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Risk assessment of supply chain of hybrid corn

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Abstract. The supply chain network of hybrid corn collaborating with more than a thousand farmers and retailers are facing many risks. This paper identifies and investigates the risks of supply chain using House of Risk method. It begins with development of the activity mapping of supply chain actors of hybrid corn. Then, the possible risks in the supply chain of hybrid corn are identified from related studies and validated by industry and academic experts. Finally, the risk analysis is conducted to determine the severity and occurrence of the risks. Based on the results, identified a total of 38 risk events and 36 risk agents in the supply chain of hybrid corn. In addition, a total of 22 risk agents according to the value of Aggregate Risk Potential are selected and prioritized. The results indicate the changes in weather as the most risks agent occurred in the supply chain of hybrid corn. This study hoped can aid the supply chain actors of hybrid corn to prioritize the proactive actions as well as to reduce the aggregate impacts of risks occurred.

1. Introduction

Agricultural supply chain is generally a very complex system due to the product characteristics as well as the nature of production process. The agricultural supply chain is facing many risks related to weather, natural disasters, biological and environmental, market, logistics and infrastructural, management and operational, public policy and institutional, and political [1]. Thus, it is necessary to assess the potential risks occurred in the agricultural supply chain. Assessing the risk level related to supply chain in which organization operates is a crucial step in the supply chain risk management [2].

Risk is a function of the degree of uncertainty and impact of an event [3]. Understanding and managing risk in the supply chain has become an important issue for companies. Risk management in the supply chain is allied to costs; therefore it is needed to manage the risks and to identify the sources of risks [4]. Supply chain risk management is intended to reduce the likelihood of occurrence of risk events and to increase the ability to recover from a disruption [5]. In order to survive in the current risky business environment, it is vital for a company to have an appropriate supply chain risk management.

Corn has become the second most important food crop after rice in Indonesia [6]. Corn is a versatile crop and also the second largest contributor to GDP in the food crop sector [7]. In order to meet the needs of national corn, Indonesian government has implemented a project of corn cultivation, known as hybrid corn. A large supply chain network of hybrid corn, collaborating with more than a thousand farmers and retailers will face many risks. The difference of corn quality from suppliers is one of the potential risks can be occurred in the supply chain of hybrid corn. In additions, fluctuations in demand and price are also become the high risks for each of the actors in the supply chain of hybrid corn. Weather changes are the risks for the farmers. Lack of skill and knowledge to the corn cultivation process can also be the risks for the manufacturers. The distance of location of each of the

actors of supply chain will also pose several risks. These risks include traffic accidents, shipping delays, and high transportation costs, especially for both the distributors and the retailers.

Risks that may arise in the supply chain of hybrid corn can be managed by applying supply chain risk management. Therefore, an appropriate risk management is required to achieve a higher profit for all actors in the supply chain of hybrid corn. This paper aims to identify and investigate the potential risks amongst the supply chain actors of hybrid corn. House of risk method is applied to determine the severity of risk events and the occurrence of risk agents. The risk agents are then prioritized according to the Aggregate Risk Potential (ARP) values.

2. Methodology
This research is conducted using the House of Risk method consists of three main stages.

2.1 Supply chain activity mapping
In this stage, activity mapping is conducted to each of the actors involved in the supply chain of hybrid corn. Activity mapping is aimed to determine the relationships among the actors in the supply chain of hybrid corn.

2.2 Risk identification
The second stage is to identify the possible risks in the supply chain of hybrid corn. Risk identification is aimed to understand the source of risks, the existence of risks, how those risks arise, why those risks can occur, as well as the impact of the risks that affecting the supply chain of hybrid corn. The initial list of risk events and risk agents are identified from the review of related studies. It mostly adopted from [8]. Then, each of the actors in the supply chain of hybrid corn is consulted to determine and identify the possible risks on each stage. In this step, the initial list of risk events and risk agents have modified and improved. Finally, the list of risk events and risk agents is then validated by four industry and academic experts.

