Jurnal Intelligent Decision Support System (IDSS) 7 (1) (2024), pp. 49-56

Published by: Institute of Computer Science (IOCS)

Journal of Intelligent Decision Support Systems (IDSS)

Homepage jurnal: www.idss.iocspublisher.org

Application of fuzzy logic method to determine the level of damage to buildings in elementary schools

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Info Articles

Article history:

Received Mar 16, 2024
Revised Mar 22, 2024
Received Mar 30, 2024

Keywords:

Decision Support Systems
Fuzzy Logic Methods
School Buildings

ABSTRACT

This study aims to provide information effectively and efficiently about the condition of damage to elementary school buildings to assist schools in determining decisions about buildings in schools that must be repaired immediately. In research, the application of fuzzy logic methods to assess the extent of damage to elementary school buildings will depend heavily on the research design, processes, and data used to develop and test fuzzy logic models. This approach involves reviewing, synthesizing, and evaluating a variety of literature sources, including scientific journals, books, conference papers, articles, and other written sources. It is important to consider that the value and novelty of a study can be assessed by the scientific community and practitioners in related fields, and the results will depend on the ability of that research to make a meaningful contribution. The value of applying fuzzy logic methods to determine the extent of damage to elementary school buildings will provide a more complete picture of the contribution of such research to science and practice in the field concerned.

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Introduction

Elementary school buildings are often in high use and can be damaged by factors such as age, earthquakes, extreme weather, or non-compliance (Ruang Pramuka Pu, 2022) (Daniel et al., 2014) (Batvian & Manullang, 2022). Therefore, maintenance, maintenance, and damage assessment of such buildings are essential to effectively and accurately determine damage to elementary school buildings (Rizki & Marina 2019) (Goddess, 2020).

In this study, the application of the Fuzzy Logic method is an approach in the fields of computer science and mathematics used to overcome uncertainty and variability in decision making. Conventional methods may be less able to accommodate the complexity of field realities that are often not linear. Assessment of the extent of damage to buildings often involves an element of subjectivity from experts. Fuzzy logic can help in dealing with this subjectivity by providing a clearer mathematical framework. Data on building damage are often incomplete or uncertain. Fuzzy logic can work well in situations where there is uncertainty in the data. Conventional mathematical models may not be flexible enough to model relationships between various variables that affect the extent of building damage (Rosani et al., 2020) (Dirjen et al., 2017) (Wiyanto & Justin, 2019).

The formulation of the problem for this study is how to apply the fuzzy logic method to determine the level of damage to elementary school buildings by taking into account the uncertainty, complexity, and subjectivity associated with data and assessment processes, as well as how to develop models that can provide accurate results and are useful for decision making related to maintenance and repair of elementary school buildings.

The purpose of applying fuzzy logic methods to determine the extent of damage to elementary school buildings in fuzzy inference systems can address the problem and achieve some desired results in increasing effectiveness, relevance, and helping to create a more adaptive grading system, responsive to the various conditions and variables involved (Oktavia et al., 2020) (Seth, 2019).

The research is needed to provide a more accurate assessment of building damage to prevent potential harm to students and school staff. Allocate resources efficiently by knowing the most pressing building repair priorities. Reduces subjectivity in assessments and allows for more accurate assessments even in situations of incomplete data. Enable quick and responsive evaluation of post-disaster building damage for more effective recovery. (Mathematics, 2018) (Arifin et al., 2016) (Ahsanandi & Avaludin, 2022). The purpose of this study is to be able to provide information effectively and efficiently about the extent of damage to elementary school buildings in order to assist schools in determining decisions about buildings in schools that must be repaired immediately (Ahmadi et al., 2022) (Purnawirawan dkk., 2022).

Method

Research Design

This study was designed to evaluate the effectiveness of the Fuzzy Logic method in determining the extent of damage to elementary school buildings including systematic and holistic steps (Muttaqin et al., 2021) (Pujianto et al., 2019). In this study, relevant variables have been determined and the necessary data have been collected to support the analysis (Tundo et al., 2020). Through the establishment of Fuzzy rules based on expert knowledge, Fuzzy Logic systems can be implemented to process data and generate predictions about the extent of damage to buildings (Nasution & Prakarsa, 2021) (Arjuna et al., 2021).

