Risk assessment for apartment building maintenance using Fuzzy-FMEA methods

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Abstract. In apartment buildings, damage often occurs during maintenance. This study aims to identify risks, estimate risks, and provide mitigation actions for risks in apartment building maintenance. Types of risks that often occur, namely for the kind of work (1) civil and (2) MEP (Mechanical Electrical and Plumbing). Risk assessment in this research uses the Fuzzy-FMEA method (Failure mode and effect analysis). The results of risk assessment, the most critical risk is the risk of damage to marble floors with an FRPN value of 64.7. By using the FMEA method, as we know that there are seven causes of marble floor damage, namely (1) no standard work procedures, (2) no employee training, (3) unhealthy workers, (4) drugs influence, (5) no there is an inspection at the time of handover, (6) no routine checklist, and (7) strong winds. Some mitigation actions are also describes in this paper.

1. Introduction

In building management, risk management is one of the important issues to the risk event can be controlled, accepted/paid for, or transferred [1]. The managing risk in building management will be effective if it implies the risk assessment method including determining faults of reach risk events. Risk assessment to evaluate risk events in order to determine the mitigation plans is important for company managers. Building management that applies risk assessment activity will have a level of awareness and readiness in dealing with the potential of risks. [1] suggested that risk could be accepted with proper building maintenance.

FMEA (Failure mode and effect analysis) has become a popular method and extensively used in many areas such as nuclear, maintenance waste, engine, aerospace, and others [2, 3, 4]. Authors [4] believed that the results of FMEA analysis could be used to provide information for decision making in risk management. Fuzzy in the FMEA approach has the advantage in conducting risk evaluation and prioritization based on the preferences of the experts [5]. Fuzzy-FMEA has also become extensively used in several industries. Authors [6] use Fuzzy-FMEA to analyse volume and chemical control systems in a nuclear power plant. Authors [7] developed the fuzzy-FMEA technique for estimating risk in turbo stems for a diesel engine. Authors [8] also use fuzzy-FMEA to rank RPN values from the results of evaluating risk factors for severity, occurrence, and detection as input variables of the fuzzy system.

In an apartment building, there are many uncertainties in the occurrence of a risk, according to authors [1,9], uncertainties are a state of mind filled with doubt. In reality, the building management has made various efforts such as doing routine maintenance for each building part. This does not provide a significant impact on minimizing the risks that occurred. Building management must carry out risk mitigation efforts to focus on minimizing risks. Risk identification also purposes to find risks that have not arisen but have the potential to become risks. The risk that arises also affects the...
increasing complaints from residents and guests. This study aims to (a) identify the risk event in an apartment building maintenance, (b) assess the all-risk events with the Fuzzy-FMEA method, and (c) determine risk mitigation action. The problem in this research is how a company can conduct a risk assessment to prevent risks from happening. This research is significant to be doing to provide recommendations for companies not to let a risk occur repeatedly and cause significant losses for the company.

2. Research Method

The application of the Fuzzy-FMEA approach for risk assessment to reduce risk in an apartment building department consists of several research stages. A previous research related with research stages and case study was used as base to determine research stages [1,10,11,12, 13]. A case study in apartment "A" was conducted to understand the applicability of the fuzzy-FMEA approach for risk assessment. This research was conducted with three steps, namely (1) data collection, (2) risks identification, (3) risk assessment, and (4) risk mitigation action. Several steps are needed to complete each phase. Fuzzy method is used because there is a number of uncertainties or doubts of the severity. The severity is different for each incident. Fuzzy can analyse the uncertainty and then produce output in the form of an FRPN values.

2.1. Data Collection

In this research, data collection was carried out in six months of 2019 years. Data collection method used by taking primary data from the daily operational report of the apartment building and interview with engineering supervisor to determining the score of detection parameter. The Figure 1 showed the flow of data collection.

![Figure 1. Research data collecting flowchart.](image-url)
2.2. Risk Identification
Risk identification was carried out by the daily operational reports of an apartment building. Risk identification results are dividing into two types, which are civil and MEP. The Table 1 shows the failure risk and observation results in case study.

