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DECISION SUPPORT SYSTEM FOR IDENTIFYING FIRE-PRONE AREAS USING THE FUZZY ANALYTICAL HIERARCHY PROCESS METHOD

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ABSTRACT

Fire is a harmful and difficult-to-control blaze. Recently, the occurrence of fires has often been caused by factors such as human error. This research aims to develop a decision support system to help identify fire-prone areas in the village of Made, Lamongan Regency. The study incorporates several criteria, including distance from water sources, road width, building materials, and population density. Data for this research was collected from all 27 districts, 12 sub-districts, and 476 villages in Lamongan Regency.The development of this system begins with the collection of relevant data, including the distance from water sources, road width, building materials, and population density in the village of Made. The subsequent step involves designing the decision support system using the Fuzzy Analytical Hierarchy Process (FAHP) method. The calculation of fire-prone areas is carried out using the FAHP method. Subsequently, a web-based system is built using the PHP programming language. The results indicate that this system is capable of providing information on fire-prone areas with an average user satisfaction rate of 81.6%.

***Keywords**— Decision Support System, Fire, Lamongan, FAHP*

I. INTRODUCTION

A fire is a damaging and hard-to-control blaze. In recent times, occurrences of fires are often caused by factors such as human negligence (human error). Other causes can also come from nature, such as lightning, earthquakes, or drought. Fires cannot be predicted and their timing, causes, extent, and impact cannot be determined, nor can their scope and magnitude be ascertained (Imansyah, 2021), (Bachri, 2019).

Lamongan Regency is a region prone to experiencing fire disasters. Fires in Lamongan have caused losses amounting to tens to hundreds of millions and have led residents to lose their homes. Based on initial data obtained, Lamongan Regency consists of 27 Sub-districts, 12 Urban Villages, and 476 Rural Villages. From the acquired data, all Sub-districts in Lamongan have experienced fires, but these fires are concentrated in only a few Villages, such as Deket Wetan Village, Made Village, Kandang Semangkon Village, Kranji Village, Prijekngablak Village, Sendang Rejo Village, Jetis Urban Village, Sukomulyo Urban Village, and several other Villages/Urban Villages.

The decision-making process to identify fire-prone areas requires accurate and effective decisions in order to avoid mistakes and minimize losses in terms of costs and time (Handoyo, et al., 2014). Decision Support System (DSS) is a system that can aid in making decisions within an organization or company. DSS has advantages in solving complex problems in terms of both hardware and software. DSS is also capable of generating decisions quickly and with a reliable level of accuracy. (Shodiq and Saputra, 2022), (Nugraha and Gustian, 2022), (Dewi and Putra, 2021).

There are many types of popular Multi-Criteria Decision Making methods used to solve decision-making problems, one of which is the Analytical Hierarchy Process (AHP) (Jaya et al., 2020), (Balusa and Gorai, 2019). AHP is a measurement theory used to find ratio scales by comparing factors to each other (Aprillya and Chasanah, 2022), (Faisol et al., 2014). However, AHP is less effective when applied to ambiguous problems that have uncertain parameter criteria (Balusa and Gorai, 2019).

Therefore, AHP is integrated with fuzzy logic to address the uncertainty of factors influencing decision-making (Balusa and Gorai, 2019). The Fuzzy Analytical Hierarchy Process (FAHP) method is employed to make decisions under uncertainty or ambiguity. This method is an advancement of the AHP method. The FAHP method is renowned for its ability to process the weighting of multiple criteria and categories, yielding good alternative choices (Aprillya and Chasanah, 2022).

Thus, this research will design a decision support system for identifying fire-prone areas based on predefined criteria using the Fuzzy Analytical Hierarchy Process method. The development of this system involves the application of several advanced computing technologies and techniques that are commonly used (Ardiansyah and Bianto, 2022). The goal is to construct a Decision Support System for Identifying Fire-Prone Areas that can integrate multiple specified criteria, resulting in accurate location information with potential fire susceptibility. Additionally, the system will present the outcomes of the fire-prone area calculation process using the Fuzzy Analytical Hierarchy Process method with 4 parameters.

