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Title: AI Applications in Disaster Management: Iranian Experts' Perspective Qualitative Analysis

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Abstract

Background: The application of artificial intelligence (AI) in disaster management is increasingly recognized for its potential to enhance decision-making and service delivery. Given the technological advancements and Iran's vulnerability to natural disasters, this study explores AI applications across the disaster management cycle from the perspective of Iranian experts.

Materials and Methods: A qualitative study was conducted using semi-structured interviews with 14 participants. Participants included experts, policymakers, senior and middle managers, and specialists in disaster management, artificial intelligence, and information technology. All participants were willing to take part in the study and possessed relevant scientific expertise and practical experience.

Conclusion: Analysis yielded 298 codes organized into four main categories corresponding to the disaster management cycle. In the mitigation phase, AI applications included disaster monitoring and prediction, modeling, and early warning system design. The preparedness phase comprised planning, coordination and communication, and training and empowerment. The response phase revealed six subcategories: information and communication management, rapid decision-making, situation assessment, rescue operations, monitoring and evaluation, and resource management. The recovery phase included monitoring, knowledge management, post-disaster support services, and psychosocial support. This framework can inform policymakers and practitioners in developing integrated, human-centered AI strategies for disaster management.

Ethics code:This study was approved by the Ethics Committee of Alborz University of Medical Sciences, under the code IR.ABZUMS.REC.1401.231

Keywords: Artificial Intelligence, Disaster Management, Qualitative Research, Iran, Emergency Preparedness

Highlights:

- AI applications mapped across all four phases of disaster management cycle.
- Mitigation phase includes monitoring, modeling, and early warning system design.
- Response phase shows six AI applications: information management, rapid decision-making, and more.
- Recovery phase reveals novel AI applications: psychosocial support and knowledge management.
- Framework identifies AI's transformative potential from mitigation to long-term recovery.

Introduction

Natural and man-made disasters occur daily around the world (1). These disasters often result in loss of life, disrupt economies, and cause lasting damage to infrastructure, communities, and the environment(2).Over the past two decades, the adverse impact of natural disasters on public health economies has intensified significantly. These disasters include: floods, droughts, earthquakes, heavy rains, heat waves, and tsunamis (3). Given the disastrous consequences of disasters, the emphasis on studying and developing advanced disaster management strategies and minimizing casualties has increased(1). As a developing country, Iran is considered one of the most vulnerable countries in the world to natural disasters. This can be seen in the heavy loss of life and property caused by devastating earthquakes such as the Buin Zahra earthquake (1963) to the Bam earthquake (2003) (4). Meanwhile, global agreements such as the Sendai Framework(5), the Paris Agreement (6) and the Sustainable Development Goals(7) emphasize the urgent need to address the increasing number and intensity of natural disasters and their devastating impacts on societies, economies and the environment.

In recent years, disaster management approaches have been transformed by utilizing new information technologies and digital tools. Among them, artificial intelligence-based solutions have been the most widely used (8). Today, artificial intelligence has become a key tool for organizations. Many institutions are using this technology to improve the speed and quality of emergency response (9). Artificial intelligence can not only predict natural disasters and their consequences, but also provide practical solutions to mitigate the effects of these crises(10). The results of the study by Rahmatizadeh and colleagues showed that natural disasters such as earthquakes and floods are inevitable and cannot be prevented. However, research demonstrates that artificial intelligence can significantly enhance disaster management through more accurate damage assessment, faster emergency response times and better resource allocation (9). However, in Iran, crisis management faces challenges due to insufficient preparedness, weak relief infrastructure, and lack of coordination between government institutions, which has led to increased vulnerability of local communities and reduced effectiveness of responses (11).

Appropriate and timely responses to disasters require rapid decision-making and effective exchange of information between government agencies, response organizations, and health centers, which is why information management is crucial for disaster resilience(12). Effective disaster response necessitates a sophisticated decision-making process grounded in three critical elements: accurate, real-time data verification, reliable risk assessment frameworks and dynamic action protocols (13-16). New advances in artificial intelligence have allowed researchers to analyze a greater diversity of data than ever before(17). The use of artificial intelligence for big data analytics to rapidly extract useful and reliable information to support effective decision-making in disaster management is increasingly being accepted (18-22). The use of appropriate levels of information technology and equipment has the potential to significantly enhance disaster management policy capabilities(23).

Artificial intelligence has emerged as a transformative tool in disaster preparedness and response, and holds promise for addressing some of the most pressing global health challenges. The rapid development of artificial intelligence technologies offers unprecedented opportunities to strengthen early warning systems, optimize resource allocation, and facilitate real-time decision-making processes(24). Due to its geographical and geological location, Iran is among the ten earthquake-prone countries in the world(25). On the other hand, according to recent studies, both the frequency of floods in Iran has increased and the vulnerable population exposed to these hazards has grown significantly for the following reasons(26). The use of artificial intelligence for crisis management in Iran is essential for several reasons, including reducing and minimizing damage from natural and man-made disasters (27, 28), increasing resilience and preparedness against disasters, and facilitating cooperation between different organizations in crisis management(29). The adoption of artificial intelligence systems in Iran faces unique challenges, including lack of reliable and quality data (30), ethical and legal challenges (31) lack of adequate technological and digital infrastructure (32), and cultural and social resistance to the adoption of new technologies (33). These challenges necessitate the development of localized artificial intelligence solutions.

