International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Serviceability Index of Elementary School Buildings in Coastal Areas of Jember-Indonesia

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Abstract

The school building is a school facility that must meet a certain standard in service level. Accuracy in calculating the level of damage to the building is important to find a proper serviceable capacity in order to determine the appropriate corrections. This study's objective is to calculate the elementary school buildings' damage index by using Failure Mode and Effects Analysis (FMEA). Assessment was done using a sample of 17 elementary schools in coastal areas of Jember and acquired building damage index values with 10 schools in very light damage conditions, 4 schools in light damage, 2 schools in moderate damage and 1 school in a badly damaged condition. This method would allow improvement in damage assessment and understand the serviceability of the buildings of the elementary schools in Jember. By understanding these factors, a more precise and faster response and prioritizing in repairs would be applicable.

Keywords: serviceability; damage index; damage assessment.

1. Introduction

Risk is defined as the possible dangers that may occur, causing damage and financial losses [1].

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In Indonesia until now, there are many elementary school buildings in coastal areas that have not received proper improvements, thus increasing the risk of harm to the building and its occupants.The damage is mainly divided into three parts, the damage to the structure, architecture and the mechanics [2]. The damage that occurs during the building service life is of particular concern for the government as the maintenance of school buildings determine the rate / index of damage and ultimately determine the costs and priorities given. Construction management as part of civil engineering is used to determine the management and costs[3]. It estimates the costs involved in the project implementation[4] and improvements associated with the index damage that occurs in the school building. In previous studies FMEA was used as a reliability assessment tool against failure modes [5]. The descriptions of the failure mode, can be used for the construction and building improvements[6]. This includes the structural elements (beams, columns, plates and roof) and non-structural elements (architectural elements including piping and electrical).[7] In this study, failure is determined as damaged building component. FMEA method (Failure Mode and Effect Analysis) is used to assess the damage index, where it has not been done in previous studies.

Table 1: Describes the number of districts and villages located in the coastal district of Jember.

No.	Village	sub-district
1	Paseban	Kencong
2	Mayangan	Gumukmas
3	Kirkcaldy, Puger Kulon, Puger Wetan, Mojomulyo	Puger
4	Lojejer	Wuluhan
5	Sabrang Forest, Sumberejo	Ambulu
6	Curahnongko, Andongrejo	Tempurejo

Damage to building components may affect the building service capacity. Factors that contribute to the damage are mechanical, chemical, biological, physical and environmental.[8] As one of the governmental buildings, elementary schools are expected to provide comfort and safety for users, therefore it requires good maintenance and ongoing technical evaluation of the risk factors for serviceability [9]. From the damage assessors that are regulated by the government (through the application “Elementary School Governance” or “Tata Kelola Sekolah Dasar” - Takola SD) there are still deficiencies in the calculation of damage to the elementary school buildings. The building repairs often are misdirected, resulting in schools that actually require immediate improvement to be neglected. By incorporating the requirements of “New South Wales Guide to Standards and Tolerances, 2017”, we may increase the accuracy in determining the damage index. It improves the serviceability capacity of the elementary school building and calculates damaged index with FMEA method. With this study, it is expected to add information and improve the assessment calculation index of damaged buildings. It is also a proposed simpler way to calculate damage and reparation for the government.

2. Materials and methods

This study is a qualitative study conducted to elementary school buildings in Jember coastal regions within 2 km of the shoreline. It includes 17 elementary schools, namely: SDN (Sekolah Dasar Negeri – state elementary school) Paseban 01, SDN Paseban 02, SDN Paseban 03, SDN Mayangan 05, SDN Mojomulto 02, SDN Mojosari 02, SDN Puger Kulon 01, SDN Puger Kulon 02, SDN Puger Kulon 03, SDN Puger Kulon 04, SDN

Sumberejo 06, SDN Sumberejo 09, SDN Andongrejo 02, SDN Andongrejo 03, SDN Curahnongko 01, SDN Curahnongko 06 and SDN Curahnongko 07. Data is taken from survey results and photos stored on Takola SD system, along with assessment instruments. From the results of Takola SD, the value of "severity" was acquired. The "occurrence" value was obtained from the level of frequency of damage obtained from interviews during the survey. The survey was adjusted to the Indonesian Government Regulations [10], whereas "Detection" was obtained from "New South Wales Guide to Standards and Tolerances 2017" [11].

2.1 Stages of research

The stages of research to obtain serviceability index to determine risk response is as shown below.

