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# Disaster Risk Management and AI: A Grounded Theory Approach to Epidemic Response

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**Abstract**

Over the past few years, there has been a growing interest in utilizing artificial intelligence in disaster risk management (DRM), particularly in epidemic response. This study employs a grounded theory methodology to explore expert perspectives on AI's applications, opportunities, and challenges in managing disasters, with a focus on epidemic outbreaks. AI-driven predictive analytics, real-time decision support, and resource optimization have enhanced disaster preparedness and response, but challenges such as data quality, algorithmic bias, governance frameworks, and ethical concerns remain significant. 63 experts from different backgrounds participated in our study. The findings revealed the necessity of integrating AI within regulatory structures, addressing interoperability issues, and fostering interdisciplinary collaboration to maximize its effectiveness. A theoretical model is developed, synthesizing AI applications across functional layers to provide a structured understanding of its role in DRM. The study concludes that while AI can revolutionize disaster preparedness, its success depends on balancing technological advancements with ethical considerations and governance structures. Future research should explore innovations that enhance AI's reliability, transparency, and public trust, ensuring its responsible deployment in DRM.

**Keywords:** Artificial Intelligence, Disaster Risk Management, Epidemic Response, Grounded Theory, Predictive Analytics

## Introduction

The increasing frequency and severity of disasters, both natural and man-made, have necessitated the integration of advanced technologies into disaster risk management (DRM) frameworks. AI, with its ability to process vast amounts of data, identify patterns, and generate predictive models (Esteva *et al*., 2017; Goodfellow *et al*., 2016; LeCun *et al*., 2015; Mnih *et al*., 2015; Russell & Norvig, 2020; Silver *et al*., 2017; Shahghasemi, 2025) [13, 15, 16, 20, 24, 25, 30] has emerged as a transformative tool in disaster preparedness, response, and recovery. AI applications in DRM encompass predictive analytics, real-time decision support, and automated emergency management systems, allowing authorities to optimize resource allocation and improve situational awareness (Cao, 2023) [6]. The effectiveness of AI in disaster management has been particularly evident in the wake of the COVID-19 pandemic, where machine learning (ML) and big data analytics have played a crucial role in tracking outbreaks, forecasting epidemic curves, and managing healthcare resources (Bragazzi *et al*., 2020) [4]. Despite these advancements, AI's implementation in DRM is not without challenges. Issues related to data quality, algorithmic biases, interoperability with existing systems, and ethical considerations remain significant barriers to AI's full potential in disaster risk management (Waheeb, 2024) [31].

Recent studies have underscored the value of AI in various aspects of DRM. For instance, Lombardi *et al*. (2022) [18] highlighted the role of AI and big data in epidemic disaster management, emphasizing their contribution to risk assessment and decision-making processes. Their structured literature review demonstrated how AI-driven models enhance emergency response strategies and support public health interventions. Similarly, Ramos Chaparro *et al*. (2024) [23] conducted a scoping review on AI's predictive capabilities in health emergencies, illustrating how AI facilitates early warning systems for both epidemic outbreaks and natural disasters. These studies collectively suggest that AI has the potential to transform disaster preparedness and response mechanisms by enabling rapid data analysis and evidence-based decision-making.

One of the most critical applications of AI in DRM is predictive analytics, which leverages historical data, climate trends, and geospatial information to forecast disaster events. AI-driven early warning systems can provide timely alerts to emergency responders and policymakers, enhancing preparedness and mitigating disaster impacts (Chamola *et al*., 2021) [7]. In the context of epidemics, AI has been used to predict disease spread through real-time analysis of hospital records, mobility patterns, and social media discussions (Yang *et al*., 2021) [33]. AI-based surveillance tools, such as those developed during the COVID-19 pandemic, have enabled governments to monitor infection rates, enforce containment measures, and distribute medical resources efficiently (El Khatib *et al*., 2023) [10]. However, the effectiveness of these systems is contingent on the availability of high-quality data and robust data-sharing mechanisms, which remain a challenge in many regions.

Beyond predictive analytics, AI also plays a crucial role in real-time decision support for disaster response. AI-powered decision-support systems integrate multiple data sources—ranging from satellite imagery to emergency hotline reports—to generate actionable insights for disaster management teams (Wen *et al*., 2023) [32]. These systems aid in resource allocation, crowd evacuation planning, and infrastructure damage assessment, ultimately improving response efficiency. For example, AI-driven algorithms have been employed to optimize hospital bed occupancy, allocate ventilators, and streamline vaccine distribution during pandemics (Elsotouhy *et al*., 2021) [11]. The ability of AI to process and synthesize vast datasets in real time enables authorities to make informed decisions rapidly, reducing the overall impact of disasters on affected populations. Nonetheless, concerns over the transparency and interpretability of AI-generated recommendations persist, necessitating the integration of human oversight in AI-driven decision-making processes (Cao, 2023) [6].

