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Implementation of risk management framework in supply chain: A tale from a biofuel company in Indonesia

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Implementation of Risk Management Framework in Supply Chain: A Tale from a Biofuel Company in Indonesia

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Abstract

This paper examines the implementation of risk management within a supply chain. Using FMEA(Failure Mode and Effect Analysis) methodology as the risk management framework, this research investigates the overall supply chain network in the firm, identifies the inherent risks along its supply chain, assesses those risks, categorises those risks according to their level, and explores risk mitigation strategies. The study employs a qualitative approach and gathers first-hand data by means of semi-structured interviews to collect nuanced insights that underpin the FMEA method. Interviews with the firm's supply chain experts also reveal some critical risks along with their mitigation strategies. This study offers a practical implementation of FMEA in the supply chain, increases focal points on the most imminent risks, prioritises risk mitigation plans, and improves the sustainability of the firm's overall supply chain. Optimistically, in the end, this study seeks to enhance the sustainability in Indonesia's biofuel industry.

Keywords

Supply chain management, risk management, failure mode and effect analysis, biofuels, risk assessment, mitigation strategy, small-medium enterprise

JEL Classification

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Biofuel and Its Supply Chain in Indonesia

In response to the hike in oil prices in the global market and environmental problems, Indonesia's government has developed a new blueprint of renewable energy development since 2006, which emphasises biofuel production and intensive utilisation (Wirawan and Tambunan, 2006). The Indonesian government proposed that annual production reach 720,000 kilolitres in 2010, with a steady increase to 1.5 million kilolitres by 2015. The development of the biofuel market in Indonesia has created its own domestic market, which attracts many investors, and it makes Indonesia one of the biggest suppliers of biofuel in the global market. However, the development of biofuel in Indonesia has many problems that have an impact on projects, such as natural disasters, bad transportation infrastructure, deforestation, and social conflicts. These factors can seriously disrupt biofuel production, increase costs, decrease sales, and create vulnerability. Supply chains have essential roles in the development of the biofuel industry. These roles are the structure of coordination in the supply network, alignment with customer satisfaction, and the sustainability of overall competency throughout the supply chain (Faisal and Banwat, 2006; Chopra and Sodhi, 2004). Yet, not all biofuel companies in Indonesia have developed a risk management framework systematically for their supply chain; this situation is very typical for small and medium enterprise companies. Lack of knowledge and implementation of the risk management framework in the supply chain can cause unsustainable conditions for the biofuel industry (Guha, 2004). On the other hand, rising awareness of risk in the supply chain will be the basis of innovation along the supply chain in order to improve efficiency, effectiveness, end of chain satisfaction, and also sustainability (Subroto *et.al.*, 2010). Therefore, it is important to develop a framework of risk mitigation strategies for supply chains, in order to create a sustainable biofuel industry and so the target set by the Indonesian government will be reached.

Therefore, this research seeks to answer the following questions: What is the nature of the biofuel supply chain network? What kinds of risks attach themselves along the supply chain? What is the appropriate mitigation strategy to deal with these risks?

With the intention of answering these questions, this paper sets out to propose a systematic concept of applying risk management to the supply chain by identifying, assessing and mitigating all the risks along it. I also expect to be in a position to suggest the methods with which Biofuel's actors can implement a risk management framework accurately for its supply chain. Moreover, this paper seeks to contribute to biofuel development in Indonesia by sustaining its supply chain in advance. In terms of its overall outcomes, this research reveals that there are four kinds of risk in biofuels supply chains (demand risk, supply risk, environmental risk, and operational risk) and then develops a mitigation strategy for each type of risk.

Having introduced the scope and objectives of this research, the next section describes three frameworks found in literature pertaining to this subject, those being Concept of Risk, Supply Chain Risk Management, and FMEA method. It goes on to suggest a risk management framework that uses the FMEA method. The third section reviews the methodology of this research which is followed by the fourth section which explains the field findings and examines them using Failure Mode and Effect Analysis. This fourth section also proposes recommendations for the company featured in this case study. The final section summarises and underscores some lessons learned from this research.

Connecting Risk Management and Supply Chain through FMEA method

This section describes the main theories and concepts of this research. The main theory is the concept of risk and supply chain management while Failure Mode and Effect analysis (FMEA) is used as the concept to reveal the risks found in biofuel supply chains in Indonesia.

1.1. The Concept of Risk

Concept of risk has been studied in plenty of business contexts and even in the fields of science and engineering (Sitkin and Pablo, 1992; Yates and Stone, 2002; Khan and Burnes, 2007; Rithie and Brindley, 2007; Zsidsin, 2003; Chopra and Sodhi, 2004). The study of risk has promised essential investigation of corporate functions, for example decision-making tools (Yates and Stone, 2002), operations (Khan and Burnes, 2007), and strategic management tools (Sitkin and Pablo, 1992). Companies are waking up to the need for risk management implementation for some significant time and there exists an extensive body of literature from such diverse areas as economics (e.g. Kahnemann & Tversky, 1979; Tversky & Kahnemann, 1992), finance (e.g. Smith

et. al., 1990), strategic management (e.g. Bettis & Thomas, 1990; Simons, 1999) and international management (e.g. Miller, 1992; Ting, 1988). Previous studies have suggested many definitions of risk, such as Sitkin and Pablo (1992), who defined risk as “*the extent to which there is hesitation whether potentially desired or insignificant/unwanted outcomes of decision will be realised.*” On the other hand, Mitchell (1999) described risk as *the likelihood of loss and the implication of that loss for the individual or organisation*. He formulated a principle of risk to assess the probability of loss (P) and the significance (I) of that loss as shown in the notation below.

$$\text{Risk} = P(\text{loss}) \times I(\text{loss})$$

However, this concept has been overtaken by further studies which propose that the concept of risk should be much broader than Mitchell’s formula. Zsidsin (2003) suggested that risk contains three dimensions which are outcome uncertainty, outcome expectations, and outcome potential. Moreover, Ritchie and Brindley (2007) cited that there are three dimensions of risk: (1) likelihood/probability of occurrence of certain outcomes; (2) consequences/severity from the occurrence of particular events; (3) causal pathways leading to the events. Similar to Ritchie and Brindley (2007), whose Failure Mode and Effect Analysis, as the tool used in this research, defined risk as the multiplication of likelihood of a risk event, the severity of a risk event, and the ability to detect the risk (PMBOK, 2000). It is formulated in the notation below.

$$\text{Risk} = \text{Likelihood} \times \text{severity} \times \text{Detection}$$

Considering the fact that risk management always relates to those three dimensions of risk (Rithie and Brindley, 2007), this research intends to use this definition in order to analyse the sources of risk, understand the forces which might create the occurrence of undesired event, and manage these dimensions to enhance the possibility of positive outcomes and avoid negative outcomes.

1.2. Supply Chain Risk Management

Risk management in today’s business environment has become the biggest contributor to most fields of management (Ritchie and Brindley, 2007; Mallman, 1996; Giannakis *et al*, 2004). Supply chain management, as part of management study, cannot avoid those risks which are

inherent. It is common today in supply chain management to adopt a risk concept and apply this concept as the key role in the supply chain management (Ellegard, 2008). Therefore, it is necessary to develop risk management and risk mitigation in the supply chain context. The term supply chain is defined in many ways, but it is defined in this research as the network of organisations, which are involved through upstream and downstream linkages, in different processes and activities that create value in the form products and services in the hands of customers (Christopher, 1998 cited in Peck, 2005).

