*Quest Journals*
*Journal of Architecture and Civil Engineering*
*Volume 9 ~ Issue 9 (2024) pp: 11-18*
*ISSN(Online) : 2321-8193*
www.questjournals.org

**Research Paper**

# A Risk Management Application by Failure Mode and Effect Analysis (FMEA) Method in A Road Drainage Channel Construction Project at H.M Ardan Street of South Sangatta District East Kutai, Indonesia

Ridwan Nor Diansyah[1], Lalu Mulyadi[2], Maranatha Wijayaningtyas[3].
[1, 2, 3.] *Civil Engineering Program, National Institute of Technology, Malang, East Java, Indonesia-654145*
*Corresponding Author: Lalu Mulyadi*

***ABSTRACT:*** *A construction project of road drainage channel in H.M Ardan Street, South Sangatta District (Multy Years) is included into type of construction project with high level of risk and work accidents since it has large number of workers, the use of sophisticated work tools and machines that require special methods and skills also strong supervision in its usage. These matters could bring undesirable impact potentiality in particular for the occupational safety and health aspect. A negligence of OSH implementation in the construction project can lead to work accident risk within the project.*
*A work safety management is a part of management aspect with function to prevent any work accidents. Its prevention can be done by controlling the occurrence of high-potential work accidents whether in terms of consequences, occurrence probability, also simplicity in its detection. Many safety management methods have been introduced as method that able to be used for potential work accident identification, or measure the level of work accident's risk, also for evaluating the work accidents; which leads to the Failure Mode and Effect Analysis (FMEA) method as the most appropriate method to achieve the objectives as described above.*
*The selected method for this research was Failure Mode and Effect Analysis (FMEA) method, whereas the data source of this research were primary data obtained from interviews and questionnaires, and secondary data obtained from site plan drawings and identification data of the construction of drainage channels on H.M Ardan Street of South Sanggata District (Multi Years).*
*According to FMEA analysis, there were 15 dominant risks with RPN values above the average value with 4 risks having a value of 48 as the highest RPN value found in this study. Type of risks with the highest RPN value were (a) stricken by heavy equipment and materials during loading and unloading construction materials; (b) fatigue due to an overly busy mobilization schedule; (c) workers fall while installing the formwork; (d) workers' hand was pierced by nail or getting hit by hammer or wood. Furthermore, by the domino analysis conducted for this research, it produced several precautions and prevention recommendations that grouped into three main stages: Lack of Control, Basic Causes, and Immediate Causes.*

***KEYWORDS:*** *Risk Management, Failure Mode and Effect Analysis, Construction of Drainage Channel.*

***R****eceived 02 Sep., 2024;* ***R****evised 13 Sep., 2024;* ***A****ccepted 15 Sep., 2024 © The author(s) 2024.*
***P****ublished with open access at* ***www.questjournas.org***

## I. INTRODUCTION

Risk is a matter embedded or has very close relationship to every activity. Any activity that people do definitely has potential risks, especially in the field of construction activities. For construction activities, risk is inseparable and has become a part within all work activities. This uncertainty factor causes risk to arise which can be felt by the project implementer. According to [5], a work accident is an incident or event resulted in injury or material loss which felt by the victim and the party involved. In other words, aim of controlling risk of work accident is to prevent the emergence of work accident with expectation of zero accident occurs.

Every activity in construction project has a target completion; to finish the work on punctual time with the quality and cost in accordance with the prior plan. However, many activities in project construction have several obstacles which can cause losses and delay in the completion work time and one cause that able to disrupt work activity is a work accident that may occur on construction project [6].

However, the reality in the construction world says different, in which the step that can be done is only to have risk identification or risk analysis to the construction project and only conducted qualitative analysis by using probability impact matrix analysis method. Therefore, in this research, the authors carried out a combination method by risk identification and risk analysis in quantitative nature. This research uses A Failure Mode and Effect Analysis (FMEA) method. FMEA is a structured procedure to identify and prevent as many failures to happen as possible. A failure mode is every matter that includes defects, condition outside the specified specifications, or changes in the product/work that cause disruption to the function of the product [1]. The FMEA method is used to identify the source and cause of problems that occur in each work process.

So far, discussion related to risk management implementation by Failure Mode and Effect Analysis method in the construction of road drainage channel project at H.M Ardan Street of South Sangatta District, East Kutai has not been carried out by researchers, therefore the researchers raising study problems of: (1). What is the highest risk of work accident for drainage channel work activities on H.M Ardan Street of South Sangatta District as observed by the FMEA method?, (2). How to mitigate accident risks on the road drainage channel construction project on H.M Ardan Street of South Sangatta District?

