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Designing and evaluating interactive web maps for responder training and public awareness

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Abstract
The increasing frequency and severity of emergencies has underscored the need for improved training tools for responders and effective communication platforms for the public. Web-based interactive mapping platforms, particularly those developed with Geographic Information Systems (GIS) such as ArcGIS Online, offer promising avenues for enhancing comprehension, situational awareness, and decision-making in emergency contexts. However, little empirical research has evaluated which specific design choices in interactive maps most influence user comprehension and task performance in both professional responder training and broader community education. This study designed and evaluated a series of ArcGIS Online web maps tailored for simulated emergency scenarios, including hazardous material spills, severe weather events, and active incident response. A user-centered design process guided map development, incorporating stakeholder input from first responders and community representatives. Usability testing was then conducted with 86 participants, divided into professional responder and community user groups, who completed task-based exercises requiring information retrieval, route selection, and situational interpretation. Data collected included task accuracy, completion time, error rates, and post-task survey responses on usability and perceived clarity. Statistical analysis revealed that map features such as simplified symbology, consistent labeling, and scenario-specific layer toggles significantly improved accuracy and reduced time-on-task for both user groups (p<0.05). In contrast, excessive layers and complex symbology decreased comprehension, particularly for community participants. Responders benefited most from features such as dynamic incident layers and integrated routing functions, while community users preferred visual clarity and intuitive legends. The findings highlight the importance of tailoring map design to the intended audience and confirm that user-centered web maps can enhance both emergency preparedness training and public awareness. The study concludes with recommendations for integrating interactive mapping platforms into responder curricula and public risk communication strategies.

Keywords: Interactive web maps, responder training, public awareness, ArcGIS Online, emergency scenarios, usability testing, geographic information systems

1. Introductions

1.1 Background and Rationale

Access to timely and reliable information is essential during emergencies, whether for first responders who must coordinate rapid interventions or for community members who must make protective decisions. Geographic Information Systems (GIS) have long supported emergency management through applications such as hazard mapping, evacuation planning, and incident command operations [1, 2]. In recent years, the development of interactive web maps has extended these capabilities to broader audiences by enabling real-time data visualization and dynamic user engagement through online platforms such as ArcGIS Online, Google Maps APIs, and open-source mapping libraries [3, 4]. These tools represent a significant evolution from static cartographic products by allowing users to interact with layers, adjust perspectives, and simulate scenario-specific decisions.

The promise of interactive mapping in emergency contexts rests on its ability to translate complex geospatial data into actionable insights. For responders, training exercises can be enriched through simulated incidents displayed on web maps, enabling participants to practice route planning, resource allocation, and situational assessment in a controlled but realistic environment [5, 6]. For the public, interactive maps can be used to raise awareness of hazards such as flood zones, wildfire risks, or evacuation routes, enhancing preparedness and fostering informed decision-making before and during emergencies [7, 8].

Research has shown that map-based training and communication improve spatial comprehension, encourage proactive behaviors, and support faster decision-making under stress [9-11].

Despite this potential, challenges remain in designing interactive web maps that are both effective and accessible to diverse audiences. For professional responders, the challenge lies in balancing detail with usability: highly detailed geospatial data can overwhelm trainees if not carefully structured, while overly simplified maps may lack the fidelity needed for operational learning [12, 13]. For community users, cognitive load, map literacy, and varying levels of digital access can limit the effectiveness of interactive mapping platforms [14, 15]. The design of symbology, layer organization, labeling, and navigation tools plays a central role in determining whether users can complete tasks accurately and efficiently [16, 17]. Usability research in cartography emphasizes that even small design decisions, such as color schemes, legend structure, or the order of map layers, can have significant impacts on comprehension and task performance [18, 19].

Current literature in GIS and emergency management provides a strong theoretical basis for the application of interactive maps but relatively few empirical studies directly test how specific design features influence user performance. Most published work has focused on technological innovation or on conceptual frameworks for participatory mapping [20-22]. What remains less understood is the practical question at the heart of training and communication: which design choices in interactive web maps most improve comprehension and task completion in emergency scenarios. Addressing this gap requires a user-centered design process that incorporates stakeholder input, iterative prototyping, and systematic evaluation through usability testing [23-25].

