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GIS-Based 'Banua Siaga' Platform for Enhancing Disaster Preparedness Through Health Post Mapping in Palu

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ABSTRACT

Introduction: Household safety and disaster evacuation are crucial global issues, especially in Southeast Asia, where Indonesia is highly vulnerable to natural disasters. Palu City, Central Sulawesi, frequently experiences disasters such as earthquakes, tsunamis, and landslides, necessitating effective disaster management strategies. The increasing escalation and intensity of disasters demand improved preparedness and response mechanisms. This study aims to develop an interactive platform utilizing Geographic Information System (GIS) technology to map health service posts and evacuation points in Palu City, ensuring real-time access to crucial disaster response information.

Methods: This study employs a quantitative descriptive approach with a developmental research design to create an interactive platform for mapping health service posts. The research integrates GIS technology with real-time data collection and community participation mechanisms to enhance disaster preparedness. The research process includes data source verification, user needs analysis through surveys and interviews, platform design and development, and quality control through expert reviews and usability testing. Ethical considerations were followed to ensure participant confidentiality and data security.

Results: The developed platform, Banua Siaga, utilizes GIS software to map health service locations and integrates real-time reporting features via Google Forms. Key features include interactive maps, location-based services, and real-time feedback mechanisms. The platform enables users to identify the nearest health post, access available services, and report emergency needs. The GIS-based mapping of 46 health service posts across Palu City ensures strategic placement for optimal disaster response. Initial usability tests indicate improved accessibility, faster response times, and enhanced community engagement in disaster management.

Conclusion: The integration of GIS technology in disaster preparedness significantly enhances emergency response efficiency by improving accessibility to health service posts and evacuation routes. Community participation and real-time data integration further strengthen the platform's effectiveness. Beyond its implementation in Palu City, this approach has the potential to be adapted in other disaster-prone regions, both in Indonesia and globally, to improve disaster preparedness and response. However, challenges such as resource availability, infrastructure limitations, and digital literacy must be addressed for broader implementation. Future research should focus on expanding the platform's scalability, incorporating AI-driven predictive analytics, and conducting real-world validation through disaster simulations.

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INTRODUCTION

Globally, household safety and evacuation from natural disasters are important issues affecting communities around the world (1). In particular, Southeast Asia, including Indonesia, is an area with a high risk of natural disasters. Its location in a tropical area and the phenomenon of climate change mean that Indonesia must always be alert to possible disasters that could occur at any time (2).

Natural disasters are a phenomenon that cannot be avoided, especially in Indonesia, which is prone to various natural disasters (3). The United Nations Secretariat for the International Strategy for Disaster Reduction (UNISDR) stated that Indonesia was the country with the fifth highest level of natural disasters in the world between 2005 and 2014. Natural disaster data in Indonesia also shows an increase in escalation and intensity each year (2).

Palu City in Central Sulawesi is an area vulnerable to various disasters such as floods, landslides, earthquakes, and tsunamis (4). The risk of this disaster is high and can cause significant damage and loss of life (5–8).

The history of earthquakes and tsunamis in Palu City shows that there are about 48 active faults in Sulawesi that have the potential to cause earthquakes. The North Sulawesi subduction zone is expected to experience a large 8.5 Mw earthquake that has the potential to cause a tsunami (9). The climate crisis also worsens the situation by amplifying and accelerating the impacts of natural disasters (10–12).

Seeing the high risk of disasters in Palu City, the local government requires mature and targeted disaster management planning. Researchers believe that a map of health service posts is very important to increase community preparedness and safety when a disaster occurs. Panic and trauma during a disaster cause people to flee without clear direction, so it is necessary to obtain information about which safe areas or refugee camps they should go to (13). This is in line with research, which states that it is important to increase public awareness about emergency evacuation through outreach campaigns, training, provision of easily accessible information, and the use of social media and information technology information (14,15).

To date, efforts have been made to mitigate the impact of disasters in Palu City, but there is still a need to improve the accessibility and accuracy of information related to the planning of health service posts and checkpoints. evacuation meeting. The rapid use of information and communication technologies, including interactive platforms, will provide more effective and efficient solutions. This is in line with the journal "Palu City Coastal Area Disaster Mitigation" by Ramadani et al (2022) that planning is about estimating the needs in emergency situations and identification of existing resources to meet these needs (16). This planning can reduce the negative impact of a threat. Apart from that, this is also in accordance with Zhou's (2018) research in China, namely the importance of developing a database that includes earthquake evacuation information for output to accelerate evacuation responses during disasters seismic events, evacuation speed and evacuation route options (17).