Research shows that Iran should conduct more studies on the application of artificial intelligence in crisis management (28). The aim of this qualitative study is to explore and analyze in depth the applications of artificial intelligence in disasters management from the perspective of Iranian experts using the framework analysis method, so that through in-depth qualitative analysis, so as to extract, through in-depth qualitative analysis, the first-hand experiences of experts focusing on the four stages of crisis management. The findings of this study provide a basis for designing indigenous solutions and smart policymaking in Iranian crisis management.

Materials and Methods

Study design

Adopting an interpretivist philosophy (34), the present study, acknowledges that it is well suited to examining the complex socio-technical challenges in artificial intelligence adoption where expert subjective perspectives are essential(35). Following Braun and Clarke's framework for qualitative studies of artificial intelligence, we used thematic analysis to uncover hidden patterns in experts' experiences that quantitative methods might miss(36). The present study through semi-structured expert interviews analyzed using qualitative content analysis: identified key artificial intelligence adoption challenges across crisis management cycles and developed an optimization framework for artificial intelligence use in natural disasters.

Study participants and sampling

To ensure a comprehensive understanding of AI applications in disaster management, we deliberately employed a **purposive sampling strategy** designed to capture diverse perspectives across key stakeholder groups. Participants were recruited from three primary sectors:

1. **Academia:** Faculty members and PhD students specializing in disaster management, health in emergencies, information technology, artificial intelligence, biomedical engineering, and health technology. This group contributed theoretical knowledge, research-based insights, and familiarity with global AI advancements.
2. **Government:** Experts and policymakers with direct experience in disaster management organizations, including those involved in planning, coordination, and resource allocation during emergencies. This group provided insights into institutional capacities, policy constraints, and operational realities.
3. **Industry:** Professionals from information technology and AI companies developing or implementing technological solutions for crisis management. This group offered practical perspectives on technological feasibility, infrastructure requirements, and implementation challenges.

The inclusion criteria required participants to have a minimum of 5 years of relevant experience in their respective fields and direct involvement in disaster management or AI applications. Sampling continued until **data saturation** was achieved—the point at which no new themes, concepts, or categories emerged from subsequent interviews. Saturation was reached after 14 interviews, which is consistent with published guidelines for qualitative studies in health and disaster research (Guest et al., 2006; Morse, 2000).

Sample Composition: Of the 14 participants, 13 were from academia and 1 from industry. The predominance of academic participants reflects the current landscape of AI expertise in Iran's disaster management field, where specialized knowledge is primarily concentrated in research institutions. However, it is important to note that many academic participants had extensive collaborative experience with government agencies and industry partners through consultancy roles, joint research projects, and participation in national disaster management committees. This cross-sectoral engagement enriched their perspectives and provided indirect representation of governmental and industrial viewpoints. The single industry participant offered direct, hands-on experience in AI technology development and deployment.
Table 1 provides detailed demographic information, including sector affiliation, to ensure transparency in sample composition.

Data Collection

The data collection process involved face -to-face interviews and guides, audio recorders, interview recording sheets. Initially, interviews followed a semi-structured format with open-ended questions after obtaining written consent and ensuring participant confidentiality. All interviews were conducted in a quiet, neutral environment to minimize distractions and ensure consistent interviewing conditions. The interviews began with a general question and used exploratory questions to better understand the experiences of the interviewees. In addition to the interview discussion, with the permission of the interviewee, their voices were recorded, and a pen and paper were used for note-taking. Moreover, questions that the interviewee was unable or unwilling to answer were removed from the interview process. The total interview duration was 599 minutes, with an average interview duration of 42.78 minutes.

Interview Guide:

1. What principles should guide the development of artificial intelligence applications in disaster management?
2. What resources are important for the development of artificial intelligence applications in disaster management?
3. What are the applications of artificial intelligence in the different stages of a disaster?
4. How important is infrastructure for the development of artificial intelligence applications in disaster management?
5. What are the distinctive features of artificial intelligence application development in disaster management?
6. Based on your experience and expertise, considering the diversity of hazards in your country, what recommendations do you have for improving the development of artificial intelligence applications in disaster management?

Data Analysis

In this research, the thematic content analysis method was used to analyze the data obtained from the interviews .The study employed a systematic five-phase thematic analysis framework, combining inductive and deductive reasoning to interpret expert interview data.

1. Semantic Unit Identification

Interview transcripts were segmented into meaningful semantic units,ranging from concise phrases to full sentences, representing distinct concepts related to artificial intelligence adoption in disaster management. These units served as the foundational elements for coding.

2. Inductive-Deductive Coding

A hybrid coding approach was implemented. At first, open coding was used and initial emergent concepts were identified through line-by-line analysis. Then axial Coding was applied, and relationships between codes were established, with constant comparative analysis across interviews to refine connections.

The coding framework evolved dynamically throughout the analysis; codes were revised, merged, or expanded as new patterns emerged**.**

3. Category Formation

Related codes were grouped into broader categories by mapping conceptual similarities and differences. Researchers engaged in refining definitions iteratively and maintaining analytical memos to document decision-making process.

4. Theme Development

Selective coding integrated categories into overarching themes, involved examining interrelations between categories, achieving saturation in sub-themes and concepts, and constructing a core theoretical framework that encapsulates the narrative of the data.