2.3 Risk analysis
Risk analysis is conducted to find out the causes of severity dan occurrence of the priority risks. For that purpose, Failure Mode and Effect Analysis (FMEA) method is applied. A questionnaire is then developed based on the list of risk events and risk agents obtained from the previous stage. Each of the actors of the supply chain of hybrid corn is consulted to determine the severity and occurrence values. The severity value describes risk events assessment, while the occurrence value describes risk agents assessment. The scale used ranging from 1 to 10. The severity and occurrence values are used to determine the correlation value between the risk event and risk agent. The correlation of the risks is assessed by four industry and academic experts. The correlation level is typically classified as 0 = none, 1 = low, 3 = moderate, and 9 = high [5]. Based on the values of severity, occurrence, and correlation, the Aggregate Risk Potential (ARP) value is then calculated for each of the risks in the supply chain of hybrid corn using the following equation [5]:

$$ARP_j = O_j \sum_i S_i R_{ij} \tag{1}$$

Descriptions:
ARP_j = aggregate risk potential of risk agent j
O_j = probability of occurrence of risk agent j
S_i = severity of impact if risk event i occurred
R_{ij} = correlation between risk agent j and risk event i

The Aggregate Risk Potential (ARP) values are then ranked and presented in the graphics using Pareto Diagram. The risks are classified into three classes of A, B, and C [9]. The classification also based on Pareto Curve 80:20, where 80% (in class A and B) of total risk agents have described the overall risk agents [10].

3. Results and discussions

3.1 Supply chain activity mapping

The supply chain network of hybrid corn consists of six actors i.e., supplier of raw corn (farmers), supplier of fertilizer and medicines (CV UT), manufacturer of cultivation corn (PT CNM), distributor (PT PB), retailers, and consumers. The supply chain network of hybrid corn can be seen in Figure 1.
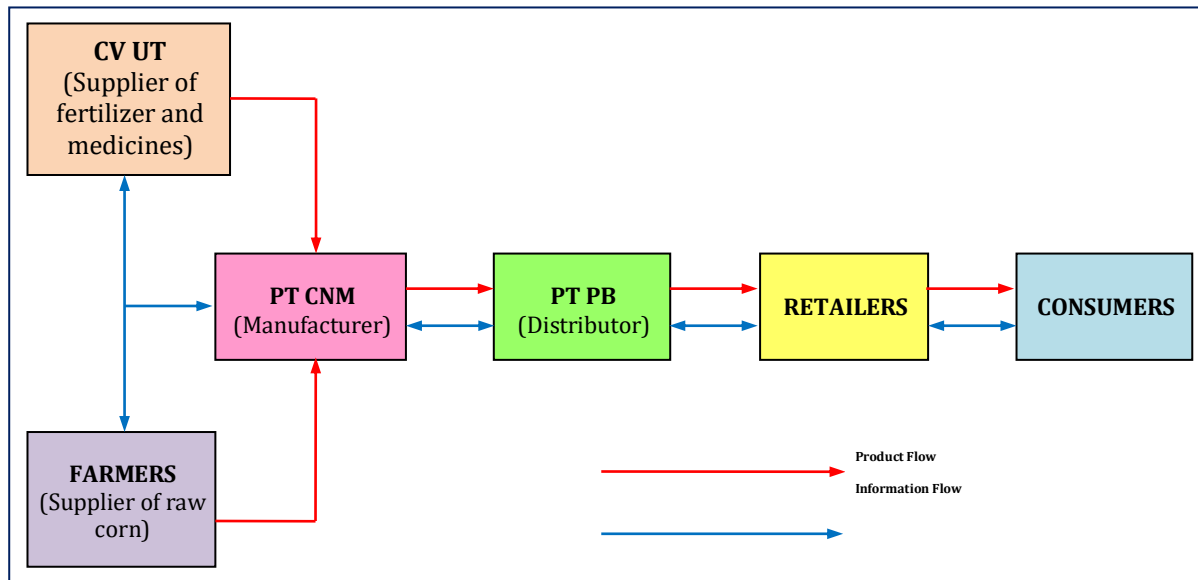
Figure 1. Supply chain network of hybrid corn

The supply chain of hybrid corn started with the cultivation process by the farmers in Paninggahan area (a total of 84 farmers) using chemical supplies and fertilizer supplied from CV UT. After the harvest time, raw corn will be processed in PT CNM using the conventional method. It depends on the employee skills to produce the final product (hybrid corn). The final product (hybrid corn) will be distributed to PT PB as a government institution of hybrid corn distributor in Indonesia. PT PB distributes the hybrid corn to some retailers in several areas. There are 7 retailers located around Bukittinggi city and Batusangkar city. These retailers will directly related to consumers as the final actor of the supply chain of hybrid corn.