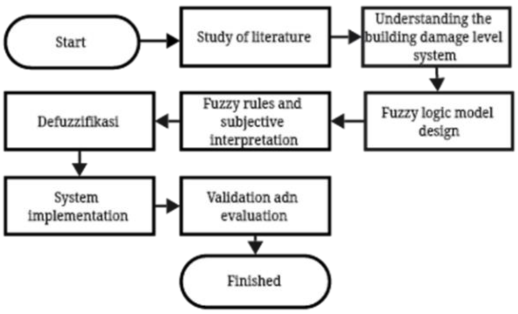

Figure 1. Research flow

Figure. 1, shown the flow of research, which starts from searching for literature studies in reputable journals, then an understanding of the level of damage to the elementary school building system is obtained, then designing a fuzzy logic model, the system is followed by fuzzy rules and subjective interpretation, then defuzzification is carried out, the results of defuzzification are implemented into the vehicle system the results are validated and evaluated.

Data Collection

The data collection process involves collecting data from category or percentage analysis and drawing the level of damage to elementary school buildings based on the extent of damage. This data can come from relevant sources, such as primary school building damage analysis data. The data in this study was taken from https://www.dapodik.co.id/2019/11/metode-analisis-tingkat-kerusakan.html web. The level of damage caused to buildings is grouped into three categories of minor damage (0-30%), moderate damage (30%-40%), heavy damage (45%-65%), and total damage of more than 65%.

Pre-processing Data

In the process of data processing to be carried out, the creation of this system applies fuzzy rules based on the data obtained (Arjuna et al., 2021). The second part is the fuzzy output visualization process. The first step that must be done is to find the output value of the fuzzy process using the Mamdani method (Muhtadi et al., 2024) (Logika et al., 2024). At this stage there are 4 (four) steps that must be done, namely the formation of Fuzzy Set (Fuzzyfication) with input variables (such as building age) and output variables (damage level) converted into fuzzy variables with appropriate membership functions (Julie &; Mardiah, 2018). Application of Implication Function, The implicit function used is the MIN method. Rule composition, formed to relate the condition of the set of fuzzy input variables with the set of fuzzy output variables. and Defuzzyfication defuzzification process converts fuzzy output into concrete values that can be interpreted. This value represents the level of volatility predicted by the model (Fibriani & Wijayanto, 2020).

Research Procedure

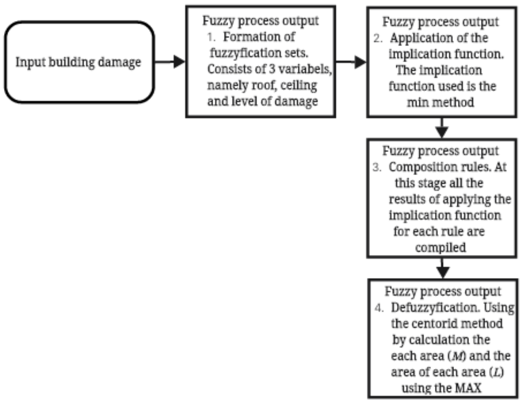

Figure 2. Schematic Diagram of the Proposed Model

Figure 2, shown workflow diagram in the application of Fuzzy Logic method with Mamdani model. Each flow corresponds to the need for research to determine the extent of damage to elementary school buildings. The formation of Fuzzy Set (Fuzzyfication) consists of 3 variables, namely Roof, Ceiling and Damage Level, to obtain membership values from fuzzy input values. Application of Implication Functions Implication functions that the MIN method uses. The MIN (minimum) implication function in fuzzy logic describes the relationship between two fuzzy sets. In other words, if A and B are two fuzzy sets, A MIN B will give a fuzzy set that guarantees a minimum membership level between elements A and B. The composition of the rules at this stage all the results of the application of the implication function of each rule are compiled using the MAX method. The defuzzyfication process converts the output of a fuzzy logic system into real values or actions in the continuous domain. In the context of determining the extent of damage to a building, defuzzyfication will produce concrete values that reflect the extent of damage.

Data Analysis

Data analysis using Fuzzy Logic methods to determine the extent of damage to elementary school buildings allows the integration of expert knowledge and input data to produce more precise estimates of damage levels.

This process includes processing input data, fuzzyfication variables, formation of fuzzy rules, inference, and defuzzyfication to produce concrete values about the extent of damage. Model validation is then performed to ensure the accuracy of the results (Muharomeita Aulia et al., 2020) (Parningotan &

Mulyanto, 2020).

This approach provides a better understanding of the condition of the building and helps in decision making regarding the maintenance, repair, or rebuilding of the primary school building.