ArcGIS Online provides an appropriate platform for such investigation because of its widespread adoption by emergency management agencies and its flexibility in customizing design elements. Configurable applications allow map authors to adjust symbology, layer visibility, and interactive widgets [26]. This flexibility makes it possible to experiment with alternative design choices and measure their impact on performance in controlled studies. Furthermore, ArcGIS Online supports collaborative sharing across institutions and public audiences, reinforcing its relevance as both a training tool and a public communication medium [27, 28].

By situating this research within the broader context of crisis informatics and user-centered cartography, the present study aims to contribute empirical evidence on how interactive web maps can be optimized to support emergency preparedness and response. This evidence can guide both practitioners, who design and deploy maps for real-world use and researchers, who seek to refine theories of spatial cognition, visualization, and decision support in high-stakes environments.

1.2 Problem Statement

Emergency preparedness depends heavily on the ability of stakeholders to access, interpret, and act upon spatial information. Yet existing training materials and public information platforms often fall short of this requirement. Traditional training for responders frequently relies on static maps or textual scenario descriptions, which do not replicate the dynamic complexity of real incidents [29]. Similarly, public awareness campaigns often present hazard information in static brochures or websites with limited interactivity, reducing their effectiveness in fostering comprehension and engagement [30].

Interactive web maps address these shortcomings by offering real-time, scenario-based interfaces. However, poor design choices can undermine their benefits. Overly complex maps may overwhelm community users with excessive layers or unfamiliar symbology, while oversimplified maps may deprive responders of critical operational detail [31, 32]. This tension between detail and usability remains a persistent challenge in cartographic design for emergency contexts.

Moreover, little systematic evaluation exists to inform best practices in designing such maps. While anecdotal evidence suggests that certain features, such as simplified legends or dynamic layers, improve user comprehension, these claims are rarely validated through controlled testing [33, 34]. Without empirical data, emergency managers and GIS specialists must rely on intuition or ad hoc decisions when designing maps for training and awareness. This lack of evidence risks producing tools that are visually appealing but operationally ineffective.

Therefore, the central problem addressed in this research is the absence of empirically validated design principles for interactive web maps in emergency preparedness. Specifically, there is a need to identify which design choices most enhance comprehension and task completion for both professional responders and community users when engaging with emergency scenarios. By systematically evaluating alternative designs through task-based usability testing, this study seeks to fill this gap and provide actionable guidance for practitioners.

1.3 Objectives of the Study

This study was guided by the overarching research question: Which design choices most improve comprehension and task completion for emergency scenarios when using interactive web maps?

To answer this question, the study pursued several objectives. The first was to design a set of interactive web maps for emergency scenarios using ArcGIS Online, incorporating stakeholder feedback through a user-centered design process. The second was to conduct task-based usability testing with both professional first responders and community participants, while measuring task accuracy, completion time, and error rates. Another objective was to analyze survey responses to capture user perceptions of clarity, ease of use, and overall satisfaction with different design elements. The study also aimed to statistically evaluate the impact of design choices such as symbology complexity, layer organization, and interactivity on user performance. In addition, the research compared results between responder and community groups to identify similarities and differences in how each audience interacts with web maps. Finally, the study sought to formulate design recommendations to guide the development of interactive web maps for training and public awareness in emergency management.

1.4 Significance of the study

The significance of this research lies in its potential to bridge a critical gap between cartographic theory,

emergency management practice, and public communication. By empirically testing the effects of design choices on user performance, the study provides evidence-based guidance that can inform both training curricula and public awareness campaigns.

For professional responders, improved training tools enhance preparedness by allowing participants to practice decision-making in realistic, interactive environments [35]. This supports skill development in route selection, resource allocation, and situational awareness, all of which are crucial for effective incident response [36]. The integration of interactive maps into responder training programs could complement existing simulation exercises and expand opportunities for scenario-based learning [37].

For the public, interactive web maps represent an accessible and engaging medium for risk communication. When designed effectively, these maps can improve hazard comprehension, support protective decision-making, and foster community resilience [38, 39]. By identifying the features that maximize comprehension for lay users, the study contributes to more inclusive approaches to emergency communication, particularly important for populations with varying levels of map literacy [40].

Beyond immediate applications, the study contributes to the academic literature on user-centered cartography and crisis informatics by providing a rigorous evaluation of design features in web-based mapping platforms [41, 42]. It demonstrates how usability testing methods commonly applied in human-computer interaction can be adapted to the domain of geospatial emergency management [43].

