

**Strategic Formulation of Mitigating Risk by Using Fuzzy TOPSIS
Model Based on House of Risk Framework**

THESIS

**Submitted to International Program Industrial Engineering Department in Partial
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YOGYAKARTA
2017**

AUTHENTICITY STATEMENT

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AUTHENTICITY STATEMENT

For the sake of Allah SWT, I confess this work is on my own work except for the excerpts and the summaries that each of their sources has already been cited and mentioned. If in the future my confession is proved to be wrong and dishonest resulting the violence of the legal regulation of the papers and the intellectual property rights, then I would have the will to return my degree to be drawn back to Universitas Islam Indonesia.

Yogyakarta, October 2017



Rhesa Rahman

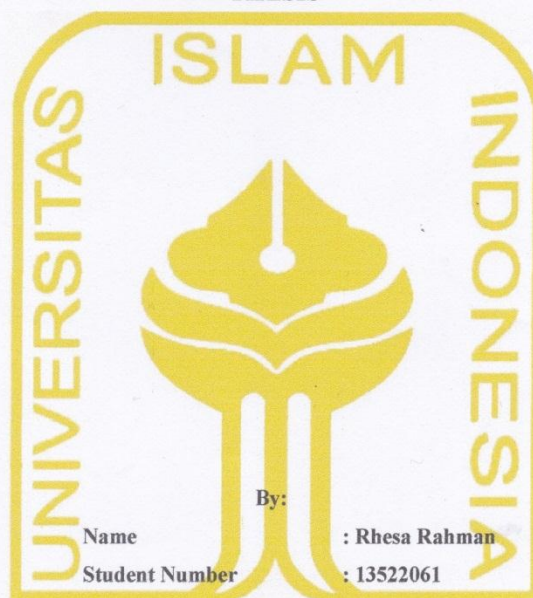
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Strategic Formulation of Mitigating Risk by Using Fuzzy TOPSIS
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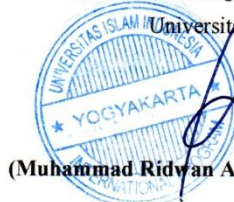
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DEDICATION PAGE

To my beloved parents, Father & Mother

My brother, Awan & Ilham

My thesis supervisor, Dr. Drs. Imam Djati Widodo, M.Eng. Sc

And All of my friends, IP TI UII batch 2013

And International Program Industrial Engineering Univeristas Islam Indonesia

Thank you for everything.

MOTIVATION PAGE

“For each one are successive [angels] before and behind him who protect him by the decree of Allah. Indeed, Allah will not change the condition of a people until they change what is in themselves. And when God intends for a people ill, there is no repelling it. And any is not for them besides Him any patron.”

(Qs. Ar-Ra’du: 11)

“For indeed, with hardship will be ease. Indeed, with hardship will be ease.”

(QS. Al-Insyirah: 5-6)

“Success is not final, failure is not fatal: it is the courage to continue that counts.”

(Winston Churchill)

“Genius is 1% inspiration, and 99% perspiration.”

(Thomas Edison)

PREFACE

Assalamualaikum Wr. Wb.

Alhamdulillah Rabbil'alam, gratitude and praise to Allah SWT for the strength, grace, and guidance, to help the Author in completing this thesis. During arranging this thesis, Author had faced so many challenges and problems. However, Author had obtained so many helps and supports, either directly or indirectly, from some parties involved. On this occasion, Author would like to appreciate and thank to all the parties below:

- a. Dr. Drs. Imam Djati Widodo, M.Eng. Sc as the supervisor who always guidance and provide knowledge to assist Author in completing this Thesis
- b. My beloved mother, father, brother, and other family members who always give prayers, supports, inspires, and encourage Author during conduct and completing this Thesis
- c. Mr. Sumartono and all employees of PT. Qumicon Indoneisa for allowed Author to collecting required data
- d. My friends of International Program Industrial Engineering batch 2013 for the spirit and enthusiasm for Author
- e. All parties that cannot be mentioned one by one by Author for the assistance in completing this Thesis

Author realize that this thesis is still not perfect and still have some weaknesses so that Author really expect any criticism and suggestions from readers for the perfection of this report. Hopefully this report and information included will be useful for Author and give benefit to other parties who read this.

Wassalamualaikum Wr. Wb.

Yogyakarta, October 2017

Rhesa Rahman

ABSTRACT

Risk management is one of important factor in running a business which needs to be managed well because it will affect in the process of decision making. The effective implementation of risk management is started by conducting risk monitoring, establishing risk assessment context, detail identification and analyzing risk, evaluating risk, and providing treatment to the risk. There are several methods to conduct the process of risk management i.e. FMEA, FMECA, HOR, and etc. This research tries to identify the potential risk and recommendation strategy of mitigation action using proposed method Fuzzy Logic modified with Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) based on House of Risk Framework (HOR). This research took place in PT. Qumicon Indonesia which concerned on business process at the company production division. In identifying the potential risk and the mitigation strategy, this research will consider the severity risk level of risk event and probability occurrence of risk agent. From HOR phase 1, it is identified 18 risk events and 21 risk agents as a cause of risk. Then by conducting Pareto diagram analysis with comparison 80:20, 16 risk agents were selected to be the prioritized risk that will exposed to the strategy of mitigation action. In HOR phase 2, this research obtains 10 strategies of mitigation action by considering with the mitigation action effectiveness and the type of risk that was selected. In implementing the strategy, it depends on the company's policy and condition at that time.

Key words: Risk Management, Fuzzy TOPSIS based on House of Risk Framework, Risk of Production Department

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CHAPTER I

INTRODUCTION

In this first chapter, there will be explained a brief introduction which elaborates the background, problem formulation, purpose, scope and benefit of the research, as well as the systematical writing.

1.1 Background

The Changing of economic, social, political, and environment condition gives direct effects to industry. Many companies that previously are the big ones then become small company or experiencing the bankruptcy because they cannot adapt with the situation and analyze potential risk that comes from many sides. Chang & Cheng (2010) stated to maintain the competitive edge of an enterprise, that will guarantee the product quality, cost and timing fit with market demand. It means that the operational or performance of the company should be monitored and controlled because improving the operational performance company will affect the industries or enterprise in increasing the profit. Many methods were used by the company that possibly of gaining operational/performance excellence. Pugna et al. (2016) stated to increase the performance of a company, different quality improvement initiatives like Total Quality Management, ISO certification, Agile & Lean manufacturing could be implemented. Besides that, one of the theories that has started to emerge is Enterprise Risk Management (ERM).

Meidell & Kaarbøe (2016) stated Enterprise risk management (ERM) has grown rapidly in organizations over the last two decades with shareholders, regulators, professional bodies and rating agencies pushing for better corporate governance, risk management, and internal control. Nocco & Stulz (2006) stated the concept of Enterprise risk management is the capability of the corporation in managing risk into

two fundamentally different ways. The first is managing risk at a time on a largely compartmentalized and decentralized basis or by managing all risks viewed together within a coordinated and strategic framework. In another term, enterprise risk management is explained as a form of planning, organizing, leading, and controlling the activities of an organization in order to minimize the effects of risk to an organization. Enterprise risk management scopes are risks associated with accidental losses, financial, strategic, operational, and other risks.

The concept of enterprise risk management is originated from ISO 31000:2009 that explains about a set of principles and guidelines on how to implement risk management. ISO 31000:2009 certification uses to certify or an agreement that a management system, manufacturing process, service or documentation procedure has all the requirements for standardization and quality assurance. Until now, a concept of risk management in ISO 31000:2009 becomes a guideline in improving the company because risk management was developed based on the condition of the company. The effectiveness of risk management will support a sound decision making, which improves company's performance by improving the precision in balancing the tradeoff between risk and expected return (Gehner, 2008). That statement was explained by Mohammed & Knapkova (2016) stated in another perspective, risk management is an effective method, applied in order to alleviate unwanted effects of exposures and earn optimum benefit from risky situations. The basic concept of risk management is identifying the risks which are to be mitigated and making calculated and concrete decisions in this regard.

A research about risk management has been conducted by Florio & Leoni (2016) in the journal of British Accounting Review about investigating a relationship between the extent of implementation of enterprise risk management (ERM) systems and the performance of Italian listed companies. This research provides a contribution to the ERM literature i.e., introduces a new and more complete measure for ERM implementation. Concerning not only corporate governance bodies dedicated to risk management but also the characteristics of the risk assessment process. The results of the research show that firms with advanced levels of ERM implementation, present higher performance both as financial performance and market evaluation.

Many tools and methods were developed to identify risk management by qualitative or quantitative explanation. The qualitative methods are Delphi, HAZOP, FMECA, Risk Matrix Chart, House of Risk (HOR) and etc. For the quantitative method are Decision Tree, Simulation, and etc. One of a mostly methods that used in risk management is FMEA (Failure Mode Analysis), this method is a systematic technique for identifying, prioritizing and acting on potential failure modes before the failures occur (Chen & Ko, 2009). Based on the FMEA and HOQ concept, there is a new method that formed from both concepts that called HOR. Pujawan & Geraldin (2009) explain the concept of HOR is a modification of FMEA for risk quantification and HOQ model for prioritizing which risk agents are to be dealt firstly and for selecting the most effective actions in order to reduce the risks potentially posed by the risk agents. This method purposed to improve the original FMEA concept because the calculation of RPN is not determining the mitigation action for the risk.

Research that uses HOR method was conducted by Luthfi et al. (2012) that explained about analyzing and evaluating the risk that might occur in supply chain management of communication company. The result of this research identifies risk from preparation when the supply chain system working. Whereas, Pujawan & Geraldin (2009) explained about a framework to manage supply chain risks. The framework will enable the company to select a set of risk agents to be treated and then prioritize the proactive actions, in order to reduce the aggregate impacts of the risk events induced by those risk agents.

Research of risk management will face with many uncertainties and vague condition because the risk generally caused by human factor, environmental factor, and poor of management policy. This condition often happens when trying to assess accident probabilities/consequences that are difficult to quantify mathematically. For example, a situation where the uncertainties are caused by the lack of knowledge. The researcher considered to use fuzzy logic as a tool in data processing because it can help to interpret the ambiguous data and the vague data. Mundi et al. (2016) stated the application of fuzzy logic eliminates some of the computational problems associated with a traditional method of ranking. Moreover, the priority to appropriate actions can be given, even if the basic scope of information is vague, ambiguous or imprecise.

Kazan et al. (2015) also said about the approach of fuzzy give capability to process the data of human beings and function making use of their experiences and intuitions. Numeric expressions are used instead of numeric expressions in giving this capability.

For supporting fuzzy calculation, the parameter class classification of variable should be declared because the concept of a fuzzy is to manage the representation of classes/categories that have boundaries with means characteristic functions in taking values of an ordered set of membership values (Silva et al., 2014). In order to classify, the researcher uses TOPSIS-Sort method because of the logical concept and simple computation. Sabokbar et al. (2016) stated the concepts of TOPSIS-Sort method uses a set reference point for sorting, and the alternatives are compared to these reference points. This set of reference points includes a value of reference profiles will specify the theoretical limits between the classes. Besides that, combining Fuzzy with TOPSIS will give certain result because simplicity of TOPSIS, the technique is often criticized because of its inability to deal adequately with uncertainty and imprecision inherent in the process of mapping the perceptions of decision-maker (Karimi et al., 2012).

There is a research that combines Fuzzy method with TOPSIS. Mahdevari et al. (2014) conducted research that related to human health and safety risks management in underground coal mines. This research proposed to assess the risks associated with human health in order to manage, control measures, and support decision making which could provide the right balance between different concerns. In this paper, Fuzzy TOPSIS is used for evaluating and ranking of risks affecting miners' health and safety. The method is applied to calculate fuzzy positive and fuzzy negative ideal situations for finding C_i index. Based on the result of this paper, risks with a C_i index value closest to 1 (maximum number of membership function) is ranked highest risk, while risks having C_i value furthest from 1 are ranked lowest risk.

Mavi et al. (2016) conducted research about supplier selection in the context of supply chain risk management. In selecting the supplier, nine criteria of quality, on time delivery and performance history and six risks in the supply chain are considered for evaluating suppliers. This paper used Shannon entropy and Fuzzy TOPSIS as a method in processing data. Shannon entropy methods used for weighting criteria and for

ranking alternatives use TOPSIS methods. Then Fuzzy approach is to assign the relative importance of the attributes in TOPSIS calculation. The result of this paper shows that the demand side risk has the most weight and environmental risk has the least weight in the supplier selection problem.

Thus, based on the previous researches on above, this research will conduct the analysis of risk management in the enterprise. This research will assess the risk that might occur in the enterprise using a proposed method of HOR modified with Fuzzy Logic theory and TOPSIS. The HOR framework was chosen because it provides a frame of a process in reducing risk by considering the occurrence of the risk agents. This is based on the notion that attacking the causes (or the risk agents) could concurrently prevent one or more risk events from happening. The proposed method starts by classifying the data result from matrix relationship use TOPSIS. The classification data are needed to manage the class and categories of membership function in the fuzzy calculation. After that, the result data from the calculation will be analyzed to choose the prioritize risk that should be mitigated because it can help the enterprise or company to choose corrective actions wisely.

1.2 Problem Formulation

Based on the description in the background above, the problems that come up in the research would be formulated and they generate research questions as follows:

1. How to develop the concept of Fuzzy TOPSIS Based HOR Framework?
2. How to identify the potential risk that might occur in a company and the strategy of mitigation action based on Fuzzy TOPSIS Based HOR Framework?

1.3 Objective Research

This paper is created to fulfill several objectives as mentioned as below:

1. To develop a concept of Fuzzy TOPSIS Based HOR Framework.
2. To identify potential risk in a company and the recommendation for mitigation action strategy that uses Fuzzy TOPSIS Based HOR Framework.

1.4 Scope of Problem

The scope of a problem is a restriction or limitation of problems to make a border in the research in order to keep the research inside the scope. There are some limitations as follows:

1. This research uses Fuzzy Logic, TOPSIS, and HOR method as a tool for analyzing the problem.
2. The research will be conducted in a small and medium enterprise (SME) in Yogyakarta.

1.5 Benefit of Research

Based on the purpose of the research, this paper is developed to give the contribution as below:

1. To conduct the research in analyzing and determining the risk that occurs in the expected company.
2. To identify the mitigation or recommendation for the risk that occurred.
3. To be a contributor in the development of knowledge.

1.6 Systematical Writing

Study writing is based on the rules of scientific writing in accordance with the systematics as follows:

1. CHAPTER I INTRODUCTION

This chapter consists of background problem, formulation of the problem, research question, problem limitation of research, the objectives or purpose research, the benefits of research and systematic writing.

2. CHAPTER II LITERATURE

In this chapter, there will be elaboration on the theories of reference books and journals as well as the results of previous researches related to the research problem which are used as a reference for problem solving.

3. CHAPTER III RESEARCH METHODOLOGY

This chapter consists of the description of the framework or concept, line schedule of research, and the methodology in conducting the research.

4. CHAPTER IV COLLECTION AND PROCESSING DATA

This chapter contains the data obtained during the research and how to analyze the data. Data processing result is displayed either in the form of tables and graphs. What is meant by processing the data also includes analysis of the results obtained. In this section is a reference to the discussion of the results to be written in Chapter V.

5. CHAPTER V DISCUSSION

This chapter presents discussion of the results of data processing that have been done in research, compatibility with the objectives of research so as to produce a recommendation.

6. CHAPTER VI CONCLUSION AND RECOMMENDATION

This chapter consists of conclusion the research and completed with the recommendation for the future research.

REFERENCES

APPENDIX

CHAPTER II

LITERATURE REVIEW

In this chapter, it will be further explained about the literature review studies which are divided into two, inductive and deductive. Inductive study is a study from previous research that already has a reputation. The deductive study would explain the basic theory that has relation with research that would be conducted from the text books, etc. Besides that, the Inductive and deductive study need to be done to find out the gap between previous studies and the research that would be conducted as well as to avoid the plagiarism. This literature review will be divided into several sub chapters.

2.1 Inductive Study

In this era of globalization, every company is required to be able to compete to survive. For that reason, one thing should do is to improve the performance of the company by controlling and managing the risks from all side of business. Chang & Cheng (2010) stated to maintain the competitive edge of an enterprise, that will guarantee the product quality, cost and timing fit with market demand. It means the operational or performance of the company should be monitored and controlled since the operational performance improvement will affect the industries or enterprises in increasing the profit. From this condition, the concept of risk management and enterprise risk management was emerged.

Sprčić et al. (2015) stated Enterprise Risk Management (ERM) encompasses the activities and strategies which enable the company to identify, measure, reduce, or exploit, as well as to control and monitor the exposure to various types of corporate risks – strategic, financial, operational, and reporting, as well as compliance risks for the purpose of increasing the organization's value to its stakeholders. That statement added by Nocco & Stulz (2006) said the concept of Enterprise risk management is the

capability of a corporation in managing risk into two fundamentally different ways. The first is managing risk at a time on a largely compartmentalized and decentralized basis or by managing all risks viewed together within a coordinated and strategic framework.

Some researches about risk management have been conducted. Florio & Leoni (2016) explained in the journal of British Accounting Review about the research that investigated whether a relationship exists between the extent of implementation of enterprise risk management (ERM) systems and the performance of Italian listed companies. The research provides a contribution to the ERM literature. The contribution introduces a new and more complete measures for ERM implementation, concerning not only corporate governance bodies dedicated to risk management, but also the characteristics of the risk assessment process. The results of the research show that firms with advanced levels of ERM implementation present higher performance, both as financial performance and market evaluation.

