Risk and Supply Chain Mitigation Analysis Using House of Risk Method and Analytical Network Process

Shelvy Kurniawan[1]*; Denny Marzuky[2]; Rio Ryanto[3]; Vanny Agustine[4]

[1,2,3,4] Management Department, BINUS Business School Undergraduate Program, Bina Nusantara University
Jl. Kebon Jeruk Raya No. 27, Kebon Jeruk, Jakarta 11530, Indonesia
[1]shelvy.kurniawan001@binus.ac.id; [2]dennymarzuky1997@gmail.com;
[3]rioryanto9@gmail.com; [4]vanny.agustine28@gmail.com

Abstract - The research studied PT XYZ, a company engaged in the palm oil industry which has eleven subsidiaries spread across five provinces in Indonesia. The research focused on analyzing supply chain risks in PT A, a subsidiary of PT XYZ. The objective was to find out and reduce unexpected costs that the company may experience caused by the risks in supply chain. Furthermore, the aim was to determine priority of risk agents and risk mitigation actions. The research method was a mixed methods, which combined both qualitative and quantitative analysis to answer the research questions. Data analysis procedure involved Supply Chain Operations Reference (SCOR), House of Risk (HOR) 1, and Analytic Network Process (ANP). The SCOR method was used for mapping supply chain activities, the HOR 1 was to determine the priority of the risk agent, and the ANP was to determine the priority of mitigation actions. The results show that there are 36 risk events and 35 risk agents. 19 risk agents are categorized as priority risks and 11 preventive actions are proposed to be implemented by PT XYZ. The research suggests that the company implement mitigation actions according to priority in accordance with the research results.

Keywords: risk analysis, supply chain analysis, mitigation analysis, House of Risk (HOR), Analytical Network Process (ANP)

I. INTRODUCTION

Competition in the current era of globalization is very high. This can be seen from the number of companies that have emerged, developed, grown, and competed in their respective fields. Based on data from the Central Statistics Agency, the number of companies in Indonesia was recorded at 26,7 million in 2016 (Agustinus, 2017). This figure increased by 3,98 million when compared to the number of companies in 2006. With intense competition, companies must be able to maintain busines processes and provide their best products or services. Companies strive to manage risk, handle unexpected disruptions, and improve performance in an uncertain and changing business environment (Munir et al., 2020). Furthermore the company is facing a higher risk in terms of supply disruptions, production, delivery delays, etc. which in turn results in lost reputation, lost sales, and bad financial performance (Sreedevi & Saranga, 2017). An understanding of how to comprehensively mitigate and respond to supply chain risk reveals additional research challenges in supply chain management (Kilubi, 2016). In order to remain competitive in supply chain ecosystem, one way is to pay attention to supply chain management. The supply chain ecosystem is the network environment in which the system operate (Macdonald et al., 2018).

Supply chain management includes all movement and storage of raw materials, work in process inventory, and finished goods from point of origin to point of consumption (Mavi et al., 2016). The supply chain is to add value to the product by moving it from one location to another, or by carrying out a process of changing it (Setiadi, Nurmalina, & Suharno, 2018). Regarding the risks in supply chain, supply chain risk management includes a wide variety of strategies aimed at identifying, assessing, mitigating, and monitoring unforeseen events that may have an impact, mostly adversely, on any part of the supply chain (Baryannis et al., 2019).

At a strategic level when dealing with Supply Chain Management, it can guide the company

in redesigning its corporate culture, processes, organizational structure among others and recognizing the general impact of supply chain management on business performance (Min, Zacharia, & Smith, 2019). Related to supply chain management, currently companies are increasingly responsible for the environmental, social and economic outcomes caused by their internal operations and by the operations of their suppliers (Koberg & Longoni, 2019).

In the supply chain, there are various risks that may occur. Based on Australian New Zealand Standard in (Anggrahini, Karningsih, & Sulistiyono, 2015) risk is an unexpected effect of a certain goal. Risk itself is often defined as a function of the probability and consequences of an uncertain outcome (Boonyanusith & Jittamai, 2019). Many companies increase their exposure to risk by having partners in business critical position in their supply chain (Finch, 2004). According to Elvandra, Maarif, & Sukardi (2018) supply chain risk is all risks from the flow of information, materials, and products or disruption caused by the complexity of the company's relationship with external parties. Supply chain risk management is done through coordination or collaboration among supply chain partners to ensure profitability and continuity (Tang, 2006), while attempts to assess risk accurately across organizational boundaries are hindered by the absence of a consistent set of risk metrics (Shi, 2004).