Despite the promise of AI in DRM, significant barriers hinder its widespread adoption. One of the primary challenges is the issue of data quality and availability. AI models rely on large volumes of high-quality data to generate accurate predictions and recommendations. However, many disaster-prone regions lack the necessary data infrastructure to support AI applications, leading to potential inaccuracies and inefficiencies (Ramos Chaparro *et al*., 2024) [23]. Additionally, the interoperability of AI systems with existing DRM frameworks presents another major hurdle. Many disaster response agencies still rely on legacy systems that are incompatible with modern AI technologies, requiring substantial investments in digital infrastructure and training (Waheeb, 2024) [31]. The financial burden associated with AI adoption further exacerbates these challenges, particularly in low-resource settings where disaster preparedness budgets are already constrained.

Ethical and governance concerns also pose significant challenges to the integration of AI in DRM. Issues such as algorithmic bias, data privacy, and accountability in AI-driven decision-making have raised ethical dilemmas among policymakers and disaster management professionals (El Khatib *et al*., 2023) [10]. Algorithmic bias, in particular, has been a pressing concern, as AI models trained on Western datasets may not perform accurately in diverse global contexts (Bragazzi *et al*., 2020) [4]. This discrepancy can lead to inequitable disaster responses, disproportionately affecting vulnerable populations. Moreover, the lack of standardized AI governance frameworks has led to inconsistencies in AI deployment across different regions, highlighting the need for international collaboration and regulatory oversight to ensure responsible AI use in DRM (Elsotouhy *et al*., 2021) [11].

To address these challenges, experts advocate for a multidisciplinary approach that combines technological innovation, ethical considerations, and policy reforms. In the age of AI, most businesses find themselves compelled to provide further education for their personnel.

Investments in AI literacy for disaster management professionals can enhance their ability to interpret and utilize AI-driven insights effectively (Zamani *et al*., 2024; Cao, 2023) [34, 6]. Additionally, fostering public-private partnerships can accelerate AI research and development while ensuring that AI technologies are accessible and ethically deployed (Wen *et al*., 2023) [32]. The establishment of international AI governance standards is also crucial in mitigating the risks associated with AI adoption in DRM. Such frameworks should emphasize transparency, fairness, and inclusivity, ensuring that AI-driven disaster management solutions are both effective and equitable (Chamola *et al*., 2021) [7].

Given the complex ecosystem in which AI capabilities, governance structures, and societal factors work together, a grounded theory approach is well-suited for examining the role of AI in DRM. This study employs grounded theory methodology to explore expert perspectives on AI's application in epidemic disaster management, with a focus on the Iranian context. Through systematic data collection and analysis, the research aims to develop an empirically grounded theoretical model that captures the opportunities, challenges, and implications of AI-driven disaster risk management. By integrating insights from AI experts, public health officials, and disaster response practitioners, this study seeks to contribute to the growing body of literature on AI's role in DRM while offering practical recommendations for policymakers and technology developers.

**Review of literature**

Lombardi *et al*. (2022) [18] conducted a structured literature review to examine the relationship between big data, AI, and epidemic disasters, including the SARS-CoV-2 pandemic. The study aimed to provide a comprehensive understanding of the existing research landscape and identify key implications for managing and preventing epidemic crises. Using a longitudinal approach, the authors analyzed two decades of literature sourced primarily from Scopus. The review highlighted the role of big data and AI in epidemic tracking, prevention, and emergency management by public and private organizations, institutions, and policymakers. Key findings emphasized the significance of smart technologies in decision-making processes, risk assessment, and response strategies. This study is notable for being the first to systematically explore the intersection of big data, AI, and epidemic disasters, offering insights into emerging challenges and opportunities in epidemic management. The authors also outlined a research agenda to guide future studies on the topic.

Ramos Chaparro *et al*. (2024) [23] conducted a scoping review to examine the role of AI in predicting health emergencies and disasters. The study aimed to assess AI's capabilities in forecasting epidemic outbreaks and natural disasters, highlighting both advancements and challenges in its application. Using PubMed, Scopus, and LILACS, the authors analyzed freely accessible articles published between 2013 and 2024 in Spanish, English, or Portuguese, focusing on AI-driven disaster prediction and management. The selected studies were categorized and key findings extracted for analysis. Results emphasized AI's growing potential in epidemic forecasting, particularly in symptom-based predictions, while also demonstrating its efficacy in predicting natural disasters such as cyclones, floods, sea-level changes, and earthquakes. However, challenges remain, including real-time data integration, regional variability, and global communication barriers. The authors concluded that AI is a transformative tool in healthcare and disaster management, but its full potential can only be realized through technological innovation, ethical considerations, and international collaboration.

Waheeb (2024) [31] explored the role of AI in improving risk management within healthcare centers, particularly in disaster and emergency scenarios. The study underscored the necessity of proactive risk assessment and preparedness planning at national, regional, and local levels to ensure healthcare continuity during crises. AI applications in healthcare were examined, including its role in reducing the burden on medical staff, optimizing treatment strategies, supporting diagnostics through image analysis, and managing emergency response logistics. The study also highlighted AI's potential in gene therapy, surgical assistance, and patient care, particularly in addressing workforce shortages and improving efficiency. While AI presents significant benefits, challenges such as ethical concerns, data accuracy, and integration complexities must be addressed. The author concluded that AI-driven innovations are essential for enhancing healthcare resilience, disaster preparedness, and emergency response capabilities, particularly in light of lessons learned from the COVID-19 pandemic.

