

AN ANALYSIS ON KRI IMPROVEMENT PROJECT IN INDONESIAN NAVAL MAIN BASE NO. V SURABAYA FASHARKAN (NAVY'S BATTLESHIPS MAINTENANCE AND REPAIRING FACILITIES USING FUZZY FMEA METHOD

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ABSTRACT

The FMEA method is a tool used to identify the consequences or consequences of a system or process failure and reduce or eliminate failure. In determining risk factors and system improvement priorities, traditional FMEA still has weaknesses, where FMEA traditionally places severity factors, occurrence, and detection at the same level of importance, even though in reality different levels of importance and the importance of FMEA assessment teams are ignored. In this study, the fuzzy method is integrated into FMEA where the severity factor, occurrence, and detection are assessed in linguistic form. In this fuzzy method, the weight of the interests of the FMEA assessment team is taken into account to do ranking and repair priorities. The application of Fuzzy methods to FMEA to determine significant risk factors and prioritizing improvements from various alternatives chosen for the process of repairing KRI in Surabaya Lantamal V, so that it is expected that the application of this method can improve the operational performance of Fasharkan to eliminate or reduce the risks that occur in the repair process ships in the eastern region of the fleet.

Keywords: Risk Management, Failure Modes and Effect Analysis (FMEA), Fuzzy Method.

1. INTRODUCTION.

Indonesian battleship (KRI) as a component of the Integrated Fleet Weapon system (SSAT) is the leading defense force to safeguard the maritime territory of the Republic of Indonesia (NKRI) with all its interests, therefore it requires operational readiness of the KRI elements. One of the inhibiting factors in KRI readiness in carrying out operations is the occurrence of a failure in the process of repairing the KRI. Failure on the system will certainly require high costs due to production losses and delays, unplanned interventions in the system and safety hazards (Sachdeva et al, 2009). To prevent these conditions from happening, it is necessary to take the

right steps to correct or eliminate failures so that the system's performance does not decrease.

The current conditions for several accidents on the KRI have caused significant material losses, like KRI Klewang 625 Missile Fast Ship (KCR) which was launched on 31 August 2012 from PT. Lundin Industry Invest Banyuwangi caught fire on Friday 28 September 2012, also KRI Teluk Peleng 535 which sank on Monday 19 November 2013 due to leakage of the vessel's age of 35 years experienced material fatigue and the KRI of Bintuni Bay 520 on October 27, 2014 experiencing a fire caused a problematic electricity on the ship, with these conditions needing

to identify the risks to the ship to reduce or avoid risks that occur in KRI making or repairing.

Determining the right steps to prevent failure is not easy. The step combines technical requirements and management strategies (Sachdeva et al, 2009). The failure events in the KRI improvement process are well studied to determine the solutions to be taken based on the form of failure, effects, and costs for all systems. Data information about failure will help personnel determine appropriate corrective actions and determine different priorities on each risk factor which is experience failure.

Based on the Naval Chief of Staff Regulation number Perkasal / 41 / V / 2010 on 18 May 2010, Fasharkan Surabaya is in charge of assisting the Commander of the Surabaya Navy V Main Base in providing maintenance and repair facilities for ships that will carry out repairs to machinery, equipment navigation, shipping, weapons, electronics, magnetic security, docking and fostering the potential of maritime services supporting the main tasks of the V Naval Base of Surabaya. In carrying out its duties Fasharkan Surabaya has the function of providing maintenance facilities and improvement for KRI which will carry out repairs, maintain the level of readiness of facilities and infrastructure to be spread out in the Fasharkan environment so that will be able to accept the task of maintaining and repairing the Navy, planning maintenance and repair activities at the depo and middle level as well as emergency repairs to the Eastern Indonesian Fleet Command along with workshop equipment based on the *Disharmap Koarmatim* plan and program and organizing support for maintenance and repair of unified vessels non-Indonesian Navy as well as commercial vessels in their area by utilizing technology that will be used in the production of ships from the start of design to the operation of the ship.

Risk management is needed to identify strengths and weaknesses for improvements and actions that can be taken to improve performance (Shinyu Mu et al., 2014) Risk analysis is becoming increasingly important now, many cases where failure to manage risk properly can result in considerable losses, both for organizations, even individuals. Several incidents such as losses suffered by companies due to misuse of employees or management, failure to anticipate economic and other crises, there are detrimental to the individual because the individual is negligent in obeying existing regulations. The potential loss from the risk will be even greater if people in the organization (the organization as a whole) do not have prudent behavior. This Incident can be avoided if we understand and manage the risk properly.