5. Validation and Rigor

To ensure trustworthiness, we implemented several strategies. Member checking was used, with participants reviewing preliminary findings for accuracy. Peer debriefing was conducted through constant comparison within the research team to cross-validate codes and themes. We ensured methodological transparency by maintaining detailed documentation, which supported transferability and reflexivity. Furthermore, researcher expertise in risk communication and prolonged engagement with the data served to mitigate potential bias.

Rigor

In this study, the Lincoln and Guba criteria (1985), which include credibility, confirmability, dependability, and transferability, were used to examine the credibility of the data and findings (37). Given the long-term involvement of the research team with the research topic and the use of mixed methods such as literature review, document review, and interviews with experts in the field, the credibility of this qualitative study was ensured.

In addition, the research team sent a written transcript of each interview to each interviewee and asked for their opinion on the accuracy of the content. To ensure reliability and trustworthiness, the researcher provided some of the interviews and coding to a professor in the field, who reviewed the data and provided their suggestions and comments.

To confirm the quality of the qualitative research, the research team described the research process in detail so that other researchers could have a correct understanding of the stages and the entire study. In this study, a detailed description of the research environment, participant characteristics, selection methods and data analysis methods were provided to increase the transferability of the study (38).

Results

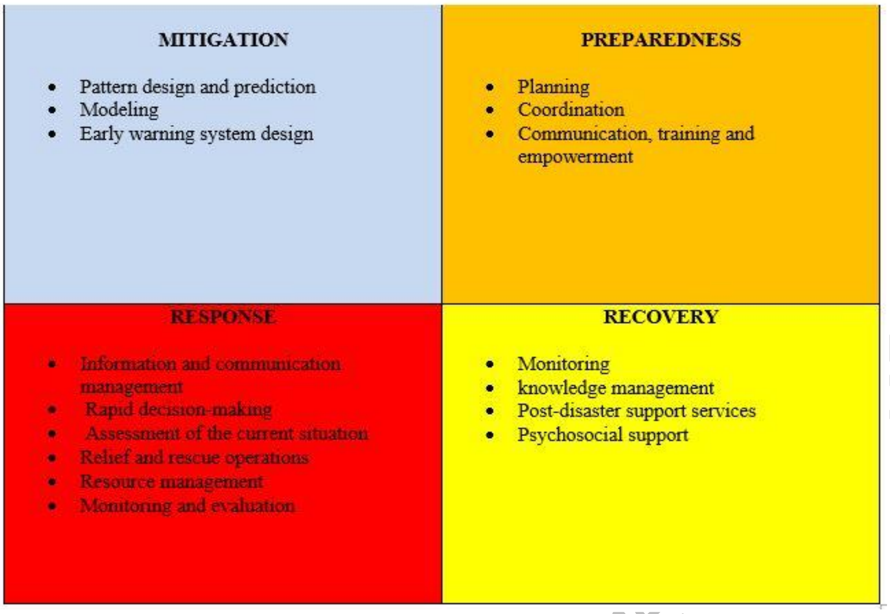
This study involved 14 experts, specialists, researchers, and faculty members with experience in artificial intelligence, healthcare, and disaster management. Their demographic information is presented in Table 1.

Table 1: Demographic Table of Research Participants

code	sex	Age	education	Job	work experience	Duration of work and study experience
P01	male	38	Biomedical Engineering	PhD student	10	5
P02	female	24	Health in Disasters and Emergencies	PhD student	8	7
P03	male	40	Health in Disasters and Emergencies	Faculty member	15	3
P04	female	49	IT	Faculty member	15	10
P05	male	42	IT	Faculty member	10	8
P06	male	35	Health in Disasters and Emergencies	Faculty member	7	3
P07	female	40	Health in Disasters and Emergencies	Faculty member	12	5
P08	female	38	artificial intelligence	PhD student	10	6
P09	male	47	Health in Disasters and Emergencies	Faculty member	16	3
P10	female	41	IT engineer	Information technology company	15	5
P11	male	39	artificial intelligence	PhD student	12	4
P12	female	28	Health technology student	PhD student	7	3
P13	male	42	IT	PhD student	20	7
P14	male	38	IT	Faculty member	12	5

A total of 489 codes were identified in this study. After multiple rounds of review and revision to remove irrelevant or duplicate codes, 298 codes remained. These codes were categorized into four main categories and its subcategories by the phases of the disaster management cycle (figure 1). The categories were: mitigation (with 3 subcategories: pattern design and prediction, modeling, and early warning system design), Preparedness (with 3 subcategories: planning, coordination and communication, training and empowerment), Response (with 6 subcategories: information and communication management, rapid decision-making, assessment of the current situation, relief and rescue operations, resource management, and monitoring and evaluation), and Recovery (with 4 subcategories: monitoring, knowledge management, post-disaster support services, and psychosocial support). Table 2 provides a detailed overview of the categories, subcategories, and selected codes.

Figure 1: Thematic Framework of AI Applications in Disaster Management
(Based on Qualitative Content Analysis of Expert Interviews)



A: Mitigation

Risk reduction is the first stage of the disaster management cycle. This phase involves the systematic identification, assessment, and management of disaster risks to reduce socio-economic vulnerabilities. Given the paradigm shift from reactive to proactive disaster risk reduction, strengthening this phase through new technologies—including artificial intelligence—can guide organizations and societies toward greater resilience.