3.2 Risk identification

In this stage, based on the literature study and validation process, it obtained a total of 38 risk events and 36 risk agents in the supply chain of hybrid corn. Of the 38 risk events, five risks are associated to Supplier (CV UT), nine risks to Farmers, ten risks to Manufacturer (PT CNM), six risks to Distributor (PT PB), five risks to retailers, and three risks to consumers as presented in Table 1.

The 36 risk agents are divided into five risks related to Supplier (CV UT), nine risks to Farmers, eight risks to Manufacturer (PT CNM), six risks to Distributor (PT PB), four risks to retailers, and four risks to consumers as shown in Table 2.

3.3 Risk analysis

In this stage, the severity of each of the risk events and the occurrence of each of the risk agents are assessed. The severity values of the risk events in the supply chain of hybrid corn are presented in Table 3. The results show the highest severity in overall is plants infected with pests (E14) with a value of 7.96. It followed by low corn productivity (E9) and delay in transshipment (E25) with a value of 6.80 and 6.00 respectively.

Table 1. Risk events in supply chain of hybrid corn

Actor	Code	Risk Event
Supplier (CV UT)	E1	Limited stock
	E2	Production process not in schedule
	E3	Product return by consumer
	E4	Shipping errors
	E5	Product delivery delay
	E6	Availability of vaccine limited to one time of harvest
	E7	Fluctuation of hybrid corn price
	E8	Fluctuation of seed price
Farmers	E9	Low corn productivity
	E10	Post-harvest damage
	E11	Wrong time in planting
	E12	Low quality of corn
	E13	Availability of fertilizers
	E14	Plants infected with pests
	E15	Differences of corn quality
	E16	Additional drying in production process
	E17	Growth of Aflatoxin fungus because of humid storage
	E18	Poor quality of hybrid corn
Manufacturer (PT CNM)	E19	Low quality of corn from suppliers
	E20	Supplier loyalty
	E21	Production process not in schedule
	E22	Limited production capacity
	E23	Exchange rate and bank interest
	E24	Fluctuation of hybrid corn demand
	E25	Delay in transhipment
	E26	Probability of accident in distribution process
Distributor (PT PB)	E27	Product damage
	E28	Limited transport capacity
	E29	Long process when handover product
	E30	Damage on road that affect product quality
	E31	Limited stock
	E32	Consumers purchase directly to distributor
Retailers	E33	Occurrence of product return by consumer
	E34	Fluctuation of hybrid corn price
	E35	Delay in arrival of hybrid corn to store
	E36	Fluctuation of hybrid corn price
Consumers	E37	Availability of hybrid corn in market
	E38	Insufficient consumer needs because of availability of corn

In term of supplier, the product delivery delay (E5) is identified as the most important risk in the supply chain of hybrid corn. Plants infected with pests (E14) is identified as the highest severity for the farmers. Pests attack is a big problem for the farmers since it potentially causes the failure of corn harvest. The highest severity of manufacturer is supplier loyalty (E20). Supplier loyalty indicates any possible fraud during planting, harvesting or shipping. It highly affects the quality of corn. The delay in transshipment (E25) is determined as the highest severity for the distributors in the supply chain of hybrid corn. This is due to the distance of location between the distributors and the retailers.

In term of retailers, the highest severity value is fluctuation of hybrid corn price (E34). Fluctuations in hybrid corn prices can be caused by the habits of farmers who do not use the planting schedule considering the needs and availability of corn on the market. This causes the fluctuations in the price of corn, due to the uncertainty of corn availability in the market and its overflow during the harvest. Insufficient consumer needs because of availability of corn (E38) is identified as the most important risk for the consumers. Consumers are usually using corn as the main ingredient on their business. Therefore, if the amount of corn is not sufficient, it will disrupt their business.