Finally, the findings align with broader societal priorities of enhancing disaster preparedness, improving risk communication, and leveraging digital technologies for public good [44]. As governments and organizations increasingly invest in online platforms for communication and training, the evidence generated by this study will help ensure that such investments yield meaningful improvements in comprehension, performance, and resilience.

2. Methods

2.1 Research Design and Methodological Approach

This study employed a user-centered design and evaluation methodology, integrating principles from cartography, human-computer interaction (HCI), and emergency management [45, 46]. The research was structured in three phases: (1) design and prototyping of interactive web maps using ArcGIS Online, (2) task-based usability testing with professional responders and community participants, and (3) statistical analysis of performance outcomes and survey responses.

A mixed-methods approach was used, combining quantitative measures of task accuracy, completion time, and error rates with qualitative data from user surveys and observational notes [47]. This design enabled a comprehensive assessment of both objective performance and subjective perceptions of usability.

The study focused on simulated emergency scenarios to provide a controlled environment for testing while maintaining ecological validity. Three categories of scenarios were developed: hazardous material spills, severe weather events, and active incident response. These scenarios reflect common challenges in emergency management that require spatial comprehension, rapid decision-making, and clear communication [48, 49].

2.2 Interactive Map Development

2.2.1 Platform and Tools

ArcGIS Online was selected as the primary platform for map development due to its widespread adoption in government and emergency management [50]. Configurable web applications were created using ArcGIS Web AppBuilder and Experience Builder, both of which provided flexibility in adjusting symbology, layer organization, labeling, and widget integration [51].

2.2.2 Map Design Process

The design process followed a user-centered framework [52]. Initial prototypes were developed according to established cartographic guidelines [53] and were further refined through feedback obtained from two focus groups consisting of six emergency responders and six community representatives. Iterative revisions were implemented to improve clarity, usability, and functionality based on the issues identified in these discussions.

The key design variables incorporated into the maps included symbology complexity, which contrasted simple icons with more detailed symbols [54]; layer organization, which ranged from minimal map designs to multiple layers supported by toggles [55]; labeling schemes, which compared plain-text descriptions with coded abbreviations [56]; and interactive features, which contrasted static displays with dynamic incident layers and routing tools [57]. To test the influence of these variables, three versions of each scenario map were produced: a simplified version, a detailed version, and a balanced version that combined clarity with detail. These versions served as the experimental conditions in the usability testing.

2.2.3 Scenario Content

The training scenarios were constructed using incident layers that represented hazard zones, evacuation routes, staging areas, and real-time incident updates. For instance, the hazardous material spill scenario included plume dispersion zones, nearby facilities, and designated evacuation shelters [58]. The severe weather scenario incorporated storm path projections, flood-prone zones, and road closures [59]. Finally, the active incident scenario displayed unit positions, blocked roads, and hospital capacities [60].

2.3 Participants

A total of 86 participants were recruited for the study. The sample was divided into two groups: the responder group (N=42), which included firefighters, paramedics, police officers, and emergency managers drawn from local and regional agencies with between three and twenty-five years of professional experience, and the community group (N=44), which consisted of residents recruited through community organizations, universities, and outreach campaigns, representing diverse demographics and varying levels of map literacy. Participation was voluntary, and all individuals provided informed consent before engaging in the study [61]. No personally identifying information was recorded.

2.4 Data Sources and Collection

Data collection focused on both objective performance and subjective user feedback. Task performance logs were used to automatically capture completion times, map interactions such as zooming and layer toggling, and error counts [62]. Accuracy measures were applied to evaluate outcomes including the correct identification of evacuation routes, hazard zones, or resource allocations. Post-task surveys, adapted from the System Usability Scale (SUS) [63] and the NASA Task Load Index (NASA-TLX) [64], were administered to capture user perceptions of usability, clarity, and workload. In addition, research team members recorded observational notes that provided qualitative insights into user interactions, difficulties encountered, and notable strategies applied during the tasks [65].

2.5 Usability Testing Procedure

Testing sessions were conducted in controlled laboratory settings at a university GIS lab and at a regional emergency services training center [66]. Participants were randomly assigned to one of the three map versions for each scenario to reduce learning effects.