Chamola *et al*. (2021) [7] conducted a comprehensive survey of machine learning (ML) algorithms applied to disaster and pandemic management, highlighting their role in prediction, response, and mitigation efforts. The study reviewed various ML techniques that process large, multidimensional datasets essential for disaster scenarios. The authors discussed ML applications across different phases of disaster management, including predisaster risk assessment, crowd evacuation strategies, and post-disaster recovery. The integration of ML with technologies such as IoT, UAVs, 5G networks, and satellite-based systems was explored, demonstrating their effectiveness in improving situational awareness and decision-making. Furthermore, ML's role in pandemic management was examined, including its use in disease prediction, outbreak monitoring, and automated diagnosis. The article also addressed challenges such as data quality, model interpretability, and computational constraints, emphasizing the need for further research and interdisciplinary approaches. The authors concluded that ML has the potential to significantly enhance disaster resilience and pandemic response when effectively integrated with emerging technologies.

Elsotouhy *et al*. (2021) [11] examined the role of big data (BD) in enhancing disaster management strategies during pandemics, emphasizing its capacity to structure and analyze vast amounts of unorganized data. The study highlighted the limitations in current research on utilizing BD for crisis response, particularly during large-scale health emergencies. The authors proposed a BD-centric approach to pandemic disaster management, leveraging text analytics for data visualization, explanation, and predictive insights. By analyzing past disaster management efforts, the study demonstrated how BD can improve future crisis responses through more effective information processing and decision-making. The findings underscored the necessity of integrating BD techniques into disaster management frameworks to enhance situational awareness and response efficiency. The authors concluded that while BD presents significant potential for mitigating pandemic-related chaos, challenges remain in fully harnessing its capabilities for disaster preparedness and management.

Cao (2023) [6] explored the role of AI and data science in enhancing resilience against emergencies, crises, and disasters (ECDs). The study provided a systematic overview of various ECDs, including natural disasters, pandemics like COVID-19, cyberattacks, and geopolitical conflicts. Traditional disaster management approaches were critiqued for their reactive nature, prompting the proposal of AI for Smart Disaster Resilience (AISDR). This framework leverages AI and big data to enable proactive disaster prediction, early warning systems, and real-time response strategies. The research identified key challenges in AISDR, including data complexity, ethical considerations, and the need for interdisciplinary collaboration. The author emphasized the importance of digital transformation in disaster management, advocating for AI-driven decision-making tools, predictive modeling, and autonomous systems to improve preparedness and recovery. The study concluded that integrating AI into disaster management can enhance resilience, optimize resource allocation, and mitigate the impact of crises, but requires addressing existing technological and governance challenges.

Elsotouhy *et al*. (2021) [11] investigated the integration of big data (BD) in disaster management to enhance crisis response during pandemics and epidemics. The study highlighted BD's ability to transform unstructured data into structured insights, addressing gaps in pandemic preparedness. The authors proposed a BD-centric approach that leverages text analytics for data visualization, explanation, and predictive analysis, allowing for a more comprehensive understanding of disaster management processes. Their findings emphasized the importance of analyzing past pandemic responses to refine future crisis strategies. Despite the widespread disruptions caused by pandemics, the study noted that communities often struggle with information overload and a lack of actionable insights. The authors concluded that BD is a crucial tool for improving pandemic response efficiency by enabling real-time data processing, decision-making, and risk assessment.

El Khatib *et al*. (2023) [10] examined the role of AI in mitigating "unknown unknown" risks—unforeseen and unquantifiable threats—during the COVID-19 pandemic. The study analyzed six case studies, revealing that unknown risks are difficult to predict and report in advance. However, AI proved to be a crucial tool for disaster recovery by enabling rapid response, decision-making, early prediction, automated processes, and tracking. The authors highlighted

AI's capacity to identify patterns in large datasets, facilitating post-event impact assessment and informing future risk mitigation strategies. The research underscored the importance of AI-driven solutions in managing crisis response, particularly in cases where traditional risk assessment methods fall short. The study concluded that AI has transformative potential in disaster recovery, offering a proactive approach to handling unpredictable crises through advanced analytics and automation.

Bragazzi *et al.* (2020) [4] examined the applications of AI and big data in managing the COVID-19 pandemic, emphasizing their role in public health surveillance, outbreak monitoring, and decision-making. The study highlighted AI's capability to process large-scale, real-time data, aiding in early detection, case tracking, and predictive modeling. The authors discussed short-term applications such as AI-driven epidemiological monitoring and diagnostics, including social media analysis and imaging-based COVID-19 detection. Medium-term applications included AI-assisted drug discovery and public health intervention strategies. In the long term, AI and big data were proposed as tools for building smart, resilient cities with enhanced public health response capabilities. The study concluded that while AI significantly enhances pandemic management, challenges such as data veracity, ethical concerns, and integration into existing health systems must be addressed to maximize its effectiveness.

