The risk assessment analysis of corn chips supply chain using Fuzzy FMEA

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Abstract. *Lembah Hijau* is one of the SMEs which produces corn chips in Lamongan District. This SME cooperates with corn farmers and retailers who joined the supply chain of corn chips. The uncertainty of the maize cropping pattern, the production process that depends on weather conditions, and the demand for fluctuating corn chips are the factors that can trigger a variety of risks. The research objective was to identify and assess the risk of corn chips' supply chain in *Lembah Hijau* and to mitigate the risks. The method used to assess the risk is Fuzzy Failure Mode Effect Analysis (FMEA) by using the questionnaires which were filled by five expert respondents. The raw material, production process and marketing are the variables that will be reviewed. The results showed that by identifying the risk of corn chip supply chain, 14 risks consisting of 3 risks in the raw material variable, 6 risks in the production process variable and 5 risks in the marketing variables were found. Based on the highest *Fuzzy Risk Priority Number* value of raw material variable, the risk found was the fluctuation of corn price. Meanwhile, the risk in the production process variable was the weather conditions that do not support the production process and the risk in the marketing variable was the return of corn chips product.

1. Introduction

Lamongan Regency is known for its vast agricultural sites. This is supported by the population majority who work in the agricultural sector. One of the leading agricultural commodities in Lamongan Regency is corn. According to Ferrianta and Rifiana [1], corn is the third largest staple crop after rice and wheat, and it is estimated that in 2050 the demand for corn will increase so that the amount of production becomes the largest in the world, especially in developing countries. Based on the data of Horticulture and Plantation Food Department of Lamongan Regency (2016), corn productivity reaches 6.2 tons/ha. This achievement has increased compared from 2015. This prompted the Lamongan Regency Government to continue developing the corn processing industry. One of the efforts made is to provide support and facilities to Small and Medium Enterprises (SMEs) in Lamongan Regency. According to Wang [2], SMEs is the most dynamic business potential to boost the economy in developing countries because it absorbs nearly 60% of the workforce in manufacturing. Nowadays, economic empowerment continuously becomes carried out by the government through facilitating the Micro SME (MSME) in order to contribute greatly and strengthen people's economy [3]. The effort to develop and strengthen the people's economy is proven by the increase of Gross Domestic Product (GDP) formation in 2011 in which MSME could contribute 57.60% [4]. Success in SMEs development can be supported by several things, in particular a good

organizational structure. Good organization sets important goals which can be achieved with a system of norms, habits, and good the relationship in individual or organization business for natural resource management [5]. According to Anatan [6] a simple supply chain has a component called as channel consists of suppliers, manufacturers, distribution centres, wholesalers, and retailers who work together in meeting consumer needs. According to Rahayu and Lindawati [7], integrated institutions can improve competitiveness and can streamline supply chains. Furthermore, Arwani et al. [8] stated that transparency in the supply chain system also plays an important role in preventing the industry from experiencing the risk falsification. *Lembah Hijau* is one of the SME that produces corn-based products in Kedungpring District, Lamongan Regency. The market leader for corn chips positioning of *Lembah Hijau* with the production capacity 5 quintals per week. The market share for this product have distribution in several modern retailers in national and international such as East Java Province and to Malaysia, Singapore and Timor Leste.

In running the corn chips business, *Lembah Hijau* works with several parties who are members of the supply chain. Supply chain is a business network from upstream to downstream between various parties ranging from suppliers to consumers through the flow of products, services, finance and information. The parties involved in the supply of corn chips include farmers as suppliers of raw materials for corn, *Lembah Hijau* as a producer of corn chips and retailers as suppliers of products to consumers. Every member of the corn chip producers cannot escape the risks that might occur. According to Ennouri [9], risk is the possibility of occurrence of an event whose consequences are not profitable. Risk assessment is an important activity carried out at this time because risks always occur in industrial activities. Risk management plays an important role in supply chain operations effectively in the face of various uncertainties [10]. SMEs do not usually consider supply chain strategies prior to product introduction which resulting the supply chain problems that are likely to harm its growth potential [11].