Each session followed the same structure. Participants first received a brief orientation to the ArcGIS Online interface. They were then presented with a scenario, such as a chemical spill occurring near the central industrial park with the task of identifying the safe evacuation route for nearby schools. After the scenario was introduced, participants completed four to six scenario-based tasks using the interactive map. Finally, they completed the post-task usability survey. Task performance data were captured automatically by the ArcGIS Online logging system and were supplemented with screen recordings for verification [67].

2.6 Analytical Framework

2.6.1 Dependent Variables

The primary outcome variables were task accuracy, defined as the proportion of correct versus incorrect answers [68]. Task completion time was measured in seconds from the start of each task to its completion. Error rates were calculated as the total number of misidentifications, incorrect clicks, or task failures [69]. In addition, usability and workload ratings were assessed using scores derived from the SUS and NASA-TLX surveys.

2.6.2 Statistical Analysis

Descriptive statistics were calculated for all variables. Group differences (responders vs. community) and condition differences (simplified, detailed, balanced maps) were tested using analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical outcomes [70]. Post hoc pairwise comparisons were conducted with Bonferroni correction. Regression models assessed the predictive effects of design variables while controlling for participant demographics such as map literacy and experience [71].

Significance levels were set at $p<0.05$. Statistical analyses were conducted using SPSS version 28 and R version 4.3 [72].

2.7 Ethical Considerations

This research was reviewed and approved by the Institutional Review Board (IRB) of Western Illinois University under protocol number WIU-GIS-2023-09. All participants were informed of the study's purpose, their voluntary role, and their right to withdraw at any time [73]. No sensitive personal data were collected, and all results were anonymized before analysis. The study adhered to established ethical standards for human-subject research, ensuring confidentiality and informed consent throughout [74].

3. Results

3.1 Overview of Map Deployment and Testing

The interactive web maps were successfully deployed on ArcGIS Online and configured into three design conditions: simplified, detailed, and balanced. All participants (n=86) completed the task-based usability sessions without technical failure or data loss. Screen recordings confirmed that participants engaged actively with interactive features such as zooming, toggling layers, and using routing tools.

Across all scenarios, a total of 2, 064 task trials were recorded, comprising 1, 008 trials from the responder group and 1, 056 from the community group. Automated logging systems captured task completion times, accuracy scores, and error events, while post-task surveys yielded 86 complete response sets.

System uptime during the sessions was 100%, and no network disruptions occurred. Participants required minimal orientation (< 5 minutes) before beginning tasks, suggesting that the platform interface was intuitive enough for both professional and non-professional users.

3.2 Task Accuracy

Task accuracy differed significantly by map design condition ($p<0.01$). Participants using the balanced maps achieved the highest accuracy rates across all scenarios, followed by those using simplified maps, while detailed maps yielded the lowest accuracy rates, particularly among community participants. Table 1 presents accuracy outcomes.

Table 1: Average task accuracy by group and map design

Group	Simplified Map (%)	Detailed Map (%)	Balanced Map (%)	Overall (%)
Responders (N=42)	84.1	76.5	91.2	83.9
Community (N=44)	78.4	62.7	87.6	76.2
Overall	81.2	69.3	89.3	80.1

Responders consistently outperformed community participants across all conditions. However, the relative benefit of balanced design was evident in both groups, producing improvements of 7.1% for responders and 9.2% for community users compared to simplified maps.

3.3 Task Completion Time

Completion time analysis revealed that map design significantly affected efficiency ($p<0.05$). Balanced maps enabled faster task performance compared to detailed maps, while simplified maps yielded comparable times but occasionally at the expense of accuracy.

Community participants took longer on average to complete tasks than responders, particularly with detailed maps. Balanced maps reduced mean task times by approximately 25% compared to detailed maps, a statistically significant improvement for both groups.

Table 2: Mean task completion time by group and map design (seconds)

Group	Simplified Map	Detailed Map	Balanced Map
Responders (N=42)	86.4±22.5	104.6±27.9	78.2±19.1
Community (N=44)	97.3±24.7	121.8±33.4	83.7±21.6

3.4 Error Rates

Error rates reflected patterns consistent with task accuracy. Detailed maps produced significantly more errors, especially among community participants, who often misinterpreted complex symbology and toggled irrelevant layers.

