Web GIS-Based Mapping of the Level of Damage to Houses Caused by Natural Disasters

M. Masruri[1], Khurotul Aeni, M. Kom[2], Fathulloh, S. T, M. Kom[3]
[1,2,3]Informatika, Fakultas Sains dan Teknologi, Universitas Peradaban
Email: [1]mhdmasruri9@gmail.com, [2]khaeni988@gmail.com, [3]fathulloh@gmail.com
Coresponden Author : mhdmasruri9@gmail.com

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Abstract - *Natural disasters can cause significant physical damage, especially to residential buildings. This study aims to develop a Web GIS-based mapping system for assessing the level of damage to houses caused by natural disasters in order to assist in the efficient identification and mitigation of post-disaster conditions. The research was conducted in Sridadi Village, Sirampog District, Brebes Regency, which is one of the areas prone to landslides. The damage assessment method uses scoring and weighting based on guidelines from the Ministry of Public Works and Public Housing, which covers building components such as foundations, columns, walls, and others. The system was built using the Django framework and PostgreSQL database. Testing was conducted using the Black Box method and User Acceptance Test (UAT). The test results showed that 91% of respondents stated that this Web GIS was very helpful for affected communities in determining the level of damage, and 78% stated that this system was useful for post-disaster planning and decision-making. These results prove that the Web GIS that was developed is effective in presenting spatial information and supporting the disaster recovery process.*

Keywoard – *Geographic Information System, Mapping, Natural Disasters*

1. INTRODUCTION

Indonesia is a country prone to natural disasters. As part of the Pacific Ring of Fire, Indonesia is classified as a country with a high risk of natural disasters. This geographical location makes Indonesia prone to earthquakes and volcanic activity. More than 130 active volcanoes are scattered throughout the region, making Indonesia's seismic activity among the highest globally. A chain of volcanoes stretches from Sumatra, Java, Sulawesi to Nusa Tenggara and forms the contours of the southern and eastern regions. Many areas consist of lowlands and ancient volcanic mountains, with geographical conditions such as swamps that increase the potential for disaster. In addition, Indonesia's position between the Indian Ocean and the Pacific Ocean contributes to high rainfall and the potential for storms[1].

Data from the National Disaster Management Agency (BNPB) shows that in April 2024, there were 122 disaster events in various regions of Indonesia. Among them were 88 floods, 12 other disasters, 11 cases of extreme weather, 9 forest and land fires, and one volcanic eruption and one earthquake each. The number and types of disasters reflect the high vulnerability of Indonesia to natural disasters. As a result of these events, approximately 3,950 houses were damaged during that month[2].

Brebes Regency, located in Central Java Province, is known to be highly vulnerable to natural disasters, such as floods, earthquakes, and landslides. One of the areas that is often affected is the southern part of Brebes, particularly Sirampog District[3]. Sirampog's topography, which consists of highlands with steep slopes, makes it prone to landslides. According to a report by Detik.com in early 2024, specifically in February, there was a landslide with moderate to high intensity. In Sridadi Village, Sirampog District, 68 houses were damaged due to ground movement. A total of 55 families were forced to evacuate for safety reasons. This incident occurred in Limbangan Hamlet, and according to the Head of Sridadi Village, Sudiryo, the disaster had been ongoing since Sunday, February 25, 2024[4].

Presidential Regulation No. 17 of 2018 concerning the implementation of disaster management in certain circumstances states that disaster management consists of the stages of emergency preparedness, emergency response, and emergency transition to recovery[5]. One of the things that needs to be done in the emergency response stage is a quick and accurate assessment or identification to map the level of damage so that it can help in determining the needs for mitigation efforts. However, Indonesia's diverse geographical conditions and difficult

access in some areas make it difficult in certain cases to identify damaged objects at disaster sites. Therefore, a system is needed to help determine and map the level of damage to a building so that it can facilitate stakeholders.

Referring to the previous background description, this study is titled “Mapping the Level of Damage to Houses Due to Natural Disasters Based on Web GIS”. This study aims to facilitate the process of identifying and mapping the level of damage to houses affected by disasters.