Other than that, Sprčić et al. (2015) explained in the journal of Economic and Financial about enterprise risk management research in state and perspectives of Enterprise risk management system development. The aim of the research is developing ERM Index that measures quality of ERM process within the company. The process was to explore level of ERM development in listed Croatian companies by employing ERM Index, explored determinants of risk management system development in listed Croatian companies, explored whether risk management decisions have different rationales in Croatian companies than among their western counterparts. The results revealed low levels of ERM development in listed Croatian companies. 38 per cent of analyzed companies have no elements of ERM system, from which 22 per cent did not manage corporate risks at all.

In the scope of project management, the research about risk management has been done by Grabovy & Orlov (2016) explained in journal Procedia Engineering about a practical procedure of the overall risk efficient management in the course of implementation of investment construction megaprojects. The research provided an application of special techniques and instruments that allow taking into account the uncertainty factor at all stages of implementation of an investment construction project

in the best possible way. From this research, the researcher gave the recommendation for the developer project aimed at reduction of the initial risk level up to the acceptable value.

Besides in the scope of project management, the application of risk management was conducted in manufacture by Gu et al. (2017) explained in journal Computer and Industrial Engineering. The research about the approach and evaluation of risk management in supply chain used a credit risk matrix and fuzzy as a method to solve the risk. The conclusion of this research is a demonstration of the credit risk of supply chain enterprises is affected by their specific conditions, but also by the conditions of the related enterprises.

The risk management was conducted by many approach methods such FMEA, Fuzzy, Delphi, Hazop, HOR and etc. The research of risk management using FMEA was conducted by Van Leeuwen et al. (2009) explained in Journal of Pharmaceutical and Biomedical Analysis about analysis in developing of Near-Infrared (NIR) analytical procedure. Whereas, another research was conducted that combines the FMEA concept to gain more analyses because the calculation of RPN is not determining the repair action that will be done. For example research of Pujawan & Geraldin (2009) that modified the failure mode and effect analysis (FMEA) model for risk quantification and adapt the house of quality (HOQ) model for prioritizing which risk agents to be dealt with first and for selecting the most effective actions in order to reduce the risks potentially posed by the risk agents i.e. HOR (House Of Risk). This research provides a framework to proactively manage SC risks. The framework will enable the company to select a set of risk agents to be treated and then to prioritize the proactive actions, in order to reduce the aggregate impacts of the risk events induced by those risk agents.

The risk management research that uses HOR as a method also conducted by Luthfi et al. (2012) that explained about analyzing and evaluating the risk that might occur in supply chain management of Communication Company. The result of this research was risk identification from preparation when the supply chain system was applied.

Other than that, most researches on risk management combine several methods to gain the optimal analysis and recommendation. For example, research by Wessiani & Sarwoko (2015) explained in journal *Procedia Manufacturing* about analysis risk in poultry feed production. This research used Fuzzy FMEA method in the analysis of risk of the feed production and identified 89 potential risks. The researcher provided mitigation recommendation by reducing the likelihood and impacts effort compared to other types of mitigation because the reducing effort is the most realistic efforts that the company can implement when the business process has been already running.

Besides Fuzzy FMEA, another combination method that was used to analyze risk is Fuzzy AHP. For example the research by Sofyalıoğlu & Kartal (2012) that explained about a selection of global supply chain risk management strategies by using fuzzy analytical hierarchy process. In this research, the researchers try to determine the most significant global supply chain risks and risk mitigation strategies for the company operating in the iron and steel industry.

There is a research that combines Fuzzy method with TOPSIS. Mahdevari et al. (2014) conducted research that related to human health and safety risks management in underground coal mines. This research proposed to assess the risks associated with human health in order to manage, control measures, and support decision making, which could provide the right balance between different concerns. In this paper, Fuzzy TOPSIS is used for evaluating and ranking of risks affecting miners' health and safety. The method is applied to calculate fuzzy positive and fuzzy negative ideal situations for finding C_i index. Based on the result of this paper, risks with a C_i index value closest to 1 (maximum number of membership function) is ranked highest risk, while risks having C_i value furthest from 1 is ranked lowest risk.

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relative importance of the attributes in TOPSIS calculation. The result of this paper showed that the demand side risk has the most weight and environmental risk has the least weight in the supplier selection problem.

Thus, based on the previous researches above, this research will conduct the analysis on risk management in the enterprise. This research will assess the risk that might occur in the enterprise using a proposed method of HOR modified with Fuzzy Logic theory and TOPSIS. The HOR framework was chosen because it provides a frame of a process in reducing risk by considering the occurrence of the risk agents. This is based on the notion that attacking the causes (or the risk agents) could concurrently prevent one or more risk events from happening. The proposed method starts by classifying the data result from matrix relationship by using TOPSIS. The data classification is needed to manage the class and categories of membership function in the fuzzy calculation. Later, the data result from the calculation will be analyzed to choose the prioritize risk that should be mitigated because it can help the enterprise or company to choose corrective actions wisely.

Based on the inductive study above, research uses a framework of HOR and Fuzzy TOPSIS was not conducted by another researcher in term of risk management. This research will assess the risk that might occur in the enterprise using a proposed method of HOR modified with Fuzzy Logic theory and TOPSIS. The HOR framework was chosen because it provides a frame of a process in reducing risk by considering the occurrence of the risk agents. This is based on the notion that attacking the causes (or the risk agents) could concurrently prevent one or more risk events from happening. The proposed method starts by classifying the data result from matrix relationship use TOPSIS. The classification data is needed to manage the class and categories of membership function in the fuzzy calculation. After that, the result data from the calculation will be analyzed to choose the prioritize risk that should be mitigated because it can help the enterprise or company to choose corrective actions wisely. Hopefully, this combination can be proposed method that can help in analyzing risk management by giving more explanation. The advantage of risk management research is a form of risk that dynamically depends on the place condition, and different research

variable also parameter, an object research. All of that reasons can be a state of the art for this research that will contribute to knowledge.

2.2 Deductive Study

2.2.1 Risk Management

Based on ISO 31000:2009, risk management is an essential business activity for enterprises of all sizes. Enterprises that manage risks effectively will thrive and produce high quality products or services where these are the organizational objectives. Gehner (2008) stated that the effectiveness of risk management will support a decision making, which improves company's performance by improving the precision in balancing. The concept of risk management process is illustrated in Figure 2.1.

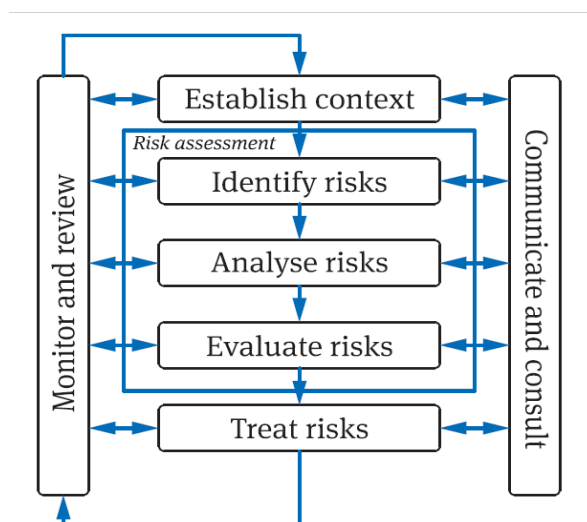


Figure 2.1 Risk Management Process

Source: ISO 31000:2009

2.2.2 Enterprise Risk Management

Nocco & Stulz (2006) said the concept of Enterprise risk management is the capability of a corporation in managing risk into two fundamentally different ways. The first is managing risk at a time on a largely compartmentalized and decentralized basis or by

managing all risks viewed together within a coordinated and strategic framework. The concept of enterprise risk framework is illustrated in Figure 2.2.

As can be seen in Figure 2.2, enterprise risk management explained as a form of planning, organizing, leading, and controlling the activities of an organization in order to minimize the effects of risk on an organization. Enterprise risk management scopes are risks associated with accidental losses, financial, strategic, operational, and other risks.

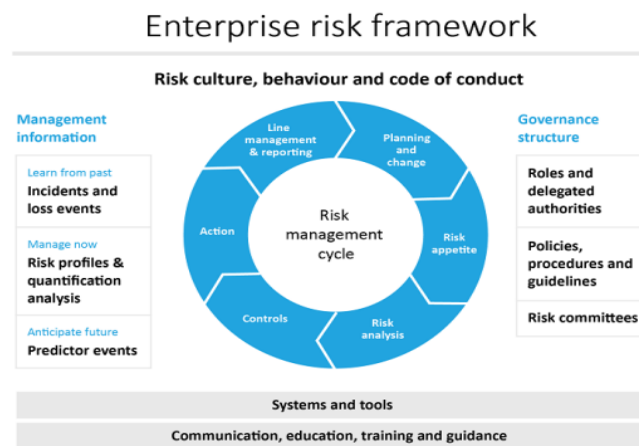


Figure 2.2 Enterprise Risk Framework

Source: Delta Lloyd Group's Risk Management Framework

2.2.3 Fuzzy Theory

The concept of fuzzy logic versions has first been introduced by L.A.Zadeh from California Berkeley University with the publication of the first essays on the subject in the year 1965. The important concept of fuzzy logic has been increased from that day onwards up today. The concept is defined as a mathematical order which has been established for the expression of uncertainties and working with uncertainties. Mundi et al. (2016) stated that the application of fuzzy will eliminate some of the computational problems with a traditional method by ranking the action. Moreover, the priority to appropriate actions can be given, even if the scope of information is unclear, ambiguous or imprecise. The approach of fuzzy gives the capabilities of the tool to process the data of human beings and function making use of their experiences and intuitions. Numeric

expressions are used instead of numeric expressions in giving this capability (Kazan et al., 2015).

Silva et al. (2014) stated fuzzy set theory is one of the concepts of science and engineering because it can manage imprecise or ambiguous information by manipulating mathematical terms. The notion of fuzzy sets is quite intuitive and transparent like captures the essence of how things are perceived and described in everyday life. The concept of a fuzzy set manages the representation of classes/categories that have boundaries with means characteristic of a functions in taking values of an ordered set of membership values. Roghanian & Mojibian (2015) explain a basic of the fuzzy logic system is formed by a set of the kind IF...THEN rule to perform the tracing of the input $U \subset R^n$ on to the output $V \subset R$. The r th fuzzy rule is presented in the following way: $x = (x_1, \dots, x_n) \in U$ is input linguistic variable and $y \in V$ is the output linguistic variable.

$$R^r = \text{if } x_1 \text{ is } \mu_{x_1}^r \text{ and } x_2 \text{ is } \mu_{x_2}^r \text{ and } x_3 \text{ is } \mu_{x_3}^r \text{ then } y \text{ is } \mu_y^r$$

Where $\mu_{x_1}^r, \mu_{x_2}^r, \mu_{x_3}^r$ and μ_y^r are the membership functions of x_1, x_2, x_3 , and y . The μ_y^r r th rule output can be obtained using minimum operation as Equation (2.1) below:

$$\mu_{R^r}(x, y) = \mu_{x_1}^r \wedge \mu_{x_2}^r \wedge \mu_{x_3}^r \dots \dots \dots (2.1)$$

Equation (2.2) below is an equation for obtaining maximum operation output.

$$\mu_{R^r}(x, y) = \bigvee_{r=1}^r R^r (x, y) \dots \dots \dots (2.2)$$

In Fuzzy Theory, there are 2 methods or styles of the calculation. The styles are Mamdani Style and Sugeno Style.

1. Mamdani Style

Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a

steam engine and boiler combination by synthesizing a set of linguistic control rules. Mamdani's style fuzzy is based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes. Although the inference process described in the next few sections differs somewhat from the methods described in the original paper, the basic idea is much the same.

2. Sugeno Style

Sugeno Style Introduced in 1985, it is similar to the Mamdani Style method in many sides. The first two parts of the fuzzy inference process, fuzzification the inputs and applying the fuzzy operator are exactly the same. The main difference between Mamdani and Sugeno is Sugeno Style output membership functions are either linear or constant.

2.2.4 Pareto Diagram Theory

Pareto diagram is used to find the 80% risk agents that contribute from total ARP. The Pareto diagram indicates that the degree of importance of reducing the probability of occurrence of each risk agent differs widely. The risk with high ARP should be prioritized and mitigate. An example of the model Pareto diagram is illustrated in Figure 2.3.

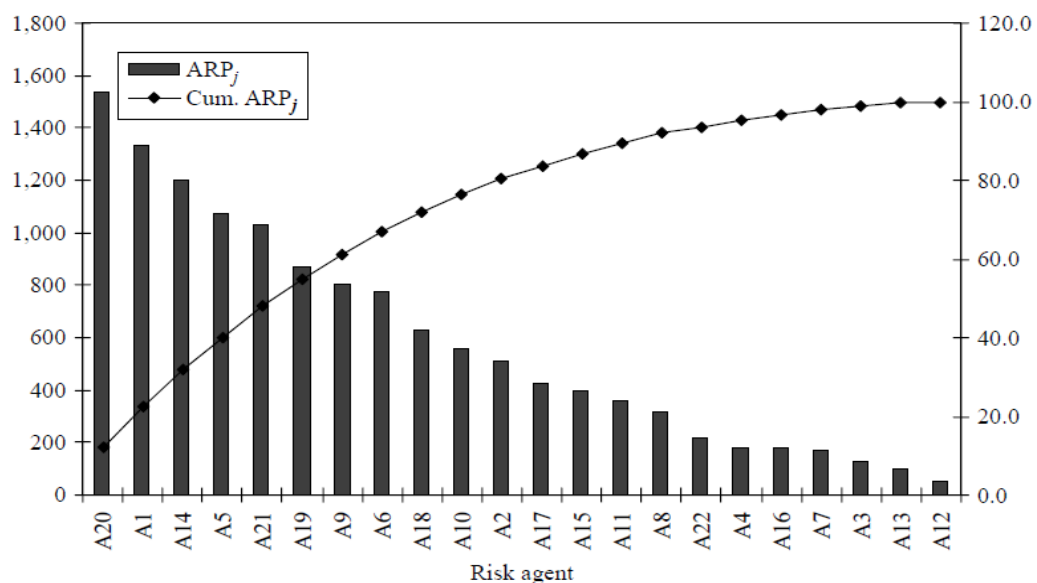


Figure 2.3 Pareto Diagram Template

Source : (Pujawan & Geraldin, 2009)

2.2.5 HOR

Pujawan & Geraldin (2009) stated that HOR is a model based on the modification of FMEA for risk quantification and HOQ model for prioritizing which risk agents are to be dealt first and for selecting the most effective actions in order to reduce the risks potentially posed by the risk agents. Luthfi et al. (2012) explained in his paper, there are 2 phases to conduct the HOR model:

1. HOR 1 is used to determine which risk agents are given the priority for preventive actions.
2. HOR 2 is to give priority to those actions considered effective but with reasonable money and resource commitments.

To conduct the HOR phase 1, there are several procedures

1. Identify risk events that could happen in each business process (E_i).
2. Assess the impact (severity) of such risk event (S_i).
3. Identify risk agents and assess the likelihood of occurrence of each risk agent (O_j).
4. Develop a relationship matrix i.e. relationship between each risk agent and each risk event (R_{ij}).
5. Calculate the aggregate risk potential of risk agent (ARP_j).
6. Rank risk agents according to their aggregate risk potentials in descending order

An example framework model of House of Risk phase 1 is illustrated in Figure 2.4. The model will consist of risk event severity score, risk agent occurrence score, a relation matrix score between risk agent and risk event, and aggregate risk potential score.

Business processes	Risk event (E_i)	Risk agents (A_j)							Severity of risk event i (S_i)
		A_1	A_2	A_3	A_4	A_5	A_6	A_7	
Plan	E_1	R_{11}	R_{12}	R_{13}					S_1
	E_2	R_{21}	R_{22}						S_2
Source	E_3	R_{31}							S_3
	E_4	R_{41}							S_4
Make	E_5								S_5
	E_6								S_6
Deliver	E_7								S_7
	E_8								S_8
Return	E_9								S_9
Occurrence of agent j		O_1	O_2	O_3	O_4	O_5	O_6	O_7	
Aggregate risk potential j		ARP_1	ARP_2	ARP_3	ARP_4	ARP_5	ARP_6	ARP_7	
Priority rank of agent j									

Figure 2.4 Table HOR Phase I

Source: (Pujawan & Geraldin, 2009)

To conduct the HOR 2, there are several procedures:

1. Select number of risk agents with high priority rank.
2. Identify actions considered relevant for preventing the risk agents.
3. Determine the relationship between each preventive action and each risk agent.
4. Calculate the total effectiveness of each action (TE_k).
5. Assess the degree of difficulties in performing each action (D_k).
6. Calculate the total effectiveness to difficulty ratio (ETD_k).
7. Assign rank of priority to each action (R_k).

An example framework model of House of Risk phase 2 is illustrated in Figure 2.5. The model will consist of preventive action difficult performance score, a relation matrix score between risk agent and preventive action, and risk agent aggregate risk potential score from HOR phase 1, and the effectiveness ratio score.

