Araştırma Makalesi / Research Article ESTU R 8(2), 2024, sy(265-280) DOI: 00.12345/resilience.1579301

RESILIENCE
e-ISSN: 2602-4667

Eskişehir Teknik Üniversitesi

Resilience

https://dergipark.org.tr/tr/pub/resilience

Key Location Attributes of Disaster Medical Services Headquarters: Developing an Urban Health Care Disaster Preparedness Model

Afetlerde Sağlık Hizmetleri Merkezinin Konumu ve Kilit Özellikleri: Kent Modelinin Geliştirilmesi

Verda TUNALIGIL [1*]
ORCID 0000-0002-4965-9231

[1] *Disaster Health and Emergency Medical Services, TR MoH Health Directorate of İstanbul, İstanbul, Türkiye*

Öne Çıkanlar / Highlights

- Effective emergency management hinges on the strategic positioning of health service headquarters during disasters.
- Across the scenarios analyzed, common themes of infrastructure damage, communication breakdowns, and access limitations surfaced as major challenges.
- A tailored qualitative framework was employed to evaluate six high-risk disaster scenarios, concentrating on vulnerabilities and communication failures.
- To address these issues, the proposed model emphasizes the importance of risk assessment, infrastructure improvement, and active community engagement to enhance resilience in disaster response efforts.
- The key findings revealed that suboptimal locations for headquarters significantly increase risks during earthquakes, leading to traffic congestion, structural damage, and shortages of essential resources.
- The findings highlight the necessity for context-specific preparedness strategies and call for further research into health service management across various disaster scenarios.

Makale Bilgisi / *Article Info*

Gönderim / Received: 04/11/2024
Kabul / Accepted: 23/12/2024

Anahtar Kelimeler

halk sağlığı acilleri, kitlesel ölümler, deprem, sel, sağlık hizmetleri, altyapı, iletişim, stratejik karar analizi, kaynak yönetimi, risk değerlendirme

Keywords

public health emergencies, mass

Özet

Afetlerde sağlık hizmetlerinin yönetildiği merkezlerin stratejik konumu, etkili acil durum yönetimi açısından kritik öneme sahiptir. Bu araştırma, afet senaryolarında sağlık hizmetlerini yönetmek için gerekli olan temel nitelikleri inceleyerek altyapı, iletişim ve kaynak yönetimine vurgu yapmaktadır. Çalışmada, kamu sağlığının korunmasına yönelik afet yönetimi hazırlıklarında model geliştirme amacıyla uyarlanmış bir nitel analiz çerçevesi kullanılmıştır. Altı yüksek-riskli afet senaryosunun tematik analizi gerçekleştirilmiştir. Bu senaryolar, afet yanıtı sırasında karşılaşılan bir dizi zorluğu kapsamaktır ve bu amaçla özgün olarak tasarlanmıştır. Kırılganlıklar ile iletişimde oluşabilecek aksaklıklar üzerinde durulmuştur. Nitel analiz yaklaşımıyla, ortak temalar belirlenmiş, hedeflenen sonuçlarla uyumlu hale getirilmiş, afetlerde sağlık hizmetinin optimum koşullarda yönetilmesi amacıyla, etkili unsurlar kapsamlı şekilde incelenmiş, nihai olarak model geliştirilmişitr. Özellikle depremlerde, sağlık hizmetleri merkezlerinin suboptimal konumlanmış olması, beraberinde önemli riskler getirmektedir. Senaryolar, acil durum yanıtını engelleyen trafik sıkışıklığı, yapısal kırılganlıklar ve sel gibi sorunları öne çıkarmaktadır. Bu zorluklar, kaynak kıtlığına yol açmakta ve kamu sağlığı müdahalelerini karmaşık hale getirmekte, yüksek riskli tesislere yakınlık ise ek tehditler oluşturmaktadır. Altı senaryonun analizi, altyapı hasarı, acil hizmetler üzerindeki baskı, iletişim hataları, erişim sınırlamaları ve ruh sağlığı etkileri gibi ortak temaları ortaya çıkarmıştır. Önerilen model, risk değerlendirmesi, altyapı iyileştirmeleri ve toplum katılımını vurgulamaktadır. Dayanıklılığım ve yanıt etkinliğinin artırılması amaçlamaktadır. Araştırmada, afet risklerini azaltmak için stratejik olarak yerleştirilmiş sağlık hizmetleri merkezlerine olan ihtiyacı vurgulanmaktadır. Model, etkin afet yönetimi konusunda önemli öngörüler sunmaktadır. Bulguların

*Correspondingauthor, e-mail: verda@post.harvard.edu

casualty incident, earthquake, flood, health services, infrastructure, communication, strategic decision analysis, resource management, risk assessment

evrensel ölçekte uygulanabilir olması ve hazırlık stratejilerinin yaygınlaştırılabilir olması için, araştırmaların sürdürülmesi önerilmektedir. Modelin bileşenlerini temsil eden bir şema, paydaşların anlayışını artırmak ve uygulamayı kolaylaştırmak amacıyla sağlanmıştır. Yapılan literatür taramasında, afetlerde sağlık hizmetleri merkezlerinin konumunu ve kilit özelliklerini tanımlayan bir kent modelinin ve buna ait bileşenlerin temsil edildiği bir şemanın ilk kez sunulduğu sonucuna varılmıştır. Bu bakış açısıyla araştırma, önemli bir eksikliğe dikkat çekmektedir.

Abstract

INTRODUCTION: The strategic location of headquarters for health services management during disasters is critical for effective emergency response. This research examines essential qualities necessary for managing health services in disaster scenarios, emphasizing infrastructure, communication, and resource management. METHODS: This study utilized an adaptive qualitative analysis framework to develop a model for public health preparedness and disaster management, employing thematic analysis of six high-risk disaster scenarios. These scenarios were deliberately selected to encapsulate a range of challenges encountered during disaster response, with a particular emphasis on vulnerabilities and communication breakdowns. The analytical approach was tailored to align with the specific themes and intended outcomes of the study, facilitating a comprehensive exploration of the factors influencing effective health service management in disaster contexts. RESULTS: The findings illustrate significant risks associated with suboptimal headquarters location, particularly during earthquakes. Scenarios highlighted issues such as traffic congestion, structural vulnerabilities, and flooding that impede emergency response. These challenges lead to resource shortages and complicate public health interventions, while proximity to high-risk facilities poses additional threats. DISCUSSION: Analysis of the six scenarios revealed common themes: infrastructure damage, strain on emergency services, communication failures, access limitations, and mental health repercussions. The proposed model emphasizes risk assessment, infrastructure improvements, and community engagement to enhance resilience and response efficacy. CONCLUSIONS: This research emphasizes the need for a strategically located headquarters for the management of health services, to mitigate disaster risks. While the model offers insights into effective disaster management, its findings are not universally applicable, necessitating further research to refine preparedness strategies in varied contexts. A diagram representing the model's components is provided to enhance stakeholder understanding and facilitate implementation. This original research study, in conclusion, identifies the primary role of location and essential characteristics of main office operation centers in health services management during disasters. In this regard, the article highlights a significant gap, presenting for the first time a city model that describes these aspects along with a diagram representing its components.