2. RESEARCH METHOD

2.1 Research Stages

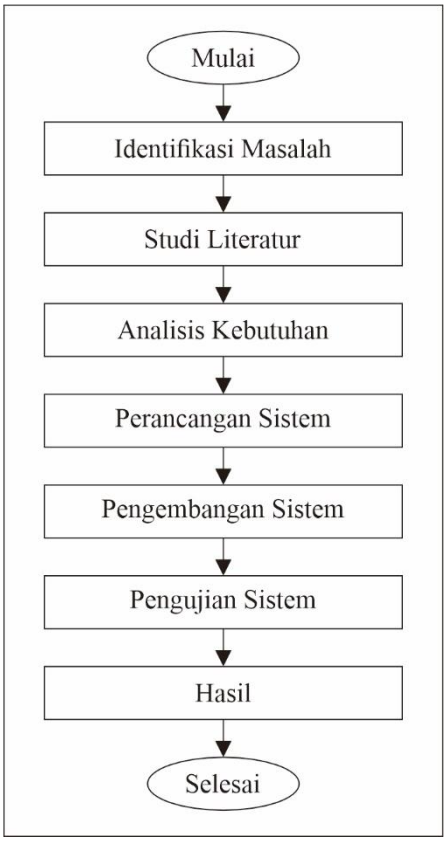

Figure 1. Research Stages

Description:

1. Problem Identification
   The problem in this study is the difficulty in accessing information on damage, resulting in delays in post-disaster management.
2. Literature Study
   The literature study was conducted by reviewing various relevant references, both from scientific journals and online sources, in order to gain an understanding of the theories and concepts that support this research topic.
3. Needs Analysis
   The requirements analysis stage aims to identify the features and specifications of the system required in accordance with the issues raised in this study.
4. System Design
   System design was carried out after the requirements analysis stage was completed, such as database design and interface design.
5. System Development
   System development is carried out using the Python and JavaScript programming languages with the selected framework, Django. The database used is PostgreSQL.
6. System Testing
   System testing is carried out using Black Box and UAT (User Acceptance Test).
7. Results

Helps in assessing the level of damage to houses and assists in planning relief and recovery efforts for stakeholders.

2.2 Scoring and Weighting Methods

Weighting is an approach to decision making that considers a number of variables simultaneously, where each variable is given a weight according to its priority level. Scoring is the process of assigning a score or value to each class in each parameter. The score value is influenced by how much that class impacts the event. The greater the impact, the higher the score value[6]. This method is used to determine the level of damage to a house. In this study, the scoring and weighting methods established by the Ministry of Public Works and Public Housing (PUPR) were used.

2.2.1 Building Damage Assessment

The assessment of building damage was carried out by researchers using a scoring and weighting method established by the Ministry of Public Works and Public Housing (PUPR). It took into account building types consisting of one floor, two floors, and three floors. The following are the scores and weights for damage assessment based on building type.

Table 1. Assessment of damage to 1-story buildings

No.	Component Name	Damage Classification and Value							Weight
		Tr	Rsr	Rr	Rs	Rb	Rsb	Kts	
1.	Pondasi	0	0,20	0,35	0,50	0,70	0,85	1	0,12
2.	Kolom	0	0,20	0,35	0,50	0,70	0,85	1	0,10
3.	Balok	0	0,20	0,35	0,50	0,70	0,85	1	0,08
4.	Atap	0	0,20	0,35	0,50	0,70	0,85	1	0,07
5.	Diding	0	0,20	0,35	0,50	0,70	0,85	1	0,215
6.	Plafon	0	0,20	0,35	0,50	0,70	0,85	1	0,10
7.	Lantai	0	0,20	0,35	0,50	0,70	0,85	1	0,145
8.	Kusen	0	0,20	0,35	0,50	0,70	0,85	1	0,01
9.	Pintu	0	0,20	0,35	0,50	0,70	0,85	1	0,015
10.	Jendela	0	0,20	0,35	0,50	0,70	0,85	1	0,02
11.	Finishing Plafon	0	0,20	0,35	0,50	0,70	0,85	1	0,03
12.	Finishing Dinding	0	0,20	0,35	0,50	0,70	0,85	1	0,04
13.	Finishing Kusen dan Pintu	0	0,20	0,35	0,50	0,70	0,85	1	0,02
14.	Instalasi Listrik	0	0,20	0,35	0,50	0,70	0,85	1	0,01
15.	Instalasi Air Bersih	0	0,20	0,35	0,50	0,70	0,85	1	0,01
16.	Drainase Limbah	0	0,20	0,35	0,50	0,70	0,85	1	0,015

Source: Technical guidelines issued by the Ministry of Public Works and Public Housing[7].

