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Risk Assessment of Papaya Supply Chain: An Indonesian Case Study

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Abstract: Risk management plays an important role in managing food supply chains effectively due to its uncertainties. The aims of this study were to identify and analyze various risks in the papaya supply chain, then assess the risks and prioritize them to be mitigated appropriately. Failure Modes and Effects Analysis (FMEA) was applied to assess the risks of papaya supply chain using three criteria, i.e., the occurrence, the likelihood of being detected and the severity. Fuzzy Analytic Network Process (FANP) was used to determine the relative importance of factors and sub-factors. A Weighted Risk Priority Number (WRPN) then was calculated to determine the risk priority. A higher WRPN score implies greater risk and should be prioritized in mitigation. The results of this study indicated that the highest ranking of the risk sub-factors were farmer knowledge in cultivation practice. Technical and vocational education/training was one of alternatives to mitigate the risk priority.

Key words: Risk management, papaya supply chain, fuzzy ANP, FMEA, mitigate

INTRODUCTION

Indonesian export of papayas has been fluctuating in both of the total volume and the total of value in over the past five years. According to the Indonesian Ministry of Agriculture, the value of export increased from USD 125,549 in 2009 to USD 514,670 and dropped to USD 29,490 in 2012 (Table 1). The agribusiness activities of papaya for the export market have not been efficient yet to be able to compete internationally due to fluctuations in the production as well as increasing in domestic demand. In general, the problems faced by fresh fruit growers and exporters in Indonesia are small scale farms which are scattered in different production area and individually managed; lack of farmer's skills; varied climatic conditions; and poor market infrastructure. The activities also require intensive effort for introducing and adopting best practices in production, postharvest and distribution handling (Perdana, 2012).

In order to improve the competitiveness of Indonesian fruits in the global market, supply chain management plays a crucial role. Not only to increase the efficiency of the chain, but also to create and distribute the added value to different stakeholders from farmers to consumers (Perdana, 2012). The activities in the papaya supply chain do not only focus on the cultivation but also focus on post-harvest activities such as grading, processing, packaging, storing and transporting to meet consumer needs by creating value through attributes such as safety, convenience, taste and nutrition. Throughout the supply chain, maintenance of papaya quality very much depends on the orchard management, harvesting practices and abovementioned post-harvest activities (Sivakumar and Wall, 2013). Rapid flesh softening, decay, physiological defect, pest infestation and improper temperature management are the factors that can cause post-harvest losses. Furthermore, the Indonesia papayas are not able to meet the export market requirements such as continuity of quantity, quality, food safety and competitive price. In order to cope with those challenges, a better supply chain management should be establish, to integrate all the process from farm to consumers.

In agricultural sector, supply chain management can be defined as comprised of a set of activities in a "farm-to-fork" sequence including farming (i.e., land cultivation, production and harvesting), processing, packaging, warehousing, transporting, distributing and marketing. Those activities then integrated into a dynamic network

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Table 1: Export and production of papaya in Indonesia

Years	Export Weight (kg)	Export Value (USD)	Production (tonnes)
2009	143,180	125,549	772,844
2010	110,841	102,951	675,801
2011	468,245	514,670	958,251
2012	25,328	29,490	906,312
2013	25,836	33,732	871,275

Indonesian Ministry of Agriculture (2015)

of producers/farmers, cooperatives, intermediaries, manufacturers/processors, research institutions/ university, industries, transporters, traders (exporters/ importers), wholesalers, retailers and consumers (Soto *et al*., 2015; Tsolakis *et al*., 2014). However, developing more integrated fruit supply chain is greatly influenced by uncertainty which can potentially turn out into unexpected disruptions (Astuti *et al*., 2013). Many researchers believe that uncertainty can trigger the risk occurrence (Hadiguna, 2012; Tang, 2006; Tang and Nurmaya, 2011). According to Tang and Musa (Tang and Nurmaya, 2011), risk is interpreted as unreliable and uncertain resources creating supply chain interruption, whereas uncertainty can be explained as matching risk between supply and demand in supply chain processes.

The sources of uncertainty in the agricultural sector can be found in upstream operations where the management of agricultural production has to deal with weather conditions, interregional disparities in climate, quality of soil, seasonal factors over time, capital availability; meanwhile the agricultural market is particularly volatile, heterogeneous and extremely sensitive to economic and financial fluctuations in the downstream operations (Borodin *et al*., 2016). In addition, fruit supply chain often described by some special characteristics such as the products are perishable, various in sizes and shapes and bulky. This supply chain also holds various partnership arrangements from informal up to very formal arrangements. Those characteristics led to complex fruit supply chain and make it harder to manage than other supply chains. Hence, to give decision makers more comprehensive view of potential problems occurred along fruit supply chain, the identification of the risks is important so that supply chain risk management strategy can be well defined to minimize the expense of disruptions risk (Astuti *et al*., 2013). The risks in the supply chain can be mitigated well if the supply chain members can prioritize the risk to be mitigated. This study was proposed to identify and analyze various risks in the papaya supply chain. The assessment of the risks then carried out to prioritize the risks in order to deciding the mitigation appropriately.

Risk assessment in supply chain: In defining the concept of Supply Chain Risk Management (SCRM), this research adopt the definition provided by Ho *et al*. (2015) based on their study from 224 reviewed journal articles in the area of SCRM. They define SCRM as "an inter-organizational collaborative endeavor utilizing quantitative and qualitative risk management methodologies to identify, evaluate, mitigate and monitor unexpected macro and micro level events or conditions which might adversely impact any part of a supply chain". The objectives of SCRM are to control, monitor and evaluate supply chain risk for optimizing actions in order to prevent disruptions or to recover quickly from them. Moreover, risk management of a supply chain has a great influence on the stability of dynamic cooperation among supply chain partners and thus very important for the performance of the supply chain operations altogether (Khan and Burnes, 2007). The process of SCRM commonly include risk identification, risk assessment and prioritizing, risk management actions and risk monitoring (Giannakis and Papadopoulos, 2016; Hallikas *et al*., 2004).