II. METHOD

The decision support system for identifying fire-prone areas based on a website employs the System Development Life Cycle (SDLC) method. The SDLC method can be seen on figure 1:

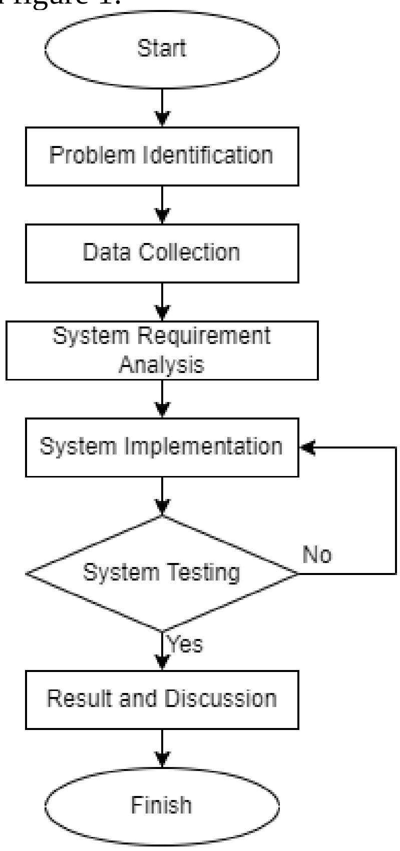

Figure 1. Flowchart System

A. Problem Identification

This phase of problem identification is carried out through literature review and field studies when observing each area in Lamongan Regency. Literature review involves understanding the factors that cause fire-prone disaster occurrences (Dharmawan and Gata, 2019).

B. Data Collection

In this phase, the necessary data for building the system is obtained, such as data on the distance from water sources, building materials, road width, and population density. The data used in this study comes from the Lamongan Regency Fire Department. Data on houses, buildings, and land are also used as alternatives in determining fire-prone areas. The parameter criteria used are the distance from water sources, building materials, road width, and population density (Dewi and Putra, 2021).

In determining the weights using the FAHP method, the criteria of building materials, road width, distance from water sources, and population density will become the main criteria. These criteria are organized into a hierarchy with the main goal, criteria, sub-criteria, and alternative solutions. Out of these 4 criteria, a questionnaire will be created and given to the Fire Department to compare which criteria are more important for fire-prone areas. Table 1 shows the comparison of linguistic scale values transformed into fuzzy number scales.

Table 1. FAHP Comparision Scale

Linguistic scale	Scale	
	AHP	TFN
Equally Important	1	(1,1,3)
Slightly More Important	3	(1,3,5)
More Important	5	(3,5,7)
Very Important	7	(5,7,9)
Most Important	9	(7,9,9)

Here are the steps that need to be taken in the calculation process of the FAHP method (Aprillya and Chasanah, 2022):

1. Defining the problem in a hierarchical structure.
2. Creating a matrix of comparisons between all criteria, then calculating the consistency ratio value of the comparison matrix with the condition CR ≤ 0.1.
3. Converting the weighting results into TFN scales as shown in Table 2.2.
4. Determining the value of the fuzzy synthetic extent Si using equations (1) to (3)

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} M_{g_i}^{j}\right]^{-1} \quad (1)$$

Where :

$$\sum_{j=i}^{m} \mathrm{M}_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (2)$$

Description:
M = TFN
m = number of criteria
j = column
i = row
g = parameter (*low, medium, upper*)
Whereas:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i-1}^{n} u_i}, \frac{1}{\sum_{i-1}^{n} m_i}, \frac{1}{\sum_{i-1}^{n} l_i}\right) \quad (3)$$

Determining the vector (V) and defuzzification ordinat value (d’). When calculating the comparison of the possibility level between 2 fuzzy numbers, for instance $M_1 = (l_1, m_1, u_1)$ and $M_2 = l_2, m_2, u_2$, assuming $M_2 \geq M_1$, then the comparison of convex fuzzy number possibility levels can use the equation (4).

$$V = (M_2 \geq M_1) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & for\ other\ condition \end{cases} \quad (4)$$

Obtained vector weights as in equation (5) as follows:

$$W = \left(d(A_1), d(A_2), \ldots d(A_n)\right)^T \quad (5)$$

Next, normalize the values of fuzzy vector weights (W') using equation (6) as follows:

$$d(A_n) = \frac{d,(A_n)}{\sum_{i=1}^{n} d,(A_n)} \quad (6)$$

C. System Requirement Analysis

System Requirement Analysis involves analyzing the attribute data requirements needed for system processing and determining the data flow to be used in designing the database. Hierarchical diagrams are used to depict data flows. The design of the database system is conducted by creating a Conceptual Data Model (CDM) and a Physical Data Model (PDM) (Mufid, R. 2017). Furthermore, the Unified Modeling Language (UML) is employed, defining a use case diagram for the developed system.

