)$$

where, A_l (l, 2, 3, ..., n) are n elements. After being normalized, the normalized fuzzy weight vector is given as:

$$W = \left(d\,(A_1), d\,(A_2), \ldots, d\,(A_n)\right)^T \qquad (14)$$

While 'W' is a non-fuzzy number. After that, by using the fuzzy scale, then determine the dependency matrix in each of the risk factors to other risk factors. The dependency matrix in this is then multiplied by the local weights of the factors determined in step 3, to calculate the interdependent weights of these factors.

Calculate the global weighting of risk sub-factors. The global sub-factor risk weighting is then calculated by multiplying the local weighting sub-factor by the interdependent weighting of the factors it has.

Weighted FMEA and RPN: FMEA is defined as "a systematic method for identifying and preventing product and process problems before they occur" (McDermott et al., 2009). The relative risk of failure and its effect in the FMEA process is determined by three dimensions:

a. Severity (S): consequences of failure
b. Occurrence (0): probability or frequency of failures
c. Detection (D): the probability of failure is discovered before the effect occurs

Using data and knowledge about processes and products in the coffee business, this study then assessed each mode and potential failure effect with the dimensions mentioned on a scale of 1-10 (with 1 being the best and 10 being the worst case). Then the Risk Priority Number (RPN) is determined for each mode and the potential failure effect by multiplying the dimension rating as shown below:

$$RPN = S \times O \times D \qquad (15)$$

Traditional RPN has limitations, to overcome this we use a weighted RPN (WRPN) value, which is determined using fuzzy ANP multiplied by the RPN value (Equation 16). Next, WRPN values will be used to sort the failure mode:

$$WRPN = RPN \times W_{FANP} \qquad (16)$$

Failure modes with higher WRPN values are assumed to be more important, thus higher priority will be given for corrective actions.

3. RESULTS AND DISCUSSION

The initial step in the process of modelling coffee quality risk is to establish risk alternatives. Based on in-depth interviews with experts, some criteria can reduce the quality of coffee beans.

Risk identification: The first and most critical step in the Supply Chains Risk Management (SCM) process is the identification of potential risks. Risks in the coffee supply chain have been identified in the literature review and expert interview stages and then validated with the actual situation of the coffee supply chain. This step involves identifying risks and factors in the coffee supply chain. Types of risks in this study include risks in the external environment, risks in the supply chain and internal risks [38]. Risks at the level of farmers and other members of the coffee supply chain can be grouped into six factors, namely: 1) Production risk (low coffee production due to poor cultivation practices, inappropriate management of pests and diseases, improper application of planting procedures, lack of technology and human risk); 2) Quality risks (inappropriate handling starts from the lack of supply of good quality agricultural inputs, processing and post-harvest activities); 3) Market risk (product volatility, uncertainty of inputs and demands and market competition); 4) Supply risk (inability to supply uniform product quality, loyalty in terms of supplier-buyer relations and continuity of supply quantities); 5) Distribution and Storage risks (originating from poor infrastructure, failing to choose appropriate transportation and improper packaging and handling of storage). 6) Social and environmental risks (unexpected weather changes, governance Effectiveness/ regulations, socio-cultural and political conditions); Besides, the ANP potential risk model consists of three levels.

The first level of this model aims to determine coffee Arabica Ijen supply chain risk weighting sub-factors. Second and third level factors and sub-factors are also related to objectives at the first level. The second level 1 factor is connected to the first level goal with a single directional arrow. While the other arrows on the second level represent deep dependence among factors. The inner dependence between markets, quality, environment, supply, production, and transportation, which is at this level is taken into account and with this, the effects of each other's factors are analysed. Sub-factors related to factors are at the third level of the model.

Risk Assessment: After identifying the risks and structuring of the ANP Model, the degree of importance of each factor and sub-factors at the second and third level of the ANP Model is determined. Their local weights are then determined by conducting a pairwise comparison matrix conducted by the expert using the scale given in Table 2. For example, the expert is asked: "With respect to objectives, how important is the market compared to quality?" and the answer "weak is more important". Thus, the linguistic scale is placed in cells that are relevant to TFN (1, 3/2, 2). Similar questions are also asked to formulate all fuzzy evaluation matrices. The importance of factor weights is then calculated using the Extent Chang Analysis method using Eq. 3-15. The corresponding M_i value can be calculated through Eq. 3-6, then the probability level for two fuzzy numbers is calculated using Equation 7-12.

