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DEVELOPMENT OF A WEB-BASED GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR DISASTER RISK MANAGEMENT IN MALAYSIA

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ABSTRACT

Gaps in access to spatial data and digital tools continue to hinder disaster risk management systems in Malaysia, particularly at the community level. This study aims to design and develop a web-based Geographic Information System (GIS) that serves as a decision-support tool for disaster response and preparedness. Using a Design Science Research (DSR) methodology, the system was built through stages of needs assessment, participatory design, open-source modular development, and both qualitative and quantitative evaluation. The results show high usability scores (average SUS >80), an average system response time of 1.2 seconds, and stable performance for up to 150 concurrent users. The platform effectively visualizes flood risk zones, evacuation routes, and shelter capacities in real time. The findings demonstrate that participatory web-based GIS tools can significantly enhance local disaster readiness and community empowerment. This research contributes to the advancement of inclusive disaster technology and offers a scalable model for implementation in other high-risk regions.

Keywords: *Geographic information system, disaster management, community participation, preparedness, Malaysia*

ABSTRAK

Kesenjangan dalam akses terhadap informasi spasial dan teknologi digital masih menjadi hambatan utama dalam sistem manajemen risiko bencana di Malaysia, khususnya pada tingkat komunitas. Penelitian ini bertujuan untuk merancang dan mengembangkan sistem Geographic Information System (GIS) berbasis web yang berfungsi sebagai alat pendukung pengambilan keputusan dalam penanggulangan bencana. Menggunakan pendekatan Design Science Research (DSR), sistem dikembangkan melalui tahapan analisis kebutuhan, desain partisipatif, pengembangan modular berbasis sumber terbuka, dan evaluasi kualitatif serta kuantitatif. Hasil pengujian menunjukkan bahwa sistem memiliki nilai System Usability Scale (SUS) tinggi (rata-rata >80) dan waktu respon rata-rata 1,2 detik, serta mampu menampung hingga 150 pengguna secara bersamaan. Sistem ini juga mampu memvisualisasikan peta risiko banjir, rute evakuasi, dan kapasitas tempat penampungan secara real-time. Studi ini menunjukkan bahwa teknologi GIS berbasis web yang dirancang secara partisipatif dapat meningkatkan kesiapsiagaan bencana dan memberdayakan masyarakat lokal. Temuan ini berkontribusi pada pengembangan teknologi kebencanaan inklusif yang dapat direplikasi di wilayah lain dengan risiko serupa.

Kata kunci: *Sistem informasi geografis, kebencanaan, partisipasi komunitas, kesiapsiagaan, Malaysia*

INTRODUCTION

Malaysia is increasingly exposed to natural disasters such as floods, landslides, and haze due to a combination of urban expansion, climate change, and deforestation (Ainun et al., 2023; Ismail et al., 2021). Despite national efforts to improve disaster response through technology and inter-agency collaboration, many regions still lack an integrated system that supports community-level decision-making. This fragmentation hampers the effectiveness of early warning systems, data sharing, and real-time coordination (Noor et al., 2020). Geographic Information Systems (GIS) have shown potential as tools to manage spatial risk information and support disaster preparedness (Abdullah et al., 2021). However, in Malaysia, GIS applications for disaster risk management are often limited to governmental agencies and not widely accessible to local stakeholders or the general public (Zainuddin et al., 2022).

A significant barrier to broader GIS adoption lies in the usability and accessibility of current platforms, which are often complex, expensive, or lack community-centered features. Most systems in Malaysia require specialized technical skills, which limits their utility for village leaders, educators, and local responders during critical situations (Rahman et al., 2019; Zulkefli & Baharuddin, 2023). Additionally, existing platforms often focus on data visualization rather than actionable planning features such as evacuation simulation or shelter allocation. These challenges point to the need for a web-based GIS platform that is not only functional but intuitive and designed for localized disaster scenarios. This aligns with recent policy directions in Malaysia, such as the National Disaster Risk Reduction Policy 2021–2030, which emphasizes inclusivity and community empowerment in disaster management (NADMA, 2021).

A web-based GIS enables real-time data access, multi-layer visualization, and spatial analytics that are critical during disasters. This is particularly relevant in Malaysia's flood-prone zones, where conditions can shift rapidly and decision-makers require up-to-date geographic insights (Rosli et al., 2021). Despite technological advancements, there is still limited research and development in Malaysia focusing on interactive GIS platforms that are both community-responsive and scalable (Mohd Salleh et al., 2022). Unlike mobile apps or static maps, a responsive GIS web portal can integrate real-time environmental data, infrastructure layers, and administrative boundaries for informed decision-making (Nordin et al., 2023). However, current platforms are generally centralized, and their functionalities are underutilized at the district or village level.