Nowadays, managing supply chains in a competitive, high uncertainty and turbulent market is very challenging. The frequent occurrence of natural disasters, labour disputes, uncertain supply and demand, supplier bankruptcy, political changes, war and terrorism have led to deeper concerns about risk management for the supply chain (Christopher and Lee, 2004). Hence, the biggest challenge in supply chains today is managing and mitigating the risks that are inherent in every business situation. Company needs to know and understand the category of the risks as well as the condition that drives the risks (Chopra and Sodhi, 2004). There are numerous definitions of risk, one of them being that offered by Sitkin and Pablo (2002), who describe it as uncertainty about potential outcome, whether it is momentous and/or insignificant in the decision that occurred. On the other hand, Faisal *et al* (2006) defined risk as consumer's perceptions of the insecurity and undesirable consequences for buying products or services.

The understanding of risk in the supply chain should accommodate each of these three components (Ellegard, 2008):

1. The knowledge of a risk event
2. The probability of occurrence of a risk event
3. The impact of a risk event

The first component is the initiative for increasing knowledge of risk as the prerequisite to reduce the probability of risk and the effect of it. The second component is related to reducing the probability of occurrence by implementing a set of actions such as increased influence in behaviour of third party (suppliers), joint collaboration, supplier development, and managing the relationships with them. The last component is trying to reduce the impact of the risk event, which can be done by preparing the supply strategy such as increasing inventory, capacity, risk

sharing, being responsive and agile, etc. (Chopra and Sodhi, 2004). In conclusion, previous research has stated that the development of supply chain risk management, as the main key role in supply chain management in today's business, should take into account these components:

1. The identification of risk type and the drivers
2. The action to seek deep knowledge about risk events
3. The well-planned strategy to reduce probability of risk events

The preparedness for risk impact by developing a set of actions is related to the supply chain strategy in order to enhance sustainability in the system.

1.3. Failure Mode and Effect Analysis

Failure Modes and Effects Analysis (FMEA) is methodology for analysing potential reliability problems or unwanted events early in the development cycle where it is easier to take actions to overcome the problems, thereby enhancing reliability through design. FMEA is implemented to identify potential failure forms, determine their impact on production, and identify actions to mitigate the failures (Crow, 2002). Failure Modes and Effects Analysis is a planning tool on developing the process, products, or the services. The use of FMEA has been developed in the deployment of products or services for troubleshooting and counteractive action. The standard of FMEA evaluation is based on the occurrence, severity, and detection for each risk event. The multiplication of these values obtain a Risk Priority Number (RPN)

$$\text{RPN} = \text{Occurrence} \times \text{Severity} \times \text{Detection}$$

The FMEA has been developed not merely for designing services, products, and so on. Recently, FMEA is being used for analysing potential risk in project management, marketing, operations, etc. This tool is very useful because it provides a simple method for analysing crucial steps to anticipate what might go wrong with products/services. If there is a case where anticipating every failure mode is impossible, the development team should invent as extensive a list of potential failure modes as possible. This research implements the RFMEA's framework in order to achieve the main objective of this research which is assessment and mitigation of risk in the supply chain.

Research Methodology

The Research Framework : Adoption of Failure Mode and Effect Analysis

The main theme of this research is the implementation the FMEA method in supply chain risk management in order to increase the sustainability along the supply chain. To do so, this research employs a case study. It is common with a case study to use multiple methods for collecting and analysing the data (Maylor and Blackman, 2005). In this research, multiple methods are applied because they have different stages. The first stage is collecting the data by using semi-structured interviews. The next stage is when the data that has been collected from interview will be analysed by using the Failure Mode and Effect Analysis method, as the techniques to asses and identify risk in supply chain. This method is a simple and systematic approach for identifying and assessing the risk (Carbone and Tippet, 2004). This research will use three phases as shown in the graphic (figure 1) below;

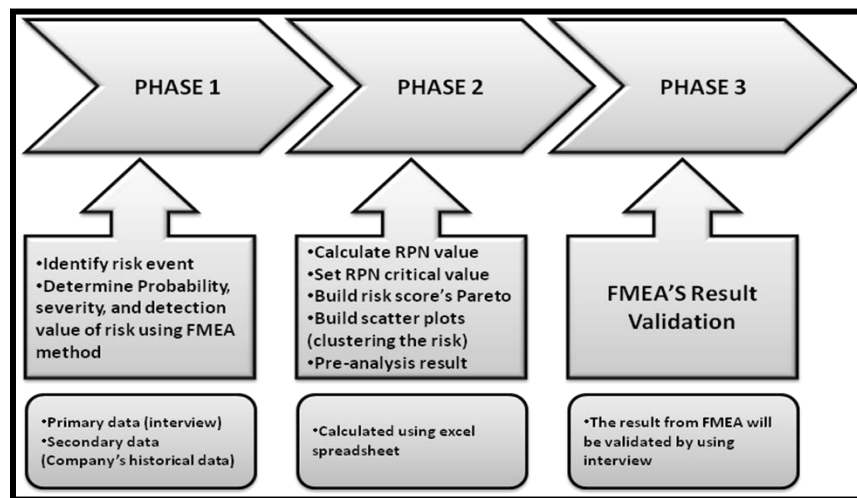


Figure 1. Research Phases (source: Author)

The first phase focuses on identifying the potential risk that is inherent in every process within the supply chain. This stage ensures that all of the risk is recognised, and then each risk will be scored for its probability, severity, and detection. FMEA provides some scaling guidelines for

scoring each risk. At this phase, all the data will be collected from interviews and the company's historical data.

The second phase for this methodology is to calculate and analyse all the collected data from phase 1. The main point of this phase is to obtain a Risk Priority Number (RPN) for each risk. After the RPN value is obtained for each risk, the Pareto analysis and risk clustering using a scatter plot (as mentioned in figure 2) can be developed. From the Pareto analysis and the scatter plot, the risk profiling and its mitigation will be developed.

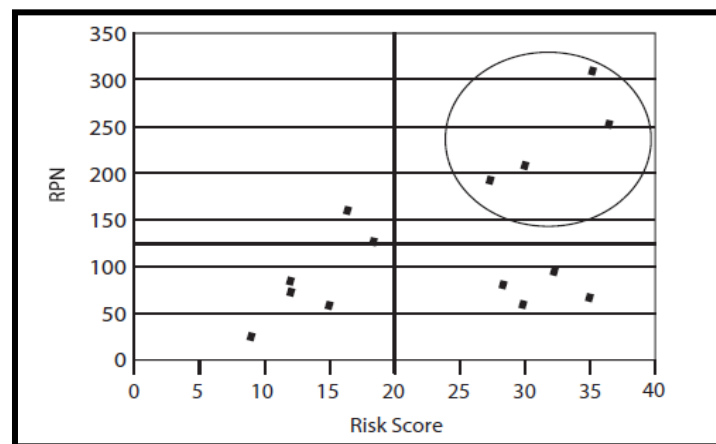


Figure 2. Risk Clustering (Carbone and Tippett, 2004)

The last step in this phase is to develop a risk mitigation plan for each risk event that is plotted in the critical section in scatter diagram. Sometimes, in extreme cases, the risk is unavoidable; therefore, the detection plan and contingency plan are required. It is essential to develop such plan, because it is common that risk occurrence is more expensive than developing the risk mitigation, detection and contingency plan.

The third phase of this research is validating the result and risk mitigation plan that has been developed from the second phase. The validation will use interviews with the same participants as in the first phase. The FMEA's result and mitigation plan will be shown to them. Then, the participants will validate the appropriateness of the result and whether it illustrates the reality of the supply chain's nature within the company. Moreover, the mitigation plan, which has been developed based on the FMEA's result, will be tested for its feasibility.