To be treated risk agent (A_j)	Preventive action (PA_k)					Aggregate risk potentials (ARP_j)
	PA_1	PA_2	PA_3	PA_4	PA_5	
A_1	E_{11}					ARP_1
A_2						ARP_2
A_3						ARP_3
A_4						ARP_4
Total effectiveness of action k	TE_1	TE_2	TE_3	TE_4	TE_5	
Degree of difficulty performing action k	D_1	D_2	D_3	D_4	D_5	
Effectiveness to difficulty ratio	ETD_1	ETD_2	ETD_3	ETD_4	ETD_5	
Rank of priority	R_1	R_2	R_3	R_4	R_5	

Figure 2.5 Table HOR Phase II

Source: (Pujawan & Geraldin, 2009)

2.2.6 TOPSIS

2.2.6.1 TOPSIS Theory

TOPSIS or Technique for Order Performance by Similarity to Ideal Solution is one of Method in Multi Criteria Decision Making. Zouggari & Benyoucef (2012), state the implementation this method is based on the principle that the chosen alternative should have the longest distance from the negative-ideal solution, i.e. the solution that maximizes the cost criteria and minimizes the benefits criteria; and the shortest distance from the positive-ideal solution, i.e., the solution that maximizes the benefit criteria and minimizes the cost criteria. In classical TOPSIS, the rating and weight of the criteria are identified precisely. The concept of distance alternative position by Zouggari & Benyoucef (2012) is illustrated in Figure 2.6.

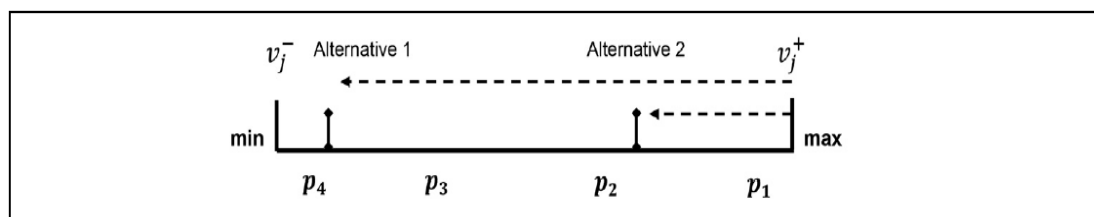


Figure 2.6 Distance Alternative Position from the Positive and Negative Ideal Solution

Source: (Zouggari & Benyoucef, 2012)

The TOPSIS Method consist of the following steps:

1. Normalize the decision matrix $X = (x_{ij})_{n \times m}$.

The formula of normalization decision matrix is illustrated in Equation (2.3).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^n x_{ij}^2}}, i = 1, \dots, n; j = 1, \dots, m \dots\dots\dots (2.3)$$

2. Calculate the weighted normalized decision matrix $V = (v_{ij})_{n \times m}$

The formula of weighting normalization decision matrix is illustrated in Equation (2.4).

$$v_{ij} = w_j r_{ij}, i = 1, \dots, n; j = 1, \dots, m \dots\dots\dots (2.4)$$

Where w_i is the relative weight of the j criterion, and $\sum_{i=1}^m w_j = 1$.

3. Determine the positive ideal and negative ideal solutions.

The formula for determining the positive ideal solution and negative ideal solution are illustrated in Equation (2.5) and Equation (2.6). Those equations use max and min function to find the benefit or cost of the variable.

$$A^+ = \{v_1^+, \dots, v_m^+\} = \{\max_j v_{ij} \mid j \in J, \min_j v_{ij} \mid j \in J'\} \dots\dots\dots (2.5)$$

$$A^- = \{v_1^-, \dots, v_m^-\} = \{\min_j v_{ij} \mid j \in J, \max_j v_{ij} \mid j \in J'\} \dots\dots\dots (2.6)$$

Where J and J' are the set of benefit criteria and cost criteria, respectively.

4. Calculate the Euclidean distances of each alternative from the positive ideal solution and the negative ideal solution, respectively.

The formula for determining Euclidean distances of each alternative from the positive ideal solution and negative ideal solution is illustrated in Equation (2.7) and Equation (2.8)

$$D_i^+ = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^+)^2}, i = 1, \dots, n \dots\dots\dots (2.7)$$

$$D_i^- = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^-)^2}, i = 1, \dots, n \dots\dots\dots (2.8)$$

5. Calculate the relative closeness of each alternative to the ideal solution.

The relative closeness of the alternative A_i with respect to A^+ is defined use Equation (2.9) :

$$cl_i = \frac{D_i^-}{D_i^+ + D_i^-}, i = 1, \dots, n \dots\dots\dots (2.9)$$

6. Rank the alternatives according to the relative closeness to the ideal solution

The best alternative is the one with the highest relative closeness to the ideal solution.

2.2.6.2 TOPSIS Sort Procedure

Sabokbar et al. (2016) stated that TOPSIS sort method pertains to the extension of TOPSIS in order to sort the alternatives. The sorting of the alternatives requires the comparison of the reference profiles that distinguish the classes. For each class k , two reference profiles, the upper limit profile $\bar{p}^k$, and the lower limit profile p^k are specified. The upper limit is the higher value than the lower limit, i.e., the upper limit of the profile of the first class is greater than the lower limit of the first class and the lower limit of the last class equals the values which are less than the upper limit of the last class. The TOPSIS Sort Method consists of the following method:

1. Establish the decision matrix $X = (x_{ij})_{n \times m}$.
2. Determine a set of profiles $P = \{(\bar{p}^1, p^1), \dots, (\bar{p}^k, p^k)\}$, where $\bar{p}^k$ is the upper limit of the class K and p^k is the lower limit of the class K .
3. Add the profiles to the decision matrix $\xi = \{X, P\}$.
4. Normalize the decision matrix ξ using the equation below.

$$r_{ij} = \left\{ \frac{\xi_{ij}}{\max x} \mid J, 1 - \frac{\xi_{ij}}{\max x} \mid J' \right\} \dots\dots\dots (2.10)$$

Where J and J' denote the sets of benefit criteria and cost criteria, respectively.

5. Execute Steps 1 to 5 of the TOPSIS method.
6. Calculate the values of cli for the decision matrix ξ .
7. Determine the values of $\overline{cl_j^{p^k}}$ and $cl_j^{p^k}$ for the profiles of each $\bar{p}^k, p^k$ where $\overline{cl_j^{p^k}}$ refers to the deviation of the upper limit profile of the class K from the ideal solution, and $cl_j^{p^k}$ is the deviation of the lower limit profile of the class K from the ideal solution.
8. Comparison the values $cl_i^{p^k}$ with the values $cl_j^{p^k}$ in the profile matrix use the Equation (2.11) below.

$$a_i^k = \in K^k \left| cl_j^{p^k} < cl_j < \overline{cl_j^{p^k}} \right. \dots\dots\dots (2.11)$$

Where $\forall i = 1, \dots, n, k = 1, \dots, K$.

9. The alternatives whose cl_j values are greater than $cl_j^{p^k}$ and less than $\overline{cl_j^{p^k}}$ are assigned to the class $\bar{K}$. At this stage, the alternatives are sorted and assigned to the classes that are already defined.

2.2.7 Fuzzy TOPSIS Based HOR Framework

Application of Fuzzy TOPSIS in HOR is to help in determining which risk agents are to be dealt first and for selecting the most effective actions in order to reduce the risks potentially posed by the risk agents. By performing this method, companies can determine which process should be prioritized to the solution in stages to minimize the occurrence of a risk. To conduct Fuzzy TOPSIS in HOR, the researcher adapts the concept of Fuzzy HOQ concept in gaining the research step. The procedures are:

First is conduct HOR 1 phase, there are several procedures:

1. Identify risk events that could happen in each business process (Ei).
2. Assess the impact (severity) of such risk event (Si).
3. Identify risk agents and assess the likelihood of occurrence of each risk agent (Oj).
4. Develop a relationship matrix i.e. relationship between each risk agent and each risk event (Rij).
5. Calculate Synthesize Severity use TOPSIS.
6. Calculate the aggregate risk potential of risk agent (ARPj) by using Fuzzy.
7. Determine the rank of risk agents according to their fuzzy aggregate risk potentials.

An example of proposed framework model of House of Risk phase 1 is shown in Table 2.1. The model will consist of risk event severity score, risk agent occurrence score, relation matrix score between risk agent and risk event, and aggregate risk potential score, and additional variable i.e. synthesize severity.

Table 2.1 Table HOR Phase 1

	Risk Event	Risk Agent				Severity Risk
		A1	A2	...	Aj	
Business Process	E1	Correlation matrix Level Score				Si
	E2					...
	...					...
	Ei					...
Severity Synthesize		Si'				
Occurrence of Risk Agent		Oj				
F. ARP		ARPj				
Priority Rank		...				

Notes:

i = 1, 2,, i represents of risk event number.

j = 1, 2,, j represents of risk agent number.

E = Risk Event from Production Department.

A = Risk Agent from Production Department.

Rij = Correlation Matrix between risk event and risk agent.

Si = Previous Severity Number.

Si' = Severity Synthesize Number.

O = Occurrence number of risk agent.

ARP = Aggregate Risk Potential.

Second is conducting the HOR 2, there are several procedures:

1. Select number of risk agents with high priority rank.
2. Identify actions considered relevant for preventing the risk agents.
3. Determine the relationship between each preventive action and each risk agent.
4. Calculate the total effectiveness of each action (TEk) use TOPSIS.
5. Assess the degree of difficulties in performing each action (Dk).
6. Calculate the total effectiveness to difficulty ratio (ETDk) using fuzzy.
7. Assign rank of priority to each action (Rk).

Table 2.2 shows the proposed framework model of HOR phase 2. As can be seen in the table, there is no additional variable and the design for this model will same as the original.

Table 2.2 Table HOR Phase 2

	Risk Agent	Mitigation Action				ARP Number
		PA1	PA2		PAk	
Business Process	A1	Correlation matrix Level Score				ARPj
	A2					...
						...
	...					...
Total effectiveness of action k		TEk				
Degree of difficulty		Dk				
Total effectiveness to difficulty ratio		ETDk				
Priority Rank						

Notes:

j = 1, 2,, i represents of risk agent number.

k = 1, 2,, j is the representations of mitigation action number.

A = Risk Agent of Production Department.

PA = Mitigation Action for each risk.

Ejk = Correlation Matrix between risk event and risk agent.

ARPj = Aggregate Risk potential; j = 1, 2,, j.

TEk = Total effectiveness of action k.

Dk = Degree of difficulty.

ETDk = Total effectiveness to difficulty ratio.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Object

3.1.1 Research Location

This research was conducted in Small and Medium Enterprise (SME) in Yogyakarta i.e. PT. Qumicon Indonesia. The company is engaged in manufacturing of various traffic signs, traffic light, road markings and other traffic completeness since 1989. The main customer of this company is Indonesian Department of Transportation, the property developer, and a firm developer that needs a traffic sign. Year by year, this company tries to increase customer satisfaction and strive to update its products and services based on time limitation and society's demands. This is demonstrated by the commitment of PT. Qumicon Indonesia in the procurement of traffic signs made by electronics and automatic settings, so it is expected to improve efficiency and help creating a good traffic on the highway.

3.1.2 Focus of the Research

This research will focus on assessing and analyzing the risk in one of companies or Small and Medium Enterprises (SMEs) in Yogyakarta. The method that will be used is modified Fuzzy TOPSIS in HOR (House of Risk).

3.2 Data Collection Method

The research will require several data that are acquired from:

1. Interview

The interview will be performed to the experts or employees that work in the production division in a company. The interview will relate with the attribute or variable research and parameters.

2. Direct Observation

The observations is directly purposed to collect the data in the research field. The data that needed are the historical data of the variable to be processed in fuzzy logic.

3. Indirect Observation

- A. Literature Review

This method is to gain data from the references, could be from books or theory that support the research. The data from literature reviews will support in determining the parameter research.

- B. Study from other science disciplines that support and relate to the topic of discussion.

- C. Report or data from the company, such as flow process, product specification, service process, and etc.

3.3 Research Tools and Device

There is a tool that implemented in this research:

1. Matlab

MATLAB (matrix laboratory) is a multi-numerical computing environment and fourth generation programming language. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, a creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran, and Python. This software consists of application Fuzzy that use to help in calculating the ambiguous or vague data.

3.4 Literature Review

Before obtaining problem identification, arranging the literature review is needed to avoid the plagiarism and obtain the state of the art of the study. The state of the art becomes the basic thinking in defining the problem identification. It is gained from an inductive study that comes from related journals. However, the deductive study is a basic theory that becomes a general study that already exists. It comes from a book or other accredited kind of literature.

3.5 Problem Identification

Problem identification is obtained after literature review. It defines a problem that will be solved in the research. Problem identification is served in question form, and the question will be answered in the conclusion.

3.6 Data Collection

Data that collected are the primary data which become the calculation input of the research. Below is the list of primary data in this research:

1. Production department business process flow.
2. Risk event in the production department.
3. Risk severity level of production department risk event.
4. Risk agent of production department risk event.
5. Risk occurrence of risk agent.
6. Correlation level between risk agent and risk event in that department.
7. Mitigation action of risk.
8. Degree of difficulty each mitigation action.
9. Correlation level between risk agent and the mitigation action.

3.7 Data Analysis

Based on the procedure calculation that was mentioned in chapter 2, Data that were collected will be processed in phase 2 of HOR. HOR phase 1 will focus on processing data of risk event and risk agent to gain the priority risk potential that will be mitigated.

Then the focus of HOR phase 2 is to process data of prioritizing aggregate risk potential number from HOR phase 1 with data of mitigation action. It used to find the effectiveness of action level for each action. Below the general explanation of data processing of each phase:

1. HOR Phase 1

A. Synthesize Severity Design

Synthesize severity design in this research is a representation of a classification the result number that gains from calculation of correlation matrix between risk agent and risk event with a previous severity level. In designing the synthesize severity, there are 2 parameters needed for risk scoring i.e. parameter of risk severity and risk correlation matrix. As shown in Table 3.1 and 3.2, parameter of risk severity and correlation matrix score in this research are divided into 5 ranks, i.e. very high, high, moderate or medium, low, and very low. The determination of parameter is based on the company policy and standard. In designing the calculation process, the researcher adapts the step of TOPSIS sort method as guidance. Table 3.3 shows the design model of synthesizing severity. Synthesize severity score of HOR phase 1 will be a variable calculation of aggregate risk potential scores.

Table 3.1 Previous Risk Severity Parameter

Effect	Criteria	Ranking
Very High	A failure that would seriously affect the ability to complete the task or cause damage, serious injury or death, took long delay time and took several days in repairing	5
High	A failure that causes significant deterioration in system performance and/or leads to minor injuries, need several hours for repairing	4
Moderate	A failure that would cause a high degree of operator dissatisfaction or that causes noticeable but slight deterioration in system performance, time for repairing less than 1 hours	3
Low	A failure that would cause slight annoyance to the operator, but that would cause no deterioration to the system	2
Very Low	A failure that has no effect on the system performance, the operator probably will not notice	1

Source : (Shirouyehzad et al., 2010)

Table 3.2 Correlation Matrix Score Parameter

Code	Correlation Matrix Level	Range Score
P1	Very High	$9 < x \leq 10$
P2	High	$7 < x \leq 9$
P3	Moderate	$5 < x \leq 7$
P4	Low	$3 < x \leq 5$
P5	Very Low	$x \leq 3$

Source: (Khoo & Ho, 1996)

Table 3.3 Design of Severity Synthesize Process

Business Process	Risk Event	Risk Agent				Severity Risk
		A1	A2	...	Aj	
	E1	Correlation matrix Level Score				Si
	E2					...
						...
	Ei					...
Severity Synthesize		Si'				

B. F.ARP Calculation

For this calculation, the researcher uses fuzzy logic to determine the number of ARP (Aggregate Risk Potential). The input needed is synthesized severity number from previous process and the occurrence score number from risk agent. Both of the input will be processed using fuzzy to gain the output, i.e. ARP number for the next calculation in HOR phase 2. As shown in Table 3.4 and 3.5, the parameter of risk occurrence and output parameters of the calculation.

Table 3.4 Risk Occurrence Parameter

Effect	Criteria	Ranking
Very High	Occur > 9 times in 6 months	5
High	Occur 7-8 times in 6 months	4
Moderate	Occur 4-6 times in 6 months	3
Low	Occur 2-3 times in 6 months	2
Very Low	Occur < 1 times in 6 months	1

Table 3.5 Variable Output of Membership Function Parameter

Category	FARP Class Interval Number
Very High	$x > 4$
High	$3 < x \leq 4$
Moderate	$2 < x \leq 3$
Low	$1 < x \leq 2$
Very Low	$0 \leq x \leq 1$

After FARP calculation, the complete HOR phase 1 table can be constructed. In HOR 1, the data from risk event and risk agent will be processed to gain the priority risk agent that will be mitigated by the researcher.

2. Pareto Diagram

Pareto diagram is used to find the 80% risk agents that contribute from total ARP. The Pareto diagram indicates that the degree of importance of reducing the probability of occurrence of each risk agent differs widely. The risk with high ARP should be prioritized and mitigated.

3. HOR Phase 2

In HOR 2, the data from mitigation action and ARP of risk agent will be processed to gain the priority rank of mitigation action. The calculation process mostly same with HOR phase 1, the difference is variable that calculated. The processes are:

A. Selecting a priority risk agent with high ARP

Selecting the number of risk agent with high priority that was determined in the Pareto diagram previously. The ARP that was selected indicates the risk agent that will be exposed with the mitigation action.

B. Total Effectiveness of Action k

To find the total effectiveness of action k or Tek, the same method as to find the numbers of synthesizing severity could be applied, i.e. by calculating correlation matrix between risk agent that was chosen and mitigation action with the ARP number of each risk agent. In designing the calculation process the researcher adapts the step of TOPSIS sort method as guidance.

C. Total Effectiveness to Difficulty Ratio Calculation

For this calculation, the researcher uses fuzzy logic to determine the number of ETDk (Total Effectiveness to Difficulty Ratio). The input needed is total effectiveness ratio number of from previous process and degree of difficulty score number of mitigation action. Both of the input will be processed using fuzzy to gain the output, i.e. ETDk ratio for the mitigation action.