PT XYZ is a company engaged in the palm oil industry and has eleven subsidiaries spread across five provinces in Indonesia, namely North Kalimantan, West Kalimantan, East Kalimantan, Central Kalimantan, and South Sumatra. PT XYZ was found in 2016. For approximately 3 years since its establishment, it is known that PT XYZ has never evaluated its supply chain process. In carrying out its supply chain activities, this company often experiences problems from the procurement, production, to delivery processes. In the research, supply chain analysis was focused on PT A, a subsidiary of PT XYZ which is located in the province of Central Kalimantan as presented in Table 1.

A supplier is a company or individual capable of providing resources, either in the form of goods or services needed by other companies (Viarani & Zadry, 2015). Currently, PT A has local and foreign suppliers. Suppliers who work with the company are suppliers for raw materials or materials used in plantation and factory operations. PT A is also working with local palm oil companies to supply fresh fruit bunches (FFB) to increase crude palm oil (CPO) and palm kernel (PK) production to match the supply demands of other companies. This business model can also be called B2B (Business to Business), a term used for commercial transactions between business people. Delivery is the process of distributing finished goods and services to meet consumer needs. This process includes order management, warehouse management such as product packaging according to company procedures, transportation management such as making deliveries with the right and on time transportation to meet planned needs (Putradi, 2017). For CPO produced by PT A, the company uses a third party service as a barge provider to load and deliver CPO to consumers in Batam, Riau Islands. Meanwhile, for PK produced by PT A, the company uses its own truck units to be sent to consumers in the South Kalimantan area.

For now, PT A has collaborated with several suppliers, including fertilizer suppliers, chemical suppliers (pest exterminators), and FFB suppliers. The problem that often occurs related to supplier operations to PT A is the problem of late delivery of the ordered materials as presented in Table 2.

Table 3 shows that the data on fruit production and outside fruit acceptance (suppliers) in 2017 and

Table 1 Comparison of PT XYZ Group Subsidiary Data

PT XYZ Group					
PT	**Estate**	**Mill**	**Afdeling**	**Area (Ha)**	**Number of Employees**
PT A	4	2	28	17.469	3.397
PT B	4	2	22	12.166	2.848
PT C	2	0	8	7.640	972
PT D	2	1	11	5.999	881
PT E	1	1	8	5.929	844
PT F	1	1	8	5.925	803
PT G	1	0	9	4.713	619
PT H	1	1	6	4.217	573
PT I	2	1	6	4.009	489
PT J	1	0	6	3.648	422
PT K	1	1	5	3.559	407

Sumber : PT XYZ (2019)

2018 did not reach the capacity set by the company. In 2017, the achievement of fruit capacity was 84,69%, which then decreased to 83,31% in 2018.

The fruit achievements described have an impact on PT A's annual CPO and Kernel production. In Table 4, it can be seen that the achievement of CPO oil production in 2017 was only 80,66% and Kernel 80,53%. In 2018, the achievement of CPO production decreased to 78,60% and Kernel dropped to 78,29%. Apart from being caused by the large number of fruit being processed, the achievement of this oil production is also caused by several factors such as the level of fruit maturity, machine breakdowns, and human negligence in the process. These achievements have indirectly impacted the process of sending CPO to consumers in Batam, Riau Islands and Kernel areas to consumers in the South Kalimantan area. As seen in Table 5, for CPO shipments, there are 2 delays out of a total of 7 shipments in 2017 and 2 times a delay out of a total of 8 shipments in 2018. For Kernel shipments, there are 4 times the delay out of a total of 35 shipments in 2017 and 6 times delays out of a total of 36 shipments in 2018. One of the reasons for this delay is the lack of CPO and Kernel produced by PT A in a certain period, so they have to wait a few days later to reach the quantity ordered by consumers. Other factors that can impact delivery delays include engine breakdowns at factories, vehicle unit breakdowns,

negligence in the oil processing process, and weather for distribution.

The delay in delivery is one of the factors causing product damage that is sent to consumers of each product. Table 6 provides data on damaged products sent by PT A in the period January 2017 to December 2018. In accordance with company policy, products that have been damaged will not be taken back by the company, and payment regulations are only made for products that are in good condition.

Companies need to realize the importance of building a good supply chain network to prevent risks that can reduce company revenues. Therefore, steps that can be taken by PT A is to evaluate supply chain performance from the starting point of planning to consumers and assess whether the performance of the supply chain currently implemented is effective and efficient so that the company's competitiveness can be improved.