The problems faced by the corn chips producers are related to raw materials, production processes and marketing. The uncertainty of the maize cropping pattern, the production process that depends on weather conditions, and the demand for fluctuating corn chips which can trigger a variety of risks. Previous study by Mustaniroh et al. [12] has also found that the risk associated with supply chain management include mistakes in planning the production process, in controlling inventory, in marketing or in import. Therefore, the aim to be achieved in this study is to identify and analyse the risk assessment of corn chips and also the alternative strategies to mitigate the risk of supply chain.

2. Research methods

This research was conducted in *Lembah Hijau*, Kedungpring District, Lamongan Regency. The method used for risk measurement in this study is Fuzzy Failure Mode Effect Analysis (Fuzzy FMEA). Fuzzy FMEA is a development of the FMEA method that provides flexibility of uncertainty due to the vague information possessed and subjective preference elements used in assessing the risk of failure [13]. The aim of FMEA is to prevent unacceptable failures and help management in more efficient allocation of resources [14]. Data analysed by the Fuzzy FMEA method were obtained from the results of filling out the questionnaire by expert respondents who were members of the corn chips supply chain. The criteria used in determining expert respondents are those who are experienced in the corn chips supply chain.

The expert respondents were categorised into four sections, including:

1. Raw material, which consists of 3 respondents, namely farmers (1 person), SMEs (1 person) and academics (1 person). The weight of interest for farmers is 40%, SMEs 35%, and academics 25%
2. Production department, which consists of 2 respondents, namely SMEs (1 person) and academics (1 person). The weight of interest for SMEs is 60% and academics are 40%.
3. The marketing department, which consists of 4 respondents, namely retailers (2 people), SMEs (1 person) and academics (1 person). The interests of retailers are 35% and 30%, SMEs 20% and academics 15%.

The data of the supply chain needs are obtained through expert opinion which is a person who has experience in their field. Assessing the importance of interest in experts is calculated based on experience and level of expertise possessed. The overall value is only worth one, if there are two or more experts, the value is averaged to get one value. The weight of interest is determined to make a difference in FMEA's assessment. Expert respondents assumed different interests due to differences in expertise, knowledge and experience in the corn chips chips supply chain. The weight of the expert respondent's interest will later be the basis in calculating Fuzzy FMEA.

Failure Mode and Effect Analysis (FMEA) is a procedure to identify and prevent the failure of a product so that the output of a production can be in accordance with the standards of the company's desires. The aim of FMEA is to find all possible causes of failure: product or process (failure modes). In particular, FMEA evaluates potential failures and possible causes by using a scale of 10 for three different aspects, including: Severity (S), Occurrence (O), and Detection (D). Based on these three aspects, the so-called Risk Priority Number (RPN) for a cause is determined by the following equation:

$$RPN = S \, x \, O \, x \, D \qquad (1)$$

Factor which has higher RPN value must be identified first in order to eliminate or reduce the failure. However, the use of FMEA still has several disadvantages, including often subjective and qualitatively described statements, parameters of severity (S), occurrence (O), detectability (D) assumed to have the same interests, ignoring the relative importance between judgments that might be different in practice and the same RPN assessment, implying different risk representation differences [15]. Fuzzy FMEA is a development of the FMEA method that provides flexibility to accommodate uncertainty due to the vague information possessed as well as subjective preference elements used in the assessment of the modes of failure that occur [16].

Gives ranking based on FRPN values, where the highest FRPN values are at the top rank and adjusts to the scale of the Fuzzy FMEA output variable as can be seen in Table 1.

Table 1. Categories of Fuzzy FMEA output variables

Output Value	Category
0-1.11	*Very Low* (VL)
1.12-2.22	*Very Low-Low* (VL-L)
2.23-3.33	*Low* (L)
3.34-4.44	*Low-Moderate* (L-M)
4.45-5.55	*Moderate* (M)
5.56-6.66	*Moderate-High* (M-H)
6.67-7.77	*High* (H)
7.78-8.88	*High-Very High* (H-VH)
8.89-10	*Very High* (VH)

3. Result and Discussion

3.1. Supply chain of corn chips in Lembah Hijau

Members of the corn chip supply chain in *Lembah Hijau* are farmers, the SMEs, retailers and consumers. The structure of the supply chain of corn chips in *Lembah Hijau* can be seen in Figure 1.

