International Journal of ASRO
Volume 9, Number 2, pp. 115-132
July-December 2018

DETERMINATION OF CRITICAL COMPONENTS FOR NAVIGATION RADAR USING FUZZY FMEA AND TOPSIS

Okol S Suharyo[1], Avando Bastari[1], Abdul Rahman[1]

[1]*Indonesian Naval Technology College, STTAL.*
Bumimoro-Morokrembangan, Surabaya 60187, Indonesia

ABSTRACT

In determining the critical components and repair priorities, traditional FMEA still have weaknesses, which puts the traditional FMEA factor severity, occurance and detection at the same level of importance, despite the fact that have different levels of interest and importance weight FMEA assessment teams are ignored. In this study integrated fuzzy method in which the FMEA factor severity, occurance and detection assessed in the form of linguistics. At this fuzzy method, the weight of the assessment team FMEA interests are taken into account. To do perangkingan and priority repair used method Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) based on criteria such as level of risk, economic costs, availability of spare parts, maintenance of economic safety and personal abilities. Application of Fuzzy and TOPSIS method in the FMEA to determine the critical components and priorities of the various alternative repair elected to damage components applied to Sperry Marine Navigation Radar system, which is expected by the application of this method can improve operational performance KRI to keep the areas of national jurisdiction.

Keywords: *Determination of Critical Components, Precautions, Failure Mode and Effect Analysis (FMEA), Fuzzy, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).*

1. INTRODUCTION

FMEA method can be used to prevent various forms of component failure, predict problems and seek solutions most optimal and economical. FMEA method can identify potential failure modes in systems, subsystems and components. This method of prioritizing all potential failure modes to determine the likelihood of the failure of preventive measures. The main difference with the FMEA method kualiatas other method is a method FMEA is an active method, while the other method is a passive method (based on the reaction), whereby when there is a failure of other methods to define some reaction that will require a lot of costs, resources and time. While FMEA method seeks to predict potential problems and risks and then take steps to reduce or eliminate these risks. This action is a precautionary measure against what would happen in the future and require low costs and time compared with the reaction action (Shekari, A. 2009).

FMEA method is one tool that can be received well to analyze realibility and safety of the equipment because it is visible and easy to use. But the FMEA team will have difficulty in applying the real industry because there are weaknesses (Yeh et al, 2007, Wang et al, 2009). These weaknesses are:

a. Information on FMEA is expressed in linguistic form as "few", "moderate" or "high". It is difficult for the conventional FMEA to precisely evaluate reability and safety of a product or process.

b. In the conventional FMEA, severity assessment on the third parameter (S), occurance (O), and detection (D) is assumed to have the same level of importance. But if applied to the real world, the rate of interest between (S), (O), and (D) are relatively different.

c. Risk Priority Number (RPN) is calculated to rank priorities in corrective action or preventive measures in the FMEA, but for the same value of the RPN may pose risks different representations.

d. When assessing the FMEA, diversity and the ability of the team members FMEA important consideration. This was done because it is difficult to share the experience of the team members to the problems faced.

To improve the performance of traditional FMEA to assess risk factors such as Severity (S), occurance (O), and Detection (D), in this penelitinan using fuzzy approach. In the traditional FMEA failure assessment factors are applied to natural language will obtain improper information (ambigue) and vague (vague) (Yeh et al, 2007).

To determine the corrective action recommendations and priorities of the various components of the damage that occurred, official (section) faced improvement criteria for the implementation of improvements. These criteria is the level of risk, economic costs, availability of spare parts, maintenance of economic safety and personal abilities. Once these criteria assessed by the assessment team FMEA, then do perangkingan or assessment of each failure mode approach TOPSIS method.

RADAR (Radio Detection and Ranging) is a navigation tool KRI which serves to determine the position of the vessel itself or another vessel. In other words Radar is the eye of the KRI to implement navigation or shipping from a place to a certain place. For that role is very important for operational Radar KRI, without Radar KRI may not be able to make the voyage. As a system, subsystem, or the active component or in other words always move (operate) certainly prone terjdinya failure / damage to the Radar. Failure / damage occurred because of wear or age care system that has not been going well.

In the Figure 1 below shows the number of KRI (Warship Republic of Indonesia) are using Radar Sperry Marine of various classes KRI and technical conditions. From the picture we can see that the number of radar that are not ready more than ready.

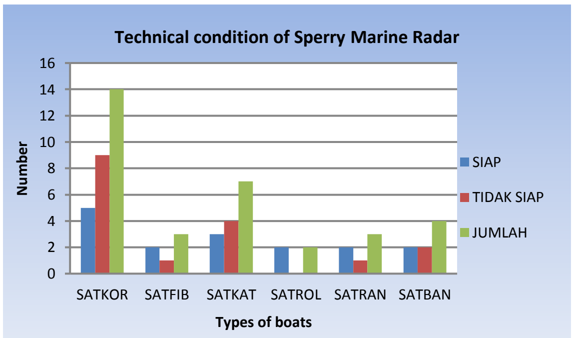

Figure 1 Technical Condition of Sperry Marine Radar (Disharkap 2018)

2. MATERIAL AND METHODS

A. Failure Mode Effect Analysis (FMEA)

Failure Modes and Effects Analysis (FMEA) is a structured procedure to identify and prevent as much as possible failure modes. FMEA has risks associated with the potential failure (failure) and providing a good basis for classifying characteristics (Pyzdek, 2002). Good FMEA analysis can assist makers in identifying potential failure mode, cause and effect. In addition, FMEA helps in making priorities and corrective measures against these failure modes.

FMEA goal is to help the analysis to identify and prevent problems that have been identified before the problem occurred. For that purpose, the risk of any failure modes will be evaluated and prioritized so that corrective action can be taken against the different failure modes.

Severity is an assessment of the seriousness of the effects. In the sense of any failures that arise will be assessed how much the level of seriousness. There is a direct relationship between the effects and severity. For example, if the effect is happening is that the critical effects, the severity value will be high. Occurance is the possibility of a cause will occur and result in the failure during use of the product.

Occurance is a rating value adjusted by the estimated frequency and or the cumulative number of failures that can occur.

Detection value associated with the current control. Detection is a measurement of the ability to control / control failures that may occur. Value Risk Priority Number (RPN) is a product of the multiplication severity, prevalence and detection rates. RPN determine the priority of the failure. RPN has no value or meaning. This value is used to rank potential process failure.