A-1: Monitoring and Prediction

Artificial intelligence algorithms can analyze and identify patterns and trends from historical data that can help predict potential risks and vulnerabilities. This enables proactive action by organizations and communities.

"Artificial intelligence has made it possible to predict climate risks with relative accuracy through the analysis of temperature and precipitation trends in recent years. The outputs of artificial intelligence algorithms can even estimate the extent of vulnerability caused by these risks and crises." (Participant 3)

A:2 - Modeling

Since disaster risk reduction depends on numerous factors, modeling existing conditions is a crucial first step. For instance, modeling population and behavioral patterns can facilitate timely and appropriate response planning, as these patterns significantly impact evacuation procedures, emergency sheltering, essential needs, and other factors during emergencies. Modeling requires basic requirements such as high-quality and comprehensive data such as spatial data (GIS) and up-to-date satellite images, appropriate algorithms for predictive models and image analysis. Furthermore, operational considerations such as integration with existing decision-making systems and interpretability of results, along with security and ethical considerations must be taken into account.

"Various models can be developed based on big data using artificial intelligence algorithms. For example, you can collect roads and routes using aerial maps and then model the roads and their accessibility for rescue operations, including alternative routes. This is particularly important in the context of the Tehran earthquake." (Participant 5)

A3: Designing Early Warning Systems

Artificial intelligence-powered early warning systems can monitor various data sources in real time to identify potential hazards or threats, including natural disasters, human-made incidents, and even security events such as cyberattacks. Continuous monitoring and timely alert issuance enable organizations to take immediate action to mitigate the impacts of these events.

The AI-powered tsunami warning system used by the Japan Meteorological Agency employs deep learning to analyze seismic data in real time and can issue warnings 30 seconds earlier than traditional systems .(40).

"Using artificial intelligence algorithms, early warning systems can be designed and deployed to send early and initial warnings by identifying emerging hazards or trends and even analyzing them. In fact, with the capabilities of artificial intelligence*, these tasks are performed automatically, based on analysis, and in the shortest possible time." (Contributor 4)*

B: Preparedness

Preparedness is a crucial phase in the disaster management cycle. It encompasses proactive, meticulously planned measures designed to ensure effective and efficient responses to potential disasters and emergencies. This preparedness must be adequate to address all types of emergencies. In other words, preparedness refers to proactive actions—grounded in comprehensive planning—that enable effective and efficient disaster response.

The preparedness phase encompasses nine key components: organizational framework, planning, assessment and situational analysis, warning systems, essential resource provision, information recording system, drills and exercises, training, and response mechanism (communication) (41).

B-1: Planning

With its capacity to analyze massive amounts of complex data, artificial intelligence is revolutionizing disaster management planning and policymaking. By simulating disaster scenarios, accurately predicting risks, optimizing resource allocation, and improving inter-organizational coordination, AI enables predictive rather than reactive planning. Artificial – intelligence - based intelligent systems can dynamically adjust response protocols, optimize evacuation routes and logistics, and even improve the readiness of relief teams through training simulations.

Planning and policymaking are one of the main pillars of disaster management. Comprehensive, dynamic and flexible planning should be done in the preparation phase, and the documented and approved duties of the response team should be prepared and updated based on the incident phase, protocols and guidelines, which will help to improve the preparedness of the health system in this area.

"Based on previous experiences, information, and existing plans and conditions, it is possible to design dynamic operational planning and even adaptive responses based on secondary emergencies using artificial intelligence" (Participant 2).

B-2: Coordination and Communication

Coordination plays a crucial role in disaster management. Given the involvement of multiple organizations in planning service delivery, relief operations, and related actions during the response phase, effective coordination—supported by a coordinating body—can significantly enhance the effectiveness of these activities. Artificial intelligence and information and communications management during the preparedness phase can facilitate access to organizational databases and provide organizations with an overview of their responsibilities, current conditions, and plans, thereby preventing duplication of effort and resource waste.

"Sharing organizational information with the aid of new technologies and artificial intelligence, such as chatbots, improves inter-organizational communication and coordination. This in turn enhances organizational and even cross-organizational preparedness in disaster response." (Participant 7).

B-3: Training and Empowerment

The preparedness of organizations for incidents and disasters is contingent upon intra- and inter-sectoral coordination, training and empowerment of human resources, planning, implementation of mandatory and basic processes, and resource provision. Public preparedness often includes measures such as training, empowerment, and trust-building. Artificial intelligence can be highly effective in planning and delivering training courses within realistic simulated environments, including natural disaster simulations and scenario development. Both specialized training and general pre-disaster education can be facilitated using AI algorithms.

Chatbots can provided engaging training to the public and create platforms for Q&A to enhance preparedness and response to disasters. This can be a very strong two-way, trust-building, and even educational interaction." (Participant 10).

