CHAPTER II

LITERATURE REVIEW

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

2.1. Inductive Study

Quality control is one of the important parts in the industry. The common function of quality control is for improving the process, such as production process. Quality control represents the most basic form of quality related activities and its main objective is to ensure that a system or a service fulfils the established quality requirements (ISO 9000:2015, 2015). It also considered to measure the performance of product and service quality to achieve the standard.

Susetyo, et al. (2011) conducted the research about product quality in convection company. This research was aimed to know the ability production according to defect product. The method that used in this research are six sigma, and kaizen. The result shows that there are several potential causes on failure and there are several control suggestions based on the implementation tools of kaizen.

James O. Westgard & Sten A. Westgard (2016) conducted the research about quality management in medical laboratories. This research was aimed for a low probability of false rejections. The methods used in this study are Six Sigma and SQC.

The result showed that there is problem occurs in an analytical run, many factors influence it, so it require careful assessment and judgement.

Purnama, et al. (2018) conducted the research about quality improvement on creative industry. This study is aimed to minimize the number of defects due to existing failure. The method that used in this research are Fuzzy AHP-FMEA and Six Sigma through phases Define, Measure, Analyse, Improve and Control (DMAIC). The result of this research is defect reduction value by implementing the improvement in Zano Production.

Kurt & Ozilgen (2013) conducted the research about practical safety improvement action. This study was aimed to analyse failure in dairy product manufacturing. This study applied the FMEA methodology for quantification of risk analysis in manufacturing processes of six widely consumed dairy products in Turkey. The result of this study concluded the most common failure modes detected during the audits, the RPN values for each failure mode, and the improvements after implementing the suggested corrective actions.

Chanamool & Naenna (2016) conducted the research about hospital as an emergency department that should be monitored. This reserach proposed the application of Fuzzy failure mode and effects analysis (FMEA) for prioritization and assessment of failures that likely occur in the working process of an emergency department. The aim of this study is to increase the level of confidence on hospitals. The result showed that Fuzzy FMEA method can detect failures in an emergency department by comparing the priority ranks of the problem before and after implementation of the method.

Colledani, et al. (2018) conducted the research about production quality improvement. This study proposed a reference framework for improving production quality performance during the system ramp-up phase. The aim of this study is to improve the production quality during the ramp-up phase of manufacturing systems to achieve a fast convergence to the desired production targets, with minimal production and resource losses. The method that used were Six Sigma and just-in-time.

Pugna, et al. (2016) conducted the research about quality imrpovement of product defect. This research applied Six Sigma, AHP and Poka-Yoke methods. The objective of this research is to provide a solution for improving an assembly process in an automotive company. After applying these methods, the result indicated that the defect was reduces to 40%. Then, this research was suggested to continue the improvement process by tackling the next nonconformities from Pareto chart and also to attempt riveting process automation, in order to eliminate possible human errors.

Adar, et al. (2017) conducted the research about failure mode analysis in supercritical water gasification (SCWG) system. The purpose of this study is to determine the problems that occur during the commissioning and operation of a continuously operated, laboratory-scale supercritical water gasification system and to identify their reasons and effects. The methods that used in this research were FMEA and Fuzzy FMEA. The result suggested problems in the system that related to the pump, gas-liquid separation, control panel/electrical circuitry, heat exchanger, reactor, operating conditions, material, feedstock, environment and operator. The suggestion for better improvement of the research is routine system checking before every operation.

Le, et al. (2017) conducted the research about quality control of Ginkgonis Semen (GS). The aim of this study is to develop HPLC method using ginkgolides based on the quantitation of GA, GB and GC for the quality control of GS with the optimization of sample preparation to enhance the analytical sensitivity and reproducibility. This research used HPLC-ELSD method to give a better analysis. The reproducibility of the method of HPLC-ELSD was verified. This research suggested HPLC-ELSD method, and the resultant content criteria derived, could be used toward for formulating a universal quality control methodology to quantify GS quality and origin.

Sirisawat & Kiatcharoenpol (2018) conducted the research about classification, ranking and giving solution of revenge logistics barriers. This research was aimed to increase efficiency in reverse logistics adaptation of the electronics industry. The method that used in this study were Fuzzy AHP and TOPSIS. The result of this study indicated there are 29 barriers and 14 solutions to minimize the barriers. It also indicated that top management awareness and support were the highest ranking value for solutions in this problem.