RPN value can be shown by the following equation:

RPN = (Severity) 1 / 3x (Occurrence) 1 / 3x (Detection) 1/3

B. Fuzzy Theory

1. The set Crisp

According to Yan et al. (1994), crisp set A is defined by the elements that exist in the set. If a ε A, then A is 1. However, if a ε A, then a is 0. The notation A = {x / P (x)} show that A contains the element x to the nature of P is true. If XA is a function of the characteristics A to the nature of P, it can be said that P (x) is true if and only if the XA (x) = 1

2. Fuzzy Association

According to Yan et al. (1994), fuzzy set based on the idea to expand the range of functions on the set of crisp characteristics such that the function will include real numbers in the interval [0,1]. Membership value indicates that an element in the universe of discourse is not only to be at zero (0) and one (1), but also the value that lies in between. The truth value of a statement is not only true or false. Value of one (1) shows the true and the value zero (0) indicates wrong, but there are values that lies between the right one (1) and one zero (0).

Fuzzy set has two attributes, namely Linguistics and Numerical. Linguistics is the naming of a group representing a state or a particular condition by using natural language, such as (high), low (low), good (good), great (big), minor (small). Is a numerical value or a number that indicates the size of a variable, such as 40, 120 and 325 (Kusumadewi and Purnomo, 2004).

Some things to keep in mind in understanding the fuzzy system (Kusumadewi and Purnomo, 2004), namely:

a. Variable fuzzy

Fuzzy variables are variables that will be covered in a fuzzy system.

b. Fuzzy set

Fuzzy set is a group that represents a specific condition in a fuzzy variable.

c. Universe of discourse

The universe of discourse is an overall value that is allowed to be operated in a fuzzy variable. This is the set of real numbers are always increasing monotonically from left to right. Value universe of discourse can be positive or negative numbers. Sometimes the universe of discourse is limited value upper limit.

d. Domain

Domain fuzzy set is permissible overall values in the universe of discourse and should be operated in a fuzzy set. As well as the universe of discourse, a domain is a set of real numbers are always increasing monotonically from left to right. Domain values can be either positive or negative numbers.

e. Fuzzification

Fuzzification is a process for converting a crisp input variables of form into linguistic variables in the form of sets of fuzzy membership functions respectively.

3. Fuzzy Membership Function

Membership function (MF) is a curve that shows the mapping of points of data input into the degree of membership that have intervals between zero (0) to one (1) (Kusumadewi and Purnomo, 2004). To get the value of fuzzy membership function approach was used. There are several membership functions that can be used, such as function-S, Gauss function, function-p, beta function, the membership function of the triangle and trapezoid membership functions.

A fuzzy membership function said membership functions if the triangle has three parameters, namely p, q, r ε R with p <q <r, and is expressed with the following rules:

$$\mu(x,p,q,r) = \begin{cases} \frac{x-p}{q-p} & p \leq x \leq q \\ \frac{r-x}{r-q} & q \leq x \leq r \\ 0 & x \leq p \text{ or } x \geq r \end{cases} \qquad (1)$$

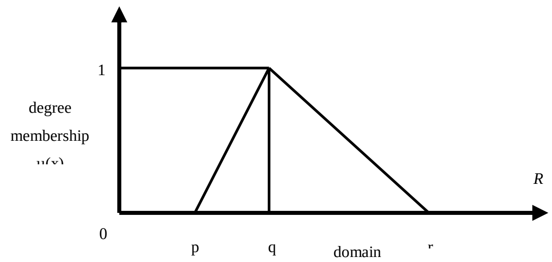

Figure 2. Curve triangular membership functions (Susilo, 2003)

A fuzzy membership function called a trapezoidal membership function if you have four parameters, namely p, q, r, s ε R with p <q <r <s, is expressed with the following rules:

$$\mu(x,p,q,r,s) = \begin{cases} \frac{x-p}{q-p} & p \leq x \leq q \\ 1 & q \leq x \leq r \\ \frac{s-x}{s-r} & r \leq x \leq s \\ 0 & x \leq p \text{ or } x \geq s \end{cases} \qquad (2)$$

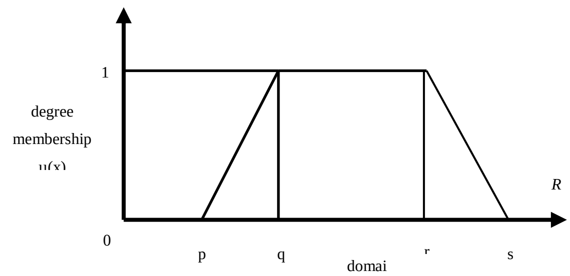

Figure 3. Curves membership functions Trapezoidal (Susilo, 2003)

4. Defuzzification

Defuzzification is a process of conversion and fuzzy quantity into a definitive quantity, where output and process fuzzy logic can be a combination of two or more fuzzy membership functions are defined in accordance with the universal conversation. Input and process defuzzy is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a fuzzy set of numbers in the domain. So if given a fuzzy set in a certain range, it must be taken a certain crisp value as output as shown in Figure 4. below.

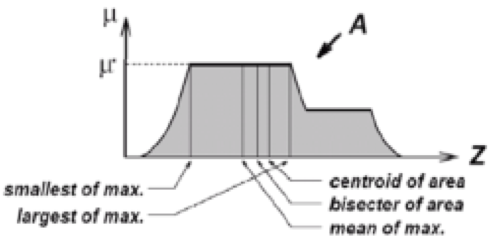

Figure 4. The process of defuzzification Mamdani methods

C. FMEA-Based Fuzzy

Some experts argue that the factors S, O and D are not easily evaluated accurately. Efforts linguistic evaluation conducted (Wang et al, 2009). The following table shows the linguistic terms and fuzzy number that is used to evaluate these factors and visualization membership function of each of these factors.