This research introduces a novel approach to disaster risk management by developing an open-access, web-based GIS tailored to Malaysian local government and community users. The system is designed to feature real-time flood data, risk heatmaps, evacuation routes, and emergency shelter information—all accessible via standard web browsers. This study is distinct from previous work because it incorporates stakeholder feedback through participatory co-design workshops during the development process (Zainal et al., 2020). Such integration of community perspectives and spatial technology is rare in the Malaysian GIS context but aligns with global calls for inclusive disaster technology frameworks (Hashim et al., 2022; UNDRR, 2022). The project aims to balance

technical functionality with public usability.

In response to increasing environmental vulnerability and data inequality, this research proposes a scalable solution for democratizing disaster information through accessible spatial technology. The prototype's modular design, use of open-source tools, and alignment with Malaysia's Smart City and MyGDI agendas enhance its adaptability across regions (Lee et al., 2023). Furthermore, it contributes to academic and practical efforts to improve digital disaster infrastructure in Southeast Asia, where technology gaps still hinder preparedness (Yusof et al., 2024). Ultimately, this web-based GIS will serve not only as a decision-support system for authorities but also as an empowerment tool for communities to better anticipate, plan for, and respond to disasters.

METHOD

This study adopts a design science research (DSR) approach, suitable for addressing real-world problems through the systematic development of technological solutions (Hevner & Gregor, 2020). DSR enables the iterative design, testing, and evaluation of an artifact—in this case, a web-based Geographic Information System (GIS) platform—tailored for disaster risk management in Malaysia. The process began with an in-depth problem analysis, focusing on gaps in current GIS usage among community stakeholders and local authorities. Data were collected through document review of national disaster frameworks, technical reports, and spatial data portals (NADMA, 2021; Lee et al., 2023). These findings informed the system's core design requirements, ensuring relevance to local disaster contexts such as flash floods and landslides.

To gather user-centered design input, the research incorporated participatory design methods involving local government officers, disaster response personnel, and NGO representatives. A total of 24 stakeholders from three flood-prone districts (in Selangor, Kelantan, and Johor) participated in focus group discussions (FGDs) and task-based usability interviews. These sessions identified key user needs such as multi-language support, mobile responsiveness, risk layering, and offline access for areas with unstable internet. The qualitative data collected were analyzed thematically to extract design criteria and functional priorities for the platform (Zainal et al., 2020; Yusof et al., 2024). This participatory process ensured that the system design was not only technically sound but also socially acceptable and usable across diverse community groups.

The development of the platform was conducted using open-source technologies, including Leaflet.js for map rendering, PostgreSQL/PostGIS for spatial databases, and GeoServer for data publishing. A modular architecture was adopted to allow future scaling and integration with national geospatial systems such as MyGDI. The web application was developed following agile sprints, with bi-weekly iterations and testing sessions involving core users (Rosli et al., 2021; Nordin et al., 2023). The core functionalities included: (1) flood hazard visualization; (2) evacuation route mapping; (3) emergency shelter capacity tracking; and (4) real-time rainfall overlay. All geospatial datasets were sourced from open government repositories or validated satellite data (e.g., JPS, MetMalaysia, Sentinel Hub).

For evaluation, the study used a mixed-methods framework combining usability testing and system effectiveness analysis. Usability was assessed using the System Usability Scale (SUS) and task success rate across 12 community users and 6 disaster officers. Quantitative results were triangulated with qualitative feedback from post-use interviews, coded according to effectiveness, efficiency, and satisfaction dimensions (Hashim et al., 2022). Additionally, technical performance was benchmarked through system load testing, response time monitoring, and spatial query execution speed. These evaluation methods align with current best practices in humanitarian technology assessment (Ismail et al., 2021; Zulkefli & Baharuddin, 2023), ensuring the platform meets both user and operational expectations for disaster preparedness and response.

RESULTS AND DISCUSSION

The usability evaluation of the web-based GIS platform involved 18 participants, comprising 12 community users and 6 disaster officers. Using the System Usability Scale (SUS), the system received high ratings across both groups. The average SUS score for disaster officers was 84.2, while community users gave an average score of 79.5, both exceeding the standard usability threshold of 68 (Brooke, 1996; Zulkefli & Baharuddin, 2023). Task completion rates were also high, indicating intuitive interaction and feature accessibility. Specifically, officers completed 93% of assigned tasks successfully, while community users achieved 88%. These results are presented in Table 1.

Table 1. Usability Testing Results

User Group	Avg. SUS Score	Task Completion Rate (%)
Disaster Officers	84.2	93
Community Users	79.5	88

To assess technical performance, three key system metrics were measured: response time, concurrent user load, and map rendering speed. Under simulated field conditions with up to 150 users, the platform maintained an average response time of 1.2 seconds per spatial query. The system also remained stable with a maximum concurrency of 150 users, demonstrating backend scalability. Furthermore, the average map rendering time, even with three overlapping layers, was 2.5 seconds, which is within the acceptable range for real-time spatial decision support systems. These metrics are shown in Table 2.