## II. LITERATURE REVIEW

### 2.1. Risk Identification in A Project

Risk identification in a project is an effort to discover or find out type of risks that may arise in activities held by companies or individuals. It has important function since risk identification is the first stage of act that must be carried out because risks and their characteristics will be determined in this stage of whether they may or may not affect the project. Failure at this stage will bring consequence on the next stage of risk management and will certainly affect the reliability of the project because of the potential of many vulnerabilities or gaps that may occur in the future. Risk identification [2] is an analytical process to systematically and continuously discover risks or potential losses that challenge the company during the project implementation.

From its function, risk identification includes several stages of planning, assessment (identification and analysis), handling, and risk monitoring. Risk assessment placed as the initial stage in a risk management program and becomes the most important stage because it affects the entire risk management program. Risk identification functions to identify areas and responsible in technical processes that may have potential risks for further analysis.

According to the SNI IEC/ISO: 31010:2016 regarding the Failure Mode and Effect Analysis (FMEA), it defines FMEA as a risk identification method by analyzing various faulty considerations from the equipment used and evaluating impact of these errors. In this matter, FMEA identifies the probability of abnormality or any deviation that may occur in components or equipment's involved in the production process along with the resulting consequences.

Next, based on identification of risks which may occur in project, there are sources of danger that can be found in the workplace that come from materials, tools/machines, characteristics of project activities, work environment, work methods and ways of working. Several things are able to support the success of risk/hazard identification program as listed below:

1. Hazard/risk identification must be in line and relevant to the project activities to make it able to function properly.
2. Hazard/risk identification must be dynamic and always consider to include the latest update of technology and science.
3. All relevant parties must be involved in the hazard/risk identification process.
4. Availability of methods, equipment, references, data and documents must be present to support the hazard/risk identification activities.

Before applying the hazard/risk identification method, it is necessary to understand the meaning and concept of hazard/risk because risk has a direct relation to danger, while danger itself is covering everything including situation or actions that have potentiality to cause accidents or injury to human, damage to equipment, or other disturbance within the project.

## III. RESEARCH METHOD

### 3.1. Population and Sample of the Study

3.1.1. Population of the Study

The population in this research is PT.RNA PRATAMA MANDIRI as the contractor of Drainage Channel Construction Project on H.M Ardan Street of South Sanggata District (Multy Years), and numbers of population within the structure of PT.RNA PRATAMA MANDIRI organization are 65 people.

3.1.2. Sample of the Study

Research sample is a small portion of population members which taken according to certain procedures so it can represent the population [7] and the sampling technique used in this research are a non-probability technique (a sampling technique in which all objects or elements of the population do not have the same chance of being selected as samples) and quota sampling as a sampling method that details everything related in advance by sampling [4]. Number of respondents involved in this research is eight respondents who are the parties responsible for carrying out this project and considered as experts with plentiful of experiences in their field and have a good competence in dealing with work accidents so that the expected results will not be much different.

### 3.2. Research Procedures

1. Identification of Failure Mode on each work activity.

   Carried out by literature studies, surveys, interviews in the work field, also questionnaire distribution which will be group into a questionnaire form.

2. Analysis of Failure Mode and Effect Analysis (FMEA)

[3] brought determination of steps required to carry out FMEA method (Dominant Risk Potential Analysis) as follows:

a) Held inspection to each work item that has most potential risk in the construction work, the inspection of work item with potential risks is conducted together with Safety Health Environment activity.
b) Creates potential impact of failure that has risk for every work item. After failure mode from each work item has been found, the analysis proceeds by determining effect (impact) of the failure mode on each work item. To determine the effect, the researchers obtained the result of questionnaire form or the risk scale form.
c) The questionnaire results then put into assessment to observe the severity level from the impact of failure on each work item. The severity determination was conducted based on severity scale table.
d) Assess the probability level of occurrence of the potential causes of failure in each work item, and probability level of occurrence is determined based on the severity scale table.
e) Assess the probability level of occurrence from the potential causes of failure in each work item. The probability level of occurrence is determined based on the severity scale table. To determine the incident scale, researchers took the results from the questionnaire form.
f) Assess the detection scale level based on design control list for each work item. The level of detection scale is determined based on the detection scale table, and for determining the detection scale, the researchers took the results from the questionnaire form.
g) Calculate the priority level or commonly called as the Risk Priority Number (RPN). The calculation is obtained from multiplicity result of severity, detection and occurrence. The highest RPN value owns the highest failure mode of the predetermined work item, but not all risks were taken, based on the previous research by [7], only the highest RPN value is taken for determining the most dominant type of risk per work item, then this value is put into domino method to find out its causal effect.