Table 1. *Fuzzy ratings for severity*

Rating	***Severity of Effect***	***Fuzzy number***
Hazardous without warning (HWOW)	The severity is very high when a potential failure mode affects the safety system without warning	(9, 10, 10)
Hazardous with warning (HWW)	The severity is very high level when a potential failure mode affects the safety system with warning	(8, 9, 10)
Very High (VH)	The system can not operate with failures cause damage without jeopardizing safety	(7, 8, 9)
High (H)	The system can not operate with damaged equipment	(6, 7, 8)
Moderate (M)	The system can not operate with only minor damage (Minor)	(5, 6, 7)
Low (L)	The system can not operate without failure	(4, 5, 6)
Very Low (VL)	The system can operate with significantly decreased performance	(3, 4, 5)
Minor (MR)	The system can be operated with the performance experienced some decline	(2, 3, 4)
Very Minor (VMR)	The system can operate with little interference	(1, 2, 3)
None (N)	No effect	(1, 1, 2)

(Wang et al, 2009)

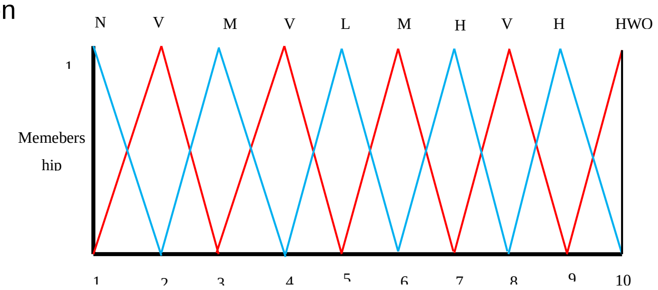

Figure 5. Value fuzzy severity and Membership function
(Wang et al, 2009)

Table 2. *Fuzzy ratings for occurance*

Rating	***Probability of***	***Fuzzy***

	occurance	*Number*
Very High (VH)	*Failure is inevitable* *Recurrent failure*	(8, 9, 10)
High (H)	*Failure often times occur*	(6, 7, 8)
Moderate (M)	*Failure relatively few*	(4, 5, 6)
Low (L)		(2, 3, 4)
Remote (R)	*Failure is not possible*	(1, 1, 2)

(Wang et al, 2009)

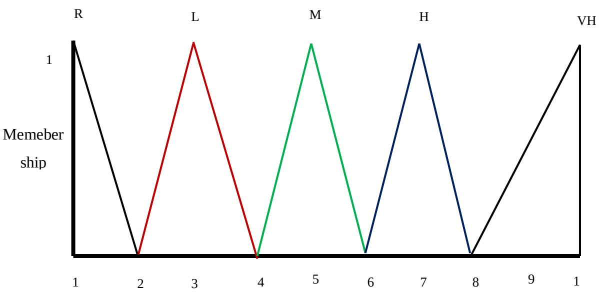

Figure 6. Value fuzzy occurance and the membership function (Wang et al, 2009)

Table 3. *Fuzzy ratings for detection*

Rating	***Possibility of Detection by a control device***	***Fuzzy Number***
Absulute Uncertainly (AU)	There is no control equipment is able to detect the cause of the failure and subsequent failure mode.	(9,10, 10)
Very remote (VR)	Very little ability to control device to detect the cause of the failure and subsequent failure mode.	(8, 9, 10)
Remote (R)	Little ability to control device detects the cause of the failure and subsequent failure mode.	(7, 8, 9)
Very Low (VL)	Very low ability of the controller to detect the cause of the failure and subsequent failure mode.	(6, 7, 8)
Low (L)	Low ability of the controller to detect the cause of the failure and subsequent failure mode.	(5, 6, 7)
Moderate (M)	Being the ability of the controller to detect the cause of the failure and subsequent failure mode.	(4, 5, 6)
Moderately High (MH)	Very moderate ability of the controller to detect the cause of the failure and subsequent failure mode.	(3, 4, 5)
High (H)	High ability of the controller to detect the cause of the failure and subsequent failure mode.	(2, 3, 4)
Very High (VH)	Very high ability to detect the cause of the failure of control equipment and subsequent failure mode.	(1, 2, 3)
Almost Certain (AC)	Almost certainly the ability of the controller to detect the cause of the failure and subsequent failure mode.	(1, 1, 2)

(Wang et al, 2009)

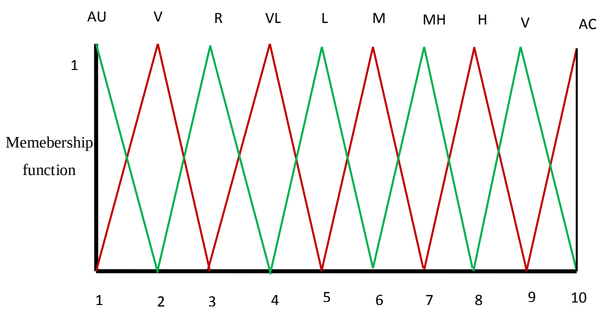

Figure 7. Value fuzzy detection and the membership function

FMEA does not take into account the relative importance of risk factors and place them with the same level of importance. Weighting the relative importance of risk factors assessed using linguistic terms that can be seen in Table 4. and membership functions can be seen in Figure 8.

Table 4. *Fuzzy weight* of risk

Linguistics	***Fuzzy Number***
Very Low (VL)	(0 ; 0 ; 0,25)
Low (L)	(0 ; 0,25 ; 0,5)
Medium (M)	(0,25 ; 0,5 ; 0,75)
High (H)	(0,5 ; 0,75 ; 1)
Very High (VH)	(0,75 ; 1 ; 1)

(Wang et all, 2009)

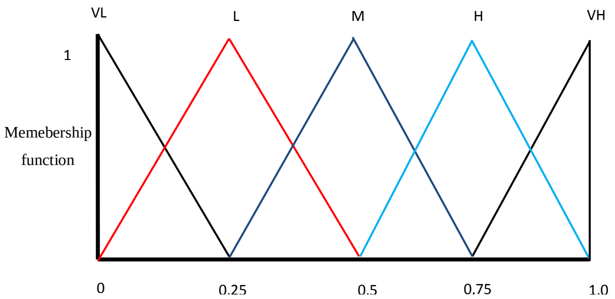

Figure 8. Membership Functions
Of fuzzy weight
(Wang et al, 2009)

Based on (Wang et al, 2009) to conduct an assessment of the factors of failure in the FMEA in the form of fuzzy, then it can do the steps as follows:

1. Collect the subjective opinion of members of the assessment team FMEA using the following equation:

$$\tilde{R}_i^O = \frac{1}{n}\sum_{j=1}^{m} hj.\ \tilde{R}_{ij}^O = \left(\sum_{j=1}^{m} hj.\ \tilde{R}_{ijL}^O, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijM1}^O, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijM2}^O, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijU}^O\right)$$

$$\tilde{R}_i^S = \frac{1}{n}\sum_{j=1}^{m} hj.\ \tilde{R}_{ij}^S = \left(\sum_{j=1}^{m} hj.\ \tilde{R}_{ijL}^S, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijM}^S, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijU}^S\right)$$

$$\tilde{R}_i^D = \frac{1}{n}\sum_{j=1}^{m} hj.\ \tilde{R}_{ij}^D = \left(\sum_{j=1}^{m} hj.\ \tilde{R}_{ijL}^D, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijM}^D, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijU}^D\right)$$

$$\tilde{R}_i^D = \frac{1}{n}\sum_{j=1}^{m} hj.\ \tilde{R}_{ij}^D = \left(\sum_{j=1}^{m} hj.\ \tilde{R}_{ijL}^D, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijM}^D, \sum_{j=1}^{m} hj.\ \tilde{R}_{ijU}^D\right)$$

$$\widetilde{W}^O = \frac{1}{n}\sum_{j=1}^{m} hj.\ \widetilde{W}_j^O = \left(\sum_{j=1}^{m} hj.\ \widetilde{W}_{jL}^O, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jM}^O, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jU}^O\right)$$

$$\widetilde{W}^S = \frac{1}{n}\sum_{j=1}^{m} hj.\ \widetilde{W}_j^S = \left(\sum_{j=1}^{m} hj.\ \widetilde{W}_{jL}^S, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jM}^S, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jU}^S\right)$$

$$\widetilde{W}^D = \frac{1}{n}\sum_{j=1}^{m} hj.\ \widetilde{W}_j^D = \left(\sum_{j=1}^{m} hj.\ \widetilde{W}_{jL}^D, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jM}^D, \sum_{j=1}^{m} hj.\ \widetilde{W}_{jU}^D\right)$$

2. Calculate the fuzzy risk priority number (FRPN) for each failure mode with the following equation:

$$FRPN_i = \left(\tilde{R}_i^O\right)^{\frac{\widetilde{W}^O}{\widetilde{W}^O + \widetilde{W}^S + \widetilde{W}^D}} x \left(\tilde{R}_i^S\right)^{\frac{\widetilde{W}^S}{\widetilde{W}^O + \widetilde{W}^S + \widetilde{W}^D}} x \left(\tilde{R}_i^D\right)^{\frac{\widetilde{W}^D}{\widetilde{W}^O + \widetilde{W}^S + \widetilde{W}^D}}$$

In the traditional FMEA RPN defined as the simple result of occurance (O), Severity (S), Detection (D) without considering the weight of its relative importance. But on Fuzzy FMEA weight relative importance of risk factors were assessed using linguistic terms.

D. Method of TOPSIS.

TOPSIS is one of multiple criteria decision making method that was first introduced by Yoon and Hwang 1981. TOPSIS based on the concept that the best alternative was selected or not only have the shortest distance from the positive ideal solution, but it also has the farthest distance from the negative ideal solution from the point of geometric perspective by using the Euclidean distance to determine the relative proximity of an alternative to the optimal solution. Positive ideal solution is defined as the sum of all the best value can be achieved for each attribute, while the negative-ideal solution consists of all the worst value achieved for each attribute.

In this study, the method used for assessment TOPSIS priority failure modes that have been identified by perangkingan the factors chosen. These factors are the level of risk, economic costs, availability of spare parts, maintenance of economic safety and personal abilities. The aim is to avoid bias in evaluating the utility function in weighting coefficients on factors severity, occurance and detection. This approach is used in research to evaluate the Risk Priority Number (RPN).

The steps of the method TOPSIS is (Sachdeva et al, 2009):

1. Establish criteria comparison matrix on TOPSIS. TOPSIS begins by constructing a matrix of decision;

X = [Xij]

Where alternative ith (i = 1, 2, 3, ... n) is evaluated against the criteria jth (j = 1, 2, 3, ... m).

2. Normalization of the original criteria comparison matrix.

Used equation (Deng et al, 2002 in Sachdeva et al, 2009). To change any element [Xij] with the equation below.

$$r_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \qquad i= 1,2,...n)$$

3. Calculation of the weight of each comparison criteria

Calculation of the weight of each criterion based on the value of entropy and then turn it into a weight that is described in the following steps:

a. Calculate the entropy value of each criterion C1, C2, ... Cn

The weight of each criterion was calculated using the concept of entropy (Sachdeva et al, 2009) e_j represent entropy j^th^

$$e_j = -\frac{1}{In(n)} \sum_{i=1}^{n} r_{ij} . \ln (r_{ij}) \qquad j = 1, 2,...n$$

Where, $\frac{1}{\ln(n)}$ is a constant that makes e_j value between 0 and 1.

b. Calculation of weights w1, w2, w3, ... wn each criterion

Objective weighting of each criterion was calculated using the following equation:

$$W_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} \qquad j = 1, 2,...m$$

4. Determination of positive ideal solution (v^+) and negative ideal solutions (v^-) for each comparison criteria. In lowering the index criteria from each of the criteria used for comparison, it is important to calculate the ideal solution both positive and negative ideal solutions for each comparison criteria using the following equation:

$$(v^+) = (max\ (r_{i1}), max(r_{i2}),..., max(r_{in}))$$
$$= (V_1^+, V_2^+,..., V_n^+)$$
$$(v^-) = (min\ (r_{i1}), min(r_{i2}),..., min(r_{in}))$$
$$= (V_1^-, V_2^-,..., V_n^-)$$

5. Distance calculations for each criterion between the positive ideal solution and negative idela solutions.

To calculate the euclidean distance g of each of the alternatives to, and using the following equation:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} Wj(v_j^+ - r_{ij})2} \qquad j = 1, 2,...n$$

$$d_i^- = \sqrt{\sum_{j=1}^{m} Wj(r_{ij} - v_j^-)2} \qquad j = 1, 2,...n$$

d_i^+ indicates the distance from the ith criteria compared to the positive ideal solution, and d_i^- shows the distance of the ith criteria were compared with the negative ideal solution.