Evaluation

The Fuzzy Logic method offers a powerful and flexible approach in determining the extent of damage to elementary school buildings. However, evaluation of these methods must consider several key factors, including prediction accuracy, conformity to diverse input data, readability of results, ease of implementation, and reliability in delivering consistent results. Despite its great potential, the evaluation shows that the Fuzzy Logic method can be a valuable tool in integrating expert knowledge and input data to improve understanding of the extent of damage to primary school buildings and assist in decision-making regarding maintenance and repair. The following is the general formula of the defuzzyfication process in order to determine the level of damage to elementary school buildings:
Let µl (*low*), µm (*Medium*), and µh (*Hig*) are membership functions for low, medium, and high damage levels, respectively, and input variables (e.g., building age, earthquake strength, etc.). In defuzzyfication, the value for the degree of damage can be calculated using the centroid method, which can be represented as:

Damage =

$$\frac{\int \mu s(low) + \int \mu n(Medium) + \int \mu h(High)}{\mu r(low) + \mu n(Medium) + \mu h(High)} \quad \text{.......} (1)$$

In the formula, integration is done to get the area under the curve of the membership function, and then divided by the total membership value to get the average or centroid value. By combining this evaluation formula and calculation, a thorough analysis of the effectiveness of the Fuzzy Logic method can be carried out in determining the level of damage to elementary school buildings.

Results and Discussion

Fuzzy set consists of 3 (three) variables, namely roof, ceiling and damage level. The variable roof has 3 (three) sets, namely small, most, whole parts. The ceiling has a set of Ringa, Medium, Heavy. Likewise, the damage level has 3 (three) sets, namely Light, Medium and Heavy.

Table 1. Set input fuzzy atap

Number	Set input Fuzzy Atap (a)		Domain
	Name	Notasi	
1	Rendah(l)	L	(50, 55)
2	Medium (m)	M	(50, 60)
3	Sum	S	(55, 60)

So that the membership value is obtained from the fuzzy input value of the roof 55, namely:
µl(55)= 0
µm(55)= $\frac{55-0}{55} = 0$
µs(55)= 0

Table 2. Set input fuzzy langit-langit (p)

Number	Set input Fuzzy Langit-langit (p)		Domain
	Name	Notasi	
1	Rendah(l)	L	(10, 20)
2	Medium (m)	M	(10, 30)
3	Sum	S	(10, 30)

While the ceiling has 3 (three) sets, namely Light, Medium and Heavy, so that it can obtain a membership value from the ceiling input value of 20, namely:

μl(20)= $\frac{30-20}{20} = 0,33$
μm(20)= $\frac{20-00}{20} = 0,667$
μh(20) = 0

The Application Implication Function used is the MIN method.
[Rule 1] if the roof is a small section and the ceiling is normal, then the degree of damage is small
a-predicate1= min (0 : 0,33) = 0
[Rule 2] if the roof is a small section and the ceiling is normal then the degree of damage is moderate
predicate-A2= min (0 : 0,667) = 0,33
[Rule 3] if the roof is small and the ceiling is heavy then the degree of damage is heavy
a-predicate3= min(0 : 0) = 0
[Rule 4] if Most of the roof and ceiling are light then the degree of damage is small
a-predicate4 = min (1 : 0,33) = 0,33

Variable output damage rate.
- Low set membership value (a1)
- Maxlow (0 : 0 : 0)
- 0 → a1 = 0 * (100 – 10) + 10 = 0
- High set membership value (a2)
- Maxtinggi (0: 0.33 : 0.667)
- 0.667 → A2 = 0.667 * (100 – 10) + 10 =70.03

The membership function obtained from the composition of the output set is:
μ (z) $= \frac{z-10}{90}, 10 \leq z \geq 70,03$
$= 0,667, z > 70,03$
Variable output damage rate:

$$M1 = \int_{0}^{10} (0) z dz = 0$$

$$M2 = \int_{10}^{70,03} \frac{z-10}{90} z\, dz$$

$$M3 = \frac{1}{90} \int_{10}^{70,03} z^2 - 10z\, dz$$

$$= \frac{1}{90} [14480.3963 - 24521.0045] - [333.333 - 100]$$

$$= \frac{1}{90} \left[\frac{1}{3} z^3 - \frac{10}{2} z^2\right]$$

$$= \frac{1}{90} [89959.3918] + [166.667]$$

$$= \frac{1}{90} [90126.0588] =] = 1001.400653$$

$$M3 = \int_{79,04}^{100} 0,667z\, dz \left[\frac{0,667}{2}\right] z^2$$

$$= \frac{0,667}{2} 100^2 - \frac{0,667}{2} 170,041^2$$

$= 3335 - 1636,018134$

$= 1698,981866$

L1= *10 * 0 = 0*

L2= $(0 + 0,667)x\frac{(70,03 - 10)}{2} = 0,667x30,015 = 20,020005$

L3= (100 – 70.03) x 0.667 = 19.98999

Center point = (*M1*+*M2*+*M3*)(*L1*+*L2*+*L3*)

$$= \frac{(0 + 1001,400653 + 1698,981866)}{0 + 20,020005 + 19,98999} = \frac{2700,282519}{40,009995}$$