Key Informants and Data Collection Method

This research uses qualitative research methods by using a semi-structured interview as the main tool for collecting the data. As mentioned earlier in the literature review, this research takes place at the functional level (transaction level) in the biofuel company. Therefore, the interview participants for this research are from functional divisions (Purchasing, Operations, and Distribution) which are involved in the supply chain within this company. The key informants for this research are Purchasing & Sourcing Manager, Chief Operations Officer, and Distribution & Merchandising Manager. They have been working for the company for more than 7 years. Therefore, the information and findings from them are valid and reliable. The participants will be asked by a set of question related to supply chain risk management in the company. In addition, this research will use secondary data which is gathered from Company's historical data. The secondary data consists of company's annual report, sales volume, production volume, suppliers' performances, and any other facts about the social, political, economic and environmental situation in Indonesia. This historical data is used in order to enhance the analysis of this research. From all the findings and information, this research builds a cross-case analysis where it compares and contrasts the answers of the key informants leading to the judgment of the hypotheses and a mitigation framework to cope with those particular risks.

The Supply Network of Indonesian Biofuels

The identification of the overall chain, which starts with obtaining the raw materials from the suppliers to the customers at its other end end, is the foundation to develop a supply chain risk management framework. The actors who are involved along the supply chain have to be identified; hence, it will give a clear understanding of the supply chain within the Biofeul Company. From the supply chain management's point of view, value-adding activity has to take place at every single part throughout the overall supply chain. Figure 3 shows the structure of the supply chain in the Company.

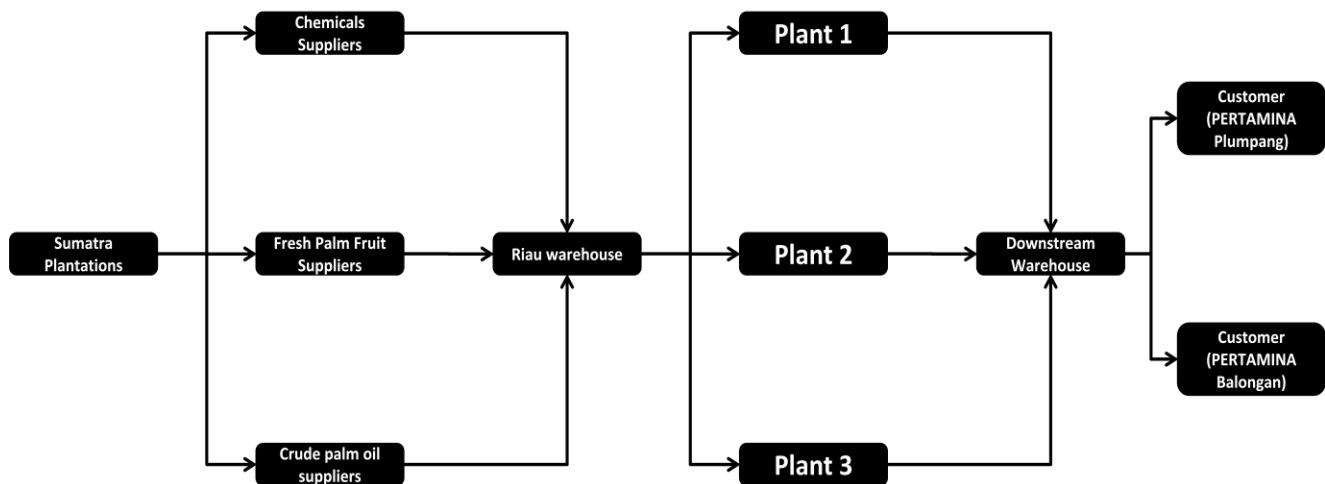


Figure 3. Biofuel Supply Chain in the Company (source: interview)

The flow of goods starts from the palm plantations which are fully owned by The Company. Palm fruit, as the main raw material for producing biofuel, is obtained from their plantations in Sumatra and Kalimantan. Since all the manufacturing plants are in Sumatra, the palm fruit from Kalimantan plantation needs to be delivered by water transport (ships) which is also owned by The Company. The other materials that are required to produce biofuel are chemical goods which are used for cracking the carbon-chain from palm to biofuel. The most essential chemicals are methanol and catalyst. Without these chemicals, the quality of biofuel becomes lower or can even fail to be produced. These components bought from local suppliers who have cooperated for almost 4 years (Ramajaya, interview, 06/07/2009). In some cases, mostly when they are lacking palm fruit supplies from their own plantations, the Company needs to buy crude palm oil from third parties. This is a very rare situation as they probably need to buy from another party only once or twice each year. Indeed, so far they have bought crude palm oil from third party only three times since they started to produce biofuel (Hendarto, interview, 09/07/09).

All of these materials will be stored in warehouses in Sumatra, which is located near the plants. There is no transformation process here, and these materials are delivered to the warehouse only to compensate for long lead times and as safety stock to support the production process in the plants. From the warehouse, these materials will be dispatched to the plants at a certain time and amount as needed by each plant (Ramajaya, interview, 06/07/09).

At the plant, the manufacturing process takes place. Figure VI.2 describes the overall process from the input of raw materials to the output of biofuel. The manufacturing process is similar for all the plants.

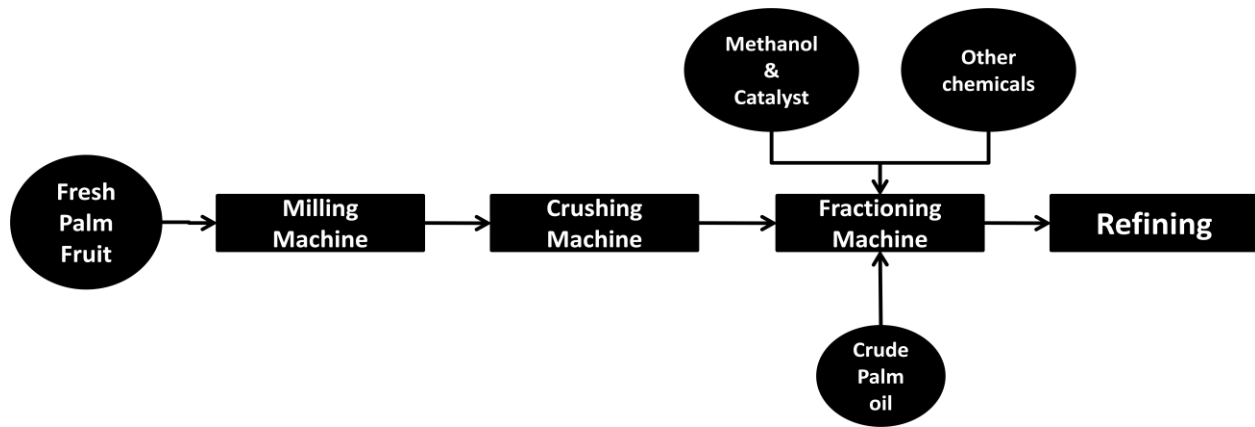


Figure 4. Biofuel Manufacturing Process (source: interview)

The process starts from cutting the fresh palm bunches into tiny slices by using a milling machine. This process aims to make the fruit small enough to be crushed easily in the crushing machine. The rationale behind this is to preserve the crushing machine which can be easily broken if some batches of intact palm fruit are processed in it. Therefore, the cutting process has to be done before the palm fruit is crushed. The tiny sliced palm fruit is crushed in order to get its concentrate. Then, this concentrate is processed in a fractionation machine. The fractioning process is crucial in producing the biofuel. At this stage all the chemicals, such as methanol and catalyst, are mixed with crude palm oil concentrate. The cracking of the hydrocarbon chain happens here, thus fractioned palm concentrate with a certain amount of carbon is obtained. Afterwards, this concentrate proceeds to the refining stage. At this stage, the concentrate undergoes thermal and physical processing with the purpose of purifying the oil from undesired substances in it. Having done that, the biofuel is produced (Ramajaya, interview, 06/07/09).

