Integrating supply chain risk management in agriculture: *A case study of East Kalimantan granary*

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Integrating supply chain risk management in agriculture: *A case study of East Kalimantan granary*

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Abstract. Managing risk in the agricultural supply chain is more complex and challenging than other commodities due to its perishable characteristic and production nature, primarily based on unpredictable weather conditions and uncontrollable biological processes. This study analyses the agricultural supply chain risk in Penajam Paser Utara Regency, one of the granaries for East Kalimantan Province. A total of 25 risks have been identified and prioritized by fuzzy FMEA, where these risks are divided into eight supply risks, 12 manufacturer risks, and five demand risks. The mitigation strategies give five options: (1) branding image, (2) market penetration, (3) partnership, (4) preventive maintenance, and (5) production capacity to choose from. Using the Analytical Network Process (ANP) method, the priority order of mitigation strategies is to adjust production capacity weighing 35,5%.

1. Introduction

The characteristics of agricultural products have some specific circumstances, such as their perishable characteristic and production nature which are primarily based on unpredictable weather conditions and uncontrollable biological processes. In the agri-food supply chain, the complexity and the uncertainty to manage the risks are rising due to its characteristics [1]. Penajam Paser Utara Regency is one of the granaries in East Kalimantan Province. The area for rice cultivation for 2020 was recorded at 15,166 hectares. The increase in rice productivity reached an average of 3,5 tons per hectare. This enhancement has affected the performance of the supply chain and its risk.

Penajam Utara has a significant contribution to food independencies in East Kalimantan, especially for rice needs. A rice milling plant, a series of machines that have a function to separate the rice grains from husks to the dry grain form to ready-to-eat rice, is needed to support the production and demand for rice. The rice production process is inseparable from the risks that disrupt the rice production process. Some of the risks commonly occurring are grain raw materials delays in the production process, damage to equipment in the rice milling machine, the rice produced in poor quality such as rice seeds that are not intact or crushed, et cetera. The risks that occur might cause several losses. For example, the disruption of the rice production process can cause the demand needs to be missed.

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Risks are an inherent part of the supply chain [2]. Supply chain risks focus on the risks that transmit among supply chain actors who manage a whole for an end-to-end supply chain [3]. Supply chain risk management manages the risks through coordination among partners to ensure profitability and continuity. The process includes risk identification, risk assessment, risk action, and risk control. In the early stage, the risk is identified from any risk sources in the supply chain. An agricultural supply chain encompasses all components of a process related to sourcing, producing, post-harvesting, storing, processing, and delivering [2].

Nowadays, supply chains are interconnected, and the business integrates across multiple players, including managing the supply chain. The research is a continuation of previous research which focused on risk mitigation in agriculture with the case study in Penajam Paser Utara's Granary. Previously, risk identification and assessment have been done using Fuzzy Failure Mode Effect Analysis (FFMEA). The mitigation strategy to reduce the frequency and impact of the risk has been chosen by Analytic Hierarchy Process (AHP) [4].

As mentioned before, the supply chains connect all actors or players. The connection might be simple or complex, and the connection among its strategies. Based on that, the research is to accomplish the selection method that refers to the characteristic of the supply chain. Many studies about risk and its evaluation have been applied in the AHP, but in some cases, supply chain risks need a method beyond hierarchical relations [5]. The ANP method can identify the intangible interdependencies and feedback among factors, subfactors, and alternatives, considering risks, feedback, and relationship [6]. The risk impact on each other or the risk interaction with the other cluster can indicate by using ANP.

2. Literature review

2.1. Supply chain risk

Risk management implements strategies and purposes to manage supply chain networks through risk assessment and reduces vulnerabilities to ensure resilience in the supply chain [7]. The risks in each supply chain are not similar, but some risks are common. In the agriculture supply chain, risk and vulnerabilities are identified in different forms, such as yield, cost, and price variability in various agricultural products [8]. In another perspective, the risk is divided into (1) weather or natural disaster risk. (2) biological and environmental risk, (3) market risk, (4) logistical and infrastructure risk, (5) political risk, (6) policy and institutional risk, (7) financial risk, and (8) operational and managerial risk [9]. The previous research related to the granary in Penajam Paser Utara has classified the risk into three common risk factors based on input, process, and output [4].

