Work Accident Analysis on the project at PT. X based on the Failure Mode & Effect Analysis (FMEA) Method

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Abstract. This study aims to analyse work accidents that occur in projects at PT. X which has been carried out previously to know the reason from accidents that often occur while doing the project. The result of the analysis is accumulated in the form of the top priority data for conducting work safety patrols on project that will or are currently being implemented. PT. x is a company that engaged in construction with shares held by the State. In addition to run a construction business, the company is engaged in the Company and etc. The company's main goal is "zero accident and keep safety work". To realize these objectives, this study aims to analyse work accidents in previous projects which is very important. This analysis used the Failure Mode & Effect Analysis (FMEA) method of a systematic approach that applies a labelling method to help the thought process used by engineers to identify potential failure modes and their effects. This result is hope useful to find out the types of accidents that often occur at PT.X as learning to make efforts to prevent accidents in 2019 for next year.

1. Introduction

Information technology (IT) has changed every aspect of life, from an individual level to a societal level and for the whole world. Advanced technology and services, such as open source software and cloud computing, bring a new possibility to the IT industry and certainly create impact on our lives. Since the 1980s, the Society for Information Management (SIM) has surveyed practitioners and researchers in IT and Information Systems (IS) fields. Therefore, to understand the most significant issues in the field, the ranking of such issues and to elucidate agreement regarding issues/ranking among participants[1]. A cultural and behavioural shift in the mind-set of all participants in the construction process especially top or senior management is necessary if the construction industry is to improve its performance and competitiveness. For innovation and continuous improvement to be encouraged and become a norm traditional practices need to be unlearnt. Historically, the construction industry has been reluctant to implement change. This process of change is especially difficult in the competitive environment in which construction takes place and where the bottom line is still the primary motivation of construction companies [2]. Construction projects are jobs that have a high risk of work accidents with the possibility of serious work accidents. The risk of work accidents is increasingly high in developing countries where the workforce used is relatively low educational background. Related to this condition, King and Hudson (1985) stated that the mortality rate in construction projects in developing countries is three times higher than the incidence in developed countries [3].
PT. X is a construction company with shareholdings held by the Republic of Indonesia and PT Z (Persero). In addition to running a construction business, the company also runs a business in the field of Engineering, Procurement, Construction (EPC), and investment. As a construction company, PT. X has built a variety of building projects in various regions in Indonesia. The project includes construction of irrigation and dams, docks, industrial buildings and EPCs, airports, hospitals, apartments and hotels, commercial buildings, highways and highways, flyovers and bridges, sports buildings, educational buildings, and various other commercial buildings. These projects have directly and indirectly contributed to the country's economy. In its long journey as a construction company, PT. X has built a number of monumental buildings that become landmarks in Indonesia. One of them is the development of the Gelora Stadium Bung Karno. It is included in one of the biggest soccer stadiums in the world. The company's main goal is "zero accident and keep safety work". To realize these objectives, this study aims to analyse work accidents in previous projects which is very important. Work accidents in the processing industry, mostly in the form of cases resulting in minor injuries. In handling minor injuries, companies can carry out referral and treatment actions, make Standard Operating Procedures (SOPs), and provide Personal Protective Equipment (PPE) as an intervention step [4]. Accidents occur because of damage to heavy equipment used to lift the engine; the engine falls and hits the worker. So there needs to be an effort to protect the safety of workers in completing their work [5]. The main advice to the Government is that the OHSs should focus on primary prevention of occupational diseases and injuries [6]. In other words, in order to contribute to the overall reduction of work related accidents, occupational HSE has been studied from different points of view [7]. FMEA is a reliability procedure which documents all possible failures in a system design within specified ground rules. It determines, by failure mode analysis, the effect of each failure on system operation. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones [8]. This analysis used the Failure Mode & Effect Analysis (FMEA) method of a systematic approach that applies a labelling method to help the thought process used by engineers to identify potential failure modes and their effects. This result is hope useful to find out the types of accidents that often occur at PT.X as learning to make efforts to prevent accidents in 2019 for next year that have occurred so as not to recur.