Risk response is very important in risk management to produce strategies, use information and knowledge about the problems that have occurred (Zhi-Ping Fan et al, 2015) Risks will arise if there is a deviation outside the plan of an event or a particular situation, the project is an attempt made to take opportunities so that the risk will always accompany it, therefore what needs to be considered is to optimize every opportunity that exists, in addition to taking steps to minimize the negative impact of risk on the goals and objectives to be achieved.

The FMEA method can be used to prevent various forms of failure, estimate problems and find the most optimal solutions economical. The FMEA method can identify potential failure modes in systems, subsystems, and components. This method prioritizes all potential failure modes to determine preventive measures for possible failure.

The application of the Fuzzy FMEA method is to determine the priority of repairs from various chosen alternatives to risks in KRI improvement

projects so that it is expected that the application of this method can improve Fasharkan operational performance in carrying out KRI maintenance and repairs.

2. MATERIALS/METHODOLOGY.

2.1 Failure Mode Effect Analysis (FMEA).

Failure Modes and Effect Analysis (FMEA) is a structured procedure for identifying and preventing as many modes of failure as possible. FMEA has some risks related to potential failure and provides a good basis for characteristic classification (Pyzdek, 2002). FMEA is a good help analysis maker in identifying potential failure modes, their causes, and effects. In addition, FMEA assists in making priorities and corrective actions for the failure mode.

The aim of FMEA is to help the analysis to identify and prevent problems that have been identified before the problem occurred. For that purpose, each risk mode failures will be evaluated and prioritized so that corrective action can be taken on different failure modes.

Severity is an assessment of the seriousness of the effects caused. In the sense that each failure that arises 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 a critical effect, then the value of severity will be high. Occurrence is the possibility of a cause that will occur and produce a form of failure during the use of the product.

Occurrence is a rating value that is adjusted to the estimated frequency and or the cumulative number of failures that can occur. Value detection is associated with current

control. Detection is a measurement of the ability to control/control failures that can occur. The value of Risk Priority Number (RPN) is a product resulting from the multiplication of severity, incidence, and detection rate. RPN determines the priority of failure. RPN has no value or meaning. This value is used to rank potential process failures.

The value of the RPN can be indicated by the equation as follows:

$$RPN = (Severity) \times (Occurrence) \times (Detection)$$

2.2 Fuzzy Theory.

2.2.1 Crisp Set (Middle).

According to Yan et al. (1994), the set of crisp A is defined by the elements that exist in that set. If $a \in A$, then A is 1. However, if $a \notin A$, then a is 0. Notation $A = \{x / P(x)\}$ indicates that A contains x element with the P property are being true. If X_A is a characteristic function A with the character P, it can be said that P(x) is true if and only if $X_A(x) = 1$

2.2.2 Fuzzy Sets.

According to Yan et al. (1994), fuzzy sets are based on the idea of extending the range of functions characteristics of the crisp set such that the function will include real numbers at intervals [0,1]. The value of membership indicates that an element in the universe of conversation is not only at zero (0) and one (1), but also the value located between them. The truth value of a statement is not only true or false. The value of one (1) indicates true and the value of zero (0) indicates false, but there are still values that lie between true one (1) and false zero (0).

The fuzzy set has two (2) attributes, there are Linguistics and Numeric. Linguistics

is the naming of a group that represents a certain condition by using natural language, such as high, low, good, big, small. Numeric is a value or number that shows the size of a variable, such as 40, 120 and 325 (Kusumadewi and Purnomo, 2004).

Some things to know in understanding fuzzy systems (Kusumadewi and Purnomo, 2004), are:

a. Fuzzy variable

Fuzzy variables are variables which will be discussed in a fuzzy system.

b. Fuzzy set

A fuzzy set is a group that represents a certain condition in a fuzzy variable.

c. The Conversation of Universe

The conversation of the universe is the whole value that is allowed to be operated in a fuzzy variable. This is a set of real numbers which always increases monotonously from left to right. The universal value of the conversation can be either positive numbers or negative. Sometimes the universe value of this conversation is limited by its upper limit.

d. Domain

The domain of fuzzy set is the entire allowable value in the universe of conversation and may be operated in a fuzzy set. As the universe of conversation, domains are sets of real numbers which always increase monotonously from left to right. Domain values can be either positive or negative numbers.

e. Fuzzification

Fuzzification is a process to convert an input variable from a crisp form into a linguistic variable in the form of fuzzy sets with their respective membership functions.

