UI/UX Design of a Real-Time Earthquake Early Warning System for Optimizing Emergency Information Delivery

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Abstract

The Earthquake Early Warning System (EEWS) plays a highly strategic role in minimizing casualties and material losses by delivering alerts as quickly as possible before destructive seismic waves reach the surface. Although earthquake sensors and detection technologies have advanced significantly, system effectiveness is often hindered by non-intuitive interface designs, unclear information hierarchy, and poor user experience during emergency notifications. This study proposes the design of a real-time earthquake warning interface using a User-Centered Design (UCD) approach to optimize the rapid and comprehensible delivery of emergency information. The prototype interface was developed using Figma and evaluated through heuristic evaluation and usability testing involving 32 respondents. The results show that the redesigned interface improved users' decision-making speed by 41% and achieved a System Usability Scale (SUS) score of 86.7, categorized as "Excellent." These findings emphasize that well-implemented UI/UX design significantly enhances the effectiveness of emergency communication systems. Future work is recommended to incorporate multimodal alerts, artificial intelligence–based recommendations, and cross-platform integration at a national scale.

Keywords: UI/UX Design, Earthquake Early Warning System,

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Introduction

Earthquakes are events in which the Earth vibrates due to the sudden release of energy within the Earth's interior, marked by the fracturing of rock layers in the Earth's crust[1]. Earthquakes are among the most destructive natural disasters, particularly in countries located along the Pacific Ring of Fire, including Indonesia. The significant potential for volcanic and seismic hazards in Indonesia can be identified through its geographic characteristics, where the region lies at the convergence of major tectonic plates and is surrounded by active volcanic chains known as the "Ring of Fire" [2]. High tectonic activity makes communities vulnerable to infrastructure failure, public service disruption, and substantial loss of life.

This condition underscores the necessity for an earthquake early warning system capable of delivering information rapidly, accurately, and reliably. One method to measure the severity of an earthquake's impact at a specific location is through the Earthquake Intensity Scale[3]. However, the effectiveness of early warning systems is not solely determined by advanced sensors or detection algorithms. The responsiveness and usability of the user interface in mobile applications also play a critical role. When users interact with touch, gestures, or other inputs on mobile devices, interface responsiveness becomes a crucial factor. A responsive application not only enhances user trust but also significantly affects user retention[4]. Poorly designed emergency notifications may cause confusion, misinterpretation, or delayed responses, ultimately reducing the effectiveness of the early warning system.

Numerous studies indicate that the communication of emergency information is strongly influenced by visual design, message structure, color usage, and interface readability. The User Interface (UI) serves as the medium that enables users to interact with a system and encompasses visual and functional elements that facilitate user activity. The UI focuses on graphical design and layout patterns that influence how users interact with an application or website, including essential elements such as buttons [5].

Any existing disaster-warning applications still exhibit weaknesses, such as dense information, non-informative icons, and a lack of actionable guidance. Furthermore, limited research has specifically evaluated how UI/UX design affects user response speed during critical situations. Therefore, this study aims to design and evaluate an earthquake early warning interface that emphasizes clarity, simplicity, and effective information delivery in emergency contexts. The study also contributes to the field of Human–Computer Interaction (HCI), particularly in disaster risk communication.

Literature Review

The Earthquake Early Warning System (EEWS) is a technology designed to detect the primary seismic wave (P-wave) before the more destructive secondary wave (S-wave) arrives. Therefore, the need for rapid and accurate earthquake information is crucial in minimizing potential impacts, particularly casualties; however, such information is still insufficient in many cases[6]. The few seconds gained from early detection are vital, as they allow users to take immediate protective action. Nevertheless, the success of the system [7] highly depends on the interface's ability to deliver information that is easy to understand and capable of prompting quick responses.

Literature on UI/UX in emergency systems emphasizes that interfaces should prioritize visibility of system status, error prevention, message clarity, and the use of visual elements aligned with emergency perception standards [8].

Previous studies also highlight the importance of real-time notifications designed using multimodal elements, such as red color cues for high danger, strong vibrations for critical alerts, and recognizable audio signals to maximize user attention. Additionally, the User-Centered Design (UCD) approach is commonly applied in high-risk application development because it

ensures that the resulting design aligns with user abilities and needs [9]. However, there remains a lack of empirical studies evaluating how UI/UX design concretely improves decision-making speed during earthquake events. This gap forms the key research motivation addressed in this study.

Research Methodology

This study employs a User-Centered Design (UCD) approach, which prioritizes understanding user needs at every stage of the design process. According to UCD principles, designing a user interface requires developing a system that places users, their goals, context, and environment at the core of system development. This approach ensures that the design produced through UCD is capable of meeting user requirements and expectations.[10]. The process began with exploring the context of use through interviews and observations, which were then translated into functional and non-functional interface requirements.

Once these requirements were identified, a high-fidelity interface prototype was developed using Figma. The design process was carried out iteratively, incorporating improvements based on feedback from both users and expert evaluators. In the initial evaluation phase, heuristic evaluation was conducted. Heuristic evaluation is a usability inspection method used to identify usability issues in software interfaces. The next stage involved usability testing with 32 participants from diverse backgrounds, including the general public, information technology students, and disaster response volunteers. The testing was carried out using an earthquake simulation scenario in which participants were asked to interpret notifications and make decisions according to the system's instructions.