Understanding and prioritizing the risks are a starting point to make good management choices in managing the risks inherent in all members of the chain. By identifying the source of risks, the decision makers also become aware about events or phenomena that cause the uncertainty (Astuti *et al*., 2013). However, risk assessment is not an easy task and requires fidelity and accuracy of the entire supply chain (Hadiguna, 2012). For this purpose, FMEA is a very powerful and effective analytical tool which is widely used to assess the relative importance of the risks, to identify their potential causes and effects and test potential correlations between the identified risks (Giannakis and Papadopoulos, 2016). FMEA initially conducted from studies in the aerospace industry on the-mid 1960s which specifically focused on safety issues such as enhancing safety, preventing defects and increasing customer satisfaction (McDermott *et al*., 2009). However, on its development, FMEA has been widely used in the risk assessment in various industries (Liu *et al*., 2013). In the FMEA process, all potential failures are evaluated in terms of three risk dimensions: likelihood, severity and detectability. A Risk Priority Number (RPN) then calculated for each potential failure and a higher RPN score implies greater risks (Curkovic *et al*., 2013).

A lot of studies have been conducted in terms of the implementation of FMEA on the supply chain risks assessment (Bradley, 2014; Chaudhuri *et al*., 2013; Chen and Wu, 2013; Curkovic *et al*., 2013; Giannakis and Papadopoulos, 2016; Liu and Zhou, 2011; Sinha *et al*., 2004) but few studies have been implemented FMEA on the agro-supply chain especially in fruit commodities (Anin *et al*., 2015; Raab *et al*., 2013). Raab *et al*. (2013) developed a proposal for the categorization of risks and systematization of preventive failure identification and evaluation in order to implementation of a proactive risk management system in global value-added chains for fruit and vegetables. In their research, FMEA was utilized to identify product-specific risk categories, to conduct risk assessment (based on supplier countries, companies and process steps) and to rank potential hazards using the risk priority number then the mitigation strategies were tested. Similarly, Anin *et al.* (2015) evaluated the overall pineapples supply chain network in Ghana using Pareto model analytical with FMEA. This approach is applied to identify the risks inherent along its supply chain, analyze the risks and then classifying them according to their impact level on the operational activities. Mitigation strategies then develop to deal with the risks. They found that lack of good planting materials, availability of skilled labors, electricity fluctuation, ineffective pre-cooling and cold chain facilities were the major risks faced by most pineapple supply chain in Ghana. However, every fruits supply chain includes different risks and risk factors. Therefore, risk identification and analysis of papaya supply chain should also to be carried out.

In terms of shortcomings of FMEA, Liu *et al.* (2013) had reviewed 75 articles on the alternative methodologies for risk evaluation in FMEA published from 1992-2012. They encapsulated many risk priority models that proposed for prioritization of failure modes aiming at accurate and robust risk evaluation due to the disadvantages of the traditional FMEA and the uncertainty of the risk factors. One of the shortcomings that received significant attention from the literature was not considering the relative importance among three risk dimensions. The three risk factors had been assumed to have the same importance. Moreover, different combinations of three risk dimensions may also produce exactly the same value of RPN for two risk components, e.g., 100 (RPN1 = 10(S)×5(O)×2(D), RPN2 = 10×2×5) which may lead to a conclusion that the priority for the corrective action applied to the two risk components is equal (Xiao *et al.*, 2011). Nevertheless, the risk implications of the two events may be very distinct due to the different severities of the failure consequence. These examples show that FMEA is not robust enough in priority ranking of failure modes. Therefore, the essential role in the critical analysis is the proper assessment of risk factor weights because it may affect the rankings of the failure modes.

In order to improve the meaningful evaluation of RPN, some authors proposed alternative methods to combine the traditional FMEA Method with Multi-Criteria Decision Making (MCDM) techniques. Chang *et al.* (2001) applied the grey theory to the FMEA to enhance product reliability and process stability during the stages of the product design and process planning. Braglia *et al.* (2003) presented fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach for prioritizing failures in failure mode, effects and criticality analysis (FMECA). Seyed-Hosseini *et al.* (2006) proposed an alternative multi-attribute decision-making approach called Decision Making Trial and Evaluation Laboratory (DEMATEL) method for reprioritization of failure modes in a system FMEA for corrective actions. Liu *et al.* (2012) used extended VIKOR method under the fuzzy environment for providing risk prioritization in FMEA method. An Analytic Hierarchy Process (AHP) combined with FMEA was applied in several cases by (Braglia, 2000; Chen and Wu, 2013; Davidson and Labib, 2003; Zhong and Lin, 2013). In a further development, due to the limitation of capturing the sound judgment in the MCDM techniques, few authors proposed advanced models by integrating with fuzzy concepts such as fuzzy AHP-FMEA (Hu *et al.*, 2009; Ilangkumaran *et al.*, 2014), fuzzy TOPSIS-FMEA (Zhang and Zhang, 2015) and fuzzy DEMATEL-FMEA (Liu *et al.*, 2015). However, there are limited publications in the literature about those concept that applied for supply chain risk assessment using fuzzy ANP with FMEA. This study proposed that method.

MATERIALS AND METHODS

Research framework: The proposed methodology consists of sequential phases for assessing the risks in papaya supply chain based on the processes for SCRM framework. The first phase will likely emphasizes on the identification of supply chain risks. Risk identification is the first and fundamental phase of the risk management practice to recognize the future uncertainties to be able to manage proactively. This phase helps to develop a common understanding of the potential problems occurred along the supply chain. Hence, risk sources should be identified according to all members of the supply chain (Astuti *et al.*, 2013). In this study, to integrate the risk assessment for the identification, the fuzzy ANP was proposed to identify and determine the relative importance of each risk factor and sub-factors of papaya supply chain.