6. Calculation of the relative Risk Priority Index (RPI) of the ideal solution

The final ranking of the alternatives obtained by reference to the relative closeness to the ideal solution. For each criterion are compared, RPI can be calculated using the following equation:

$$\text{RPI} = \frac{d_i^-}{d_i^- + d_i^+}$$

E. Application Model

The application of the model is done will be tested in operational processes Sperry Marine Radar, where there are 35 modes of failure in the operational process which can be seen in Table 4.1 derikut:

Table 5. Failure Mode

No	Function	*Failure Mode*	*Failure Effect*
1	*Scanner Unit*	*Power Supply (K1)* Component damage	Scanner unit can not operation
		Modulator (K2) Component damage	Can not radiate *(Tx/Rx)*
		Motor (K3) Motor burnt	Radiating process (Tx / Rx) stalled
		Motor Drive PCB K(4) Motor burnt	The antenna can not rotate
		Trigger board (K5) Komponen damage	Radar can not radiate (Tx / Rx)
		Drive Belt (K6) Destroyed	The motor can not rotate the antenna
		Bearing Disc (K7) Gear loss	No flash
		Bearing Disc dan Heading Marker PCB (K8) Gear loss	Heading flash lost to the direction of the vessel alu
		Magnetron (K9) Component damage	Emission / short-range radar
		Circulator (K10) Circulator damage	Radar can not radiate (Tx / Rx)
		Low Noise Front End (K11) Low Noise Front End damage	Radar can not (Rx) receive (accept)
		Limiter (K12) Limiter damage	Radar can not mendetekdi targets
		Antenna (K13) Scanner leak	Distance transmit (Tx) short radar
		House belt (K14) Hancur/rusak	The antenna can not rotate
2	CPU	*Hard Disc (K15)* Program error	Computers (Display) can not boot
		VGA Card (16) Component damage	Does not appear on the display
		Battray CMOS (K17) Damaged / no voltage	CPU can not operate / work
		Power Supply CPU (K18) Component damage	Components damaged / burnt
3	Monitor	*Potensiometer Cahaya K19)* Component damage	Setting light on the display can not be
4	GPS	*Antena GPS/Receiver (K20)* antenna	Unable to display the data of latitude and longitude

		corrosion	
		Display (K21) Component damage	Display is not readable
		Processing Unit (K22) Component damage	Processor can not work
		Power Supply PCB (K23) Component damage	GPS can not operate / work
5	Gyro Compass	*Power Supply PCB (K24)* Component damage	Gyro compass can not operate / work
		Connector PCB (K25) broken /Loss	Gyro data can not be sent
		Sensor PCB (K26) Component damage	Unable to display the data halu / direction of the ship
		Auter Sphere (K27) Heater broken	Can not meridian / northern right
		Encoder COMPL (K28) Signpost broken	Can not meridian / northern right
		Pump Gyro (K29) The pump can	Can not meridian / northern right

		not be positioned in the middle of the gyro ball	
		Gyro Sphere (K30) *Gyro Sphere* broken	Can not meridian / true north and hunting
		Fuse (K31) burnt	Voltage is not entered, the gyro can not operate
6	Power Supply	*Isolating Transformer (K32)* Broken.corrosion	Required voltage is not appropriate
		Stavol (K33) Burned	Unstable voltage
		MCB (K34) broken	Unable to break the power over so damaging electronic components
		UPS (K35) Can not save power	Gyro can not work

3. RESULTS AND DISCUSSION

Comparison of results for the NDP, FRPN and RPI

Tabel 6. Comparison of *RPN*, *FRPN* and *RPI* Result

Failure Mode	***FMEA***		*FUZZY FMEA*		***TOPSIS***	
	RPN	***Rank***	*FRPN*	*Rank*	***RPI***	***Rank***
Power Supply (K1) Component damage	**6,84**	**8 - 9**	6,25	11	**0,304**	**25**
Modulator (K2) Component damage	**4,76**	**14**	5,89	13	**0,294**	**26**
Motor (K3) Motor burnt	**5,94**	**12**	6,83	7	**0,245**	**30**
Motor Drive PCB K(4) Motor burnt	**6,32**	**11**	6,53	9	**0,379**	**15**
Trigger board (K5) Komponen damage	**4,48**	**15**	6,51	10	**0,316**	**23**
Drive Belt (K6) Destroyed	**9,32**	**1 - 2**	7,37	3	**0,835**	**3**
Bearing Disc (K7) Gear loss	**9,32**	**1 - 2**	7,50	2	**0,838**	**1**

Bearing Disc dan Heading Marker PCB (K8) Gear loss	**8,96**	**4**	7,21	5	**0,474**	**10**
Magnetron (K9) Component damage	**4,16**	**16**	4,48	25	**0,518**	**9**
Circulator (K10) *Circulator* damage	**3,3**	**23 - 24**	4,50	24	**0,344**	**18**
Low Noise Front End (K11) *Low Noise Front End* damage	**2,88**	**25 - 26**	4,04	28	**0,332**	**22**
Limiter (K12) Limiter damage	**2,52**	**28 - 30**	3,86	30	**0,435**	**13**
Antena (K13) Scanner leak	**2,29**	**31 - 33**	4,00	29	**0,103**	**35**
House belt (K14) Hancur/rusak	**8,32**	**5 - 6**	6,90	6	**0,823**	**4**
Hard Disc (K15) Program error	**3,91**	**19 - 20**	4,63	22	**0,448**	**12**
VGA Card (16) Component damage	**3,42**	**22**	4,72	19	**0,306**	**24**
Battray CMOS (K17) Damaged / no voltage	**2,52**	**28 - 30**	3,62	32	**0,283**	**27**
Power Supply CPU (K18) Component damage	**5,24**	**13**	5,27	14	**0,460**	**11**
Potensiometer Cahaya K19) Component damage	**1,59**	**34 - 35**	2,80	35	**0,266**	**29**
Antena GPS/Receiver (K20) antenna corrosion	**2,71**	**27**	4,25	27	**0,366**	**17**
Display (K21) Component damage	**2,52**	**28 - 30**	3,34	34	**0,271**	**28**
Processing Unit (K22) Component damage	**4,12**	**17 - 18**	4,53	23	**0,335**	**19**
Power Supply PCB (K23) Component damage	**6,84**	**8 - 9**	6,65	8	**0,637**	**7**
Power Supply PCB (K24) Component damage	**8,32**	**5 - 6**	7,22	4	**0,835**	**2**
Connector PCB (K25) broken /Loss	**1,59**	**34 - 35**	3,38	33	**0,194**	**32**
Sensor PCB (K26) Component damage	**3,78**	**21**	4,83	18	**0,416**	**14**
Auter Sphere (K27) Heater broken	**6,87**	**7**	5,24	15	**0,674**	**6**
Encoder COMPL (K28) Signpost broken	**4,12**	**17 - 18**	4,38	26	**0,335**	**20**
Pump Gyro (K29) The pump can not be positioned in the middle of the gyro ball	**6,65**	**10**	6,20	12	**0,522**	**8**
Gyro Sphere (K30) *Gyro Sphere* broken	**9**	**3**	7,79	1	**0,737**	**5**
Fuse (K31) burnt	**2,88**	**25 - 26**	4,68	20	**0,227**	**31**
Isolating Transformer (K32) Broken.corrosion	**2,29**	**31 - 33**	3,77	31	**0,136**	**34**
Stavol (K33) Burnt	**3,3**	**23 - 24**	4,67	21	**0,333**	**21**
MCB (K34) broken	**2,29**	**31 - 33**	4,90	16	**0,159**	**33**
UPS (K35) Can not save power	**3,91**	**19 - 20**	4,88	17	**0,372**	**16**

Analysis of the RPN, FRPN and RPI

In Table 5.1 above we can see that of the 35 component failure mode there are 22 groups of components that have a value of RPN and the same rank. Table 7. below shows the same RPN value of 22 groups.