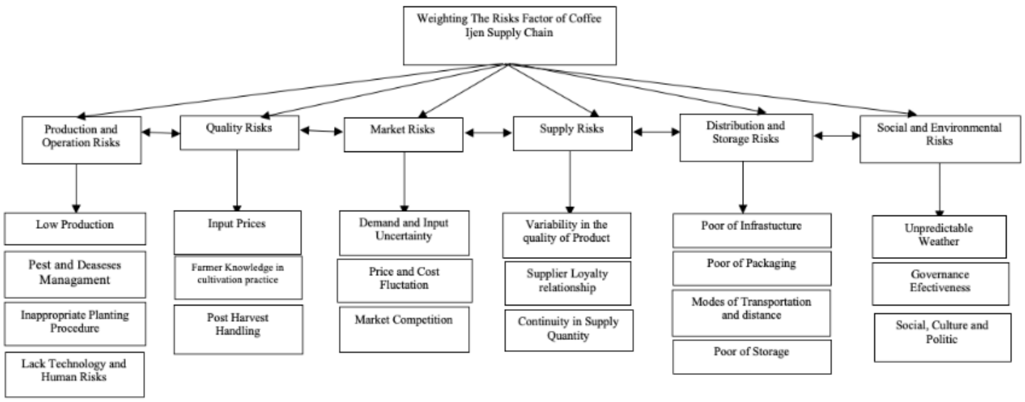

Figure 2 ANP Model of Identification Potential Risk for Arabica Ijen Coffee Supply Chains

Table 1 Category of Risk factors and sub-factors

No	Risk Factor	Sub Factor	Sources (References)
1.	Production and Operation Risks	Low Production	low production of coffee due to the poor agricultural practices
		Pest and Diseases Management	Pests and diseases have been shown to be very important factors in reducing yield and marketability of coffee (expert's opinion)
		Inappropriate Planting Procedure	Inappropriate procedure of planting causes flower of coffee had not been pollinated and therefore failed to develop into a fruit (expert's opinion)
		Lack Technology and Human Risks	Lack of technology and innovation, rural exodus and lack of training programs of farmer (expert's opinion)
2.	Quality Risk	Farmer Knowledge in cultivation practice	Variation of personal skill and lack of knowledge off armer [8]
		Input prices	Coffee quality is affected by availability of affordable inputs (expert's opinion)
		Post-Harvest Handling	Inappropriate practices in harvesting, field handling, sorting, grading, postharvest treatments, and packing have a great impact on maintaining the optimum organoleptic, nutritional, and functional quality attributes of the coffee fruit (Sivakumar and Wall, 2013)
3.	Market Risks	Demand and Input Uncertainty	Variability and distortion of information about demand makes it difficult for retailers to expect long-term consumer demand [13]
		Price and Cost Fluctuation	Fluctuations in product prices are caused by oversupply, reduced demand and other factors related to inflation, changes in interest rates, changes in currency values, etc. [39]
		Market Competition	Competition with other fruits in availability, price and quality of products (expert's opinion)
4.	Supply Risks	Variability in the quality of Product	Branding of agriculture product is widely considered to be difficult because of the variability in quality of the product and irregularity of supply [40]
		Supplier Loyalty relationship	Failures in managing and maintaining loyal suppliers offers a number of disadvantages including inconsistent supplies, higher transaction costs, inefficiency and increased post-harvest losses (expert's opinion)
		Continuity in Supply Quantity	Shortage of shipment capacity, shortage of products in distribution center, lead time uncertainties and delay in delivery [41]
5.	Distribution and Storage Risks	Poor of Infrastructure	Agricultural supply chains increasingly face risks related to logistics and infrastructure, (e.g. access to asphalt road, lacking communication

			infrastructures), that affect the availability and timing of goods and services [13]
		Poor of Packaging	Since coffees are highly sensitive to mechanical damage, proper packaging is needed to reduce damage, improve marketability and prolong shelf-life of coffee fruits
		Modes of Transportation and distance	Inappropriate use of transportation modes and long shipping distances, will cause quality degradation, increase transportation costs and problems along the supply chain (expert opinion) (expert's opinion)
		Poor of Storage	Due to the climacteric fruit characteristics, non-optimal temperature of storage will cause coffee can be ripened to the undesired level
6.	Social and Environmental Risks	Unpredictable Weather	Non-extreme weather events (e.g., too much or little rainfall, or too high or low temperatures) often affect agricultural supply chains for a single production cycle (expert's opinion)
		Government Effectiveness	Government policy and institutional risks have major direct and indirect impacts on shaping incentives and decision-making in agricultural supply chains
		Social, Culture and Politic	changes in consumer attitudes, changes in trade relations, levels of farmers' welfare and health, risks related to security, etc. (Expert opinion)