Anggrahini et al. (2015) examine problems in the supply chain of frozen shrimp products. The research uses the Supply Chain Operations Reference (SCOR) and House of Risk (HOR) methods. The results shows there are 41 risk events and 52 risk agents, 11 of which are categorized as priority risks and 12 mitigation actions are proposed to be implemented. Ratnasari, Hisjam, and Sutopo (2018) examine problems in the supply chain of printing companies. This study uses

Table 2 Data on PT A Material Receipts for the Period Jan 2017 - Dec 2018

Type of Goods	Total Receipts	Number of Late Receipts	Percentage of Late Receipts
Fertilizer	91	22	24,18%
Chemical	15	4	26,67%
Outer FFB	243	31	12,76%

Source: PT XYZ (2019)

Table 3 Data of Production and Receipt of PT A Fruit for 2017 - 2018

	2017			2018		
	Actual (Ton)	Target (Ton)	Target Achievement	Actual (Ton)	Target (Ton)	Target Achievement
Core Fruit	136.688,14	164.273	83,21%	145.936	179.188	81,44%
Outer Fruit	40.798,19	45.291	90,08%	45.332,23	50.388	89,97%
Total	177.486	209.564	84,69%	191.268	229.576	83,31%

Source: PT XYZ (2019)

Table 4 PT A's CPO and Kernel Production 2017 - 2018

	CPO Production at PT A (Ton)			Kernel Production at PT A (Ton)		
	Actual (Ton)	Target (Ton)	Target Achievement	Actual (Ton)	Target (Ton)	Target Achievement
2017	39.721,44	49.247,54	80,66%	5.360,09	6.655,74	80,53%
2018	42.404,17	53.950,36	78,60%	6.139,71	7.842,00	78,29%

Source: PT XYZ (2019)

Table 5 CPO and Kernel Delivery Data for the 2017 - 2018 Period

	CPO			Kernel		
	Delivery Frequency	Late Delivery Frequency	Percentage of Late Shipments	Delivery Frequency	Late Delivery Frequency	Percentage of Late Shipments
2017	7	2	28,57%	35	4	11,43%
2018	8	2	25,00%	36	6	16,67%

Source: PT XYZ (2019)

Table 6 Data on Products Received by Consumers in 2017 - 2018

Tahun	CPO			Kernel		
	Quantity Delivered (Ton)	Quantity Rejected (Ton)	Quantity Accepted (%)	Quantity Delivered (Ton)	Quantity Rejected (Ton)	Quantity Accepted (%)
2017	38.300	2.849	92,56%	5.292	244	95,39%
2018	43.700	4.107	90,60%	6.070	371	93,89%

Source: PT XYZ (2019)

the SCOR and HOR methods. The results contains 24 risk events and 20 risk agents, two of which are categorized as priority risks and 9 mitigation actions are proposed to be implemented. The HOR model is based on the proactive assumption that supply chain risk management should try to focus on preventive measures, namely reducing the possibility of risk agents and models capable of determining which risk agents have the greatest potential to cause risk events (Hartono, Christiani, & Lasiman, 2018). Furthermore, according to Chotimah, Purwanggono, and Susanty (2017), the SCOR Model includes an assessment of delivery and demand fulfillment performance, inventory and asset management, production flexibility, warranties, process costs, and other factors that affect the overall performance assessment of a supply chain. According to APICS, the framework of SCOR model is divided into Plan, Source, Make, Deliver, Return, and Enable (Ben-Daya, Hassini, & Bahroun, 2017).

Ramadhani and Baihaqi (2018) analyze the correlation relationship by combining two methods, namely the Analytic Network Process (ANP) and House of Risk (HOR) methods. The end result of the two methods finds that there are 30 causes or sources of risk and 13 critical risks that have 28 risk management strategies with 15 priority strategies that can be implemented by the company. Ratnasari et al. (2018) map risks in printing companies and formulate risk mitigation alternatives to reduce risk. HOR method is chosen to select a series of proactive actions that are considered cost-effective in managing supply chain risk in newspaper companies. Laksmita and Widodo (2018) use House of Risk method to mitigate risks and successfully identify four priority risks, namely A8 (car problems), A4 (human error), A3 (error deposits through banks and underpayments), and A6 (past accidents cross) that must be reduced.

The initial stage carried out is mapping supply chain activities. The mapping of supply chain activities at PT A is obtained by conducting interviews with related parties in the company. The interview is held directly to the Operations and Budgeting Senior Manager of PT XYZ who is an expert in the field of operations at PT XYZ. Questionnaires are filled out by respondents at PT A who have the biggest role or responsibility related to the operations of PT A company, namely the General Manager of the Central Kalimantan Region. Next, PT A's supply chain activities are mapped in the SCOR model. SCOR is an approach method for measuring the performance of a supply chain developed by the SCC (Supply Chain Council), which was formed in 1996 (Putradi, 2017). SCOR method is used since this method can classify supply chain activities into five processes, namely Plan (planning process), Source (procurement process), Make (production process), Deliver (delivery process), and Return (return process) so that activity mapping can be made more structured. The SCOR model is very effective as a frame of reference for identifying supply chain performance metrics in five important activities in supply chain management (Kusmantini, Guritno, & Rustamaji, 2015).