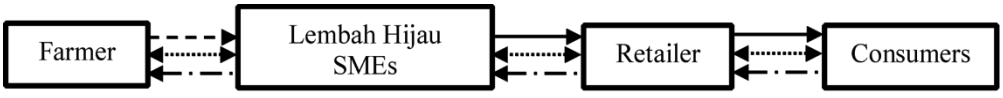

Figure 1. The structure of the supply chain of corn chips in *Lembah Hijau*

Figure 1 shows that there are four types of flow that occur in the supply chain of corn chips in *Lembah Hijau*, including raw material flow, product flow, information flow and financial flow. According to Timisela, Masyhuri, Darwanto and Hartono [17], there are three types of flows that must be managed in the supply chain. Goods flows from upstream to downstream. The flow of money (financial) that flows from downstream to upstream. Information flow that occurs from upstream to downstream and vice versa. Farmers are suppliers of corn raw materials to *Lembah Hijau*. Farmers are the beginning of the supply chain of corn chips. According to Basoand [18], producers will produce products based on production schedules which are then sent to consumers in the right amount and time at the lowest possible cost while maintaining product quality.

Retailers are those who sell corn chips directly to end consumers. According to Chopra and Meindl [19], retailers must have sensitivity to consumer needs. Retailers need to modify their policies and strategies if necessary in order to anticipate the changes in consumer needs. Consumers are the final destination in the corn chips supply chain. According to consumers usually order products with specifications and desired quantities to retailers which are then referred to as consumer demand. All members of the corn chips supply chain are integrated in collaboration to be able to meet consumer demand for corn chips, both in quantity and quality.

3.2. The assessment of risk for corn chips supply chain

3.2.1. Raw material

In the raw material variables, there are three risks that can affect the performance of the corn chips supply. The results of the calculation of FRPN values indicate the order of priority risks that must be immediately addressed in the raw material variables as can be seen in Table 2.

Table 2. FRPN value of raw material risk

Risk	RiS	RiO	RiD	FRPN	Ranking	Category
Corn price fluctuation	6.80	5.80	4.00	4.63	1	*Moderate* (M)
Delay in corn supply	6.57	4.00	5.05	4.20	2	*Moderate* (M)
Corn defects	5.77	3.13	3.6	2.06	3	*Low* (L)

Based on Table 1, the corn price fluctuation is risky and ranked first on raw material variables with aggregate severity value (RiS) 6.8, aggregate occurrence value (RiO) 5.38, aggregate detection value (RiD) 4 and the FRPN value 4.63 in the moderate category. Fluctuations in corn prices almost always occur every year. Fluctuations in corn prices greatly affect the level of farmer income and production costs that must be spent by *Lembah Hijau*. Therefore, fluctuating corn prices are a priority risk to be addressed first. According to Rattray [20], the prices of major agricultural commodities such as corn, wheat and soybeans are very difficult to predict in the long term because they are influenced by several factors. Weather conditions, global population growth, as well as political and international trade factors can influence supply and demand levels. According to Davidek [21], to obtain quality raw material supplies basic commodity standards are needed, but supply quantities need to pay attention to plant productivity.

Corn prices are usually influenced by the corn availability. During the main harvest season, the availability of corn will be abundant, so the selling price of corn tends to be low, which is around IDR. 3.000 to 3.500 per kilogram. When the availability of corn is low, the selling price of corn will increase to IDR. 4.000 per kilo. According to Zubachtirodin et al. [22] Maize cropping patterns are uneven throughout the year, so the possibility of price fluctuations is very high. In September-December, the amount of demand for corn is greater than the amount of production, so the price of corn is high. In January-April, the amount of corn production was higher than the amount of corn needed, resulting in an overproduction that caused the price of corn to be low. According to

Dewantara et al. [23], the price of food products is relatively volatile because food commodities have several characteristics, namely depending on the biological conditions in the agricultural environment, such as pests, diseases and climate, the existence of time lags when decisions on using inputs and selling outputs, market conditions, and the impact of institutions.