Table 2. Risk Agents in Supply Chain of Hybrid Corn

Actor	Code	Risk Agent
Supplier (CV UT)	A1	Ordering process not in schedule
	A2	Availability of ordered materials
	A3	Accuracy of delivery and receipt document
	A4	Wrong amount of ordered product
	A5	Merger product in shipping process
Farmers	A6	Changes in weather
	A7	Lack of knowledge in cultivation
	A8	Seasonal demand factors
	A9	Occurrence of natural disasters
	A10	Government policies (such as increase in fuel prices)
	A11	Lack of accessibility in pricing information
	A12	Quality of soil
	A13	Lack of capital for production requirement
	A14	Incorrect selection of planting schedules
	A15	Changes in weather
	A16	Government policies (such as increase in fuel prices)
Manufacturer (PT CNM)	A17	Damage of production tools
	A18	Use of conventional technologies
	A19	Limited storage
	A20	Lack of employees skill
	A21	Competitor Product
	A22	Ordering process not in schedule
Distributor (PT PB)	A23	Incorrect selection of transport routes
	A24	Government policies (such as increase in fuel prices)
	A25	Human error at delivery process
	A26	Seasonal demand factors
	A27	Changes in weather
	A28	Distance of marketing area
Retailers	A29	Ordering process not in schedule
	A30	Less number of products ordered
	A31	Uncertainty of consumer demand
	A32	Government policies (such as increase in fuel prices)
	A33	Government policies (such as increase in fuel prices)
Consumers	A34	Purchase directly to distributor
	A35	Seasonal conditions (such as Ramadhan/Eid Mubarak)
	A36	Changes in weather

The occurrence assessment is then conducted to obtain the risks occurrences frequency and assess the likelihood of occurrence of each of the risk agents. The occurrence values of the risk agents in the supply chain of hybrid corn are presented in Table 4. The results show for both the retailers and distributors identified in overall the government policies (such as increase in fuel prices) (A24 and A32) as the highest occurrence with a value of 8.33 and 7.71 respectively. It followed by changes in weather (A15) and competitor product (E21) with a same value of 7.67.

In term of supplier, the ordering process not in schedule (A1) is suggested as the major cause of the risks of supplier in the supply chain of hybrid corn. Changes in weather (A6) is suggested as the highest occurrence for the farmers. It possible to obstruct the production process of the farmers because of the plant is very sensitive to weather. The harvest time usually occurred in the rainy season, thus the farmer will be difficult to conduct the drying process in order to be able to meet the quality standards. The highest occurrence values for manufacturer are changes in weather (A15) and product competitor (A21). PT CNM uses the conventional method in production process of the raw corn into the hybrid corn. The production process highly depends on the weather, especially on the drying process. If corn is too wet or too dry, it will decrease the genetic quality of corn.

Table 3. Severity values of risk events

Actor	Risk Event Code	Severity value
Supplier (CV UT)	E1	1.33
	E2	2.33
	E3	2.67
	E4	2.67
	E5	3.33
	E6	4.57
	E7	3.65
	E8	3.72
Farmers	E9	6.80
	E10	4.65
	E11	3.87
	E12	5.76
	E13	4.91
	E14	7.96
	E15	4.00
	E16	2.67
	E17	4.00
	E18	4.33
Manufacturer (PT CNM)	E19	3.33
	E20	5.33
	E21	3.00
	E22	3.33
	E23	3.33
	E24	4.33
	E25	6.00
	E26	3.33
Distributor (PT PB)	E27	4.33
	E28	3.00
	E29	4.33
	E30	4.33
	E31	4.86
	E32	3.86
Retailers	E33	5.14
	E34	5.29
	E35	5.00
	E36	4.11
Consumers	E37	4.32
	E38	4.47

The government policies (such as increase in fuel prices) (A24) is identified as the highest occurrence for the distributors in the the supply chain of hybrid corn. The increasing fuel prices will affect the transportation costs. Increasing transportation costs also have an impact on the increase in the price of hybrid corn. In term of retailers, government policies (such as increase in fuel prices) (A31) has the highest occurence value. Similar to distributors, government policies (such as increase in fuel prices) has also affect the fluctuation price of hybrid corn for the retailers due to the increasing the transportation costs. The changes in weather (A36) is identified as the highest occurrence for the consumers. Similar to farmers, the plant is very sensitive to the weather, so if consumers buy products in the rainy season it will be difficult to produce the hybrid corn.

The next step is determining the correlation between risk events and risk agents in the supply chain of hybrid corn. Based on the values of severity, occurrences, and correlation, then calculated Aggregate Risk Potential (ARP) for each of the risks in the supply chain of hybrid corn. The Aggregate Risk Potential (ARP) values of the risks in the supply chain of hybrid corn are then ranked in descending order. The ranking of risks based on the ARP is presented as Pareto diagram in Figure 2. It can be seen the changes in weather (A6 and A15) is identified as the highest ARP with a value of

989.20 and 917.44. It followed by uncertainty of consumer demand (A31), and occurrence of natural disasters (A9) with a value of, 760.20, and 747.19 respectively. These high priority risks can be used to determine the preventive actions to minimize the risks in the supply chain of hybrid corn.