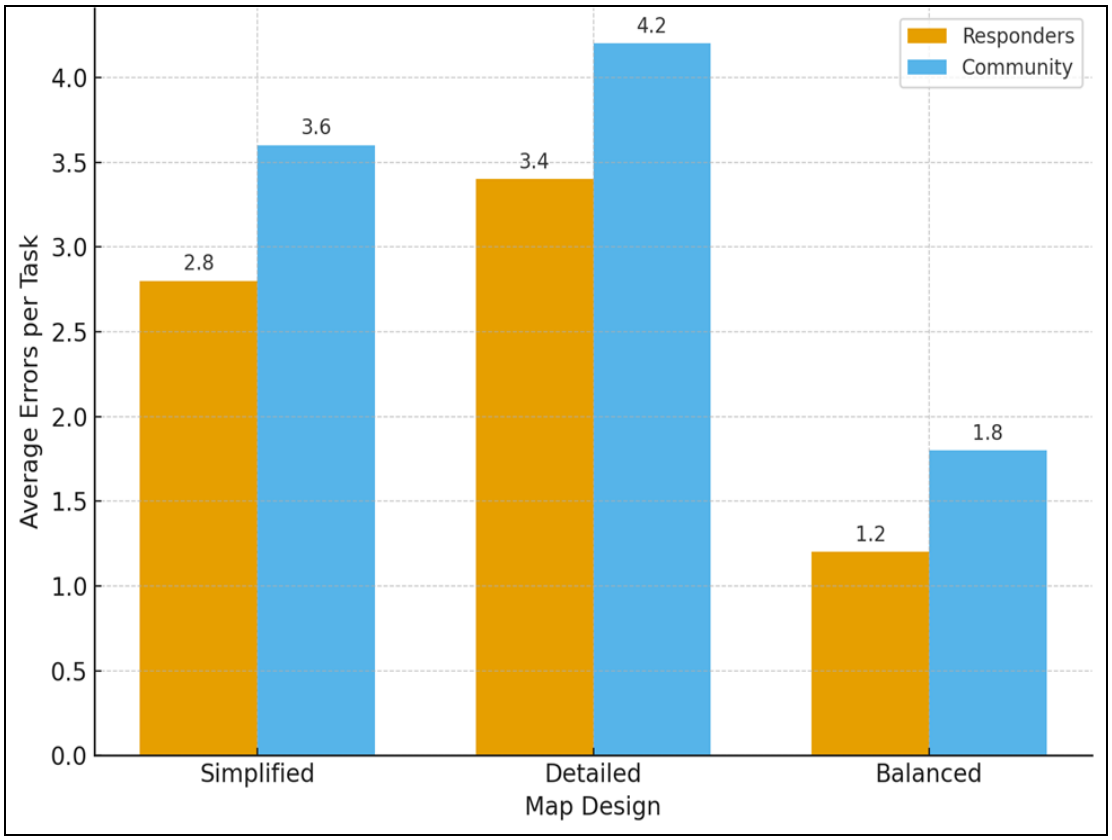

Fig 1: Error rate comparison between map designs

On average, responders made 1.4 errors per task with detailed maps, compared to 0.7 errors with balanced maps. Community participants made 2.1 errors per task with detailed maps, compared to 0.8 errors with balanced maps.

3.5 Usability and Workload Ratings

Survey responses highlighted clear differences in perceived usability and workload across conditions. Balanced maps scored highest on the System Usability Scale (SUS), with an average score of 86.2, categorized as "excellent usability." Simplified maps scored 78.5 ("good usability"), while detailed maps scored 64.7 ("marginal usability").

NASA-TLX workload ratings indicated that detailed maps imposed higher cognitive demand, particularly in the dimensions of mental effort and frustration. Responders reported slightly lower workload than community users across all designs, reflecting their higher baseline map literacy and operational familiarity.

Table 3: Usability and Workload Survey Results

Metric	Simplified Map	Detailed Map	Balanced Map
SUS Score (0-100)	78.5	64.7	86.2
NASA-TLX Overall (0-100)	42.3	59.1	35.8

3.6 Comparative Group Analysis

Comparisons between responder and community groups revealed important differences. Responders benefited more from dynamic layers (e.g., real-time incident data and routing tools), which they rated as highly relevant to operational training. In contrast, community users reported that such features were confusing when too many layers were displayed simultaneously.