Table 2. Assessment of damage to 2- and 3-story buildings

No.	Component Name	Damage Classification and Value							Weight	
		Tr	Rsr	Rr	Rs	Rb	Rsb	Kts	2 floors	3 floors
1.	Pondasi	0	0,20	0,35	0,50	0,70	0,85	1	0,10	0,10
2.	Kolom	0	0,20	0,35	0,50	0,70	0,85	1	0,13	0,13
3.	Balok	0	0,20	0,35	0,50	0,70	0,85	1	0,12	0,12
4.	Plat Lantai	0	0,20	0,35	0,50	0,70	0,85	1	0,07	0,10
5.	Tangga	0	0,20	0,35	0,50	0,70	0,85	1	0,03	0,03
6.	Atap	0	0,20	0,35	0,50	0,70	0,85	1	0,10	0,07
7.	Diding	0	0,20	0,35	0,50	0,70	0,85	1	0,15	0,0625
8.	Plafon	0	0,20	0,35	0,50	0,70	0,85	1	0,06	0,08
9.	Lantai	0	0,20	0,35	0,50	0,70	0,85	1	0,09	0,10
10.	Kusen	0	0,20	0,35	0,50	0,70	0,85	1	0,015	0,015
11.	Pintu	0	0,20	0,35	0,50	0,70	0,85	1	0,01	0,01
12.	Jendela	0	0,20	0,35	0,50	0,70	0,85	1	0,0125	0,0125
13.	Finishing Plafon	0	0,20	0,35	0,50	0,70	0,85	1	0,01	0,03
14.	Finishing Dinding	0	0,20	0,35	0,50	0,70	0,85	1	0,05	0,05
15.	Finishing Kusen dan Pintu	0	0,20	0,35	0,50	0,70	0,85	1	0,01	0,03
16.	Instalasi Listrik	0	0,20	0,35	0,50	0,70	0,85	1	0,02	0,03
17.	Instalasi Air Bersih	0	0,20	0,35	0,50	0,70	0,85	1	0,01	0,015
18.	Drainase Limbah	0	0,20	0,35	0,50	0,70	0,85	1	0,0125	0,015

Source: Technical guidelines issued by the Ministry of Public Works and Public Housing [7].

3. RESULTS AND DISCUSSION

3.1 System Design

3.1.1 Database Design

Database design using Entity Relationship Diagrams (ERDs). Entity relationship diagrams explain the relationships between objects used in programs. Each object is called an entity, and each entity has attributes that identify it. Entities are also interconnected, forming a relationship.

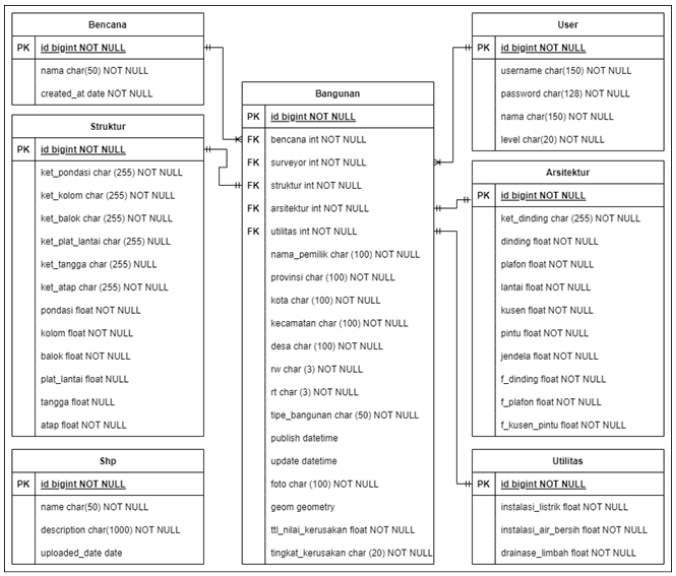

Figure 1. *ERD (Entity Relationship Diagram)*

3.2 System Implementation

3.2.1 Website Display

1. Home Page Display

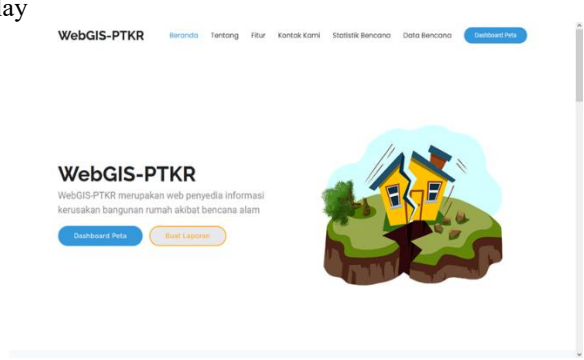

Figure 3. Home page display

The initial display on the WebGIS system is shown through a page that provides general information for users.