This biofuel is then stored in the warehouse before it is dispatched to the customers. The warehouse is located in the same complex as the plants. The complex is near the sea and it has its own dock where the ships moor. In the warehouse, as well as in the raw materials' warehouse, there is no value-adding or transformation process for the biofuel. It is only stored to reduce the lead times to customer and create buffer stock especially for the high season (Susanto, interview, 13/07/09).

From the warehouse, the biofuel is moved to the ships by truck. Subsequently, the biofuel is dispatched to the customer by ship. There is only one customer for biofuel which is Pertamina, the Indonesian state-owned enterprise responsible for oil and energy supply, which has two main depots in Plumpang and Balongan. As requested by their customer, the biofuel has to be delivered to those two main depots that are located in different places (Susanto, interview, 13/06/09). Actually, not all the biofuel is sold to Pertamina as some of it is used by The Company itself because it has adopted new technology for all their machines and other facilities which utilise biofuel as the source of energy (Ramajaya, interview, 06/07/09).

To sum up this section, The Company's supply chain has several key components; The plantation where the palm trees grow and are harvested, The Company as the producer and owner of the palm plantation, the methanol supplier, the catalyst supplier, other chemicals supplier, and PERTAMINA as the customer for Company's biofuel.

The Risk(s) of Indonesian Biofuels Supply Chain

The development of the risk mitigation framework by using FMEA has several steps as explained in the literature section. The first step is the identification of risk that is inherent in every single link along the supply chain. At this stage, identifying the risk is based on literature about supply chain risk management from Chopra and Sodhi (2004), Manuj (2005), Cucchiella and Gastaldi (2005), Blackhurst *et al* (2008), and Peck (2005). From those key writings, as stated in the literature section, the risk in the supply chain can be categorised into four elements; demand risk, supply risk, operational risk, and environmental risk. Therefore, the process of risk identification follows this concept.

First, demand risk is the occurrence of an undesired event, which is mostly caused by fluctuation in customer demand. Forecast becomes more inaccurate if the fluctuation is really high, and the further result from forecast inaccuracy is the bullwhip effect as the most undesired outcome from this risk (Chopra and Sodhi, 2004).

As for supply risk, Manuj (2005) stated that it pertains to supplier performance. All the core materials are bought from the suppliers. The quality of products, firm ability to cope with consumer expectations and the level of purchasing cost are really dependent on suppliers. Low

ability to manage suppliers can increase the supply risk level (Peck, 2005). Supply risk refers to the increments of purchasing cost that is caused by price increase from suppliers, delivery delay from suppliers that can increase production cost, quality cost because of the low quality of inbound materials or even defects (Chopra and Sodhi, 2004).

Third, operational risks affect manufacturing or the production process (Manuj, 2005). Likewise, Cucchiella and Gastaldi (2005) defined operations risk is being the risk that has an effect on a company's internal ability to produce goods or services. Furthermore, the concept of operational risk is not only about risk that threatens production process, but also the information that flows along the information network within a firm and between firms (Chopra and Sodhi, 2004). Collapse of information structure, although it is not common, can destroy these extremely networked environments nowadays.

The last source of risk that needs to be identified is environmental risk. Several factors taken into consideration are technological, social, political and economic circumstances. However, natural phenomena, such as geological, metrological, disease and any other uncontrollable events have to be taken into consideration too (Peck, 2005). Identically, Blackhurst (2005) noted that external risks that may affect supply chain are natural disaster (earthquake, tsunami, forest fire, etc.), war and terrorism, and political problems that may take place where the firm conducts business.

From the interview with three experts (production manager, procurement manager, and supply chain director), source of risks have been gathered as shown on the table 1 below,

RISKS	Quote from interview
Demand Risks	
demand fluctuation	Our Customer demand is not entirely predictable; it fluctuates over the past few years (Ramajaya, interview)
negative campaign	Another factor that affects demand is negative campaign about palm biofuels, which is our product (Susanto, interview)
economic condition	Economic condition influences customer demand. PERTAMINA as our main customer, really depend on national energy demand. In recession like today, national energy consumption is lower than before (Susanto, interview)
Environmental Risks	
earthquake	>Natural disasters such as; earthquake, tsunami, fireS in the forest, and landslideS mostly occur every year (Ramajaya, interview) >During the dry season, there are a lot of forest fires near our plantations and plant (Hendarto, interview) >On the other hand, during the rainy season landslides are a major threat to the materials delivery (Hendarto, interview)
forest fire during dry season	
landslide	
tsunami	

currency exchange	Another risk is currency exchange rate, this becomes a risk since our customer (PERTAMINA) sell the biofuels for their external customers by using US dollar (Susanto, interview)
oil price decrease	Oil price is another external risk that affects our business. The decrease of oil price reduces the demand of biofuels, it is mostly caused by forward buying through the oil trader (Susanto, interview)
Supply Risks	
inbound product quality	So I can say there is a risk in here, if the suppliers deliver it late or it is low quality, we will have a big problem. (Hendarto, interview)
uncertainty in palm's harvest season	It is quite difficult to predict the amount of palm fruit when it is harvests nowadays, because it depends on the weather which cannot be forecasted accurately due to climate change (Ramajaya, interview)
product arrival variability(delays)	So I can say there is a risk here, if the suppliers deliver it lately or low quality, we will have a big problem. (Hendarto, interview)
deforestation problem	There is a risk here, we cannot easily cut all the trees in the forest or burn it down, there are many procedures that we have to obey, it takes time and might be a big obstacle for our business development (Ramajaya, interview)
palm life cycle risk	Undeniably, the palm has a product life cycle. It produces palm fruit after 3-5 years from the first implant, and then it will slightly decline and reach lowest level on the 15 th -20 th year (Ramajaya, interview)
Operations Risks	
Chemicals mixing in fractionation machine	In the fraction machine, the operators have to combine the crude palm oil with methanol and catalyst. The composition of those chemicals have to be highly accurate, otherwise it cannot be a biofuel, it might becomes something else or even if it is extremely inaccurate can cause an explosion and then devastate the whole facilities in the plant (Ramajaya, interview)
fractioning machine breakdown	There are two critical machines in our plant; a refining machine and a fractioning machine. I can say this stage is key for producing high quality biofuels. Failure to do so, and we are in a dangerous situation (Ramajaya, interview)
refining machine breakdown	
IT breakdown	It covers the flow of information from the upstream (plantations) to downstream (distribution). If we cannot maintain this system, obviously, we will have serious problem (Susanto, interview)

Table 1.Source of Risk (source: interviews)

Risk Assesment

The next step to develop the risk mitigation framework is assessing all the risks that have been identified in the previous section. The method of assessment follows FMEA's guidelines that have been described in an earlier section. The concept of assessing the risk basically uses the score for the probability of the risk occurrence, the impact from the risk, and the identification method that the firm has to reduce the impact of the risk. The scoring value has been explained previously . All the values are calculated to obtain the risk priority number (RPN) and risk score value (RSV) by using the formula below.

$$RPN = Occurrence\ score \times Severity\ score \times Detection\ score$$

$$RSV = \text{Occurrence score} \times \text{Severity score}$$

After the score is determined from the interview and the RPN and RSV has been calculated, all the risks will be categorised by their RPN and RSV, then they will be plotted on the scatter diagram in order to prioritise which risk needs to be mitigated immediately.