The existence of corn defect is a risk in the raw material variable which has the lowest rating with aggregate severity value (RiS) 5.77, aggregate occurrence value (RiO) 3.13, aggregate detection value (RiD) 3.6 and FRPN 2.06 value who are in the low (low) category. Corn with defects cannot be processed into corn chips because it can reduce the quality of the product. However, the level of corn defect tends to be low, no more than 10% of the amount of corn harvested, and farmers can quickly detect corn defect so that the corn defect will not be distributed to *Lembah Hijau*, so that the risk falls into the low category. Corn defect is usually caused by pests or mice, improper post-harvest handling and weather constraints. According to De Andrade et al. [24], harvest time and water content at harvest are factors that can influence the quality of corn, so farmers need to estimate possible losses during harvesting and drying processes.

Quality assurance of the production process will also greatly affect the quality of the final product. Ensuring the quality of raw materials, production processes and final products to comply with predetermined standards Production processes that do not work well can cause product defects which can reduce the quality of corn chips. According to Radej et al. [25] quality assurance of corn chips production process is carried out at each stage of the process. Every stage of the production process must be carried out with due regard to the hygiene of the machinery and equipment used and the cleanliness of the workforce.

3.2.2. Production Process. In the production process variable, there are six risks that can affect the performance of the corn chips supply. The calculation results of FRPN values indicate that the priority risk order must be immediately addressed in the production process variables as shown in Table 3.

Table 3. FRPN value of production process risk

Risk	RiS	RiO	RiD	FRPN	Ranking	Category
Weather conditions that don't support the production process	8.6	5.0	6.6	9.69	1	*Very High* (VH)
Shortage of labor	8.0	5.0	6.4	8.74	2	*Very High* (VH)
Delay processing of corn chips	8.4	5.0	5.4	7.74	3	*High* (H)
Contamination during the production process	6.6	7.5	4.2	7.10	4	*High* (H)
Production machine and equipment flaws	8.4	2.5	7.2	5.16	5	*Moderate* (M)
Defect products	5.7	3.5	4.6	3.12	6	*Low* (L)

Based on Table 2, it can be seen that weather conditions which do not support the production process is risky and ranked first on the production process variable with an aggregate value of severity (RiS) 8.6, aggregate occurrence value (RiO) 5, aggregate detection value (RiD) 6.6 and the value of FRPN 9.69 which is in the very high category (very high). Weather conditions are very influential on the process of drying corn and corn chips. If the weather conditions are cloudy, *Lembah Hijau* cannot carry out the production process, so that it can lead to delays in processing corn chips which has an impact on delaying the delivery of products to consumers. Weather conditions are increasingly unpredictable because climate change is increasingly uncertain, so the risk falls into the very high category. Therefore, weather conditions that do not support the production process became the prioritized risk which needs to be addressed first since it greatly determines the success of the corn chips production process and the quality of the products produced. Weather conditions greatly affect

the success of the production process of corn chips, especially for the drying process. The non-optimal drying process can reduce the quality of the corn chips produced. According to Gumus and Ketebe [26] the drying process is mostly done to maintain the quality and increase the shelf life of agricultural products. As highlighted by Mohamed and Khan [27], good quality production can help reduce costs and improve the company's productivity and reputation. Weather conditions greatly affect the process of drying corn chips that require hot weather, so that the corn chips can dry to the maximum. When the weather is cloudy, SMEs are blocked from being able to carry out the drying process.

The corn used to produce corn chips is a hybrid variety of corn in the form of dry shelled. The risk of damage to corn can be caused of pests / rats, weather that does not support the process of drying corn, and improper post-harvest handling. According to Suciantini [28], the water content of corn seeds harvested in the rainy season is still high, ranging between 25-35%, if not handled properly, may have a chance to be infected with fungi that produce aflatoxin mycotoxins. Corn that has been overgrown with mushrooms cannot be used for the production of corn chips. Age of hybrid corn in general is 120-125 days, if corn is harvested before 120 days old, the results will not be good. At the time of harvest, the amount of corn that can be harvested is usually abundant, so the process of corn shelling cannot be done all at once, so that the corn must be stored in a lump form, this can trigger a risk of damage to the corn that is not immediately treated.

The existence of defects in the product is a risk in the production process variable which has the lowest rank with an aggregate value of severity (RiS) of 5.67, aggregate value of insurance (RiO) 3.5, aggregate value of detection (RiD) 4.6 and FRPN 3.12 which are considered low for the category. Product defects can reduce the quality of corn chips. However, these defects are rare and quickly detected, because each production process of corn chips has been carried out by workers who already have their respective expertise. Defects in the product both can be caused by the presence of corn chips which were destroyed during the flushing process and also by the packaging quality. According to Abdalkarim and Hrezay [29] packaging that cannot fully protect the product has the potential to cause defects and excess waste, reduce shelf life and decrease quality.