3.8 Research Flowchart

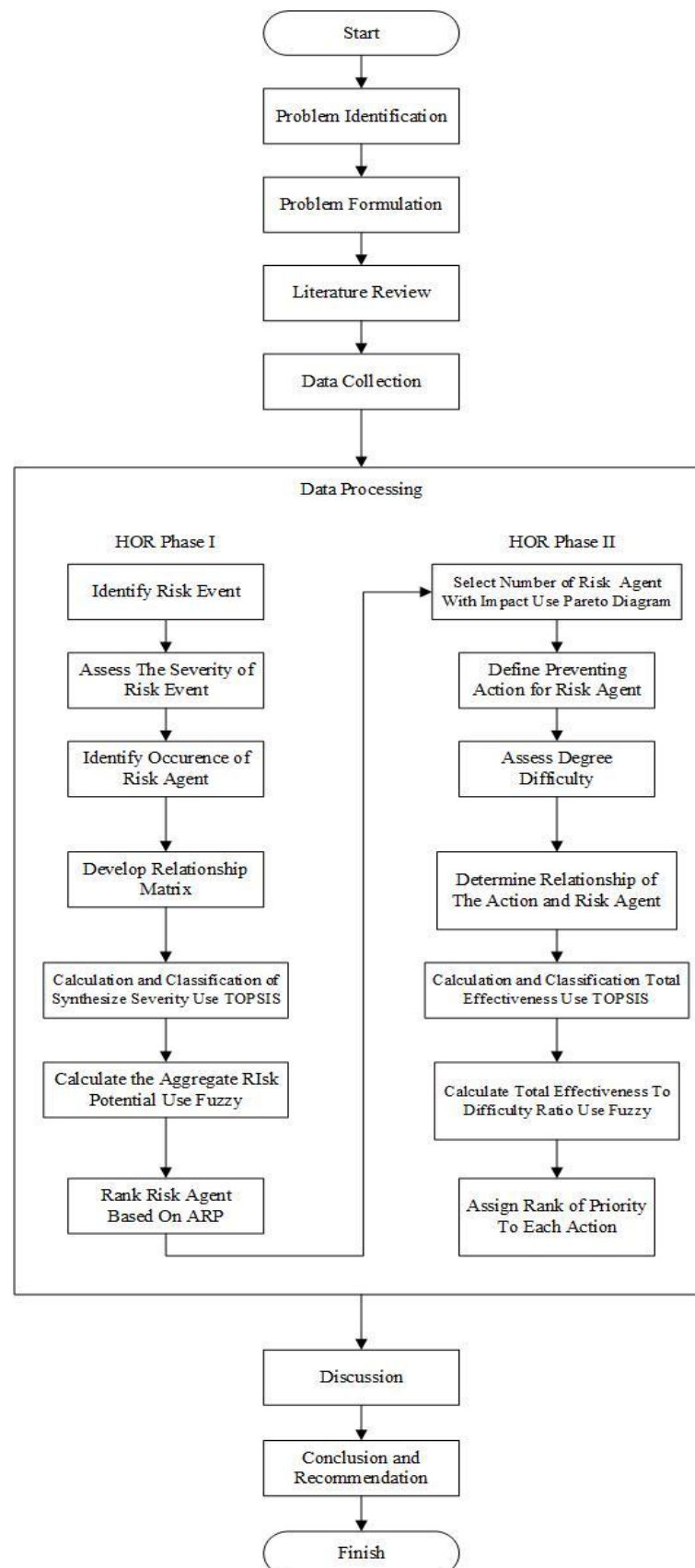


Figure 3.1 Research Flowchart

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collection

4.1.1 Company Profile

This research was conducted in Small and Medium Enterprise (SME) in Yogyakarta i.e. PT. Qumicon Indonesia. The company is engaged in manufacturing of various traffic signs, traffic light, road markings and other traffic completeness since 1989. The main customer of this company is Indonesian Department of Transportation, the property developer, and a firm developer that needs a traffic sign. Year by year, this company tries to increase customer satisfaction with strives to update its products and services. That mission is implemented by commitment of PT. Qumicon Indonesia in the procurement of traffic signs with electronics and automatic settings. So it is expected to improve efficiency and help create a good traffic on the highway.

4.1.2 List Product of PT. Qumicon Indonesia

PT Qumicon Indonesia is engaged in the production and procurement of various traffic signs, traffic light, road markings and other traffic completeness. The product are:

1. Traffic light.
2. Solar cell street lighting.
3. Street mark applicator machine.
4. Brake tester portable.
5. Portable Weigher.
6. Nail marker.
7. Traffic cone.
8. Delineator.

9. Traffic sign.
10. RPPJ.
11. Traffic light controller.
12. Counting down.
13. LED Module.
14. Lamp box.
15. Thermoplastic mark applicator.
16. Celtron.

4.1.3 Production System PT. Qumicon Indonesia

In producing the product, PT. Qumicon uses the flow production system of the material. It starts with the material procurement by making the purchase order list to the supplier. Materials that usually order by the company i.e. small bulb, an electronic circuit, printed circuit board (PCB), iron pole, and etc. The PO is made by Purchase Order Department and for receiving the material, it will be managed by the production department. After the material sent by a supplier, the material will be kept in the warehouse as an inventory. The materials for production will be divided according to type or specification of product demand. Then the finished product will be sent to the customer directly with the truck. A summary of the flow production process in PT. Qumicon Indonesia is illustrated in Figure 4.1.

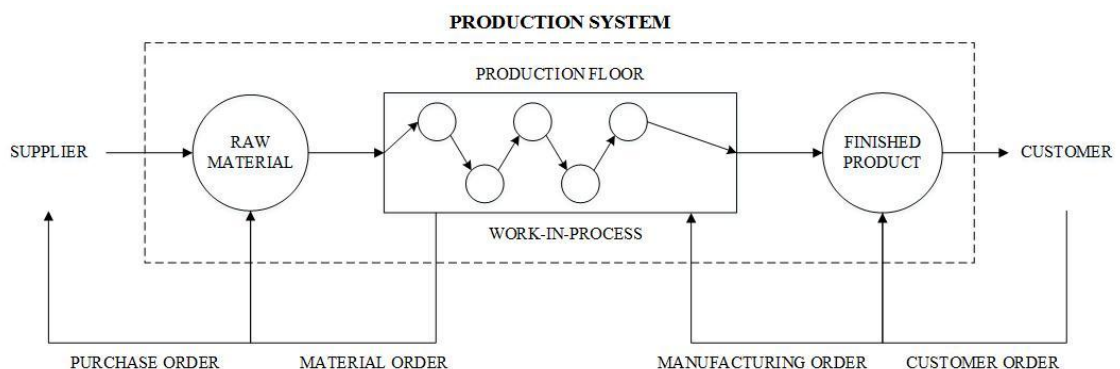


Figure 4.1 Production System Flow of PT. Qumicon Indonesia

4.2 Data Processing

4.2.1 Risk Event of Production Department in PT. Qumicon Indonesia

Risk event can happen in any business process of the company. The researcher identifies the risk event by asking the expert in the production department, observation in the production field, breaking down the business process of the company, and mapping the supply chain activities of the department such planning, procurement, process, and delivery. As shown in Table 4.1, there are 18 risk events that might happen in the business process of the production department.

Table 4.1 Risk Event of Production Department

Code	Business Process	Risk Event
E1	Planning	Mistake in product design
E2	Planning	Mistake of amount order to supplier
E3	Planning	Stock out material in supplier
E4	Procurement	Late of delivery material from supplier
E5	Procurement	Delayed paying process to a supplier
E6	Procurement	Stored material destructed
E7	Procurement	Material damaged when delivering process from supplier
E8	Procurement	Ordered material not fit with the specification
E9	Process	Not enough resource when process production
E10	Process	Work accident
E11	Process	Production delayed
E12	Process	Defect product
E13	Process	Material shortage when process
E14	Delivery	Accident in delivering product to customers
E15	Delivery	Lacking order amount
E16	Delivery	Product damaged when delivery to customer
E17	Delivery	Late delivery product
E18	Delivery	Product specification doesn't fit

The existing risk events will be scored based on the severity risk parameters. Table 4.2 shows the score of 18 risk events severity based on the level of effects parameter criteria (1=Very low, 2= Low, 3=Moderate, 4=High, 5=Very high).

Table 4.2 Risk Severity of Risk Event

Code	Risk Severity
E1	2
E2	3

Code	Risk Severity
E3	5
E4	3
E5	1
E6	2
E7	2
E8	3
E9	4
E10	3
E11	3
E12	2
E13	1
E14	2
E15	2
E16	2
E17	2
E18	2

Risk event with score 1 means that the risk has no effect on the system. Score 2 means the risk causes slight annoyance to the operator. Score 3 means the risk would cause a high degree of operator dissatisfaction, score 4 means the risk causes significant interference, and for score 5 means the risk seriously affects the system.

4.2.2 Risk Agent of Production Department in PT. Qumicon Indonesia

Risk agent can be activity, disaster, or something that makes the risk event occur. To find the risk agent, the researcher should know the risk event first, and then it will be broken down to find the causes of that risk. As shown in Table 4.3, there are 21 risk agents that might occur in process business of production department. The researcher identified 21 risk agents by conducting direct observation in field production and interviewing the expert.

Table 4.3 Risk Agent of Production Department

Code	Risk Agent
A1	Material order information not clear
A2	Human error factor (employee mistake)
A3	Increasing of material demand in market
A4	Material extinction
A5	Natural disaster
A6	Road jam condition when delivery material
A7	Supplier sent different material
A8	Supplier has not delivered material

Code	Risk Agent
A9	No standard operational for storing material
A10	Warehouse has not fulfilled the standard
A11	Lack of material quality control
A12	Delivery process does not fulfill the standard operational
A13	Miscommunication between supplier and company
A14	Electricity resource not stable (lack of power)
A15	Employee has not follow the standard operational
A16	Less quality of safety tools
A17	Material inventory shortage
A18	Damaged tools of production
A19	No inventory
A20	Miscommunication of order amount between company and customer
A21	Driver negligence

From the table, it can be seen that the majority of risk agents in this research are caused by the mistakes made by the system and the human. The risk agent that identified will be scored by questioning the expert in the department by questionnaire and interview. The researcher adapts the Likert scale as guidance in fulfilling the data, it is considered as easily understood by the experts. Table 4.4 shows the score of 21 risk agents based on the probability of occurrence in causes of the risk event.

Table 4.4 Risk Occurrence of Risk Agent

Code	Risk Occurrence
A1	3
A2	2
A3	3
A4	3
A5	1
A6	4
A7	2
A8	3
A9	2
A10	2
A11	1
A12	3
A13	2
A14	2
A15	2
A16	2
A17	3
A18	3
A19	2
A20	3
A21	2

Risk agent with score 1 means that the risk occurs less than 1 in 6 months. Score 2 means that the risk occurs 2-3 times in 6 months. Score 3 means that the risk occurs 4-6 times in 6 months, score 4 means that the risk occurs 7-8 times in 6 months, and for score 5 means that the risk occurs more than 9 times in 6 months.

4.3 Computational Result

The result of the calculation is gained by following several steps, i.e. calculations of synthesizing severity, calculation of fuzzy ARP, calculation of total effectiveness, and calculation of effectiveness to ratio. Besides, to gain the complete analysis, the statistic chart and additional notes will be given.

4.3.1 Synthesize Severity

Synthesize severity in this research is a representation of classification of result number that gained by calculation of correlation matrix between risk agent and risk event with the previous severity level. In designing the calculation process, the researcher adapts the step of TOPSIS sort method as guidance. The calculation process will be:

1. Establishing the Decision Matrix of Risk Agent and Risk Event

Here, the researcher develops the matrix based on the HOR phase 1 matrix frame. In HOR 1, the matrix shows the correlation of risk agent and risk event. Each of column and row will be filled by the score or point that shows the level of correlation risk event and the causes (risk agent). Table 4.5 shows the decision matrix of a risk event and risk agent. The calculation involves the 18 risks event and 21 risk agents.

From that table, the relationship of risk agent and risk event have relative same score. The risk with score 1 means the risk event and risk agent has a very low relationship, the risk with score 3 means the risk event and risk agent has a low relationship, and the risk with score 9 means the risk event and risk agent has a high relationship. The different of relationship may happen in each risk, perhaps it occurs because of the effect and impact of risk agent that also different.

2. **Determining the Set Classification Parameter p^k and The Weight of Each Class**
 Set classification parameter p^k will be used to make the limit of each classifying class. the profile can be defined by determining the parameter of correlation scoring. For the weight of the class, the researcher analogies the severity score that was determined in above. Table 4.6 shows the matrix of a set parameter and weight of each risk event. The purpose of using severity because the synthesizes severity or the new severity number is obtained by calculating the correlation of risk agent, risk event, and also the severity.

3. **Normalize the Risk Agent and Risk Event Decision Matrix and Parameter Matrix**
 Normalization is conducted by transforming various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Table 4.7 and 4.8 shows the result of risk agent and risk event normalization of decision matrix and parameter matrix. The zero number from the decision matrix table is obtained since the risk agent and risk event have no correlation. It means that the risk agent not influence occurrence of the risk event.

4. **Weighting Normalize Decision Matrix**
 To conduct the calculation, the researcher multiplies each column of the normalized decision matrix by its associated weight. Table 4.9 and 4.10 show the result of risk agent and risk event weighting normalize decision matrix and parameter matrix. The big number and a small number of decision matrix and parameter matrix depend on the weight (the severity number).

5. **Determine the Ideal Solution**
 The ideal solution is divided into two, which are positive ideal solution and negative ideal solution. The positive ideal is the best level for all attributes considered. Then the negative is the worst attribute values. Where J and J' are the set of benefit criteria and cost criteria. Table 4.11 and 4.12 below show the ideal solution of risk agent and risk event decision matrix and parameter matrix. The row of maximum number in that table describes the positive ideal solution and the minimum number describes a negative ideal solution.

Table 4.5 Decision Matrix of Risk Agent and Risk Event

Risk Event	Risk Agent																				
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21
E1		9													3						
E2	3	3											3								
E3			3	3	3																
E4					1	3		1													
E5							3	3													
E6					3				3	9											
E7					1						3	3									
E8	3	1											3								
E9					3									3							
E10															3	3					
E11														3			1	3			
E12		3													3			3			
E13																			3		
E14												3									1
E15	1																			3	
E16												3									1
E17					3	3															
E18	3															1		1			

Table 4.6 Classification Parameter p^k and Weight Each Risk Event

[illegible]

P1 = Classification Score Parameter 1
P2 = Classification Score Parameter 2
P3 = Classification Score Parameter 3
P4 = Classification Score Parameter 4
P5 = Classification Score Parameter 5
P6 = Classification Score Parameter 6

[illegible]

Table 4.9 Result of Weighting Normalize Risk Agent and Risk Event Decision Matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18
A1	0	1.7321	0	0	0	0	0	2.0647	0	0	0	0	0	0	0.6325	0	0	1.81
A2	1.8974	1.7321	0	0	0	0	0	0.6882	0	0	0	1.1547	0	0	0	0	0	0
A3	0	0	2.8868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A4	0	0	2.8868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A5	0	0	2.8868	0.9045	0	0.603	0.4588	0	2.8284	0	0	0	0	0	0	0	1.4142	0
A6	0	0	0	2.7136	0	0	0	0	0	0	0	0	0	0	0	0	1.4142	0
A7	0	0	0	0	0.7071	0	0	0	0	0	0	0	0	0	0	0	0	0
A8	0	0	0	0.9045	0.7071	0	0	0	0	0	0	0	0	0	0	0	0	0
A9	0	0	0	0	0	0.603	0	0	0	0	0	0	0	0	0	0	0	0
A10	0	0	0	0	0	1.8091	0	0	0	0	0	0	0	0	0	0	0	0
A11	0	0	0	0	0	0	1.3765	0	0	0	0	0	0	0	0	0	0	0
A12	0	0	0	0	0	0	1.3765	0	0	0	0	0	0	1.8974	0	1.8974	0	0
A13	0	1.7321	0	0	0	0	0	2.0647	0	0	0	0	0	0	0	0	0	0
A14	0	0	0	0	0	0	0	0	2.8284	0	2.0647	0	0	0	0	0	0	0
A15	0.6325	0	0	0	0	0	0	0	0	2.1213	0	1.1547	0	0	0	0	0	0
A16	0	0	0	0	0	0	0	0	0	2.1213	0	0	0	0	0	0	0	0.6
A17	0	0	0	0	0	0	0	0	0	0	0.6882	0	0	0	0	0	0	0
A18	0	0	0	0	0	0	0	0	0	0	2.0647	1.1547	0	0	0	0	0	0.6
A19	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8974	0	0	0
A21	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6325	0	0.6325	0	0

Table 4.10 Result of Weighting Normalize Parameter Matrix

[illegible]

Table 4.11 Maximum Number and Minimum Number of Risk Agent and Risk Event Decision Matrix

[illegible]

Table 4.12 Maximum Number and Minimum Number of Parameter Matrix

[illegible]

6. Calculate the Euclidean Distances of Each Alternative From The Positive Ideal Solution and Negative Ideal Solution respectively

As shown in Table 4.13 and 4.14, the Euclidean distances of each ideal solution of the decision matrix and parameter matrix. The result from Euclidean distance of each solution will determine the closeness of alternative to the solution.