D. System Implementatiton

In this phase, the implementation of the previously created Conceptual Data Model (CDM) will be carried out into the database. This process involves data entry for criteria, sub-criteria, and alternatives, as well as coding the program using the PHP (Hypertext Preprocessor) programming language. The implementation of this system will result in an application that can be utilized to support the decision-making process (Komara et al., 2016).

E. System Testing

The system testing and maintenance process is carried out using the trial and error method. Through this process, the system's performance is evaluated, and potential issues are identified. Evaluation is conducted by distributing a questionnaire to ten respondents, and the results are calculated using predetermined formulas. From this evaluation, feedback is obtained that can be used for system improvement and maintenance to ensure optimal performance (Aprillya and Chasanah, 2022).

$$Satisfication\,\% = \frac{\sum Score}{S\,maximal}\, x\, 100\,\% \quad (7)$$

F. Result and Discussion

The data obtained from the implementation and testing of the developed and outlined system lead to conclusions drawn from that data. Through these conclusions, the issues raised can be addressed using the FAHP algorithm method for identifying fire-prone areas (Dewi and Putra, 2021) (Sundari et al., 2019).

III. RESULT AND DISCUSSION

A. Web Design Result

1. Admin Login Page

The displayed admin login of the decision support system for identifying fire-prone areas. The admin must enter a username and password to access the system and proceed to the admin dashboard page.

2. Dashboard Admin Page

Inside the Admin Page, there is a sidebar that provides menus accessible only by the admin, including:

a. Criteria Data Menu

The interface display of the criteria data menu in Figure 4 is a menu containing criteria data within the fire-prone area decision support system. Admin can manage criteria data, such as adding, deleting, and editing data.

b. Fire prone area data menu

The interface display of the fire-prone area data menu in Figure 5 is a menu containing fire-prone area data, where this data represents the fire-prone area's neighborhood data. Admin can manage fire-prone area data, such as adding, deleting, and editing data.

c. Home Data Menu

The interface display of the house data menu in Figure 6 is a menu containing complete house data along with criteria data. Admin can manage house data, such as adding, deleting, and editing data if there is incomplete data.

3. Identification Of Fire Prone Areas

The interface display of the fire-prone area identification page in Figure 7 is a user interface designed to identify fire-prone areas. Users can fill in the categories based on the criteria, and the data will later be processed and displayed in the results page.