2.2. Integrated supply chain risk management

Identifying risk sources is an important issue of integrated supply chain risk management. Context analysis consists of the definition of the issue to be managed. It is followed by risk identification, risk evaluation, strategy selection for risk treatment, strategy implementation, control, and monitoring [10]. The supply chain connects the process across the supplier-user relationship, beginning from raw material and ending in finished products.

The supply chain covers all the internal and externals factors which enable the value chain. Essentially, it combines supply and demand management within and across business entities. This idea focusses on how the process business improves business performance through the coordination, material, logistics, distribution, transportation within a supply chain organization as an integrative strategic initiative related to risk supply chain management [11]. Integration usually results in the synchronous implementation of information sharing, marketing alliances, demand forecast, or partnerships with other partners [12].

2.3. Fuzzy failure mode and effect analysis

The research is a continuation of previous research in Penajam Paser Utara's granary. The risk factor is identified in table 1 and proceeds by FFMEA calculation. Fuzzy FMEA help to present the uncertainty of crisps ranking to be more realistic.

Table 1. Risk identification.

No.	Risk Factor	Risk Identification
1	Input	1. Failed harvest 2. Delayed harvest 3. High rice water content 4. Decline of rice quality due to pest attack 5. The rice mixed by other type 6. Rice planting pattern 7. Rice buyer competitor 8. Unfitted demand with the rice type
2	Process	1. Uncomfortable work environment 2. Delay of production process 3. Runout the machine fuel 4. Power outage 5. Damage of the machine main motor 6. Damage to the series of rice milling tools 7. Broken of main belt of rice milling tools 8. The un-spread distribution of oven heat 9. The broken of oven 10. The broken of packaging machine 11. The crushed of rice grain 12. Lack of packaging wrap
3	Output	1. Damage during storage 2. Customer delivery lateness 3. Supplier competitor 4. Unsuited demand with the production 5. Payment lateness

Fuzzy RPN (FRPN) results from the multiplication of members' function for severity, occurrence, and detection criteria.

2.4. Analytic network process

Multiple criteria decision analysis has evolved and is widely used to support decision-making problems in the various field [13]. A well-known technique in this domain is the Analytic Network Process (ANP), which is a generalization of the Analytic Hierarchy Process (AHP) that can handle complex decision problems [14].

Analytic Network Process or ANP is a general theory on relative measurement to decrease composite priority ratio of mutually interactive elements related to control criteria [14], as seen in Figure 1. ANP is a mathematical theory that systematically manages dependence and feedback to capture and combine tangible and intangible factors[15]. Control hierarchy includes high-level criteria involved in decision making and provides a way to compare each interaction in the network.

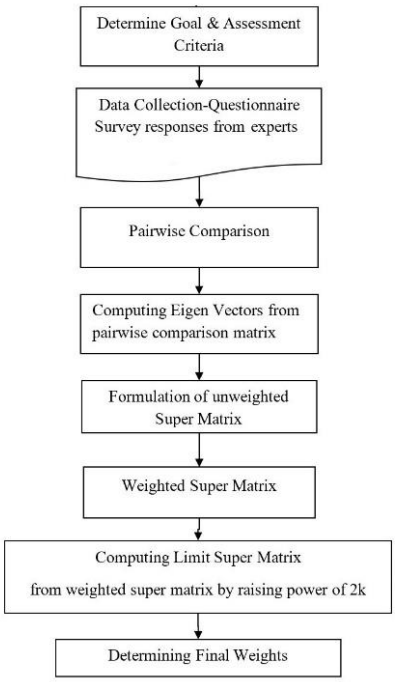

Figure 1. Weight calculation in ANP.

It categorizes four basic control hierarchies, including many aspects, i.e., benefit, opportunity, cost, and risk, known as the BOCR model. The control criteria must not be used when there are irrelevant criteria to the case of decision making involved. BOCR concept focuses further on deciding criteria and sub-criteria for a decision-making model, as seen in Figure 1. Besides, the BOCR model facilitates source persons with different backgrounds resulting in different viewpoints in assessing problems influencing evaluation when doing a paired comparison.

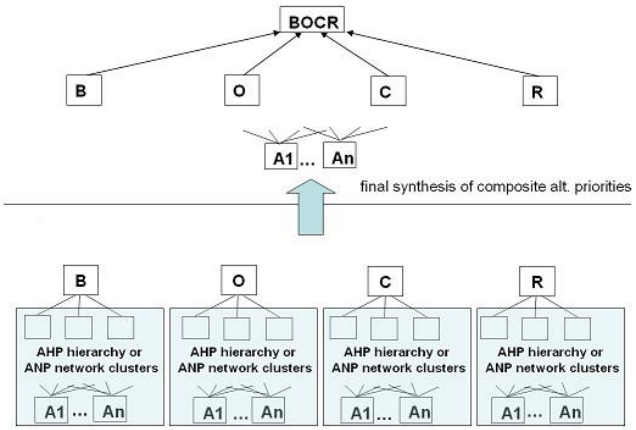

Figure 2. BOCR analysis.