Subsequently, after all the inherent risks have been identified, the next step is to assess each risk by using the FMEA method. Every risk is assessed by its likelihood value, impact value and detection method value. Determining those values is based on the secondary data and interviews with the experts. By having experienced professionals as the key informants, the quality of the data and analysis is highly enhanced. All the informants enter values for the probability, impact and detection methods for each risk, and then they are adjusted by using past historical data (sales, volume of productions, suppliers performance and the occurrence of risks). All the values which informants have given in the interviews are described on the table 2 below;

RISKS	PROBABILITY			SEVERITY			DETECTION		
	COO	PROC MGR	DISTR MGR	COO	PROC MGR	DISTR MGR	COO	PROC MGR	DISTR MGR
Demand Risks									
demand fluctuation	7	6	6	5	4	6	3	3	4
negative campaign	8	4	7	5	4	4	7	6	6
economic condition	7	8	8	5	4	7	6	4	4
Environmental Risks									
earthquake	5	4	5	9	8	8	7	8	7
forest fire during dry season	9	8	8	6	6	5	5	4	4
landslide	8	6	7	6	7	7	4	5	4
tsunami	6	4	6	7	8	5	4	7	5
currency exchange	8	7	7	3	4	5	6	6	6
oil price decrease	7	7	5	4	4	5	5	6	6
Supply Risks									
inbound product quality	6	4	4	6	5	7	6	8	5
uncertainty in palm's harvest season	7	6	5	4	5	5	7	6	6
product arrival variability(delays)	6	6	7	6	7	7	6	5	5
deforestation problem	6	6	7	5	6	5	6	7	5
palm life cycle risk	7	5	5	6	6	5	6	5	5
Operations Risks									
Chemicals mixing in fractionation machine	5	4	4	9	8	8	7	6	8
fractioning machine breakdown	3	4	3	6	5	5	6	7	6
refining machine breakdown	3	3	4	6	5	5	5	6	5
IT breakdown	5	3	3	7	7	6	6	6	4

Table 2. Risks Score Values (Source: Interviews)

Table 9 shows the perception of each key informant of every risk. The values entered depend entirely on their personal opinion and experience, thus, the entered values are not consistent for every informant. So, this data cannot be used as the final result of risk assessment and it still requires an adjustment and validation to gain consistent data for further analysis. All the values from the informants have to be unanimous (Carbone, 2004). Therefore, after the values have been adjusted according to the secondary data, then they will be validated using the experts' (informants) judgment. The resulting risk score values for all the risks are shown on the table 3 below;

RISKS	PROBABILITY	SEVERITY	DETECTION	RPN	RSV
Demand Risks					
demand fluctuation	6	5	3	90	30
negative campaign	8	5	6	240	40
economic condition	7	5	6	210	35
Environmental Risks					
earthquake	4	8	7	224	32
forest fire during dry season	8	5	5	200	40
landslide	7	6	5	210	42
tsunami	4	8	7	224	32
currency exchange	8	4	6	192	32
oil price decrease	7	5	5	175	35
Supply Risks					
inbound product quality	6	6	6	216	36
uncertainty in palm's harvest season	6	5	7	210	30
product arrival variability(delays)	6	6	5	180	36
deforestation problem	6	6	5	180	36
palm life cycle risk	7	5	5	175	35
Operations Risks					
Chemicals mixing in fractination machine	5	8	6	240	40
fractioning machine breakdown	4	5	6	120	20
refining machine breakdown	4	5	6	120	20
IT breakdown	5	6	4	120	30

Table 3. Validated Risks Score and Calculated RPN & RSV

Having calculated the risk score and risk priority number values, the next step is to figure out the critical RPN and risk score values by using Pareto analysis (Carbon, 2004). The 80:20 rule says that 20% of the work can gain 80% of all the benefits that can be obtained. The Pareto analysis is applied to set out RPN and risk score threshold values and this is a critical step (Bongiorno,

2001). The Pareto chart for RPN and risk score values are described in figure 5 and figure 6, respectively, below;