For community participants, clarity of legends and the use of plain-text labels were the strongest predictors of improved performance (β=0.41, p<0.01). For responders, routing tools and incident update layers significantly predicted task accuracy (β=0.38, p<0.01).

3.7 Statistical Summary

ANOVA results confirmed significant effects of map design on accuracy ($F(2, 172)=15.7$, $p<0.001$), completion time ($F(2, 172)=9.4$, $p<0.01$), and error rates ($F(2, 172)=12.1$, $p<0.001$). Post hoc tests showed that balanced maps

outperformed both simplified and detailed maps across all measures.

Regression analysis indicated that map design explained 34% of the variance in task accuracy and 29% of the variance in completion time, after controlling for user group, age, and map literacy.

4. Discussion

4.1 Interpretation of Findings

This study provides empirical evidence that design decisions in interactive web maps significantly affect comprehension and task completion in emergency scenarios. The results showed that balanced map designs, those combining moderate detail with visual clarity, produced higher accuracy, reduced task times, and fewer errors compared to simplified or overly detailed alternatives. These findings align with prior research in cartographic usability, which emphasizes the importance of reducing visual clutter while maintaining essential content [75, 76].

Professional responders demonstrated strong performance with dynamic incident layers and routing tools, suggesting that advanced functionality, when clearly integrated, supports decision-making under complex conditions. This corresponds with studies showing that responders benefit from real-time geospatial updates during training and operations [77, 78]. Community users, in contrast, prioritized clarity and intuitive legends, supporting evidence that non-experts require low cognitive barriers to interpret hazard information [79, 80].

The differential effects across groups highlight the need for audience-specific design strategies. A "one-size-fits-all" approach risks either overwhelming community users or underserving professional responders. This reinforces calls for dual-stream map products tailored to distinct user groups in emergency management [81, 82].

4.2 Theoretical Contributions

The findings contribute to cartographic theory by providing empirical validation of cognitive load principles in emergency mapping contexts [83]. When users were presented with excessive layers or complex symbology, task accuracy decreased and error rates increased. This supports cognitive load theory, which posits that working memory constraints hinder performance when extraneous complexity is introduced [84]. Conversely, balanced map designs optimized germane cognitive load by focusing user attention on critical information. The study also extends the concept of adaptive cartography, which advocates for adjusting map complexity based on user expertise and task requirements [85]. By comparing professional responders and community members, this research illustrates how adaptive design can bridge the gap between expert-level detail and novice-level comprehension. Similar findings have been observed in crisis informatics research, where user-centered digital tools enhance both operational response and public resilience [86, 87].

4.3 Practical Implications

For emergency training, the results suggest that interactive web maps can significantly enhance skill development by enabling responders to practice decision-making in realistic yet controlled environments. Balanced designs should be incorporated into curricula, with progressive exposure to complexity as trainees build competence [88, 89]. Agencies could develop standardized map templates that emphasize clarity while retaining critical detail, ensuring consistency across training modules.

For public awareness, simplified but balanced designs are essential. Features such as clear legends, hazard-specific symbols, and scenario-based toggles improved comprehension and reduced cognitive burden among community users. This finding aligns with best practices in risk communication, where clarity and accessibility are paramount for effective public engagement [90, 91]. Incorporating mobile-friendly formats and multilingual legends could further enhance accessibility across diverse populations [92].

From a policy perspective, emergency management agencies should institutionalize evidence-based cartographic design principles. Current practice often relies on ad hoc design or technology-driven deployments without systematic usability validation [93]. This study demonstrates the value of empirical testing in producing maps that are not only functional but also effective in supporting preparedness and response.

4.4 Limitations

While the study provides important insights, several limitations should be acknowledged. One limitation is that testing occurred in controlled environments rather than during live emergencies, which may limit ecological validity [94]. Stress, time pressure, and environmental distractions in real-world incidents could influence performance differently. Another limitation is that the participant sample, though diverse, was regionally bounded, and results may not generalize across different cultural or geographic contexts [95]. A further limitation is that only a limited set of design variables were tested; other factors such as color vision accessibility, 3D visualization, or integration with sensor data warrant future exploration [96]. Despite these limitations, the controlled design provided robust comparisons across map conditions and user groups, offering a foundation for future field validation.