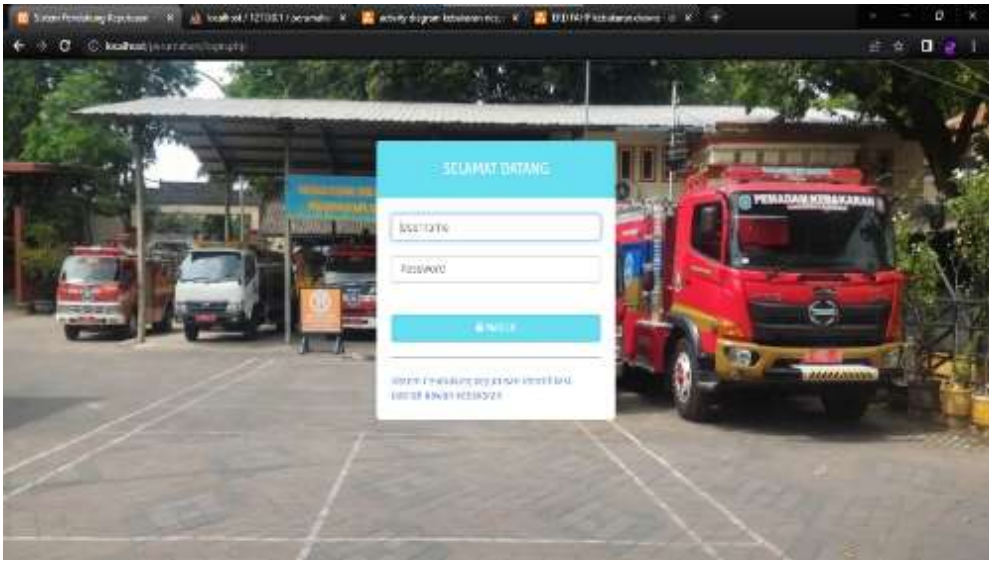

Figure 2 Admin Login Page

Figure 3 Dasboard Admin Page

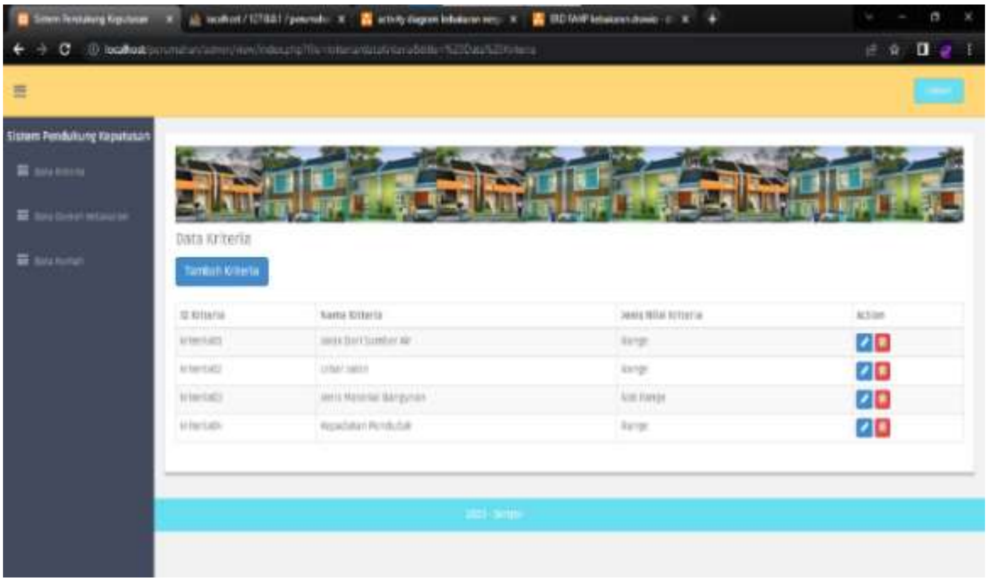

Figure 4 Criteria Data Menu

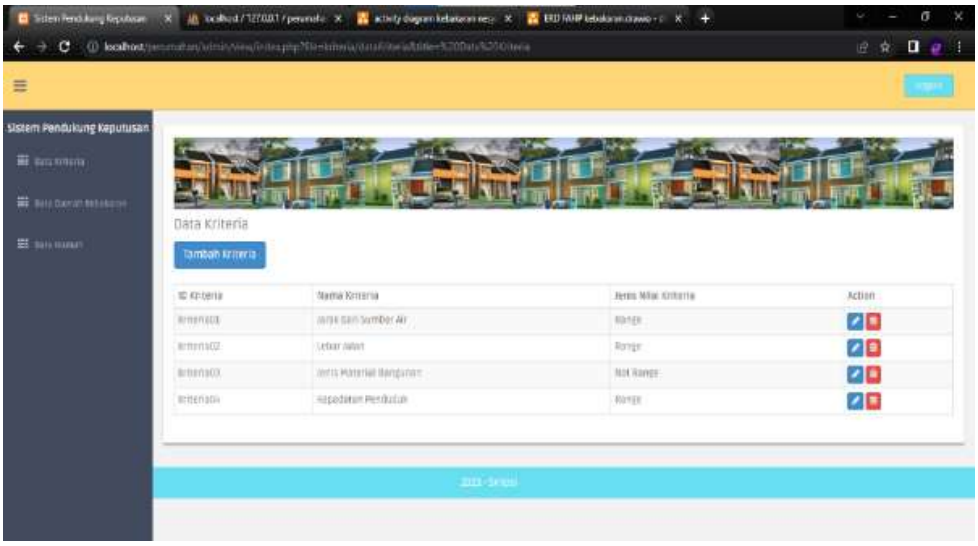

Figure 5 Fire prone area data menu

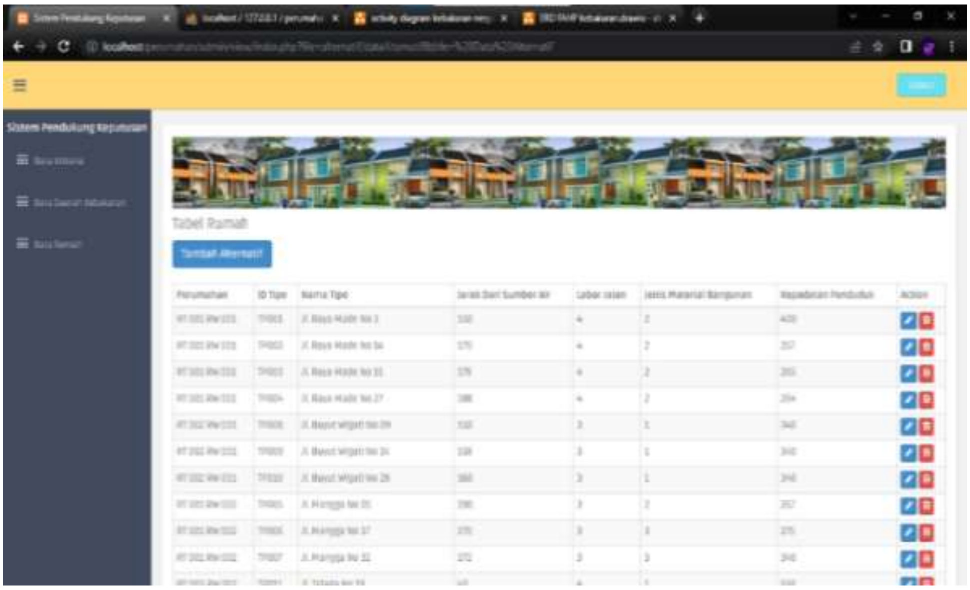

Figure 6 Home Data Menu

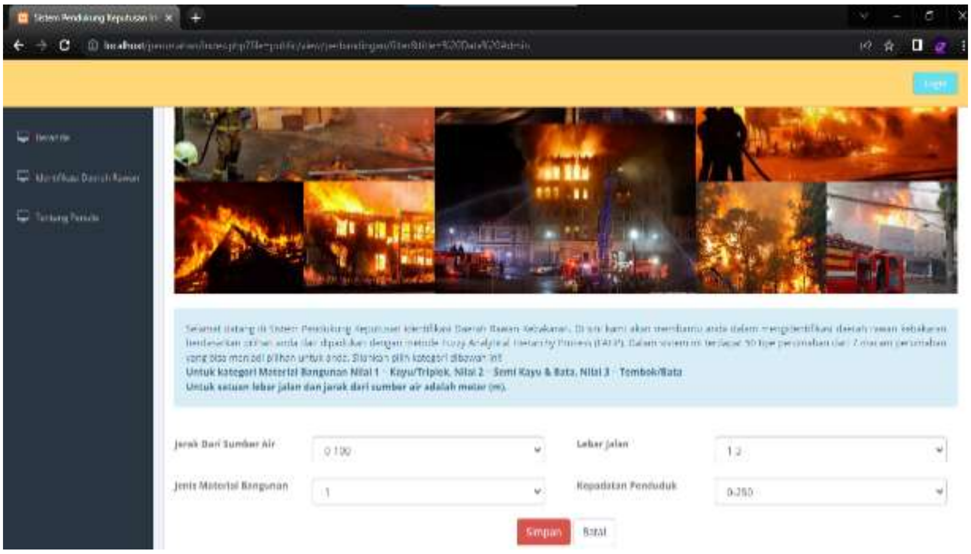

Figure 7 Identification of Fire Prone Areas

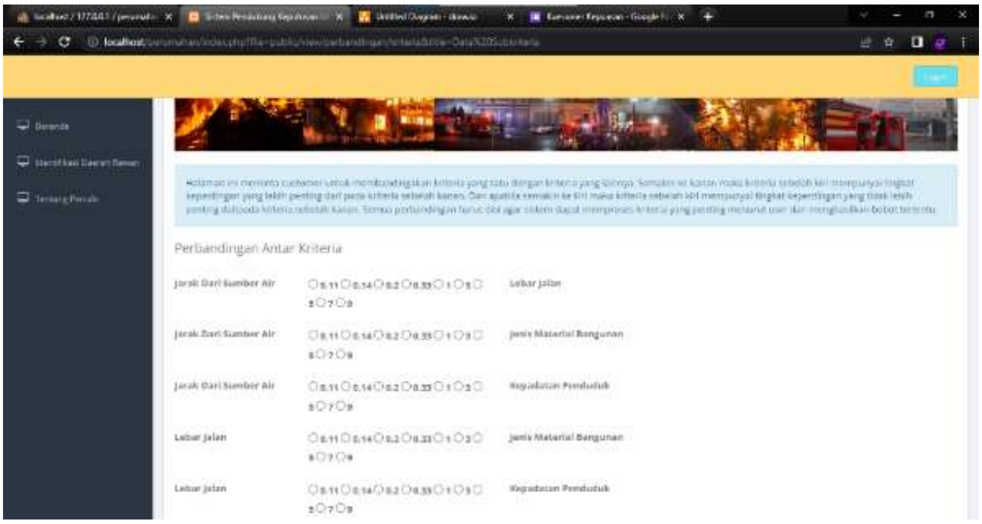

Figure 8 Page for Comparisons Between Criteria

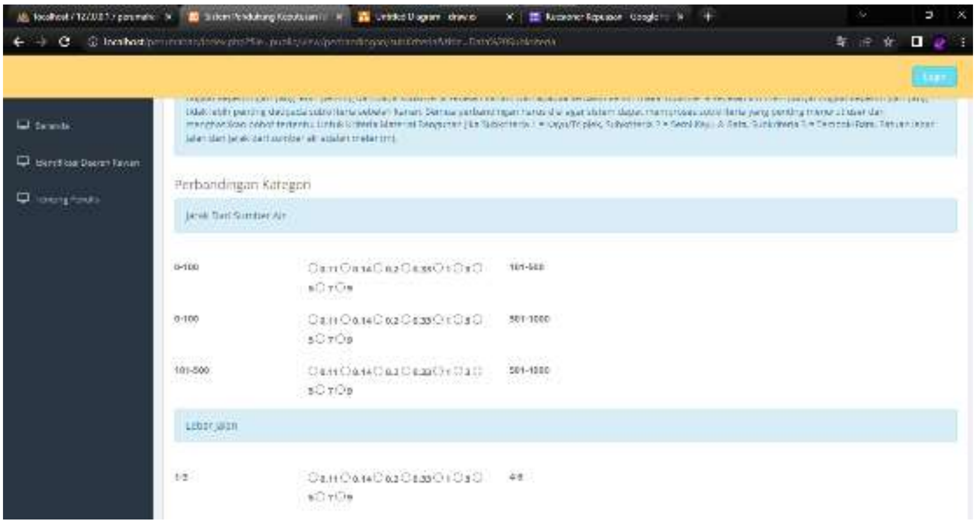

Figure 9 Page for Comparisons Between Sub Criteria

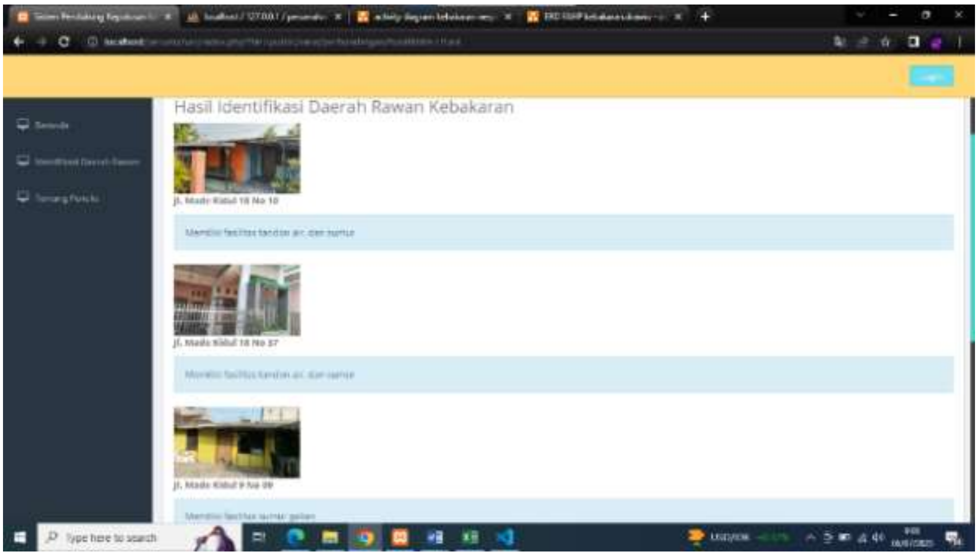

Figure 10 Results Of Fire-Prone Area Identification

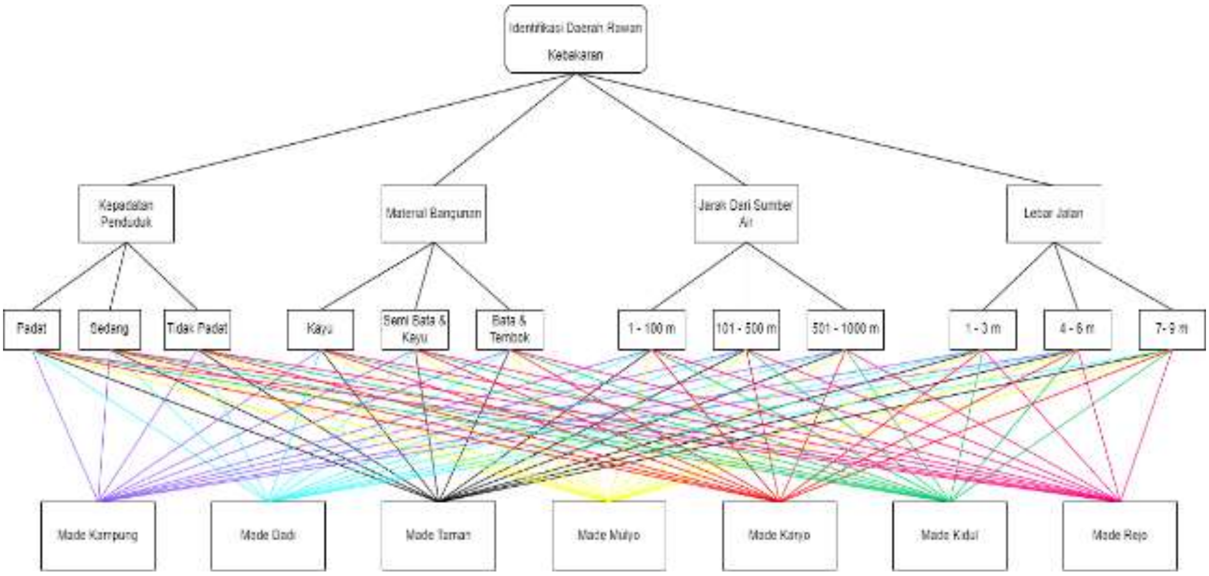

Figure 11 Hierarchical Structure

4. Page for Comparisons Between Criteria and Subcriteria