1. INTRODUCTION

The main headquarters (HQ) for managing health services in emergencies should possess several key attributes. A strategic location is crucial for ensuring easy accessibility by emergency response teams. The HQ should be situated near affected areas to facilitate rapid assessments and deployment. A sturdy and resilient infrastructure and trans-disciplinary research to enhance health systems' disaster readiness is advocated in earlier research. The urgent need for effective prevention and preparedness in the face of increasing natural hazards and their significant economic and life impacts (Shover, 2007). The HQ must ensure well-established foundation, reliable and effective communication systems, addressing the urgent need for improved health system readiness and disaster response, especially in the face of increasing natural hazards. The central HQ responsible for overseeing health services during emergencies should have several essential characteristics.

Comprehensive communication systems are crucial, as advanced communication tools enable effective coordination with various agencies, health personnel, and the public during emergencies. Effective communication is vital in disaster management. Studies highlight the importance of a clear command structure to optimize resource use, identify persistent communication failures that hinder casualty management and responder safety, and emphasize the need for improved training and local readiness through disaster drills to enhance health system resilience (De Cauwer *et al*., 2023; Shover, 2007; Watson *et al*., 2012).

The HQ should be staffed with trained professionals and skilled personnel who specialize in emergency management, public health, logistics, and communication to ensure a competent response. One study found that United States (U.S.) military health care personnel involved in global health missions exhibited moderate preparedness for disaster management, with various factors influencing their readiness (King *et al*., 2019), while a review highlighted the need for improved disaster preparedness among nurses in developing countries, emphasizing the importance of structured educational programs and training to enhance their competencies (Songwathana & Timalsina, 2021).

The premises of a disaster medical services HQ must possess advanced data management capabilities, comprising systems for the collection, analysis, sharing and dissemination of health data. These capabilities are essential to support informed decision-making processes. A scoping review highlights the critical role of public health emergency operations centers in managing public health crises, emphasizing the necessity of effective data management for operational efficiency and decision-making (Allen & Spencer, 2023). A study on Hurricane Maria emphasizes the importance of integrating meticulous data collection and visualization systems into disaster preparedness (Kress *et al*., 2022). Lessons from the SARS-CoV-2 pandemic further reveal the need for safeguarding data integrity amid emergencies (Black, Moncada, & Herstad, 2021). A proposed framework for geographically distributed data management aims to enhance response times and data analysis across multiple centers as data volumes increase (Emara *et al*., 2023).

Flexibility and adaptability are crucial. The structure must be able to quickly adjust to changing circumstances and emerging needs in response to crises. Effective resource management is vital, and the facility should implement efficient inventory management systems for medical supplies, equipment, and personnel to ensure optimal operation. Collaboration facilities are necessary. Spaces must be provided for joint operations with other agencies and stakeholders to enhance teamwork and coordination in emergency response efforts. The inclusion of training and simulation areas is essential for ongoing training, to enable staff to prepare for various emergency scenarios and to ensure readiness when crises arise. Public health expertise entails access to epidemiologists and public health officials who can provide guidance on health interventions based on the latest data and evidence. A review highlights the urgent need to assess nations' readiness for public health emergencies (Haeberer *et al*., 2021), while an article discusses the increasing complexity and financial challenges that hinder agencies from responding effectively, emphasizing that the aforementioned features and indispensable characteristics are paramount for the HQ to coordinate health services and manage emergencies swiftly and efficiently (Chiang *et al*., 2020). These critical attributes ensure that the HQ can competently coordinate health services and respond to emergencies (Table 1).

Table 1. Key attributes for the main headquarters for managing disaster medical services in public health emergencies.

Criteria	Description
Strategic location	Easily accessible for emergency response teams, close to affected areas for rapid deployment.
Robust infrastructure	Reliable utilities such as electricity, water, communication systems to ensure effective operation during crises.
Comprehensive communication systems	Advanced tools for coordinating with agencies, health personnel, and the public.
Skilled personnel	Staffed with trained professionals in emergency management, public health, logistics, communication.
Data management capabilities	Systems for collecting, analyzing, and sharing health data to inform decision-making.
Flexibility and adaptability	Ability to quickly adjust to changing circumstances and emerging needs.
Resource management	Effective inventory management systems for medical supplies, equipment, and personnel.
Collaboration facilities	Spaces for joint operations with other agencies and stakeholders to enhance teamwork and coordination.
Training and simulation areas	Facilities for ongoing training and simulations to prepare staff for various emergency scenarios.

Public health expertise	Access to epidemiologists and public health officials to guide health interventions based on the latest data.

This study aims to identify and delineate the essential qualities that a primary HQ should possess for the effective management of health services during disaster situations. The objective of this study is distinctly original. In pursuing this goal, the research addresses a notable gap in the existing literature on disaster management. The methodology consisted of several distinct phases, including the examination of empirical case studies and events, the development of case scenarios for pedagogical elucidation, qualitative data collection, thematic analysis, and the construction of theoretical models.

2. METHODS

This research utilized qualitative analysis to construct a public health services preparedness and disaster health management model, focusing on the essential qualities required for the main HQ managing health services during disasters. The study employed a qualitative analysis method that has been adapted to align with the theme and intended outcome. The methodology involved distinct phases such as case scenario selection, qualitative data collection, thematic analysis, and model construction.

2.1 Case Scenario Selection

The research began with an analysis of empirical disaster events, followed by the development of six high-risk case scenarios, each illustrating distinct facets of disaster management. These formulated scenarios were based on historical data and expert opinions regarding vulnerabilities in disaster health management. The selected scenarios included large-scale earthquake in an urban environment, flooding in a low-lying area, biological outbreak following a disaster, fire in a high-density residential area, terrorist attack involving mass casualties, chemical spill near a health care facility.

The scenarios were chosen to encompass a range of potential disasters, ensuring a comprehensive exploration of the qualities necessary for effective health service management.