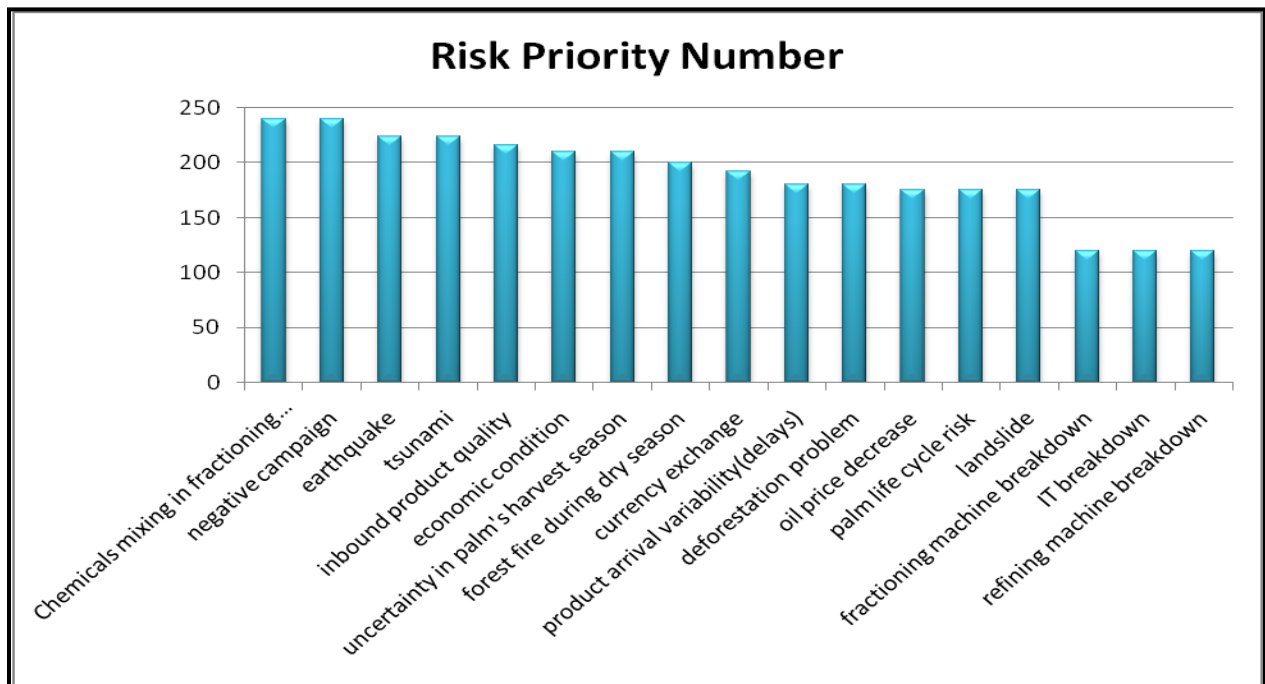


Figure 5. Risk Priority Number's Pareto Chart

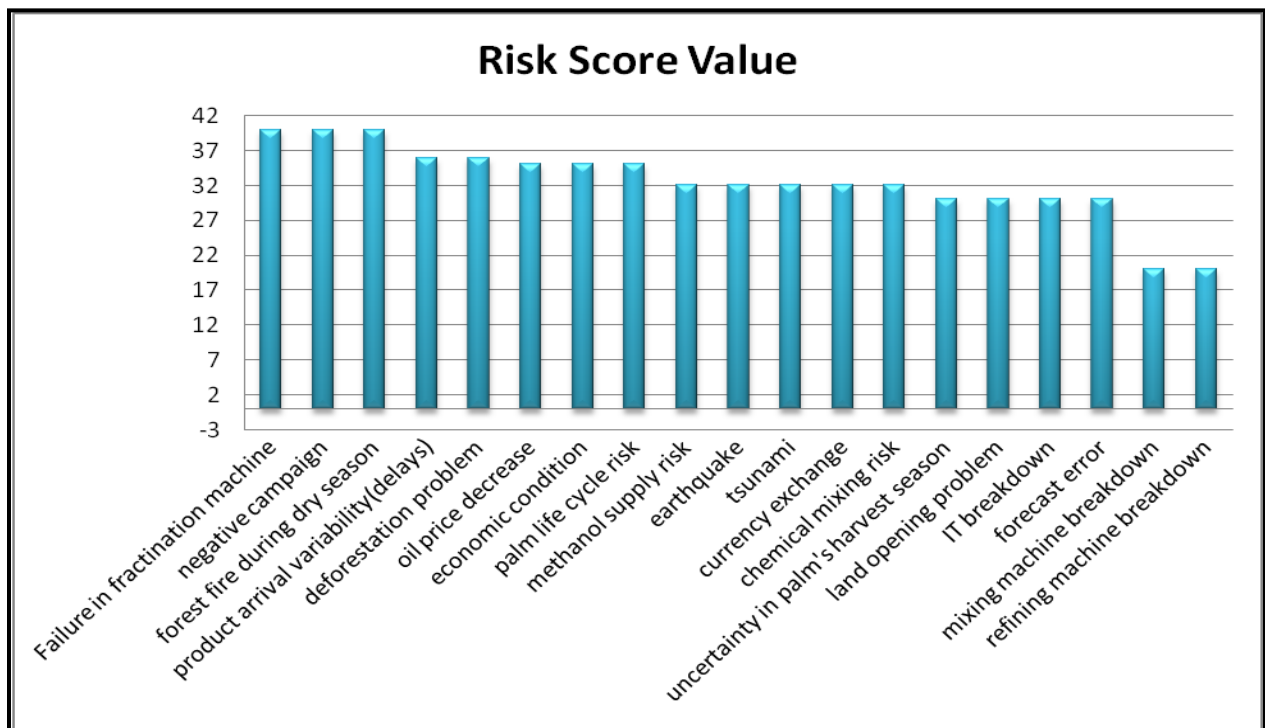


Figure 6. Risk Score Value's Pareto Chart

These two Pareto charts above help determine the critical RPN values for risk scores. These charts are made simply to give guidance for prioritising risk response planning. In selecting critical values, there is no scientific rule of thumb (Carbone, 2004). It really depends on the nature of the business or project, for this reason the critical value for this project is based on the Pareto chart. From the charts, also the Pareto rule, the critical value for RPN is 200 and for risk the score is 35. The next step is to build a scatter diagram for the RPN plotted against the risk score values. The critical value for both the RPN and the risk are plotted as well. The aim of doing this is to find the intersection of those two critical values to reveal the set of risks that have high risk scores which need to be responded to and managed first. The scatter diagram is shown on the graph below (figure 7).

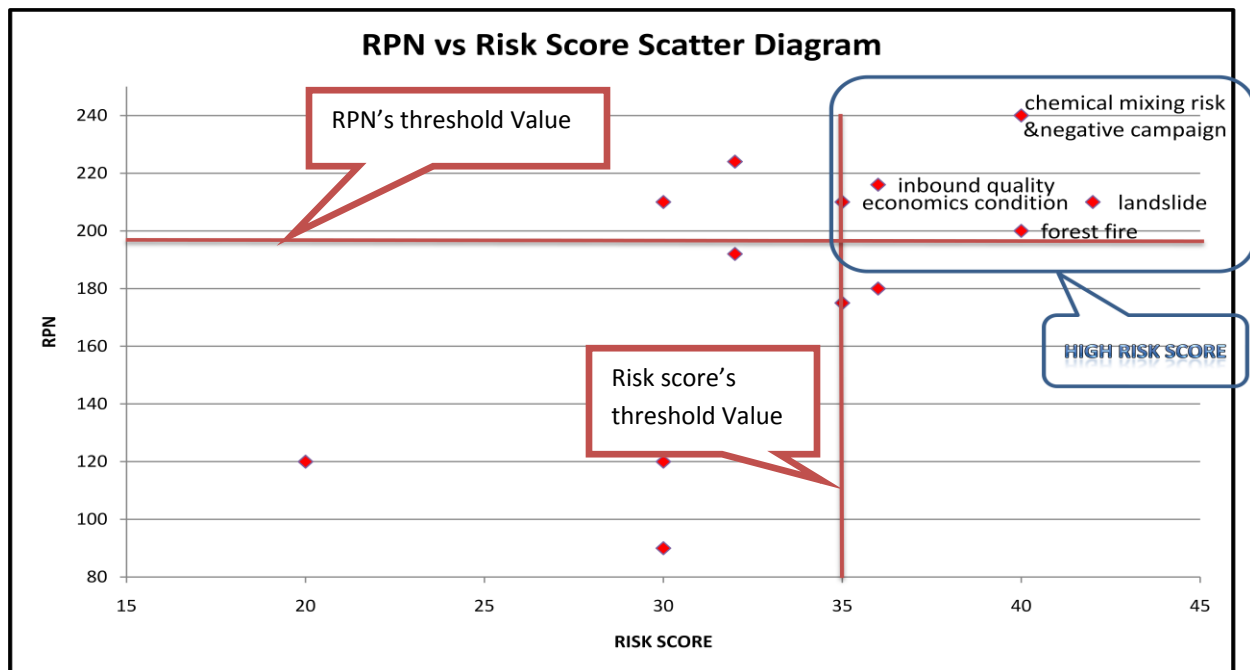


Figure 7. RPN versus Risk Score Scatter Diagram

The scatter diagram shows that the critical values of RPN and risk scores divide the diagram into four areas. The upper-right area is the most urgent risk that should be addressed early on. There are six risks in that area; chemical mixing risk in the fractioning machine, negative campaign risk from competitor, landslide risk, inbound product quality risk, economic conditions, and forest fire risk. These high scored risks are the main concern in the supply chain, therefore the mitigation strategy for these risks is urgently needed. The discussion about this mitigation framework is presented in the next section.

The Strategy for Mitigating The Risk: Some Recommendations

Once the supply chain risk has been identified and assessed, information about the level of urgency of the risk can be obtained. Since the level of risk has been revealed in the previous section, those high scored risks have to be mitigated by using specific supply chain strategies. Further investigation shows two out of the six highest risks are of the environmental type; forest fire and landslide. The other two risks are categorised as demand risk, negative campaign from customer, and national economic conditions. The last two risks are inbound product quality and chemical mixing risk in the fractioning machine, these risks are inherent in supply risk and operations risk, respectively.