2. Disaster Statistics Display

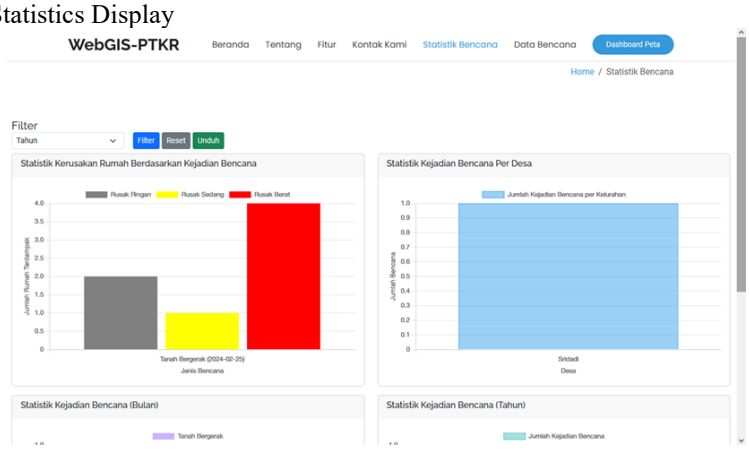

Figure 4. Disaster statistics page display

The disaster statistics page is a page that contains statistical information on disaster events.

3. Disaster Data Display

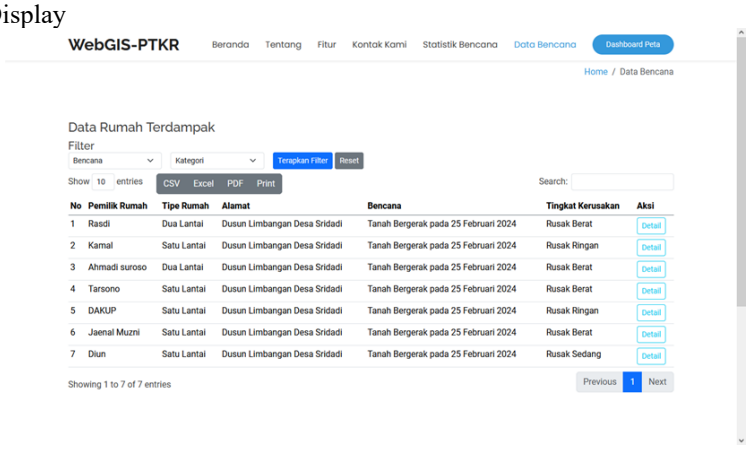

Figure 5. Disaster data page display

The disaster data page contains information on disaster events and affected buildings.

4. Map Dashboard Display

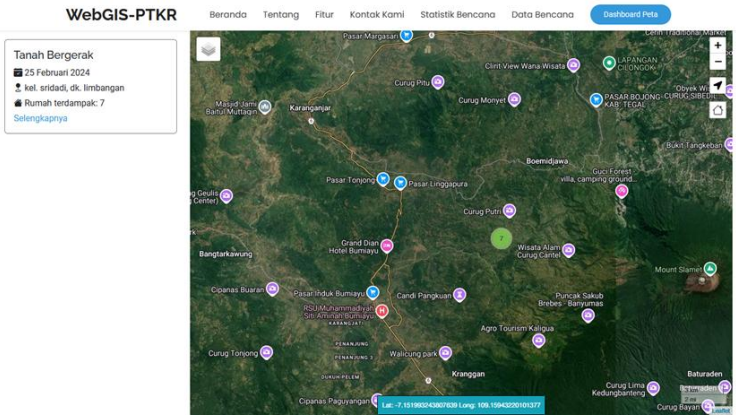

Figure 6. Map dashboard page display

The map dashboard page contains information on disaster articles and the locations of buildings affected by disasters.

3.3 Testing

3.3.1 Black Box Testing

Testing is conducted to assess the system's response to specific inputs without considering internal processes, ensuring that all features perform as expected..