2.2 Thematic Analysis

The qualitative analysis focused on examining the six high-risk case scenarios to identify essential qualities for effective disaster management HQ. The analysis was conducted using a thematic analysis approach, adapted from Braun and Clarke, 2006 (Braun & Clarke, 2006). Familiarization involved the researcher thoroughly reviewing each case scenario to analyze the context and determine key elements presented. Initial coding followed, where the scenarios were systematically analyzed using an inductive process to identify significant features and recurring patterns, allowing for flexibility in capturing various disaster management aspects. Theme development emerged as the generated codes were grouped into broader themes that represented the qualities essential for an effective disaster management HQ. Review and refinement were conducted in the final stage, to ensure the coherence and relevance of the identified themes, with the investigator cross-checking them against the case scenarios to validate their alignment and refining them for enhanced clarity and applicability. This thematic analysis led to the formulation of a comprehensive model highlighting the critical qualities required for disaster health management, drawing directly from the insights gained through the detailed examination of the case scenarios.

2.3 Model Construction

A conceptual model of public health services preparedness and disaster health management was developed based on key themes identified from the scenarios. The model emphasizes mapping the risk components to understand vulnerabilities and resource needs. It uses six high-level risk scenarios to illustrate potential challenges and responses in order to pinpoint recurring themes in earthquake risks and health care access, such as infrastructure damage and communication breakdowns. The model includes components such as strategic location, infrastructure resilience, effective communication systems, resource management, training and simulation, and collaboration with community organizations. A diagram visually represents the interconnections among these elements, enhancing

understanding and communication among stakeholders involved in disaster health management planning and implementation (Figure 2).

2.4 Ethical Considerations

The research adhered to ethical guidelines for qualitative original research articles by confirming that the case scenarios were specifically and uniquely created by the researcher. This reflects a commitment to originality and ethical integrity. The investigator maintained transparency regarding the study's objectives and methodologies. The development and use of these scenarios were conducted with scholarly rigor.

2.5 Limitations

While the research methodology offers rich insights, the findings are not completely generalizable due to the absence of study participants or empirical phenomena, as the research relied solely on created scenarios. Future research is expected to build on this study by incorporating quantitative measures, exploring additional disaster scenarios, and integrating data from drills and empirical outcomes to enhance understanding.

This methodological framework lays the groundwork for developing an applicable model aimed at improving the preparedness of health services in disaster situations, ultimately striving to enhance outcomes for affected populations. The aim of this study is notably original, addressing a gap in the existing literature on disaster management, and the methodology employed is both innovative and creative.

3. RESULTS

The case examples demonstrated in this article illustrate failures resulting from an incorrectly located health services HQ during a large-scale earthquake in a metropolitan area that serves as the financial and cultural heart of the country. Traffic congestion arises because the HQ is situated in a crowded downtown area where critical access routes become blocked by debris, preventing emergency vehicles from reaching the facility and delaying medical assistance to injured individuals. The HQ, positioned in a seismically vulnerable zone, additionally suffers significant structural damage during the earthquake, rendering it unusable and hampering emergency operations and coordination of health services. Limited accessibility occurs as the facility is on a narrow street that quickly becomes inaccessible due to fallen buildings, making it difficult for first responders and medical personnel to reach the HQ and resulting in a backlog of patients needing immediate care. Located in a high-risk area, the HQ is furthermore cut off from supply routes due to landslides, leading to critical shortages of essential medical supplies and equipment that undermine response efforts citywide. Public panic escalates as the HQ is near cultural landmarks, drawing crowds seeking help, which creates chaos and complicates triage efforts. Delayed communication follows, as the HQ is in an area where communication networks are easily disrupted, preventing timely information dissemination about available medical services and leaving many unaware of where to seek help. Inadequate evacuation routes also present a concern. If the HQ is in a low-lying area prone to flooding, aftershocks could isolate the building, preventing safe transport of patients and personnel and resulting in unnecessary loss of life. As the city's heart, the location of the HQ can divert attention from other critical facilities, and if it fails to operate effectively, nearby hospitals and clinics may become overwhelmed, leading to a cascade of failures in the health care system and significant losses across the metropolitan area. These examples emphasize the crucial importance of strategically locating emergency response facilities in order to minimize losses during a disaster.

3.1 Mapping the Risk Components

High-risk buildings have the potential to cause significant harm not just to people, but also to the surrounding environment, making their resilience critical in earthquake-prone areas. They primarily pose threats to the community and the environment during earthquakes. Chemical and hazardous material facilities pose a risk of dangerous spills or explosions if damaged, as they store or process toxic chemicals. Landfills and waste management sites can experience compromised containment systems during earthquakes, potentially releasing contaminants into the environment. Oil refineries and storage

tanks have the potential to leak or explode, leading to fires and environmental contamination. Structural failures in dams and water reservoirs can result in catastrophic flooding, impacting communities downstream. Sewage treatment plants, if damaged, may release untreated sewage into water systems, posing significant health risks. Agricultural facilities, such as silos and processing plants, can disrupt food supply chains and lead to the loss of agricultural products.

Damage to public transportation routes and terminals, like train stations or bus depots, can additionally hinder emergency responses and evacuations, compromising community safety. A variety of high-risk objects that criminals use for arson are present in the HQ settlement or campus. These items are often chosen for their flammability or ability to create significant fire hazards and include old vehicle tires, gasoline and other flammable liquids, propane tanks, aerosol cans, wood pallets and crates, chemical containers, fireworks, and paper and cardboard.

Stray city dogs are typically well-fed, but during times of food scarcity, such as after an earthquake or other disasters, they can become dangerously hungry.

A maximum-security prison poses a significant risk of escape and public safety threats if its structural integrity is compromised during a large-scale earthquake. Located near the HQ settlement, the prison is well-protected under normal circumstances, but if the wall collapses during a large-scale earthquake, prisoners may escape and pose a threat to the public, the casualties, and the medical staff, potentially leading to violent incidents.

3.2 Six High-Level Risk Case Scenarios

Six high-level risk case scenarios illustrate how the wrong location of a health services HQ could lead to significant losses in a metropolitan area after a large-scale earthquake (Figure 1).