Due to the high level of risk from all types of supply chain risk, supply, demand, operations, and environment risks, the mitigation strategy has to cover the entire risk. Every single type of risk has its own mitigation strategy. The enablers of risk mitigation have been identified by previous research. Faisal *et al* (2006) found that information sharing, agility in the supply chain, trust among supply chain counterparts, collaborative partnerships, risk sharing and transfer, increased knowledge of supply chain risk, and continuous risk analysis and assessment are the enablers of risk mitigation in the supply chain. Moreover, increasing some factors such as capacity, inventory level, number of suppliers, responsiveness, and the number of customer accounts can be mitigation strategies to reduce the impact of supply chain risk (Chopra and Sodhi, 2004). Nevertheless, previous research from Manuj *et al* (2005), who focus on developing global supply chain risk management strategies, accounted for six management strategies to reduce the impact of supply chain risk. Those mitigation strategies are postponement, speculation, hedging, avoidance, backward and forward integration, and security strategy (Manuj *et al*, 2005).

Unfortunately, there is no perfect weapon to protect a firm's supply chain from the inherent risk. However, the firms have to understand the overall risks that need to be tackled and which strategy works best against those risks (Chopra and Sodhi, 2004). Furthermore, different supply chain conditions and the nature of business affect the suitability of the various strategies. Managers have to recognize the benefits and disadvantages of the strategies, and understand to what extent that strategy is appropriate to implement (Manuj, 2005). Therefore, the firms need to consider the trade-off between risk and the cost to mitigate it, also their capability to develop the

mitigation strategy. There is a rule of thumb for risk mitigation strategies for the supply chain, it shown on the graph below (figure 8).

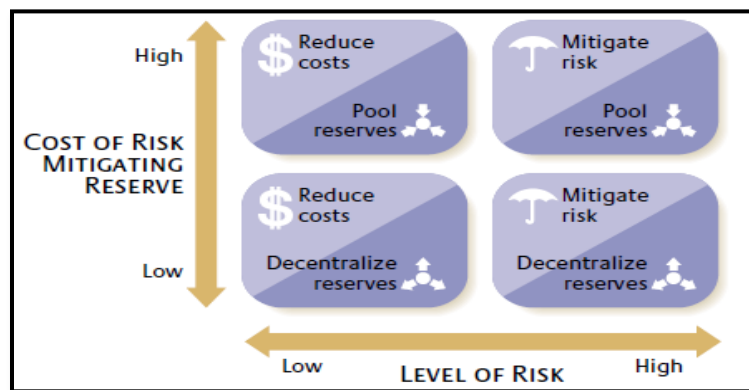


Figure 8. Rule of Thumb for Risk Mitigation Strategies

(Source: Chopra and Sodhi (2004), page 59)

In view of the fact that the main focus for this study is to mitigate the high level of risk in supply chain, based on the rule of thumb, there are two basic strategies: using pool reserves or decentralising reserves. Indeed, these tactics are basic and need to be modified. Decisions about which strategy will be implemented really depend on the risk and the firm's ability.

Landslides and forest fires constitute environmental risks in biofuel supply chain. These two risks are categorised as very risky since its RPN and risk score values are beyond the threshold value. The occurrence of these risks interrupts the flow of goods along the chain. The delivery of raw materials from suppliers or delivery of products to the customers will face delays. This is the lowest impact and most likely occurs in the supply chain. Perhaps, these risks can be a serious threat if it happens near the plants and plantations and directly affects them. In order to mitigate these risks the most appropriate strategy is using safety stock and buffer stock (increase inventory). Safety stock levels are increased to compensate for the delay of materials delivery from supplier if this risk event occurs and buffer stock levels are enhanced to ensure customer demand can still be fulfilled during the risk event (Slack and Johnston, 2005). All the inventory resources are decentralised in warehouses, plants and any pool of reserves. The decentralisation of reserves is appropriate for this case since the demand for biofuel is quiet predictable (Chopra and Sodhi, 2004). To avoid the property loss if a landslide or forest fire directly cracks down the resources, business interruption insurance can be used (Svenssons, 2004). These strategies also

can be applied for mitigating the other supply chain risks in the biofuel supply chain. Even though those risks are not categorised as extreme, the firm has to prepare for the worst case that might occur.

Two demand risks have been identified and grouped as extremely risky. Those risks are negative campaign from competitor and national economic conditions (instability). Fundamentally, the effect of these risks is decreased forecast accuracy, thus it might increase the cost of inventory or stock. In order to mitigate these risks, the firm can use pool or aggregate demand forecasting (Chopra and Sodhi, 2004). Seeing as the nature of demand for biofuel is quite predictable, collaborative demand planning with customers (downstream) is a useful option to tackle this type of risk (Tang and Tomlin, 2008). Due to the fact that The Company only has one main customer for their biofuel, it is reasonable and applicable to implement this strategy. Furthermore, the impact of fluctuations in demand can be reduced by using postponement strategy. Seeing as biofuel is one of the by products of palm fruit, delaying the point of product differentiation until the actual demand from customer is revealed is possible to implement. This strategy can improve The Company's product flexibility and then it will mitigate the demand risk (Tang and Tomlin, 2008). For example, they can postpone the process just before the last stage of biofuel production so if the demand is lower than the forecast, it can be switched to another product. In an attempt to overcome the effect of a negative campaign about palm biofuel from competitors, they can improve its corporate social and environmental responsibility activity. Since the competitors' campaign about palm plantations reduce the amount of forest due to public concern about it being burned or cut before planting the palm, The Company has to counteract this campaign by implementing an environmentally friendly replanting programme in all of their plantations and then publicise this activity by using an effective marketing campaign. For the sake of their corporate image, this strategy is urgently required. Empirical findings from Kovacs (2008) stated that firms from product chain faced more environmental responsibility demand in the downstream part of their supply chain rather than the upstream. Therefore, palm biofuel's image can be renovated by executing CSR and CER (corporate environmental responsibility) and publicising them intensively in the society. By doing this, the demand of palm biofuel is expected to be enhanced or even more sustainable for longer period.

The other risk that needs to be mitigated is the quality of inbound products from suppliers. This risk is categorised as supply risk, which is mostly caused by the supplier. The impact of the low

quality of the inbound products affects the quality of biofuel. The purpose of mitigating this risk relationship with the supplier is the key tool. Implementing collaborative relationships with the suppliers are extremely desirable to reduce the prevent the occurrence and impact of this risk. It supports the improvement of flexibility and ability, thereby reducing the risk (Faisal *et al*, 2006). Certainly, building such relationships requires trust and information sharing between firms for a long-term period along with commitment to share risk and, in the end, joint business sustainability plan can be achieved (Tang and Tomlin, 2008; Christopher and Peck, 2003). On the other hand, there is another strategy to mitigate supply risk which has more redundant suppliers (reconfiguring supply base). This strategy increases supply flexibility for the firms due to having more suppliers, and it automatically increases the buyer's bargaining power (Chopra and Sodhi, 2004; Tang and Tomlin, 2008). The choice of which strategy is the most suitable for the biofuel supply chain entirely depends on the nature of the firm and its external parties, which is why a mitigation strategy needs to be customized (Chopra and Sodhi, 2004). Acquiring more suppliers is favourable for high volume products with an abundant supply of materials.

Finally, the last risk that needs mitigation strategy immediately is the chemical mixing risk in the fractioning machine, which is categorised as an operational risk. Operational risk is described as a transformation process therefore consideration about ex ante (prevention), in process, and ex post (after the risk event) mechanisms is needed (Lewis, 2002). Preventive control is identical to Quality Management concepts about "doing right at first time" and mistake proofing (poka yoke). An example of this strategy is building standard operating procedures (SOP), assigning quality control and inspection to ensure that all the processes comply with the SOP accurately (ex ante mechanism), and human safety management can be implemented to reduce the impact if the risks that occur (in process mechanism). Regarding the nature of this operational risk that is categorised as high-impact but low occurrence, all The Company needs to do is ensure that all the processes follow all the standards. If the risk accidentally occurs, Company can only reduce the impact of that risk, the worst of which would be plant breakdown, by obtaining business interruption insurance in advance (Svenssons, 2004).