Wen *et al.* (2023) [32] conducted a bibliometric analysis to explore the role of digital technologies in the emergency management of global public health emergencies. The study examined research trends from 2003 to 2022 using data from the Web of Science Core Collection, analyzing author collaborations, institutional contributions, keyword co-occurrence, and research frontiers. Findings revealed exponential growth in publications on this topic, with the USA, China, and the UK leading in contributions, though global cooperation remains limited. Key research areas included AI-driven machine learning, deep learning, big data analytics, blockchain, and the Internet of Things (IoT), all of which were applied to disease identification, outbreak prediction, and crisis response. The social media have had an increasing role in all aspects or people's lives (Zamani *et al.*, 2021) [34], becoming a cornerstone of modern society—reshaping economies through digital marketplaces and influencer capitalism, redefining political discourse, altering cultural norms, and even influencing public health behaviors (Arsalani *et al.*, 2024). This study highlighted the importance of social media data analysis for public health decision-making and identified future research directions, including enhanced smart governance for public health crises. The authors concluded that while digital technologies significantly improve emergency preparedness, challenges such as data governance, ethical considerations, and interdisciplinary collaboration must be addressed.

## Methodology

This study employs grounded theory methodology to explore the role of AI in disaster risk management during epidemics, with a focus on insights from Iranian experts. Grounded theory is an inductive research approach that facilitates the development of theoretical models based on systematic data collection and analysis (Birks & Mills, 2015; Bryant & Charmaz, 2019; Charmaz, 2014; Corbin & Strauss, 2015; Glaser & Strauss, 1967; Urquhart, 2013) [3, 5, 8, 9, 14, 29]. Given the rapidly evolving landscape of AI applications in epidemic management and the need for an in-depth understanding of its opportunities and challenges, grounded theory was deemed the most suitable methodological framework. This approach allowed us to extract patterns, themes, and relationships from expert insights while ensuring that the resulting theoretical model is empirically grounded rather than based on pre-existing assumptions.

### Research Design

The research was conducted in three iterative phases—data collection, coding (open, axial, and theoretical), and model development. Semi-structured interviews were conducted with Iranian experts in AI, public health, and disaster management, ensuring a diverse range of perspectives. The interview questions focused on AI's role in epidemic surveillance, decision support, resource optimization, public communication, ethical concerns, and regulatory challenges. Interviews were audio-recorded and transcribed verbatim, with additional field notes taken to capture contextual insights. Data collection continued until theoretical saturation was reached, ensuring that no new themes emerged from additional interviews.

### Sampling Strategy

A purposive sampling technique was employed to recruit participants with expert knowledge and practical experience in AI-driven disaster risk management. The inclusion criteria required participants to have at least five years of experience in either AI research and development, public health policy, or emergency management. Snowball sampling was also utilized to identify additional experts based on recommendations from initial participants. This strategy ensured that the sample included individuals with diverse yet complementary expertise, allowing for a holistic analysis of AI's application in epidemic disaster management. Overall, 63 people participated in our research. Previous to the interview, interviewees' informed consent was obtained.

### Data Analysis Process

Data analysis was conducted using three stages of grounded theory coding:

Open Coding – This initial stage involved breaking down the raw interview data into meaningful conceptual units. A total of 412 initial codes were identified and subsequently grouped into 36 conceptual categories representing key AI applications and challenges in epidemic risk management. Examples of open coding categories included AI-driven early warning systems, real-time data analytics, misinformation control, healthcare resource allocation, and regulatory challenges.

Axial Coding – In this phase, conceptual categories were refined and linked based on their relationships, resulting in six major thematic clusters: AI in Surveillance and Early Detection, AI in Decision Support for Policymakers, AI in Public Communication and Risk Perception Management, AI-Enabled Healthcare Resource Optimization, Ethical and Societal Challenges in AI Deployment, and Institutional and Regulatory Readiness for AI Adoption. These clusters established the structural foundation for the final theoretical model.

Theoretical Coding – The final coding stage involved integrating axial coding categories into a coherent theoretical framework. The AI-Enabled Epidemic Risk Management Model emerged, synthesizing AI applications across four key functional layers: Input Layer (AI-driven data sources), Processing Layer (AI decision models), Output Layer (Policy and Public Communication), and Feedback Loop (Ethical, Social, and Regulatory Considerations). The model illustrates AI's dynamic role in predicting, mitigating, and responding to epidemic risks, while also accounting for governance challenges and societal trust issues.

**Validation and Theoretical Saturation**

To ensure the credibility and reliability of findings, multiple validity checks were employed throughout the research process. Member checking was conducted, where selected participants reviewed preliminary findings to verify the accuracy of interpretations. Intercoder reliability was assessed through independent coding by two researchers, and only items approved that achied a high level of agreement in code classification. Theoretical saturation was determined when new interviews yielded no additional categories or insights, indicating that the developed theoretical model comprehensively captured the phenomenon under study.

**Ethical Considerations**

The study adhered to ethical research principles, ensuring informed consent, confidentiality, and voluntary participation. All participants were provided with detailed information about the study's objectives, their rights, and data protection measures. Interview data were anonymized to protect participant identities, and all recordings and transcripts were securely stored with restricted access.

**Findings**

**Open Coding**

Open coding was performed as the initial stage of data analysis, where significant statements, phrases, and themes were identified from the expert interviews. This process allowed us to categorize and label emergent concepts that define how AI is utilized in disaster risk management during epidemics. A total of 412 initial codes were extracted, and after a thorough review, these were grouped into 36 conceptual categories.