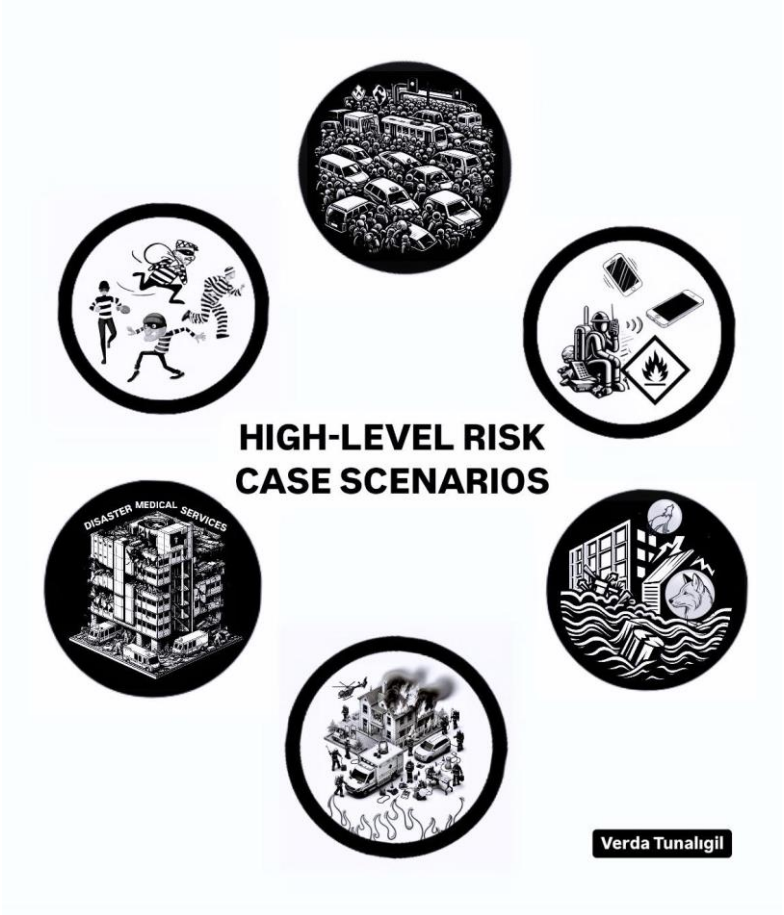

Figure 1. An illustration of risks indicating potential losses resulting from the improper positioning of health services headquarters following an earthquake.

3.2.1 High-Level scenario 1: Chaos and resource strain

After an earthquake, the risks include severe traffic congestion, public panic, overcrowding, trapped vehicles, resource strain, and stray dogs. In the immediate aftermath, widespread fear drives people to evacuate buildings, leading to gridlock that hinders emergency responders. Many individuals become stuck in their cars, amplifying urgency and chaos as crowds gather in search of safety. Emergency services face overwhelming demand, with numerous injured or traumatized individuals. The presence of street animals, typically well-fed in urban environments under normal circumstances, may become a concern post-earthquake, as their hunger drives them to seek food aggressively in the days following the event. This behavioral shift introduces an additional layer of unpredictability and potential danger, complicating rescue operations in an already chaotic environment. A mix of delays, overcrowding, and stray animals complicates rescue efforts and heightens risks for all involved.

The risk components include traffic chaos and delays, public panic and overcrowding, trapped vehicles, resource strain, and the presence of stray dogs.

The impact entails impaired emergency response, increased injuries, psychological stress, complicated rescue operations, and the potential for additional conflicts.

This scenario emphasizes the critical need for effective disaster preparedness and response strategies to manage chaos and ensure the safety of both individuals and emergency responders in the aftermath of an earthquake.

3.2.2 High-Level scenario 2: Structural collapse and security threats

When an earthquake strikes, it precipitates catastrophic structural collapse at the HQ, leading to dire consequences. The violent tremors cause buildings to crumble, trapping both staff and patients inside. In the midst of this chaos, prisoners escape from a nearby facility, heightening panic and fear within the community. Their presence not only intensifies public anxiety but also complicates rescue operations, as responders must navigate the dual crisis of rescuing those trapped while also addressing the potential threat posed by escaped inmates. As news of the disaster spreads, families and onlookers are engulfed in fear for their loved ones' safety. The situation reveals how natural disasters can severely undermine structural integrity and human behavior, creating a complex web of security threats that complicates recovery efforts. This crisis underscores the urgent need for preparedness and effective response strategies to protect both lives and community stability in the face of such overwhelming challenges.

The risk components include structural collapse of the HQ, threat posed by escaped prisoners, compromised rescue efforts and equipment, safety of patients, and heightened public fear.

The impact involves trapped individuals facing life-threatening conditions, overwhelmed emergency responders, escalating public fear, delays in rescue operations, and community unrest and uncertainty.

This multifaceted crisis illustrates the far-reaching impacts of a natural disaster, where every element, be it structural integrity or human behavior, can dramatically alter the outcome for those affected.

This harrowing scenario emphasizes the urgent need for comprehensive emergency planning that addresses not only structural safety but also the management of potential secondary threats to ensure the safety and well-being of all individuals during a disaster.

3.2.3 High-Level scenario 3: Communication breakdown and fire risk

In the event of an earthquake, significant hazards arise, including communication breakdowns and fire risks. Poor communication within the HQ prevents crucial supply information from being relayed, leading to a disorganized response. The chaos increases security threats, particularly around flammable materials stored in the facility. This volatile situation complicates efforts to coordinate with emergency services, leaving staff and patients vulnerable. The likelihood of significant fires escalates,

overwhelming already stretched emergency responders. Panic spreads among those trapped inside as they confront these threats.

The risk components include communication breakdowns, fire risk, disorganized response, vulnerability of staff and patients, and chaos from escalating dangers.

The impact entails ineffective resource allocation, increased likelihood of fire spreading, overwhelming challenges for emergency responders, heightened panic among those trapped, and compromised safety and security.
This scenario highlights the critical importance of effective communication during emergencies, as its breakdown can exacerbate risks and hinder timely responses, endangering lives and complicating recovery efforts.

3.2.4 High-Level scenario 4: Flooding and neglect of resources

In a chaotic scenario of simultaneous flooding and an earthquake, significant hazards emerge, such as structural damage to the HQ and the flooding of essential resources. The earthquake compromises the HQ's integrity and triggers nearby flooding, isolating patients and staff inside while other facilities remain unutilized. As floodwaters rise, trapped individuals face drowning threats and fear from stray dogs. Focus on rescuing those within the HQ neglects alternative care options, overwhelming emergency responders. With panic escalating, staff struggle to care for patients amid these dangers, while inaccessible nearby facilities leave many without crucial support.

The risk components include structural damage to the HQ, inundation of critical resources, presence of stray dogs, limited access to alternative care facilities, and strained emergency response.

The impact involves the immediate threat of drowning for trapped individuals, panic among staff complicating patient care, neglected alternative care options, escalating fear and chaos diminishing morale, and an overall hindered emergency response leading to delayed assistance and greater loss of life.