Table 4.13 Euclidean Distances of Risk Agent and Risk Event Matrix Ideal Solution

	D+	D-
A1	54.860925	10.935885
A2	57.095056	8.4070175
A3	59.063477	8.3333333
A4	59.063477	8.3333333
A5	42.101754	19.725678
A6	58.033174	9.3636364
A7	66.89681	0.5
A8	62.805901	1.3181818
A9	65.578628	0.3636364
A10	64.124083	3.2727273
A11	65.502073	1.8947368
A12	58.302073	9.0947368
A13	60.133652	7.2631579
A14	55.133652	12.263158
A15	59.563477	6.2333333
A16	61.078628	4.8636364
A17	65.028389	0.4736842
A18	59.982137	5.9601276
A19	66.39681	1
A20	63.79681	3.6
A21	63.39681	0.8

Table 4.14 Euclidean Distances of Parameter Matrix Ideal Solution

	D+	D-
P1	0	59.534091
P2	3.1704545	35.227273
P3	12.681818	17.261364
P4	22.545455	8.8068182
P5	35.227273	3.1704545
P6	59.534091	0

7. Calculate the Relative Closeness of Each Alternative to The Ideal Solution

Table 4.15 and 4.16 show the relative closeness of each alternative to the ideal solution of the decision matrix and parameter matrix. The number of closeness

will be classified in 5 ranks, which are. very high, high, moderate or medium, low, and very low.

Table 4.15 Relative Closeness of Risk Agent and Risk Event Matrix Ideal Solution

	cl_i
A1	0.17
A2	0.13
A3	0.12
A4	0.12
A5	0.32
A6	0.14
A7	0.01
A8	0.02
A9	0.01
A10	0.05
A11	0.03
A12	0.13
A13	0.11
A14	0.18
A15	0.09
A16	0.07
A17	0.01
A18	0.09
A19	0.01
A20	0.05
A21	0.01

Table 4.16 Relative Closeness of Parameter Matrix Ideal Solution

	cl_i
P1	1
P2	0.92
P3	0.58
P4	0.28
P5	0.08
P6	0

The result from relative closeness number risk agent with risk event above is a synthesizing severity number. The number will become variable on calculation in fuzzy to find the aggregate risk potential number.

4.3.2 Fuzzy Aggregate Risk Potential

For this calculation, the researcher uses fuzzy logic to determine the number of ARP (Aggregate Risk Potential). The input needed is a synthesized severity number from previous process and occurrence score number of risk agent. Both of the input will be processed using fuzzy to gain the output as an ARP number for the next calculation in HOR phase 2. The calculation will be:

1. Define the Rule of Fuzzy

Before calculating the input fuzzy, the first step is defining the fuzzy rule of each input. According to (Roghanian & Mojibian, 2015) the basic of fuzzy logic system is formed by a set of the kind IF...THEN rule to perform the tracing of the input universe $U \subset R^n$ on to the output universe $V \subset R$. The r th fuzzy rule is presented in the following way: $x = (x_1, \dots, x_n) \in U$ is input linguistic variable and $y \in V$ is the output linguistic variable. In here, the fuzzy rule consists of two variables that present for risk agent and risk event. The rules are:

- A. IF synthesize severity is very low and occurrence is very low Then ARP is very low.
- B. IF synthesize severity is very low and occurrence is low Then ARP is low
- C. IF synthesize severity is very low and occurrence is medium Then ARP is low.
- D. IF synthesize severity is very low and occurrence is high Then ARP is low.
- E. IF synthesize severity is very low and occurrence is very High Then ARP is medium.
- F. IF synthesize severity is low and occurrence is very low Then ARP is low.
- G. IF synthesize severity is low and occurrence is low Then ARP is low.
- H. IF synthesize severity is low and occurrence is medium Then ARP is medium.
- I. IF synthesize severity is low and occurrence is high Then ARP is medium.
- J. IF synthesize severity is low and occurrence is very high Then ARP is high.
- K. IF synthesize severity is medium and occurrence is very low Then ARP is low.
- L. IF synthesize severity is medium and occurrence is low Then ARP is medium.

- M. IF synthesize severity is medium and occurrence is medium Then ARP is medium.
- N. IF synthesize severity is medium and occurrence is high Then ARP is high.
- O. IF synthesize severity is medium and occurrence is very high Then ARP is high.
- P. IF synthesize severity is high and occurrence is very low Then ARP is low.
- Q. IF synthesize severity is high and occurrence is low Then ARP is medium.
- R. IF synthesize severity is high and occurrence is medium Then ARP is high.
- S. IF synthesize severity is high and occurrence is high Then ARP is high.
- T. IF synthesize severity is high and occurrence is very high Then ARP is very high.
- U. IF synthesize severity is very high and occurrence is very low Then ARP is medium.
- V. IF synthesize severity is very high and occurrence is low Then ARP is high.
- W. IF synthesize severity is very high and occurrence is medium Then ARP is high.
- X. IF synthesize severity is very high and occurrence is high Then ARP is very high.
- Y. IF synthesize severity is very high and occurrence is very high Then ARP is very high.

This rule not only use for the calculation in aggregate risk potential but also the calculation of total effectiveness of difficulty ratio in HOR 2.

2. Define Fuzzy Input

The inputs of fuzzy calculation are synthesized severity and occurrence score number that was defined. In calculation process of both inputs, the parameter of the membership function variable should be declared in Matlab software because this parameter will measure the membership function of each risk agent and synthesize severity.

A. Membership Function Parameter of Synthesize Severity

$$\mu_{Very\ low}(x) = \begin{cases} 0, & x \geq 0.28 \\ \frac{0.28 - x}{0.2}, & 0 \leq x < 0.28 \\ 1, & x < 0.08 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x \leq 0.08 \text{ or } x \geq 0.5 \\ \frac{x - 0.08}{0.2}, & 0.08 < x \leq 0.28 \\ \frac{0.5 - x}{0.22}, & 0.28 \leq x < 0.5 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 0.28 \text{ or } x \geq 0.72 \\ \frac{x - 0.28}{0.22}, & 0.28 < x \leq 0.5 \\ \frac{0.72 - x}{0.22}, & 0.5 \leq x < 0.72 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 0.5 \text{ or } x \geq 0.92 \\ \frac{x - 0.5}{0.22}, & 0.5 < x \leq 0.72 \\ \frac{0.92 - x}{0.20}, & 0.72 \leq x < 0.92 \end{cases}$$

$$\mu_{Very\ high}(x) = \begin{cases} 0, & x \leq 0.72 \\ \frac{x - 0.72}{0.2}, & 0.72 < x \leq 0.92 \\ 1, & x > 0.92 \end{cases}$$

From the result, it can be seen that if the membership function for parameter very low is 0 to 0.28, low is 0.08 to 0.5, medium is 0.28 to 0.72, high is 0.5 to 0.92, and very high is 0.72 to 1. That membership parameter number will be made into a curve for fuzzy calculation. As shown in Table 4.17, summarize of membership function parameter for synthesizing severity. The synthesize severity membership function parameter that was inputted in Matlab was illustrated in Figure 4.2.

Table 4.17 Membership Function Parameter of Synthesize Severity

Category	Curve Type	Parameter
Very Low	Trapezoidal	[0 0 0.08 0.28]
Low	Triangle	[0.08 0.28 0.5]
Medium	Triangle	[0.28 0.5 0.72]
High	Triangle	[0.5 0.72 0.92]
Very High	Trapezoidal	[0.72 0.92 1 1]

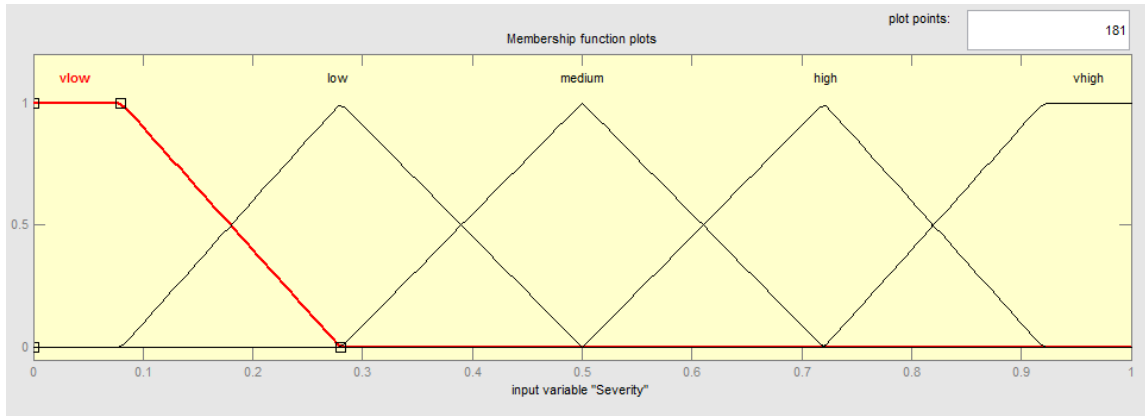


Figure 4.2 Membership Function Parameter of Synthesize Severity Curve

B. Membership Function Parameter of Occurrence

$$\mu_{Very\ low}(x) = \begin{cases} 0, & x \geq 2 \\ \frac{2-x}{1}, & 0 \leq x < 2 \\ 1, & x < 0 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x \leq 1 \text{ or } x \geq 3 \\ \frac{x-1}{1}, & 1 < x \leq 2 \\ \frac{3-x}{1}, & 2 \leq x < 3 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 2 \text{ or } x \geq 4 \\ \frac{x-2}{1}, & 2 < x \leq 3 \\ \frac{4-x}{1}, & 3 \leq x < 4 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 3 \text{ or } x \geq 5 \\ \frac{x-3}{1}, & 3 < x \leq 4 \\ \frac{5-x}{1}, & 4 \leq x < 5 \end{cases}$$

$$\mu_{Very\ high}(x) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{1}, & 4 < x \leq 5 \\ 1, & x \geq 5 \end{cases}$$

From the result, it can be seen that if the membership function for parameter very low is 0 to 2, low is 1 to 3, medium is 2 to 4, high is 3 to 5, and very high is 4 to 5 or more. That membership parameter number will be made into a curve for fuzzy calculation. As shown in Table 4.18, the summarize of risk occurrence membership function parameter. The illustration of risk occurrence membership function parameter number that was inputted in Matlab was illustrated in Figure 4.3.

Table 4.18 Membership Function Parameter of Occurrence

Category	Curve Type	Parameter
Very Low	Trapezoidal	[0 0 1 2]
Low	Triangle	[1 2 3]
Medium	Triangle	[2 3 4]
High	Triangle	[3 4 5]
Very High	Trapezoidal	[4 5 6 6]

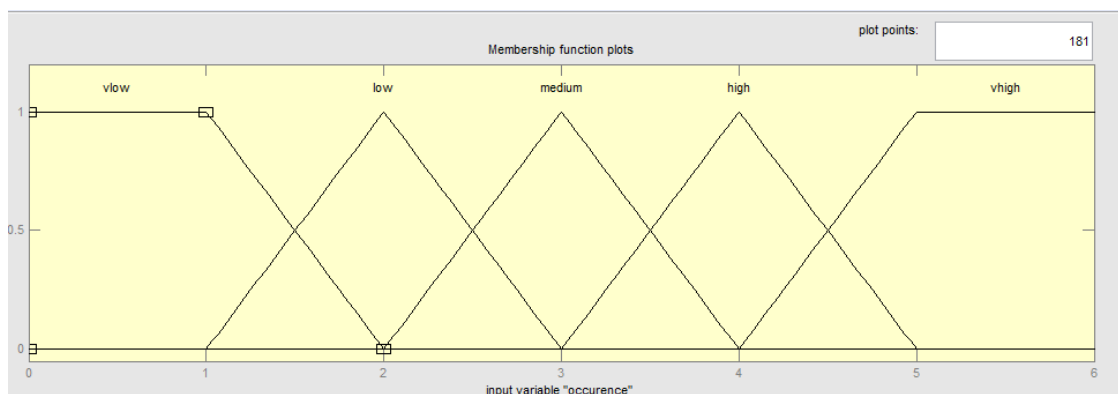


Figure 4.3 Membership Function Parameter of Occurrence Curve

3. Define Fuzzy Output

As explained in above, the output of fuzzy calculation is the Aggregate Risk Potential Number. The number got from the fuzzy calculation of synthesizes severity and the occurrence. Same with the input, the parameter of output membership function variable should be declared in Matlab software. Table 4.19 shows the variable output membership function parameter of fuzzy Aggregate Risk Potential.

Table 4.19 Parameter of Fuzzy ARP

Category	F.ARP Class Interval Number
Very High	$x > 4$
High	$3 \leq x \leq 4$
Moderate	$2 \leq x \leq 3$
Low	$1 \leq x \leq 2$
Very Low	$0 \leq x \leq 1$

The scale number of each class is determined based on the Likert scale. Data from that table should be declared in a curve as a parameter in Matlab software. The parameter membership function will be:

A. Membership Function Parameter of Aggregate Risk Potential

$$\mu_{Very\ low}(x) = \begin{cases} 0, & x \geq 2 \\ \frac{2-x}{1}, & 0 \leq x < 2 \\ 1, & x < 1 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x \leq 1 \text{ or } x \geq 3 \\ \frac{x-1}{1}, & 1 < x \leq 2 \\ \frac{3-x}{1}, & 2 \leq x < 3 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 2 \text{ or } x \geq 4 \\ \frac{x-2}{1}, & 2 < x \leq 3 \\ \frac{4-x}{1}, & 3 \leq x < 4 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 3 \text{ or } x \geq 5 \\ \frac{x-3}{1}, & 3 < x \leq 4 \\ \frac{5-x}{1}, & 4 \leq x < 5 \end{cases}$$

$$\mu_{Very\ high}(x) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{1}, & 4 < x \leq 5 \\ 1, & x \geq 5 \end{cases}$$

The result shows, the membership function for parameter very low is 0 to 2, low is 1 to 3, medium is 2 to 4, high is 3 to 5, and very high is 4 to 5 more. That membership parameter number will be made into a curve for fuzzy calculation. As shown in Table 4.20, summarize of aggregate risk potential membership function parameter. The illustration of aggregate risk potential membership function parameter number that was inputted in Matlab was illustrated in Figure 4.4.

Table 4.20 Membership Function Parameter of Aggregate Risk Potential

Category	Curve Type	Parameter
Very Low	Trapezoidal	[0 0 1 2]
Low	Triangle	[1 2 3]
Medium	Triangle	[2 3 4]
High	Triangle	[3 4 5]
Very High	Trapezoidal	[4 5 6 6]

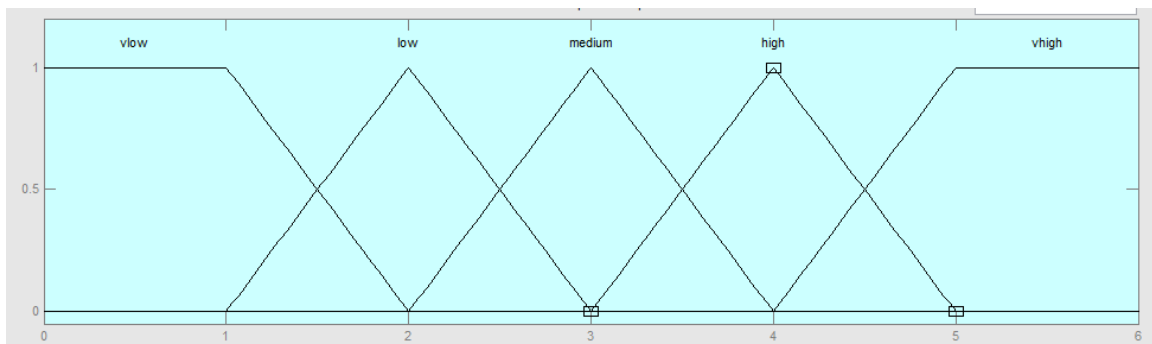


Figure 4.4 Membership Function Parameter of Aggregate Risk Potential Curve

4. Calculation Result

After arranging the curve of variable input and output, the calculation can be conducted by inputting the score number of synthesizing severity and occurrence risk. The result of fuzzy aggregate risk potential calculation was shown in Table 4.21.

Table 4.21 Result of Calculation of Fuzzy Aggregate Risk Potential

Synthesize Severity	Occurrence of Risk Agent	Fuzzy Aggregate Risk Potential (FARP)	Priority Rank of Agent
0.17	3	2.46	1
0.13	2	2	7
0.12	3	2.24	4
0.12	3	2.24	5
0.32	1	2	8
0.14	4	2.33	2
0.01	2	2	9
0.02	3	2	10
0.01	2	2	11
0.05	2	2	12
0.03	1	0.762	21
0.13	3	2.29	3
0.11	2	2	13
0.18	2	2	14
0.09	2	2	15
0.07	2	2	16
0.01	3	2	17
0.09	3	2.07	6
0.01	2	2	18
0.05	3	2	19
0.01	2	2	20

The result of a calculation will be sorted based on the rank of the fuzzy aggregate risk potential and the table of HOR 1 is completed constructed. The data from HOR 1 will divided into two group i.e. prioritize and non-prioritize group. The risk that included in prioritizing group will be mitigated to decrease and prevent the impact of the risk. In determining the prioritize and non-prioritize group, the researcher uses the benefit of Pareto diagram that can show the percentage of the potential risk that may happen. Table 4.22 below shows the complete table of HOR 1.