The next stage is the data processing stage which includes risk analysis. In data processing, there are several methods such as Failure Mode and Effect Analysis (FMEA) and HOR. FMEA is a structured procedure to identify and prevent as many failure modes as possible. From the mapping of supply chain activities using the SCOR method, brainstorming is carried out to find out various forms of risk events that occur. FMEA has widely used techniques to identify and eliminate potential failures to improve system security and reliability (Ghadge et al., 2017). After that, the risk assessment is calculated through the calculation of the Risk Priority Number (RPN) obtained from

multiplying three factors, namely the level of damage produced (Severity), the probability of risk occurrence (Occurrence), and the level of possibility of detection (Detection) for each risk event and prioritizing risky events that require further treatment (Hapsari, 2018). Meanwhile, the HOR method according to Pujawan and Geraldin in Putri (2017) is a modification of the House of Quality (HOQ) and Failure Mode and Effects Analysis (FMEA) methods to compile a framework for managing supply chain risk.

In HOR method, a risk agent that has a high Aggregate Risk Potential (ARP) is selected, which means that the risk agent has a high probability of events and causes many risk events with severe impacts. Then, mitigation actions are prepared for selected risk agents based on the ratio of total effectiveness for the level of difficulty and mitigation actions that can reduce many risk agents with high ARP values (Cahyani, Pribadi, & Baihaqi, 2016). Brainstorming with the company is carried out to examine risky events that occur. In contrast to the FMEA method, the HOR 1 method calculates ARP which is obtained from three factors, namely the level of risk source probability, the impact of damage to risk events, and the level of relationship between risk events and risk sources. One risk agent can induce multiple risk events, and vice versa, thus the HOR 1 method is chosen since it is considered more effective than the FMEA method by considering the level of the relationship between risk events and risk agents.

After the risk analysis stage, the next stage is the risk management stage by looking for mitigation action priorities. In this stage, there are several methods such as HOR 2, Analytical Hierarchy Process (AHP), and Analytical Network Process (ANP). The HOR 2 method is used for taking effective action to reduce the probability of a risk agent (Putri, 2017). In the HOR 2 method, the calculation of the ratio of effectiveness to level of difficulty is based on three factors, namely the level of effectiveness of mitigation actions, the level of difficulty to be implemented, and the level of relationship between risk agents and mitigation actions using AHP. Thomas L. Saaty engineered a major breakthrough in the 1970s by formulating the AHP (Baffoe, 2019; Chan, Sun, & Chung, 2019). It is a method for making a sequence of alternative decisions and selecting the best alternative. The AHP method solves complex problem structures by dividing the parts into a hierarchy. Processing is carried out with a pairwise comparison matrix (Sasongko, Astuti, & Maharani, 2017). Another method that can be implemented at this stage is ANP method, which is the development of AHP for dependence feedback cases and generalizes to the supermatrix approach. It also allows interaction and feedback within clusters (inner dependence) and between clusters (outer dependence) for decision making (Adams & Saaty, 2016). ANP is a generalization of the AHP, by considering the dependence between elements of the hierarchy. Many decision problems cannot be structured hierarchically since they involve the interaction and dependence of

higher level elements in the hierarchy at lower level elements (Kusnadi, Surarso, & Syafei, 2016). Similar with AHP method, the ANP method also performs processing with a pairwise comparison matrix between criteria and alternatives. The ANP method is able to improve AHP's weaknesses in the form of the ability to accommodate linkages between criteria or alternatives (Pungkasanti & Handayani, 2017). The ANP method is also superior when compared to the HOR 2 method since the ANP method can adjust the number of assessment criteria for alternatives according to the research needs. Thus, the ANP method is chosen for the research as it provides a clearer and more detailed description of the implementation compared to the HOR 2 and AHP methods.

Analyzing supply chain performance using the HOR and ANP methods is needed to be able to provide solutions that can improve supply chain performance. The objectives of research are: 1) to identify risk events that have the potential to disrupt supply chain activities, 2) to determine the causes of risk (Risk Agent) that most influence the supply chain process by calculating the value of ARP, and 3) to determine the best strategy of mitigation (preventive action) carried out by PT XYZ, especially in the supply chain, to minimize risk by using the ANP method.