The second phase encompasses the assessment of risks using FMEA. All the identified risks from the first step are assessed in terms of their likelihood of occurrence and the consequences that they may have on

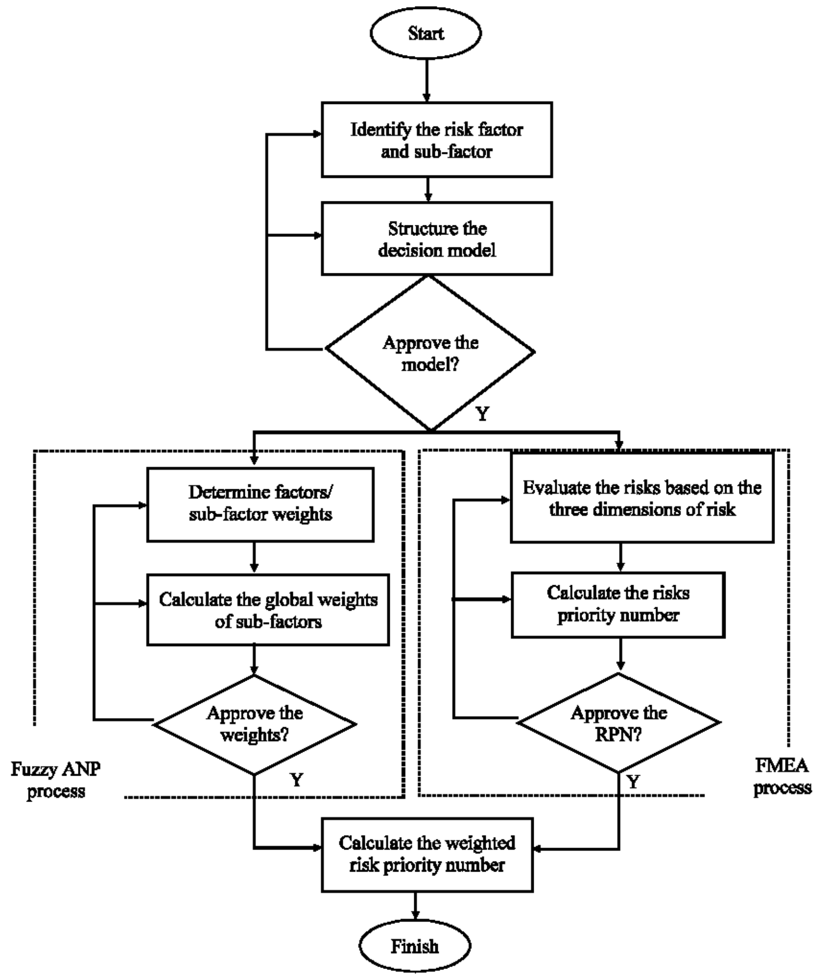

Fig. 1: Schematic diagram of the proposed model for papaya supply chain risk assessment

supply chain performance. Following the assessment of risks, FMEA proceeds with a calculation of RPN based on the three dimensions of risk. Furthermore, the third phase computes RPN with the weight of risk factors obtained from the fuzzy ANP which provides a weighted RPN. The multiplication of these components enables the prioritization of risk factors to determine the suitable management actions according to the situation of the supply chain. The research framework is shown in Fig. 1.

Data collection: The data were collected based on an in-depth interview with experts who represent members of the chain or those who have expertise in papayas business. In this study, 6 experts were selected from farmers group of Calina papaya, represents supply chain manager of wholesaler and retail in Bogor, researcher from Center for Tropical Fruit Studies and academician from university. The questionnaire consisted of two sections: first are referring to supply chain risks and second are referring to risk assessment. The ANP survey aimed to evaluating the comparability of the perceived criteria for supply chain risk factors. Risks assessment then measured according to the supply chain risks using FMEA.

Fuzzy analytic network process: ANP which firstly introduced by Saaty in 1996, is a generalization of the AHP (Saaty, 2008). Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy of lower-level elements. AHP models assume a simple hierarchical relationship among decision levels. On the other hand, ANP methods allows for more complex interactive dependence within the clusters (inner dependence) and between the clusters (outer dependence) through the development of a supermatrix (Chang *et al*., 2015; Dagdeviren *et al*., 2008). In the same way with AHP, ANP uses the fundamental comparison scale (1-9) to assess the preferences of decision makers,

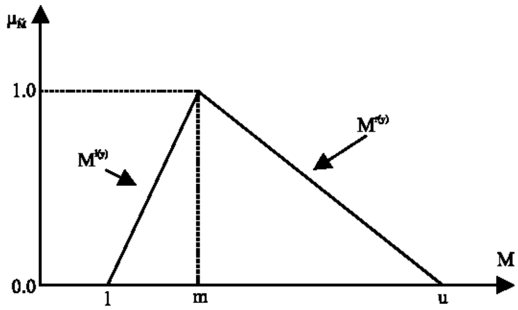

Fig. 2: A triangular fuzzy number

except in the case of fuzzy representation, the Triangular Fuzzy Numbers (TFN) are used (Mahanti and Kaur, 2008). The Fuzzy Set Theory (FST) was introduced by Zadeh (1965) to deal with the uncertainty in the process of human judgment due to imprecision and vagueness. Decision makers usually quantify uncertain events and objects using vague language, like 'equally', 'moderately', 'strongly', 'very strongly', 'absolutely' and a 'significant degree'. FST enables them to solve the ambiguities problem involved in the process of the linguistic assessment of the data (Onut *et al*., 2011). In this study, it is proposed to incorporate the concepts of FST with the ANP Method. Fuzzy ANP has been recognized as a well-accepted technique to adequately handle the limitation of conventional ANP in the decision-making process (Buyukozkan *et al*., 2004; Dagdeviren *et al*., 2008; Shafiee, 2015; Valipour *et al*., 2015).