Tabel 7. RPN Value

No	***Nilai RPN***	***Mode Kerusakan***
1	9,32	K6/K7
2	8,32	K14/K24
3	6,84	K1/K23
4	4,12	K22/K28
5	3,91	K15/K35
6	3,3	K10/K33
7	2,88	K11/K31
8	2,52	K12/K17/K21
9	2,29	K13/K32/K34
10	1,57	K19/K25

From the table it appears that there are some components that have the same value of RPN. This is because the traditional FMEA severity factors (S), occurance (O) and detection (D) is considered to have the same level of importance, in fact, has a different level of importance. So is the importance weight FMEA assessment team was not taken into account. Thus users can not determine which components are considered critical and can not determine the priority of the components to be repaired. For instance, K6 and K7 components with the same RPN value is 9.32, so that users can not afford to determine which of the two components is a priority for improvement.

By using fuzzy approach to the FMEA, where every failure has a value rating of different fuzzy and level of interest as well as the weight of FMEA assessment team considered, then after calculating the value of FRPN then each component has a different rank.

For instance, K14 and K24 components that have a fuzzy rank respectively 8 and 9, where the traditional FEMA both components have the same value, namely 8.32 RPN rated 5-6. After fuzzy approach to calculate the value FRPN, then these two components have FRPN 6.905 and 7.217, and rank the different ie 6 and 4.

By using fuzzy approach to the FMEA, it will be easier for users to differentiate risks in failure mode that has the same value of RPN. The rating derived from FMEA method can cause confusion, especially when the data used for the analysis is accompanied by a high degree of uncertainty.

Analysis FMEA, FMEA and FUZZY TOPSIS

TOPSIS method used for the assessment of priority failure modes that have been identified by perangkingan against selected criteria such as level of risk, economic costs, availability of spare parts, maintenance of economic safety and personal abilities. The aim is to avoid bias in evaluating the utility function in weighting coefficients on factors severity, occurance and detection. This approach is used to evaluate the Risk Priority Number (RPN).

After calculating the RPI value, and compared with the value of PRN and FRPN, we can see that there are differences in rank / priority every failure. From table 5.1 above we take the 10 components that have the highest ranking value (1-10) of the value of RPN, FRPN and TOPSIS. This is shown in Table 8 below.

Tabel 8. RPN, FRPN TOPSIS Value

K	RPN	Rank	K	FRPN	Rank	K	RPI	Rank
K1/ K23	6,84	8 - 9	K3	6,831	7	K6	0,835	3
K6/ K7	9,32	1 - 2	K4	6,534	9	K7	0,838	1
K6/ K7	9,32	1 - 2	K5	6,512	10	K8	0,474	10
K8	8,96	4	K6	7,375	3	K9	0,518	9
K14/K 24	8,32	5 - 6	K7	7,503	2	K14	0,823	4
K1/ K23	6,84	8 - 9	K8	7,208	5	K23	0,637	7
K14/K 24	8,32	5 - 6	K14	6,905	6	K24	0,835	2
K27	6,87	7	K23	6,649	8	K27	0,674	6
K29	6,65	10	K24	7,215	4	K29	0,522	8
K30	9	3	K30	7,788	1	K30	0,737	5

From Table 8 above it can be seen that the traditional FMEA components On K6 / K7 meliliki 1 rank with a value of 9.32 RPN. With fuzzy approach components K6 and K7 rank 3 rank 2. While the RPI calculations taking into account several criteria factor level of risk, economic costs, availability of spare parts, economic safety and maintenance of personal ability, then K6 be obtained ratings / priorities 3 and K7 be ranked / priority 1. Likewise with priority components 3, 4 to 10, where there are changes in rank / priority repair of each component with each of these approaches.

By doing calculations RPN, FRPN and RPI, where there are 10 of these components (corresponding rank), which became a critical component of Sperry Marine navigational radar. Only a change in the ranking of each approach used. Thus it can be said that the determination of the critical components ranked / priority improvements to the mode of failure / damage by using TOPSIS method in accordance with the real conditions in the field.

Sensitivity Analysis

The analytical sensitivity analysis is conducted to determine the result of the changing parameters in one or more parts associated with the other parts. By analyzing sentivitas then the possible consequences of these changes can be known and previously diantisifikasi.

In this study, the sensitivity analysis is done by making changes in the weights of 30%, 40% and 50% of the 5 (five) criteria, ie; FRPN (Fuzzy Risk Priority Number), Economic Cost (EC), the Economic Safety (ES), Spare Part (SP) and Maintenance Ability (MA). Weight changes done with a change of 30% of the existing conditions. With the change in the weight of each of these criteria we can see the resulting impact, if there is a change rankings or fixed. Thus we can see which criteria influence on the determination of critical components.