Table 2: Framework analysis results: Themes and codes for mitigation and preparedness phases

Categories	subcategories	Selected codes
Mitigation	Monitoring and Forecasting	Air Quality Monitoring and Weather Forecasting Traffic Image Surveillance Water Level Assessment and Flood Forecasting Urban Security Monitoring for Terrorist Incidents Weather Hazard Prediction Vulnerability Assessment
	Modelling	Population Pattern Modelling Modelling Behavioural Patterns Predictive Event Modelling Road and Accessibility Modelling
	Designing Early Warning Systems	Establishing Early Warning Systems Identifying emerging threats or trends Predicting and analysing risks Receiving and sending early and timely warnings
Preparedness	Planning	Dynamic Operational Planning Adaptive Response Planning Developing communication strategies, public messaging campaigns, early warning systems, and information dissemination channels using artificial intelligence -based tools
	Coordination and Communication	Resource sharing Information sharing Effective communication in disasters Enhancing community participation before, during and after crises Building connections and coordination among these stakeholders Increasing intra- and inter-organizational coordination
	Training and Capacity Building	Simulation of natural disasters for training Developing prediction and event scenarios Preparing and responding strategies for complex emergency scenarios Specialized and general pre-disaster training Training and awareness for managers and experts

A: Response

The implementation and execution of the operational response plan in accidents and disasters, across various organizational levels, including staff, public, and others, necessitates effective and timely command, guidance, control, and support management(16). During response operations, given the crucial importance of speed and accuracy in actions, artificial intelligence can offer significant assistance in providing services, making decisions, redesigning plans, and evaluating the current situation.

C-1: Information and Communications Management

In times of disaster, a wide range of information reaches managers from various sources. On the other hand, communication infrastructure such as electricity, telephone lines, and mobile phones may be damaged or inoperable. Artificial intelligence can analyze data from various sources to predict the potential impact of a disaster or emergency and help responders better prepare and allocate resources. It can also provide new and backup communication channels for communicating with the field and the relief organizations and forces.

"One of the problems during crises is the existence of a lot of information that may even confuse managers. The existence of a large information bank that can collect, categorize and analyze all data and provide appropriate output to managers can also increase the speed of actions and decisions." (Participant 7).

C-2: Rapid Decision-Making

In addition to assisting responders in making crucial decisions by providing real-time information, recommendations, and insights based on data analysis, artificial intelligence algorithms can also facilitate rapid evidence-based decision-making.

"In critical situations where a tense situation requires quick and intelligent decision-making with the lowest possible margin of error, artificial intelligence and its deep neural algorithms can assist in such decision-making." (Participant 14)

C-3: Situation Assessment

Assessment is one of the most important management tasks, and by examining the current situation, the need for transparent support mechanisms can become clear. To perform this function, it is necessary to use appropriate and standard tools. Determining damaged buildings, blocked water and blocked highways, and quickly assessing the status of injured and dead people by drones, the Internet of things and robots is possible and increases the speed of assessment.

"In disaster situations, especially floods and earthquakes, access to difficult areas will often be difficult. Today, machines equipped with the Internet of Things and drones can play the role of rapid assessment in affected areas." (Participant 11).

C-4: Resource Management

Artificial intelligence can help optimize the allocation of resources such as personnel, equipment, emergency supplies, the selection of suitable locations for emergency shelters, and rapid and preliminary damage during a disaster by analyzing data and matching it to existing conditions and resources.

"We really have a waste of resources, especially in the first few hours and days... Sending specialized personnel to an area at risk, sending ambulances and helicopters and medical equipment and... even housing and public aid... With artificial intelligence, these can be planned and managed based on the population involved, the type and severity of the incident, the number of potential casualties, the economic and safety status of the area under review." (Participant 1)

C-5: Monitoring and Evaluation

Monitoring the implementation of operational plans and protocols and providing feedback should be a priority for managers and experts from the beginning of the response phase to improve decision-making in the continuation of response operations. The Internet of Things, evaluation of reports, and analysis of documents by artificial intelligence algorithms can provide qualitative and quantitative evaluation of the efficiency and effectiveness of rescue operations.

"Unfortunately, monitoring and control are often neglected during disaster response due to chaotic and confusing conditions. However, we need to have an advanced and adaptable process to the existing conditions, which requires continuous change and updating. This change and updating need monitoring and supervision." (Participant 5)

C-6: Rescue Operations

Chatbots can help people affected in disaster zones find safe evacuation routes and reach shelters more quickly and safely. By using navigation services and real-time data processing, these chatbots can suggest the safest and most efficient routes to rescue teams based on real-time changes.

"Artificial intelligence can really cause a quick reaction with minimal mistakes and even harm to rescuers in the operations phase... For example, robots are being designed in Iran that do the work of search and rescue dogs... Or, for example, by using offline artificial intelligence *-based navigation routes, rescuers can find the best routes to their destination." (Participant 3).*

D: Recovery

Recovery is the fourth phase of the disaster management cycle. However planning for community recovery must begin during the response phase. This planning, based on a continuous assessment of damages and needs, should aim to restore the community to at least its pre-disaster condition. This has various dimensions, including the psychological, physical, social, economic, and spiritual recovery of the affected community. This phase should also consider monitoring all actions, recording lessons learned, and ensuring the livelihood of affected individuals(16).

D-1: Monitoring

Artificial intelligence can analyze data from previous phases of the disaster management cycle to predict future trends and outcomes and help organizations make informed decisions about resource allocation and recovery strategies. Additionally, artificial intelligence --equipped sensors and devices can remotely monitor infrastructure, equipment, and systems, enabling early detection of problems and timely intervention to prevent disruptions, such as in emergency housing situations.

"We really need more accurate monitoring during the recovery phase.. The safety of people in the accommodation area is very important.. Monitoring of arrivals and departures.. Using artificial intelligence to recognize people's faces and register them to prevent strangers from entering the area can be very helpful."(Participant 8).