The fuzzy sets then defined by the membership functions which will assign each object a grade of membership ranging between 0 and 1 (Dagdeviren *et al*., 2008). A triangular fuzzy number ($\tilde{M}$), as shown in Fig. 2, is defined as (l, m, u), where $l \le m \le u$. The parameters l represents the smallest possible value, the parameter m represents most promising value and the parameter u represents largest possible value that describes a fuzzy event. The TFN membership function can be defined as follows:

$$\mu\left(x|\tilde{M}\right) = \begin{cases} 0 & x < 1 \\ (x-1)/(m-1) & 1 \le x \le m \\ (\mu - x)/(\mu - m) & m \le x \le \mu \\ 0 & x > \mu \end{cases} \quad (1)$$

A fuzzy number can always be given by its corresponding left and right for each degree of membership:

$$\tilde{M} = \left(M^{l(y)}, M^{r(y)}\right) = \begin{pmatrix} 1 + (m-)y, & u + \\ (m-u)y & \end{pmatrix} \quad (2)$$
$$y \in [0, 1]$$

Table 2: Linguistic Scale for the Level of Importance

Linguistic scale for important reciprocal scale	Triangular fuzzy	Triangular fuzzy scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Where l(y) and r(y) represent the left side and the right side of a fuzzy number, respectively. The detailed definitions and discussion of the arithmetic operations on triangular fuzzy numbers can be found in Kahraman *et al*. (Kahraman *et al*., 2002). Furthermore, on designing the scale of relative importance to construct the pairwise comparison/evaluation matrix, the TFN are used to improve the classical nine-point scaling design. The fuzzy linguistic scale regarding relative importance to measure the relative weights (Kahraman *et al*., 2006) is given in Fig. 3 and Table 2.

In the present work, it is proposed to utilize the fuzzy ANP method that will determines the importance weights of listed risks of papaya supply chain. The important elements of the integrated of ANP and fuzzy set theory are as follows:

- Identifying the factors and sub-factors of papaya supply chain risk that will be used in the model.
- Structuring the ANP model (goal, risk factors, risk sub-factors)

Determining the local weights of the risk factors and sub-factors by using pairwise comparison matrices (assumption: no dependence among the factors). In this step, it is needed to aggregate fuzzy numbers into crisp values using Chang's Extent Analysis method. Compared with the other approaches, this method is easier and has been widely accepted to calculate fuzzy aggregate importance weights for the fuzzy input pairwise evaluation matrix (Mangla *et al*., 2014). The details of Chang's extent analysis method calculation (Chang, 1996) are: if extent analysis values for the ith object are represented by, M^1_{gi}, M^2_{gi} , M^3_{gi} ... where (i = 1, 2, 3, ..., n) and all the M^j_{gi} (j = 1, 2, 3, …, m) are TFNs, then corresponding fuzzy synthetic extent shall be represented as:

$$S_i = \sum_{j=1}^{m} M^i_{gi} \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}^i_{gi} \right]^{-1} \quad (3)$$

The fuzzy addition operation of m extent analysis values to a particular matrix then performed to obtain $\sum_{j=1}^{m} \tilde{M}^i_{gi}$.

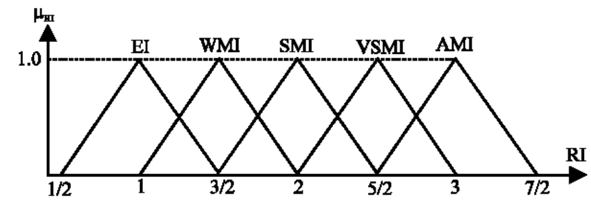

Fig. 3: Linguistic scale of Relative Importance (RI)

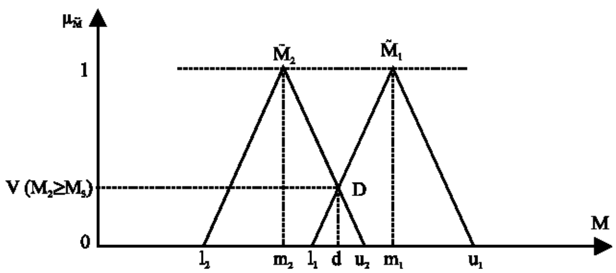

Fig. 4: Representation of intersection between M1 and M2

$$\sum_{j=1}^{m} \tilde{M}_{gi}^{i} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} \mu_j \right) \quad (4)$$

and the fuzzy addition operation of M_{gi}^{j} j = 1, 2, 3, …, m) values are performed to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{i}\right]^{-1}$:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{i} = \left(\sum_{i=1}^{n} li, \sum_{i=1}^{n} mi, \sum_{i=1}^{n} \mu i \right) \quad (5)$$

and then compute the inverse of the vector in Eq. 5:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{i}\right]^{-1} = \left(\frac{1}{\sum_{i}^{n} ui}, \frac{1}{\sum_{i}^{n} mi}, \frac{1}{\sum_{i}^{n} li} \right) \quad (6)$$

Next, by considering the minimum and maximum values for fuzzy number, the degree of possibility for two fuzzy numbers $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is represented as:

$$v(M_2 \geq M_1) = \sup\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \text{where} \quad x, y \in R \text{ and } x \geq Y \text{where } X, y, R \text{ and } X, Y \quad (7)$$

Noted that, if x, Y and $uM_2(x) = uM_2(y) = 1$ then $V(M_2 \geq M_1$. Since, M_2 and M_1 are two convex fuzzy numbers, it satisfies the properties mentioned as:

$$v(M_2 \geq M_1) = 1 \text{ if } m_2 \geq m_1 \quad (8)$$

$$v(M_2 \geq M_1) = 1 \text{ if } l_2 \geq u_2 \quad (9)$$

$$v(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu M_2(d) \quad (10)$$

where, d represent the highest intersection point D between μM_2 and μM_2 (Fig. 4) and further, D is given as:

$$v(M_2 \geq M_1) = hgt(M_1 \cap M_2) = (l_1 - u_2) - (m_2 - u_2) - (m_1 - u_1) \quad (11)$$

We need both the values of $V(M_1 \geq M_2)$ and $V(M_1 \geq M_2)$ to compare M_1 and M_2. Next, the possibility degree for 'k' convex fuzzy numbers $M_l(l = 1, 2, 3, ..., m)$ is calculated as:

$$v(M \geq M_1, M_2, ..., M_k) = v\begin{bmatrix}(M \geq M_1) \text{and} (M \geq M_2) \\ \text{and...and}(M \geq M_k)\end{bmatrix} = \min v(M \geq M_1),\ i = 1, 2, ..., K \quad (12)$$

By assuming that $d(A_i) = \min V(S_i \geq S_2)$ for k = 1, 2, …, n; k≠i, the weight vector is given by:

$$W = \left(d(A_1), d(A_2), ..., d(A_n)\right)^T \quad (13)$$

where, $A_i(1, 2, 3, ..., n)$ are n elements. After normalizing, the normalized fuzzy weight vectors are given as:

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

while 'W' is a non-fuzzy number. By using fuzzy scale (Table 2), then determine the inner dependence matrix of each risk factor to another risk factors. This inner dependence matrix then multiplied by the local weight of the factors which are determined in step 3, to compute the interdependent weight of the factors.