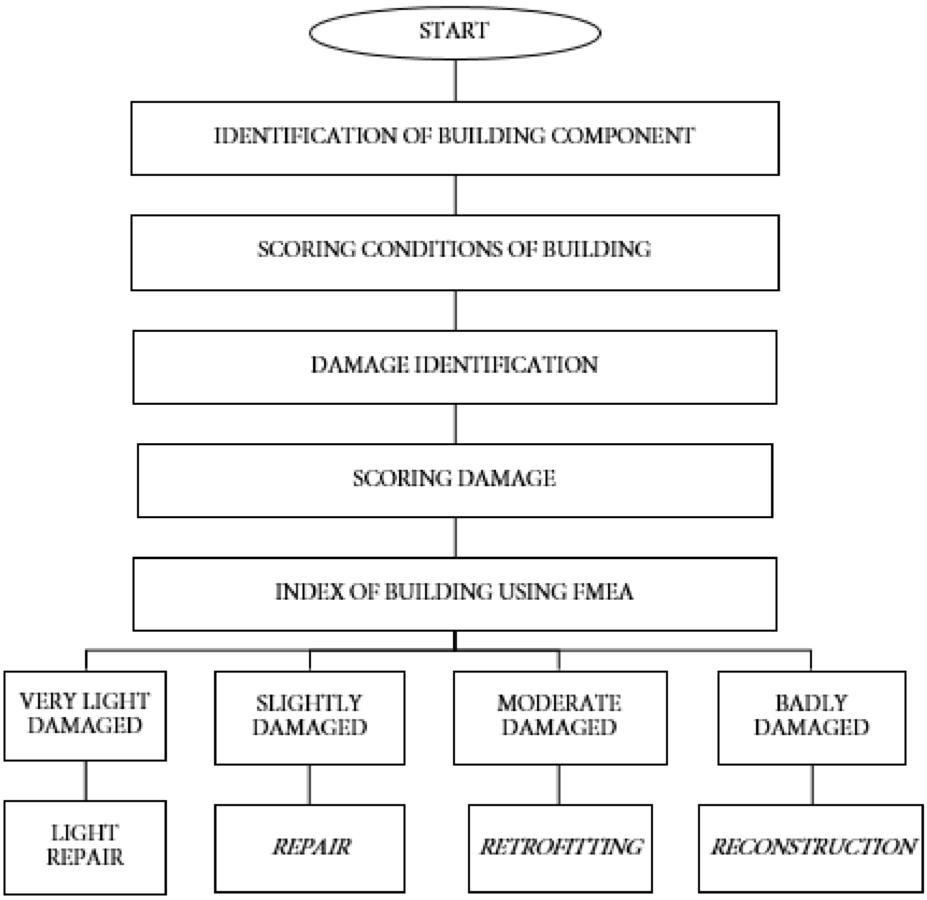

Figure 1: Stages research

The studied components of damage to the elementary school's buildings are the roof (the roof covering and the roof frame), ceiling (ceiling frame and ceiling cover), wall (column, beam, wall and wall paint), doors and windows (frames/sills, doors and shutters), floor (floor covering) and utilities (electrical installations).

2.2 Damage index calculation method using FMEA

Damage index calculation with FMEA method is by calculating the value of the RPN (Risk Priority Number) by the following formula [12]:

Risk Priority Number (RPN) = S x O x D ………………………….………………………………………(1)

Where: S = Severity

O = Occurrence

D = Detection

FMEA calculation steps:

1. Identification of damaged components as a potential failure. This is done by observation / direct field observation and data of damage (from Takola forms).
2. Determining Severity Index (Severity / S).
3. Determining the level of frequency damage occurrences (Occurrence / O).
4. Detecting damage (Detection / D).
5. Calculation of the RPN as an index value of damage.