The paired comparison is carried out on criteria and sub-criteria to obtain global weights from each control criteria. The weight is multiplied and entered into a matrix known as *weighted supermatrix*. Each column of the supermatrix is normalized to obtain each value called *limiting supermatrix*. Supermatrix (W) will increase as in formula (1) to obtain global priority [14].

$$\lim_{k\to\infty} W^k \qquad (1)$$

If *W* affects the system, then two or n limiting supermatrices are possible. In this case, Cesaro's (2) calculation is used to obtain average priority weight.

$$\lim_{k\to\infty}\left(\frac{1}{N}\right)\sum_{i=1}^{N}W_i^k \qquad (2)$$

The convergent value for each element shows the global weight of the system. The global weight is normalized to obtain the relative weight of each alternative. The alternative is evaluated based on the control hierarchy of benefit, cost, opportunity, and risk. If each control hierarchy is given the same weight, all evaluation of each alternative is obtained with formula (3).

$$Multiplicative\,Score = \frac{(Benefits)\times(Opportunities)}{(Costs)\times(Risks)} \qquad (3)$$

3. Method

The risk priority has identified and assessed earlier [4], as given in table 2. The data collected from rice mill Sido Muncul at Labangka Village, Penajam Paser Utara.

The given risks priorities to mitigate are the rice buyer competitor, the breakdown machine, and the rice supplier competitor. Strategies developed to mitigate the highest priority risk based on FFMEA. Further, the risk mitigation strategy is constructed and chosen using ANP. The alternative strategy must be fitted to criteria and sub-criteria in the BOCR model, divided into input, process, and output. The criteria, sub-criteria, and alternative strategy are driven from literature, research study, and interviews with supply chains actors.

Table 2. Risk Priority on Raw Material, Production Process, and Finished Good.

Failure Mode	Potential Effect of Failure	Potential Cause of Failure	Detection/Current Control	FRPN
Rice buyer competitor	-Production process lateness -Production rate decrease -Production process stopped -Reduction the amount of rice	-The increase of competitor -Lack of work relation with farmers	-Build cooperation with farmers -Trust commitment -Promotion to farmers	894
Breakdown of main mill machine	-Production process lateness -Production process stopped -Production decrease -Cost of machine repair	-Lack of routine machine maintenance -Over use machine	-Preventive machine maintenance -Machine spare part allocation -Use the machine according to the instruction	883
Rice supplier competitor	-Alight of demand -Decrease of sell -Drop down of turnover	-The increase of competitor -Lack of working relation -Poor rice quality	-Build relationship with buyers -Promotion to buyers -Maintain rice quality	748

The results were used to develop the ANP risk mitigation model based on BOCR and perform pairwise comparisons rated by the Sido Muncul Rice Mill manager. Dedicated software (super decisions) was used. Within this model, the relevant alternatives are represented. The estimation of the model is structured as a network of nodes and clusters. The decision alternatives in the model are the action of the risk mitigation strategy, and the results are coefficients that describe the relative dominance of the alternatives.

4. Result and Discussion

The result for determining the decision to select the priority of the mitigation strategy are as follows:

4.1 Determination of criteria, sub-criteria, and alternative strategies

Criteria and sub-criteria referring to BOCR as seen in Table 3. Based on risk priority, the possible alternative strategies are an action to maintain the current condition, which reduces the failures. The strategies as a solution to control the failure condition.

Table 3. Criteria and sub-criteria referring to BOCR.

Criteria	Sub criteria
Benefit	Investment Paddy Quality Market
Opportunity	Rice Demand New technology Farmer's relationship
Cost	Purchasing cost Production Cost Maintenance cost Marketing cost Transportation & Distribution Cost
Risk	Regulation Competitor Lack of supply Machine Downtime

The strategy to reduce the failure is (1) branding image, (2) market penetration, (3) partnership, (4) preventive maintenance, and (5) production capacity, considered to control the impact of the risk. Also, the strategies were developed by examining the implementation possibility.