Table 9. Results of RPI calculation with a weight change of 30%

Unchanged weight			*FRPN*		*ES*		*EC*		*SP*		*MA*	
K	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank
1	0,304		0,311		0,29495		0,305		0,302		0,302	
2	0,294		0,301		0,26950		0,302		0,293		0,300	
3	0,245		0,256		0,22435		0,248		0,245		0,245	
4	0,379		0,386		0,36394		0,389		0,376		0,376	
5	0,316		0,325		0,28981		0,311		0,328		0,321	
6	0,835	**3**	0,836	**3**	0,84864	**3**	0,841	**2**	0,839	**3**	0,814	**3**
7	0,838	**1**	0,840	**1**	0,85157	**1**	0,844	**1**	0,842	**1**	0,817	**2**
8	0,474	**10**	0,482	**10**	0,45088	**10**	0,475	**10**	0,488	**10**	0,468	**10**
9	0,518	**9**	0,514	**9**	0,49074	**9**	0,523	**9**	0,530	**9**	0,523	**8**
10	0,344		0,344		0,31468		0,337		0,355		0,360	
11	0,332		0,331		0,30432		0,326		0,344		0,349	
12	0,435		0,431		0,41528		0,431		0,444		0,449	
13	0,103		0,106		0,09422		0,105		0,100		0,107	
14	0,823	**4**	0,823	**4**	0,83790	**4**	0,829	**4**	0,828	**4**	0,802	**4**
15	0,448		0,447		0,42733		0,450		0,463		0,450	
16	0,306		0,307		0,28010		0,307		0,318		0,311	
17	0,283		0,281		0,25923		0,279		0,296		0,295	
18	0,460		0,460		0,43775		0,467		0,474		0,454	
19	0,266		0,261		0,24343		0,256		0,286		0,278	
20	0,366		0,364		0,35193		0,365		0,383		0,363	
21	0,271		0,268		0,24851		0,274		0,284		0,277	
22	0,335		0,336		0,30700		0,341		0,346		0,339	
23	0,637	**7**	0,640	**7**	0,63417	**7**	0,644	**7**	0,640	**7**	0,628	**7**
24	0,835	**2**	0,836	**2**	0,84925	**2**	0,835	**3**	0,840	**3**	0,821	**1**
25	0,194		0,193		0,17793		0,205		0,189		0,202	
26	0,416		0,416		0,39768		0,419		0,425		0,418	
27	0,674	**6**	0,670	**6**	0,66746	**6**	0,686	**6**	0,682	**6**	0,663	**6**
28	0,335		0,334		0,30646		0,335		0,353		0,339	
29	0,522	**8**	0,525	**8**	0,49461	**8**	0,527	**8**	0,535	**8**	0,521	**9**
30	0,737	**5**	0,742	**5**	0,72568	**5**	0,747	**5**	0,744	**5**	0,725	**5**
31	0,227		0,230		0,22485		0,231		0,221		0,228	
32	0,136		0,137		0,12442		0,137		0,132		0,145	
33	0,333		0,333		0,32137		0,345		0,330		0,330	
34	0,159		0,164		0,14585		0,166		0,155		0,162	
35	0,372		0,373		0,35734		0,389		0,369		0,369	

Table 10. Results of RPI calculation with a weight change of 40%

Unchanged weight			**FRPN**		**ES**		**EC**		**SP**		**MA**	
K	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank
1	0,304		0,314		0,29205		0,305		0,302		0,302	
2	0,294		0,303		0,26127		0,304		0,293		0,301	
3	0,245		0,260		0,21750		0,249		0,245		0,245	
4	0,379		0,389		0,35893		0,393		0,374		0,375	
5	0,316		0,328		0,28096		0,309		0,332		0,323	
6	0,835	**3**	0,837	**2**	0,85326	**3**	0,843	**2**	0,841	**3**	0,807	**3**
7	0,838	**1**	0,841	**1**	0,85610	**1**	0,846	**1**	0,844	**1**	0,810	**2**
8	0,474	**10**	0,485	**10**	0,44321	**10**	0,475	**10**	0,493	**10**	0,467	**10**
9	0,518	**9**	0,513	**9**	0,48185	**9**	0,525	**9**	0,535	**9**	0,525	**8**
10	0,344		0,344		0,30506		0,335		0,358		0,365	
11	0,332		0,330		0,29502		0,324		0,347		0,354	
12	0,435		0,429		0,40870		0,430		0,446		0,454	
13	0,103		0,106		0,09134		0,106		0,099		0,108	
14	0,823	**4**	0,823	**4**	0,84285	**4**	0,831	**4**	0,829	**4**	0,796	**4**
15	0,448		0,446		0,42039		0,451		0,468		0,450	
16	0,306		0,308		0,27154		0,307		0,322		0,312	
17	0,283		0,280		0,25131		0,278		0,300		0,299	
18	0,460		0,461		0,43049		0,470		0,479		0,453	

19	0,266		0,259		0,23599		0,253		0,292		0,282	
20	0,366		0,364		0,34729		0,364		0,388		0,362	
21	0,271		0,267		0,24091		0,274		0,288		0,279	
22	0,335		0,336		0,29762		0,343		0,350		0,341	
23	0,637	**7**	0,641	**7**	0,63313	**7**	0,647	**7**	0,641	**7**	0,624	**7**
24	0,835	**2**	0,837	**3**	0,85385	**2**	0,835	**3**	0,841	**2**	0,816	**1**
25	0,194		0,192		0,17250		0,209		0,187		0,204	
26	0,416		0,416		0,39164		0,420		0,428		0,419	
27	0,674	**6**	0,669	**6**	0,66540	**6**	0,689	**6**	0,685	**6**	0,660	**6**
28	0,335		0,334		0,29709		0,335		0,358		0,340	
29	0,522	**8**	0,526	**8**	0,48561	**8**	0,529	**8**	0,539	**8**	0,521	**9**
30	0,737	**5**	0,744	**5**	0,72184	**5**	0,750	**5**	0,747	**5**	0,721	**5**
31	0,227		0,231		0,22409		0,232		0,219		0,228	
32	0,136		0,137		0,12062		0,137		0,131		0,148	
33	0,333		0,334		0,31766		0,349		0,330		0,330	
34	0,159		0,166		0,14139		0,168		0,154		0,162	
35	0,372		0,373		0,35253		0,394		0,368		0,368	