Severity assessment is done by calculating the area of damage of each building component. Damage criteria uses a rating scale of 1-5 with the lowest one.(1) with no damage (0% damage), (2) very light (≤ 30% damage), (3) slight damage (30% - 45% damage), (4) moderate damage (45% - 65% damage), and (5) badly damaged (> 65% damage). The rate of "occurrence" is by counting the frequency of damage occurring on any building component that produces a form of failure. Occurrence was determined with a scale of 1-5, with the criterion from the lowest to the highest as follows: (1) When in 20 years there is no damage, it is considered "never happened". (2) Once in 10 years is determined as "rarely". (3) Once in 5 years is "frequent". (4) Once a year, and (5) 2 times a year is considered "often". "Detection" is the measurement of the damage, following the guideline of "New South Wales Guide to Standards and Tolerances, 2017". The calculation is performed on each component of the building. Criteria for detection uses a scale of 1-5 from variables with the lowest criteria to the highest: (1) difficult to detect, (2) able to be seen visually, (3) visually visible damage and requires measurement, (4) easy to detect damage, and (5) very obvious damage. A damage assessment from the lowest to the highest are discerned for the variables using the following [11]:

1. Roofs: leak due to cracks in the roof covering; edge cover of roof covers the inside of gutter as far as 50-65 mm; sheet of roof covers the inside of gutter as far as 35-65 mm, within 4m on a piece of the roof, there are different sizes exceeding 20 mm in straightness; corrosion; folded; separate; dents; loose connections; cracked; distortion.
2. Roof frames: connection cracks; vertical deviation ≥ H / 50; truss buckles horizontally ≥ L / 200/50 mm, where L = length of the rod; folded connection; separate; dents; loose, corrosion.
3. Frames and ceiling cover: spots on the ceiling and humidity; wide cracks in the ceiling> 1 mm; bending in frame≥ L / 200 or50 mm; the width of the connection cracks> 1 mm; partial ceiling collapse.
4. Columns and beams: cracks with a width <0.2 mm; cracks in the concrete surface with crack width

between 0.2 mm - 1.0 mm; cracks are visible with the wide cracks between 1-2 mm; concrete reinforcement visible; reinforcement bending / tilt / deflection.

5. Wall filling: hairline cracks with a crack width <0.2 mm; width of cracks> 0.3 mm; bending crack spreads and continue along the walls; change of horizontal position; collapsed in part or total collapse.
6. Paint on walls: damp; fading; blistering; flaking; peeling.
7. Sills: damp; moldy; damage with connections and the volume; the distance between the sills and window; deflection.
8. Doors: non-uniform distances; handles and locks do not function properly; the distance between the doors of the <2 mm or> 5 mm of width; the distance between the door and the floor> 20mm; looseness.
9. Window shutters: distances are not uniform; handles and locks do not function properly; porous; the distance between the shutters <2 mm or> 5 mm of width; separation.
10. Floor: cracked; chipped; a decrease in the span of 2 m by 4 mm; separation; floor rise> 40 mm.
11. Electrical installations: nonfunctioning; broken lights; broken plugs and switches; plugs; switch; lights not installed; sockets; lights; Broken cables / not installed.

The RPN calculation with a value of "severity", "detection", and "occurrence" in accordance with the criteria per building component.

Table 2 is an example to calculate RPN for SDN Puger Kulon 02, using FMEA Executive DemoV6.0-2012-01-01 software from Symphonytech. Through this table, we can get the result of index of building damaged for each component.