This crisis situation highlights the need for comprehensive emergency preparedness that addresses multiple hazards for effective responses.

3.2.5 High-Level scenario 5: Public panic and communication gaps

In the aftermath of an earthquake, the situation is filled with challenges and hazards that can escalate quickly. Buildings may collapse, trapping individuals and causing panic, while essential services like electricity, water, and communication are disrupted. Evacuations overwhelm emergency response teams, and shelters become overcrowded, complicating care for the injured. Communication failures hinder the flow of crucial information about resources and evacuation procedures. Secondary hazards, such as ruptured gas lines and unstable structures, add to the danger.

The risk components include structural damage to the HQ, inundation of critical resources, limited access to alternative care facilities, and strained emergency response.

The impact involves the immediate threat of drowning for trapped individuals, panic among staff complicating patient care, neglected alternative care options, escalating fear and chaos diminishing morale, and an overall hindered emergency response leading to delayed assistance and greater loss of life.

Effective coordination among emergency services is essential to address the needs of those affected, highlighting the importance of preparedness and resilience in facing such disasters.

3.2.6 High-Level scenario 6: Evacuation failures and arson threats

In an earthquake, evacuation challenges and the threat of arson from escaped prisoners create a dangerous situation. Structural failures impede the safe movement of patients and staff, complicating

evacuation efforts. If a nearby maximum-security prison's wall collapses, inmates could escape, posing serious risks to the public and rescue personnel. This chaos may lead to arson using hazardous materials, endangering trapped patients and emergency responders. The combination of blocked evacuation routes, unpredictable prisoner behavior, and fire risks makes the situation highly volatile, highlighting the urgent need for effective emergency plans to address these complexities and protect everyone involved.

The risk components include evacuation complications, threat from escaped prisoners, potential for arson, violent confrontations, and compromised emergency response.

The impact involves increased risk of injury or fatalities among trapped individuals, heightened danger for emergency responders, delayed evacuation efforts, escalation of chaos and fear within the community, and overall strain on emergency services.

This emphasizes the urgent need for comprehensive emergency plans that account for such complexities, ensuring that all potential risks are addressed effectively to safeguard both those in need of care and the responders risking their lives to help them.

4. DISCUSSION

A central HQ for disaster health services must prioritize robust infrastructure and effective communication to enhance health system readiness and response. Given the increasing frequency of natural hazards, the HQ should not only manage health services during emergencies but also strengthen system resilience. Key features include strict building codes and strategically located facilities to minimize vulnerabilities, as many existing hospitals are not designed to withstand significant earthquakes, raising injury risks (Peleg, Reuveni, & Stein, 2002). The HQ must additionally facilitate swift medical responses, including the rapid deployment of field hospitals, as local medical staff may be overwhelmed. Regular training exercises and effective communication systems are vital for coordinated response efforts. The psychological impact of disasters, especially on children, emphasizes the need for mental health support for victims and rescue teams. Innovative logistics models can further optimize disaster response. A humanitarian relief logistics model can minimize costs, address personnel shortages, and reduce evacuation failures, effectively managing resource distribution and victim evacuation (Ghasemi, Goodarzian, & Abraham, 2022). A well-equipped and strategically designed HQ for disaster health services management is essential. Health system resilience and response can be significantly improved in the face of increasing natural hazards. This improvement depends on strong infrastructure, effective communication, and comprehensive preparedness strategies.

Effective management of health services during emergencies requires strategic planning and specific attributes for the HQ overseeing these operations. Key elements include a strategic location for quick access by emergency teams, robust infrastructure to ensure utilities function reliably, and advanced communication systems for coordination among agencies and the public. The increasing vulnerability to natural disasters necessitates multidisciplinary research to strengthen disaster readiness. A 2011disaster report highlights the significant loss of life and economic impact caused by natural disasters, which have increased in frequency since the 1970s, drawing attention to the critical need for effective disaster preparedness (Guha-Sapir, Vos, Below, & Ponserre, 2011; Watson *et al*., 2012). Communication failures have historically impeded effective emergency response, as shown in a review of incidents from 1995 to 2017, which found that inadequate training, outdated equipment, and damaged infrastructure persist despite previous lessons learned. This emphasizes the necessity for improved resources and training in emergency services (De Cauwer *et al*., 2023). Enhancing local health system resilience hinges on educating health care professionals through local disaster drills (Watson *et al*., 2012). Employing skilled professionals in emergency management, public health, and logistics is vital. A study assessing U.S. military health care personnel revealed moderate preparedness levels influenced by factors such as disaster training and experience (King *et al*., 2019). In developing countries, health care workers often demonstrate inadequate preparedness for disasters, emphasizing the need for enhanced training and educational resources (Songwathana & Timalsina, 2021).

Sophisticated data management systems are critical for effective decision-making during crises. A scoping review stated that public health emergency operations centers must prioritize robust data management capabilities to optimize functionality (Allen & Spencer, 2023). Lessons from Hurricane Maria emphasize integrating data management into disaster preparedness and developing flexible systems to handle unforeseen challenges (Kress *et al*., 2022). The COVID-19 pandemic further revealed vulnerabilities in data management, necessitating strategies for secure data safeguarding and integrity during emergencies (Black *et al*., 2021). Lastly, a framework for geographically distributed data management aims to enhance large-scale data analysis, addressing storage and processing challenges in emergency contexts (Emara *et al*., 2023).

A review highlighted the importance of assessing countries' preparedness for public health emergencies, especially following recent disease crises. The study evaluated 12 existing assessment tools, using a framework to gauge their effectiveness and utility. While there was general agreement on key elements of preparedness, the tools varied significantly in their focus, assessment methods, and user-friendliness. The study concluded that improvements are needed in these assessment tools, as well as in applied research to identify valid indicators of system response capabilities (Haeberer *et al*., 2021). An article discussed the increasing complexity and cost of public health emergencies in the U.S., which often overwhelm agencies designed for routine health functions. It highlighted the unpredictability of emergencies and the challenges in preparing staff for rapid response due to resource limitations and lack of real-world data linking preparedness to outcomes. The study suggested metrics for emergency managers to consistently assess agency preparedness, positioning the framework as a valuable complement to existing preparedness strategies in public health agencies (Chiang *et al*., 2020).

4.1 Recurring Themes in Earthquake Risks and Health Care Access in a Six-Scenario Analysis

The qualitative analysis includes a detailed breakdown of the recurring themes related to earthquake risks and health care access across the six scenarios. The themes collectively emphasize the need for a holistic approach to disaster preparedness in urban health care systems. Comprehensive planning must consider not only the physical infrastructure but also the interconnectedness of emergency services, communication systems, resource management, and mental health support. This understanding can guide the development of strategies aimed at improving resilience and response effectiveness in the face of natural disasters (Table 2).