D-2: Knowledge Management

Documenting individual and organizational experiences and lessons learned, exchanging them at national and international levels, and applying this knowledge in future programs will lead to the improvement of the disaster management process. In some studies, it has been suggested that a documentation team should be present alongside the monitoring and evaluation team from the beginning of the process. Knowledge management and documentation of information flows improving processes, lead to training and empowerment and prevent the waste of resources by avoiding the repetition of past mistakes.

"In a disaster, everyone is busy with work.. When we get to recovery, there's no one left to do the documentation. However, if we can use ChatGPT or robots, this process of collecting documentation can start from the previous phases and be aggregated during recovery.. One person can then evaluate and give final approval." (Participant 2).

D-3: Post-Disaster Support Services

Chatbots can continue to be of service even after the disaster is over, providing information and counseling support services during the post-disaster reconstruction period. These services can help people access relief programs, learn about insurance claims processes, and rebuild their lives.

"There is a need for support services in the recovery phase... both for the mental health management of responders and workers, and for reviewing response plans, and it can even help with requesting resources needed for future crises." (Participant 6).

D-4: Psychosocial Support

Leveraging new technologies and artificial intelligence for the provision of mental health, physical, and social rehabilitation services has become very common. In the post-pandemic period, the experience of using easy communication devices for online conversations and consultations, and websites for evaluating mental health conditions and prescribing management solutions using artificial intelligence, indicates good progress in this field.Chat-bots equipped with natural language processing (NLP) technology can provide counseling and psychological services to affected individuals.

"Unfortunately, monitoring and control during disaster response is neglected due to the chaotic and distraught conditions, while we should have an upgraded and adaptable process to the existing conditions, which requires ongoing change and updates." (Participant 5).

Table 3: Framework analysis results: Themes and codes for response and rehabilitation phases

Categories	subcategories	Selected codes
Response	Information and Communications Management	Faster access to information Collecting data from the physical environment and quickly transmitting this data to different parts of the city Automated collection and processing of information Rumour management Identifying fake news and information
	Rapid Decision-Making	Decision support tools Providing fast and accurate decisions Providing correct and fast solutions based on analysed data Solutions must be tailored to the specific needs and challenges of the Iranian context
	Situation Assessment	Rapid and accurate assessment of damage to infrastructure and buildings Assessment of the local, indigenous, and cultural conditions of the affected area Assessment of the extent of damage
	Emergency Response Operations	Use of search and rescue robots Distribution of supplies in hard-to-reach areas by drones Rescue in difficult-to-access areas by robots
	Resource Management	Automated search and rescue operation planning Remote and automated operation execution Optimization of resource allocation such as personnel, equipment, and supplies during a disaster using data analysis of needs and availability Uninterrupted communication between response teams Enhancing agility in response
	Monitoring and Evaluation	Monitoring infrastructure, equipment and systems Monitoring assistance to the affected community Conducting impact assessments, evaluating outcomes, and incorporating stakeholder feedback to continuously improve the effectiveness and efficiency of interventions Monitoring the recovery of facilities and infrastructure Monitoring and controlling the reconstruction process
Rehabilitation	Monitoring	Identification of temporary accommodation sites Identification of resources and capacities Identification of low-risk areas for temporary accommodation Analysis of the emergency situation Analysis of social media messages
	Knowledge Management	Documentation of lessons learned Conducting debriefing sessions Analysis of scenarios and incidents
	Post-Disaster Support Services	Fostering interaction between the people and the government Encouraging private sector investment Uninterrupted communication between recovery groups Social work
	Psychosocial Support	Solutions should be tailored to the needs and challenges of affected groups Spiritual rehabilitation using artificial intelligence Early detection of problems and timely intervention to prevent disruption Designing a recovery program with minimal cost

Discussion

The present study, by analyzing the opinions of Iranian experts, provides a complete map of the applications of artificial intelligence in all stages of crisis management. The most important finding is the diversity and sophistication of artificial intelligence tools in each stage. Unlike global studies that usually focus on disaster response(16), our findings show that artificial intelligence has a huge potential-yet to be fully utilized-in mitigation, preparedness, and especially post-disaster recovery. These results reveal the gap between global technologies and operational needs in countries like Iran.

Second, our findings challenge the technologically deterministic view that AI solutions can be directly transplanted across contexts. The experts' emphasis on infrastructural deficits, data quality issues, and inter-organizational coordination gaps in Iran suggests that AI adoption is fundamentally a socio-technical process. This aligns with and extends the work of Sun et al. (2020) and Abid et al. (2021), who called for greater attention to contextual factors in AI implementation. Recent research confirms that the effectiveness of AI models depends heavily on the quantity and quality of available data, and that 'sparse and imbalanced datasets' remain a significant challenge in disaster management contexts . Furthermore, institutional fragmentation and interoperability barriers have been identified as primary obstacles to AI-enabled disaster risk management in countries like Iran . Our study provides empirical evidence from a developing country context, contributing to a more globally representative understanding of AI in disaster management.