Table 1. Result of risk identification in an apartment building.

| Risk Code | Risk Event                                      | Observations Results | Occurrence | Severity (IDR) | Detection |
|-----------|-------------------------------------------------|----------------------|------------|----------------|-----------|
| Civil     | C1 Cracked Ceiling                              |                      | 58.00      | 500,000.00     | 460.00    |
|           | C2 Broken Main Door                             |                      | 57.00      | 110,000.00     | 115.00    |
|           | C3 Loose Parquet                                |                      | 22.00      | 700,000.00     | 605.00    |
|           | C4 Cracked Wall                                 |                      | 69.00      | 700,000.00     | 845.00    |
|           | C5 Torn Wallpaper                               |                      | 12.00      | 300,000.00     | 340.00    |
|           | C6 Marble Damage                                |                      | 10.00      | 2,000,000.00   | 1110.00   |
|           | C7 Broken Ceramic                               |                      | 17.00      | 300,000.00     | 555.00    |
|           | C8 Broken Glass                                 |                      | 16.00      | 1,200,000.00   | 630.00    |
|           | C9 Balcony frame broken                         |                      | 6.00       | 450,000.00     | 390.00    |
|           | C10 Cracked Natural Stone                       |                      | 32.00      | 450,000.00     | 220.00    |
| MEP       | M1 AC temperature is not appropriate            |                      | 77.00      | 300,000.00     | 220.00    |
|           | M2 Electrical installation damage               |                      | 82.00      | 300,000.00     | 255.00    |
|           | M3 Lights Out                                   |                      | 98.00      | 130,000.00     | 95.00     |
|           | M4 Clogged Floor Drain                          |                      | 53.00      | 100,000.00     | 165.00    |
|           | M5 Broken at Building automation system         |                      | 16.00      | 150,000.00     | 185.00    |
|           | M6 Sink damage                                  |                      | 40.00      | 200,000.00     | 305.00    |
|           | M7 Broken Urinal/ Closet                        |                      | 40.00      | 500,000.00     | 245.00    |
|           | M8 Cleaning Air Conditioner                     |                      | 84.00      | 100,000.00     | 135.00    |
|           | M9 Lack of Electrical power                     |                      | 10.00      | 1,200,000.00   | 165.00    |
|           | M10 Damage at Sky pool area                     |                      | 19.00      | 150,000.00     | 160.00    |
|           | M11 Clogged Grease trap                         |                      | 15.00      | 400,000.00     | 245.00    |
|           | M12 AHU/FCU damage                              |                      | 15.00      | 500,000.00     | 185.00    |
|           | M13 Gas installation leakage                    |                      | 16.00      | 100,000.00     | 105.00    |
|           | M14 Broken Exhaust fan/blower                   |                      | 11.00      | 500,000.00     | 185.00    |
|           | M15 Sprinklers/Smoke detector/hydrant           |                      | 22.00      | 500,000.00     | 330.00    |

The next step for each risk event is measured S, O, and D values from the daily report and also interviews with the engineer.
2.3. Measurement and Data Processing

Data collected from several sources, such as daily reports and interview results, are then measured, and is the values of each parameter. The next step in data processing is changing the value of each parameter into a value on a scale that has been determined for the input parameter on the step calculating RPN and FRPN. Change the score with interpolation formula and Calculation RPN with FMEA classical method. The Table 2 shows the score of FMEA parameter for each risk event. Calculation RPN with FMEA classical method is multiplying severity, occurrence, and detection.

\[
\text{RPN} = S \times O \times D
\]  

Calculation of the scale value by using the interpolation formula to change the value of the input parameter from the actual value to the scale value of area of the fuzzy input one to five for the input. The input detection value has a scale value of one to four. The following is an example of calculating the scale value for the ceiling damage occurrence input parameter.

| Risk Code | Parameter | RPN |
|-----------|-----------|-----|
| Civil     |           |     |
| C1        | 4.3       | 1.83| 2.02| 15.90 |
| C2        | 4.24      | 1   | 1   | 4.24  |
| C3        | 2.02      | 2.25| 2.72| 12.36 |
| C4        | 5         | 2.25| 3.11| 34.99 |
| C5        | 1.38      | 1.4 | 1.83| 3.54  |
| C6        | 1.25      | 5   | 4   | 25.00 |
| C7        | 1.7       | 1.4 | 1.72| 4.09  |
| C8        | 1.63      | 3.31| 3.22| 17.37 |
| C9        | 1         | 1.72| 2.83| 4.87  |
| C10       | 2.65      | 1.72| 1.63| 7.43  |
| MEP       |           |     |
| M1        | 4.05      | 1.73| 2.44| 17.10 |
| M2        | 4.27      | 1.73| 2.5 | 18.47 |
| M3        | 5         | 1.11| 1   | 5.55  |
| M4        | 2.95      | 1   | 1.66| 4.90  |
| M5        | 1.27      | 1.18| 2.38| 3.57  |
| M6        | 2.36      | 1.36| 3.5 | 11.23 |
| M7        | 2.36      | 2.45| 2.94| 17.00 |
| M8        | 4.36      | 1   | 1.38| 6.02  |
| M9        | 1         | 5   | 1.66| 8.30  |
| M10       | 1.41      | 1.18| 1.88| 3.13  |
| M11       | 1.23      | 2.09| 2.94| 7.56  |
| M12       | 1.23      | 2.45| 2.38| 7.17  |
| M13       | 1.27      | 1   | 1.09| 1.38  |
| M14       | 1.05      | 2.45| 2.38| 6.12  |
| M15       | 1.55      | 2.45| 4   | 15.19 |
2.4. Fuzzy-FMEA design
Fuzzy-FMEA design using MATLAB Software. The system has three input parameters like severity, occurrence, and detection, and one output is fuzzy risk priority number. After designing inputs and outputs, fuzzy rules are making from values determined by researchers with a total are a hundred rules. The Table 3 shows the fuzzy rules in risk assessment.