II. METHODS

The research applies mixed methods which aim to answer research questions that cannot be answered with qualitative or quantitative methods alone. Mixed methods research focuses on collecting, analyzing, and combining both quantitative and qualitative data in a single study or a series of studies (Sekaran & Bougie, 2016). This type of research is a descriptive research. Descriptive research is research whose aim is to obtain data that describes events to make systematic, factual descriptions or descriptions of facts and relationships between the phenomena being investigated to produce recommendations for future needs (Sekaran & Bougie, 2016).

The research is conducted by means of interviews and also distributing questionnaires to sources who best understand the company's supply chain. Interviews are conducted to determine the supply chain process series and also to analyze the risks that may occur in the supply chain process using the SCOR method. Results of the interviews shows that there are 36 risk events and 35 risk agents in the entire supply chain process. The questionnaire is distributed to one person who is considered to have the most responsibility for the operations of PT A. The first questionnaire is conducted to see how the severity of risk events and risk agent incidence rates and the level of relationship between risk events and risk agents. The results of the first questionnaire are processed using the HOR phase 1 method to find the impact resulting from each risk based on the ARP value. After the ARP value is obtained, the process continues to rank the risks from

the highest to the lowest ARP and divide these risks into 2 categories, which are priority and non-priority. Of the 35 risk agents, 19 are categorized as priority risk and 16 of them are categorized as non-priority risk. Next step is to design or propose mitigation actions against the 19 priority risks. Based on the results of the discussion, 11 mitigation actions and 3 assessment criteria are obtained, namely the level of difficulty, effectiveness, and cost, which are compiled into a second questionnaire. The second questionnaire is conducted to see how the proposed criteria and alternatives are related. The results of the second questionnaire are processed using the ANP method and the help of the Super Decision Software v 2.10 application to see the priority order of the proposed mitigation actions.

The research is expected to become a consideration or evaluation for the company to implement the research results in the form of a priority order of the proposed mitigation actions and apply the methods in the research in the future.

III. RESULTS AND DISCUSSIONS

From the results of interviews and activity mapping using the SCOR method, there are 36 risk events and 35 risk agents. Risk events are those that can disrupt supply chain activities at a company. Risk events are obtained from interviews with PT XYZ which are then coded using the letter E to facilitate further reading. Company risk events can be seen in Table 7.

Risk agents are things that can cause a risk event to occur so that it can disrupt supply chain activities at the company. The risk agent is obtained from the results of the interview which are then coded using the letter A which aims to facilitate further reading. The company's risk agent can be seen in Table 8.

These risks are processed into a questionnaire to determine the severity of risk events, risk agent incidence rates, and the relationship between risk events and risk agents. The results of the questionnaire are then processed using the HOR phase 1 method, and the risk order is obtained based on the highest to lowest ARP value as presented in Table 9.

Table 9 shows the order of risks based on the ARP value. These risks are categorized into two categories, namely priority and non-priority with the application of the Pareto theory. Risk agents that have an influence of 80% are categorized as priority risks and the result is 19 risks, while the rest are categorized as non-priority risks. Of the 19 prioritized risk agents, 11 mitigation actions are proposed to reduce the level of risk events in Table 10.

Table 7 Risk Events at PT XYZ

Activity	Sub-Activity	Risk Event	Code
Plan	Demand Forecasting	Improper forecasting of the number of requests	E_1
	Material Planning	Gap between recorded and available stock	E_2
	Production Planning	Sudden change in production plans	E_3
	Shipping Planning	Product delivery plan error	E_4
	Adjustment of Human Resources to Supply Chain Requirements	Incompatibility of existing resources with supply chain needs	E_5
Source	Supplier Selection	Improper supply ability	E_6
		The price offered exceeds the company budget	E_7
	Scheduling Product Delivery from Suppliers	Late delivery of products from suppliers	E_8
		Products damaged in transit	E_9
		Sudden need for goods	E_{10}
	Product Acceptance	Uneven maturity of FFB	E_{11}
		The number of products received did not match the agreement	E_{12}
		Lack of transport manpower on the day concerned	E_{13}
	Quality Checks	The quality of the product received is not up to standard	E_{14}
		There is damage to the product packaging	E_{15}
	Product Storage	Product damage while in warehouse	E_{16}
		Inadequate warehouse capacity	E_{17}
	Product Payment	There is a price change from the agreed price	E_{18}
		The company's inability to pay for the product	E_{19}
Make	Production Scheduling	Mistakes in making a production plan	E_{20}

Table 7 Risk Events at PT XYZ (Continued)