Kim, et al. (2018) conducted the research about engineering failure analysis. This study was aimed to analyse the failure of heat exchanger tube for high temperature fuel cell. FEA and CFD are the methods used in this research. The result suggested the system should have a risk of Vortex induced due to the large number of resonant modes that can be identified. This study suggested an optimal design for improvement with numerical simulation by FEA.

From the inductive study that already performed, the literature survey that would be used in this research, which is product defect analysis that designated to improve the quality of the product using integration of Fuzzy AHP-FMEA and Six Sigma through phases Define, Measure, Analyse, Improve, Control (DMAIC). The summary of related research is shown in Table 2.1.

Table 2.1. Literature Survey

No	Author	Method													Manufacturing Application					
		Six Sigma	Kaizen	AHP	TOPSIS	SQC	HPLC	CFD	FEA	Just-in time	Poka Yoke	FMEA	Fuzzy FMEA	Fuzzy AHP	Automotive	F&B	Electronics	Chemicals	Hospital	Others
1	(Susetyo, et al., 2011)	√	√																	●
2	(James O. Westgard & Sten A. Westgard, 2016)	√				√													●	
3	(Purnama, et al., 2018)	√										√		√						●
4	(Kurt & Ozilgen, 2013)											√				●				
5	(Chanamool & Naenna, 2016)											√	√						●	
7	(Colledani, et al., 2018)	√								√					●					
8	(Pugna et al., 2016)	√		√							√				●					
9	(Adar, et al., 2017)											√	√					●		
10	(Le, et al., 2017)						√											●		
11	(Sirisawat & Kiatcharoenpol, 2018)				√									√			●			

No	Author	Method													Manufacturing Application					
		Six Sigma	Kaizen	AHP	TOPSIS	SQC	HPLC	CFD	FEA	Just-in time	Poka Yoke	FMEA	Fuzzy FMEA	Fuzzy AHP	Automotive	F&B	Electronics	Chemicals	Hospital	Others
12	(Kim, et al., 2018)							√	√						●					
13	(Salsabil, 2018)	√										√		√		●				

2.2 Deductive Study

There is one important thing beside inductive study, which is deductive study. Deductive study explains about the theories that support the research. This deductive study will be the basic for the analysis and help in solving problems in this research. The deductive study will be discussed in this research are Quality Control, Six Sigma, Failure Mode and Effect Analysis (FMEA), Analytical Hierarchy Process (AHP), and Fuzzy AHP.

2.2.1. Quality Control

Quality control represents the most basic form of quality related activities and its main objective is to ensure that a system or a service fulfils the established quality requirements (ISO 9000:2015, 2015). Quality control is examining control materials of known substances along with patient samples to monitor the accuracy and precision of the complete examination (analytic) process. The aims of quality control are to detect errors and solve the problem before customer results are reported.

2.2.2. Six Sigma

According to Pugna, et al. (2016) explained the concept of Six Sigma as a methodology for improving quality products and services better, faster, and cheaper. Six Sigma has two approaches, such as DMAIC (D-Define, M-Measure, A-Analyse, I-Improve and C-Control), which is applicable to an existing process or product to be improved, and DMADV (D-Define, M-Measure, A-Analyse, D-Design, V-Verify) which is applicable to new products or processes, to be designed and / or implemented in a manner that will provide a Six Sigma performance.

There are 5 stages in this implementation, which are Define, Measure, Analyse, Improve, and Control (DMAIC), it will be used to measure the quality of products and services as well as to control their quality (Syukron & Kholil, 2012). Six sigma cycle of continuous improvement is shown in the Figure 2.1.

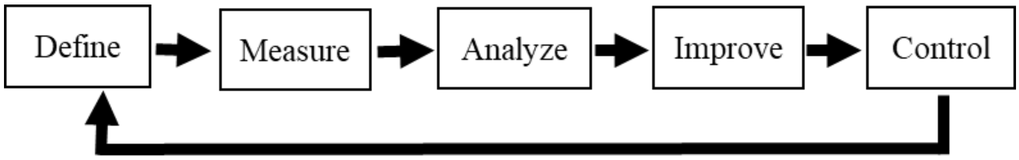

Figure 2.1. Six Sigma Cycle of Continuous Improvement

Purnama, et al. (2018) mentioned the definition of each phase in DMAIC.

