Risk mitigation strategy of rice seed supply chains using fuzzy-FMEA and fuzzy-AHP (Case study: PT. XYZ)

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Abstract. Every supply chain activity is always related to risk. Indonesia is an agricultural country as well as a rice seed producer. In rice seed supply chain activities, there are still some problems, namely the unstable amount of consumer demand, product competition, and delays in receiving raw materials. The purpose of this study was to determine the priority level of risk in the rice seed supply chain, and also determine alternative of risk mitigation strategies. The method used was Fuzzy Failure Mode and Effect Analysis (FMEA) and Fuzzy Analytical Hierarchy Process (AHP). This study used an expert survey with 4 respondents consisting of 2 people from the manufacture level (manager and assistant production manager) and 2 people from farmer level (as supplier). There were 14 risks identified from the manufacture level and from the farmer level. Based on the results of calculations with the fuzzy FMEA method, the manufacture level obtained the highest risk result, namely the risk of competition in rice seed products with a Fuzzy Risk Priority Number (FRPN) with value of 7.019. For farmer level, the highest risk was the high competition with other farmers with FRPN 7.812. 80% of critical risks from manufacturing and farmer level were analyzed using fuzzy AHP to determine priority of risk mitigation strategies. Alternative strategies for manufacture level were production planning and inventory control and machine maintenance. Alternative strategies for farmer level were improving information access, maintain quality, and production planning and inventory control.

1. Introduction
Seed is one of the main production facilities in crop cultivation. The need for rice seeds in Indonesia in 2015 was quite high at 345,881,300 kg of quality seeds but only 62% was fulfilled by Indonesian Government [1]. While Indonesia's harvested area in 2015 reached 13,835,252 ha [2]. This condition causes Indonesian farmers still use the seeds that produced by themselves with unstandardized quality. Therefore, the supply of quality seeds for rice farmers should be increased. Providing quality rice seeds can be improved, if the supply chain flow in the rice seed company is good [3].

PT. XYZ is a state-owned company engaged in agriculture, especially in the supply of rice seeds. PT. XYZ processes dry rice crops (gabah kering panen/GKP) into certified seeds. The parties involved in the rice seed processing supply chain are farmers as suppliers and PT. XYZ as a rice seed processing company. PT. XYZ experienced problems with the unstable number of demand. This happened because of a competing product that also offered certified rice seeds. In addition, the activities of receiving raw materials from farmers often experience delays which can also cause delays
in the production of rice seeds. It makes the production capacity of rice seeds is unstable. Delays in supply occur because rice is attacked by pests. Beside that, rice is one of the agricultural products which has a susceptible nature due to uncertain seasons and weather. These problems can cause losses for PT. XYZ.

All activities within the company including supply chain activities can allow risk to the company. Risk is the possibility of an event that can harm the company. Therefore, measurement and risk mitigation strategies are important to be applied to supply chain activities at PT. XYZ to meet consumer demand and reduce loss. The purpose of this study was to determine the order of supply chain risk priorities for rice seed products on the level of farmers and PT. XYZ as manufacture level, as well as to determine alternative strategies for risk mitigation.

2. Materials and Methods
2.1. Materials and instruments
This research was conducted at PT. XYZ Indonesia on January to March 2017. The data processing is done at Computational and System Analysis Laboratory, Department of Agro-Industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang. Methods used in this research were fuzzy Failure Mode and Effect Analysis (FMEA) and fuzzy Analytical Hierarchy Process (AHP). Respondents for this research are 2 experts from PT. XYZ (rice seed manufacturer) and 2 farmers from farmer level (as rice seed supplier).

2.2 Method
The first step was to identify risks at the manufacture level and also farmer level, by interviewing related experts and literature studies. Those identified risks are listed in Tables 1 and 2.