Below is a table summarizing representative open coding results from the expert interviews:

**Table 1:** Sample Open Coding Results

| Conceptual Code | Representative Quotes from Experts | Thematic Area |
|---|---|---|
| **AI-driven early warning systems** | "AI can predict the likelihood of outbreaks by analyzing social media discussions, hospital records, and environmental factors." | Surveillance & Detection |
| **Real-time data analytics for decision-making** | "We use AI to consolidate epidemiological reports from different provinces to make decisions on lockdowns." | Decision Support |
| **AI for misinformation control** | "AI models help us detect and flag fake news about COVID-19 treatments, preventing public panic." | Public Communication |
| **AI in hospital resource allocation** | "Predictive algorithms allocate ventilators based on patient influx data, preventing shortages in hospitals." | Healthcare Optimization |
| **AI-assisted logistics for emergency response** | "We leveraged AI to optimize the distribution of vaccines in rural areas with limited transport infrastructure." | Healthcare Optimization |
| **Privacy concerns in AI-based contact tracing** | "Some citizens refused AI-driven contact tracing due to data privacy fears, limiting its effectiveness." | Ethical & Legal Challenges |
| **Algorithmic biases in AI models** | "Most AI models are trained on Western datasets, making them less effective in Iran's unique demographic and healthcare context." | Ethical & Legal Challenges |
| **Challenges of integrating AI with legacy health systems** | "One of the biggest barriers is that hospitals still rely on outdated data management systems that don't integrate well with AI platforms." | Institutional Readiness |
| **Need for regulatory frameworks for AI deployment** | "We lack standardized AI governance policies, leading to hesitancy in fully integrating AI into epidemic management." | Institutional Readiness |

**Thematic Clusters Identified**

Through open coding, patterns emerged, revealing six key thematic clusters that encapsulate the major discussions among Iranian experts:

1. AI in Surveillance and Early Detection
   - AI models analyzing epidemiological data, social media trends, and environmental sensors.
   - AI's role in predicting and preventing potential outbreaks before they escalate.
2. AI in Decision Support for Policymakers
   - Use of AI in scenario modeling for lockdowns, vaccinations, and resource distribution.
   - AI-generated insights guiding policymakers in real-time decision-making.
3. AI in Public Communication and Risk Perception Management
   - AI-powered sentiment analysis for understanding public fears and concerns.
   - AI's role in countering misinformation and providing accurate health advisories.
4. AI-Enabled Healthcare Resource Optimization
   - Predictive modeling for hospital bed occupancy, ICU demands, and ambulance logistics.
   - AI-driven drug distribution systems optimizing medical supply chains.
5. Ethical and Societal Challenges in AI Deployment
   - Public distrust in AI recommendations and fears about privacy violations.
   - Biases in AI algorithms leading to inaccurate predictions for non-Western populations.
6. Institutional and Regulatory Readiness for AI Adoption
   - Lack of comprehensive AI governance policies.
   - Challenges in integrating AI with existing public health infrastructure.

**Sample Coding Breakdown**

To illustrate the open coding process in greater depth, we provide an example of coding applied to an interview segment.

**Table 2:** Example of Coding Process from Expert Interview

| Raw Interview Excerpt | Identified Code | Category |
|---|---|---|
| "AI has been useful in analyzing mobility patterns to predict where the next outbreak might happen. We use real-time GPS data and machine learning to anticipate hotspot regions." | AI-driven early warning systems | AI in Surveillance and Early Detection |
| "We developed an AI model that allocates vaccines based on real-time demand and risk factor analysis. This has prevented wastage and improved distribution efficiency." | AI in vaccine distribution | AI-Enabled Healthcare Resource Optimization |
| "The public has expressed concerns about AI tracking systems, especially in terms of privacy violations. People feel uncomfortable being monitored without explicit consent." | Public distrust in AI-driven monitoring | Ethical and Societal Challenges in AI Deployment |
| "Our AI models rely mostly on European and North American datasets, which means their predictions sometimes don't work well in Iran's unique demographic landscape." | Algorithmic bias due to non-local datasets | Ethical and Societal Challenges in AI Deployment |

Through this coding process, we identified critical themes and laid the foundation for the next phase: Axial coding, where relationships between different concepts were established.

**Axial Coding**

Axial coding was conducted to establish relationships between the conceptual codes identified during open coding. Through this process, we categorized and grouped the 36 conceptual codes into six overarching thematic categories, revealing how different AI applications interact within disaster risk management during epidemics.

**Axial Coding Themes and Categories**

The table below summarizes how conceptual codes from open coding were consolidated into higher-order categoriesduring axial coding.