1. Stage of Define
   Define is purposed to identify the production process and types of defects in industry.
2. Stage of Measure
   Measure is conducted by using defect per million opportunities (DPMO) to rate the recent company's performance, specifically in quality of management and to calculate sigma level from DPMO.
3. Stage of Analyse
   Analyse is to identify the root cause of defect on the production.
4. Stage of Improve
   Improvement is to determine the solution to minimize or prevent the possibility defect.
5. Stage of Control
   Control is to conduct the actions to minimize or reduce the defect.

2.2.3. DPMO and Sigma Level

Defects per million opportunities (DPMO) refers to the number of defects that would have been produced for 1 million products that had been manufactured. In most processes it would take forever to produce a million of something, therefore measure only a sample and use statistics to predict the outcome of the total by Odendaal & Claasen (2002). Equation 2.1 shows how to measure the DPO and Equation 2.2 shows how to measure the DPMO.

$$DPO = \frac{Number\ of\ Defect}{(amounts\ of\ defect's\ possibility) \times (numbers\ of\ examination)} \quad (2.1)$$

$$DPMO = DPO\ x\ 1.000.000 \tag{2.2}$$

After resuming the value of DPMO, sigma level can be calculated by using following formula on the Equation 2.3.

$$Sigma\ Level = normsinv\left(\frac{1000000 - DPMO}{1000000}\right) + 1{,}5 \tag{2.3}$$

2.2.4. Failure Mode and Effect Analysis (FMEA)

Failure mode and impact analysis (FMEA) is a systematic method for analysing and ranking the hazards associated with different products or processes and prioritizing hazards to propose appropriate corrective actions and achieve a desirable situation (Barends, et al, 2012). From the definition of FMEA, which refers to the quality, it can be concluded that FMEA is a method used to identify and analyse a failure and consequently to avoid failure. In the context of occupational health and safety (K3), the failure represents a danger arising from a process. Failures are grouped based on the impact given to the success of a mission from a system. In general, FMEA is defined as a technique that identifies three things:

1. Potential failure of the system, design, product, and process during its life cycle.
2. Effects of the failure.
3. The criticality level of failure effect on system function, design, product, and process.

In addition, FMEA is also a method that aims to evaluate the design of the system by considering the various modes of failure of the system consisting of component components and analyse the influence on the reliability of the system. By tracking the effects of component failures according to the system level, critical items can be assessed and actions improvements are required to improve the design and eliminate or reduce the probability of critical failure modes. The FMEA method is an approach method to help the operator to determine potential failure modes and the effects. In FMEA RPN calculations can be performed to determine the highest failure rate. Risk Priority Number (RPN) is a relationship between three variables, which are Severity, Occurrence, and Detectability. FMEA scale for probability of severity (S), occurrence (O), and detectability (D) as shown on the table below.

Table 2.2 FMEA Scale for Probability of Severity (S)

Rank	Severity	Description	Characterictic
10	Dangerous without warning	Failure of a system that produces a very dangerous effect	System shut down and chemical substance leaked
9	Dangerous with warning	System failure that produces harmful effects	Sirine as warning sensor turn on
8	Very high	The system is not operating	The sensors missread and given wrong command
7	High	The system operates but can not run in full	Sugar contain contaminants
6	Medium	The system is operating and secure but decreased performance that affected output	Grain size did not pass, dust absorption is not optimal
5	Low	Step by step decreased the performance	Sugar scattered on the floor
4	Very low	Small effect on system perforance	The box fall down and broken
3	Small	Very small on system performance	Sacks of sugar fall down
2	Very small	Negligible effect on system performance	The number on expired date is not too clear enough
1	No effect	No effect	Sugar not in a good condition

Table 2.3 FMEA Scale for Probability of Occurrence (O)