In analyzing the identification of the causes of work accident risks, the researchers use Domino method with its steps explained by [7] in the following paragraph:

1. Identifies the potential risks that occur in the road drainage channel construction project at H.M Ardan Street of South Sangatta District (Multy Years) based on the result of the highest RPN value.
2. After identifying problem as the cause of failure that taken from the highest RPN value, next step is to seek any risks that may occur and able to bring significant impact on the smoothness run of the project. The method for identifying risk is using Domino diagram or Heinrich's theory.
3. Once the upcoming risks are known, the researchers create assessment criteria for these risks based on their severity level. Apart from that, the assessment also based on the possibility of level of accident or dangerous situation. The identification assessment was carried out by interview and risk identification on risks related to the road drainage channel construction project on H.M Ardan Street of South Sangatta District (Multy Years) where the value is only for identification and not in the form of nominal amount.

4. Once the level of work risk is known, several efforts were planned for dealing with the risks. From the risks that already handled or was treated by preventive measures, level of risk must be reduced and the expectation is to produce low risk level value.
5. From this process, a table for grouping the most dominant causes can be created by using the Domino method.

## IV. RESULT AND DISCUSSION

### 4.1. Analysis of RPN Determination

Risk Priority Number (RPN) determination in the FMEA table is conducted by identify processes that have dominant risks. This assessment is using a predetermined scoring guideline where the Severity (S), Occurrence (O) and Detection (D) index values are multiplied to get the RPN value for each process. The analysis result will display the RPN values as sorted from the largest value to the smallest value, reflecting the potential risk of each process step. The higher the RPN value of a risk factor, the greater the potential negative impact for the project implementation.

Table 1. is a table showing results of RPN assessment for all risks that have been identified based on three levels of assessment scale.

**Table 1.** RPN Assessment

| Code | Severity (S) | Occurrence (O) | Detection (D) | RPN Value |
|---|---|---|---|---|
| R01 | 3 | 4 | 4 | 48 |
| R03 | 4 | 4 | 3 | 48 |
| R34 | 3 | 4 | 4 | 48 |
| R36 | 3 | 4 | 4 | 48 |
| R10 | 5 | 3 | 3 | 45 |
| R07 | 3 | 3 | 4 | 36 |
| R09 | 4 | 3 | 3 | 36 |
| R12 | 3 | 4 | 3 | 36 |
| R23 | 3 | 4 | 3 | 36 |
| R33 | 3 | 4 | 3 | 36 |
| R35 | 4 | 3 | 3 | 36 |
| R38 | 3 | 3 | 4 | 36 |
| R37 | 4 | 2 | 4 | 32 |
| R15 | 3 | 3 | 3 | 27 |
| R39 | 3 | 3 | 3 | 27 |
| R05 | 3 | 4 | 2 | 24 |
| R06 | 4 | 2 | 3 | 24 |
| R20 | 4 | 3 | 2 | 24 |
| R21 | 4 | 2 | 3 | 24 |
| R22 | 3 | 2 | 4 | 24 |
| R24 | 2 | 4 | 3 | 24 |
| R27 | 2 | 3 | 4 | 24 |
| R29 | 3 | 2 | 4 | 24 |
| R02 | 3 | 2 | 3 | 18 |
| R19 | 3 | 2 | 3 | 18 |
| R25 | 3 | 3 | 2 | 18 |
| R26 | 2 | 3 | 3 | 18 |
| R31 | 2 | 3 | 3 | 18 |
| R32 | 2 | 3 | 3 | 18 |
| R40 | 3 | 2 | 3 | 18 |
| R11 | 4 | 2 | 2 | 16 |

| | | | | |
|---|---|---|---|---|
| R14 | 4 | 1 | 4 | 16 |
| R08 | 3 | 2 | 2 | 12 |
| R18 | 3 | 2 | 2 | 12 |
| R28 | 2 | 3 | 2 | 12 |
| R30 | 2 | 2 | 3 | 12 |
| R16 | 3 | 1 | 3 | 9 |
| R17 | 2 | 2 | 2 | 8 |
| R13 | 2 | 1 | 3 | 6 |

### 4.2. The Dominant Risk

After the Risk Priority Number (RPN) calculation has been performed, the next step is identifying the dominant risks of the project. This process is carried out by calculating average RPN value of all risk variables where in this study is found to be 25 risk variables. A risk is considered dominant if the RPN value exceeds the average value. On the contrary, risks with RPN value equal or below the average value are considered to have a higher security level. A graphic visualization of dominant risks in this study is presented in the following figure (Figure 1).