2.2.3 Fuzzy Membership Functions.

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

A fuzzy membership function is said to be a triangle membership function if it has three parameters, there are $p, q, r \in R$ with $p < q < r$, and stated by the following rules:

$$\mu(x,p,q,r) = \begin{cases} \frac{x-p}{q-p} & p \leq x \leq q \\ \frac{r-x}{r-q} & q \leq x \leq r \\ 0 & x \leq p \text{ atau } x \geq r \end{cases} \quad (2.1)$$

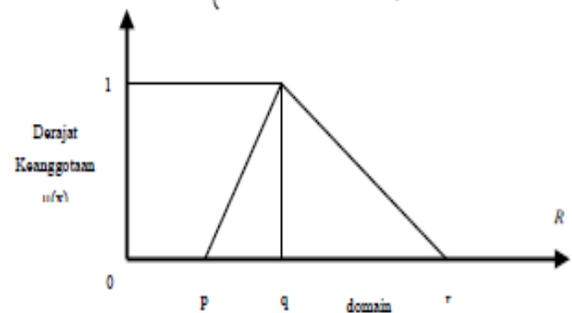


Fig. 1 Triangle Membership function curve (Source: Susilo, 2003).

A fuzzy membership function is called a trapezoidal as membership function if it has four parameters, there are $p, q, r, s \in R$ with $p < q < r < s$, expressed by the following rules:

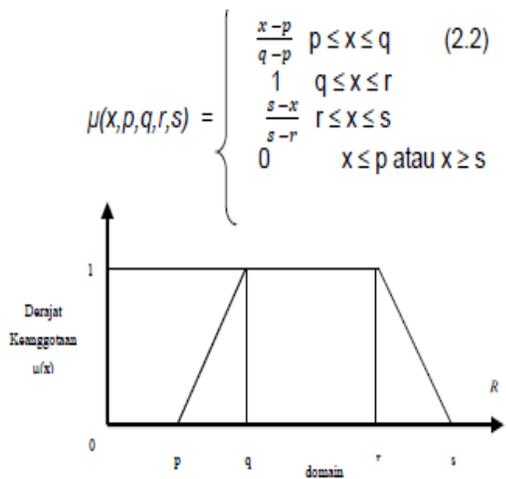


Fig. 2 Trapezoid membership function curve.

2.3 FMEA based fuzzy.

Some experts argue that the S, O and D factors are not easily evaluated accurately. Evaluation efforts have done linguistically (Wang et al, 2009). The following table shows the linguistic and fuzzy terms number used to evaluate these factors and visualize the membership function of each of these factors.

Table 1. Fuzzy ratings for severity

Rating	Severity of Effect	Fuzzy number
Hazardous without warning (HWOW)	Level of brightness is very high when the failure model potential affect the system safety without warning	(9, 10, 10)
Hazardous with a warning (HWW)	Level of brightness is very high when the failure model potential affect the system safety with warning	(8, 9, 10)
Very high (VH)	The system cannot operate with failure cause damage without endangering the safety	(7, 8, 9)

High (H)	The system cannot operate with equipment damage	(6, 7, 8)
Moderate (M)	The system cannot operate with minor damage	(5, 6, 7)
Low (L)	The system cannot operate without failure	(4, 5, 6)
Very Low (VL)	The system can operate with experience having a significant decline	(3, 4, 5)
Minor (MR)	The system can operate with experience having some decline	(2, 3, 4)
Very Minor (VMR)	The system can operate with a bit of a nuisance	(1, 2, 3)
None (N)	There is no influence	(1, 1, 2)

Source : (Wang et al, 2009)

Table 2. Fuzzy ratings for the occurrence

Rating	Probability of occurrence	Fuzzy Number
Very High (VH)	Failure can't be avoided	(8, 9, 10)
High (H)	The failure happens repeatedly	(6, 7, 8)
Moderate (M)	Failure sometimes times happened	(4, 5, 6)
Low (L)	A little Relative failure	(2, 3, 4)
Remote (R)	Failure might not happen	(1, 1, 2)