The interface display of the Comparisons Between Criteria page in Figure 8 is a user interface designed to compare criteria. Users can select the level of importance for each criterion comparison. After selecting the importance levels for criterion comparisons, users will be directed to the subcriteria comparison page.

The interface display of the Subcriteria Comparison page in Figure 9 is a user interface designed to compare subcriteria. Users can select the level of importance for each subcriteria comparison. After selecting the importance levels for subcriteria comparisons, users will be directed to the fire-prone area identification results page.

5. Results Of Fire-Prone Area Identification

The display of the fire-prone area identification results in Figure 11 represents the final outcome data from the FAHP method calculation applied within the system, showing areas with the highest vulnerability level.

B. Analysis of the FAHP Method

1. Determination of Hierarchial Structure

The hierarchical structure of fire-prone area identification can be seen in Figure 4.24. The first level represents the objective, which is the identification of fire-prone areas. The second level consists of criteria used, including distance from water source, road width, building material, and population density. The third level involves subcriteria, such as the range 0 meters – 100 meters, 101 meters – 500 meters, 501 meters – 1000 meters, range 1 meter – 3 meters, 4 meters – 6 meters, 7 meters – 9 meters, Wood/Particle Board, Semi Wood & Brick, Brick/Wall, Dense, Moderate, Not Dense. The fourth level encompasses the alternatives used, including Made Dadi, Made Kampong, Made Karyo, Made Taman, Made Mulyo, Made Kidul, and Made Rejo.

2. Used Criteria and Sub-criteria

The criteria used in this study are distance from water source, road width, building material, and population density. The subcriteria for each criterion can be seen in Table 2.

Table 2 Criteria and Sub-criteria

No.	Criteria	Sub-Criteria
1.	Distance From Water Source	0 meter – 100 meter 101 meter – 500 meter 501 meter – 1000 meter
2.	Road Width	1 meter – 3 meter 4 meter – 6 meter 7 meter – 9 meter
3.	Building Material	Wood/Particle Board Semi Wood & Brick Brick/Wall
4.	Population Density	Dense Moderate Not Dense

3. Comparison Matrix

There are 4 criteria used, namely distance from water source (DWS), road width (RW), building material (BM), and population density (PD). Furthermore, calculating the relative importance level of one criterion to another can be seen in the pairwise comparison table in Table 3.