Table 2 Local Weights and Pairwise Comparison Matrix of Main Factor

Factors	Production	Quality	Market	Supply	Distribution	Social and Environment	Local Weights
Production	(1/2, 2/3, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(2/3, 1,2)	(1, 1, 1)	(1, 3/2, 2)	0.1887
Quality	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(2/3, 1,2)	0.1330
Market	(1, 1, 1)	(1, 3/2, 2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1, 3/2, 2)	(3/2, 2, 5/2)	0.2266
Supply	(2/3, 1, 2)	(1, 3/2, 2)	(1, 3/2, 2)	(1, 1, 1)	(112, 1, 3/2)	(3/2, 2, 5/2)	0.2069
Distribution	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)	0.1187
Distribution	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)	0.1187
Social and Environment	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1/2, 1, 3/2)	0.1261

Table 3 Weight of Factors and Sub-Factors Based on Expert Assessment

Factors	Weights of factor	Sub-factors	Weights of sub-factors	Global weights
Production	0.1779	Low Production	0.1330	0.0237
		Pests and diseases	0.2266	0.0403
		Inappropriate planting procedure	0.1330	0.0237
		Lack of technology	0.1261	0.0224
Quality	0.1676	Input Prices	0.3333	0.0559
		Farmer knowledge in cultivation	0.3333	0.0559
		Postharvest handling	0.3333	0.0559
Market	0.1965	Price and cost fluctuations	0.0970	0.0191
		Demand uncertainty	0.5584	0.1097
		Market competition	0.3446	0.0677
Supply	0.2080	Variability of product quality	0.0970	0.0202
		Supplier loyalty	0.5584	0.1161
		Continuity of supply	0.3446	0.0717
Distribution	0.1219	Poor of infrastructure	0.2266	0.0276
		Packaging	0.1330	0.0162
		Modes of transportation and distance	0.1261	0.0154
		Storage during shipment	0.1187	0.0145
Social and environment	0.1280	Weather related risks and natural disruptions	0.4572	0.0585
		Governance Effectiveness	0.0857	0.0110
		Social, culture and politic	0.4572	0.0585

The minimum weight vector calculated is then operated to obtain the normal value and the weight vector using Eq. 14. As a result, weighting vectors for risk factors (eg, 0.2266, 0.1330, 0.1261, 0.2069, 0.1887 and 0.1187) were established. In the same way, the importance of weights for subfactors has been calculated. All-important weights calculated for factors and sub-factors are given in Table 3. In the next step, the weights of the interdependent factors are calculated taking into account dependencies among the factors. Pairwise comparisons are used to analyse the impact of each factor on other factors to determine the dependency between these factors. Therefore, the following question is asked to experts "What is the relative importance of 'quality' when compared to "social and environmental" concerning market risks? "and the answer" Very more important "is changed to TFN (3/2, 2, 5/2) as stated in Table 4.

Table 4 The Interdependent Weights of Risk Factor

Factors	Respect to	Local Weights
Quality	Production	0.2144
Market		0.1850
Supply		0.2015
Distribution		0.1591
Social and Environment		0.2400
Production	Quality	0.2701
Market		0.1046
Supply		0.2876
Distribution		0.2015
Social and Environment		0.1362
Production	Market	0.1993
Quality		0.2833
Supply		0.0894
Distribution		0.1116
Social and Environment		0.3163
Production	Supply	0.2260
Quality		0.2260
Market		0.2260
Distribution		0.1642
Social and Environment		0.1577
Production	Distribution	0.1664
Quality		0.1856
Market		0.2233
Supply		0.8894
Social and Environment		0.3163
Production	Social and Environment	0.2276
Quality		0.2276
Market		0.1763
Supply		0.2276
Distribution		0.1407