Source: (Wang et al, 2009)

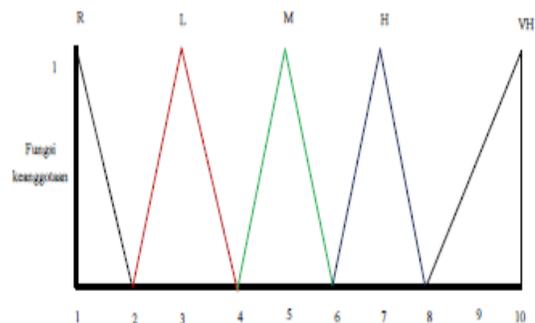


Fig. 3 Occurrence and membership function Fuzzy Values (Source: Wang et al, 2009)

Table 3. Fuzzy ratings for detection

Rating	Probability Detection By controlling device	Fuzzy Number
Absolute Uncertainty (AU)	There is no controller that can detect the cause of failure and the next failure mode.	(9,10, 10)
Very remote (VR)	The controlling device has an extremely narrow ability in detecting failure causes and another failure phase	(8, 9, 10)
Remote (R)	The controlling device has the narrow ability in detecting failure causes and another failure phase	(7, 8, 9)
Very Low (VL)	The controlling device has an extremely narrow ability in detecting failure causes and another failure phase	(6, 7, 8)
Low (L)	The controlling device has the narrow ability in detecting failure causes and another failure phase	(5, 6, 7)
Moderate (M)	Failure and another failure phase.	(4, 5, 6)
Moderately High (MH)	The ability of the device is on an average level on the controller detects the cause of failure and the next failure mode.	(3, 4, 5)
High (H)	The high ability of the controller detects the cause of failure and failure mode.	(2, 3, 4)
Very High (VH)	Very high ability of the controller to detect the cause failure and failure mode	(1, 2, 3)
Almost Certain (AC)	Almost certainly the ability of the controller detects the cause of failure and failure mode.	(1, 1, 2)

(Source: Wang et al, 2009)

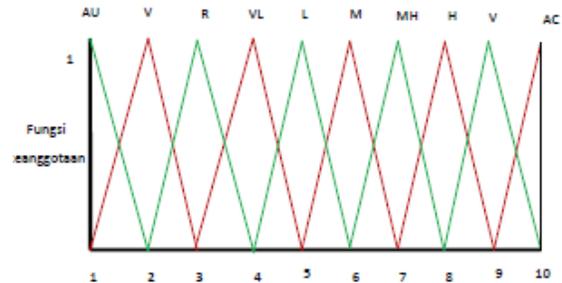


Fig. 4 Detection and membership function Fuzzy Values (Source: Wang et al, 2009)

Traditional FMEA does not consider the relative importance of risk factors and places them at the same level of importance. The weight of the relative importance of the interests by using linguistic terms that can be seen in table 2.4 and its contribution function can be seen in Figure 2.4.

Table 4. Fuzzy weight for the relative importance

Linguistic Form	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)

Source : (Wang et al, 2009)

Based on (Wang et al., 2009) to evaluate the failure factors in FMEA in fuzzy form, steps can be taken as follows:

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

$$R_i^O = \frac{1}{n} \sum_{j=1}^m h_j \cdot R_{ij}^O = \left(\sum_{j=1}^m h_j \cdot R_{ij}^O, \sum_{j=1}^m h_j \cdot R_{ij}^O, \sum_{j=1}^m h_j \cdot R_{ij}^O \right)$$

$$R_i^S = \frac{1}{n} \sum_{j=1}^m h_j \cdot R_{ij}^S = \left(\sum_{j=1}^m h_j \cdot R_{ij}^S, \sum_{j=1}^m h_j \cdot R_{ij}^S, \sum_{j=1}^m h_j \cdot R_{ij}^S \right)$$

$$R_i^D = \frac{1}{n} \sum_{j=1}^m h_j \cdot R_{ij}^D = \left(\sum_{j=1}^m h_j \cdot R_{ij}^D, \sum_{j=1}^m h_j \cdot R_{ij}^D, \sum_{j=1}^m h_j \cdot R_{ij}^D \right)$$