Table 3 Comparison Matrix

Criteria	DWS	RW	BM	PD
DWS	1,000	9,000	7,000	5,000
RW	0,111	1,000	5,000	3,000
BM	0,143	0,200	1,000	3,000
PD	0,200	0,333	0,333	1,000
AMOUNT	1,454	10,533	6,333	12,000

Next, perform calculations for the priority weight matrix and the total matrix based on criteria to obtain the consistency ratio value, with the condition CR ≤ 0.1, as shown in the calculation table 4 below:

Table 4 Matrix Rasio Consisstency

Criteria	Amount	Priority	Results
DWS	4,7908	0,7660	5,5569
RW	1,2731	0,3027	1,5758
BM	0,5301	0,1313	0,6614
PD	0,3742	0,0763	0,4505
Amount			8,2446

From the calculations conducted above, the maximum λ value found is 2.06. The CI value is -0.65. The IR value is 1.24, and the consistency ratio value is -0.52, indicating that this matrix is consistent. Furthermore, the weight results from the paired comparison assessment will be transformed into the TFN scale as indicated in the table above. The following are the results of calculating the sum of each TFN number and the results of the total sum inverse, according to Equation 3 displayed in Table 5 and Table 6 below.

Table 5 Invers Criteria

	Low	Middle	Upper
DWS	16,0000	22,0000	26,0000
RW	5,1111	9,1111	13,1429
BM	2,2540	4,3429	6,5333
PD	1,5429	1,8667	3,3333
AMOUNT	24,9079	37,3206	49,0095
INVERS	0,0401	0,0268	0,0204

Next, finding the fuzzy synthetic extent value S_i as shown in the following table.

Table 6 Fuzzy Synthetic Extent

	Low	Middle	Upper
DWS	0,3265	0,5895	1,0438
RW	0,1043	0,2441	0,5277
BM	0,0460	0,1164	0,2623
PD	0,0315	0,0500	0,1338

The next step is to compare the possibility level of the fuzzy synthetic extent value with its minimum value using equation 4, which generates the vector weights among the main criteria, as listed in Tables 7 below.

Table 7 Normalization of Vector Weight

	d(A1)	d(A2)	d(A3)	d(A4)	
W	0,49	0,18	0,27	0,06	1,000

The next step is to perform Fuzzy AHP calculations for each house in Made Village to display fire-prone areas based on the ranking of weights that are most susceptible to fire. There are 5 fire-prone houses out of 50 house data. The following is the list of fire-prone houses determined by the highest weight values, which can be seen in Table 8.

Table 8 Fire Prone Areas

No.	Alamat Rumah	Nilai Bobot
1.	Jl. Made Kidul 18 No 10	0,68692
2.	Jl. Made Kidul 18 No 37	0,68692
3.	Jl. Made Kidul 9 No 09	0,68692
4.	Jl. Made Kidul 2 No 17	0,68692
5.	Jl. Masjid No 11	0,57102

User acceptance testing involves creating a questionnaire containing questions about the built system. The questionnaire is distributed to respondents along with their names, ages, and occupations. The questionnaire consists of around ten objective questions, where respondents can select answers based on the issues at hand. The questionnaire is in the form of a Google Form and is filled out by the firefighting team. The assessment uses a scoring range of 5 for Yes (Y), 3 for Uncertain (U), and 1 for No (N). The following is the result of respondent satisfaction based on the questionnaire satisfaction, as shown in Table 9.

Table 9 Penilaian Kuesioner

Questions	Score	Presentase
P1	25	100%
P2	13	52%
P3	25	100%
P4	25	100%
P5	9	36%
P6	23	92%
P7	25	100%
P8	9	36%
P9	25	100%
P10	25	100%
Total	204	81,6%

Based on the average results of the system evaluation, a satisfaction rate of 81.6% was obtained regarding the presence of the decision support system for identifying fire-prone areas in Made Village, Lamongan District.

IV. CONCLUSION

Based on the results obtained from the research on the development of a decision support system for identifying fire-prone areas using the Fuzzy Analytical Hierarchy Process (FAHP) method, it can be concluded that:

1. The implementation of the Fuzzy Analytical Hierarchy Process (FAHP) method in the decision support system for identifying fire-prone areas can process data to generate decisions in the form of ranking values. These values can be used as assistance in objectively determining fire-prone areas based on the results of criteria comparison and calculation.
2. The findings of this research provide information about the processing and calculation of fire-prone areas using the decision support system with the Fuzzy Analytical Hierarchy Process (FAHP) method with 4 parameters. The testing results of the decision support system yielded a satisfaction rate of 81.6%."

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