Table 4. Severity values of risk agents

Actor	Risk Agent Code	Occurence value
Supplier (CV UT)	A1	6.67
	A2	6.00
	A3	4.67
	A4	4.67
	A5	2.67
	A6	7.22
	A7	2.48
	A8	2.78
Farmers	A9	4.33
	A10	4.43
	A11	2.22
	A12	2.41
	A13	4.00
	A14	2.54
	A15	7.67
	A16	6.67
	A17	3.33
Manufacturer (PT CNM)	A18	4.67
	A19	3.00
	A20	3.67
	A21	7.67
	A22	2.67
	A23	4.00
	A24	8.33
Distributor (PT PB)	A25	4.00
	A26	4.67
	A27	4.00
	A28	5.33
	A29	5.57
Retailers	A30	4.71
	A31	7.14
	A32	7.71
	A33	4.05
Consumers	A34	1.21
	A35	3.21
	A36	4.74

4. Conclusions

This paper has identified the possible risk events and risk agents in the supply chain of hybrid corn. Then, the severity and the occurrence of those risks are determined. The results show plants infected with pests is identified as the highest severity level, followed by low corn productivity and delay in transhipment. In term of occurrence level, the government policies (such as increase in fuel prices) is suggested as the highest occurrence in the supply chain of hybrid corn for both the retailers and distributors, followed by changes in weather and competitor product. Changes in weather is identified as the highest priority risk followed by uncertainty of consumer demand and occurrence of natural disasters. Future research will incorporate these results to determine the preventive actions suggested to be implemented in improving the performance of the supply chain of hybrid corn.
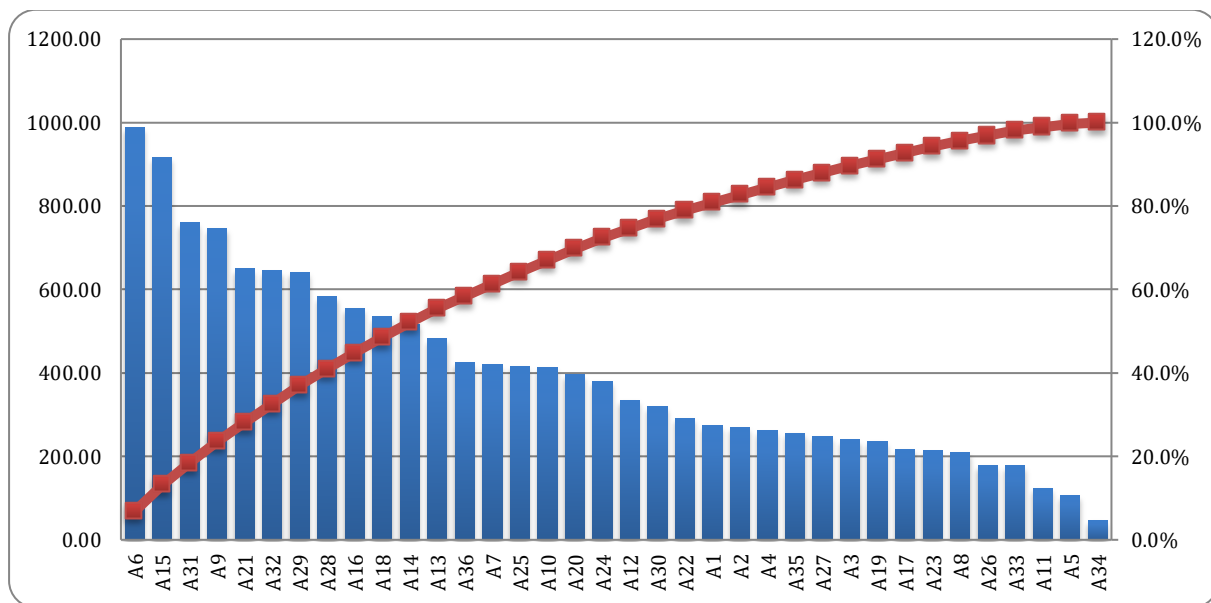
Figure 2. Aggregate risk potential values

Acknowledgments

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