Table 1. Risk indicators on manufacture level (PT. XYZ).

| Code | Risk event |
|------|------------|
| M1   | The quality of rice that is not in accordance with the standards |
| M2   | Late supply of rice from farmers |
| M3   | Damage of production machine and equipment during the production process |
| M4   | Late production of rice seeds |
| M5   | Fluctuating production capacity |
| M6   | Out of stock |
| M7   | Market competition |

Table 2. Risk indicators on farmer level.

| Code | Risk event |
|------|------------|
| F1   | Fluctuating rice demand from the company |
| F2   | Rice damage during the planting process due to pests, plant fungi and climate |
| F3   | Out of stock |
| F4   | Rising prices of pesticide and fertilizer [4] |
| F5   | Fluctuating of production capacity |
| F6   | Delay in the supply of seeds and fertilizer [4] |
| F7   | Competitor from other regional farmer |

The next step is Fuzzy Failure Mode and Effect Analysis (FMEA) data processing [5]:

a. Determine the severity (S), occurrence (O), and detection (D) values
b. Calculate the aggregation of Fuzzy ratings on severity, occurrence, and detection factors, based on equations (1), (2), and (3).

\[
\hat{R}^S = \frac{1}{n}\sum_{i=1}^{n} h_j R^S_{ij} = (\sum_{j=1}^{m} h_j R^S_{ij})/\sum_{j=1}^{m} h_j R_{ij} \quad \hat{R}^O = \frac{1}{n}\sum_{i=1}^{n} h_j R^O_{ij} = (\sum_{j=1}^{m} h_j R^O_{ij})/\sum_{j=1}^{m} h_j R_{ij} \quad \hat{R}^D = \frac{1}{n}\sum_{i=1}^{n} h_j R^D_{ij} = (\sum_{j=1}^{m} h_j R^D_{ij})/\sum_{j=1}^{m} h_j R_{ij} \]

\[
R = \hat{R}^S \times \hat{R}^O \times \hat{R}^D \]
Where:

- $\bar{R}_i^O$ = Aggregate of O (occurrence)
- $\bar{R}_i^S$ = Aggregate of S (severity)
- $\bar{R}_i^D$ = Aggregate of D (detection)
- $h_j$ = Weight of respondents
- $n$ = Fuzzy number

Performing aggregate weighting calculations for severity, occurrence, and detection factors based on Equation (4), (5), and (6).

\[
\begin{align*}
\bar{W}_j^O &= \frac{1}{n} \sum_{j=1}^{n} h_j \bar{w}_j^O = (\sum_{j=1}^{n} h_j w_{j1}^O, \sum_{j=1}^{n} h_j w_{j2}^O, \sum_{j=1}^{n} h_j w_{j3}^O) \\
\bar{W}_j^S &= \frac{1}{n} \sum_{j=1}^{n} h_j \bar{w}_j^S = (\sum_{j=1}^{n} h_j w_{j1}^S, \sum_{j=1}^{n} h_j w_{j2}^S, \sum_{j=1}^{n} h_j w_{j3}^S) \\
\bar{W}_j^D &= \frac{1}{n} \sum_{j=1}^{n} h_j \bar{w}_j^D = (\sum_{j=1}^{n} h_j w_{j1}^D, \sum_{j=1}^{n} h_j w_{j2}^D, \sum_{j=1}^{n} h_j w_{j3}^D)
\end{align*}
\]

Where:

- $\bar{W}_j^O$ = Aggregate weight of fuzzy O (occurrence)
- $\bar{W}_j^S$ = Aggregate weight of fuzzy S (severity)
- $\bar{W}_j^D$ = Aggregate weight of fuzzy D (detection)
- $h_j$ = Weight of respondents

- $n$ = Fuzzy number

d. Determine the Fuzzy Risk Priority Number (FRPN) for each risk events, based on equation (7).

\[
FRPN_i = (\bar{R}_i^O) \frac{\bar{W}_j^O}{\bar{W}_j^O + \bar{W}_j^S + \bar{W}_j^D} \times (\bar{R}_i^S) \frac{\bar{W}_j^S}{\bar{W}_j^O + \bar{W}_j^S + \bar{W}_j^D} \times (\bar{R}_i^D) \frac{\bar{W}_j^D}{\bar{W}_j^O + \bar{W}_j^S + \bar{W}_j^D}
\]  

(7)

e. Ranking is done from the FRPN value, where the top ranking is the largest FRPN value.