3.2.3. Marketing

In the marketing variable, there are five risks that can affect the performance of the corn chips supply chain. The results of the calculation of FRPN values indicate the priority risk order that must be addressed immediately in the marketing variable as can be seen in Table 4.

Table 4. FRPN value of marketing risk

Risk	RiS	RiO	RiD	FRPN	Ranking	Category
Corn chips sales returns	7.1	5.4	6.1	7.31	1	*High* (H)
Competition with other products	6.6	7.0	4.1	5.97	2	*Moderate* (M)
Fluctuating corn chips demand	5.3	5.0	6.1	5.03	3	*Moderate* (M)
Competition with similar products	6.2	5.6	3.1	3.40	4	*Low* (L)
Shortage of corn chips	6.1	4.0	3.6	2.76	5	*Low* (L)

The presence of corn chips sales returns is a risk that ranked first on the marketing variable with an aggregate severity value (RiS) of 7.1, aggregate occurrence value (RiO) 5.375 aggregate detection value (RiD) 6.1 and FRPN 7.31 value which are considered high for the category. The return of corn chips is almost always happening and the number of sales returns can reach 10-20% of total shipments for 6 months. Corn chips sales returns can be a loss for *Lembah Hijau* because of reduced revenue due to unsold products. Corn sales returns are difficult to predict because of the fluctuating demand for corn chips, so the risk falls into the high category. Therefore, the existence of corn sales returns is a priority risk which needs to be addressed first because it has a considerable influence on the success of

marketing corn chips. According to Shulman et al. [30] unsold products will be returned by retailers to producers at the end of the sales season as a result of inventory excess. According to Shaharudin et al. [31] product returns can be caused by product defects, not according to orders, entering expiration and items not sold. Sales returns occur when corn chips have entered the expiration period but have not sold 10-20% of the total product. This requires retailers to return the product to *Lembah Hijau*. The existence of corn chips sales returns can result in losses due to reduced income due to unsold corn chips.

The shortage of corn chips is a risk in the marketing variable that has the lowest rating with an aggregate severity value (RiS) of 6.1, aggregate occurrence value (RiO) 4, aggregate detection value (RiD) 3.6 and a FRPN value of 2.76 which considered low for the category. Lack of inventory can cause consumer demand cannot be fulfilled, so it can cause disappointment to consumers. However, shortages of corn chips are rare and retailers can detect them quickly if there is a shortage of inventory, so the risk is in the low category. Customer demand that cannot be fulfilled because of the lack of inventory (out of stock) can cause problems for all members of the supply chain. Shortages of inventory can reduce sales by at least 5%. In addition to sales losses, inventory shortages can have a long-term negative impact, such as reduced customer loyalty and operational inefficiencies of the company. The delay in the supply of corn can delay the production of corn chips and delay the delivery of products to retailers, which can cause disappointment to consumers. According to Akindipe [32] the availability of raw materials in the right quality and quantity will maintain the quality and quantity of output produced. Completion of orders in accordance with a predetermined time period will guarantee customer satisfaction, which is one way to gain trust from consumers. According to Syakur et al. [33], one indicator to determine the success rate of the supply chain is to know the efficiency of marketing. The marketing system can be said to be effective if it is able to deliver products from producers to consumers at the lowest cost.

4. Conclusions

The risk identification results of corn chips supply in *Lembah Hijau*, show that there are 14 risks consisting of 3 risks in the raw material variable, 6 risks in the production process variable and 5 risks in the marketing variable. The results of the risk assessment of corn chips with Fuzzy FMEA method show the priority of risk based on the highest FRPN value in each variable. The risk with the highest FRPN value in the raw material variable is fluctuating corn prices. The risk with the highest FRPN value in the production process variable is the weather conditions that do not support the production process. The risk with the highest FRPN value in the marketing variable is the return of sales of corn chips. The results of the risk assessment are used as a basis for priority corn chips supply mitigation strategies.

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