Calculating risk sub-factor's global weight. Global sub-factor of risks weights then computed by multiplying the local weight of the sub-factors with the interdependent weights of the factors to which it belongs.

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

- Severity (S): the consequences of the failure
- Occurrence (O): the probability or frequency of the failure occurring
- Detection (D): the probability of the failure being found before effects is happen

By using data and knowledge of the process or product in papaya business, this study then rated each potential failure mode and effect by abovementioned dimensions on a scale from 1-10 (with 1 being the best and 10 being the worst case). A Risk Priority Number (RPN) then determined for each potential failure mode and effect by multiplying the ranking of the dimensions:

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

In order to overcome the limitation of traditional RPN, the weighted RPN (WRPN) values are determined by using fuzzy ANP multiplied by RPN values (Eq. 16). Next, the WRPN values will be used to sort the failure modes:

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

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

RESULTS AND DISCUSSION

Risk identification: The initial and most critical step of the SCRM process is the identification of potential risks. The risks in the papaya supply chain have been identified in stages of literature review and expert interviews and then validated with the actual situation of papaya supply chain. This step involves identification of risks and factors in the papaya supply chain. The type of risks in this study includes risks in the external environment, risks within the supply chain and internal risks (Lin and Zhou, 2011). The risks faced by farmers and other supply chain members are described in Table 3 and can be organized into six factors, namely: market risks (arise from the volatility of papaya prices, uncertainties of input and demand and market competition); quality risks (result of improper handling activities ranging from providing good-quality seeds and farm inputs, cultivating and postharvest activities); social and environment risks (unpredictable changes in weather, government policy/regulations and social, culture and politic); supply risks (inability to supply uniform quality of products, loyalty in supplier-buyer relationship and continuity in supply number); production risks (low production of papaya due to the poor agricultural practices, i.e., pests and diseases management, inappropriate application of procedures in planting and lack of technology and human risks); transportation risks (comes from poor infrastructures, fail to select appropriate transportation and improper packaging as well as storage handling during shipment). Furthermore, the ANP Model of potential risks is composed of three levels as shown in Fig. 5.

The first level of the model aims to determining sub-factors weights of papaya supply chain risks. The second and third level factors and sub-factors are also related to goal in first level. The factors 1 the second level are connected to the first level's goal by a single directional arrow. While another arrows in the second level represent the inner-dependence among the factors. The inner-dependence among market, quality, environmental, supply, production and transportation, which are at this level are taken into account and by this, the effects of the factors on each other are analyzed. Sub-factors related to the factors are in the third level of the model.

Risk assessment: After identifying the risk and structuring the ANP Model, the importance degrees of each factors and sub-factors in the second and third levels of ANP Model were determined. Their local weight then determined by doing a pairwise comparison matrices which performed by the expert using the scale given in Table 2. For example, the expert was asked: "with respect to the goal, how important is market compared to quality?" and the answer is "weakly more important". Thus, the linguistic scale was placed in the relevant cell against the TFN (1, 3/2, 2). Similar questions were also asked to formulate all the fuzzy evaluation matrices. The importance weights for factors then calculated using Chang's Extent Analysis method using Eq. 3-15. The associated M_i values can be computed through Eq. 3-6, for example:

$$\begin{aligned} S_1 &= (6.500, 9.000, 11.500) \times \\ &\left(\frac{1}{28.0333}, \frac{1}{28.6667}, \frac{1}{54.0000}\right) \\ &= (0.1204, 0.2328, 0.4102) \end{aligned} \quad (17)$$