Previous studies have highlighted the importance of utilizing information and communication technology (ICT) to support disaster preparedness and response, as demonstrated in Zhou's (2018) research, which emphasized the development of a database to accelerate evacuation during seismic events (17). Additionally, Ramadani et al. (2022) stressed that data- and technology-based planning can enhance the effectiveness of disaster mitigation in Palu's coastal areas (16). However, there remains a gap in research regarding the integration of interactive technology-based platforms specifically designed for mapping health service posts in disaster scenarios. While some studies have discussed the importance of fast and accurate information during evacuation (14,15), few have developed systems that connect health service location data with real-time evacuation needs in Palu. Therefore, this study aims to fill that gap by developing an interactive platform that provides real-time information on the locations of health service posts and evacuation assembly points. Thus, this research not only contributes to the literature on technology-based disaster management but also offers a practical solution for communities and stakeholders in Palu to improve disaster preparedness and response.

METHOD

Design Research

This research adopts a quantitative descriptive approach that allows for the collection of data that can be measured numerically and analyzed using statistical methods. Regarding the research design, the method applied is development. This approach is specifically designed to create innovations or new solutions in response to existing problems. In the context of this research, the innovation takes the form of an interactive platform to map security posts and health services in the event of disasters. With this approach, it is expected that the resulting solution can be effective in improving household safety during disaster situations in Palu City (19).

To ensure the accuracy and reliability of the data used in the GIS mapping process, this research applies a systematic data validation approach with the following procedures:

Data Source Verification

1) This research utilizes authoritative sources such as government databases (e.g., BNPB, BPBD, and local health department records) and satellite imagery from reputable providers to ensure data authenticity. 2) Community-collected data is cross-verified with official records to minimize errors and inconsistencies.

Investigation procedures

Analysis of user needs: 1) To Identify the needs and preferences of users that will guide the development of the platform. 2) Conduct surveys or interviews with the community, disaster post (BPPBD) officials and other related parties to understand their needs. 3) Review related literature and similar case studies to gain deeper insight into user needs.

Platform design: 1) Design a use that is easy to understand. 2) Determine the main features to include in the platform, such as interactive maps, disaster-safe outpost location information, availability of assistance, etc. 3) Design the functionality of the platform according to the user needs analysis previously carried out.

Platform development: 1) Create applications or software based on agreed designs. 2) Implement features that have been designed into the platform. 3) Ensure that target users can access and use the platform correctly.

Platform implementation: 1) Launch of the platform to the target community or users. 2) Socialize the use of the platform and its benefits to the community, related agencies and parties involved in disaster management. 3) Ensure the platform is widely available and easily accessible to all parties who need it.

Preparation of reports

1) Document all research steps that have been carried out. 2) Analyze the research results, findings and conclusions drawn from the development of the platform. 3) Prepare research reports covering all relevant aspects of the research, including methodology, results and recommendations for further development.

Error Detection and Correction

1) Spatial data is processed using GIS software equipped with automatic error detection tools to identify anomalies such as duplicate entries, missing data, or incorrect georeferencing. 2) Manual validation is performed by comparing mapped data with field observations.

Quality Control Measures

1) GIS models undergo peer review by experts in disaster management and geospatial analysis. 2) Initial platform testing is conducted in selected areas to verify functionality, data accuracy, and usability before full-scale implementation.

By implementing these rigorous procedures, this research ensures that the GIS-based mapping platform provides reliable and accurate information, enhancing disaster preparedness and response efforts in Palu City.

Ethical Consideration

This study has not been cleared by the Ethics Committee yet. Nonetheless, the study was done following The Declaration of Helsinki and the pertinent research ethical guidelines in Indonesia. During data collection, each participant was given ample information regarding the aims of the study including how the study was to be conducted, its anticipated benefits, as well as its risks. There was no coercion to partake in the study and respondents who gave consent to partake provided it verbally after being briefed on the research. In addition, confidentiality and anonymity of participants' information was guaranteed, which meant that no personal data was going to be shared or utilized outside the study parameters. In due course, the researchers will file the necessary documents with the relevant committee to obtain ethical clearance and to comply with the rest of the ethical research requirements.

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RESULTS

The initial design of this platform began with the process of drawing or mapping post points based on coordination with the head of the local health center and the subdistrict heads. The layout is carried out using GIS software, specifically Google Earth, which facilitates the visualization of the geographical location of each disaster

site. With this coordination, the location of command posts can be more strategic, ensuring that each location that needs assistance has quick and accurate access.