Table 2. A structured summary of the qualitative analysis of recurring themes related to earthquake risks and health care access across six high-risk case scenarios, outlining the themes, implications, and modeling approaches.

Theme	Description	Examples	Implication	Modeling Approach	Components
Infrastructure damage	Vulnerability of health care facilities.	Structural damage and collapse risks.	Shortage of care facilities, poor patient outcomes.	Risk assessment model	GIS for analysis; scoring system for facility risks.
Emergency services strain	Overload of emergency services.	Delays in ambulance responses.	Increased mortality due to delayed care.	Emergency response coordination model	Centralized command system; regular training drills.
Communication breakdowns	Failures in communication systems.	Disrupted lines hinder collaboration.	Poor decision-making and resource allocation.	Communication infrastructure model	Backup communication channels; public information strategies.
Access limitations	Barriers to accessing care.	Transportation issues; evacuation challenges.	Untreated conditions worsen public health crises.	Infrastructure enhancement model	Seismic retrofitting; establishment of temporary facilities.

Resource shortages	Shortage of medical resources.	Overcrowded hospitals; supply delays.	Preventable deaths and reduced care quality.	Resource management model	Real-time inventory tracking; mutual aid agreements.
Mental health impacts	Psychological effects post-earthquake.	Increased demand for mental health services.	Neglect of mental health complicates recovery.	Mental health preparedness model	Training for responders; public education on mental health resources.
Community engagement and resilience	Building community preparedness.	Workshops and community initiatives.	Enhances readiness and response capability.	Community engagement and resilience model	Preparedness workshops; local support networks.

4.1.1. Infrastructure damage

Each scenario highlights the vulnerability of health care infrastructure to the direct and indirect impacts of an earthquake, demonstrating how such events can severely compromise medical services. In Scenario 1, for instance, hospitals experience structural damage that significantly reduces their capacity to care for patients. In Scenario 5, the existing issues of overcrowding and outdated seismic codes heighten the risk of collapse for high-rise medical facilities. The cumulative effect of these damages results in a critical shortage of available care facilities, which not only jeopardizes patient outcomes but also undermines the overall resilience of the health care system in the face of natural disasters.

4.1.2. Emergency services strain

A common theme across multiple scenarios is the overwhelming of emergency services in the aftermath of a disaster. In Scenarios 1, 2, and 3, the reports of overloaded emergency dispatch systems highlight critical delays in ambulance responses and insufficient triage capabilities. This strain on resources not only hampers the delivery of timely care but also exacerbates mortality rates, as the chaos following a disaster makes it increasingly difficult for emergency services to effectively respond to the needs of the affected population.

4.1.3. Communication breakdowns

The failure of communication systems emerges as a recurrent issue that complicates coordination among hospitals and emergency responders during crises. Scenarios 1 and 4 specifically illustrate how power outages and infrastructure damage can sever communication lines, obstructing effective collaboration. This breakdown hinders real-time decision-making and resource allocation, ultimately undermining patient care and recovery efforts in the wake of a disaster, when swift and coordinated responses are crucial.

4.1.4. Access limitations

Physical barriers to accessing health care facilities pose a significant concern across all scenarios. Scenario 2, for instance, illustrates how transportation disruptions make many clinics inaccessible, while Scenario 6 highlights evacuation challenges that particularly affect vulnerable populations. These obstacles can result in untreated medical conditions, exacerbating public health emergencies as patients struggle to reach essential care when they need it most.

4.1.5. Resource shortages

Many scenarios emphasize a critical lack of essential medical resources, including personnel, equipment, and supplies. For example, Scenario 3 notes that hospitals become overcrowded with both physical and mental health patients, significantly stretching available resources. Additionally, Scenario 2 highlights delays in the delivery of medical supplies, further limiting treatment options. These resource shortages can result in preventable deaths and a decreased quality of care, placing additional strain on already overwhelmed health systems during times of crisis.

4.1.6. Mental health impacts

The psychological effects of an earthquake are prominently emphasized, particularly the surge in mental health issues that follow such disasters. For instance, Scenario 3 highlights the mental health crisis that ensues, where the increased demand for services far exceeds available capacity. This strain not only leads to immediate challenges but can also create long-term mental health issues within the community. Neglecting these mental health needs can result in a cycle of worsening outcomes, further complicating the recovery process and placing additional burdens on already strained health care systems.

4.2 Modeling Approach and Methodological Framework

The terms "frameworks," "approaches," "methodologies," and "models" differ significantly. An "approach" is a broad strategy for achieving a goal, while a "methodology" outlines specific methods for problem-solving. A "framework" offers guidance and proven practices for developing methodologies, and a "model" is a simplified representation that aids understanding and analysis (Gale *et al*., 2013; McMeekin *et al*., 2020).

To develop effective solutions for disaster preparedness in urban health care systems, a modeling framework can be used that incorporates the identified themes and potential interventions. This framework will outline strategies to enhance resilience against earthquake risks, improve health care access, and streamline emergency responses **(Table 2)**. By implementing these models, urban health care systems can significantly improve their preparedness for earthquakes. This structured approach will facilitate better access to care, enhance emergency responses, and ultimately save lives during and after a disaster. Regular evaluations and updates to the models based on evolving risks and community needs will ensure ongoing effectiveness and resilience.

The aim of a "risk assessment model" is to identify and prioritize earthquake-related risks in urban areas using Geographic Information Systems (GIS) to analyze fault lines, building vulnerabilities, and population density. Despite the key advantages of GIS integration, including improved resource allocation and enhanced emergency response, challenges such as data quality and the need for real-time adjustments highlight the necessity of integrating GIS technology with public health strategies to bolster disaster management and community resilience amid urbanization and seismic risks (Tunalıgil, 2024). A risk scoring system will also evaluate facilities based on structural integrity, historical performance, and current capacity, facilitating targeted interventions and resource allocation. The purpose of an "infrastructure enhancement model" is to strengthen health care facilities against earthquakes. This involves prioritizing seismic retrofitting for hospitals and clinics based on risk assessments to ensure structural resilience. Establishing temporary clinics and mobile units will additionally diversify health care access and meet community health needs in the aftermath of a disaster. The goal of an "infrastructure enhancement model" is to strengthen health care infrastructure against earthquakes by prioritizing seismic retrofitting for hospitals and clinics based on risk assessments. Diversifying health care access through temporary clinics and mobile units will also ensure community health needs are met in the aftermath of a disaster. The objective of an "emergency response coordination model" is to enhance coordination among emergency services and health care providers during disasters. This involves creating an Integrated Incident Command System for real-time collaboration among hospitals, emergency services, and public health officials, alongside regular training simulations to improve response times and familiarize stakeholders with emergency protocols. To ensure effective communication during disasters, a "communication infrastructure model" emphasizes the implementation of redundant systems, such as satellite phones and two-way radios, for reliable connectivity. Developing clear public information strategies is crucial for informing the community about resources, evacuation plans, and health care access, significantly improving emergency response and resilience. A "resource management model" focuses on optimizing resource allocation before and after a disaster. Key strategies include implementing inventory management systems for real-time tracking of medical supplies and personnel, and establishing mutual aid agreements among health care facilities for sharing essential resources during emergencies. These measures enhance efficiency and responsiveness in crisis situations. To integrate mental health services into disaster preparedness, a "mental health preparedness model" prioritizes two components. The first is training first responders to recognize and address mental health crises. The second is launching community awareness programs to