**Table 3:** Axial Coding Categories and Corresponding Conceptual Codes

| Axial Coding Category | Conceptual Codes (from Open Coding) | Description |
|---|---|---|
| **AI in Surveillance and Early Detection** | - AI-driven early warning systems<br>- Real-time epidemiological modeling<br>- Mobility pattern tracking for outbreak prediction | AI's role in predicting and preventing outbreaks before they escalate. Experts emphasized AI's ability to analyze diverse datasets (social media, GPS data, hospital records) to detect early signs of an epidemic. |
| **AI in Decision Support for Policymakers** | - AI-driven predictive modeling for policy decisions<br>- AI in epidemic scenario simulations<br>- AI-powered dashboards for real-time monitoring | AI's integration into **government decision-making** processes, including simulations for **quarantine policies, vaccine rollouts, and resource allocation**. |
| **AI in Public Communication and Risk Perception Management** | - AI for misinformation control<br>- AI-powered sentiment analysis<br>- AI-driven chatbots for public health guidance | AI's role in managing **public sentiment**, countering **misinformation**, and providing **real-time guidance** through **automated systems**. |
| **AI-Enabled Healthcare Resource Optimization** | - AI for hospital resource allocation<br>- AI in vaccine distribution<br>- AI-assisted logistics for emergency response | AI's contribution to optimizing **medical resource allocation**, including **ICU bed predictions, ventilator management, and PPE distribution**. |
| **Ethical and Societal Challenges in AI Deployment** | - Privacy concerns in AI-based contact tracing<br>- Algorithmic biases in AI models<br>- Public distrust in AI-driven monitoring | Challenges associated with **public trust**, **privacy concerns**, and **biases in AI decision-making** that limit adoption and acceptance of AI solutions. |
| **Institutional and Regulatory Readiness for AI Adoption** | - Challenges of integrating AI with legacy health systems<br>- Need for regulatory frameworks for AI deployment<br>- Lack of AI governance policies | The **institutional and infrastructural barriers** preventing AI's full integration into epidemic disaster management. |

**Establishing Relationships Between Categories**

Through axial coding, we identified interdependencies between different thematic categories. The AI-Enabled Epidemic Risk Management Model emerged, demonstrating how AI applications interact within disaster risk management.

The relationships between the axial coding categories illustrate the interconnected nature of AI applications in epidemic risk management. At the foundation of this framework lies AI in Surveillance and Early Detection, which serves as the primary driver of epidemic response. AI systems collect and analyze real-time epidemiological data, including mobility patterns, social media sentiment, and hospital reports, to detect potential outbreaks before they escalate. This early detection capability informs AI-driven decision support mechanisms, which form the next layer of the framework.

AI in Decision Support for Policymakers functions as a central hub that connects surveillance insights with government decision-making. AI-driven dashboards and predictive modeling tools allow policymakers to simulate different epidemic control scenarios, optimizing responses such as lockdowns, resource allocation, and vaccine distribution strategies. However, the ethical dimensions of AI-driven decision-making cannot be overlooked. Research shows that even highly educated individuals often lack awareness of ethical rules, particularly in complex domains such as technology development, underscoring the need for ethical education and oversight in AI deployment (Sabbar *et al*., 2019) [26]. The effectiveness of AI-driven decision-making is heavily influenced by two interrelated domains: AI in Public Communication & Risk Management and AI-Enabled Healthcare Resource Optimization.

On one hand, AI in Public Communication and Risk Management ensures that accurate, real-time information reaches the public, mitigating misinformation and fear-driven responses. AI-powered sentiment analysis and automated response systems help policymakers assess public concerns and trust levels. However, the role of media in shaping public perception during crises cannot be underestimated. As studies demonstrate, media often employs political narratives to frame societal issues, influencing how events are understood and perceived by the public (Kharazmi & Mohammadi, 2020) [17]. On the other hand, AI-Enabled Healthcare Resource Optimization ensures that medical infrastructure, including hospitals, ICU beds, ventilators, and emergency response units, is distributed efficiently based on AI-generated forecasts. The coordination between public communication and healthcare optimization is crucial in ensuring compliance with epidemic control measures and maintaining public confidence in AI-driven interventions.

However, these AI applications do not operate in isolation; they are deeply influenced by societal, ethical, and regulatory factors. Ethical and Societal Challenges in AI Deployment emerge as a critical layer within the model, acting as a moderating force that shapes AI adoption. Concerns such as privacy, data security, algorithmic bias, and public trust in AI-driven decisions significantly impact the success of AI in epidemic risk management. Maleki Borujeni *et al*. (2022) [19] highlight how systemic issues such as social inequality and injustice exacerbate societal challenges, emphasizing the need for equitable policies and preventive measures to address these disparities and build resilience. The presence of algorithmic biases, particularly in non-Western datasets, was identified as a major limitation in developing AI models that cater specifically to Iran's healthcare and demographic landscape.

At the core of these challenges lies Institutional and Regulatory Readiness, which represents the final layer of the framework. Research argues that the efficiency of laws and policies is crucial for fostering societal trust and compliance, emphasizing that well-designed regulatory frameworks rooted in formal and substantive principles are more effective in addressing systemic challenges (Aghigh *et al*., 2022) [1]. Without strong AI governance mechanisms, ethical considerations, and clear regulatory policies, the full potential of AI in epidemic risk management cannot be realized. This highlights a continuous feedback loop, where institutional preparedness dictates the extent to which AI solutions can be effectively deployed, influencing decision-making, resource allocation, and public engagement strategies.

**Sample Coding Breakdown**

To illustrate how raw data was synthesized through axial coding, the table below presents an example of how expert statements were coded into thematic categories.