2. Method
In doing this study, we used a descriptive method. We illustrated a number of the data then analysed it using a specific method and presented the results of such research. The research obtained from collaboration between us and resource persons in the company is used as a research object. The initial stage is done through direct observation and data collection through the interview stage. Once the appropriate data used, we conducted the categorization of data that can be used with the method of analysis to be used. The primary data were collected from the case company through observations including recordings, measurements and discussions with line managers and operators. To get relevant secondary data, the documentations of the company, with special focus to weaving section, were critically assessed [9].

Process FMEA concentrates on solving difficulties associated with manufacturing processes. The first step is to study and analysis of each step of the manufacturing process and preparing of the flow chart. Next is to identify potential failure modes and respective causes; then, the current controls are determined, followed by the effects of failures on the manufacturing line operators and product end-users. The risks of these effects are then assessed accordingly [10].

Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent failure modes that might occur. A failure mode is what is included in disability, conditions beyond the specifications set forth, or changes in the project that can affect the performance of the project [5].

There is a goal that can be achieved by the application of FMEA:
1. Identifying failure modes and the level of influence the effect.
2. Identifying the critical characteristics and significant characteristics.
3. Sorting potential design and process deficiencies.
4. Help engineers focus on preventing problems.
When implementing FMEA, each component is examined to identify possible failures. Three steps to consider: the possibility of failure (Occurrence), the impact or severity of failure (Severity), and the ability to detect failures before they occur (Detection).

2.1 Severity
Severity or risk reduction should be considered only on the "effect", reducing the severity of the risk is only possible through changes in processes and activities. There are several quantitative factors to the severity of this risk that is expressed on a scale of 1 to 10 (see table 1).

| Effect       | Severity Of the Effect                                                                 | Rank |
|--------------|---------------------------------------------------------------------------------------|------|
| Hazardous    | Risk causes an impact on costs, time and / or scope so severe that there is no chance for recovery. This requires the closure of the project process in practice. | 8-10 |
| Serious      | Risk affects the cost, time and / or scope, requiring action by the manager to achieve the project's (revised) goals. The impact requires a significant delay and / or increase in costs, and functional loss in the project. This requires project change management, approval, contingency plans, and review of new goals for project continuity. | 6-7  |
| Major        | Risks affect costs, time and / or scope, and require action from managers to achieve project goals. This requires a project change management process in practice, with the company's approval of this change. | 4-5  |
| Minor        | The risk does not cause a small loss to the project objectives, requires reworking or minor corrections in the project deliverable, no additional time or budget is needed | 2-3  |
| None         | The risk causes a small tightening of restrictions on the project, with no impact on quality, cost, time and scope. | 1    |

2.2 Detection
The probability of the detection is one type of assessment to identify the cause / mechanism of risk. The project team must use evaluation criteria and system bases if some changes are needed in special cases. It is to determine the best control as early as possible during the project. In addition, the team should review the potential risk score after scoring and ensure that these ratings are remain. Although FMEA prioritize critical failures, it also requires an analysis of each component of the system and this may take the available resources. How to determine the value of detection is using a rating of 1-10 (see table 2).

| Detection          | Possible detection                                                                 | Rank |
|--------------------|------------------------------------------------------------------------------------|------|
| Not detected        | There is no preventive action against risk, or systematic action to monitor and control risk. (Detection is less than 1% of the time, and risks usually affect the project) | 8-10 |
| Little possibility  | There are no precautions against risk, but there are actions for risk monitoring and control, with no further level to guarantee repetition, procedures and frequency needed for effective management. (Does not prevent risk, but detects 50% after occurrence, before affecting project objectives) | 6-7  |
Detection Possible detection Rank
medium There is little chance of detecting risks before they occur. (Detects and avoids occurrence 30% of the time, and only detects for the rest) 4-5
High High likelihood of detecting causes of risk before they occur. (Detects and avoids occurrence 70% of the time, and only detects for the rest) 2-3
Almost certain The exact cause of risk will be detected before it happens (Detects and avoids occurrence 100% of the time) 1