inform residents about available mental health resources and coping strategies. These initiatives together support a holistic approach to disaster preparedness. A "community engagement and resilience model" aims to build community resilience through preparedness and awareness by hosting workshops on emergency preparedness and establishing resilience networks. These actions empower residents with essential skills and foster social connections, equipping communities to respond effectively during crises.

The disaster preparedness framework relies on a strategic, phased approach that targets high-risk areas identified through risk assessments. This staged rollout allows for effective resource allocation and focused efforts. A reliable feedback loop will help us learn from drills and real events, ensuring our plans evolve with practical experiences. Collaborating with local governments, health care providers, and community organizations is essential for comprehensive planning and resource sharing, enhancing overall resilience and readiness. These elements together create a dynamic framework that prepares us for the unexpected and strengthens our collective response and recovery capabilities.

4.3 Diagram Structure

A flowchart or diagram that illustrates the interconnected components and their relationships is presented in this article to visualize the modeling for disaster preparedness in urban health care systems. This model should be regarded as a prototype, warranting further refinement and adaptation to enhance its applicability in diverse contexts. Continuous evaluation and iterative improvements are essential to ensure its effectiveness in addressing the dynamic challenges posed by urban health crises.

4.3.1. Title

"Urban Health Care Disaster Preparedness Model"

4.3.2. Central node

Urban health care preparedness is the main focus of the diagram.

4.3.3. Surrounding nodes

These branch out from the central node.

- The "risk assessment model" using GIS provides effective risk scoring.
- The "infrastructure enhancement model" focuses on seismic retrofitting and diversification of facilities.
- The "emergency response coordination model" includes an integrated command system and training simulations.
- The "communication infrastructure model" emphasizes redundant communication systems and public information systems.
- The "resource management model" incorporates inventory management systems and mutual aid agreements.
- The "mental health preparedness model" includes mental health training and community awareness initiatives.
- The "community engagement and resilience model" involves community preparedness workshops and resilience networks.

4.3.4. Connections

Arrows may be drawn to indicate relationships and interactions between models. In the proposed framework, several models are interconnected to illustrate their relationships and interactions (Figure 2).

- The "risk assessment model" is linked to the "infrastructure enhancement model," indicating that the insights gained from risk assessments play a crucial role in informing necessary upgrades to infrastructure.

- The "emergency response coordination model" additionally connects to the "resource management model," demonstrating that effective coordination during emergencies heavily relies on the availability and management of resources.
- The "mental health preparedness model" is further associated with the "community engagement and resilience model," emphasizing the significance of community involvement in the success of mental health initiatives. These connections highlight the collaborative nature of these models and their collective contribution to enhancing overall resilience and preparedness.

4.3.5. Additional features

Color coding can be employed to use different hues for each model, allowing for easy visual differentiation. Icons and symbols should be incorporated to enhance understanding, using relevant imagery such as hospital symbols for health care models and gear icons for management frameworks. Legends and notes are also important; including a brief explanation of key components or relationships can provide additional clarity and ensure that viewers fully grasp the information presented.

4.4 Example Layout for Modeling

The following diagram will provide a clear, visual representation of the complex interactions among various components of the disaster preparedness model, facilitating understanding and communication among stakeholders involved in planning and implementation.
Based on the identified themes, a conceptual model of public health services preparedness and disaster health management was developed. This model integrates the essential qualities derived from the qualitative analysis, emphasizing the key components.

4.4.1. Mapping the risk components

The model identifies and maps the critical risk factors associated with disaster scenarios, providing a framework for understanding vulnerabilities and resource needs.

4.4.2. Six high-level risk case scenarios

Each component is informed by the analysis of six high-level risk scenarios, which serve as case studies to illustrate potential challenges and the necessary responses in disaster situations.

3.4.3. Recurring themes in earthquake risks and health care access

The analysis revealed recurring themes related to earthquake risks and health care access, highlighting common challenges such as infrastructure damage, communication breakdowns, and resource shortages.

The model specifically highlights several key elements essential for effective disaster management. It primarily emphasizes the "strategic location" of HQ to ensure optimal access and visibility during emergencies. It also emphasizes "infrastructure resilience," advocating for buildings designed to withstand disaster impacts and featuring redundancy for essential utilities. "Effective communication systems" are crucial, facilitating timely information dissemination and coordination among various agencies involved in disaster response. "Resource management" frameworks are provided to efficiently track medical supplies and personnel, streamlining operations. The model incorporates "training and simulation" facilities dedicated to ongoing training and preparedness drills for staff, also stressing the importance of "collaboration and community engagement," promoting partnerships with local organizations and communities to foster a coordinated response (Figure 2).

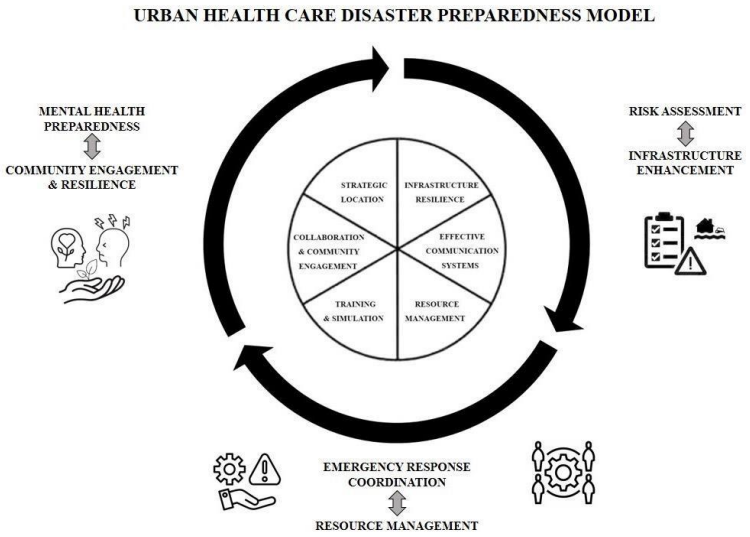

Figure 2. A diagram illustrating the essential characteristics influencing the strategic placement of disaster medical services in urban settings, highlighting their role in effective emergency response and health care delivery during disasters.