Activity	Sub-Activity	Risk Event	Code
	Production Process	Insufficient amount of raw material	E_{21}
		The quality of the fruit produced is not up to standard	E_{22}
		Unfulfilled fruit production targets	E_{23}
		Damage to factory machines	E_{24}
		Unfulfilled oil production targets	E_{25}
	Product Quality Check	The quality of the oil does not match the existing standards	E_{26}
	Product Storage	Oil quality deteriorates in storage	E_{27}
		There is a leak in the oil storage area	E_{28}
Deliver	Unit Preparation	Less / unavailable transportation	E_{29}
	Product Delivery	Late delivery of products	E_{30}
		Unit accident during delivery	E_{31}
	Product Acceptance	The number of products sent did not match the agreement	E_{32}
		The quality of the products shipped has decreased	E_{33}
	Product Payment	Late payment from consumers	E_{34}
		The nominal paid does not match	E_{35}
Return	Return of Defective Products to Suppliers	Late arrival of product replacement from suppliers	E_{36}

Source: PT XYZ (2019)

Table 8 Risk Agent in PT XYZ

Risk Agent	Code
Forecasting that does not pay attention to external factors	A_1
Seasonal factor	A_2
Information and communication errors	A_3
Error in supplier selection	A_4
There was damage to the transportation unit / machine	A_5
Bad weather	A_6
The transport truck has an accident on the way	A_7
There is a sudden demand from consumers	A_8
The occurrence of damage to goods in the warehouse	A_9
Workers only pursue daily targets regardless of the level of fruit maturity	A_{10}
Error in harvesting fruit	A_{11}
Lack of attention to essential oil palm care	A_{12}
Lack of supervisor's supervision of workers	A_{13}
Shipments of unsealed products	A_{14}
Worker's negligence when loading goods	A_{15}
Lack of coordination	A_{16}
Workers do not pay attention to the applicable SOP	A_{17}
Worker's inaccuracy in quality checking	A_{18}
Error in product packaging process	A_{19}
Error in storage of raw materials	A_{20}
Warehouse conditions that are not considered	A_{21}
The arrival of products from suppliers outside of schedule	A_{22}
Price fluctuation	A_{23}
Payment policy changes	A_{24}

Table 8 Risk Agent in PT XYZ (Continued)

Risk Agent	Code
Lack of monitoring of worker attendance levels	A_{25}
Fruit that is damaged by being in the open for a long time	A_{26}
Improper and irregular machine maintenance	A_{27}
Use of machines that exceed capacity	A_{28}
Unattended oil storage area	A_{29}
Drivers who do not have a driver's license	A_{30}
Rare truck maintenance	A_{31}
Truck loads that exceed capacity	A_{32}
There is fraud committed by workers	A_{33}
There is no driver standby when needed	A_{34}
Human error	A_{35}

Source: PT XYZ (2019)

Table 9 Order of Risk Based on ARP Value

Risk Agent	ARP	Rank	Percentage	Cumulative	Category
A_3	3.591	1	6,10%	6,10%	Priority
A_5	3.360	2	5,71%	11,81%	
A_7	3.186	3	5,41%	17,22%	
A_{35}	3.143	4	5,34%	22,56%	
A_{10}	2.968	5	5,04%	27,60%	
A_{28}	2.872	6	4,88%	32,48%	
A_{17}	2.695	7	4,58%	37,06%	
A_{16}	2.583	8	4,39%	41,45%	
A_{27}	2.513	9	4,27%	45,72%	
A_{13}	2.457	10	4,17%	49,89%	
A_{18}	2.304	11	3,91%	53,81%	
A_{29}	2.100	12	3,57%	57,37%	
A_6	2.085	13	3,54%	60,92%	
A_{11}	2.009	14	3,41%	64,33%	
A_{12}	2.009	15	3,41%	67,74%	
A_{31}	2.009	16	3,41%	71,16%	
A_{32}	2.008	17	3,41%	74,57%	
A_{21}	1.482	18	2,52%	77,08%	
A_{20}	1.434	19	2,44%	79,52%	
A_9	1.398	20	2,38%	81,90%	Non-Priority
A_{23}	1.206	21	2,05%	83,94%	
A_{34}	1.134	22	1,93%	85,87%	
A_{30}	1.071	23	1,82%	87,69%	
A_{26}	1.050	24	1,78%	89,47%	
A_{25}	882	25	1,50%	90,97%	
A_8	788	26	1,34%	92,31%	
A_2	770	27	1,31%	93,62%	
A_{33}	768	28	1,30%	94,92%	
A_{15}	555	29	0,94%	95,87%	
A_{22}	540	30	0,92%	96,78%	