Table 3. Fuzzy rules.

| D=VL | F | RPN |     |     |     |
|------|---|-----|-----|-----|-----|
|      |   |     | VL  | L   | M   |
| S    | VL| VL  | VL  | VL  | VL  |
| L    | VL| VL  | L   | L   | L   |
| M    | VL| L   | M   | M   | M   |
| H    | L | M   | M   | M   | H   |
| VH   | L | M   | M   | H   | H   |

| D=L  | F | RPN |     |     |     |
|------|---|-----|-----|-----|-----|
|      |   |     | VL  | L   | M   |
| S    | VL| VL  | L   | L   | L   |
| L    | L | L   | M   | M   | M   |
| M    | L | M   | M   | M   | H   |
| H    | M | M   | H   | H   | H   |
| VH   | M | H   | H   | H   | H   |

| D=M  | F | RPN |     |     |     |
|------|---|-----|-----|-----|-----|
|      |   |     | VL  | L   | M   |
| S    | L | L   | L   | M   | M   |
| L    | L | L   | M   | M   | M   |
| M    | L | M   | M   | H   | H   |
| H    | M | M   | H   | H   | H   |
| VH   | M | H   | H   | H   | VH  |

| D=H  | F | RPN |     |     |     |
|------|---|-----|-----|-----|-----|
|      |   |     | VL  | L   | M   |
| S    | L | L   | M   | M   | M   |
| L    | L | M   | M   | M   | M   |
| M    | M | M   | H   | H   | H   |
| H    | M | H   | H   | VH  | VH  |
| VH   | H | H   | VH  | VH  | VH  |
FRPN value calculation manually by inputting the value of each parameter into the fuzzy rules that have been made.

Table 4. FRPN score for each risk event in an apartment building.

| Risk Code | Severity | Occurrence | Detection | FRPN |
|-----------|----------|------------|-----------|------|
| Civil     | C1       | 1.83       | 4.3       | 2.02 | 26.20   |
|           | C2       | 1.00       | 4.24      | 1    | 7.52    |
|           | C3       | 2.25       | 2.02      | 2.72 | 26.60   |
|           | C4       | 2.25       | 5         | 3.11 | 45.00   |
|           | C5       | 1.40       | 1.38      | 1.83 | 8.20    |
|           | C6       | 5.00       | 1.25      | 4    | 64.70   |
|           | C7       | 1.40       | 1.7       | 1.72 | 8.41    |
|           | C8       | 3.31       | 1.63      | 3.22 | 45.00   |
|           | C9       | 1.72       | 1         | 2.83 | 14.10   |
|           | C10      | 1.72       | 2.65      | 1.63 | 14.10   |
| MEP       | M1       | 1.73       | 4.05      | 2.44 | 41.60   |
|           | M2       | 1.73       | 4.27      | 2.5  | 45.00   |
|           | M3       | 1.11       | 5         | 1    | 7.52    |
|           | M4       | 1.00       | 2.95      | 1.66 | 15.00   |
|           | M5       | 1.18       | 1.27      | 2.38 | 21.70   |
|           | M6       | 1.36       | 2.36      | 3.5  | 25.00   |
|           | M7       | 2.45       | 2.36      | 2.94 | 38.40   |
|           | M8       | 1.00       | 4.36      | 1.38 | 7.52    |
|           | M9       | 5.00       | 1         | 1.66 | 32.30   |
|           | M10      | 1.18       | 1.41      | 1.88 | 7.99    |
|           | M11      | 2.09       | 1.23      | 2.94 | 25.00   |
|           | M12      | 2.45       | 1.23      | 2.38 | 23.50   |
|           | M13      | 1.00       | 1.27      | 1.09 | 7.52    |
|           | M14      | 2.45       | 1.05      | 2.38 | 23.50   |
|           | M15      | 2.45       | 1.55      | 4    | 25.00   |

The table 4 describes the highest RPN for civil and MEP risk event are risk code C2 and M2. Risk code C2 is for risk event Marble damage, and M2 is for risk event in electrical installation damage.
3. Results and Discussion
In this study, the result of the calculation of the value FRPN with the fuzzy-FMEA method can be used as a reference value, which states that it can be the most critical risk if it has the highest FRPN value. Following the result analysis of all fields both Civil and MEP to obtain the most critical risks that must be immediately handled by Building management in case study. The average scores for work categories each element and the ranking of risk event FPRN value in the civil field is shown in Table 5 and Table 6.