Rank	Occurrence	Description	Characteristic
10	Very High	Often fails	System fails
9			
8	High	Repeated failure	There is no box partition in the weigher, machine error, sensor closed by huge sugar
7			
6	Medium	Infrequent failure	Speed of the machine, no balance of the material or product
5			
4	Low	Very small failure	Overflow vibrating, torn packaging, dust collector full of dust
3			
2	No effect	Almost no failure	Partial system/machine error
1			

Table 2.4 FMEA Scale for Probability of Detectability (D)

Rank	Detectability	Description	Characteristic
10	Not sure	Preventive treatment will not always be able to detect potential causes or failure mechanisms and failure modes	Residual mitigation
9	Very small	Preventive treatment has the possibility of very remote to be able to detect potential causes or failure mechanisms and failure modes	Residual mitigation plan
8	Small	Preventive treatment has possible remote for able to detect cause potential or failure mechanism and failure mode	Residual mitigation plan
7	Very low	Preventive treatment has possibly very low to be able to detect potential causes of failure and failure mode	Routine part of machine checking

Rank	Detectability	Description	Characteristic
6	Low	Preventive treatment has low probability for able to detect cause potential or mechanism failure and failure mode	Routine sub module of machine checking
5	Medium	Preventive treatment has possible moderate for detecting potential causes or failure mechanism and failure mode	Routine module of machine checking
4	Moderately high	Preventive treatment has possible moderately high to detect cause potential or failure mechanism and failure mode	Routine machine checking, increase the supervision, enlarge screen size
3	High	Preventive treatment has high possibility to detecting potential causes or failure mechanism and failure mode	Capability of man-power
2	Very high	Preventive treatment has chances are very high for detecting potential causes or failure mechanism and failure mode	Operation procedure, collect and clean tge sugar, clean dust collector, flip over and rip off the packaging to the barrel reject.
1	Almost certainly	Preventive treatment will always be detecting potential causes or failure mechanism and failure mode	Operation whole procedure

Adar, et al. (2017) explained that RPN method is used to prioritize the failures identified. RPN is a product of severity (S), occurrence (O), and detectability (D). It is calculated using the formula on the Equation 2.4.

$$RPN = S \times O \times D \tag{2.4}$$

2.2.5. Analytical Hierarchy Process (AHP)

Based on Durmusoglu, (2018) Analytical Hierarchy Process (AHP) is one of the most powerful and popular methods for group decision making. The Analytic Hierarchy Process (AHP), introduced by Saaty (1980), is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process.

The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that the best option is the one which optimizes each single criterion, rather the one which achieves the most suitable trade-off among the different criteria.

AHP is one of the most popular MCDM tools for formulating and analysing decisions especially problem in operation management. According to Subramanian & Ramanatan (2012) the application of AHP to a decisions problem involves four steps, which is:

1. Structuring of the decision problem into hierarchical model

   It includes decomposition of the decision problem into elements according to their common characteristic and the formation of a hierarchical model having different levels. A simple AHP has three levels (goal, criteria, and alternatives) though more complex models with more levels could be formulated. The analytical hierarchy process (AHP) structures the problem as a hierarchy shown in Figure 2.2.

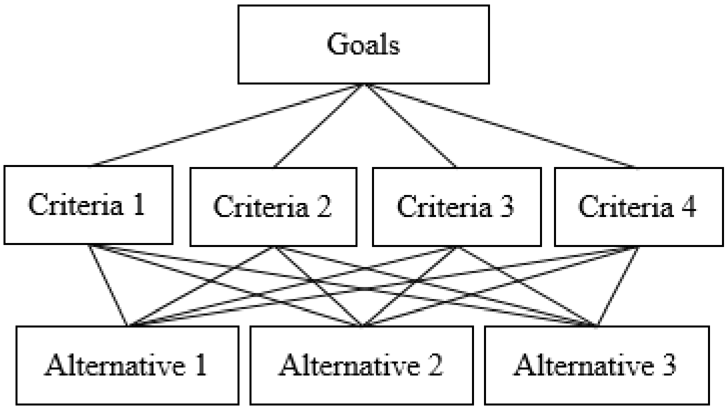

Figure 2. 2. The Hierarchy

The first level of the hierarchy is the goal. The second level in the hierarchy is constituted by the criteria. The third level consists of the available alternatives. The advantages of this hierarchical decomposition are clear. By structuring the problem in this way, it is possible to better understand the decision to be achieved, the criteria to be used and the alternatives to be evaluated. This step is crucial and in more complex problems, it is possible to request the participation of experts to ensure that all criteria and possible alternatives have been considered. Also, in complex problems, it may be necessary to include additional levels in the hierarchy such as sub-criteria.