The results of risk measurement will then be used to determine the supply chain risk mitigation strategy using the Fuzzy AHP method. The steps in preparing Fuzzy AHP include:

1. Formulate the problem of the highest risk and determine the objectives, factors, and alternative strategies to minimize the risks events. The objectives, factors, and alternatives used are the problems that exist in manufacture level and farmer level.

2. Discuss the determination of alternative strategies with experts at PT. XYZ and farmers. As well as observing how evaluations are implemented by the company and farmers for these alternative strategies so that the risk can be minimized.

3. Creating pairwise comparison matrix,

5. Calculate Consistency Ratio (CR) with equation (8).

\[
CR = CI/RI
\]

(8)

A paired comparison matrix is specified consistent with the Consistency Ratio (CR) value of $\leq 10\%$. The Random Index table (RI) can be seen in Table 3.

|    | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|----|----|----|----|----|----|----|----|----|----|----|
| RI | 0  | 0  | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Source: Alonso [6]

Further analysis of the data by combining AHP calculation with Fuzzy. The steps are as follows [6]:

1. Fuzzy Pairwise Comparison Matrix

2. Equality values $\sum_{j=1}^{m} M_{ij} = \sum_{j=1}^{m} \hat{M}_{ij} \cdot \sum_{j=1}^{m} m_{j} \cdot \sum_{j=1}^{m} u_{j}$ with addition operations on each Triangular Fuzzy Number (TFN) in each row.

3. Equality Fuzzy Synthetic Extent
4. Equality the vector value (V) and the value of defuzzification ordinates (d)

The probability level for fuzzy numbers can be obtained by equation (9):

\[
V(M2 \geq M1) = \begin{cases} 
1 & \text{if } m2 \geq m1, \\
0 & \text{if } m1 \geq m2, \\
it - \mu^2 & \text{if } 11 \geq \mu^2, \\
(10) & \text{others}
\end{cases}
\]

Where:
- M : TFN number
- m : number of criterias

5. Normalization of Fuzzy (W) vector weights

Normalization values can be obtained by equation (10):

\[
d(An) = \frac{d^f(An)}{\sum_{i=1}^{n} d^f(An)}
\]

3. Results and Discussion

3.1. Rice seed supply chain level

1. Farmer Level

Up to now, there are 20 farmers who have partnership with PT. XYZ with a total land area of about 235 hectares. According to Rukka et al. [7], one of the efforts to develop the capacity of farmers is through institutions or groups that play an important role in changes of their members’ behaviour and establish cooperation between members.

2. Manufacture Level

Manufacture in this rice seed supply chain is PT. XYZ. This company has obtained a quality management system certificate from the Quality System Certification Institute (LSSM) for rice seed products. There are four types of rice seed products produced by PT. XYZ: Ciberang, Setuba Gendit, Mekongga and Impari 32. The rice seed product is packed with a weight of 5 kg per package.

3.2. Rice seed supply chain activities

The flow of rice seeds is carried out by farmers who sell dry rice crops to PT. XYZ. The dry rice crops is sent by the farmer to PT. XYZ, where farmers preceded by contacting PT. XYZ to provide information about the number and quality grade of dry rice crops requested. Dry rice crops is delivered by using a type of transportation car. Weighing is carried out at PT. XYZ and supervised by the farmers concerned. This is done to avoid misunderstanding between farmers and PT. XYZ. The supply chain of rice seed products uses “retail storage with customer pickup” distribution network. This is because PT. XYZ as the manufacturer distributes the goods first to the distributor, then the distributor to the retailer. The retailer placed the products on the display and the consumer takes the product to be purchased. Retail storage with customer pickup is a type of distribution network where inventory is stored locally in retail stores, customers go to retail stores or order online or by telephone and pick it up at retail stores [8].