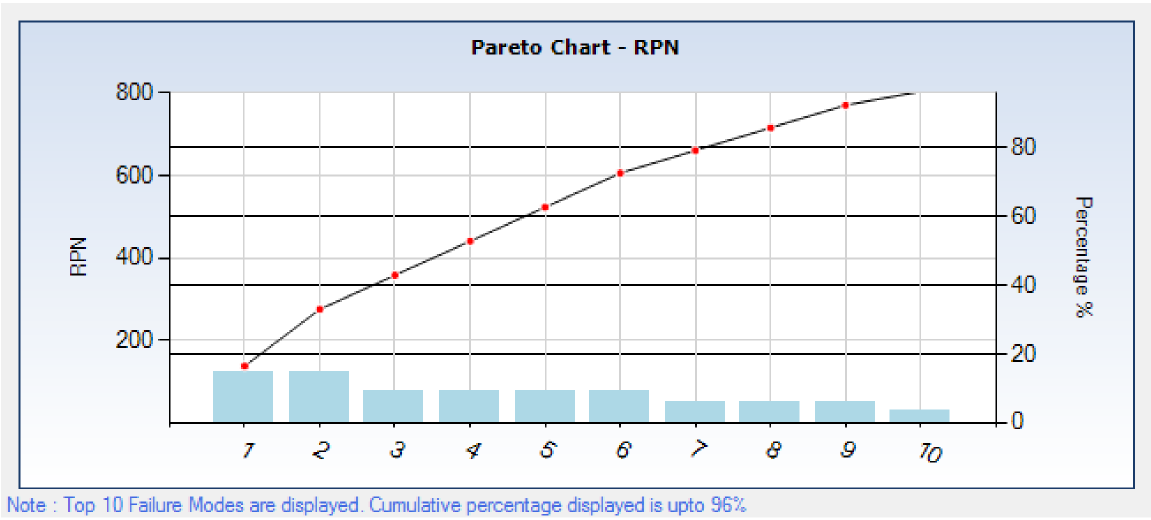

Figure 2: Pareto Chart

Pareto chart is used to identifying a potential cause of problem based on frequency and severity. [13] Top 10 values of failure mode is identified on figure 2. By calculate the average of RPN value from research data, we get the information that damaged index, for this school is 69.

Table 2: Sample calculation of damage index

Failure Mode Description	Effect Description	Severity	Cause Description	Controls Prevention	Occurrence	Controls Detection	Detection	RPN	Cumulative %
FMEA No : 17 - SDN PUGER KULON 02 FMEA Desc : SDN PUGER KULON 02 System : 11 Type : P									
Roofs : crack, deviation, corrosion, buckles, separate, dents	Collapse	5	weathered, dents, overload	identification, replace improper structure	5	visualize and measuring	5	125	17%
Roof frames: damp, fading, blistering, flaking peeling	User convenience	5	service period, moist	identification	5	visualize and measuring	5	125	33%
Frames and ceiling cover: cracked, chipped, separation, floor rise	User convenience	5	overload, service period	identification	3	visualize and measuring	5	75	43%
Columns and beams: Damp, moldy, connection failure	User convenience, worn, weathered	5	weathered, service period, deflection, looseness	identification	3	visualize and measuring	5	75	53%
Wall filling: Function failure, distance with sills	User convenience, worn, weathered	5	weathered, service period, looseness	identification	3	visualize and measuring	5	75	63%
Paint on walls: function failure, distance between sills	User convenience, worn, weathered	5	weathered, service period, looseness	identification	3	visualize and measuring	5	75	73%
Sills: crack, leaking	User convenience, life safety , leak	5	overload, distortion	identification	2	visualize and measuring	5	50	79%
Doors: spot, crack, bending	User convenience, life safety, leak	5	Leak, crack connection, service period	identification	2	visualize and measuring	5	50	86%
Window shutters: nonfunctioning, broken	User convenience	5	service period	identification	2	visualize and measuring	5	50	92%
Floor: crack ,changed of horizontal position	User convenience, life safety ,collapse	5	service period, moist	identification	2	visualize and measuring	3	30	96%
Electrical installation: Crack, weathered	Collapse, life safety	3	overload, service period	identification	3	visualize and measuring	3	27	100 %

3. Result and discussion

By using the FMEA method, it can achieve RPN values that could immediately determine two damage indexes, namely building component damage index and damaged school in coastal area index. Figure 3 shows the results of calculation of the index of building component damage from the RPN values.

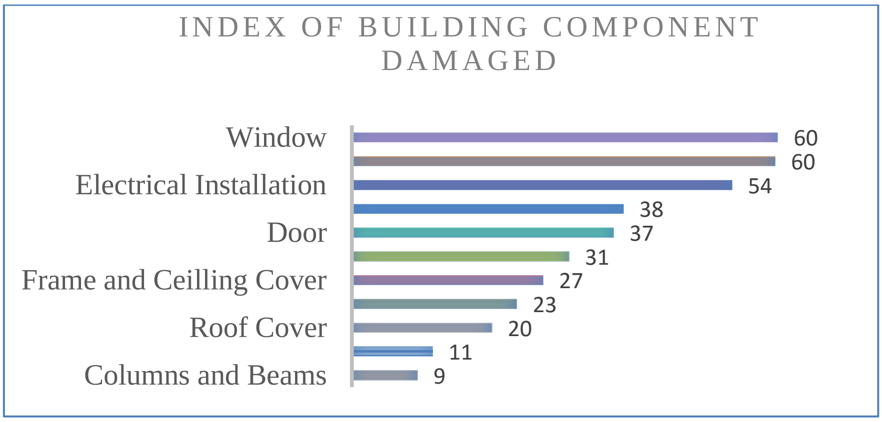

Figure 3: Index of damaged building components

The building component damage index is divided into three criteria. Minor damage (damage index 0-23) derived from component of columns and beams, wall charger, roofing and roof frame. Moderate damage (damage index > 23-46) from components of the framework and ceiling coverings, flooring, doors, sills. And damaged (damage index > 46-69), namely the electrical installation components, wall paint and window shutters. Elementary School building damage index, which is divided into 4 criteria: very mild damage (0-30 damage index), slightly damaged (damage index 30-45). moderate damage (damage index 45-65) and heavy damage (damage index> 65). RPN calculation results are shown in Figure 4.