Experts emphasized the role of artificial intelligence in proactive mitigation and going beyond traditional, purely reactive models. Other studies of its applications in monitoring (flood forecasting and early warning) and modeling (e.g., estimating population dynamics) shift the paradigm from responding to disasters to predicting and preventing them (٤٤-٤٢) . However, a major obstacle remains: While experts predicted advanced early warning systems, they also highlighted fundamental obstacles such as data shortages and infrastructure deficits(45, 46). This suggests that in the Iranian context, the development of early data infrastructure is a prerequisite for the effective deployment of advanced artificial intelligence forecasting models. Other studies show that artificial intelligence techniques can quickly analyze large amounts of data for timely risk assessment (٤٨ ,٤٧), and artificial intelligence techniques can also quickly analyze large data and perform predictive analysis to support decision-making in disaster management (١٦). These analyzes can be used for modeling and predicting hazards, which is consistent with the results of the present study.

According to experts, artificial intelligence can be helpful in designing early warning systems. Identifying impending disasters in real time and sending early warnings are practical solutions for disaster preparedness. In this field, reliance is usually placed on expert analysis and judgments of sensor measurements in the field, and artificial intelligence techniques can act as a cost-effective alternative to predicting future events such as the path of approaching storms and hurricanes (٥٠ ,٤٩). A study by Chung et al. showed that with the implementation of the Internet of Things, cloud services can quickly share accurate information about disaster status for early warnings (٥١). Timely warning for response readiness, even in emergency evacuation situations, will play a very important role in reducing the number of deaths and injuries.

In the preparedness phase, planning plays a crucial role in timely response, staff training and exercises, and equipment and supplies storage. Event maps and damage information generated from various artificial intelligence methods can provide critical information for planning search and rescue operations, staging and deploying resources, and understanding short-term housing needs (٥٣ ,٥٢). These findings support this study as research participants identified information and communication management, rapid decision-making, situational assessment, rescue operations, monitoring and evaluation, and resource management were mentioned by research participants as key application of artificial intelligence in the response phase.

Among the phases of disaster management, the response phase has the largest number of artificial intelligence applications. Common artificial intelligence methods in this phase include the use of classifiers, reinforcement learning, and sentiment analysis techniques to process social media data, which have been discussed in various studies (٥٦-٥٤). The findings of this study, in line with other studies, confirm the critical role of artificial intelligence in information and communication management during disasters. By rapidly analyzing large amounts of data (big data), this technology enables effective decision-making and improves operations management (10). For example, data mining can be used to identify fake news (٥٨ ,٥٧) and track information dissemination patterns (٥٩). Artificial intelligence tools in areas such as rumor management and damage assessment address two major and perennial challenges in disasters: information ambiguity and situational uncertainty. This emphasis on finding solutions tailored to the Iranian context provides important insight. This suggests that off—the--shelf artificial intelligence solutions may fail therefore, developing intelligent "culture--aware" and "local context--sensitive" solutions that pay attention to local logistics, languages, and social structures is essential for success.

Participants in the current study cited monitoring, knowledge management, post-disaster support services, and psychological support as applications of artificial intelligence in the recovery phase of disaster management. A key contribution of this study is the detailed mapping of artificial intelligence in the recovery phase, an area that has been severely under-researched in the literature. Since disaster recovery typically takes a long time, including detailed damage assessment, budgeting, planning, permitting, design, and construction, artificial intelligence can be an important module to support more rapid and precise disaster recovery management (١٦). The use of artificial intelligence for psychosocial support (e.g., spiritual rehabilitation, early problem detection) and for strengthening public private partnerships represents a promising innovation. This study introduces artificial intelligence not only as a logistical tool, but also as a catalyst for community resilience and social cohesion in the long post-disaster period.

In the post-disaster recovery and reconstruction phase, governments must take timely action to assist in the reconstruction of homes and rehabilitation efforts. This requires a rapid assessment of damages and repair costs. Artificial intelligence methods can aid in estimating disaster damages and reconstruction costs. Specifically, supervised learning models, such as regression and neural networks, have been used to rapidly process images to identify structural damage, assess reconstruction needs, and estimate associated costs. Artificial intelligence has also been employed to analyze historical disbursement data for disaster recovery funds to allocate budgets and process insurance claims more efficiently (٦٢-٦٠) . A study by Kezdi et al. demonstrated that Artificial intelligence can be utilized for more effective disaster management, aiming to mitigate and minimize damages and enable more responsive incident response (٢٨).

The experts' perspective shows a clear dichotomy between optimism and realism. On the one hand, the broad horizons of artificial intelligence are outlined, and on the other, there are clearly visible structural obstacles such as data management problems, gaps in inter-organizational coordination, and a shortage of specialized personnel. This dichotomy is itself a key finding. It shows that the path forward for artificial intelligence in Iran's crisis management is not just a technical problem, but a profound socio-organizational challenge. Achieving success on this path requires simultaneous investment in three areas: technical infrastructure, policy frameworks, and human resource education and training. These three factors are essential foundations for success that are unfortunately usually ignored in purely technological plans.

This study has a methodological limitation due to its focus solely on expert opinions. Although this approach provides valuable insights, it ultimately reflects a "top-down" perspective. To complement this perspective, it is suggested that future research also examine the direct experiences of local aid workers and communities directly affected by the crisis, to develop a "bottom-up" perspective. In addition, the practical feasibility and cost-effectiveness of the proposed solutions need to be assessed using quantitative methods.

The generalizability of findings may be constrained by the study's specific focus on the Iranian context. However, the analytical framework and thematic findings provide a foundation for future comparative studies in similar settings.