Once the layout is completed, this platform is integrated with Google Forms, which functions as a means of complaints and suggestions for the public. Google Forms allows the public to submit real-time reports on conditions in the field, such as urgent needs, command post obstacles, or other emergency situations. The use of Google Forms was chosen for its ease of access and flexibility on various devices, especially smartphones, so that stakeholders can respond to reports quickly and efficiently.

Figure 1. GIS layout of the "Banua Siaga" command post

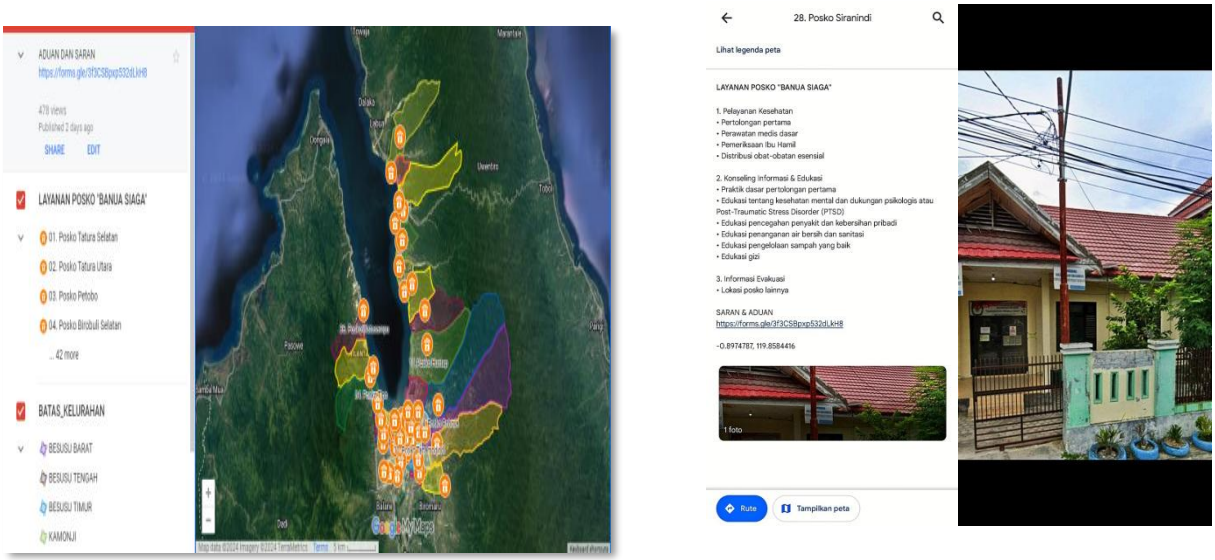

Figure 2. Popup display of postal services and route functions

To further increase ease of access, this platform is also equipped with a Route feature, which allows users to see directions to the stand, similar to the service offered by Google Maps. With this feature, users can easily find the fastest and closest route, so they can get to the post more efficiently. This routing feature is very important, especially in emergency situations where every second counts. With clear and accurate maps as well as interactive service information features, the public can easily find the location of the nearest post and understand the services available, which is especially important in emergency situations where time is of the essence.

Table 1. Location of Palu City Subdistrict Coordinates

No	Coordinate	Information
1	-0.9145582, 119.8721739	Post Tatura Selatan
2	-0.9114674, 119.8766521	Post Tatura Utara
3	-0.9385354, 119.9337329	Post Petobo
4	-0.9284908, 119.8943309	Post Birobuli Selatan
5	-0.9184315, 119.8927454	Post Birobuli Utara
6	-0.9029833, 119.8826972	Post Lolu Selatan
7	-0.9022920, 119.8739237	Post Lolu Utara
8	-0.8887649, 119.8667883	Post Besusu Barat
9	-0.8900650, 119.8746673	Post Besusu Tengah
10	-0.8937653, 119.8810899	Post Besusu Timur
11	-0.8977677, 119.8927907	Post Tanamodindi
12	-0.8982035, 119.9025522	Post Lasoani
13	-0.9069776, 119.9213907	Post Kawatuna
14	-0.8784913, 119.9233816	Post Poboya
15	-0.8829342, 119.8924410	Post Valangguni
16	-0.8830163, 119.8763212	Post Talise
17	-0.8330131, 119.9063157	Post Tondo
18	-0.8073826, 119.9027960	Post Layana
19	-0.9198596, 119.8658516	Post Tavanjuka
20	-0.9313510, 119.8604519	Post Palupi
21	-0.9291134, 119.8477168	Post Pengau
22	-0.9275227, 119.8397671	Post Duyu
23	-0.9092283, 119.8574100	Post Bayaoge
24	-0.9081549, 119.8637983	Post Nunu
25	-0.9062917, 119.8383794	Post Balaroa
26	-0.8991670, 119.8388829	Post Donggala Kodi
27	-0.8968052, 119.8540351	Post Kamonji
28	-0.8974787, 119.8584416	Post Siranindi
29	-0.9027613, 119.8645376	Post Ujuna
30	-0.8921894, 119.8578344	Post Baru
31	-0.8889255, 119.8562757	Post Lere
32	-0.8882856, 119.8349592	Post Kabonena
33	-0.8771336, 119.8300330	Post Silae
34	-0.8568085, 119.8184388	Post Tipo
35	-0.8498221, 119.8228128	Post Buluri
36	-0.8073165, 119.8083061	Post Watusampu
37	-0.7933070, 119.8708834	Post Mamboro Barat
38	-0.7875294, 119.8830180	Post Mamboro
39	-0.7746661, 119.8627995	Post Tipo
40	-0.7562188, 119.8651438	Post Ky.Pajeko
41	-0.7542677, 119.8676312	Post Ky. Ngapa
42	-0.7420399, 119.8566419	Post Panau
43	-0.7327267, 119.8688006	Post Lambara
44	-0.7261739, 119.8631952	Post Baiya
45	-0.7043609, 119.8505465	Post Pantoloan
46	-0.6779698, 119.8643874	Post Boya