2. Making pair-wise comparisons and obtaining the judgmental matrix

In this step, the elements of a particular level are compared with respect to a specific element in the immediate upper level. The resulting weights of the element may be called the local weights. Elements are compared pair-wise and judgments on comparative attractiveness of element are captured using a rating scale (1-9). Pair-wise rating scale shows on the Table 2.3.

Table 2.5 Pair-wise Rating Scale (Saputra, 2018)

Level of Importance	Definition	Information
1	Equally important	Both elements have the same effect.

Level of Importance	Definition	Information
3	Slightly more important	Decisions are siding with one important element that is compared to their pair.
5	Much more important	Decisions show a joy over one activity over another.
7	Far more important	Decisions show a strong passion for one activity over another.
9	Extremely more important	An absolute element is preferred when compared to its important partner, at the highest confidence level.
2,4,6,8	Middle value between 2 level of decision	When compromise is required.

An element receiving higher rating is viewed as superior or more attractive compared to another one that receive a lower rating. Result of weighting criteria above is a matrix MxM, where M is the number of criteria.

3. Normalize the data

Normalize the data by dividing the value from each element in the pair-wise matrix with the total value of each column. Normalization done to divide the element matrix by the number of all elements that exist, the result matrix as follows on the Equation 2.5.

$$N = \begin{bmatrix} n1 = \dfrac{s1}{\sum_{t=1}^{n} Si} \\ n2 = \dfrac{s2}{\sum_{t=1}^{n} Si} \\ n3 = \dfrac{s3}{\sum_{t=1}^{n} Si} \end{bmatrix} \tag{2.5}$$

4. Calculate eigen vector and test of consistency value

Maximum eigen vector can be obtained by using software or manual, calculate the eigen vector from each pair-wise comparison matrix. Eigen vector is the weight of each element, this step is to synthetize the options in the priority assignment of elements at the lowest hierarchy level to achieve the goal.

5. Test consistency of the hierarchy

Consistency ratio can be seen with consistency index. Consistency is expected to be near perfect to produce a decision that is close to valid (Saputra, 2018). With the AHP, model can use the decision maker's perception as input inconsistency may occur because humans have limitations in expressing their perceptions consistently especially when it must compare many criteria, consistency ratio is a parameter used to check pairwise comparisons that have been carried out consequently or not. The consistency measurement of a matrix is based on the maximum eigen value, where the value of the consistency index can be calculated by using formula on the Equation 2.6.

$$CI = \frac{\pi \max - n}{n - 1} \tag{2.6}$$

Where:
CI = Consistency index
n = number of alternatives
πmax = the largest eigenvalues from the matrix order

If Cl is zero, then the pairwise comparison matrix is consistent. The predetermined inconsistency limit is determined by using a Consistent Ratio (CR), that is, the index ratio is consistent with the value of the Random Index (RI) obtained from an experiment by the Oak Ridge National Laboratory developed by the Wharton School (Saputra, 2018). This value depends on the matrix order formula for Consistency Ratio that is shown on the Equation 2.7.

$$CR = \frac{CI}{RI} \tag{2.7}$$

Where:

CR = Consistency Ratio

CI = Consistency Index

RI = Random Index

Table 2.6 Random Index (RI) Value

N	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

If the pairwise comparison matrix with CR value is less than 0.100 then the inconsistency of opinion from the decision maker is still acceptable otherwise the assessment needs to be repeated.