This dependency matrix for these factors is formed using the relative importance weights calculated from the previous step. Next, the matrix is multiplied by the local weights of the main factors in Table 4. Then we calculate the weights of the interdependent factors. As for the results of these calculations are as follows:

$$\begin{bmatrix} 0.1779 \\ 0.1676 \\ 0.1965 \\ 0.2080 \\ 0.1219 \\ 0.1280 \end{bmatrix}$$

The results of weighting between factors indicate that there are significant differences when compared to weighting factors without regard to other factors as in Table 4. Weight changes from 0.2266 to 0.1965 for market factor weights, 0.1330-0.1676 for quality factor weights, 0, 1261-0.1280 for social and environmental factors, 0.2069-0.2080 for supply weight, 0.1887 to 0.1777 for production; 0.1187-0.1219 for the distribution factor. Next, we calculate global weights for sub-factors by multiplying local weights by sub-factors with interdependent weights of each risk factor. After the weighted factors are verified and the weighted sub-factors are calculated, the risk rating is identified in this study by considering the RPN results from the FMEA process.

RPN value is a combination of product value from the severity, appearance, and detection. For risks related to "farmers' knowledge in cultivation practices", the severity is 7, the occurrence is 8, detection is 7, so the RPN value is 8 x8 x7 = 392. Example Sub-factor weighting, then calculated by multiplying the RPN value by weight sub-factor, for example, Ri from "farmers' knowledge in cultivation practices" and obtained values of 392x0,0559 = 20,2358. The overall results of each Ri are shown in Table 7 below.

A higher RPN weighting indicates a risk with a higher mitigation priority. To determine the focus of risk mitigation, the Pareto Principle is used with the idea that by reducing 20% of risk, we can produce 80% of risk mitigation benefits. While the RPN weighted cumulative weighted from the risk rating, shows the value of "Ri" farmers' knowledge of cultivation practices is 21.9%. This means that mitigation must focus on increasing farmers' knowledge and skills in terms of coffee cultivation techniques, so that the benefits of risk mitigation can be obtained entirely.

Technical training is one alternative to reduce risk priorities. If farmers have better knowledge and skills in terms of cultivation, they will also follow proper planting procedures, be able to handle pests and diseases of coffee plants and can control seed quality. Thus, it will be able to achieve increased production and reduce coffee quality variability. Expanding knowledge and technology plays an important role in increasing production and detecting risks to future productivity arising from climate change. High coffee production is likely to guarantee the availability of raw materials and continuity of supply. Other efforts to increase production in the future are to encourage the involvement of private sector institutions and strengthen coordination between producers and management instructors. Coordination will combine business knowledge and skills to develop the ability of farmers to handle post-harvest products and create competitive advantage. Besides technical training for farmers, they can be equipped with life skills (for example, social and legal awareness) to increase farmers' awareness of how to become loyal suppliers in a coffee supply chain.

4. CONCLUSION

The development of the Ijen Arabica coffee supply chain, like other agricultural products, is strongly influenced by the potential for uncertain risks. In this study, an attempt was made by the Arabica Ijen to develop a structural model to identify and prioritize risks, by identifying six factors and 20 sub-factors using FMEA and determining the relative weights using Fuzzy ANP, as the framework carried out in this study. This study has the following main points: First, this model shows the potential benefits of detecting high risk priorities in the Ijen Arabica coffee supply chain systematically and effectively. Second, this study combines the FMEA and Fuzzy ANP methods to assess the risk of the Ijen Arabica coffee supply chain which is difficult to find in previous studies. Fuzzy ANP methodology is very important in determining the importance of risk factor weights. Whereas the FMEA method can be used to assess risk factors in three dimensions: incidence, severity, and detection ability. Weights obtained from the ANP fuzzy method are then used as input to determine the weight of the RPN in multiplication with the RPN value of the FMEA technique. Risks are then sorted by weighted RPN value to determine priority risks that need to be reduced. The results of this study reveal that farmers' knowledge and skills in terms of cultivation techniques are the main risks inherent in the Ijen Arabica coffee supply chain and thus require attention. Technical education and training are one alternative to reduce this risk. Factors that prevent farmers from accessing and implementing training must be considered so that the provision of knowledge and skills can be carried out effectively.

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