1. Homepage Testing

Table 3. Homepage testing

Scenario	**Action**	**Function**	***Output***	**Result**
Map Dashboard Button	Press the map dashboard button	Go to the Map Dashboard page	Map dashboard page	Success ful
Create Report Button	Press the button to create a report	Displaying house type modals	*Modals select House Type*	Success ful
One Floor Button	Pressing the button for one floor	Go to the one-story building data input form page	Single-story building data input form page	Success ful
Two Floor Button	Pressing the two-floor button	Go to the two-story building data input form page	Two-story building data input form page	Success ful
Three Floor Button	Press the three-floor button	Go to the three-story building data input form page	Three-story building data input form page	Success ful
Home Link	Menekan tautan beranda	Go to the home page	Home page	Success ful
Home Link	Menekan tautan tentang	Go to the home page section about	Home page section about	Success ful
Fiture Link	Menekan tautan fitur	Go to the features homepage	Home page features section	Success ful

Scenario	Action	Function	*Output*	Result
Contact Link	Click on our contact link	Go to our contact page	Our contact page	Successful
Disaster Statistics Links	Pressing the disaster statistics link	Go to the disaster statistics page	Disaster statistics page	Successful
Disaster Data Links	Pressing the disaster data link	Go to the disaster data page	Disaster data page	Successful
Map Dashboard Link	Click on the map dashboard link	Go to the map dashboard page	Map dashboard page	Successful

2. 2. Disaster Statistics Page Testing

Table 4. Statistical page testing

Scenario	Action	Function	*Output*	Result
Filter Button	Pressing the filter button	Filter the data displayed on the chart according to the filter	*Disaster statistics filter*	Successful
Reset Button	Pressing the reset button	Removing filters on disaster statistics data	Disaster statistics	Successful
Download button	Pressing the download button	Download disaster statistics data	Disaster statistics data.xlxs	Successful

3. 3. Disaster Data Page Testing

Table 5. Disaster data page testing

Scenario	Action	Function	*Output*	Result
Tombol Filter	Pressing the filter button	Filter the data displayed in the table	Filter data bencana	Successful
Tombol *Reset*	Pressing the reset button	Remove filters on tables on the disaster data page	Disaster data	Successful
Tombol Detail	Pressing the details button	Display detailed information from disaster data in a table	Detailed disaster data information	Successful
Tombol *CVS*	Press the CVS button	Download disaster data with cvs file extension	Disaster data.cvs	Successful
Tombol *Excel*	Pressing the excel button	Download disaster data with xlxs file extension	Disaster data.xlxs	Successful
Tombol *PDF*	Press the pdf button	Download disaster data with pdf file extension	Disaster data.pdf	Successful
Tombol *Print*	Press the print button	Print disaster data in a table	Disaster data	Successful

4. 4. Map Dashboard Page Testing

Table 6. Map dashboard page testing

Scenario	Action	Function	*Output*	Result
Tautan Selengkapnya	Menekan Tautan Selengkapnya	Displays details of the article on the map dashboard page	Disaster article details	Successful
Tombol Tampilkan Dipeta	Menekan tombol tampilkan dipeta	Menampilkan koordinat lokasi rumah terdampak pada peta	Coordinates of the location of the affected house	Successful
Control Layer	Menekan *control layer*	Memberikan pilihan tampilan peta dasar	Basemap	Successful
Marker	Menekan *marker*	Melihat informasi dari penanda	Popup	Successful
Tombol Detail	Menekan tombol detail	Menampilkan detail informasi dari penanda	Information details of the marker	Successful
Zoom Control	Menekan *zoom control*	Memperbesar dan memperkecil tampilan peta	*Zoom in and zoom out map view*	Successful
Tampilkan Lokasi Anda	Menekan tombol tampilkan lokasi anda	Menampilkan posisi lokasi pengguna	Marker	Successful

Scenario	Action	Function	*Output*	Result
Zoom to Layer	Press the zoom to layer button	Restores the initial position of the map	Map center position	Successful

5. 5. Form Page Testing

Table 7. Form page testing

Scenario	Action	Function	*Output*	Result
Next Button	Pressing the next button	Displays the next stage of filling in the form page	Next stage	Successful
Previous Button	Pressing the previous button	Displays the previous filling stage section on the form page.	Previous stages	Successful
Eye Icon	Press the eye icon	Shows examples of damage according to the description with modals	Example of damage	Successful