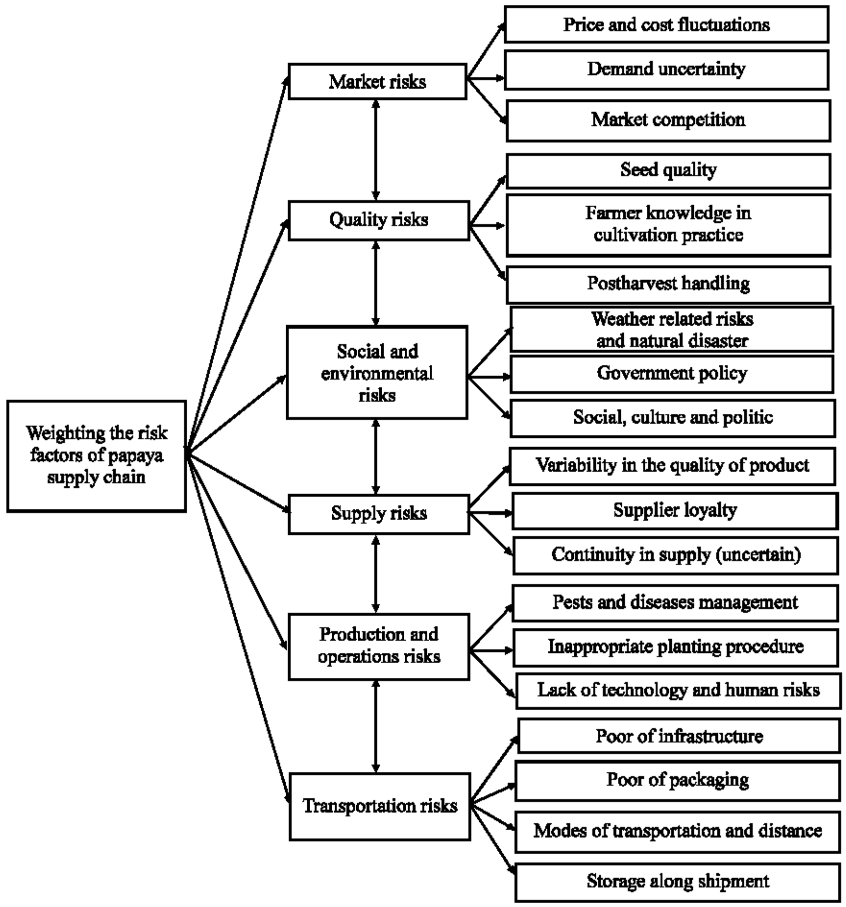

Fig. 5: The ANP Model to identify the risk of papaya supply chain

$$S_2 = (3.6667, 5.000, 7.500) \times \left(\frac{1}{28.0333}, \frac{1}{28.6667}, \frac{1}{54.0000}\right) = (0.0679, 0.1293, 0.2675) \quad (18)$$

$$S_3 = (3.6667, 5.000, 7.500) \times \left(\frac{1}{28.0333}, \frac{1}{28.6667}, \frac{1}{54.0000}\right) = (0.0660, 0.1250, 0.2556) \quad (19)$$

$$S_4 = (5.6667, 8.000, 11.000) \times \left(\frac{1}{28.0333}, \frac{1}{28.6667}, \frac{1}{54.0000}\right) = (0.1049, 0.2069, 0.3924) \quad (20)$$

$$S_6 = (3.4667, 4.6667, 6.8333) \times \left(\frac{1}{28.0333}, \frac{1}{28.6667}, \frac{1}{54.0000}\right) = (0.0642, 0.1207, 0.2438) \quad (21)$$

By using the Eq. 7-12, the degree of possibility for two fuzzy numbers is given as:

$$\begin{aligned} v(S_1 \geq S_2) &= 1.0000 \\ v(S_1 \geq S_3) &= 1.0000 \\ v(S_1 \geq S_4) &= 1.0000 \\ v(S_1 \geq S_5) &= 1.0000 \\ v(S_1 \geq S_6) &= 1.0000 \end{aligned} \quad (22)$$

$$v(S_2 \geq S_1) = \frac{(0.1204 - 0.2675)}{(0.1293 - 0.2675) - (0.2328 - 0.1204)} = 0.5872 \quad (23)$$

$$v(S_2 \geq S_3) = 1.0000 \quad (24)$$

$$v(S_2 \geq S_4) = \frac{(0.1049 - 0.2675)}{(0.1293 - 0.2675) - (0.2069 - 0.1049)} = 0.6770 \quad (25)$$

Table 3: Category of the risk factors and sub-factors

Risk factors	Sub-factors	Sources (references)
Market risk	Price and cost fluctuations	Product price fluctuations are caused by over supply or lack of demand and factors related to changes in currency value, changes in interest rates, inflation, etc. (Akcaoz, 2012)
	Demand uncertainty	Variability and distortion information in demand are cause difficulties for retailers to provide long term forecasts of consumer demand (Anin *et al*., 2015)
	Market competition	Competition with other fruits in availability, price and quality of products (expert's opinion)
Quality risk	Seed quality	Papaya quality is affected by availability of affordable inputs and quality of seeds (expert's opinion)
	Farmer knowledge in cultivation	Variation of personal skill and lack of knowledge of farmer (Astuti *et al*., 2013)
	Harvesting and postharvest 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 papaya fruit (Sivakumar and Wall, 2013)
Social and environment risk	Weather and natural disaster related risk (climate change)	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 growing season and/or production cycle
	Government policy	Government policy and institutional risks have major direct and indirect impacts on shaping incentives and decision-making in agricultural supply chains (Astuti *et al*., 2013)
	Social, culture and politic	Changing consumer attitudes, changes in foreign trade relation, level of corruption, farmer welfare and health, security-related risks, etc. (expert's opinion)
Supply risk	Variability in quality of product	Branding of fruit is widely considered to be difficult because of the variability in quality of the product and irregularity of supply (Richards, 2000)
	Supplier loyalty	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)
	Supply uncertainty	Shortage of shipment capacity, shortage of products in distribution center, lead time uncertainties and delay in delivery (Pujawan and Geraldin, 2009)
Production and operation risk	Pests and diseases	Pests and diseases have been shown to be very important factors in reducing yield and marketability of papaya (expert's opinion)
	Inappropriate planting procedure	Inappropriate procedure of planting causes flower of papaya had not been pollinated and therefore failed to develop into a fruit (expert's opinion)
	Technology and human risk	Lack of technology and innovation, rural exodus and lack of training programs of farmer (expert's opinion)
Transportat-ion risk	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 (Anin *et al*. 2015)
	Packaging	Since papayas are highly sensitive to mechanical damage, proper packaging are needed to reduce damage, improve marketability and prolong shelf-life of papaya fruits
	Modes of transportation and distance	The improper of transportation modes and long distance shipping could lead to decrease quality, increase transportation cost and problems along supply chain (expert's opinion)
	Storage during shipment	Due to the climacteric fruit characteristics, non-optimal temperature of storage will causes papaya can be ripened to the undesired level (Paull *et al*., 1997)

$$v(S_2 \geq S_5) = \frac{(0.0957-0.2675)}{(0.1293-0.2675)-(0.1853-0.0957)} = 0.7541 \quad (26)$$

$$\begin{aligned} v(S_2 \geq S_6) &= 1.0000 \\ v(S_3 \geq S_1) &= 0.5566 \\ v(S_3 \geq S_2) &= 0.9776 \\ v(S_3 \geq S_4) &= 0.6479 \\ v(S_3 \geq S_5) &= 1.0000 \\ v(S_3 \geq S_6) &= 1.0000 \end{aligned} \quad (27)$$