Table 9 Order of Risk Based on ARP Value (Continued)

Risk Agent	ARP	Rank	Percentage	Cumulative	Category
A_{14}	480	31	0,82%	97,60%	
A_1	456	32	0,77%	98,37%	
A_{24}	432	33	0,73%	99,11%	
A_{19}	351	34	0,60%	99,70%	
A_4	174	35	0,30%	100,00%	
Total	**58.863**				

Source: The Researchers (2019)

Table 10 Proposed Mitigation Actions

No.	Mitigation Action	Code
1	Conduct a briefing in the morning before starting work and an evaluation in the afternoon after work hours	PA 1
2	Perform regular periodic checks on the transportation/machine unit	PA 2
3	Ensure all unit operators have a SIM according to each unit	PA 3
4	Provide incentives to workers who clean warehouse & oil storage areas	PA 4
5	Provide counseling regarding company SOPs to all employees including new employees	PA 5
6	Provide written sanctions/fines for losses that have been done	PA 6
7	Make a place/partition for each material along with a bincard	PA 7
8	Create a staff level daily field inspection template for monitoring inspection levels	PA 8
9	Create a template for daily activity reports for all employees submitted to their respective superiors	PA 9
10	Improve the condition of the main garden road	PA 10
11	Expand the current warehouse/build a new warehouse	PA 11

Source: The Researchers (2019)

The 11 mitigation actions proposed are processed into a questionnaire to find the priority order of mitigation actions based on three criteria, namely difficulty level, effectiveness, and cost. Based on the network model formed and the results of questionnaire filled out by the respondents, three pair comparisons are obtained: 1) the pairwise comparison of the criteria w.r.t. objective, 2) alternative pairwise comparison w.r.t. criteria and 3) pairwise comparison criteria w.r.t. alternative.

In Table 11, it can be seen that the most influential criterion in determining the best mitigation action at PT A is the effectiveness criteria with a weight of 0,57690. It is followed by the criteria for the level of difficulty in the second priority with a weight of 0,34200 and the cost criteria for the last priority with a weight of 0,08110. Therefore, it can be interpreted that companies prioritize the effectiveness of a proposed mitigation action to see how big is the impact given if the company implements a mitigation action. After effectiveness, the company will see the level of difficulty of a mitigation action. With the company that has only been established for approximately three years, the company will see its capacity in implementing mitigation action. The cost criterion is the least influential criterion for selecting a mitigation action since the criteria for effectiveness and the level of difficulty in implementing mitigation action are considered more important than the cost of implementing it.

Table 12 shows the weight of each alternative against each criterion. For example, PA 10 has the highest weight with a value of 0,31023 among other alternatives on the cost criteria. Thus it can be interpreted that PA 10 requires the greatest cost among other alternatives. From the effectiveness criteria, PA 11 has the highest weight with a value of 0,28625, which can be interpreted that PA 11 has the greatest effectiveness among other alternatives. From the difficulty level criteria, PA 10 has the highest weight with a value of 0,31832, which can be interpreted that PA 10 has the highest difficulty level to be implemented.

Table 13 shows the weight of each criterion against each alternative. For example, in PA 1, the weight of effectiveness is 0,69231, the weight of the difficulty level is 0,23077, the weight of the cost is 0,07692. Thus it can be interpreted that the effectiveness criterion has the greatest weight because implementing PA 1 can reduce the error rate that may occur in the supply chain process. It is considered not too difficult to implement, and the required costs are little or no cost at all.

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From the priority criteria to the objectives and the comparison between the criteria and alternatives, a synthesis stage is carried out to see the priority order of mitigation actions that the company should take. The synthesis results can be seen in Table 14.

Table 11 Pairwise Comparison of Criteria

Criteria	Weight	Rank
Effectiveness	0,57690	1
Degree of difficulty	0,34200	2
Cost	0,08110	3

Table 12 Alternative Pairwise Comparison

Criteria	Alternative	Weight	Inconsistency
Cost	PA 1	0,01637	0,09787
	PA 2	0,13838	
	PA 3	0,02384	
	PA 4	0,06747	
	PA 5	0,02063	
	PA 6	0,01496	
	PA 7	0,12632	
	PA 8	0,02591	
	PA 9	0,02380	
	PA 10	0,31023	
	PA 11	0,23209	
Effectiveness	PA 1	0,09126	0,09980
	PA 2	0,04356	
	PA 3	0,0570	
	PA 4	0,02136	
	PA 5	0,03214	
	PA 6	0,18722	
	PA 7	0,02546	
	PA 8	0,01429	
	PA 9	0,01945	
	PA 10	0,22199	
	PA 11	0,28625	
Degree of difficulty	PA 1	0,03453	0,08618
	PA 2	0,15715	
	PA 3	0,01273	
	PA 4	0,02142	
	PA 5	0,02622	