The final model is visually represented in a diagram, illustrating the interconnections among these components. This visual representation aids in enhancing understanding and communication among stakeholders involved in planning and implementing disaster health management strategies (Figure 2).

5 CONCLUSIONS

This study highlights the critical importance of strategically locating disaster emergency medical services HQ to enhance urban health care disaster preparedness. The findings reveal that the attributes of these locations can significantly influence emergency response effectiveness, drawing attention to the need for meticulous planning and assessment. The analysis of six diverse disaster scenarios elucidates the multifaceted challenges faced by health services, including infrastructure vulnerabilities, communication failures, and logistical constraints that can severely hinder response efforts.

The proposed model serves as a vital framework for public health preparedness, emphasizing essential components such as risk assessment, infrastructure enhancement, and community engagement. By prioritizing these attributes, urban health care systems can build resilience, ensuring that they are not only equipped to respond to immediate crises but also capable of mitigating long-term impacts on public health.

Recognizing that the findings of this study are context-specific is crucial. Different urban environments present unique challenges and opportunities that require tailored approaches. While the theoretical foundation of the proposed model is strong, future work should focus on the practical application and empirical validation of the model in real-world scenarios to assess its effectiveness across diverse settings and disaster situations. Continued research is, thus, imperative to further refine and adapt our model across varied contexts and crises.

A collective commitment to improving the location and operational capacity of disaster medical services HQ will be instrumental in safeguarding communities worldwide against future disasters, ultimately saving lives and enhancing the resilience of health care systems in countries at high risk in all regions.

REFERENCES

Allen, T., & Spencer, R. (2023). Barriers and enablers to using an emergency operations center in public health emergency management: A scoping review. *Disaster Medicine and Public Health Preparedness*, 17, e407. https://doi.org/10.1017/dmp.2023.50

Black, M., Moncada, K., & Herstad, K. (2021). Critical steps in data management during a crisis. *Cytometry Part A*, 99(1), 60-67. https://doi.org/10.1002/cyto.a.24265

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Chiang, S. C., Fisher, H. H., Bridwell, M. E., Trigoso, S. M., Rasulnia, B. B., & Kuwabara, S. A. (2020). Applying the ready, willing, and able framework to assess agency public health emergency preparedness: The CDC perspective. *Health security*, *18*(2), 75–82. https://doi.org/10.1089/hs.2019.0090

De Cauwer, H., Barten, D., Willems, M., Van der Mieren, G., & Somville, F. (2023). Communication failure in the prehospital response to major terrorist attacks: Lessons learned and future directions. *European Journal of Trauma and Emergency Surgery*: *Official publication of the European Trauma Society*, *49*(4), 1741–1750. https://doi.org/10.1007/s00068-022-02131-6

Emara, T. Z., Trinh, T., & Huang, J. Z. (2023). Geographically distributed data management to support large-scale data analysis. *Scientific Reports*, 13(1), 17783. https://doi.org/10.1038/s41598-023-44789-x

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology*, *13*, 117. https://doi.org/10.1186/1471-2288-13-117

Ghasemi, P., Goodarzian, F., & Abraham, A. (2022). A new humanitarian relief logistic network for multi-objective optimization under stochastic programming. *Applied Intelligence*, 52(12), 13729-13762. https://doi.org/10.1007/s10489-022-03776-x

Guha-Sapir, D., Vos, F., Below, V., & Ponserre, P. (2011). *Annual Disaster Statistical Review 2010: The numbers and trends*. Centre for Research on the Epidemiology of Disasters. https://www.preventionweb.net/files/27782_adsr2011.pdf

Haeberer, M., Tsolova, S., Riley, P., Cano-Portero, R., Rexroth, U., Ciotti, M., & Fraser, G. (2021). Tools for assessment of country preparedness for public health emergencies: A critical review. *Disaster Medicine and Public Health Preparedness*, *15*(4), 431–441. https://doi.org/10.1017/dmp.2020.13

King, H. C., Spritzer, N., & Al-Azzeh, N. (2019). Perceived knowledge, skills, and preparedness for disaster management among military health care personnel. *Military Medicine*, 184(9-10), e548-e554. https://doi.org/10.1093/milmed/usz038

Kress, M. M., Chambers, K. F., Hernández-Abrams, D. D., & McKay, S. K. (2022). Principles for data management, visualization, and communication to improve disaster response management: Lessons from the Hurricane Maria response mission. *Journal of Emergency Management (Weston, Mass.)*, *19*(8), 255–269. https://doi.org/10.5055/jem.0658

McMeekin, N., Wu, O., Germeni, E., & Briggs, A. (2020). How methodological frameworks are being developed: Evidence from a scoping review. *BMC Medical Research Methodology*, 20(1), 173. https://doi.org/10.1186/s12874-020-01061-4

Peleg, K., Reuveni, H., & Stein, M. (2002). Earthquake disasters—lessons to be learned. *Israel Medical Association Journal*, *4*(5), 361-365.

Shover, H. (2007). Understanding the chain of communication during a disaster. *Perspectives in Psychiatric Care*, 43(1), 4-14. https://doi.org/10.1111/j.1744-6163.2007.00100.x

Songwathana, P., & Timalsina, R. (2021). Disaster preparedness among nurses of developing countries: An integrative review. *International Emergency Nursing*, *55*, 100955. https://doi.org/10.1016/j.ienj.2020.100955

Tunaligil, V. (2024). Developing geographic information systems in health care for earthquake-prone metropolitan cities: A methodological approach. *Medical Science and Discovery*, *11*(9), 260–268. https://doi.org/10.36472/msd.v11i9.1191

Watson, S., Petterson, M., Lang, S., Kienberger, S., Hagenlocher, M., Rudge, J., & Coker, R. (2012). Trans-disciplinary research to improve health systems' disaster readiness and response. *Bulletin of the World Health Organization*, *90*(8), 558–558A. https://doi.org/10.2471/BLT.12.106120.