2.3 Occurrence
Occurrence is the probability of a particular cause or mechanism to emerge. In other words, occurrence is the probability of a specific occurrence at the frequency of potential error events. The probability of occurrence is assessed by numbers 1 to 10 from the help of archival surveys and previous documents, examining control processes, and labour laws. Prevention or control of one or several error mechanisms is the only way that can reduce the rate of occurrence through the formation of changes in design or design processes such as design checklist, design review, design guidelines, and others. Thus, only by eliminating or reducing the cause or mechanism of each hazard is expected to reduce the number of values of the probability of occurrence (see table 3).

Table 3. Occurrence Level

| Probability of Failure | Possible Failure Rates | Failure Rates | Rank |
|------------------------|------------------------|---------------|------|
| Very high: failure is almost inevitable. | >1 in 3 | 8-10 |
| High: generally associated with previous processes that often lead to failure | 1 in 20 | 6-7 |
| Low: isolated failure related to identical processes. | 1 in 15,000 | 4-5 |
| Very low: only isolated activities related to nearly identical processes | 1 in 150,000 | 2-3 |
| Almost impossible: impossible failures, there have never been failures in identical processes | < 1 in 1,500,000 | 1 |

From the value of severity, occurrence, and detection the RPN value can be obtained, namely by multiplying the three elements (RPN = S x O x D). Based on the RPN value that has been obtained, the ordering is based on the highest to lowest RPN values. Production activities with the highest RPN value is the main target which must be considered by the company to be in the next year it can be a bit in anticipation of the beginning[8].

3. Results and Discussion
Based on the results of previous studies, this study identified 8 potential workplace accidents that occurred in 3 projects. Furthermore, these 8 work accidents are used as a basis for identifying work accidents that have occurred in the work that has been carried out in the 3 (see table 4, table 5, and table 6). Furthermore, the activities of these 3 projects will be assessed at the level of work accident risk based on the value of accident data that has been collected to be 8 potential work accidents at most to calculate the RPN value using FMEA, Failure Mode and Effect Analysis (FMEA) is the risk assessment stage for several projects that have been identified from the implementation, external and operational planning aspects. The results of the FMEA risk assessment are Risk Priority Numbers (RPN)[3]. Before determining the Risk Priority Number (RPN) weighting of severity, occurrence and detection is carried out.
3.1 Calculation of Severity Value
Severity value is a step to calculate how much impact or intensity of events can affect the final outcome of the process. The impact is notated on a scale of 1 to 10, where the value of 1 is the lowest impact and the value of 10 is the worst impact.

Table 4. Detail data calculation Severity Value of Project A

| No | Potential Failure   | Severity |
|----|---------------------|----------|
| 1  | Facial injury       | 2        |
| 2  | Lower Leg injury    | 9        |
| 3  | Finger injury       | 9        |
| 4  | Lower Arm injury    | 2        |
| 5  | Upper Arm injury    | 1        |
| 6  | Eyes injury         | 2        |
| 7  | Toe injury          | 3        |
| 8  | Inner body injury   | 1        |

Table 5. Detail data calculation Severity Value of Project B

| No | Potential Failure   | Severity |
|----|---------------------|----------|
| 1  | Facial injury       | 1        |
| 2  | Lower Leg injury    | 8        |
| 3  | Finger injury       | 5        |
| 4  | Lower Arm injury    | 4        |
| 5  | Upper Arm injury    | 3        |
| 6  | Eyes injury         | 2        |
| 7  | Toe injury          | 1        |
| 8  | Inner body injury   | 2        |

Table 6. Detail data calculation Severity Value of Project C

| No | Potential Failure   | Severity |
|----|---------------------|----------|
| 1  | Facial injury       | 4        |
| 2  | Lower Leg injury    | 10       |
| 3  | Finger injury       | 7        |
| 4  | Lower Arm injury    | 3        |
| 5  | Upper Arm injury    | 4        |
| 6  | Eyes injury         | 1        |
| 7  | Toe injury          | 1        |
| 8  | Inner body injury   | 1        |

3.2 Calculation of Occurrence Value
Occurrence value (O), is an estimate of the probability or chance that a cause will occur and produces a failure mode that causes a certain effect. Occurrence value obtained by observing directly the actual conditions in the field, interviews with related divisions and see the project progress reports before (see table 7, table 8, and table 9).