$$W_i^O = \frac{1}{n} \sum_{j=1}^m h_j \cdot W_{ij}^O = \left(\sum_{j=1}^m h_j \cdot W_{ij}^O, \sum_{j=1}^m h_j \cdot W_{ij}^O, \sum_{j=1}^m h_j \cdot W_{ij}^O \right)$$

$$W_i^S = \frac{1}{n} \sum_{j=1}^m h_j \cdot W_{ij}^S = \left(\sum_{j=1}^m h_j \cdot W_{ij}^S, \sum_{j=1}^m h_j \cdot W_{ij}^S, \sum_{j=1}^m h_j \cdot W_{ij}^S \right)$$

$$W_i^D = \frac{1}{n} \sum_{j=1}^m h_j \cdot W_{ij}^D = \left(\sum_{j=1}^m h_j \cdot W_{ij}^D, \sum_{j=1}^m h_j \cdot W_{ij}^D, \sum_{j=1}^m h_j \cdot W_{ij}^D \right)$$

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

$$FRPN_i = \left(\tilde{R}_i^O \right)^{\frac{W_i^O}{W_i^O + W_i^S + W_i^D}} \times \left(\tilde{R}_i^S \right)^{\frac{W_i^S}{W_i^O + W_i^S + W_i^D}} \times \left(\tilde{R}_i^D \right)^{\frac{W_i^D}{W_i^O + W_i^S + W_i^D}}$$

Traditional FMEA defines RPN as a simple result from Occurrence (O), Severity (S), and Detection (D) without considering the weight of its relative importance. But at Fuzzy FMEA weights, the relative importance of risk factors are assessed using linguistic terms.

3. RESEARCH METHODS.

This study examines the application of the Fuzzy FMEA method to the improvement of KRI Operational Radar Navigation Sperry Marine Warships of the Republic of Indonesia.

Application of the Model.

The model implementation will be tested on the Radar Sperry Marine operational process, where there are 35 failure modes in the operational process which can be seen in the following table 4.1:

Table 5. Damage Mode

No	Dimension	Failures Modes
1	D1 - Force Majeure	D1.1: Fire
		D1.2: Flood
		D1.3: Earthquake
		D1.4: Storm
2	D2 - management	D2.1: Inaccurate from plan design
		D2.2: Supervisor
		D2.3 : accuracy for personel selection
		D2.4: coordination implementation
3	D3 – engineering and Implements	D3.1: Time accuracy and job desk
		D3.2: accuracy in material execution
		D3.3: experts availability
		D3.4: Availability of field workers
		D3.5: Damage from tools
		D3.6: Variation in work Productivity
		D3.7: Technology expert in repairing process
		D3.8: Work accidents
		D3.9: Quality of work results
4	D4 - Contract and law	D4.1: The article is less complete
		D4.2: The article is unclear
		D4.3: Different interpretation
		D4.4: Payment setting
		D4.5: Security problems

5. RESULTS AND DISCUSSION.

5.1 Comparative Results of RPN, FRPN.

Table 6. Comparison of results of RPN, FRPN, and RPI

No	RPN	FMEA Failures Modes	FRPN	Fuzzy FMEA Failures Modes
1	196	D1.1: Fire	5,358	D1.1: Fire
2	108	D1.2: Flood	4,531	D1.2: Flood
3	40	D1.3: Earthquake	3,722	D1.3: Earthquake
4	63	D1.4: Storm	3,981	D1.4: Storm
5	216	D2.1: Inaccurate from plan design	6,161	D2.1: Inaccurate from plan design
6	100	D2.2: Supervisor	6,008	D2.2: Supervisor
7	80	D2.3: selection	5,466	D2.3: selection
8	216	D2.4: coordination implementation	5,768	D2.4: coordination implementation
9	441	D3.1: Time accuracy and job desk	7,501	D3.1: Time accuracy and job desk
10	512	D3.2: accuracy in material execution	8,501	D3.2: accuracy in material execution
11	294	D3.3: experts availability	7,194	D3.3: experts availability
12	180	D3.4: Availability of field workers	6,453	D3.4: Availability of field workers
13	729	D3.5: Damage from tools	8,914	D3.5: Damage from tools
14	245	D3.6: Variation in work Productivity	6,529	D3.6: Variation in work Productivity
15	216	D3.7: Technology expert in repairing process	6,332	D3.7: Technology expert in repairing process
16	175	D3.8: Work accidents	6,275	D3.8: Work accidents
17	120	D3.9: Quality of work results	5,847	D3.9: Quality of work results
18	90	D4.1: The article is less complete	4,635	D4.1: The article is less complete
19	80	D4.2: The article is unclear	4,667	D4.2: The article is unclear
20	36	D4.3: Different interpretation	4,002	D4.3: Different interpretation
21	50	D4.4: Payment setting	3,243	D4.4: Payment setting