**Table 4:** Example of Axial Coding Process

| Raw Expert Quote | Conceptual Code (Open Coding) | Axial Coding Category |
|---|---|---|
| "AI helps predict outbreaks by analyzing social media posts and hospital admission rates." | AI-driven early warning systems | AI in Surveillance & Early Detection |
| "We use AI-based decision models to estimate the impact of different quarantine scenarios." | AI-driven predictive modeling for policy decisions | AI in Decision Support for Policymakers |
| "People often mistrust AI-generated health advice because they feel it lacks human oversight." | Public distrust in AI-driven monitoring | Ethical & Societal Challenges in AI Deployment |
| "One of the barriers to AI adoption is that our hospitals still use outdated data systems, making integration difficult." | Challenges of integrating AI with legacy health systems | Institutional & Regulatory Readiness for AI Adoption |
| "AI-driven logistics helped us distribute vaccines efficiently by prioritizing high-risk areas." | AI in vaccine distribution | AI-Enabled Healthcare Resource Optimization |

The axial coding process provided a structured understanding of AI's role in epidemic disaster risk management in Iran, highlighting its growing significance in surveillance, risk modeling, and resource allocation. While AI-driven decision-making is becoming more prominent in government responses, its integration with public health infrastructure remains a challenge, primarily due to outdated systems and inconsistent data management practices. Moreover, public trust and ethical concerns pose significant barriers to AI adoption, necessitating greater transparency in algorithmic decision-making and stronger regulatory oversight to address issues such as privacy, bias, and data security. Moein *et al*. (2023) [21] highlight that adherence to principles such as certainty and consistency is essential for maintaining trust in systems. Deviations, such as inconsistent practices or lack of accountability, can erode trust and lead to broader societal and organizational challenges. The most critical limiting factor, however, is institutional readiness, as many public health agencies still rely on legacy systems and lack clear policies for AI deployment, inhibiting the full potential of AI-driven epidemic management. These findings establish the foundation for theoretical coding, where the relationships between these factors will be synthesized into a comprehensive AI-Enabled Epidemic Risk Management Model.

**Theoretical Coding**

Theoretical coding is the final stage of grounded theory analysis, where we integrate axial coding categories into a coherent theoretical framework. This stage synthesizes findings into an AI-Enabled Epidemic Risk Management Model, explaining how AI contributes to disaster risk management during epidemics.

**Theoretical Model Construction**

The relationships established during axial coding were examined to construct a higher-order theoretical framework. The model demonstrates how AI applications interact dynamically to enhance epidemic risk management.

From axial coding, six core categories were identified. In theoretical coding, we refined these into four key components of an AI-driven epidemic risk management system:

**Table 5:** Theoretical Coding Framework

| Theoretical Component | Axial Categories Mapped to this Component | Role in AI-Enabled Epidemic Risk Management |
|---|---|---|
| **1. Input Layer – AI Data Sources & Collection Mechanisms** | - AI in Surveillance and Early Detection<br>- AI-Enabled Healthcare Resource Optimization | Collecting large-scale epidemiological data (e.g., hospital admissions, GPS tracking, social media trends) to anticipate outbreaks and resource needs. |
| **2. Processing Layer – AI Analytics & Decision Models** | - AI in Decision Support for Policymakers<br>- AI-Enabled Healthcare Resource Optimization | AI processes real-time data, generates epidemic forecasts, and optimizes resource allocation (e.g., vaccines, ICU beds). |
| **3. Output Layer – Policy Actions & Public Communication** | - AI in Public Communication and Risk Perception Management<br>- AI in Decision Support for Policymakers | AI helps policymakers implement interventions (e.g., lockdowns, public advisories) and manage risk perception(e.g., misinformation control). |
| **4. Feedback Loop – Ethical, Social, and Regulatory Considerations** | - Ethical and Societal Challenges in AI Deployment<br>- Institutional and Regulatory Readiness for AI Adoption | The effectiveness of AI is shaped by public trust, regulatory policies, and institutional preparedness. |

### The AI-Enabled Epidemic Risk Management Model

The theoretical model presents AI-driven disaster risk management as a cyclical process with continuous feedback loops between data collection, AI analytics, policy actions, and societal responses.

### Sample Theoretical Coding Breakdown

The following table demonstrates how expert interview quotes were integrated into the final theoretical framework.

**Table 6:** Theoretical Coding – Expert Quotes and Model Components

| Raw Expert Quote | Axial Coding Category | Mapped Theoretical Component |
|---|---|---|
| "AI models analyzing social media and hospital records helped us predict outbreaks before they escalated." | AI in Surveillance and Early Detection | **1. Input Layer – AI Data Sources** |
| "Our AI-based forecasting tools allowed us to allocate hospital beds in advance, preventing shortages." | AI-Enabled Healthcare Resource Optimization | **2. Processing Layer – AI Decision Models** |
| "We used AI-driven policy simulations to evaluate whether lockdowns were necessary in specific cities." | AI in Decision Support for Policymakers | **2. Processing Layer – AI Decision Models** |
| "People were hesitant to trust AI-driven epidemic control measures because they feared government surveillance." | Ethical and Societal Challenges in AI Deployment | **4. Feedback Loop – Ethical, Social, and Regulatory Considerations** |
| "AI-driven sentiment analysis helped us gauge public sentiment towards vaccination campaigns." | AI in Public Communication and Risk Perception Management | **3. Output Layer – Policy & Public Actions** |