Conclusion

This study provides a comprehensive, phase-based conceptual framework of artificial intelligence applications in disaster management, grounded in the perspectives of Iranian experts. By mapping AI applications across the four phases of the disaster management cycle—mitigation, preparedness, response, and recovery—this research moves beyond a simple inventory of technologies to offer a structured understanding of how AI can transform disaster management practices.

The framework reveals that AI's potential extends far beyond the response phase, which has been the traditional focus of disaster technology research. In the mitigation phase, AI enables proactive risk reduction through advanced monitoring, predictive modeling, and early warning systems. In the preparedness phase, AI supports dynamic planning, enhances inter-organizational coordination, and facilitates realistic training through simulations. The response phase benefits from AI's capacity for rapid information processing, real-time decision support, situational awareness, and optimized resource allocation. Importantly, this study identifies underexplored applications in the recovery phase, including AI-powered monitoring, knowledge management, post-disaster support services, and psychosocial interventions—areas that have received limited attention in existing literature.

Theoretically, this study contributes to the growing body of knowledge on AI in disaster management by offering a contextually-grounded framework that can be tested, refined, and adapted in other settings. The findings challenge the prevailing emphasis on reactive applications and demonstrate that AI's transformative potential lies in its integration across the entire disaster continuum.

For policymakers and practitioners, this framework serves as a strategic roadmap. It highlights priority areas for investment, including: (1) developing robust data infrastructure and interoperable systems; (2) fostering cross-sectoral collaboration between academia, government, and technology industries; (3) establishing ethical guidelines and regulatory frameworks specific to AI use in disaster contexts; (4) designing educational programs to build a workforce proficient in both AI and disaster management; and (5) creating culturally-sensitive AI solutions that address local needs and contexts.

Strengths and Limitations

A key strength of this study is its qualitative depth, capturing rich, experiential knowledge from experts across multiple disciplines. However, several limitations should be acknowledged. First, the sample, while achieving saturation, was predominantly drawn from academia, with limited representation from government and industry sectors. Future research should seek to include more diverse perspectives, particularly from frontline responders and technology developers. Second, the findings reflect the Iranian context; while this provides valuable insights for similar settings, the transferability of the framework to other cultural and infrastructural contexts requires further investigation. Third, as a qualitative study, the framework identifies "what" AI applications are possible but does not evaluate their effectiveness, feasibility, or cost-benefit ratios—areas that warrant future quantitative and mixed-methods research.

Sample Composition and Representation: While the sample achieved thematic saturation and included participants with diverse expertise, we acknowledge an imbalance in sector representation. The predominance of academic participants (13 out of 14) means that governmental and industrial perspectives were primarily accessed indirectly through academics' collaborative experiences, rather than directly from policymakers or industry practitioners. This limitation reflects the current reality in Iran, where specialized knowledge of AI in disaster management is largely concentrated in academic institutions, and where access to high-level government officials and industry leaders for in-depth qualitative interviews can be challenging due to institutional barriers and time constraints.

To mitigate this limitation, we intentionally recruited academics with documented histories of collaboration with government agencies and industry partners. Additionally, our interview

guide included questions specifically designed to elicit perspectives on policy-level challenges and technological implementation barriers. Nevertheless, future research would benefit from dedicated efforts to recruit more participants directly from government and industry sectors. This could be achieved through formal institutional partnerships, targeted sampling strategies, and extended fieldwork periods.
Despite this limitation, the depth and richness of data obtained from the 14 participants provide a robust foundation for the proposed conceptual framework. The findings offer valuable insights that can inform hypothesis generation and guide subsequent quantitative research with larger, more representative samples across all three sectors.

Recommendations for Future Research

- Based on these findings, we propose several directions for future inquiry:
- Conduct empirical studies to evaluate the actual implementation and impact of specific AI applications in real-world disaster settings
- Develop and validate metrics for assessing AI readiness across different phases of disaster management
- Explore the ethical, legal, and social implications of AI deployment in disaster contexts, particularly regarding data privacy, algorithmic bias, and accountability
- Investigate community perspectives on AI use in disasters to complement the expert views presented here
- Examine how AI can be integrated with traditional disaster management practices and indigenous knowledge systems

Ethical consideration

This study was approved by the Ethics Committee of Alborz University of Medical Sciences (Ethics Code: IR.ABZUMS.REC.1401.231). Before each interview, the study objectives, data usage procedures, and participant expectations were explained in simple language. All participants were informed that their participation was completely voluntary and that they could withdraw at any stage without penalty. Written informed consent (or audio-recorded verbal consent for online interviews) was obtained from all participants.
To ensure confidentiality, participants were assured that no names, organizational affiliations, or any identifying information would be disclosed; all quotes and data are presented using alternative codes (e.g., "Expert 1"). All audio and text files were stored on an encrypted hard drive and will be deleted upon participant request after analysis. The research team carefully avoided questions that could cause psychological or social discomfort. Participants were also given the opportunity to review and revise their interview transcripts before analysis. Any potential relationships between researchers and participants (e.g., prior professional collaboration) were disclosed and managed to maintain objectivity.

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Competing interests

The authors declare that they have no financial or personal conflict of interest.

Authors' contributions

Study conception and design: Z.E, A.D.; data collection: A.D. and Z.E.; analysis and interpretation of results: A.D. and Z.E.; draft manuscript preparation: Z.E, A.D. All authors reviewed the results and approved the final version of the manuscript.

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Data availability

The authors confirm that the data supporting the findings of this study are available within the article or indexes.

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