Table 4.22 Complete HOR Phase 1

Business Process	Risk Event	Risk Agent																					Severity Risk
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	
Planning	E1		9													3							2
	E2	3	3											3									3
	E3			3	3	3																	5
Procurement	E4					1	3		1														3
	E5							3	3														1
	E6					3				3	9												2
	E7					1						3	3										2
	E8	3	1											3									3
Process	E9					3									3								4
	E10															3	3						3
	E11														3			1	3				3
	E12		3													3			3				2
	E13																			3			1
Delivery	E14												3									1	2
	E15	1																			3		2
	E16												3									1	2
	E17					3	3																2
	E18	3															1		1				2
Synthesize Severity		0.17	0.13	0.12	0.12	0.32	0.14	0.01	0.02	0.01	0.05	0.03	0.13	0.11	0.18	0.09	0.07	0.01	0.09	0.01	0.05	0.01	
Occurrence of Agent		3	2	3	3	1	4	2	3	2	2	1	3	2	2	2	2	3	3	2	3	2	
Fuzzy Aggregate Risk Potential (FARP)		2.46	2	2.24	2.24	2	2.33	2	2	2	2	0.762	2.29	2	2	2	2	2	2.07	2	2	2	
Priority Rank of Agent		1	7	4	5	8	2	9	10	11	12	21	3	13	14	15	16	17	6	18	19	20	

4.3.3 Pareto Diagram

Pareto diagram is used to find the 80% risk agent that contributes from total ARP. The concept of Pareto diagram can be used to determine which is the risk that should be mitigated or not by identifying the prioritize risk. To identify prioritize and non-prioritize risk, the ARP number data should be ranked from high ARP to small ARP. As shown in Table 4.23, the ARP number is sorted to prioritize and non-prioritize. The risk with high ARP should be prioritized and mitigated.

Table 4.23 Result of Sorted ARP

Risk Agent	Rank	F.ARP	Cumulative F.ARP	% F.ARP	% Cumulative F.ARP	
A1	1	2.46	2.46	5.802981695	5.802981695	
A6	2	2.33	4.79	5.49632006	11.29930176	
A12	3	2.29	7.08	5.401962634	16.70126439	
A3	4	2.24	9.32	5.284015852	21.98528024	
A4	5	2.24	11.56	5.284015852	27.26929609	
A18	6	2.07	13.63	4.882996792	32.15229289	
A2	7	2	15.63	4.717871296	36.87016418	Prioritize
A5	8	2	17.63	4.717871296	41.58803548	
A7	9	2	19.63	4.717871296	46.30590677	
A8	10	2	21.63	4.717871296	51.02377807	
A9	11	2	23.63	4.717871296	55.74164937	
A10	12	2	25.63	4.717871296	60.45952066	
A13	13	2	27.63	4.717871296	65.17739196	
A14	14	2	29.63	4.717871296	69.89526326	
A15	15	2	31.63	4.717871296	74.61313455	
A16	16	2	33.63	4.717871296	79.33100585	
A17	17	2	35.63	4.717871296	84.04887715	Non Prioritize
A19	18	2	37.63	4.717871296	88.76674844	
A20	19	2	39.63	4.717871296	93.48461974	
A21	20	2	41.63	4.717871296	98.20249104	
A11	21	0.762	42.392	1.797508964	100	

As can be seen, there are 16 risks that included into prioritize risk and 5 risks include to non-prioritize risk. The result from the table above will be made into the diagram, the illustration is shown in Figure 4.5.

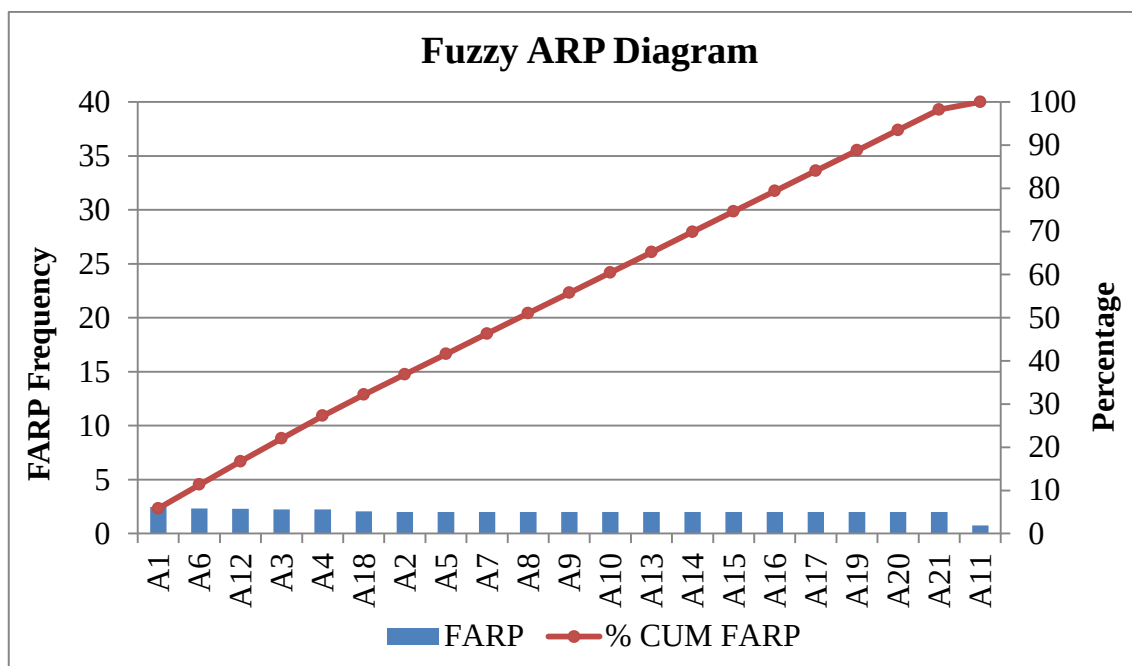


Figure 4.5 Fuzzy ARP Pareto Diagram

The Pareto diagram indicates that the degree of importance on reducing the probability of each risk agent occurrence differs widely. From the diagram above, it is shown that the 16 risk agents contribute in existing risk in the company will be exposed to the mitigation action.

The risk agents that will be exposed to the mitigation activities will be processed by conducting the calculation in HOR 2. Generally, mitigation action can be done by form of strategic or tactical way. Jüttner et al. (2003) suggested that mitigation actions could be in the form of avoidance, control, cooperation, and flexibility. For example, risk avoidance could be done by dropping specific products/geographical markets. Risk control can be done by vertical integration and increasing the inventory buffer, while cooperation can be in the form of sharing risk information with suppliers. Flexibility can be done through postponing risky activities before receiving orders from customers and establishing multiple suppliers. Similarly, Homrich et al. (2003) provided list of mitigation strategy in supply chain management. These include information sharing, trust among supply chain partners, collaborative relationship, information security, aligning incentives and revenue sharing policies in a supply chain, risk strategic planning, risk sharing in a supply chain and continual risk analysis and assessment.

The process of calculation in HOR 2 mostly the same with HOR 1, but the difference calculation is on the both of variable inputs. Previously the input used risk event and risk agent data, but in HOR 2 the inputs are the risk agents with high ARP number and data from mitigation action.

4.3.4 Total Effectiveness of Action

Total effectiveness action in this research is representing an effectiveness of the action to prevent the risk and it is obtained from the calculation of correlation matrix between mitigation action and risk agent with aggregate risk potential score that was selected. In designing the calculation process the researcher adapts the step of TOPSIS sort method as guidance. The calculation process will be:

1. Establishing the decision matrix of Risk Agent and Preventive Action

Here, the researcher develops the matrix based on the HOR phase 2 matrix frames. In HOR 2, the matrix shows the correlation of mitigation action and risk agent. Each of column and row will be filled by the score or point that shown the level of correlation mitigation action and risk agent. Table 4.24 below shows the decision matrix of preventive action and risk agent. The calculation involved the 11 risk agents and 9 preventive actions.

Table 4.24 Decision Matrix of Risk Agent and Preventive Action

Risk Agent	Preventive Action (PAk)									
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10
A1	3	3					3			
A6				5						
A12							5			
A3			3							
A4			5							
A18									3	5
A2	3	3					1			
A5			3							
A7		3			3					
A8					3	3				
A9							5			
A10							3			
A13	1	5								

Risk Agent	Preventive Action (PA _k)									
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10
A14								5		
A15							5			
A16									5	3

From that table, the relationship of risk agent and preventive action has a relative same score. The risk with score 1 means the risk event and risk agent have a very low relationship, the risk with score 3 means that the risk event and risk agent have a low relationship, and the risk with score 9 means that the risk event and risk agent have a high relationship. The different of relationship may happen in each risk, perhaps it occurred because the effect and impact of preventive action that also different

2. Determining the Set Classification Parameter p^k and The Weight of Each Class

Set classification parameter p^k will be used to made the limit of each classifying class. For the weight of the class, the researcher analogies the aggregate risk potential score that was determined previously. Table 4.25 shows the matrix of a set parameter and weight of each risk agent. In the calculation of synthesizing severity, it uses a severity score as a weight, but in calculation of total effectiveness, an aggregate risk potential numbers as a weight will be used.

3. Normalize the Risk Agent and Preventive Action Decision Matrix and Parameter Matrix

Normalization is conducted by transforming various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Table 4.26 and 4.27 show the result of risk agent and preventive action normalization decision matrix, and parameter matrix. The zero number of the decision matrix table is obtained since the risk agent and risk event have no correlation. It means that the risk agent and preventive action are not influencing each other.

4. Weighting Normalize Decision Matrix

To conduct the calculation the researcher multiplies each column of the normalized decision matrix by its associated weight. Table 4.28 and 4.29 show

the result of weighting normalization risk agents, preventive action decision matrix and parameter matrix. The big number and a small number of decision matrix and parameter matrix depend on the weight (the severity number).

5. Determine the Ideal Solution

The ideal solution is divided into two, which are positive ideal solution and negative ideal solution. The positive ideal is the best level for all attributes considered. Then the negative is the worst attribute values. Where J and J' are the set of benefit criteria and cost criteria. Table 4.30 and 4.31 shows the ideal solution of the risk agent and preventive action decision matrix and parameter matrix. The row of maximum number in that table describes the positive ideal solution and the minimum number describe a negative ideal solution.

6. Calculate the Euclidean Distances of Each Alternative from the Positive Ideal Solution and Negative Ideal Solution respectively.

As shown in Table 4.32 and 4.33, the Euclidean distances of each ideal solution of the risk agent and preventive action decision matrix, and parameter matrix. The result from the Euclidean distance of each solution will determine the closeness of alternative to the solution.

7. Calculate the Relative Closeness of Each Alternative to the Ideal Solution.

Table 4.34 and 4.35 show the relative closeness of each alternative to the ideal solution of risk agent, preventive action decision matrix and parameter matrix. The number of closeness that gate will classified in 5 ranks, i.e. very high, high, moderate or medium, low, and very low

P6 = Classification Score Parameter 6

[illegible]

[illegible]

Table 4.29 Result of Weighting Normalize Parameter Matrix

[illegible]

Table 4.30 Maximum Number and Minimum Number of Risk Agent and Preventive Action Decision Matrix

[illegible]

Table 4.31 Maximum Number and Minimum Number of Parameter Matrix

[illegible]

Table 4.32 Euclidean Distances of Risk Agent and Preventive Action Ideal Solution

	D+	D-
PA1	54,3204	4,06578
PA2	49,85886	9,75809
PA3	45,58175	14,0352
PA4	54,18805	5,4289
PA5	55,61695	4
PA6	57,61695	2
PA7	39,30302	19,4718
PA8	55,61695	4
PA9	52,9704	5,13424
PA10	53,10629	4,59066

Table 4.33 Euclidean Distances of Parameter Matrix Ideal Solution

	D+	D-
P1	0	34,1095
P2	1,816484	20,1832
P3	7,265935	9,88975
P4	12,91722	5,04579
P5	20,18315	1,81648
P6	34,10953	0

Table 4.34 Relative Closeness of Risk Agent and Preventive Action Decision Matrix Ideal Solution

	cl_i
PA1	0,07
PA2	0,16
PA3	0,24
PA4	0,09
PA5	0,07
PA6	0,03
PA7	0,33
PA8	0,07
PA9	0,09

Table 4.35 Relative Closeness of Parameter Matrix Ideal Solution

	cl_i
P1	1
P2	0.92
P3	0.58
P4	0.28
P5	0.08
P6	0

The result from relative closeness number risk agent with preventive action in above is a total effectiveness score. The number will become variable calculation in fuzzy to find the effectiveness to difficulty ratio.

4.3.5 Effectiveness to the Difficulty Ratio

Before calculating the input fuzzy, the first step is to define the fuzzy rule of each input. Here, the fuzzy rule consists of two variables that present for the total effectiveness of action number and degree of difficulty ratio. Both of the inputs will be processed using fuzzy to gain the output as an ETD number. The calculation will be:

1. Define the Rule of Fuzzy

Here, the fuzzy rule consists of two variables that present for the total effectiveness of action and degree of difficulty. The rules are:

- A. IF total effectiveness of action is very low and degree of difficulty is very hard Then effectiveness to the difficulty ratio is very low.
- B. IF total effectiveness of action is very low and degree of difficulty is hard Then effectiveness to the difficulty ratio is low.
- C. IF total effectiveness of action is very low and degree of difficulty is medium Then effectiveness to the difficulty ratio is low.
- D. IF total effectiveness of action is very low and degree of difficulty is easy Then effectiveness to the difficulty ratio is low.
- E. IF total effectiveness of action is very low and degree of difficulty is very easy Then effectiveness to the difficulty ratio is medium.
- F. IF total effectiveness of action is low and degree of difficulty is very hard Then effectiveness to the difficulty ratio is low.
- G. IF total effectiveness of action is low and degree of difficulty is hard Then effectiveness to the difficulty ratio is low.
- H. IF total effectiveness of action is low and degree of difficulty is medium Then effectiveness to the difficulty ratio is medium.
- I. IF total effectiveness of action is low and degree of difficulty is easy Then effectiveness to the difficulty ratio is medium.

- J. IF total effectiveness of action is low and degree of difficulty is very easy
Then effectiveness to the difficulty ratio is high.
- K. IF total effectiveness of action is medium and degree of difficulty is very hard
Then effectiveness to the difficulty ratio is low.
- L. IF total effectiveness of action is medium and degree of difficulty is hard
Then effectiveness to the difficulty ratio is medium.
- M. IF total effectiveness of action is medium and degree of difficulty is medium
Then effectiveness to the difficulty ratio is medium.
- N. IF total effectiveness of action is medium and degree of difficulty is easy
Then effectiveness to the difficulty ratio is high.
- O. IF total effectiveness of action is medium and degree of difficulty is very easy
Then effectiveness to the difficulty ratio is high.
- P. IF total effectiveness of action is high and degree of difficulty is very hard
Then effectiveness to the difficulty ratio is low.
- Q. IF total effectiveness of action is high and degree of difficulty is hard
Then effectiveness to the difficulty ratio is medium.
- R. IF total effectiveness of action is high and degree of difficulty is medium
Then effectiveness to the difficulty ratio is high.
- S. IF total effectiveness of action is high and degree of difficulty is easy
Then effectiveness to the difficulty ratio is high.
- T. IF total effectiveness of action is high and degree of difficulty is very easy
Then effectiveness to the difficulty ratio is very high.
- U. IF total effectiveness of action is very high and degree of difficulty is very hard
Then effectiveness to the difficulty ratio is medium.
- V. IF total effectiveness of action is very high and degree of difficulty is hard
Then effectiveness to the difficulty ratio is high.
- W. IF total effectiveness of action is very high and degree of difficulty is medium
Then effectiveness to the difficulty ratio is high.
- X. IF total effectiveness of action is very high and degree of difficulty is easy
Then effectiveness to the difficulty ratio is very high.
- Y. IF total effectiveness of action is very high and degree of difficulty is very easy
Then effectiveness to the difficulty ratio is very high.

2. Define Fuzzy Input

As explained, the input of fuzzy calculation is the total effectiveness of action number and degree of difficulty ratio. In conducting calculation, the parameter of each variable should be declared. The membership function parameter will of each variable be:

A. Membership Function Parameter of Total Effectiveness Ratio

$$\mu_{Very\ low}(x) = \begin{cases} 0, & x \geq 0.28 \\ \frac{0.28 - x}{0.2}, & 0 \leq x < 0.28 \\ 1, & x < 0.08 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x \leq 0.08 \text{ or } x \geq 0.5 \\ \frac{x - 0.08}{0.2}, & 0.08 < x \leq 0.28 \\ \frac{0.5 - x}{0.22}, & 0.28 \leq x < 0.5 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 0.28 \text{ or } x \geq 0.72 \\ \frac{x - 0.28}{0.22}, & 0.28 < x \leq 0.5 \\ \frac{0.72 - x}{0.22}, & 0.5 \leq x < 0.72 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 0.5 \text{ or } x \geq 0.92 \\ \frac{x - 0.5}{0.22}, & 0.5 < x \leq 0.72 \\ \frac{0.92 - x}{0.20}, & 0.72 \leq x < 0.92 \end{cases}$$

$$\mu_{Very\ high}(x) = \begin{cases} 0, & x \leq 0.72 \\ \frac{x - 0.72}{0.2}, & 0.72 < x \leq 0.92 \\ 1, & x > 0.92 \end{cases}$$

From the result, it can be seen that if the membership function for parameter very low is 0 to 0.28, low is 0.08 to 0.5, medium is 0.28 to 0.72, high is 0.5 to 0.92, and very high is 0.72 to 1. That membership parameter number will be

made into a curve for fuzzy calculation. As shown in Table 4.36, summarize of membership function parameter for total effectiveness number. The total effectiveness membership function parameter that was inputted in Matlab was illustrated in Figure 4.6.