5.2 RPN, FRPN and RPI Analysis.

5.2.1 Analysis of FMEA and FUZZY FMEA .

In Table 5.1 above we can see that from 22 failure KRI repair models in Fasharkan Lantamal V Surabaya risk failure groups have the same RPN and ranking values.

From the table above, it can be seen that there are several components that have the same RPN value. This is because, in FMEA traditional factors of severity (S), assurance (O) and detection (D) are considered to have the same level of importance; in fact they have different levels of importance. Likewise, the weight of the

interests of the FMEA assessment team is not taken into account.

By using a fuzzy approach to FMEA, where each failure has different fuzzy rating values and the level of importance and weight of the FMEA assessment team is considered, then after calculating the FRPN value each component has a different ranking. By using a fuzzy approach to FMEA, it will be more easy for users to distinguish risk in failure mode which has the same RPN value.

5.2.2 Analysis of FMEA, FUZZY FMEA

After analyzing the KRI repair project in Fasharkan Navy Main Base, Surabaya, table 5.1 gives the results of conventional FMEA and fuzzy theory approaches, using the FMEA method makes it difficult for principals to determine the priority order of the failure modes that occur.

From table 5.1 it can also be seen that from the twenty-two failure modes of the KRI repair project in Lantamal V Surabaya there is no same FRPN value for each identified failure mode so that each failure has its own priority rating, this is due to the assessment of severity (S), occurrence and detection (D) factors taking into account the weight of the interests of FMEA assessment team members and the weight of each factor (S, O, and D) in each failure mode that occurs.

D2.4 failure mode coordination implementation, D3.7 mastery of technology in the process of improvement and D2.1 inaccurate planning has the same RPN value that is equal to 216, with the model approach developed, failure modes D2.4, D3.7 and D2. 1 has a different fuzzy rating for each failure

mode which is 5.768; 6.332 and 6.161, by using fuzzy on FMEA it is easier for users to distinguish risk representations in failure mode which has the same RPN value, failure modes D2.4, D3.7 and D2.1 have the same RPN but all three have risks that different, using the proposed method failure modes D2.4, D3.7 and D2.1 have different risk levels and ranking of the three with the proposed approaches, they are 7,9 and 12. Ranking obtained by the FMEA method can result in errors especially if the data used for analysis is accompanied by a high degree of uncertainty.

6. CONCLUSION.

From the results of data collection and processing, and analysis and interpretation of the results of data processing that has been done, the conclusions that can be taken in this study are:

a. A significant risk factor in the KRI repair project in Fasharkan, the Main Navy Base of Surabaya V is

- 1) Work equipment damage with a value of 8,914
- 2) The accuracy of material procurement with a value of 8.501
- 3) Timeliness of work with a value: 7,501

b. Handling the risk response to risks that are likely to occur and have a significant impact on the KRI repair project in Surabaya's Fasharkan Main Base V Surabaya is expected to minimize the risks that occur or may be able to eliminate the risk response risk as follows:

- 1) Working equipment damage is by controlling periodic service on existing equipment, controls the calibration of the equipment that has been used validation and buying new equipment and maintenance regularly to reduce expenditure costs.

- 2) The accuracy of material procurement is by using previous historical data to estimate work
- 3) Timeliness of work is by using time management of project implementation must be done by staff officers with the selection of the right method because it becomes a bond in the contract with a fine who force and carry out overtime work.

Suggestions

- a. In this study, it is better to do hypotheses for more and more mastering respondents who have experience in handling risks that occur in KRI repair projects in Surabaya's Fasharkan Main Base V Surabaya so the results this research can be used as a reference in implementing projects using risk management in subsequent projects.
- b. For the next researchers who are interested in a similar type of research, it is better to develop it by combining with other methods to analyze more complex problems.

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