The AI-Enabled Epidemic Risk Management Model highlights four critical insights into the role of AI in disaster risk management during epidemics. First, an increasing number of people are now on social media (Nosrati *et al.*, 2023) [22] and AI relies on high-quality data inputs such as health records, social behavior tracking, and mobility patterns to generate accurate predictions and inform decision-making. Without comprehensive and reliable data, AI's ability to detect outbreaks and allocate resources is severely limited. Second, AI's true value lies in its capacity to model complex epidemic scenarios and provide data-driven decision support for policymakers. By simulating various intervention strategies, AI helps governments optimize public health measures, including lockdowns, vaccination rollouts, and medical supply distribution. Third, AI-powered public communication tools play a crucial role in mitigating misinformation, ensuring that the public receives accurate and timely health advisories. However, public trust in AI remains a significant barrier, as skepticism about algorithmic decision-making and fears of surveillance continue to hinder AI adoption. Finally, ethical concerns and regulatory gaps present major challenges, necessitating the development of robust policy frameworks to address issues such as data privacy, algorithmic bias, and transparency in AI-driven decision-making (Sarfi *et al.*, 2021) [28].

The theoretical coding process synthesized the axial coding categories into four core AI functions: (1) the Input Layer, which involves AI-driven data collection; (2) the Processing Layer, where AI systems analyze data and support decision-making; (3) the Output Layer, where AI applications contribute to epidemic response and public communication; and (4) the Feedback Loop, which encompasses AI's governance, ethical considerations, and societal impact. These components form the basis of the AI-Enabled Epidemic Risk Management Model, which illustrates AI's role in predicting, mitigating, and responding to epidemic risks. The findings emphasize that AI's effectiveness in disaster risk management is not solely determined by technological advancements but is highly dependent on public perception and regulatory structures. Regarding public perception, there is a critical point that should be taken into consideration: How public perception can be shaped and influenced by external sources. Research shows that societal narratives and media consumption can significantly impact how individuals perceive even the most personal issues, such as how they see themselves and their cultural identity (Sabbar *et al.*, 2023) [27]. This is something that must be carefully considered when addressing public trust in AI systems, as these external influences can shape acceptance or resistance to technology. Without clear AI governance policies and efforts to build public trust, even the most sophisticated AI-driven epidemic management systems may face resistance or limited adoption. Thus, successful AI integration requires a balanced approach, combining technological innovation, transparent policymaking, and ethical AI governance.

**Conclusion**

This study has explored the integration of AI in disaster risk management (DRM), particularly in the context of epidemic response. AI's capabilities in predictive analytics, real-time decision support, and resource optimization highlight its transformative potential in mitigating disaster impacts. Through the application of grounded theory methodology, expert perspectives on AI-driven DRM were examined, leading to the development of a theoretical model that synthesizes AI applications across various functional layers. The findings emphasize that while AI significantly enhances disaster preparedness and response, its effectiveness is contingent on data quality, governance frameworks, and ethical considerations.

AI-driven predictive analytics play a crucial role in early warning systems, offering governments and disaster response agencies the ability to forecast potential crises with higher accuracy. Machine learning models and big data analytics facilitate epidemic surveillance, mobility tracking, and outbreak prediction, allowing for more informed decision-making. Additionally, AI-powered decision support systems enable rapid responses by integrating real-time data from diverse sources, optimizing the allocation of medical resources, emergency personnel, and logistics. However, the successful deployment of AI in DRM depends on its integration with existing disaster management infrastructures and regulatory policies that ensure transparency and accountability.

Despite its advantages, AI adoption in DRM faces significant challenges. One major barrier is the issue of data quality and interoperability. Inconsistencies in data collection, limited data-sharing mechanisms, and reliance on legacy systems hinder the full potential of AI applications in disaster response. Furthermore, ethical concerns such as algorithmic bias, data privacy, and the risk of over-reliance on AI-driven decision-making remain pressing issues that require robust governance frameworks. Without addressing these challenges, the deployment of AI in DRM may lead to unintended consequences, including unequal disaster response and public distrust in AI-driven interventions.

The study also highlights the importance of policy reforms and interdisciplinary collaboration in maximizing AI's potential in DRM. Investments in AI literacy and training for disaster management professionals can enhance their ability to interpret and apply AI-generated insights effectively. Additionally, fostering international cooperation in AI governance can ensure that AI applications in DRM adhere to ethical principles and promote equity in disaster response efforts. The development of standardized regulatory frameworks is essential to mitigate risks associated with AI deployment, ensuring that AI-driven disaster management solutions are both effective and ethically sound.

Based on our findings, therefore, we claim that AI represents a powerful tool for enhancing disaster risk management, particularly in epidemic response. However, its successful implementation requires a balanced approach that integrates technological advancements, governance structures, and societal considerations. By addressing data quality issues, strengthening regulatory oversight, and fostering interdisciplinary collaboration, AI can be leveraged to improve disaster preparedness, mitigate risks, and optimize emergency response strategies. Future research should continue exploring the evolving role of AI in DRM, focusing on innovations that enhance its reliability, transparency, and ethical application in global disaster management efforts.

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