Table 2. System Performance Metrics

Metric	Result
Average Response Time	1.2 seconds
Max Concurrent Users	150 users
Map Rendering Time	2.5 seconds

The effectiveness of the platform's disaster-specific features was further evaluated

during scenario-based simulations. Three disaster contexts were modeled: flash flood, landslide, and prolonged rainfall with shelter overcapacity. For each case, users were able to visualize risk areas using heatmaps, define evacuation zones, and simulate population movements using the route planning module. Key functional performance indicators were gathered and are summarized in Table 3, indicating high accuracy and functional stability across multiple simulated events.

Table 3. Scenario-Based Functionality Assessment

Feature	Accuracy (%)	User Satisfaction (1–5)	Notes
Flood Risk Layer	94	4.7	Based on Sentinel-2 overlays
Evacuation Route Simulation	91	4.6	Dynamic routing tested
Shelter Capacity Estimation	89	4.4	Based on real-time input

Qualitative feedback supported the quantitative findings, highlighting that the system significantly enhanced participants' understanding of spatial risk. Respondents particularly valued the multilingual interface, color-coded hazard zones, and mobile responsiveness. Disaster officers reported improved coordination potential due to integrated overlays and administrative boundary tools. Additionally, NGOs emphasized the system's utility for disaster preparedness training and community awareness campaigns, especially in rural zones. Common recommendations for future versions included offline map caching, printable reports, and integration with WhatsApp alert systems. These findings demonstrate that the platform is both technically robust and socially aligned with community needs.

The findings of this study reaffirm the importance of localized technological solutions in disaster risk management, particularly in regions like Malaysia that face recurrent hydrometeorological hazards. The high usability ratings from both community members and disaster officers validate prior research asserting that participatory co-design leads to higher adoption and effectiveness of GIS platforms (Zainal et al., 2020; Nordin et al., 2023). Unlike generic or top-down disaster management systems, the developed web-based GIS was tailored specifically to community needs through iterative feedback sessions. This aligns with recent global studies advocating for community-centered disaster tech as a means to bridge digital equity gaps in risk mitigation (UNDRR, 2022; Yusof et al., 2024). Furthermore, this research extends current literature by validating system use not only in response but also in proactive disaster preparedness simulations.

This study's novelty lies in its modular architecture and real-time disaster simulation capabilities—features rarely found in open-access GIS tools used at the community level. Most previous GIS implementations in Southeast Asia have been static, desktop-based, or limited to topographical data visualization (Mohd Salleh et al., 2022; Rosli et al., 2021). The integration of shelter capacity monitoring, flood overlays, and

dynamic evacuation routing in one browser-based interface makes this system distinct. By embedding live data sources from MetMalaysia and JPS, the platform achieves a higher level of spatial-temporal responsiveness, supporting calls for real-time decision-making tools in disaster governance (Ismail et al., 2021; Hashim et al., 2022). Additionally, the multilingual interface and simplified design contribute to digital inclusivity, especially for low-literacy users.

The global relevance of this platform is underscored by its replicability in other climate-vulnerable nations with similar infrastructural and socio-economic profiles. Countries in Southeast Asia, Sub-Saharan Africa, and South America continue to face challenges related to inaccessible GIS technology and low disaster awareness among rural populations (ADB, 2021; World Bank, 2022). This research contributes to international best practices by providing a blueprint for integrating open-source tools into local governance systems. The web-based design allows for scalability and minimal maintenance, making it attractive for adoption by NGOs, municipal governments, and humanitarian agencies (UNDP, 2023). Moreover, the platform's design aligns with the Sendai Framework's priority of strengthening disaster risk governance and enhancing the availability of accessible risk information (UNDRR, 2022).

Finally, this study provides empirical evidence that user-friendly disaster information systems can shift community roles from passive recipients to active risk managers. Participants reported increased confidence in understanding hazard exposure and acting during simulated events, echoing recent findings that technology-mediated awareness boosts resilience (Zulkefli & Baharuddin, 2023; Lee et al., 2023). The study also fills a gap in Malaysian research, where community-based digital preparedness remains underexplored (Rahman et al., 2019). In synthesizing geospatial analysis, participatory development, and usability testing, this research creates a new model of disaster tech innovation. As climate-related risks escalate globally, such integrative and inclusive platforms will be essential in transforming how communities access, interpret, and respond to disaster information.

CONCLUSION

This study concludes that a participatory and contextually designed web-based Geographic Information System (GIS) can significantly enhance disaster risk management at the community level in Malaysia. By integrating real-time data, multi-layer hazard visualization, and intuitive interfaces, the developed platform addressed both technical and social dimensions of risk communication. The system demonstrated high usability, functional reliability, and adaptability, making it a viable tool for empowering local stakeholders in disaster preparedness and response. Its open-source, modular design also offers potential for replication in other climate-vulnerable regions, aligning with global resilience goals under the Sendai Framework and SDG 13. Thus, the research contributes not only to academic knowledge but also to practical strategies for inclusive and data-driven disaster governance.

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