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Risk management of shallot supply chain using failure mode effect analysis and analytic network process (case study in Batu, East Java)

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Abstract. Shallot is one of the perishable horticultural commodities. Therefore, proper supply chain management is needed. This study aimed to identify risks from each supply chain actor, as well as to carry out risk measurement, and formulate priority risk mitigation strategies from the shallot supply chain. The methods used in this study were failure mode effect analysis (FMEA) and (analytic network process) ANP. The FMEA method was used to measure the priority risks that have been identified. While, ANP was used for weighting strategies in determining supply chain risk mitigation strategies. Research results showed that there are several risks identified by supply chain actors. Priority risks for the supply chain of farmers (suppliers) were risks related to government policies, namely import-related policies. Distributor supply chain priority risk was the risk associated with competition with imported shallots, and the risk of retailer supply chain priority was the risk of competitors with other retailers. There were six alternative mitigation strategies, the highest priority was choosing the right variety followed by maintaining quality, increasing promotion, forging partnerships, maintaining supply and maintaining price stability.

1. Introduction

Indonesia produces various types of crops which are called big as business fields. Starting from agricultural products to horticultural products, all have very high economic values. Many communities cultivate various agricultural and horticultural products as a promising business potential. One of the horticultural commodities that many Indonesian people cultivate is shallots. Many farmers are cultivating them due to their economic benefits.

Shallots are annual plants that form upright grass with a height of up to 15-50 cm and clumps [1]. Shallots plants cannot grow and produce well in any place or region. The environment must be naturalay ideal, either from the physical or chemical conditions of the soil, climate, altitude, air temperature, wind, rainfall, sunlight, and relative humidity [2].

The main producer area of shallots in East Java is Batu city. Batu City has great potential related to shallots production. For example, in Torongrejo Village, on average the farmers have less than 5,000 m² of land for shallots. The farmers can harvest the shallots leaves when they reach age of 40-50 days, or the shallots tubers at 80 days old with approximately production of 1.5-2 tons per 1,000 m². Besides that, the shallots production in Batu City Java increased from 2011 to 2013.



An increase in shallots production needs to be supported by appropriate supply chain management. Supply chain management for shallots is different compared to manufacture products because of: (1) agricultural products are perishable, (2) the process of planting, growing, and harvesting depends on climate and season, (3) yields are varying in shape and size, and (4) agricultural products are difficult to handle. Therefore, supervision is critical to avoid problems and bottle neck at any point in the supply network [3].

The challenges and opportunities of the global market have increased the needs to increase competitiveness and create added value in the supply chain of the shallots production. Therefore, it is necessary to carry out risk identification, risk assessment and risk mitigation. Once the priority of the supply chain risk is identified, a risk management is needed. Risk management is a systematic approach to determine quality management policies, procedures and practices based on risk assessment, risk control, and risk evaluation [3]. Risk management refers to all aspects that include planning, monitoring and controlling activities based on information generated by risk analysis activities.

One of the methods can be used to identify risks of each actor in the shallots supply chain actor is Analytical Network Process (ANP). According to Saaty [4], ANP is an analytical tool that is able to represent the importance of various parties by considering the dependency relationship between criteria and sub-criteria. By using ANP method, it is expected to capture the high dependency interaction between the types of risks and risk factors that influence in improving shallot supply chain risk management. Thus, the risk priorities and alternative risk control options can be determined accurately to make better decisions. The results obtained from ANP are identification of the most influential risk weights in the shallot supply chain. The risk analysis and evaluation stage is generally carried out using the Failure Mode Effect Analysis (FMEA) method, but according to Chen [5], the method only assesses the risks without considering the alternative interest relationship with the mitigation plan. Therefore, the integration between ANP and FMEA methods was used to calculate the weight of each risk and its relationship with risk mitigation for each actor in the shallots supply chain. At this stage, a new approach was used, which is Weighted Failure Mode Effect Analysis (WFMEA) known as a technique of recognizing and evaluating the failure of a product or process introduced by Huang et al. [6].

The purpose of this research was to explain the condition of the shallot supply chain, to identify the risks and priority risks faced by the shallot supply chain actors and to formulate strategies to mitigate the risks.

2. Research Method

The data used in this study are primary data and secondary data. Primary data was obtained through interviews and questionnaires for farmers, distributors, and retailers by filling out questionnaires and interviews. While, secondary data was obtained from books, journals, and the internet. From the collected, identification of risk factors was carried out using ANP method. Followed by risk analysis and evaluation using WFMEA method. The WFMEA method used a weighted assessment to obtain more accurate and continuous results from the previous risk assessment stages. The weight of each risk can be calculated using the Weighted Risk Priority Number (WRPN) calculation formula in equation below:

$$WRPN_n = S_i \times O_i \times D_i \times f(W_i) = RPN_n \times f(W_i) \quad (1)$$

Where:

S_i = severity
 O_i = occurrence
 D_i = detection
 $f(W_i)$ = weight

Based on formula (1), if failure modes have a higher Risk Priority Number (RPN), they are assumed to be more important and given a higher priority than that of with lower RPNs [7]. Risk evaluation is comparing the level of risk that has been calculated at the stage of risk analysis using the standard criteria. Variable output values, namely WRPN, are used to represent priorities in corrective actions on a scale of 1–250 with five interval classes classification (Table 1).