$$\begin{aligned} v(S_4 \geq S_1) &= 0.9132 \\ v(S_4 \geq S_2) &= 1.0000 \\ v(S_4 \geq S_5) &= 1.0000 \\ v(S_4 \geq S_6) &= 1.0000 \end{aligned} \quad (28)$$

$$\begin{aligned} v(S_5 \geq S_1) &= 0.8329 \\ v(S_5 \geq S_2) &= 1.0000 \\ v(S_5 \geq S_3) &= 1.0000 \\ v(S_5 \geq S_4) &= 0.9212 \\ v(S_5 \geq S_6) &= 1.0000 \end{aligned} \quad (29)$$

$$\begin{aligned} v(S_6 \geq S_1) &= 0.5240 \\ v(S_6 \geq S_2) &= 0.9533 \\ v(S_6 \geq S_3) &= 0.9763 \\ v(S_6 \geq S_4) &= 0.6169 \\ v(S_6 \geq S_5) &= 0.6961 \end{aligned} \quad (30)$$

$$d'(A_1) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\left.\right) = \min(1,1,1,1,1) = 1 \quad (31)$$

$$d'(A_2) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\left.\right) = \min(0.5872, 1, 0.6770, 0.7541, 1) = 0.5872 \quad (32)$$

Table 4: Local weights and pairwise comparison matrix of main factors

Factors	Market	Quality	Social and environment	Supply	Production	Transpor-tation	Local weights
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
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
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
Supply	(2/3, 1, 2)	(1, 3/2, 2)	(1, 3/2, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	0.2069
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
Transporta-tion	(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

Table 5: Weight of factors and sub-factors based on expert assessment

Factors	Weights of factor	Sub-factors	Weights of sub-factors	Global weights
Market	0.1965	Price and cost fluctuations	0.0970	0.0191
		Demand uncertainty	0.5584	0.1097
		Market competition	0.3446	0.0677
Quality	0.1676	Seed quality	0.3333	0.0559
		Farmer knowledge in cultivation	0.3333	0.0559
		Postharvest handling	0.3333	0.0559
Social and environment	0.1280	Weather related risks and natural disruptions	0.4572	0.0585
		Government policy	0.0857	0.0110
		Social, culture and politic	0.4572	0.0585
Supply	0.2080	Variability of product wuality	0.0970	0.0202
		Supplier loyalty	0.5584	0.1161
		Continuity of supply	0.3446	0.0717
Production	0.1779	Pests and diseases	0.2266	0.0403
		Inappropriate planting procedure	0.1330	0.0237
		Lack of technology	0.1261	0.0224
Transportation	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

$$d`(A_3) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\right) = \min \left(0.5566, 0.9776, 0.6479, 1, 1\right) = 0.5566 \tag{33}$$

$$d`(A_4) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\right) = \min \left(0.9132, 1, 1, 1, 1\right) = 0.9132 \tag{34}$$

$$d`(A_5) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\right) = \min \left(0.8329, 1, 1, 0.9212, 1\right) = 0.8329 \tag{35}$$

$$d`(A_6) = \min\left(V\left(S_1 \geq\right]\right)S_2, S_3, S_4, S_5, S_6\right) = \min \left(0.5240, 0.9533, 0.9763, 0.6169, 0.6169\right) = 0.5240 \tag{36}$$

These calculated minimum weight vectors were further operated to obtain the normalized value and weight vector by using Eq. 14. As a result, the weight vectors for the risk factors (i.e., 0.2266, 0.1330, 0.1261, 0.2069, 0.1887 and 0.1187) were established (Table 4). In the same way, the importance weights for sub factors have been computed. All calculated importance weights of the factors and sub-factors are given in Table 5.

In the following step, interdependent weights of the factors were calculated by considering the dependencies among the factors. Pairwise comparisons were used for analyzing the impact of each factor to another in order to determine the dependencies among the factors. Hence,

Table 6: The Interdependent weights of the factors

Factors	Respect to	Local weights
Quality	Market	0.2833
Social and environment		0.0894
Supply		0.3163
Production		0.1993
Transportation		0.1116
Market	Quality	0.2701
Social and environment		0.1046
Supply		0.2876
Production		0.2015
Transportation		0.1362
Market	Social and environment	0.1763
Quality		0.2276
Supply		0.2276
Production		0.2276
Transportation		0.1407
Market	Supply	0.2260
Quality		0.2260
Social and environment		0.1577
Production		0.2260
Transportation		0.1642
Market	Production	0.1850
Quality		0.2144
Social and environment		0.2015
Supply		0.2400
Transportation		0.1591
Market	Transportation	0.2233
Quality		0.1856
Social and environment		0.2120
Supply		0.2128
Production		0.1664

the following question was asked to the expert "What is the relative importance of 'quality' when compared to 'social and environment' with respect to market risk?" and the answer "Strongly more important" was replaced to the TFN (3/2, 2, 5/2) as denoted in Table 6.

The dependence matrix of the factors then formed by using the computed relative importance weights from previous steps. Next, by multiplying that matrix with the local weights of the factors provided in Table 4, the interdependent weights of each factors can be determined. The interdependent weight of factors are calculated as follows:

$$\begin{bmatrix} 1.0000 & 0.2701 & 0.1763 & 0.2260 & 0.1850 & 0.2233 \\ 0.2833 & 1.0000 & 0.2276 & 0.2260 & 0.2144 & 0.1856 \\ 0.0894 & 0.1046 & 1.0000 & 0.1577 & 0.2015 & 0.2120 \\ 0.3163 & 0.2876 & 0.2276 & 1.0000 & 0.2400 & 0.2128 \\ 0.1993 & 0.2015 & 0.2276 & 0.2260 & 1.0000 & 0.1664 \\ 0.1116 & 0.1362 & 0.1407 & 0.1642 & 0.1591 & 1.0000 \end{bmatrix} \begin{bmatrix} 0.2266 \\ 0.1330 \\ 0.1261 \\ 0.2069 \\ 0.1887 \\ 0.1187 \end{bmatrix} = \begin{bmatrix} 0.1965 \\ 0.1676 \\ 0.1280 \\ 0.2080 \\ 0.1779 \\ 0.1219 \end{bmatrix} \quad (37)$$

The results of the interdependent weight of the factors demonstrate the significant differences if compared to the factor weights without respecting other factors (Table 4). The weight change from 0.2266-0.1965, 0.1330-0.1676, 0.1261-0.1280, 0.2069-0.2080, 0.1887 to 0.1779 and 0.1187-0.1219, for the weight of market, quality, social and environmental, supply, production and transportation factor, respectively. The global weight for the sub-factors, by using interdependent weight of factors and local weight of the sub-factors will also determine in this calculations. The global weight for the sub-factors then calculated by multiplying local weights of the sub-factors with the interdependent weight of their respective risk factor. After verifying calculated weight of factors and sub-factors, the ranking of the identified risks in this study then determined by considering the RPN results from the FMEA process.