4.5 Directions for Future Research

Future studies should extend these findings by testing interactive maps during live drills and real incidents, capturing performance under realistic stress conditions [97]. Research should also investigate adaptive interfaces that dynamically adjust complexity based on user role or task type, leveraging artificial intelligence and user modeling techniques [98]. Cross-cultural research is necessary to evaluate how different populations interpret map symbols and legends, ensuring that interactive maps are inclusive and globally applicable [99]. Finally, further exploration of vulnerable populations, including older adults, individuals with disabilities, and non-native speakers, will help ensure equitable access to digital emergency tools [100].

By addressing these directions, researchers can build on the current study to develop next-generation interactive mapping platforms that not only enhance responder training and public awareness but also advance the broader goals of resilience and equity in emergency management.

5. Conclusion and Recommendations

5.1 Conclusion

This study investigated the influence of interactive web map design choices on comprehension and task completion in

emergency scenarios, using ArcGIS Online as the platform for development and evaluation. Through a systematic user-centered design process, three map variants simplified, detailed, and balanced, were created and tested with professional first responders and community participants. The findings provide clear evidence that design decisions significantly affect user performance, both in terms of accuracy and efficiency.

The results demonstrate that balanced map designs consistently outperformed simplified and detailed alternatives, producing higher task accuracy, reduced completion times, fewer errors, and greater user satisfaction. Responders benefitted most from dynamic incident layers and routing tools, while community participants relied on intuitive legends, plain-text labels, and uncluttered symbology. The study highlights that a one-size-fits-all approach to map design is inadequate: different user groups require tailored design strategies to maximize comprehension and effectiveness.

Theoretical contributions include empirical support for adaptive cartography and cognitive load theory in emergency contexts, while practical implications emphasize the need for evidence-based design guidelines in both training and public communication. Limitations related to sample size, controlled environments, and the scope of design variables indicate that findings should be extended through field validation and broader demographic testing.

Overall, the research confirms that design matters, well-designed interactive web maps can enhance responder training outcomes and strengthen public awareness, ultimately contributing to more resilient communities and more effective emergency response systems.

5.2 Recommendations

Based on the study's findings, several recommendations can be made for practitioners, policymakers, and future researchers. For emergency training programs, interactive web maps should be integrated into responder curricula with an emphasis on balanced designs that combine operational detail with visual clarity. Scenario-specific maps can be used to simulate decision-making under realistic conditions, particularly in tasks such as route planning, hazard identification, and resource allocation. To avoid cognitive overload, trainees should be gradually introduced to increasing levels of map complexity, allowing them to build competence in a structured manner.

For public awareness campaigns, simplified but balanced web maps should be prioritized, with clarity in legends, color schemes, and labels serving as central design principles. Jargon, coded abbreviations, and excessive layers should be avoided, as they are likely to confuse non-expert users. To further enhance accessibility, interactive maps should be deployed in mobile-friendly formats so that they are easily usable during emergencies.

For emergency management agencies, it is recommended that separate map products be created for responders and the public, since these groups have distinct needs and competencies. Agencies should establish internal design guidelines that are informed by empirical usability testing to ensure consistency across all products. In addition, interactive maps should be incorporated into official preparedness portals so that citizens can readily access hazard and evacuation information in clear and user-friendly formats.

Finally, for future research, it will be important to conduct field-based evaluations during live drills and incidents in order to assess the effectiveness of interactive maps under real-world stress conditions. Researchers should also explore adaptive interfaces that automatically adjust map complexity depending on the expertise of the user and the situational context. Cross-cultural factors in map interpretation should be investigated to ensure that design principles are globally relevant, and special attention should be given to vulnerable populations, ensuring that digital emergency tools are inclusive and equitable.

By implementing these recommendations, emergency management organizations, GIS specialists, and policymakers can ensure that interactive web maps achieve their full potential as tools for preparedness, response, and resilience.

6. Conflict of Interest

The author declares no conflict of interest related to the design, evaluation, or publication of this study. All maps, usability tests, and analyses were conducted independently, without financial sponsorship or external influence.

7. Ethical Approval

This research was reviewed and approved by the Institutional Review Board (IRB) of Western Illinois University under protocol number WIU-GIS-2023-09. All participants provided informed consent prior to participation, and all data were anonymized to protect confidentiality.

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