2.2.6. Fuzzy Analytical Hierarchy Process

Gungor, et al. (2009) explain that Fuzzy Analytical Hierarchy Process (AHP) method is a systematic approach to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis. The decision maker can specify preferences in the form of natural language or numerical value about the importance of each performance attribute. The F-AHP is applied to evaluate the best adequate personnel dealing with the rating of both qualitative and quantitative criteria. According to Gungor, et al. (2009) the following are the steps to complete the Fuzzy Analytical Hierarchy Process:

a. Determine pair-wise comparison matrices using Fuzzy Triangular Number (TFN)

$$A = \left(a_{ij}\right)_{mxn} = \begin{bmatrix} (1,1,1) & (L_{12}, m_{12}, u_{12}) & \cdots & L_{1n}, m_{1n}, u_{1n} \\ L_{21}, m_{21}, u_{21} & (1,1,1) & \vdots & L_{2n}, m_{2n}, u_{2n} \\ \vdots & \vdots & (1,1,1) & \vdots \\ L_{n1}, m_{n1}, u_{n1} & L_{n2}, m_{n2}, u_{n2} & \ldots & (1,1,1) \end{bmatrix} \tag{2.8}$$

$$Where\ a_{ij} = (L_{ij}, m_{ij}, u_{ij}) = a_{ij}^{-1} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right) for\ i,j = 1, \ldots, n; and\ i\ \neq 1 \quad (2.9)$$

In order to obtain a useful scale when comparing the two elements, a comprehensive understanding of the elements being compared is needed and their relevance to the variables or objectives being studied. In the preparation of the interest scale, the current scale is transformed to the fuzzy number triangulation listed in the following Table 2.5.

Table 2.7 TFN Membership Adjustments

Priority Rating	Fuzzy Scale	Reverse Fuzzy Scale
1	(1,1,3)	(1/3,1/1,1/1)
3	(1,3,5)	(1/5,1/3,1/1)
5	(3,5,7)	(1/7,1/5,1/3)
7	(5,7,9)	(1/9,1/7,1/5)
9	(7,9,9)	(1/9,1/9,1/7)
2	(1,2,4)	(1/4,1/2,1/1)
4	(2,4,6)	(1/6,1/4,1/2)
6	(4,6,8)	(1/8,1/6,1/4)
8	(6,8,9)	(1/9,1/8,1/6)

b. After all elements of the pairwise comparison matrix converted to TFN (Triangulated Fuzzy Number), the geometric mean method is applied to calculate the priority criteria using following formula on the Equation 2.10.

$$\begin{aligned} &G_1 = (l_i, m_i, u_i); \\ &l_i = (l_{i1}\ x\ l_{12}\ x \ldots x\ l_{ik})^{\frac{1}{k}} for\ 1 = 1,2, \ldots, k; \\ &m_i = (m_{i1}\ x\ m_{12}\ x \ldots x\ m_{ik})^{\frac{1}{k}} for\ 1 = 1,2, \ldots, k; \\ &u_i = (u_{i1}\ x\ u_{12}\ x \ldots x\ u_{ik})^{\frac{1}{k}} for\ 1 = 1,2, \ldots, k. \end{aligned} \quad (2.10)$$

c. After calculated the mean geometric value, next step is defuzzification for each geometric mean result from each criterion. Defuzzification calculation using Center of Gravity (COG) method using following formula on the Equation 2.11.

$$F_{ij} = \frac{[(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})]}{3} + l_{ij}$$

$$F_{ij} = \frac{l_{ij} + m_{ij} + l_{ij}}{3} \quad (2.11)$$

d. After obtaining the defuzzification value, then next normalize weights can be performed by using this formula on the Equation 2.12.

$$N_{ij} = \frac{F_{ij}}{\sum_{j=1}^{n} F_{ij}} \quad (2.12)$$

After getting the final result in the form of the weighted value, next step is to do sorting based on the normalizing weight result weight of each criterion.

2.2.7 Fuzzy AHP-FMEA

According to Basuki (2015), calculation of Risk Priority Number (RPN) on Fuzzy AHP-FMEA is different with conventional FMEA, it used Fuzzy for severity (S), occurrence (O), and detectability (D) then multiplied it with weight of every S, O, D factor. To calculate weight of every FMEA factor, it used Fuzzy AHP. Then, formula for RPN on Fuzzy AHP-FMEA is shown on Equation 2.3.

$$RPN = (WS \times S) + (WO \times O) + (WD \times D) \quad (2.13)$$

Where W_S, W_O, and W_D are the relative weights of severity, occurrence, detectability factors while S, O, and D each represented the score of S, O, and D value.