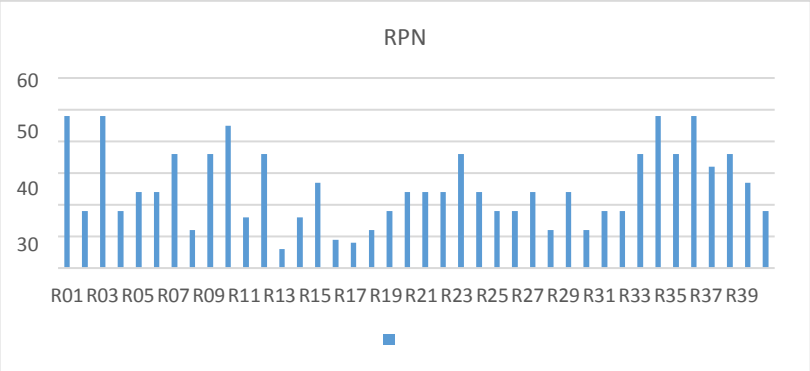


Figure 1. RPN Value Graphic

The graph is displaying a comparison between RPN values which are above and below the average value. From this analysis, there were 15 variables identified to have RPN value above the average value. These risks were identified by codes (R01, R03, R07, R09, R10, R12, R15, R23, R33, R34, R35, R36, R37, R38, and R39) and further details regarding these dominant risks can be seen in the following table (Table 4.2).

**Table 2.** The Dominant Risks.

| Work Item | Risk | RPN Value | Code |
|---|---|---|---|
| General Division | Get hit by heavy equipment and material during loading and unloading work | 48 | R01 |
| | Fatigue due to overly busy mobilization schedule | 48 | R03 |
| Formwork Construction Work | Workers falling during formwork installment | 48 | R34 |
| | Workers' hand were pierced by nails or wood or get hammered | 48 | R36 |
| Drainage Division | Respiratory problem caused by dust and soil | 45 | R10 |
| | Injured by mortar mixer machine | 36 | R07 |
| | Injured while arranging the mountain stones | 36 | R09 |
| Geosynthetic and Groundwork Division | Workers fall or stumble into dug hole in the ground | 36 | R12 |
| Structure division | Pinched by cutting tool for iron/steel frames | 36 | R23 |
| Formwork Construction Work | Workers' head get hit by formwork | 36 | R33 |
| | Formwork material falls of height and struck on workers | 36 | R35 |

| | | | |
|---|---|---|---|
| Dewatering Work | Injury from high pressure water at discharge | 36 | R38 |
| | Electric shock when handling work equipment in wet condition | 32 | R37 |
| Geosynthetic and Groundwork Division | Health Problem due to general condition | 27 | R15 |
| Dewatering Work | Injury from operating drill equipment | 27 | R39 |

Based on the occurences of 15 dominant risks, there are four risks with the highest RPN value found with value of 48 in the risk codes of R01 (get hit by heavy equipment and material during loading and unloading work), R03 (fatique due to overly busy mobilization schedule), R34 (workers falling during installing the formwork), and R36 (hand of workers were pierced by nails or wood or get hammered).

### 4.3. The Domino Analysis

The Domino theory was originally developed by H.W Heinrich in 1931 which later updated by Frank E.Bird as quoted from Handika (2015). It is a conceptual model that explains series of events that lead to work accidents. This theory analogizes the occurrence of accidents to the effect of falling dominoes where one event triggers the next event in an interconnected series.

According to this theory, researchers analyzed four dominant risks which had been identified are present in the road drainage channel construction project on H.M Ardan Street of South Sanggala District, East Kutai, where the highest RPN value found in this project is 48. This analysis helps to identify the critical points where intervention can be executed to prevent work accidents.