Table 1. Risk categories based on WRPN.

Output value	Risk Category	Control
1-50	Very low	Receive
50-100	Low	Receive
100-150	Middle	Avoid
150-200	High	Mitigation
200-250	Very high	Mitigation

3. Results and discussion

Risk is the possibility of deviations from expectations that can cause losses. Meanwhile, risk management is an effort that is rationally aimed at reducing the likelihood of losses from the risks faced. The purpose of risk management is to minimize losses and increase opportunities. When viewed as a loss, risk management can cut the chain of loss events which can prevent the dominance effect to occur. By combining supply chain management and risk management, it is expected that future business challenges (i.e. business uncertainty) can be handled properly, by managing and reducing the risks. With this, a robust supply chain can also be achieved.

3.1. Identify the shallot supply chain

The shallot supply chain activity in Torongrejo Village includes several activities from providing seeds or raw materials to marketing or selling process. Each supply chain has its own activities which are varied from other supply chain agents.

3.1.1. Supply chain activities of farmers (suppliers)

The first activity carried out by farmers is purchasing seeds and fertilizer through the Agriculture store of Torong Makmur provided by Gapoktan Torong Makmur. This store sells seeds, organic and inorganic fertilizers, as well as organic and inorganic agricultural pesticides for farmers in Torongrejo Village who are members of Torong Makmur Gapoktan or non-members. Purchases can only be made in cash. Facilities that need to be provided to increase production include nationally standardised seeds, fertilizers, and pesticides.

Then, Torong Makmur Gapoktan dispatched production facilities ordered by farmers using the transportation provided. In some conditions, delays can occur due to the large number of orders received, damage to transportation facilities, and unavailability of goods ordered. In any industry, transportation has an important role and it is considered as one of the main activities in logistics. Therefore, delivery of goods has a mission of delivering the right goods at the right place and time.

The last step is to plant shallot seeds on land owned by the farmers themselves or rent from someone else's land until the shallots reaching the age of 80 days. Then harvesting shallots is manually done by hand or by a simple tool, following with drying. Harvested shallots must be immediately dried to prevent damage caused by fungi or spoilage bacteria [2]. After the drying process, shallots are ready to be marketed. While, the shallots leaves can be directly sells after harvesting.

3.1.2. Activity of wholesaler (distributor) supply chain

The first activity carried out by wholesalers /middlemen (distributors) is to buy shallots from farmers around Torongrejo Village. Then, the shallots were sent to the Karangploso Market to directly sell to the end consumers and the retailers. Reservations can be made on the same day or not. The distributors

deliver their orders directly to the farmers (suppliers). The main job of the wholesalers is to distribute the product as much as possible and as largely as possible to the retailers or to the direct consumers.

Wholesalers also supply other agricultural products besides shallots, such as celery, prawn leaves, sweet corn, cauliflower, and cabbage. Thus, they are not solely depend on shallots sales. The marketing or sales was done directly or without going through an intermediary. A direct marketing was employed to simplify the sales process and to prevent any extra costs. Also, shallots can be directly ordered to the wholesaler to avoid any mistakes in ordering information. Direct marketing is a direct relationship with individual consumers, enabling the sellers to build responses and lasting customer relationships [8].

3.1.3. Supply chain activities of retailers

The activity of retailers is to sell directly to the end customer. Retailers get a supply of shallots from a distributor which is then sold directly to the final consumer at the Karangploso Market, Malang Regency. Information flow on retailers is from two directions. First, retailers are a source of information about company products to consumers. Second, feedback information as an important point from customers to companies that sell their products through retailers [9].

Retailer also supplies other agricultural products besides shallots, such as red chili, green chili, small chillies, tomatoes, lemongrass, ginger, and lime, to avoid them from single dependancy in shallots products. Sales/marketing was carried out directly or without going through an intermediary process, thus it is easier for them to make sales. Information about ordering shallots can be done directly to the retailer to avoid any error information in ordering the products.

3.2. Supply chain flow pattern

Shallots flow in Torongrejo Village involves farmers (suppliers), middlemen (distributors), retailers (retailers), and consumers. The shallots flow starts from the farmer (supplier) who sells shallots to the wholesalers/middleman (distributors) which then flows to the retailer (retailer) and reaches the consumer. The shallots supply chain flow pattern can be seen in Figure 1.