$= 67,49269824$

From the above calculations, it can be estimated that the consequences of the level of damage to the building are:
67, 49 %

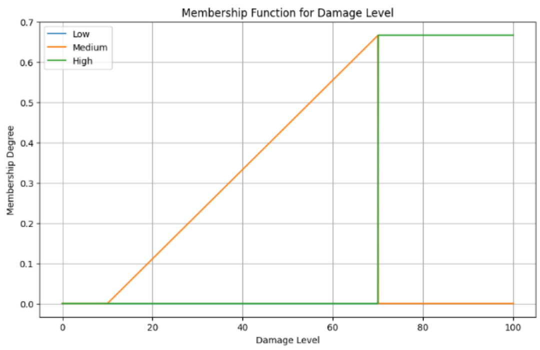

Figure 3. Chart membership function for Damage Level

Figure 3, Low Damage Rate This fuzzy set has a high membership value (value 1) in the range of values from 0 to about 10, indicating that a low level of damage would be very likely to occur in buildings with minor damage, such as cosmetics or insignificant damage. This fuzzy set had a membership value that increased linearly from about 10 to about 70, indicating that moderate levels of damage were likely to occur in buildings with more significant damage, but still in the manageable category or in need of considerable repair. This fuzzy set has a fixed membership value of around 0.667 for a damage value above about 70, indicating that a high level of damage is likely to occur in buildings with very serious damage, such as structural damage or even conditions that compromise safety.

Results Discussion

In the application of this method, there are three fuzzy sets for building damage levels (M1, M2, M3), each with a different membership function. The input variable used is the length of the crack in the building. Through the calculation of the given integral and mathematical formulas, the values of the fuzzy sets M1, M2, and M3 are calculated based on the given input data. Furthermore, linguistic values (L1, L2, L3) are also calculated based on input data, indicating the contribution of each fuzzy set to the degree of damage. Using a central point, fuzzy set values and linguistic values are used to determine the final result on a percentage scale, which is an estimate of the degree of damage to elementary school buildings. Based on calculations, the result of the damage rate of elementary school buildings is 67.49%. This indicates that the building has suffered a significant level of damage, but is still in the manageable category or needs further repair. Thus, the results of applying the Fuzzy Logic method provide a useful estimate of the extent of damage to an elementary school building, but still need to be considered along with other information to make an informed decision regarding the repair or maintenance of the building.

Conclusion of Discussion

This method uses two input variables, namely the condition of the roof and ceiling of the building, with each having three fuzzy sets describing different conditions. The membership function is used to determine the membership level of each input variable on the relevant fuzzy set. The MIN method is used in implication function applications, where fuzzy rules are used to determine the degree of damage based on the membership value of the input variable. After applying the implication function, set composition is performed to generate variable membership values from the output of the building's damage rate. Through the process of defuzzyfication, the membership value of the output set is converted into a single value that represents the degree of damage to the building concretely. From the calculations made, it is estimated that the damage rate of elementary school buildings is 67.49%. Thus, the conclusion of the application of the Fuzzy Logic method is that this method can be used to provide an estimate of the level of damage to elementary school buildings based on the observed roof and ceiling conditions.

Conclusion

This research will contribute to the development of more effective and accurate assessment methods to determine the extent of damage to elementary school buildings, providing a stronger foundation in decision-making related to repair and maintenance. By providing a more precise assessment of building damage, the study will contribute to improving the safety of students and school staff from potential hazards arising from damaged buildings. The scientific contribution of this research makes an important contribution in the development of more sophisticated and efficient building damage assessment methodologies, providing a solid scientific foundation for the management and maintenance of primary school infrastructure. It will also pave the way for the use of other analytical techniques in similar contexts. This research may be limited by the availability of accurate and complete data on damage to elementary school buildings. Field validation is needed to ensure that the fuzzy logic methods developed can really be applied well in real situations and produce relevant predictions. Future research may try to develop a more comprehensive model by considering more variables that influence damage to primary school buildings. Using multi-site case studies can help in validating the effectiveness of fuzzy logic methods across multiple geographic contexts and building environments. Technology integration such as the use of satellite imagery or remote sensing for monitoring and mapping building damage could also be the focus of future research.

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