Table 11. Results of RPI calculation with a weight change of 50%

Uunchanged weight			***FRPN***		***ES***		***EC***		***SP***		***MA***	
K	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank
1	0,304		0,316		0,28911		0,305		**0,301**		0,302	
2	0,294		0,305		0,25294		0,306		**0,292**		0,303	
3	0,245		0,263		0,21057		0,250		0,245		0,245	
4	0,379		0,391		0,35387		0,396		0,373		0,374	
5	0,316		0,330		0,27200		0,308		0,336		0,324	
6	0,835	**3**	0,837	**2**	0,85794	**3**	0,844	**2**	0,842	**3**	0,801	**3**
7	0,838	**1**	0,841	**1**	0,86069	**1**	0,847	**1**	0,845	**1**	0,804	**2**
8	0,474	**10**	0,487	**10**	0,43546	**10**	0,476	**10**	0,497	**10**	0,465	**10**
9	0,518	**9**	0,512	**9**	0,47287	**9**	0,526	**9**	0,539	**9**	0,527	**8**
10	0,344		0,344		0,29534		0,333		0,362		0,370	
11	0,332		0,330		0,28562		0,323		0,351		0,360	
12	0,435		0,428		0,40205		0,429		0,449		0,458	
13	0,103		0,107		0,08843		0,107		0,098		0,109	
14	0,823	**4**	0,823	**4**	0,84786	**4**	0,833	**4**	0,831	**4**	0,789	**4**
15	0,448		0,446		0,41336		0,451		0,473		0,450	
16	0,306		0,308		0,26289		0,308		0,325		0,314	
17	0,283		0,279		0,24330		0,276		0,304		0,302	
18	0,460		0,461		0,42314		0,472		0,483		0,451	
19	0,266		0,257		0,22847		0,250		0,298		0,286	
20	0,366		0,363		0,34259		0,364		0,394		0,361	
21	0,271		0,266		0,23324		0,275		0,292		0,281	
22	0,335		0,336		0,28814		0,345		0,354		0,342	
23	0,637	**7**	0,642	**7**	0,63207	**7**	0,649	**7**	0,642	**7**	0,622	**7**
24	0,835	**2**	0,837	**3**	0,85851	**2**	0,835	**3**	0,843	**2**	0,811	**1**
25	0,194		0,192		0,16700		0,212		0,186		0,207	
26	0,416		0,416		0,38554		0,421		0,431		0,419	
27	0,674	**6**	0,668	**6**	0,66331	**6**	0,693	**6**	0,688	**6**	0,656	**6**
28	0,335		0,334		0,28763		0,335		0,364		0,341	
29	0,522	**8**	0,527	**8**	0,47650	**8**	0,530	**8**	0,543	**8**	0,521	**9**
30	0,737	**5**	0,746	**5**	0,71796	**5**	0,753	**5**	0,749	**5**	0,717	**5**
31	0,227		0,232		0,22332		0,233		0,217		0,228	
32	0,136		0,138		0,11677		0,138		0,130		0,151	
33	0,333		0,334		0,31391		0,352		0,329		0,329	
34	0,159		0,168		0,13689		0,170		0,152		0,163	
35	0,372		0,373		0,34767		0,399		0,366		0,367	

From Table 9, 10 and 11 above we can see that there is a change ratings of any failure. This means that the weight of each criterion is very influential on the determination of the critical component (priority / ranking). In the table above was taken 10 critical components where the change of criteria weight by 30%, then the priority / ranking of the 10 components are also changing. But if we look at the changes are not so significant. For components K8, K14, K27 and K30 does not change whether the rankings with weight change or not.

But in general we see that the ranking changes in the components of the weighting factor changes occur in the economic costs of spare parts, maintenace ability. This shows that all three factors is exactly what influence the determination of critical components and repair priorities. This is shown by K24 component wherein the weight change and the economic costs of spare parts, K24 has ranked 3rd, segangkan with weight changes in maintenance ability K24 components changed the rating to rank 1. This means that each criterion has a different level of importance.

4. CONCLUSIONS

1. Determination of critical components and priority repairs to damage components with fuzzy FMEA method capable of improving the determination and improvement priorities kritasi components of traditional FMEA method. This can be seen in fuzzy FMEA there are components that have the same RPN value.
2. To determine priorities and recommendations to the damage prevention measures TOPSIS method considering the criteria according the real conditions in lapangan.Kriteria-criteria to be considered is the level of risk, economic safety, economic
cost, ease of maintenance spare parts and personal abilities.
3. Determination of critical components and recommendations for improvements to the mode damage to components with TOPSIS method is able to improve the results of the priority method and the method of fuzzy FMEA FMEA. It can be seen from the results of the priority order of RPI.
4. The result of the determination of critical components and recommendation
improvements to component failure mode with TOPSIS method more
reliable to be done and in accordance with the real conditions of the company.
5. Changes in weight each criterion will be influential in determining the critical components and repair priorities especially changes in the weight of the economic cost of spare parts and maintenance abiliy.

REFFERENCES

Alfian Anhar dan Agus Widodo, “Kombinasi Metode TOPSIS (*Technique for Order Preference by Similarity toIdeal Solution*) dan AHP (*Analytical Hierarchy Process)* dalam Menentukan Objek Wisata Terbaik di Pulau Bali” Jurusan Matematika, F.MIPA, Universitas Brawijaya, Malang, Indonesia.

Pyzdek (2002), The Six Sigma Handbook, PT.Salemba Patria, Jakarta

Pillay, A., Wang, J (2003), *"Modified Failure Mode and Effects Analysis Using Approximate Reasoning", Reliability Engineering & System Safety* 139,379 -394

Anish Sachdeva (2009), "*Multi factor failure model critically analysis using TOPSIS".* Journal of Industrial Engineering International Islamic Azad University, South Tehran Branch January 2009, Vol. 5, No. 8, 1-9.

K. Shahroudi, H. Rouydel (2012), "*Using a multi-criteria decision making approach (ANP-TOPSIS) to evaluate suppliers in Iran's auto industry*. International Journal of Applied Operational Research Vol. 2, No. 2, pp. 37-48, July 2012

Ravendra Singh, Hemant Rajput, Vedansh Chaturvedi, Jyoti Vimal (2012), "*Supplier Selection By Technique Of Order Preference By Similariry To Ideal Solution (TOPSIS) Method for Automotive Industry* International Journal of Advanced Technology & Engineering Research (IJATER) VOLUME 2, ISSUE 2, MARCH 2012.

Rakesh. R, Bobin Cherian Jos, George Mathew (2013), "*FMEA Analysis for Reducing Breakdowns of a Sub System in the Life Care Product Manufacturing Industry*". International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 2, March 2013.

Ved Parkash, Deepak Kumar, Chandan Kumar, Rakesh Rajoria (2013), "*Failure Mode and Effect Analysis of Automotive Charging syste".* International Journal of Software and Hardware Research Engineering Volume 1, Issue 3, Nopember 2013.

Yonas Mitiku Degu dan R. Srinivasa Moorthy (2014), "*Implementation of Machinery Failure Mode and Effect Analysis in Amhara Pipe Factory P.L.C."* American Journal of Engineering Research (AJER) e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-03, Issue-01, pp-57-63.