Table 7. Detail data calculation Occurrence Value of Project A

| No | Potential Failure   | Occurrence |
|----|---------------------|------------|
| 1  | Facial injury       | 1          |
| 2  | Lower Leg injury    | 10         |
| 3  | Finger injury       | 10         |
| 4  | Lower Arm injury    | 3          |
| 5  | Upper Arm injury    | 1          |
| 6  | Eyes injury         | 3          |
### Table 8. Detail data calculation Occurrence Value of Project B

| No | Potential Failure       | Occurrence |
|----|-------------------------|------------|
| 7  | Toe injury              | 4          |
| 8  | Inner body injury       | 1          |

### Table 9. Detail data calculation Occurrence Value of Project C

| No | Potential Failure       | Occurrence |
|----|-------------------------|------------|
| 1  | Facial injury           | 3          |
| 2  | Lower Leg injury        | 9          |
| 3  | Finger injury           | 8          |
| 4  | Lower Arm injury        | 2          |
| 5  | Upper Arm injury        | 1          |
| 6  | Eyes injury             | 2          |
| 7  | Toe injury              | 1          |
| 8  | Inner body injury       | 1          |

### 3.3 Detection Value Calculation

Detection Value (D), is the value of subjective estimates of how effective and methods of prevention or detection. The detection value is obtained through interviews and looking at field progress reports from similar projects in the previous period (see table 10, table 11, and table 12).

### Table 10. Detail data calculation Detection Value of Project A

| No | Potential Failure       | Occurrence |
|----|-------------------------|------------|
| 1  | Facial injury           | 9          |
| 2  | Lower Leg injury        | 1          |
| 3  | Finger injury           | 1          |
| 4  | Lower Arm injury        | 7          |
| 5  | Upper Arm injury        | 9          |
| 6  | Eyes injury             | 7          |
| 7  | Toe injury              | 6          |
| 8  | Inner body injury       | 9          |

### Table 11. Detail data calculation Detection Value of Project B

| No | Potential Failure       | Occurrence |
|----|-------------------------|------------|
| 1  | Facial injury           | 8          |
| 2  | Lower Leg injury        | 2          |
| 3  | Finger injury           | 2          |
| 4  | Lower Arm injury        | 8          |
| 5  | Upper Arm injury        | 8          |
| 6  | Eyes injury             | 6          |
| 7  | Toe injury              | 5          |
| 8  | Inner body injury       | 8          |
Table 12. Detail data calculation Detection Value of Project C

| No | Potential Failure          | Occurrence |
|----|-----------------------------|------------|
| 1  | Facial injury               | 9          |
| 2  | Lower Leg injury            | 2          |
| 3  | Finger injury               | 2          |
| 4  | Lower Arm injury            | 6          |
| 5  | Upper Arm injury            | 8          |
| 6  | Eyes injury                 | 6          |
| 7  | Toe injury                  | 5          |
| 8  | Inner body injury           | 8          |

3.4 Calculation of Risk Priority Number (RPN)

After obtaining severity, occurrence and detection values from any deviations in GMP (failure) aspects, the RPN calculation process can be performed. RPN is obtained by multiplying the severity, occurrence and detection values. The highest risk indicator value from the highest RPN average value is the main target that must be considered in the following year (see table 13). RPN calculation on planning risk indicators is as follows example:

1. Severity = \(2+9+9+2+1+2+3+1\) = \(29 / 8 = 3.63\)
2. Occurrence = \(1+10+10+3+1+3+4+1\) = \(33 / 8 = 4.13\)
3. Detection = \(9+1+1+7+9+7+6+9\) = \(49 / 8 = 6.13\)
4. RPN = Severity X Occurrence X Detection
   = \(3.63 \times 4.13 \times 6.13 = 91.9\)

Table 13. Calculation RPN use all project

| No | Potential Failure    | S  | O  | D  |
|----|----------------------|----|----|----|
|    | Project A            | 2  | 1  | 9  |
| 1  | Facial injury        |    |    |    |
|    | Project B            | 1  | 3  | 8  |
|    | Project C            | 4  | 3  | 9  |
|    | Average (SOD Weight Indicator) | 2.3 | 2.3 | 8.6 |
| 2  | Project A            | 9  | 10 | 1  |
|    | Lower Leg injury     |    |    |    |
|    | Project B            | 8  | 9  | 8  |
|    | Project C            | 10 | 8  | 7  |
|    | Average (SOD Weight Indicator) | 20.3 | 21.6 | 11.3 |
| 3  | Project A            | 9  | 10 | 7  |
|    | Finger injury        |    |    |    |
|    | Project B            | 8  | 9  | 6  |
|    | Project C            | 8  | 8  | 5  |
|    | Average (SOD Weight Indicator) | 19.6 | 9.6 | 6  |
| 4  | Project A            | 2  | 3  | 9  |
|    | Project B            | 3  | 4  | 7  |
|    | Project C            | 2  | 4  | 8  |
|    | Average (SOD Weight Indicator) | 2.3 | 5.6 | 8  |
| 5  | Project A            | 1  | 1  | 7  |
|    | Upper Arm injury     |    |    |    |
|    | Project B            | 3  | 1  | 3  |
|    | Project C            | 4  | 2  | 8  |
|    | Average (SOD Weight Indicator) | 5.3 | 1.3 | 6  |
| 6  | Project A            | 2  | 3  | 7  |
|    | Eyes injury          |    |    |    |
| No | Potential Failure | S | O | D |
|----|-------------------|---|---|---|
| 4  | Project B         | 4 | 4 | 6 |
| 5  | Project C         | 3 | 1 | 4 |
|     | Average (SOD Weight Indicator) | 3 | 2.6 | 5.6 |
| 7  | Toe injury        |   |   |   |
| 8  | Project A         | 3 | 4 | 6 |
| 9  | Project B         | 6 | 4 | 9 |
| 10 | Project C         | 2 | 2 | 10 |
|     | Average (SOD Weight Indicator) | 9.6 | 3.3 | 8.3 |
| 8  | Inner body injury |   |   |   |
| 11 | Project A         | 1 | 1 | 9 |
| 12 | Project B         | 1 | 1 | 9 |
| 13 | Project C         | 1 | 1 | 9 |
|     | Average (SOD Weight Indicator) | 1 | 1 | 9 |

**Risk Indicator**

| RPN | 
|-----|
| 1 Facial injury | 45.4 |
| 2 Lower Leg injury | 4954.8 |
| 3 Finger injury | 1128.9 |
| 4 Lower Arm injury | 103.04 |
| 5 Upper Arm injury | 41.3 |
| 6 Eyes injury | 43.6 |
| 7 Toe injury | 262.9 |
| 8 Inner body injury | 9 |
| Total Risk Priority Number (RPN) | 6588.94 |
| critical value | 823.6 |

4. Conclusion

Conclusions of the analysis of workplace accidents that often occur in the PT. X using FMEA method that uses the data in three projects in 2019 obtained three accidents that often occur and should be in monitoring for the next year. Each RPN value from the three accident categories is 4954.8 for Lower Leg injury, 1128.9 for Finger injury, and 262.9 for Toe injury (see table 13). The results of this study hope that the company can reduce the number of accidents in accordance with the many categories of accidents obtained in 2019.

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