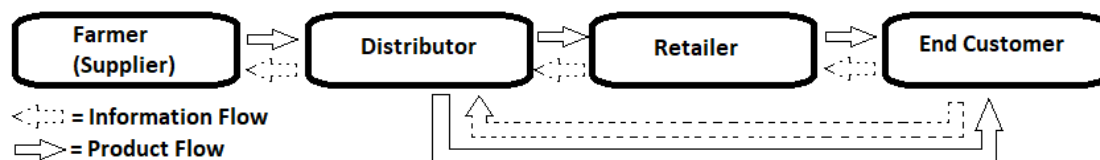


Figure 1. Procedures for shallot supply chain flow.

As shown in Figure 1, the shallot supply chain uses a retail storage distribution with customer collection and distribution in two channel types. This is because shallots are distributed to middlemen (distributors) first and then distributed to retailers. Consumers can collect the shallots themselves from the retailer. In retail storage with customer collection, inventory is stored locally in retail stores, customers walk to retail stores or order online or by telephone and collect it at retail stores [10].

3.3. Supply chain risk identification

Risk identification is carried out by filling out the questionnaire by the respondent, after that validation is done by conducting in-depth interviews with respondents. Based on the results of the questionnaire and brainstorming, the risks faced by the shallot supply chain actors were shown in Table 2.

The risks faced by shallots farmers (suppliers) are experiencing land shortage problems, experiencing an order change from the distributor, seed/variety mismatch, rising seed/variety prices, competitors from other regional farmers, scarcity fertilizer, experiencing delays in seed and fertilizer supply, running out of stock, decreasing the amount of harvest, damage to machinery and equipment when harvesting, experiencing problems during the rainy season, risks related to government policies, risks related to competition with imported shallots, and risks related to post-harvest handling.

Table 2 also shows that the risks faced by middlemen (distributors) shallots are experiencing a change in orders from retailers, competitors with other distributors, shallots quality decline, delays in the supply, having out of stock, the associated risks competition with imported shallots, and experiencing shallots stockpiles. The risks faced by shallots retailers are experiencing changes in orders from consumers, having competition with other retailers, decreasing shallots quality, experiencing delays in the supply of shallots, and having out of stock when there is an order.

Table 2. Results of expert evaluation with FMEA.

Supply Chain Agents	Identified Risk	S	O	D	RPN
Supplier	Risk of experiencing land shortages	7	7	5	12.005
	The risk of experiencing an order change from the distributor	6	7	5	15.33
	Risk of incompatibility of seeds/varieties	8	6	6	21.024
	The risk of increasing the price of seeds/varieties	7	6	5	3.15
	Risk of competitors from other regional farmers	8	7	5	20.44
	Risk of experiencing scarcity of fertilizer	7	7	5	3.675
	The risk of experiencing delays in the supply of seeds and fertilizer	8	6	5	17.52
	The risk of experiencing out of stock when there is an order	7	6	6	18.396
	The risk of decreasing the amount of harvest	9	6	5	19.71
	Risk of damage to machinery and equipment when harvesting	7	6	6	0.756
	The risk of experiencing problems during the rainy season	8	7	4	16.352
	Risks related to government policies	8	7	8	74.816
	Risks related to competition with imported shallots	8	7	7	65.464
	Risks related to post-harvest handling	7	6	5	15.33
Middleman	The risk of experiencing an order change from the retailer	5	5	5	10.875
	Risk of competitors with other distributors	6	7	4	28.056
	The risk of decreasing the quality of shallots	6	6	4	19.152
	Risk of delays in the supply of shallots	5	5	5	16.625
	The risk of experiencing out of stock when there is an order	5	6	6	23.94
	Risks related to competition with imported shallots	7	7	5	52.43
	The risk of experiencing a buildup of shallots stock	6	5	5	19.95
Retailers	Risk of experiencing changes in orders from consumers	5	5	5	20.875
	Risk of competitors with other retailers	7	8	6	84
	The risk of decreasing the quality of shallots	6	6	5	30.06
	Risk of delays in the supply of shallots	6	4	4	16.032
	The risk of experiencing out of stock when there is an order	6	6	5	44.82

3.4. Priority strategy

ANP processing results using Criterium Decision Plus software produced weight and priority strategies that influence the determination of shallots supply chain risk mitigation strategies in Batu City, East Java, as shown in Table 3.

Table 3. Priority strategies for determining mitigation strategies.

No.	Factor	Weight	Priority
1	Choose the right variety	0.391	1
2	Maintain quality	0.161	2
3	Increase promotion	0.135	3
4	Establish partnerships	0.133	4
5	Maintain supply	0.097	5
6	Maintain price stability	0.083	6

Based on the Table 3, there are six mitigation strategies where the highest priority was on the strategy of selecting the right variety. Then followed by strategies to maintain quality, increase promotion, establish partnerships, maintain supply and maintain price stability.

4. Conclusion

Priority risk for farmers (suppliers) was risks related to government policies of imported shallots. The priority risk for distributors (distributors) was the risk associated to the competition with imported shallots, and the priority risk for retailers was the competition with other retailers. There were three strategies, based on their high priority rank, can be used to mitigate those risks include choosing the right variety, establishing partnerships, and increasing promotion.

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