The RPN value is the product combined-values of severity, occurrence and detection dimensions. For the risk related to "farmer knowledge in cultivation practice", the severity was 8, the occurrence was 8, the detection was 7, so the RPN value is $8\times8\times7 = 448$. According to the column ''weight of Sub-factors'', the weighted RPN (Ri) then calculated by multiplied the RPN values to weight of sub-factors. For example, the Ri of "farmer knowledge in cultivation practice" is $448\times0.0559 = 25.0258$. The overall results of each Ri are shown in Table 7.

For all sub-factors, a higher weighted RPN means that the higher priority of the risk to be mitigated. Pareto Principle was used to determine the focus of the risk mitigation with the idea that by mitigating 20% of the risk then we can generate 80% of the benefit of mitigating the entire risks. According to the cumulative weighted RPN of ordered rank of risks, Ri values of farmer knowledge in cultivation practice is 22%. It means that the mitigation should be focused on increasing farmer knowledge in cultivation practice, thus all the the benefit of mitigating the entire risks can be obtained.

Technical/vocational education and training was one of the alternatives to mitigate the risk priority. If farmers had a better knowledge in cultivation practice, then they will also follow the proper procedure in planting, able to handle pests and diseases of papaya plants and able to control the seed quality. Thus will reduce the variability of papaya quality. Expanding knowledge and technology

Table 7: The global weights, RPN and weighted RPN

Risk factors and sub-factors					Risk assessment					
Factors	Weights of factor	Sub-factors	Weights of sub-factors	Global weights	S	O	D	RPN	Weighted RPN	Rank
Market	0.1965	Price and cost fluctuations	0.0970	0.0191	3	3	3	27	0.5146	18
		Demand uncertainty	0.5584	0.1097	3	3	3	27	2.9626	11
		Market competition	0.3446	0.0677	5	5	5	125	8.4642	6
Quality	0.1676	Seed quality	0.3333	0.0559	8	3	4	96	5.3627	7
		Farmer knowledge in cultivation	0.3333	0.0559	8	8	7	448	25.0258	1
		Postharvest handling	0.3333	0.0559	5	5	8	200	11.1722	4
Social and environment	0.1280	Weather related risks and natural disruptions	0.4572	0.0585	6	2	3	36	2.1068	14
		Government policy	0.0857	0.0110	7	4	3	84	0.9214	17
		Social, culture and politic	0.4572	0.0585	5	4	3	60	3.5113	10
Supply	0.2080	Variability ofproduct quality	0.0970	0.0202	6	8	5	240	4.8422	8
		Supplier loyalty	0.5584	0.1161	5	5	3	75	8.7110	5
		Continuity of supply	0.3446	0.0717	6	6	6	216	15.4822	2
Production	0.1779	Pests and diseases	0.2266	0.0403	7	5	8	280	11.2874	3
		Inappropriate planting procedure	0.1330	0.0237	8	5	5	200	4.7321	9
		Lack of technology	0.1261	0.0224	4	8	3	96	2.1536	13
Transportation	0.1219	Poor of infrastructure	0.2266	0.0276	5	5	3	75	2.0717	15
		Packaging	0.1330	0.0162	6	5	3	90	1.4591	16
		Modes of transportation and distance	0.1261	0.0154	4	2	3	24	0.3689	19
		Storage during shipment	0.1187	0.0145	6	5	6	180	2.6045	12

plays an important role in increasing agricultural production as well as detect significant risks to future productivity posed by climate change. The extensive papaya production will likely guarantee the continuity of supply. Another efforts to increasing agricultural production need to be taken in the future are encourage greater private-sector institution's involvement and also strengthen the coordination between producers and management extension specialists. That coordination will incorporating business knowledge and skills to develop the farmer's skill in handling postharvest product and making competitive advantage. The technical and vocational training can also be complemented with life skills (e.g., social and law awareness) to increase the farmer's awareness of being a loyal suppliers.

CONCLUSION

The development of the papaya supply chain, like other agricultural products in Indonesia is heavily affected by uncertain potential risks for the chain. In this study, an effort has been made to develop a structural model to identify and prioritize the risks. By identifying the six factors and 19 sub-factors using FMEA and determining the relative weights using FANP, the proposed framework was exercised in this study. This study has the following key points. First, this model shows its potential advantage in detecting high risk of papaya supply chain systematically and effectively. Second, incorporating the FMEA and FANP methodology to assess the risk of papaya supply chain can hardly be found in other studies. The methodology of fuzzy ANP is crucial in deciding the importance weight of the factors of risk and the FMEA can be utilized to assess the risk factors in terms of three risk dimensions: occurrence, severity and detectability. The weights obtained from the fuzzy ANP method then used as an input in multiplication with the RPN value from FMEA technique in order to determine the weighted RPN. Finally, the risks then ranked according to its weighted RPN value to obtain the priorities of risks that need to be mitigated. The results of this study revealed that farmer knowledge in cultivation practice was the key risk inherent in papaya supply chain, thus require attention. Technical/vocational education and training was one of alternatives to mitigate that risk. The contextual factors that prevent small farmers from accessing and applying training have to be considered to provide the knowledges and skills effectively.

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