3.3 Supply chain risk analysis

3.3.1. Calculation of occurrence, severity and detection values aggregation

Assessment of aggregation results in the value of occurrence, severity and detection for each risk is shown in Table 4.

3.3.2. Calculation of interest and aggregation occurrence, severity, and detection factors

The aggregation values of fuzzy number weights and aggregate mean factors of occurrence, severity and detection in manufacturing and farmers are shown in Table 5 and Table 6.
Table 4. Aggregation of O, S, D values of manufacture level (M) and farmer level (F)

| Code | O  | S  | D  | Code | O  | S  | D  |
|------|----|----|----|------|----|----|----|
| M1   | 5  | 5.5| 3.5| F1   | 6.25| 6  | 5  |
| M2   | 5  | 5  | 6.5| F2   | 6.25| 7.5| 5.5|
| M3   | 6.25| 6  | 8  | F3   | 6.25| 8  | 5.5|
| M4   | 5  | 5.5| 7  | F4   | 6.25| 7  | 6.5|
| M5   | 5  | 5.5| 7  | F5   | 5   | 9  | 5  |
| M6   | 5  | 5.5| 6  | F6   | 7.5 | 8.5| 4.5|
| M7   | 6.25| 7  | 8.5| F7   | 7.5 | 8.5| 7.5|

3.3.3. FRPN value calculation
The FRPN value is obtained by calculating based on equation (7). Risk event with the largest value of FRPN is the first priority. This shows that these risks need more attention or should be mitigate first.

Table 5. Aggregation values of weights, fuzzy numbers and averages for manufacture level.

| Factor | Aggregate | Rank |
|--------|-----------|------|
| O      | 0.625     | 0.385|
| S      | 0.625     | 0.385|
| D      | 0.375     | 0.231|

Table 6. Aggregation values of weights, fuzzy numbers and averages for farmer level

| Factor | Aggregate | Rank |
|--------|-----------|------|
| O      | 0.75      | 0.462|
| S      | 0.5       | 0.308|
| D      | 0.375     | 0.231|

3.4. FRPN manufacture level
The result of the FRPN value from the manufacturers and farmers for each risk can be seen in Table 7. Based on Table 7, it can be seen that the highest risk that occurs in the supply chain of rice seed products for manufacturing (PT. XYZ) is the risk of rice seed products having competitor products that is equals to 7.019. The competitors are rice seed products that has cheaper selling price. The most significant thing about this risk is competition in getting customers which is related to company profits. To overcome the existence of competitors, companies must be able to generate new innovations of rice seed products. According to Mueller, et al. [9], the strategy that can be applied to overcome competition are by market penetration, development of new existing products (developing new products for old markets) and market expansion (selling old products in new markets).

Table 7. FRPN value from manufacture level (M) and farmer level (F).

| Code | FRPN | Rank for | Code | FRPN | Rank for |
|------|------|----------|------|------|----------|
|      |      | Manufacture Level |      |      | Farmer Level |
| M1   | 5.319| 6        | F1   | 5.870| 7        |
| M2   | 4.785| 7        | F2   | 6.428| 5        |
| M3   | 6.728| 2        | F3   | 6.556| 3        |
| M4   | 5.613| 3        | F4   | 6.544| 4        |
| M5   | 5.613| 4        | F5   | 5.998| 6        |
| M6   | 5.419| 5        | F6   | 6.939| 2        |
| M7   | 7.019| 1        | F7   | 7.812| 1        |
3.5. FRPN farmer level
Based on Table 7, it can be seen that the highest risk in the supply chain of rice seed products for farmers is the risk of competitor from other regional farmers that is equal to 7.812. PT XYZ has had some farmers as partner to supply raw material (dry rice crops) regularly, but there are still many other farmers who also compete in supplying dry rice crops to PT. XYZ. This other farmer comes from another area. Farmers assisted by PT. XYZ must maintain the quality of the dry rice crops produced, so as not to suffer losses. According to Dewi et al. [10], the risks of competitor from other regional farmers increase in number. Tight competition requires farmers to maintain their sustainability by maintaining the quality of rice plants and also their customer engagement.