Criteria	Alternative	Weight	Inconsistency
	PA 6	0,01544	
	PA 7	0,13609	
	PA 8	0,04116	
	PA 9	0,02204	
	PA 10	0,31832	
	PA 11	0,21489	

Source: The Researchers (2019)

Tabel 13 Alternative Pairwise Comparison

Alternative	Criteria	Weight	Inconsistency
PA 1	Cost	0,07692	0,00000
	Effectiveness	0,69231	
	Degree of difficulty	0,23077	
PA 2	Cost	0,63699	0,03703
	Effectiveness	0,25828	
	Degree of difficulty	0,10473	
PA 3	Cost	0,10203	0,02795
	Effectiveness	0,72585	
	Degree of difficulty	0,17212	
PA 4	Cost	0,69552	0,07348
	Effectiveness	0,22905	
	Degree of difficulty	0,07543	
PA 5	Cost	0,09534	0,01759
	Effectiveness	0,65481	
	Degree of difficulty	0,24986	
PA 6	Cost	0,08967	0,01759
	Effectiveness	0,70503	
	Degree of difficulty	0,2053	
PA 7	Cost	0,69096	0,05156
	Effectiveness	0,21764	
	Degree of difficulty	0,09140	
PA 8	Cost	0,07543	0,07348
	Effectiveness	0,69552	
	Degree of difficulty	0,22905	
PA 9	Cost	0,07543	0,07348
	Effectiveness	0,69552	
	Degree of difficulty	0,22905	
PA 10	Cost	0,75825	0,03112
	Effectiveness	0,15125	
	Degree of difficulty	0,09051	
PA 11	Cost	0,72585	0,02795
	Effectiveness	0,17212	
	Degree of difficulty	0,10203	

Source: The Researchers (2019)

Tabel 14 Mitigation Action Priority Sequence

Mitigation Action	Code	Rank
Improve the condition of the main garden road	PA 10	1
Expand the current warehouse/build a new warehouse	PA 11	2
Perform regular periodic checks on the transportation / machine unit	PA 2	3
Make a place/partition for each material along with a bincard	PA 7	4
Provide written sanctions/fines for losses that have been done	PA 6	5
Provide incentives to workers who clean warehouse & oil storage areas	PA 4	6
Conduct a briefing in the morning before starting work and an evaluation in the afternoon after work hour	PA 1	7
Ensure that all Unit Operators have a SIM in accordance with each unit	PA 3	8
Provide counseling regarding company SOPs to all employees including new employees	PA 5	9
Create a staff level daily field inspection template for monitoring inspection levels	PA 8	10
Create a template for daily activity reports for all employees submitted to their respective superiors	PA 9	11

Source: The Researchers (2019)

IV. CONCLUSIONS

The research results show that there are thirty-six risk events in PT A's supply chain for the period January 2017 - December 2018. Three risk events include a unit accident during delivery, insufficient warehouse capacity, and damage to factory machinery. The risk events analyzed in PT A are caused by the risk agent or risk cause. 35 risk agents in the supply chain of PT A were obtained in the period of January 2017 - December 2018, 19 of which were categorized as priority risks. The three priority risks include misinformation and communication, damage to the transportation unit/engine, and the truck accident on the way. To reduce the occurrence of risk events, companies need to reduce the incidence rate of risk agents. As many as 11 mitigation actions for the 19 priority risks are proposed. Three mitigation actions include improving the condition of the main garden road, expanding the current warehouse/building a new warehouse, and conducting routine checks on certain periods of the transportation/machinery unit.

By looking at the many risks that could potentially arise in the supply chain process of PT A, the researchers suggest that the company is able to implement mitigation actions according to priority in accordance with the research results, for example, by improving the condition of the main garden road. By implementing these mitigation actions, the company incurs significant costs initially, but is expected to reduce indirect costs in the long run, such as unit repair costs due to accidents that occur continuously. For supply chain risk analysis and other fields, it is recommended that companies are able to apply: 1) the SCOR method to help map activities, 2) the HOR method to analyze risk since it considers the relationship between risk events and risk agents, and 3) the ANP method to seek mitigation action priorities since ANP can accommodate the linkages between criteria and alternatives.

The research has limitations since it investigates only in one palm oil company in Indonesia. Future research is suggested to examine several oil palm companies to compare the results of their research whether it can be generalized. In addition, it is suggested that there is future research on other industries outside of plantations.

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