In order to improve user engagement and platform experience, the system contains a feedback mechanism that enables users to give input on any issues, suggested changes, and their experiences with regard to health service postings and evacuation routes. Health service posts and evacuation routes are examples of user provided input that is received through integrated Google forms and analyzed to improve the platform's functionality. Usability tests are also performed among community members and disaster response officials to ensure that the system is accessible and efficient, and iterative updates are made based on feedback. Such approaches not only make the system reliable, but improves trust and adoption among stakeholders which result in better disaster preparedness and response in Palu City.

DISCUSSION

The use of Geographic Information System (GIS) technology in the development of the "Banua Siaga" platform is a strategic step aimed at increasing the effectiveness of comprehensive disaster management. GIS technology has proven capable of accurately mapping critical locations during emergency situations, especially in terms of distribution of aid and health services. According to research by Rahman et al. (2023), GIS-based mapping allows for a faster and more optimal response to face disaster emergency situations, because it is capable of providing accurate geospatial information in real time (20). This is relevant to the "Banua Siaga" platform, where the use of Google Earth for three-dimensional mapping of health posts makes it easier for the community and emergency response teams to access information on geographical conditions and the nearest posts.

According to the researchers' assumptions, the integration of GIS technology will increase the speed of aid distribution, which is very important, especially in areas vulnerable to natural disasters like Palu. Apart from that, community participation in the development of this platform through real-time reporting using Google Forms is also an important step. Zhou et al. (2020) found that the use of participatory GIS-based technology in disaster management can help improve emergency responses by directly involving the community in the transmission of information (21). In this case, the "Banua Siaga" platform provides easy access to the public to report on field conditions, such as availability of facilities and obstacles faced, to which authorities can then respond immediately.

Furthermore, the strategic location of posts taking into account topography and road accessibility is one of the main advantages of using GIS (22–26). According to research conducted by Karakostas et al. (2022), mapping aid locations using coordinate-based GIS can maximize accessibility and reduce delays in aid distribution during disasters (27). This is especially important for the “Banua Siaga” platform, which uses geospatial coordinates to ensure that each health post is located at a point that is easily accessible to the public and emergency response teams. Thus, the researchers hypothesize that GIS-based mapping will have a positive impact on the speed of community access to health services during emergency situations.

The determination of the location of the post in Palu City was carried out through coordination between the head of the subdistrict, the mayor of Palu, BPBD, the head of the Health Service and the head of the local health center. This coordination is determined by ensuring that the location of each position has considered field conditions, community needs, and potential risks in the affected area. The head of the sub-district and the head of the community health center provide information on the situation in their area, while the BPBD, the head of the health service and the mayor ensure that the posts are established in strategic and safe locations and support the distribution effective support and health services.

Another aspect that supports the effectiveness of this platform is the presentation of real-time information on the availability of the service at each position (28–30). Li & Shen's (2023) research results show that platforms that present real-time data have a higher level of trust among the public, because the information they receive is always up-to-date and relevant (31). At "Banua Siaga", information on the post's services, such as the availability of medical staff, medications and the types of services available, is updated regularly so that it can be relied upon by people in need of emergency services.

By using advanced GIS technology, engaging the community in real-time reporting and presenting continuously updated data, the "Banua Siaga" platform is in line with modern disaster management practices supported by technology. The researchers hypothesize that this implementation will provide significant benefits to the community and government by responding to disasters more effectively and efficiently, as well as increasing public awareness of disaster mitigation.