4.2 Develop a network structure

Processing for ANP is carried out with Superdecisions software, as shown in Figure 3.

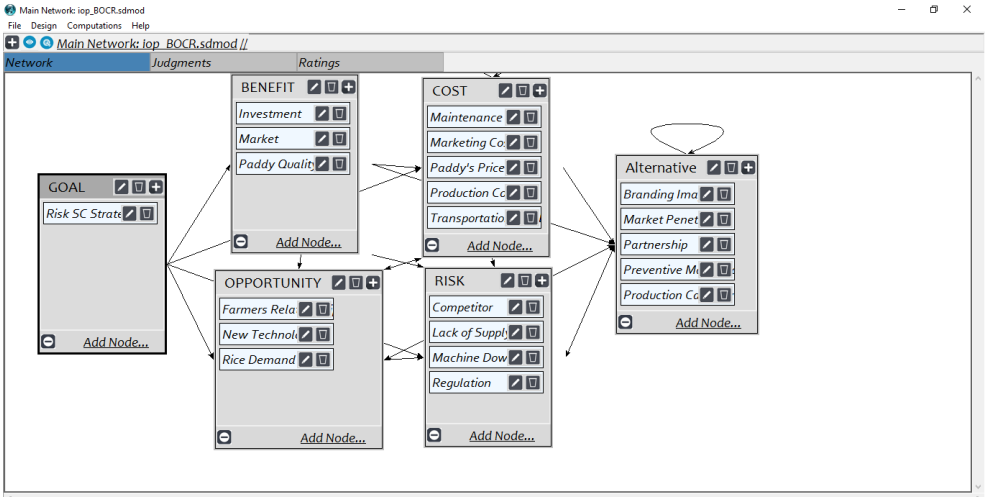

Figure 3. The networks.

The node presents the sub-criteria under criteria and connects based on the respondent feedback. From the pairwise comparison, all nodes' networks get the relation and scaled.

4.3 Form a pairwise comparison matrix and normalization

The pairwise comparison compares connected criteria, sub-criteria, and the strategy in judgement window in super decisions. All the calculations generate automatically in super decisions, including the consistency ratio. The synthesis of models and priorities overall is based on four aspects that become control of strategy selection criteria through opinion the combination of expert sources. Normalized BOCR aspect value is used as a basis for prioritization. Aspect BOCR with a larger normalized value has a higher rank, as shown in Figure 4. The results of the synthesis show aspects benefit as the first rank, which is much greater than risk aspects as the last rank.

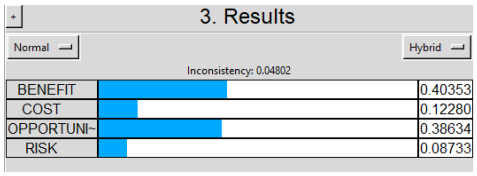

Figure 4. Result of BOCR Criteria.

4.4 Determination of priority criteria

In selecting strategies to mitigate the risk in the supply chain in the granary, alternative strategies that provide an advantage benefit, the biggest one, should be chosen. In contrast, the lowest ranking is the aspects of risks. This matter means that in the selection of alternatives strategies, the risk that may arise gets the lowest priority compared to others. BOCR results for each alternative strategy are calculated to obtain overall outcomes so that strategic priorities can be set in several different scenarios.

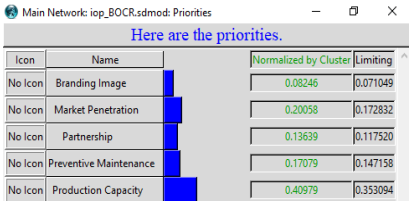

Figure 5. Strategies priorities.

The best alternative strategy is the adjustment of production capacity. It gives the maximum benefit and impact to other strategies given. As assumed in the scenario, the increase in production capacity can spread market penetration and affect the maintenance plan. The strategy can be a solution for the company to mitigate their risk.

5. Conclusion

In deciding which strategy is the most possible to mitigate the risk, adjustment production capacity is chosen from 5 alternatives, i.e., branding image, market penetration, partnership, preventive maintenance, and adjustment of production capacity. Based on the rank of ANP calculation, the priority obtained is 35,3%. In order to implement strategies that are recommended, it is necessary to cooperate with other actors in the supply chain. The strategies cannot be effective if there is a lack of support from other actors.

Further, the research needs to develop general strategies for the agricultural industry related to rice production, including its regulation.

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