3.3.2 Testing Using the User Acceptance Test Method

User Acceptance Testing (UAT) was conducted by distributing questionnaires to the community and relevant parties in the Sridadi Village area, Sirampog District, Brebes Regency. The purpose of this testing was to obtain feedback from users regarding their level of satisfaction with the PTKR Web GIS system that was developed. The questionnaire used the Likert scale approach, which is a measurement method that asks respondents to indicate their level of agreement with a given statement. The assessment was carried out by assigning a score to each answer choice, then multiplying it by the number of respondents to obtain the maximum score. The following is a table showing the maximum score calculation.:

Table 8. Maximum score

Answer	score	Maximum score **(Score × total Responden)**
Strongly agree	5	100
Agree	4	80
Undecided	3	60
Disagree	2	40
Strongly disagree	1	20

Next, the percentage of each option can be calculated using the following formula:

Y = (TS / Maximum Score) × 100%

Where:

Y = Percentage score

TS = Total Respondent Score = ∑ score x respondents

Maximum Score = score x number of respondents = 5 x 20 = 100

From the analysis of 10 questions answered by 20 respondents, the percentage of each answer was obtained based on the calculations that had been made..

1. First Question

   Question: “Web GIS is easy to use even for users who have no technical experience.” A summary of the questionnaire results for the first question is presented in Table 9 below..

Table 9. First statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
1	Strongly agree	5	5	25	(73:100) × 100% = 73%
	Agree	4	7	28	
	Undecided	3	4	12	
	Disagree	2	4	8	
	Strongly disagree	1	0	0	
	Total		20	73	

Based on the percentage values shown in the table, it can be concluded that 73% of respondents stated that this Web GIS is quite easy to operate, even for users without technical expertise.

2. Second Question

   Question: “The Web GIS interface is easy to understand.” A summary of the questionnaire results for the second question is presented in Table 10 below..

Table 10. Second statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
2	Strongly agree	5	2	10	(70:100) × 100% = 70%
	Agree	4	9	36	
	Undecided	3	6	18	
	Disagree	2	3	6	

Question	Answer	Score	Respondents	Total Score	Percentage Value
	Strongly disagree	1	0	0	
	Total		20	70	

Based on the data in the table above, 70% of respondents stated that the Web GIS interface was easy to understand..

3. Third Question

Question: "The process of mapping damage to houses can be done quickly and efficiently." A summary of the questionnaire results for the third question is presented in Table 11 below..

Table 11. Third statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
3	Strongly agree	5	0	0	(59:100) × 100% = 59%
	Agree	4	9	36	
	Undecided	3	3	9	
	Disagree	2	6	12	
	Strongly disagree	1	2	2	
	Total		20	59	

Based on the percentage values shown in the table, it can be concluded that 59% of respondents feel that the process of mapping damage to residential buildings can be carried out quickly and efficiently..

4. Fourth Question

Question: "I can easily find the information I need through this Web GIS." A summary of the questionnaire results for the fourth question is presented in Table 12 below..

Table 12. Fourth statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
4	Strongly agree	5	3	15	(69:100) × 100% = 69%
	Agree	4	8	32	
	Undecided	3	4	12	
	Disagree	2	5	10	
	Strongly disagree	1	0	0	
	Total		20	69	

Based on the percentage values shown in the table, it can be concluded that 69% of respondents feel they can easily find the information they need through this Web GIS.

5. Fifth Question

Question: "Web GIS is capable of providing accurate information on damage to residential buildings." A summary of the questionnaire results for the fifth question is presented in Table 13 below.

Tabel 13. Pernyataan kelima

Question	Answer	Score	Respondents	Total Score	Percentage Value
5	Strongly agree	5	2	10	(76:100) × 100% = 76%
	Agree	4	12	48	
	Undecided	3	6	18	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	76	

Based on the percentage values shown in the table, it can be concluded that 76% of respondents feel that Web GIS is capable of providing accurate information on damage to residential buildings..

6. Sixth Question

Question: "Mapping of damage to houses based on the situation in the field." A summary of the questionnaire results for the sixth question is presented in Table 14 below..

Table 14. Sixth statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
6	Strongly agree	5	6	30	(81:100) × 100% = 81%
	Agree	4	9	36	
	Undecided	3	5	15	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	81	

Based on the percentage values shown in the table, it can be concluded that 81% of respondents felt that the mapping of damage to their homes was accurate..

7. Seventh Question

Question: "The features in Web GIS (such as mapping, reporting, and directions) work well." A summary of the questionnaire results for the seventh question is presented in Table 15 below..