With this approach, the designated posts are not only safe from danger, but are also easily accessible and have adequate infrastructure to serve disaster-affected communities.

The implementation of the “Banua Siaga” platform, however, suffers from significant challenges, especially with resources and scaling up. One of the issues is securing the technical and financial resources for the maintenance of real time GIS based mapping and data updating services. This is a tedious process as it requires constant server availability, dependable internet, and manpower. For instance, Palu is a disaster-prone region with severe infrastructure damage that makes unfettered access to geospatial information very challenging. Furthermore, scalability poses an additional problem; the system must be capable of responding to growing volumes of data and user activity during critical times without any slow-down or technical glitches. It is also essential to integrate community-based real time reporting; this will require strong filtering systems to curb false reports and ensure prompt and accurate responses to emergencies. These issues point to the requirement for sustained funding, reliable IT systems, and an adequately skilled workforce to enhance the impact on disaster mitigation.

Limitations and Cautions

When analysing the result of the study, there are a few limitations that must be considered. The first one is the accuracy of the GIS-based mappings and the functionality of the platform, which depends on community reports, as well as the official correspondence. These sources are quite outdated, and require significant resources to be put in to have any semblance of accuracy. The integration of interactive technology undoubtedly increases the efficiency of disaster response after it has taken place, but problems such as poor internet connectivity, accessibility for users, and low levels of digital skills in the affected communities can considerably reduce its effectiveness. The case study is particularly based on Palu City, which is one of the reasons why it is difficult to generalize the findings to other areas that have diverse socio-economic and geographic factors. Furthermore, while the study sets out to achieve rapid improvements in preparedness and response to disasters, its efficacy under deployed real disaster situations has not been properly proven yet. More validation through practical exercises in the field and long-term monitoring is necessary. Subsequent studies will be able to overcome these gaps through real-life usability tests in different areas prone to disasters, as well as modifying the system to allow for effortless and dependable accessibility to the platform.

Recommendations for Future Research

Future research should focus on enhancing the integration of real-time data collection and analysis to improve the accuracy and efficiency of GIS-based disaster management platforms. Expanding the study to include multiple disaster-prone regions with diverse geographic and socio-economic conditions would provide a more comprehensive understanding of the platform's adaptability and scalability. Additionally, further investigation into the impact of digital literacy, community engagement, and infrastructure constraints on the effectiveness of technology-driven disaster response systems is necessary. Researchers should also explore the use of advanced technologies such as artificial intelligence (AI) and machine learning (ML) to optimize evacuation planning and resource allocation. Finally, longitudinal studies assessing the real-world implementation and effectiveness of the platform during actual disaster events would provide valuable insights for refining and improving future disaster management strategies.

CONCLUSION

The Banua Siaga platform utilizes GIS technology, which increases the efficiency of health service and evacuation access during emergencies. The platform has the potential to adapt and be implemented into other disaster-prone areas, and also into national disaster management policies beyond its primary use in Palu City. This would allow for greater impact and applicability on a long-term scale. Looking at how other countries utilize similar platforms can help identify valuable best practices and technological advancements that can enhance its effectiveness worldwide. However, this does present challenges that have to be solved, such as limitations on infrastructure, the availability of resources, and a lack of digital literacy. This research has shown how real time, interactive mapping solutions can improve disaster response strategies and resilience. Future steps in the platform should enhance its scalability while also integrating AI, and validating effectiveness of the platform through disaster simulations can hone in the application of the research.

AUTHOR'S CONTRIBUTION STATEMENT

Each author played a vital role in the conceptualization, planning, and overall implementation of the research. The study design and methodology were developed by Budiman, who also supervised the integration of GIS technology into disaster management. Ahmad Yani carried out the collection, validation, and analysis of spatial data, making certain spatial mapping accuracy and reliability. Fatmawati assisted in the platform development as well as in its implementation, and served as a liaison to some of the stakeholders during usability testing. All of author undertook the literature review components of the study and provided the theoretical framework as well as the discussion of the relevant findings in light of the research. All authors ensured their participation in all stages of writing the manuscript, including revision and review, and they reached a consensus afterward regarding publication.

CONFLICTS OF INTEREST

The authors acknowledge that certain contributors to this manuscript also hold editorial roles in the journal where it is being submitted. To maintain transparency and safeguard the integrity of the editorial process, the peer review and decision-making for this manuscript have been conducted independently, without any influence from the authors in their editorial positions. This measure ensures the objectivity and reliability of the review process.

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