Additionally, these strategies can be applied to mitigate the other risks. For instance, the implementation of Quality Management tools might prevents the occurrence of operational risks. Moreover, reconfiguring the supply base increases the quality control for inbound products, also

it can prevent the material delivery problem to avoid delay. In conclusion, mitigation strategies within the supply chain are shown on table 4 below;

Category of Risk	Risk	Level of Risk	Mitigation Strategies
Demand Risk	negative campaign from competitor	High	> Collaborative Forecast Planning with customer > Product Postponement > CSR and CER implementation
	instability in economics condition		
	fluctuation demand	Low	
Supply Risk	inbound product quality	High	> Reconfiguring supply base (add more suppliers) > Increase Inventory Level (safety stock level)
	uncertainty in palm's harvest season	Low	
	product arrival variability (delays)		
	deforestation problem		
	palm life cycle risk		
Operational Risk	Chemicals mixing in fractionation machine	High	> Implementing Quality Management > Implementing Human Safety Management > Acquiring business disruption insurance
	fractioning machine breakdown	Low	
	refining machine breakdown		
	IT breakdown		
Environmental Risk	landslide	High	> Implementing optimum inventory level (buffer &safety stock) > Decentralised Inventory Resources > Acquiring business disruption insurance
	forest fire during dry season		
	earthquake	Low	
	tsunami		
	currency exchange		
	oil price decrease		

Table 4. Risk Mitigation Strategies for Company's Biofuel Supply Chain

Conclusion and Implications of The Research

Having explained the overall findings and constructed the mitigation strategies framework for the supply chain of a biofuel company in Indonesia, I shall now present the conclusion of this study. Since this study seeks to address the supply chain risk assessment and mitigation with three sub-questions, I present three arguments regarding the research questions. The first part summarised the overall supply chain networks in the biofuel company. The second one concludes the findings about the inherent risk in biofuel supply chain, as well as the results for the hypotheses. The last summarised the mitigation strategies to reduce the supply chain risks, which have been investigated earlier.

Firstly, referring back to the opening section, this research seeks to address “*How a biofuel company in Indonesia assesses and mitigates the risk in its supply chain?*” In order to answer this, the first question which asks “*How is the supply chain network in Indonesian biofuel Company?*”, has been answered in the graph of supply chain networks and the actors of a biofuel supply chain company, as described in figure 9 below;

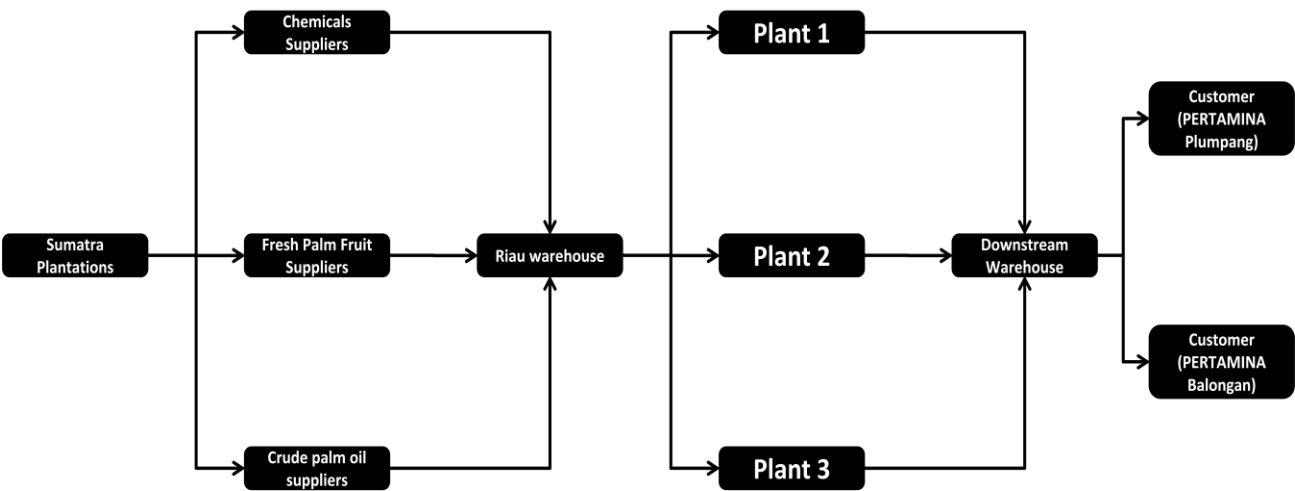


Figure 9. The Supply Network

Secondly, the second research question seeks to figure out the inherent risks in the supply chain which are presented in table 5 below, and thus it answers the second research question.

SUPPLY CHAIN RISKS	
Demand Risks	Supply Risks

demand fluctuation	inbound product quality
negative campaign	uncertainty in palm's harvest season
economic condition	product arrival variability (delays)
Environmental Risks	deforestation problem
earthquake	palm life cycle risk
forest fire during dry season	Operations Risks
landslide	Chemicals mixing in fractioning machine
tsunami	fractioning machine breakdown
currency exchange	refining machine breakdown
oil price decrease	IT breakdown

Table 5. The Inherent Risk in Supply Chain

Finally, the last research question tries to find and explore the risk mitigation strategies framework to reduce the supply chain risk. Previously, risk assessment has been carried out to seek the high level of risk to be mitigated. As the result of the mitigation strategies for all the risks, table 6 gives the explanation of it below;

Category of Risk	Mitigation Strategies
Demand Risk	<ul style="list-style-type: none"> > Collaborative Forecast Planning with customer > Product Postponement > CSR and CER implementation
Supply Risk	<ul style="list-style-type: none"> > Reconfiguring supply base (add more suppliers) > Increase Inventory Level (safety stock level)
Operational Risk	<ul style="list-style-type: none"> > Implementing Quality Management > Implementing Human Safety Management > Acquiring business disruption insurance
Environmental Risk	<ul style="list-style-type: none"> > Implementing optimum inventory level (buffer & safety stock) > Decentralised Inventory Resources > Acquiring business disruption insurance

Table 6. Risk Mitigation Strategies Framework

All the explanations above, together, have answered the main research question laid out in the first section as to how a biofuel company in Indonesia assesses and mitigates the risk in its supply chain.

What are the implications of this study? I propose no less than two parallel implications.

First, the implications of this study for Company itself are: (1) Company has a clear framework of risk mitigation for their biofuel supply chain, hopefully, this framework can enhance the sustainability of their biofuel business; (2) this study can be used as the foundation for risk management strategy for all their business units; and (3) this study enhances their awareness of the threats that might interrupt or even demolish their company. To conclude, this study offers a practical implementation of risk management strategy in order to achieve sustainability of the business.

Second, the implications for the biofuel industry development in Indonesia are: (1) it is hoped that this study might influence the other actors in the biofuel sector in Indonesia to implement a risk management strategy to sustain their industry and (2) encourage the Indonesian government to give instruction to all the components who are involved in biofuel development in Indonesia.

In conclusion, the main implications of this study are to encourage the company, especially its supply chain division, to implement the concept of supply chain risk management in order to ensure the continuity of their supply chain and their business as a whole.

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