Table 15. Seventh statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
7	Strongly agree	5	3	15	(78:100) × 100% = 78%
	Agree	4	12	48	
	Undecided	3	5	15	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	78	

Based on the percentage values shown in the table, it can be concluded that 78% of respondents feel that the features on Web GIS work well..

8. Eighth Question

Question: "This Web GIS helps communities affected by disasters to determine the extent of damage to their buildings." A summary of the questionnaire results for the eighth question is presented in Table 16 below..

Table 16. Eighth statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
8	Strongly agree	5	11	55	(91:100) × 100% = 91%
	Agree	4	9	36	
	Undecided	3	0	0	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	91	

Based on the percentage values shown in the table, it can be concluded that 91% of respondents feel that this Web GIS helps communities affected by disasters to determine the extent of damage to their buildings..

9. Ninth Question

Question: "Web GIS is useful in assisting the planning and decision-making processes after a disaster." A summary of the questionnaire results for the ninth question is presented in Table 17 below..

Table 17. Ninth statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
9	Strongly agree	5	5	25	(78:100) × 100% = 78%
	Agree	4	8	32	
	Undecided	3	7	21	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	78	

Based on the percentage values shown in the table, it can be concluded that 78% of respondents feel that this Web GIS is useful in assisting the planning and decision-making processes after a disaster..

10. Tenth Question

Question: "This Web GIS makes it easier for the government or relevant agencies to detearmine building repair priorities." A summary of the questionnaire results for the tenth question is presented in Table 18 below..

Table 18. Tenth statement

Question	Answer	Score	Respondents	Total Score	Percentage Value
10	Strongly agree	5	3	15	(66:100) × 100% = 66%
	Agree	4	13	39	
	Undecided	3	4	12	
	Disagree	2	0	0	
	Strongly disagree	1	0	0	
	Total		20	66	

Based on the percentage values shown in the table, it can be concluded that 66% of respondents feel that this Web GIS makes it easier for the government or related agencies to determine building repair priorities..

A summary of the User Acceptance Test results is presented in Table 19 below..

Table 19. Summary of User Acceptance Test results

	Question	Percentage
A.	**Ease of Use**	
1.	Web GIS is easy to use, even for users with no technical experience.	73%
2.	The Web GIS interface is easy to understand.	70%
3.	The process of mapping house damage is quick and efficient.	59%
4.	I can easily find the information I need through this Web GIS.	69%

	Question	Percentage
B	**Web GIS Functionality**	
	5. Web GIS is capable of providing accurate information on house damage.	76%
	6. The resulting house damage mapping reflects the situation on the ground.	81%
	7. Web GIS features (such as mapping, reporting, and directions) function well.	78%
C.	**Benefits and Influence of Web GIS**	
	8. This web GIS helps disaster-affected communities assess the extent of damage to their buildings.	91%
	9. This web GIS is useful in assisting post-disaster planning and decision-making.	78%
	10. This web GIS makes it easier for the government and relevant agencies to prioritize building repairs.	66%

4. CONCLUSION

Conclusions that can be drawn after developing a Web GIS-based Mapping of the Level of Damage to Houses Caused by Natural Disasters. This research has produced a Web GIS system capable of mapping the level of damage to houses caused by natural disasters using a scoring and weighting method from the Ministry of Public Works and Public Housing. The developed system has been tested through Black Box and User Acceptance Tests, showing excellent results with a high level of user satisfaction. This Web GIS is considered to make it easier for the community to accurately determine the level of damage to their buildings, as well as assist the government or related agencies in determining repair priorities and post-disaster planning. Thus, this system is effective and relevant for rapid and appropriate mitigation and disaster impact management..

5. SUGGESTIONS

As a contribution to the development of this research, the following are recommendations from the author that can be used as a reference for further research:

1. This system can be improved with real-time data integration features from disaster sensors or satellite imagery data to speed up the identification process.
2. Developing the system into a mobile application (mobile app) is highly recommended to increase user flexibility and mobility, especially when used in disaster-affected locations. Being mobile-based, the system can also be equipped with a local storage feature, which allows users to continue recording and mapping when there is no internet connection, and the data can be resynchronized when an internet connection is available. This feature is important considering that field conditions after a disaster often experience network constraints.

With these developments, the system will be more adaptive and responsive to user needs and support the disaster mitigation and recovery process more effectively..

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