Table 4.36 Membership Function Parameter of Total Effectiveness Ratio

Category	Curve Type	Parameter
Very Low	Trapezoidal	[0 0 0.08 0.28]
Low	Triangle	[0.08 0.28 0.5]
Medium	Triangle	[0.28 0.5 0.72]
High	Triangle	[0.5 0.72 0.92]
Very High	Trapezoidal	[0.72 0.92 1 1]

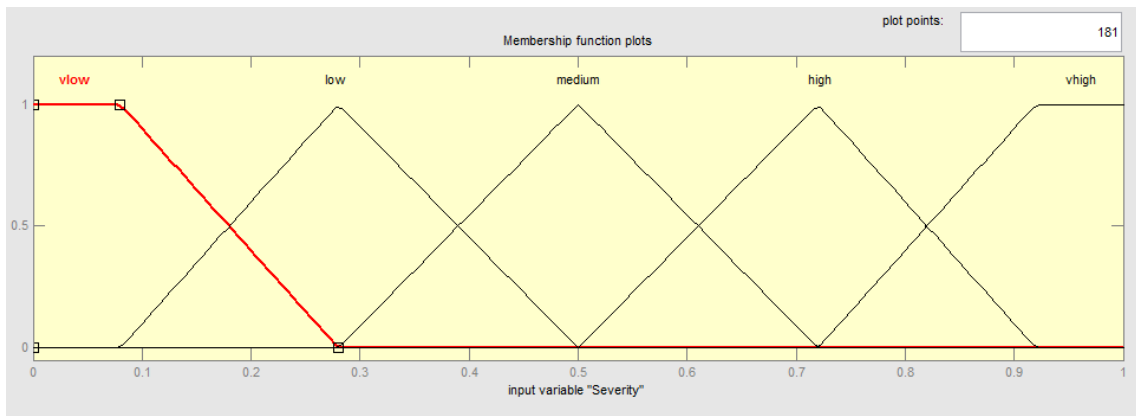


Figure 4.6 Membership Function Parameter of Total Effectiveness Ratio Curve

B. Membership Function Parameter of Degree Difficulty

$$\mu_{Very\ easy}(x) = \begin{cases} 0, & x \geq 2 \\ \frac{2-x}{1}, & 0 \leq x < 2 \\ 1, & x < 1 \end{cases}$$

$$\mu_{easy}(x) = \begin{cases} 0, & x \leq 1 \text{ or } x \geq 3 \\ \frac{x-1}{1}, & 1 < x \leq 2 \\ \frac{3-x}{1}, & 2 \leq x < 3 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 2 \text{ or } x \geq 4 \\ \frac{x-2}{1}, & 2 < x \leq 3 \\ \frac{4-x}{1}, & 3 \leq x < 4 \end{cases}$$

$$\mu_{Hard}(x) = \begin{cases} 0, & x \leq 3 \text{ or } x \geq 5 \\ \frac{x-3}{1}, & 3 < x \leq 4 \\ \frac{5-x}{1}, & 4 \leq x < 5 \end{cases}$$

$$\mu_{Very\ hard}(x) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{1}, & 4 < x \leq 5 \\ 1, & x \geq 5 \end{cases}$$

The result shows, the membership function for parameter very hard is 0 to 2, hard is 1 to 3, medium is 2 to 4, easy is 3 to 5, and very easy is 4 to 5 r more. That membership parameter number will be made into a curve for fuzzy calculation. As shown in Table 4.37, summarize of degree of difficulty membership function parameter. Degree of difficulty membership function parameter that was inputted in Matlab was illustrated in Figure 4.7.

Table 4.37 Membership Function Parameter of Degree of Difficulty

Category	Curve Type	Parameter
Very Easy	Trapezoidal	[0 0 1 2]
Easy	Triangle	[1 2 3]
Medium	Triangle	[2 3 4]
Hard	Triangle	[3 4 5]
Very Hard	Trapezoidal	[4 5 6 6]

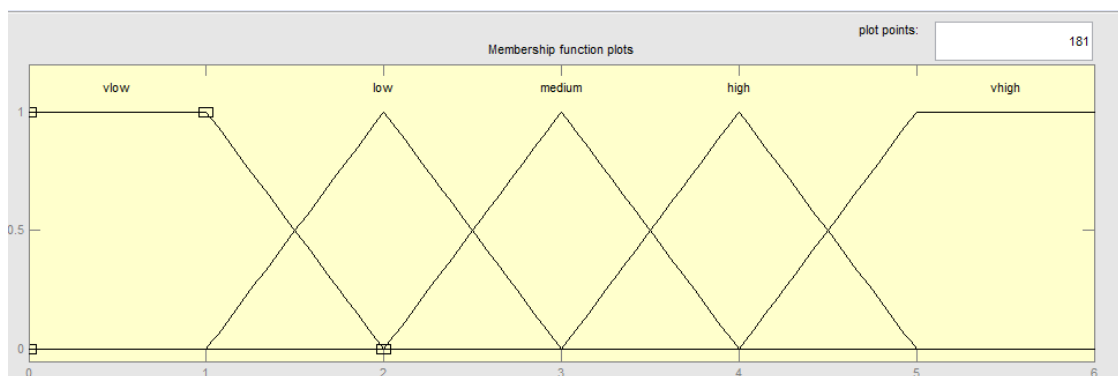


Figure 4.7 Membership Function Parameter of Degree of Difficulty Curve

3. Define Fuzzy Output

As explained in above, the output of fuzzy calculation is the Effectiveness to The Difficulty Ratio. The number is obtained from the fuzzy calculation of total effectiveness of action number and degree of difficulty ratio. Similar with the input, the parameter of output membership function variable should be declared in Matlab software. Table 4.38 shows the variable output membership function parameter of total effectiveness to difficulty ratio.

Table 4.38 Parameter of Effectiveness to the Difficulty Ratio

Category	ETDk Class Interval Number
Very High	$x > 4$
High	$3 \leq x \leq 4$
Moderate	$2 \leq x \leq 3$
Low	$1 \leq x \leq 2$
Very Low	$0 \leq x \leq 1$

The scale number of each class is determined based on the Likert scale. Data from that table should be declared in a curve as a parameter in Matlab software. The parameter membership function will be:

A. Membership Function Parameter of Effectiveness to Difficulty Ratio

$$\mu_{Very\ low}(x) = \begin{cases} 0, & x \geq 2 \\ \frac{2-x}{1}, & 0 \leq x < 2 \\ 1, & x < 1 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x \leq 1 \text{ or } x \geq 3 \\ \frac{x-1}{1}, & 1 < x \leq 2 \\ \frac{3-x}{1}, & 2 \leq x < 3 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 2 \text{ or } x \geq 4 \\ \frac{x-2}{1}, & 2 < x \leq 3 \\ \frac{4-x}{1}, & 3 \leq x < 4 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 3 \text{ or } x \geq 5 \\ \frac{x-3}{1}, & 3 < x \leq 4 \\ \frac{5-x}{1}, & 4 \leq x < 5 \end{cases}$$

$$\mu_{Very\ high}(x) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{1}, & 4 < x \leq 5 \\ 1, & x \geq 5 \end{cases}$$

The result shows, the membership function for parameter low is 0 to 2, very low is 1 to 3, medium is 2 to 4, high is 3 to 5, and very high is 4 to 5 more. That membership parameter number will be made into a curve for fuzzy calculation. As shown in Table 4.39, summarize of total effectiveness to difficulty ratio membership function parameter. Total effectiveness to difficulty ratio membership function parameter number that was inputted in Matlab was illustrated in Figure 4.8.

Table 4.39 Membership Function Parameter of Variable Output

Category	Curve Type	Parameter
Very Low	Trapezoidal	[0 0 1 2]
Low	Triangle	[1 2 3]
Medium	Triangle	[2 3 4]
High	Triangle	[3 4 5]
Very High	Trapezoidal	[4 5 6 6]

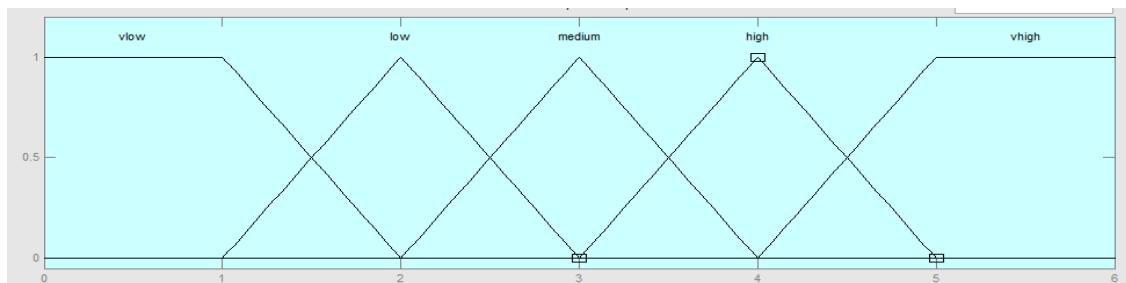


Figure 4.8 Membership Function Parameter of Variable Output Curve

4. Calculation Result

After arranging each curve of variable input and output, the calculation can be conducted. The calculation is carried out by inputting the score number that was obtained from previous calculation and interview. The result of fuzzy calculation for total effectiveness ratio is shown in Table 4.40.

Table 4.40 Result of Calculation of Effectiveness to The Difficulty Ratio

Code	Mitigation Action	Degree of Difficulty (Dk)	TEk	ETD	Rank
PA1	Make a note or order list report	1	0.07	3	3
PA2	Increase the intensity communication with supplier	1	0.16	3.42	1
PA3	Make an inventory production planning and control	2	0.24	2.76	4
PA4	Make transportation and route planning	2	0.09	2.07	5
PA5	Define the rule of lateness delivery	2	0.07	2	7
PA6	Increase the pay charge for lateness	2	0.03	2	8
PA7	Updating new standard operational for every system, infrastructure and activities	2	0.33	3.27	2
PA8	Have reserve electricity power	2	0.07	2	9
PA9	Standardize for safety equipment and production tools	2	0.09	2.07	6
PA10	Scheduling for maintenance tools and safety equipment	2	0.08	2	10

From the table it can be seen, the mitigation action with high total effectiveness ratio is updating new standard operational for every system, infrastructure, and activities and establishing an inventory production planning and control. By improving the new standard and establishing inventory control, it hopefully can increase the company performance, quality product, and employee convenience

Table 4.41 Complete HOR Phase 2

Risk Agent	Preventive Action (PAk)										F.ARP
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	
A1	3	3					3				2.46
A6				5							2.33
A12							5				2.29
A3			3								2.24
A4			5								2.24
A18									3	5	2.07
A2	3	3					1				2
A5			3								2
A7		3			3						2
A8					3	3					2
A9							5				2
A10							3				2
A13	1	5									2
A14								5			2
A15							5				2
A16									5	3	2
Total effectiveness of action (Tk)	0.07	0.16	0.24	0.09	0.07	0.03	0.33	0.07	0.09	0.08	
Degree of difficulty performing action	1	1	2	2	2	2	2	2	2	2	
Effectiveness to difficulty ratio (ETD)	3	3.42	2.76	2.07	2	2	3.27	2	2.07	2	
Rank	3	1	4	5	7	8	2	9	6	10	

CHAPTER V

DISCUSSION

5.1 Explanation of Concept Fuzzy TOPSIS Based HOR Framework

In this research, a concept calculation of proposed model presented in order to manage the enterprise risk. The concept method is adapted from HOR to determine which preventive action that should be implemented first and select the prioritize risk with large aggregate risk potential number. The purpose of this model mostly same with the original HOR, but with the difference framework design, the calculation process, and an additional variable that included in the framework.

In previous HOR, there are 2 phases of procedure calculation. The first phase is focused on finding the aggregate risk potential with a high score. The calculation of aggregate risk potential involves several variables, i.e. severity level of risk event, occurrence level of risk agent, and the correlation matrix for risk agent and risk event. The overall process calculation of phase 1 is conducted by multiplying each level that was mentioned. Then, the second phase is focused on finding which preventive action that should be implemented. The process involves several variables, i.e. total of effectiveness preventive action, aggregate risk potential that prioritized from HOR phase 1, and degree of difficulty for implementation preventive action. The process calculation of this phase is same with previous phase, i.e. multiplication each score of variable. The preventive action can be said effective or not depends on the effectiveness action ratio from that calculation. In a concept of the proposed model, the calculation involves 2 phases of procedure calculation. Each phase will consist of a same calculation process, and this model is involving TOPSIS and fuzzy method in order to find the aggregate risk potential score and the effectiveness level of preventive action.

In this research, TOPSIS method is used because the concept of the method that can find the alternative result based on the similarity to ideal solution and capability of the method in classification the result. In conducting calculation, the determination of weight each criterion should be determined firstly because its process to increase the validity of the calculation. Based on the reason, the method still needs to be combined with another method. Then, the simplicity of TOPSIS is often criticized because of its inability to deal adequately with uncertainty and imprecision inherent in the process of mapping the perceptions of decision-maker (Karimi et al., 2012). Based on the reason, the calculation of fuzzy is used because the capability of the method that can interpret imprecise data, uncertainty data, and ambiguous data.

In phase 1, the calculation of correlation matrix with the severity risk uses TOPSIS method. In this case, the calculation result of correlation matrix score between risk agent and risk event and severity risk needed to be classified into 5 categories to complete the analysis calculation. The represent number from the calculation result of TOPSIS in phase 1 will be named as synthesizes severity. Then, to find the aggregate risk potential number, fuzzy that involves the synthesize severity risk number and occurrence risk will be applied. For the second phase, the method of calculation also uses TOPSIS and fuzzy, but without an additional variable. It means that the framework of phase 2 will consist the same variable with the original model. Summary of explanation and comparison on process calculation for previous model and proposed model are shown in Figure 5.1 and Figure 5.2.

As an illustration of application Fuzzy TOPSIS based HOR framework, data from a company was presented and calculated in previous chapter. The purpose of the proposed model is intended to be generic in nature, so that it can be implemented in any type of companies without much changes needed.

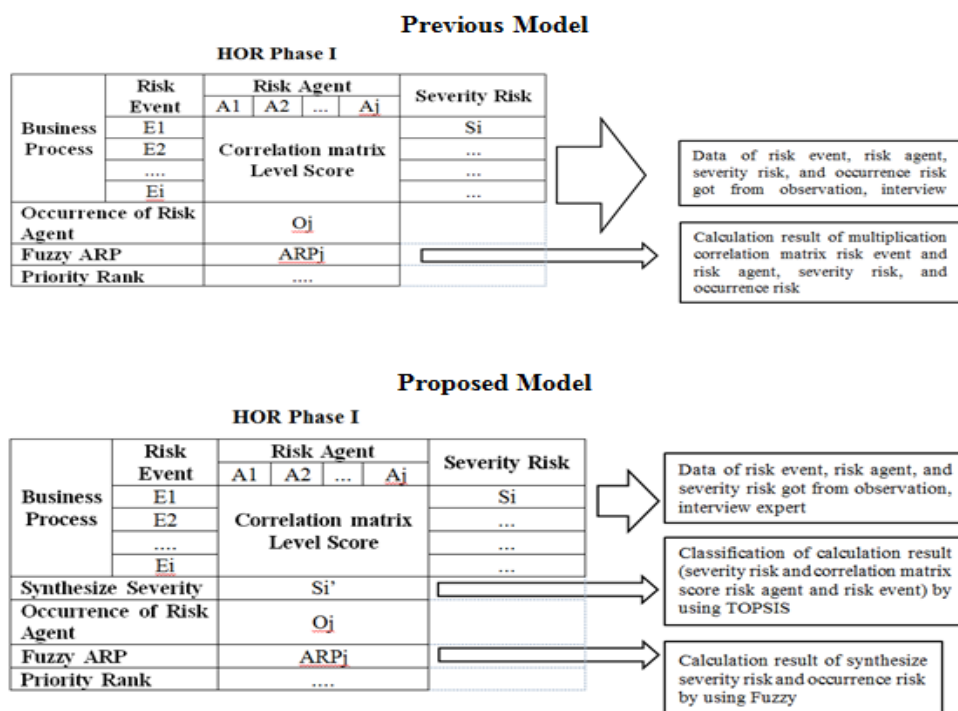


Figure 5.1 HOR Phase 1 Process Comparison of Previous Model and Proposed Model

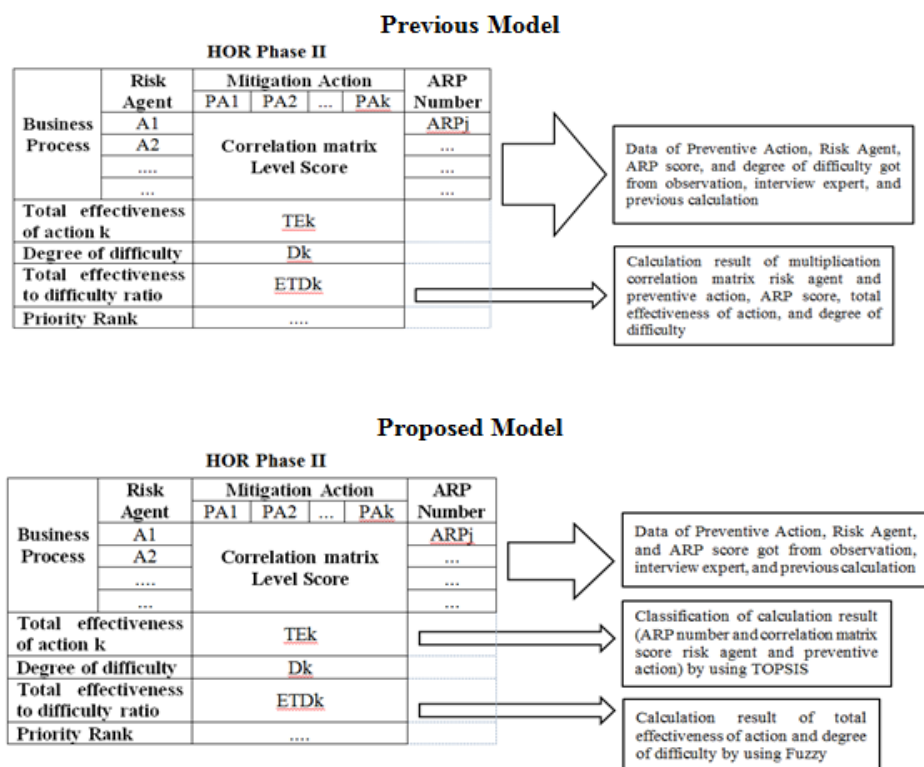


Figure 5.2 HOR Phase 2 Process Comparison of Previous Model and Proposed Model

5.2 Identification of Potential Risk and The Strategy of Mitigation Action

The determination of risk agent and risk event are depending on the condition that happens in the company. Risk event is activities of risk, and then risk agent is causes of the risk event. In this research, there are 18 risk events and 21 risk agents that were mentioned in the chapter before. The calculation of risk event and risk agent was conducted in HOR 1 and the result is a score of aggregate risk potential that shows which risk that should be mitigated. In the calculation, this research uses TOPSIS and Fuzzy as method find ARP score. The TOPSIS is applied to find the synthesise severity and fuzzy calculation for find the ARP. The aggregate risk potential that was calculated will be ranked to prioritize and non-prioritize based on the score. The result shows rank aggregate risk potential of 16 risk agents after filtered based on 80% of occurring risk are:

1. Material order information not clear (A1), the ARP is 2.46.
2. Road jam condition when delivery material (A6), the ARP is 2.33.
3. The delivery process does not fulfill the standard operational (A12), the ARP is 2.29.
4. Increasing of material demand in the market (A3), the ARP is 2.24.
5. Material extinction (A4), the ARP is 2.24.
6. Damage tools of production (A18), the ARP is 2.07.
7. Human error factor (employee mistake) (A2), the ARP is 2.
8. Natural disaster (A5), the ARP is 2.
9. The supplier sent different material (A7), the ARP is 2.
10. The supplier has not deliver material (A8), the ARP is 2.
11. No standard operational for storing material (A9), the ARP is 2.
12. Warehouse does not meet the standard (A10), the ARP is 2.
13. Miscommunication between supplier and company (A13), the ARP is 2.
14. Electricity resource not stable (lack of power) (A14), the ARP is 2.
15. The employee does not follow the standard operational (A15), the ARP is 2.
16. Less quality of safety tools (A16), the ARP is 2.

The 16 risk agents will be exposed to the action based on the relationship, the effectiveness of action, difficulty ratio in implementation. Generally, mitigation action can be carried out by forming of strategic or tactical in nature. Jüttner et al. (2003) suggested that mitigation actions could be in the form of avoidance, control, cooperation, and flexibility. For example, risk avoidance could be done by dropping specific products/geographical markets. Risk control can be performed by vertical integration and increasing the inventory buffer, while cooperation can be in the form of sharing risk information with suppliers. Flexibility can be done through postponing risky activities before receiving orders from customers and establishing multiple suppliers. Similarly, Homrich et al. (2003) provides list of mitigation strategy in supply chain management. These include information sharing, trust among supply chain partners, collaborative relationship, information security, aligning incentives and revenue sharing policies in a supply chain, risk strategic planning, risk sharing in a supply chain and continual risk analysis and assessment. In the calculation of total effectiveness, this research used TOPSIS method concept for calculation by analogizing the score of aggregate risk potential as weight, and also involves the score of relationship matrix between risk agent and the mitigation action. The final result is obtained by conducting the calculation using a fuzzy concept with total effectiveness score and difficulty ratio score as an input. Based on discussion and analysis with the expert of company, there are 9 mitigation actions can be implemented as described below:

1. Make Order List Report

This mitigation action has a total effectiveness as much as 0.7, difficulty ratio is 1, which means that the action is very easy to be implemented, and the effectiveness to difficulty ratio is 3. When doing the transaction, the employee should make a detail order list and it should be evaluated each month or week depends on the company's policy. The importance of order report is used when the supplier or customer doing complain, the company can provide some evidence and it will give the advantage for company. Besides that, the report can show the flow of transaction that was processed and become the company's guidance for making/updating a new policy.

2. Increase the Intensity Communication with Supplier

This mitigation action has total effectiveness value as much as 0.16, difficulty ratio is 1 means the action is very easy to be implemented, and the effectiveness to difficulty ratio is 3.42. Communication is basic of doing business and clear communication will give an advantage to the company. For example, performing good negotiation with customer and supplier could demonstrate good perception for the company itself and high intensity of communication can decrease the mistake in order the amount of material, product, and the number of the price that should be pay.

3. Make a Production Planning and Inventory Control

This mitigation action has a total effectiveness as much as 0.24, with difficulty ratio is 2 which means that the action is easy to be implemented, and the effectiveness to difficulty ratio is 2.76. The importance of making production planning and inventory control is the company able to identify when the material stock is used up and when material should be ordered to the supplier. Good of production planning can avoid the stock out of material because without a material the company cannot produce a product and it could lead to financial loss.

4. Planning the Transportation Route

This mitigation action has a total effectiveness as much as 0.09, difficulty ratio is 2 which means that the action is easy to be implemented, and the effectiveness to difficulty ratio is 2.07. The company should make planning the transportation route because it can help the product delivered on time to the customer. The planning of route can map the region that usually has a high traffic jam, hence the company can avoid that route.

5. Defining and Affirmed the Lateness Rule

This mitigation action has a total effectiveness as much as 0.07, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 2. The company should define and affirm the lateness rule for the supplier because it can increase the company's commitment to be on time in

production and delivery time. The impact of on time activities will give direct advantages to the company.

6. Increase the Pay Charge of Lateness

This mitigation action has a total effectiveness as much as 0.03, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 2. The importance of this action is to make the supplier always on time when delivering the material, and it will give wary effect.

7. Updating new standard operational for every system, infrastructure. and activities

This mitigation action has a total effectiveness as much as 0.33, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 3.27. Standardization of all aspects should be conducted by the company because it will provide direction for the company's staffs in carrying out their work. For example, the clear SOP will make the job description clearer and the performance of company's staffs will be well maintained. This SOP should continue to be evaluated and developed. Within a certain period of at least 6 months, the SOP should be evaluated and updated to improve the company's overall performance.

8. Have Another Electricity Resource

This mitigation action has a total effectiveness as much as 0.07, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 2. The disruption in electric power can interrupt all company activities, especially in production. The delay production can cause a financial loss to the company because the products are manufactured under certain schedule. The company should reserve electricity power to avoid all of the risks, it can employ genset or another electricity power.

9. Standardize the Safety Equipment and Production Tools

This mitigation action has a total effectiveness as much as 0.09, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 2.07. Standardization of safety equipment and production tools can support the performance of employees in doing the job, because it can increase the employee convenient, safety feel, and etc.

10. Scheduling For Maintenance Tools and Safety Equipment

This mitigation action has a total effectiveness as much as 0.08, difficulty ratio is 2 with mean the action is easy to be implemented, and the effectiveness to difficulty ratio is 2. Maintenance activities or preventive action can be done as follows:

- A. Performing maintenance on different time periods i.e. do check-up routine every month. Especially on machines that often interrupt
- B. Improving or changing the machine if necessary

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Based on the calculation above, a conclusion can be drawn to answer the problem identification. It is stated in following statements:

1. In the concept of proposed model, the calculation involves 2 phases of calculation procedures. The phase will consist of same variable with 1 additional variable, and the difference calculation. The calculation of the model covers TOPSIS and fuzzy method in order to find the aggregate risk potential score and the effectiveness level of preventive action. TOPSIS method is used because the concept of the method that can find the alternative result based on the similarity to ideal solution and capability of the method in classification the result. In conducting calculation, the determination of weight on each criterion should be determined first to increase the validity of the calculation. Based on the reason, the method still needs to be combined with another method. Then, the simplicity of TOPSIS is often criticized because of its inability to deal adequately with uncertainty and imprecision inherent in the process of mapping the perceptions of decision-maker (Karimi et al., 2012). Based on the reason, the calculation of fuzzy is used due to its capability of the method that can interpret imprecise data, uncertainty data, and ambiguous data. In phase 1, the calculation of correlation matrix with the severity risk uses TOPSIS method. The reason of using TOPIS because the concept of the method that can find the alternative result based on the similarity to ideal solution and capability of the method in classification the result. In this case, the result of calculation of correlation matrix score between risk agent and risk event, and severity risk need to be classified into 5 categories in order to complete the analysis calculation. The representing number from the calculation

result of TOPSIS in phase 1 will be named as synthesizes severity. Then, to find the aggregate risk potential number, fuzzy that involve the synthesize severity risk number and occurrence risk will be used. For the second phase, the method of calculation also uses TOPSIS and fuzzy, but without an additional variable. It means the framework consists the same variable as in original HOR.

2. The calculation of risk event and risk agent was conducted in HOR 1 and the result is a score of aggregate risk potential that shows which risk that should be mitigated. In the calculation, this research uses TOPSIS and Fuzzy as a method to find an aggregate risk potential, and it will be ranked based on the score. The result shows rank aggregate risk potential of 16 risk agents after filtered based on 80% of occurring risk:

- A. Material order information not clear (A1), the ARP is 2.46.
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- C. The delivery process does not fulfill the standard operational (A12), the ARP is 2.29.
- D. Increasing of material demand in the market (A3), the ARP is 2.24.
- E. Material extinction (A4), the ARP is 2.24.
- F. Damage tools of production (A18), the ARP is 2.07.
- G. Human error factor (employee mistake) (A2), the ARP is 2.
- H. Natural disaster (A5), the ARP is 2.
- I. The supplier sent different material (A7), the ARP is 2.
- J. The supplier has not deliver material (A8), the ARP is 2.
- K. No standard operational for storing material (A9), the ARP is 2.
- L. Warehouse does not meet the standard (A10), the ARP is 2.
- M. Miscommunication between supplier and company (A13), the ARP is 2.
- N. Electricity resource not stable (lack of power) (A14), the ARP is 2.
- O. The employee does not follow the standard operational (A15), the ARP is 2.
- P. Less quality of safety tools (A16), the ARP is 2.

The risk agent that was filtered in the Pareto diagram will give the preventive action or mitigation action in HOR phase 2. Based on the score of effectiveness to difficulty ratio, the mitigation actions are:

- A. Increase intensity communication with the supplier.
- B. Updating new standard operational for every system, infrastructure, and activities.
- C. Make a note or order list report.
- D. Make an inventory production planning and control.
- E. Make transportation and route planning.
- F. Standardize for safety equipment and production tools.
- G. Define and affirm the rule of lateness delivery.
- H. Increase the payment charge for lateness.
- I. Have Another Electricity Power
- J. Scheduling for maintenance tools and safety equipment.

6.2 Recommendation

Some recommendations are given in this study as follows:

1. This research is conducted in the production department only. For next research, risk data from another department, such marketing, financial, human resource can be added to obtain more detail mitigation actions.
2. The researcher uses TOPSIS to classify the synthesise severity and find the total effectiveness. Considering the complexity calculation in part of synthesizing severity and total effectiveness calculation, the simply calculation with another method for finding classifying is suggested. For future research, the classifying process still can be developed and modified by another method such as method of multi criteria decision making (MCDM).

REFERENCES

- Chang, K.-H., & Cheng, C.-H. (2010). A risk assessment methodology using intuitionistic fuzzy set in FMEA. *International Journal of Systems Science*, 41(12), 1457–1471.
- Chen, L.-H., & Ko, W.-C. (2009). Fuzzy linear programming models for new product design using QFD with FMEA.pdf. *Applied Mathematical Modelling*, 33(2), 633–647.
- Florio, C., & Leoni, G. (2016). Enterprise risk management and firm performance: The Italian case. *The British Accounting Review*.
- Gehner, E. (2008). *Knowingly taking risk*.
- Grabovy, P. G., & Orlov, A. K. (2016). The Overall Risk Assessment and Management: Implementation of Foreign Investment Construction Megaprojects by Russian Development Companies. *Procedia Engineering*, 153(905), 195–202.
- Gu, J., Xia, X., He, Y., & Xu, Z. (2017). An approach to evaluating the spontaneous and contagious credit risk for supply chain enterprises based on fuzzy preference relations. *Computers & Industrial Engineering*.
- Homrich, D. S., Inácia, M., Salum, F., Coelho, A. S., & Rodriguez, C. M. T. (2003). Risk management and mitigation strategies in the supply chain : A case study in the aeronautical industry ., 1–11.
- Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics: Research & Applications*, 6(4), 197–210.
- Karimi, M., Moztarzadeh, F., Pakzad, A., Beynaghi, A., & Mozafari, M. (2012). Application of Fuzzy TOPSIS for Group Decision making in Evaluating Financial Risk, 21–22.
- Kazan, H., Çiftçi, C., & Hobikoğlu, E. H. (2015). The Fuzzy Logic for the Selection of the Transportation Type A firm Application. *Procedia - Social and Behavioral Sciences*, 195, 1593–1601.
- Khoo, L. P., & Ho, N. C. (1996). Framework of a fuzzy quality function deployment system. *International Journal of Production Research*, 34(2), 299–311.
- Luthfi, Achmad dan Irawan, H. (2012). Analisis Risiko Rantai Pasok Dengan Model

- House Of Risk (HOR). *Jurnal Manajemen Indonesia*.
- Mahdevari, S., Shahriar, K., & Esfahanipour, A. (2014). Science of the Total Environment Human health and safety risks management in underground coal mines using fuzzy TOPSIS. *Science of the Total Environment, The*, 488–489, 85–99.
- Mavi, R. K., Goh, M., & Mavi, N. K. (2016). Supplier Selection with Shannon Entropy and Fuzzy TOPSIS in the Context of Supply Chain Risk Management. *Procedia - Social and Behavioral Sciences*, 235(October), 216–225.
- Meidell, A., & Kaarbøe, K. (2016). How the enterprise risk management function influences decision-making in the organization e A field study of a large, global oil and gas company. *British Accounting Review*.
- Mohammed, H. K., & Knapkova, A. (2016). The impact of total risk management on company's performance. *Procedia - Social and Behavioral Sciences*, 220(March), 271–277.
- Mundi, M. I., Alemany, M. M. E., Poler, R., & Fuertes-Miquel, V. S. (2016). Fuzzy sets to model master production effectively in Make to Stock companies with Lack of Homogeneity in the Product. *Fuzzy Sets and Systems*, 293, 95–112.
- Nocco, B. W., & Stulz, R. M. (2006). Enterprise Risk Management: Theory and Practice. *Journal of Applied Corporate Finance*, 18(4), 8–20.
- Nyoman Pujawan, I., Geraldin, L. H., Pujawan, I. N., & Geraldin, L. H. (2009). House of risk: a model for proactive supply chain risk management. *Business Process Management Journal*, 15(6), 953–967.
- Pugna, A., Negrea, R., & Miclea, S. (2016). Using Six Sigma Methodology to Improve the Assembly Process in an Automotive Company. *Procedia - Social and Behavioral Sciences*, 221, 308–316.
- Roghanian, E., & Mojibian, F. (2015). Using fuzzy FMEA and fuzzy logic in project risk management. *Iranian Journal of Management Studies*, 8(3), 373–395.
- Sabokbar, H. F., Hosseini, A., Banaitis, A., & Banaitiene, N. (2016). A novel sorting method topsis-sort: An application for tehran environmental quality evaluation. *E a M: Ekonomie a Management*, 19(2), 87–104.
- Shirouyehzad, H., Badakhshian, M., Dabestani, R., & Panjehfouladgaran, H. (2010). The Journal of Fuzzy FMEA Analysis for Identification and Control of Failure Preferences in ERP Implementation Abstract ERP began in the 1960s as material

- requirements planning , an outgrowth of early efforts in bill of material processing . However ERP , 4(4), 366–376.
- Silva, M. M., de Gusmão, A. P. H., Poletto, T., Silva, L. C. e, & Costa, A. P. C. S. (2014). A multidimensional approach to information security risk management using FMEA and fuzzy theory. *International Journal of Information Management*, 34(6), 733–740.
- Sofyalıoğlu, Ç., & Kartal, B. (2012). The Selection of Global Supply Chain Risk Management Strategies by Using Fuzzy Analytical Hierarchy Process – A Case from Turkey. *Procedia - Social and Behavioral Sciences*, 58, 1448–1457.
- Sprčić, D. M., Kožul, A., & Pecina, E. (2015). State and Perspectives of Enterprise Risk Management System Development - The Case of Croatian Companies. *Procedia Economics and Finance*, 30(15), 768–779.
- van Leeuwen, J. F., Nauta, M. J., de Kaste, D., Odekerken-Rombouts, Y. M. C. F., Oldenhof, M. T., Vredenburg, M. J., & Barends, D. M. (2009). Risk analysis by FMEA as an element of analytical validation. *Journal of Pharmaceutical and Biomedical Analysis*, 50(5), 1085–1087.
- Wessiani, N. A., & Sarwoko, S. O. (2015). Risk Analysis of Poultry Feed Production Using Fuzzy FMEA. *Procedia Manufacturing*, 4(Iess), 270–281.
- Zouggari, A., & Benyoucef, L. (2012). Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem. *Engineering Applications of Artificial Intelligence*, 25(3), 507–519.