**Table 3..** The Domino Analysis

| No | Dominant Risk | Analysis by Domino Method | | | | |
|---|---|---|---|---|---|---|
| | | **Lack of Control** | **Basic Cause** | **Immediate Cause** | **Incident** | **Loss** |
| 1. | Get hit by heavy equipment and material during loading and unloading work (R01) | Lack of strict safety procedure | Inadequate training and time pressure | Unsafe material placement and lack of communication | Worker get hit by heavy work equipment or material | Serious injury, death, and equipment damage |
| 2. | Fatigue due to overly busy mobilization schedule (R03) | Weak system safety management and supervision | Lack of Management training and pressure for finishing the project faster than the due date. | Mobilization schedule to tight; inadequate resting time between work journey | Physically and mentally fatigue on workers, decline alertness and concentration on workers | Work or traffic accident, decline work productivity and quality |
| 3. | Workers falling during formwork installment (R34) | Lack of protection system to avoid fell | Poor workplace design | No safety protection equipment; slippery work surface | Workers fell down from higher place | Serious Injury, loss of work time |
| 4. | Workers' hand were pierced by nails or wood or get hammered (R36) | Lack of Safe Work Standard | Work Equipment is not ergonomic, pressure to work fast | Unsafe hand position; hands do not wear protective gloves | Injury on the hand of workers | Wound, infection, loss of work time |

Based on the Domino theory, researchers able to see the work accident prevention can be done by breaking the chain of events at each stage, in particular at the initial stage, such as by increasing the control and addressing the basic cause. The following paragraph is the further analysis of each stage through Domino theory:

1. Lack of Control:
   a). All risks indicate deficiencies in the safety management system, such as inadequate procedures, lack of supervision, or ineffective protective systems.
2. Basic Causes:
   a). Personal factor: lack of work training, fatique, and lack of danger awareness.

b). Work factor: poor workplace design, unergonomic equipment and time pressure.

3. Immediate Causes:
   a). Unsafe conditions: unsafe material placement and slippery work surfaces.
   b). Unsafe actions: do not use PPE and careless handling of the work materials.
4. Incident:
   a). All risks have potential to cause serious accidents such as struck by heavy objects or injured by sharp objects.
5. Loss:
   a). Potential losses include serious injury, death, lost work time and equipment damage.

After performing the Domino analysis, the researchers compiled several risk mitigations that could be carried out, as listed in the following table (Table 4.4).

**Table 4.** Risk Responses from Domino Method

| No | Dominant Risk | Risk Responses | | |
|---|---|---|---|---|
| | | **Lack of Control** | **Basic Cause** | **Immediate Cause** |
| 1. | Get hit by heavy equipment and material during loading and unloading work (R01) | Implementing a Safety Management System specifically for loading/ unloading work operation | Give a Comprehensive Work Training about safe procedure of loading or unloading material | Put up warning signs in loading or unloading work area |
| | | Appoints safety supervisor to supervise the unloading material process | Adjust or repair the work design area (for loading process) to make sure it has adequate work space | Give mandatory instruction for using PPE in complete uniform during the loading material process takes place. |
| 2. | Fatigue due to overly busy mobilization schedule (R03) | Implementation of a Comprehensive Safety Management System | Conduct regular training about Exhaustion Management for all employees | Optimizing mobilization schedule by considering length of distance and resting time |
| | | Implementation of Strict Supervision of Work Schedule and Break Time | Creating a realistic project schedule by considering the safety of the employees | Set a minimum standard break time between work trips |
| 3. | Workers falling during formwork installment (R34) | Develop a comprehensive system management in dealing with risk of falling | Give an intensive training about working in height (or higher place) | Install an adequate Fall Protection System (by giving safety fence or safety net) |
| | | Apply work permit system for work in a high altitude | Adjust or repair the design of work area in the high altitude for increasing security level | Mandatory act to use rope as safety tool when working in height |
| 4. | Workers' hand were pierced by nails or wood or get hammered (R36) | Develop a safe work procedures for hand tools usage. | Give a training on the correct technique of safe hand tools usage | Mandatory act to use hand gloves that suitable for type of work with any injury or puncture risk. |
| | | Conduct regular inspection to observe the condition of the hand tools. | Provide hand tools by considering ergonomic aspect/have ergonomic design to reduce the risk of injury. | Implementing or adding supporting equipment such a magnetic nail holder |

By additional analysis with Domino theory to the result of this research highlights several important aspects in the Occupational Safety Management. This theory emphasizes interactions among elements, where each stage in the chain of events is closely related to the others. According to the presented data, it is clear that there are deficiencies in the early stage (such as a lack of management control) that have a chain effect that leads to work accident. It showed that the most effective intervention must be carried out in the early stages, especially in the aspect of management control and basic cause treatments.