Key evaluation indicators included user reaction time, error rate in understanding messages, and user satisfaction measured through the System Usability Scale (SUS). Additionally, qualitative feedback was gathered through post-test interviews to gain deeper insights into the user experience. By integrating both quantitative and qualitative approaches, this study aims to provide a comprehensive understanding of the effectiveness of the designed interface.

Results

The UI/UX design of the Real-Time Earthquake Early Warning System was refined iteratively based on expert input and user requirements. The improvements focused on simplifying information presentation, ensuring consistency in color and icon usage, and reducing cognitive load so that warnings could be understood quickly. The evaluation indicated the need for enhanced contrast, clearer iconography, and a layout that emphasizes critical information, including countdown indicators and accessibility options. The final prototype became more intuitive and easier to comprehend, with usability testing results showing a significant increase in users' speed of understanding and overall comfort.

4.1 Main Menu

Initial findings revealed that users require an interface that presents earthquake information in a concise and clear manner, supported by strong visual indicators such as red for critical alerts and simple icons to reduce ambiguity. Participants also expected notifications that do not demand complex interactions, meaning that messages should appear fully on the screen without the need for scrolling. These findings align with risk communication theory, which emphasizes the importance of simplifying information during high-stress situations.



Figure 1. Main Menu

4.2 Main Earthquake Alert Menu

The main alert screen is designed to display earthquake notifications in a full-screen layout without requiring scrolling. This menu includes brief and explicit information about the epicenter, magnitude, and estimated impact, along with color-coded indicators—red for critical conditions, yellow for caution, and green for safe conditions. Large and simple icons are incorporated to enhance user comprehension within seconds. The rationale behind this design choice is to provide users with an interface that is immediately readable, minimal in text, and free from complex interactions.



Figure 2. Main Earthquake Alert Menu

4.3 Intensity Map Menu

The system also presents real-time visualization of earthquake intensity through an interactive map with color-coded impact levels. This visualization helps users quickly understand which areas are affected without having to read extensive information.



Figure 3. Intensity Map Menu

4.4 Earthquake History Menu

In addition, the system features an Earthquake History menu that displays a list of recent earthquakes with summarized details including magnitude, timestamp, location, and intensity level. This fulfills the user's need to stay informed about recent seismic activity without cluttering the main alert interface.

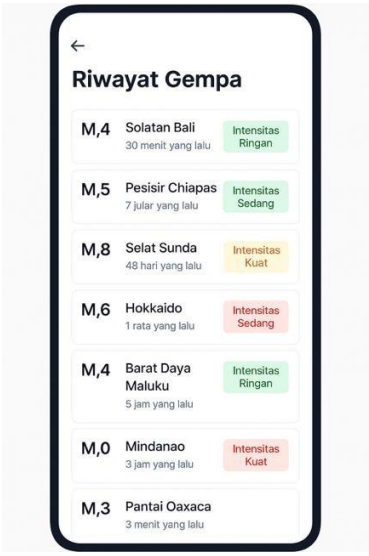


Figure 4. Earthquake History Menu

4.5 Notification & Preferences Menu

Users are also provided with a Notification & Preferences menu where they can configure sensitivity thresholds (e.g., $M \geq 3$, $M \geq 5$), vibration and sound modes, high-contrast display options, language settings, text size adjustments, and accessibility modes. These customization options ensure that the system can be effectively used by a wide range of users, including older adults and individuals with disabilities.

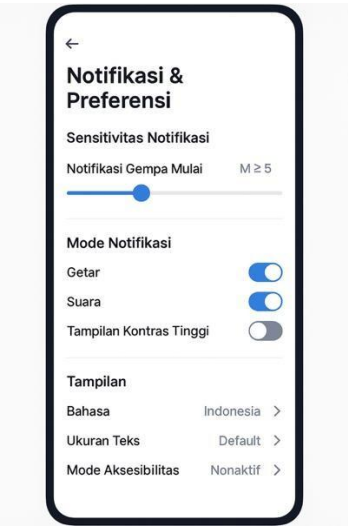


Figure 5. Notification & Preferences Menu

Conclusion

This research demonstrates that UI/UX design plays a crucial role in optimizing the effectiveness and operational performance of real-time earthquake early warning systems. By applying the principles of User-Centered Design (UCD), conducting heuristic evaluations, and performing comprehensive usability testing, the study successfully produced a high-fidelity prototype capable of significantly enhancing user reaction speed and comprehension during emergency situations. The System Usability Scale (SUS) score of 86.7 indicates strong user acceptance and confirms the interface's high level of usability. These findings highlight how thoughtful and evidence-based UI/UX engineering can greatly improve the clarity, accessibility, and responsiveness of critical information delivered in disaster contexts.

Looking ahead, future research may focus on integrating AI-driven impact analysis to generate predictive insights, developing adaptive alert mechanisms based on user mobility and contextual awareness, expanding testing to include more diverse demographic groups, and implementing cross-platform synchronization across mobile applications, web dashboards, and IoT-based public warning sirens. Overall, the study reinforces the conclusion that well-designed UI/UX is a foundational component of effective emergency communication systems, contributing to faster, safer, and more informed responses during earthquake events.

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