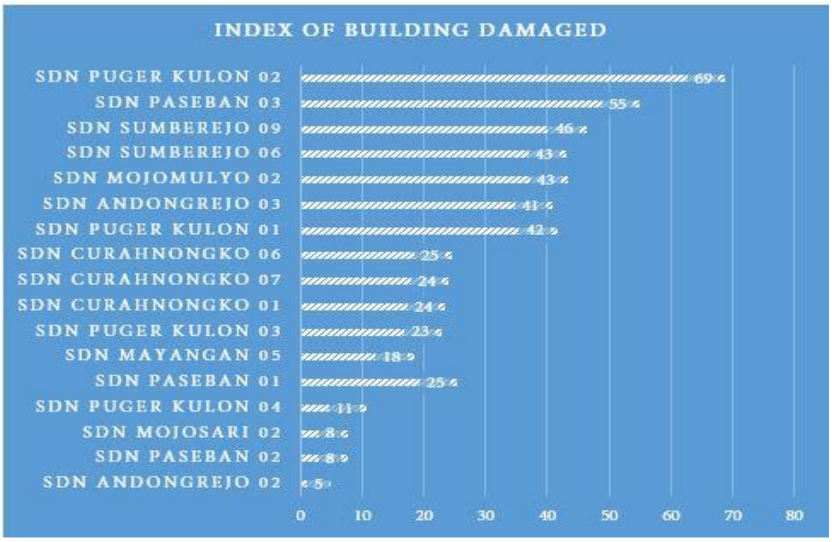

Figure 4: Building damage index

After the value of RPN is obtained, a risk response action needs to be done to the studied building. RPN levels 30-45 RPN would need minor repairs; 45-65 require retrofitting; and > 65 requires reconstruction. This is in order to restore the serviceability of the building in accordance with their original functions.

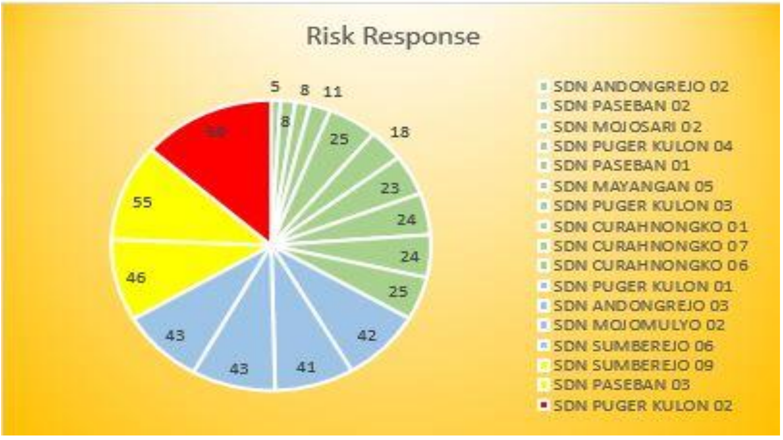

Figure 5: Risk Response

4. Conclusion

The calculation of damage Index using the FMEA method can be used to help complete the damage management instruments owned by the Government of Indonesia. By calculating the damage index of each component of the building as well as the criteria of damage to buildings, the method could holistically help in devising responses to elementary school building damage. Assessment was done using a sample of 17 elementary schools in coastal areas of Jember and acquired building damage index values show that there were 10 schools with 0-30 damage index categorized as very light damage conditions therefore needs light repair, 4 schools with 30-45 damage index categorized as light damage therefore needs repair, 2 schools with 45-65 damage index categorized as moderate damage therefore needs retrofitting and 1 school with > 65 damage index categorized as badly damaged condition therefore needs reconstruction.

Acknowledgement

This report was conducted as a suggestion in the improvement of implementation in calculating damage to buildings by the Takola SD program. This is in order to facilitate assessment of damage index and risk response to the current building conditions.

5. Recommendation

Based on this study, it is recommended to use the Failure Mode and Effects Analysis (FMEA) method in order to accelerate the process of assessing damage and serviceability on elementary school building for proposing repair and calculate a suitable repair conditions.

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