This analysis also revealed common patterns that found across all dominant risk namely the lack of management control, inadequate training and non-compliance with the safety procedures. These patterns depict key focus area that need improvement in the overall safety system. The Domino theory also explains how the cumulative effect of various factors can cause work accident. In the context of this study, the combination from several factors such as lack of supervision, worker fatique, and without or not using personal protective equipment, altogether bring significant increase to the level of accident risks.

The risk response proposed in this study reflects a layered prevention approach conforming to the principle of the Domino theory. For example, to overcome a risk of falling, there are some preventive measures including training, physical protection system, and use of personal protective equipment, each of which acts as a barrier to prevent the occurrence of work accident. Domino analysis also helps in identifying the underlying root problem where in this study is rooted from the lack of effective safety management system. Adressing the issue can have a far-reaching positive impact on the overall safety of the project.

As the last point, this theory emphasizes on the importance of human factor in the work safety aspect. The proposed risk responses in forms of training and awareness improvement showing a recognition to the important role of human factor in preventing work accident. By the presence of the additional analysis, it reinforces the importance of a systematic and comprehensive approach to occupational safety management in accordance with principle of Domino theory. Understanding and addressing each element in the chain of events can significantly reduces risk of accidents and creating a safer and more productive work environment.

## V. CONCLUSION

From the result of this research, there are several conclution able to be drawn for this study:

1. The result of risk identification had found 40 relevant risk variables present in this study. Based on FMEA analysis, there are 15 dominant risks with RPN value above the average value and there are 4 risks with highest RPN value as mentioned to be 48 in:
   a. Struck or hit by heavy equipment also materials during loading and unloading process (General Division).
   b. Fatigue because of overly busy mobilization schedule (General Division).
   c. Workers fall when installing formwork (Formwork Work).
   d. Workers' hand pierced by nail, wood or get hammered (Formwork Work).
2. From the mitigation conducted for this study, there are several prevention recommendations can be proposed as the solution of problem study. The recommendations are obtained from the risk analysis using Domino theory which produce recommendations that grouped into three main stages: lack of control, basis causes and immediate cause, focusing on:
   a. Reinforces the safety management system through development of special procedures and increased supervision.
   b. Upgrade the employee competency and awareness through intensive training programs.
   c. Provide a safer work environment by implementing appropriate personal protective equipment and protection systems.
   d. Implement a holistic approach in risk management to break the chain of events that potentially able to cause work accident.
   e. Build a sustainable safety culture at all levels in the project organization.

## REFERENCES

[1]. Carlson, Carl. (2012). Effective FMEAs: Achieving safe, Reliable, and economical products and processes using failure mode and effect analysis. Canada: United State of America.
[2]. Darmawi, Hermawan. (2011). Manajemen Resiko. Bumi Aksara, Jakarta. Gita,
[3]. Gita, AM. (2015). Analisa Risiko Kec elakaan Kerja Proyek Marvell City Linden Tower Surabaya Dengan Metode FMEA (Failure Mode and Analysis) dan FTA (Fault Tree Analysis), Jurusan Teknik Sipil Instittut Teknologi Sepuluh November, Surabaya.
[4]. Hasan, Iqbal, M. (2018). Pokok – Pokok Materi Statisktik 2 (Statistik Inferensif). Jakarta: Bumi Aksara.
[5]. Ramli, Soehatman. (2009). Sistem Manajemen Keselamatan dan Kesehatan Kerja OHSAS 18001. Jakarta: Dian Rakyat
[6]. Sepang, B. A.W. (2013). Manajemen Risiko Keselamatan dan Kesehatan Kerja (K3) pada Proyek Pembangunan Ruko Orlens Fashion Manado. Jurnal Sipil Statik. 1(4), 282-288
[7]. Wibisana, Awalurahma, Deta (2016). Analisa Risiko Kecelakaan Kerja Proyek Bendungan Tugu Kabupaten Trenggalek Menggunakan Metode FMEA (Failure Mode and Effect Analysis) dan Metode Domino. Tugas Akhir, Program Studi Teknik Sipil Institut Teknologi Sepuluh November, Januari 2016.