Table 5. The average score of FMEA parameter for each risk types.

| Element  | Average score |
|----------|---------------|
|          | Civil     | MEP       |
| Severity | 2.19      | 1.88     |
| Occurrence| 2.52     | 2.36     |
| Detection| 2.41      | 2.28     |
| RPN      | 12.97     | 8.85     |
| FRPN     | 25.98     | 23.10    |

Table 6. Ranking of risk event FRPN value in the civil field.

| Code of Risk Event | FRPN | Ranking |
|--------------------|------|---------|
| Civil              |      |         |
| C1                 | 26.20| 5       |
| C2                 | 7.52 | 10      |
| C3                 | 26.60| 4       |
| C4                 | 45.00| 2       |
| C5                 | 8.20 | 9       |
| C6                 | 64.70| 1       |
| C7                 | 8.41 | 8       |
| C8                 | 45.00| 3       |
| C9                 | 14.10| 6       |
| C10                | 14.10| 7       |

In the civil risk-ranking (see Table 6), the highest rating is obtained on the C6 risk code, namely broken or cracked marble with an FRPN value of 64.70. This risk is state as a critical risk in case study. For this reason, risk mitigation is needed to reduce the level of occurrence or severity. The Figure 2 showed the fault three analysis in a marble damage.

Making fault tree analysis is based on the causes of each top event, and the causes varied as technician errors and lack of experience from cleaning service. There are also causes of natural factors, like strong winds that make the marble fall and break. following the relationship between causes and top events.

In marble damage, there are six cut sets and seven basic events, where the damage is caused by collision or release. Top event collision has two cut sets, which are less experienced technicians because there are no SOPs and no training, or human error due to lack of health and emotional factors. Whereas the top event apart has two cut sets, namely strong winds and initial installation, because there is no checking during the handover or there is no routine checklist.
Figure 2. Fault tree analysis of a marble damage

From the data above, the writer can create a basic event table and recommendations for each of the basic events. This is necessary for the company as a preventative measure to prevent such damage. Table 7 shows the basic events and recommendations.

Table 7. Recommendations for each basic event in marble damage.

| No | Basic Event                                      | Recommendation                                                                 |
|----|--------------------------------------------------|-------------------------------------------------------------------------------|
| 1  | There is no procedure standard for work          | Made procedure standard for work in an area containing marble in detail.       |
|    |                                                  | Given training or upgrading knowledge about marble, how it is                 |
|    |                                                  | treated for the technicians and cleaning services. Supervision during         |
|    |                                                  | the field.                                                                    |
| 2  | There is no training                             | Make a form that states the technician’s condition is healthy, and that       |
|    |                                                  | form signed for accountability.                                              |
| 3  | Unhealthy                                        | Make a form that states the technician is not on drugs influence, and         |
|    |                                                  | that form signed for accountability.                                         |
| 4  | Drugs influence                                  | Layered area checklist (more than one person) when there is marble            |
|    |                                                  | installation in the new unit area.                                            |
| 5  | There is no checking at hand over               | Making a checklist form and schedule based on area and for a certain time.   |
| 6  | There is no routine checklist                    |                                                                               |

These recommendations can be made to reduce the risk of marble damage in case study. After the above recommendations are executed, it is analyzed again how often the risk event occurs. After that, it is re-analyzed how the recommendation is right on target or not.
4. Conclusions
Based on the fuzzy-FMEA method, the most critical risk out of 25 identified risks is the C6 risk code. There is marble damage which has an FRPN value of 64.7. Based on the FTA method of the most critical risks obtained seven basic events: There is no SOP for work, no training, not feeling well, mental disorders, no checking during handover, no routine checklist, and strong winds. This research was only carried out at the analysis stage and the improvement plan and had not yet reached the implementation and Plan-Do-Check-Action stages. Many other factors, such as safety risk and fire risk that exist in an apartment building that can be assessment and improved to reduce the risk. Basic events that fondly through the FTA method can be recalculated using the FMEA table. Suggestions for further research from this research are that actual calculations can be applied to other apartment building case studies that have similar characteristics. The value of existing risks can be compared between one building and another.

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