3.6. Risk mitigation in the manufacture level (PT. XYZ)
On PT. XYZ, there are 5 risks that are mitigated. Based on the calculation, the CR value are smaller than 0.1. This shows that the questionnaire that is filled is consistent and there is no repetition in filling. After obtaining the results of normalization of weight vector values then aggregate calculations are performed between alternative strategies. The aggregate results between strategies are obtained from the average normalization value of the weight vector that is the end of the calculation of the FAHP value for each strategy that is rooted according to the number of experts, namely 2 persons from farmer level. Aggregate values between strategies on five risk factors can be seen in Table 8.

| Risk events                                                                 | Alternative strategies                                      | The aggregate value of strategy | Rank |
|-----------------------------------------------------------------------------|------------------------------------------------------------|--------------------------------|------|
| Late production of rice seed (M4)                                           | Maintain quality                                           | 0.23                           | 3    |
|                                                                             | Manpower training                                          | 0.3                            | 2    |
|                                                                             | Production planning and inventory control                  | 0.33                           | 1    |
|                                                                             | Machine maintenance                                        | 0.09                           | 4    |
| Damage of production machines and equipment during production process (M3)  | Maintain quality                                           | 0.13                           | 4    |
|                                                                             | Manpower training                                          | 0.14                           | 3    |
|                                                                             | Production planning and inventory control                  | 0.29                           | 2    |
|                                                                             | Machine maintenance                                        | 0.34                           | 1    |
| Fluctuating production capacity (M5)                                        | Maintain quality                                           | 0.16                           | 3    |
|                                                                             | Manpower training                                          | 0.27                           | 2    |
|                                                                             | Production planning and inventory control                  | 0.28                           | 1    |
|                                                                             | Machine maintenance                                        | 0.14                           | 4    |
| Out of stock (M6)                                                           | Maintain quality                                           | 0.11                           | 4    |
|                                                                             | Manpower training                                          | 0.3                            | 2    |
|                                                                             | Production planning and inventory control                  | 0.32                           | 1    |
|                                                                             | Machine maintenance                                        | 0.23                           | 3    |
| Market Competition (M7)                                                     | Maintain quality                                           | 0.37                           | 1    |
|                                                                             | Manpower training                                          | 0.25                           | 3    |
|                                                                             | Production planning and inventory control                  | 0.3                            | 2    |
|                                                                             | Machine maintenance                                        | 0.05                           | 4    |

Based on Table 8 the strategy of production planning and inventory control becomes the highest ranking to handle the risk of delay in rice seed production by 0.33, fluctuating production results by 0.28 and out of stock by 0.32. This strategy is very influential because PT. XYZ can plan a production
schedule so that there is no delay in the production of rice seeds and the production capacity will not be fluctuated. In addition, it can overcome the risk of running out of stock so that consumer demand can be met. Therefore, production planning and inventory control need to be implemented in order to maintain smooth production and PT. XYZ does not get loss. This strategy is in line with the opinion of Vrat [11], if a company does not have inventories, there will be shortages, production delays, and project delays.

The machines maintenance strategy gets the highest value to overcome damage of production machine with a value equal to 0.34. By performing regular and periodic maintenance, the machines in PT XYZ are not damaged quickly and the rice seed production process is not hampered due to sudden machine damage. This strategy is in accordance with the opinion of Velmurugan and Dhingra [12], that poorly maintained machines or equipment may lead to random breakdowns causing unavailability for production or service. The strategy to maintain quality gets the highest value to reduce market competition with a weight value of 0.37. This strategy to maintain quality is also important because products that have high quality will be favored by consumers.

3.7. Risk mitigation in the farmer level
On the level of the farmers, there are 4 risks that are mitigated. Based on the calculation, the CR value are smaller than 0.1. Aggregate values between strategies on four risk factors can be seen in Table 9. Based on Table 9 the strategy of inventory planning and control has the highest value to reduce the risk of rice supply deficiency (out of stock) that is equal to 0.34. The strategy of production planning and inventory control aims to prevent rice supply from running out and delays in the supply of seeds and fertilizers. Information access improvement strategies get the highest weight score to reduce the risk of rising prices for pesticides and fertilizers by 0.32. This strategy has the highest aggregate value because it is very influential to minimize the risk of rising prices of pesticides and fertilizers. By improving information access with agricultural shop sellers, price increases can be minimized. So that farmers can meet the needs of pesticide and expected profit. In addition, strategies to improve information access also get the highest weight score to reduce the risk of delays in the supply of seeds and fertilizers by 0.32. According to Kartika [15], improving access to information also needs to be done with competitors with farmers from other region, so that misunderstandings do not occur and compete well. Inaccurate information can lead to inefficiencies in the supply chain such as lack of raw materials, low use of factory capacity and too much finished goods inventory.

| Risk events                          | Alternative strategies          | The aggregate value of strategy | Rank |
|-------------------------------------|---------------------------------|---------------------------------|------|
| Rising prices of pesticide and fertilizer (F4) | Maintain quality | 0.15 | 4 |
|                                     | Improved access to information  | 0.25                           | 2   |
|                                     | Inventory planning and control  | 0.22                           | 3   |
|                                     | **Improved access to information** | **0.32**                     | **1** |
| Delay in the supply of seeds and fertilizer (F6) | Maintain quality | 0.15 | 4 |
|                                     | Establish partnership           | 0.24                           | 2   |
|                                     | Inventory planning and control  | 0.22                           | 3   |
|                                     | **Improved access to information** | **0.32**                     | **1** |
| Competitors from other regional farmer (F7) | Maintain quality | 0.33 | 1 |
|                                     | Establish partnership           | 0.25                           | 2   |
|                                     | Inventory planning and control  | 0.23                           | 3   |
|                                     | Improved access to information  | 0.12                           | 4   |
| Out of stock (F3)                   | Maintain quality                | 0.2                            | 3   |
|                                     | Establish partnership           | 0.3                            | 2   |
|                                     | **Inventory planning and control** | **0.34**                   | **1** |
|                                     | Improved access to information  | 0.14                           | 4   |

Table 9. Aggregate strategic values for 4 risk factors
The highest alternative strategy to mitigate the risk of competitors with other regional farmers is by maintaining quality with an aggregate value of 0.33. By maintaining the quality of dry rice crops, it can also maintain the partnership between farmers and PT. XYZ. The strategy to maintain quality is in accordance with Khadka and Maharjan [13]. Service quality, product quality and value for money have a direct positive impact on customer satisfaction.

4. Conclusion
Based on Fuzzy FMEA calculation, on the manufacture level, the five highest FRPN ranking for risk mitigation strategies are the risk of market competition of 7.019, damage to production machine and equipment during the production process of 6.728, late production of rice seed of 5.613, fluctuating production result to 5.613, and the risk of rice seed products experiencing an inventory run out of 5.419. On the farmer level, the four highest FRPN risks were taken, namely: the risk of competitors from other regional farmers equal to 7.812, delays in the supply of seeds and fertilizers of 6.939, lack of inventory of 6.556, and rising price of pesticide and fertilizer by 6.544. Alternative strategies for supply chain risk mitigation for manufacture level include: maintaining quality, manpower training, production planning and inventory control, and machine maintenance. Alternative strategies for supply chain risk mitigation on farmer level include maintaining quality, establish partnerships, inventory planning and control, and improve access to information.

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