

Decision-making on Hospital Emergency Evacuation in Disasters and Emergencies: Findings From a Systematic Review

Tahereh Yaghoubi,^{1,2} Ali Ardalani,^{2,3,4} Davoud Khorasani Zavareh,^{5,6,7,*} Hamidreza Khankeh,⁸ Amir Nejati,² and Abass Ebadi⁹

¹School of Nursing and Midwifery, Health Sciences Research Center, Mazandaran University of Medical Sciences, Sari, IR Iran

²Department of Disaster Public Health, School of Public Health, Tehran University of Medical Sciences, Tehran, IR Iran

³Department of Disaster and Emergency Health, National Institute of Health Research, Tehran University of Medical Sciences, Tehran, IR Iran

⁴Harvard Humanitarian Initiative, Harvard University, Cambridge, MA, USA

⁵Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Sciences, Tehran, IR Iran

⁶Department of Health in Disaster and Emergency, School of Health, Safety and Environment, Shahid Beheshti University of Medical Sciences, Tehran, IR Iran

⁷Department of Clinical Science and Education, Karolinska Institute, Stockholm, Sodertjukhuset, Sweden

⁸Department of Disaster and Emergency Health, University of Social Welfare and Rehabilitation, Tehran, IR Iran

⁹Faculty of Nursing, Baqiyatallah University of Medical Sciences, Tehran, IR Iran

*Corresponding author: Davoud Khorasani Zavareh Department of Health in Disaster and Emergency, School of HSE, Shahid Beheshti University of Medical Sciences, Tehran, Iran, Department of Clinical Science and Education, Karolinska Institute, Stockholm, Sodertjukhuset, Sweden, E-mail: davoud.khorasani@gmail.com

Received 2017 April 30; Revised 2017 May 29; Accepted 2017 July 29.

Abstract

Context: Disasters are increasing worldwide, with more devastating effects than ever before. Hospitals must maintain their normal functions or have an evacuation plan due to the rate of damages at the time of a sudden disaster. The present study was conducted to determine the effective determinants and components in hospital evacuation decision-making.

Evidence Acquisition: In this systematic review study, which was conducted in 2016, bibliographies, citation databases, and other available records such as international guidelines, documents and reports of organizations and academic dissertations were used to find an answer to the following question: What are the effective components in hospital evacuation decision-making? Finally, 34 articles were included in this systematic review. This systematic review article was checked with PRISMA checklist.

Results: The common factors affecting hospital emergency evacuation decision-making were classified into 4 general categories and 40 subcategories, which have been explored during thematic analysis. These 4 categories included hospital infrastructure consequences, threat, internal factors, and external factors. Level of risk was the most important component of threat category and it was mentioned in most of the reviewed literature. Loss of electricity and water, communication and transportation, resources such as staff, and removing patient devices were the most mentioned factors in hospital infrastructure consequences, external factors, and internal factors, respectively.

Conclusions: Different variables affect the process of hospital emergency evacuation decision-making. Thus, further studies are needed to develop a decision-making tool for hospital emergency evacuations in Iran.

Keywords: Hospital Evacuation, Decision-Making, Disasters, Emergencies

1. Context

The percentage of disasters and their devastating concerns is increasing worldwide. It was reported that 3.3 million people died in disasters globally from 1970 to 2010 (1, 2). Despite advances in science and technology, it is not yet possible to forecast unexpected events such as earthquakes. In the critical situations following disasters, mortality and morbidity as well as the demand for health care services suddenly increase (3).

Health system has a special place among other organizations involved in crisis management because it is the first and foremost need at the time of crises during disasters and unexpected circumstances (4). Hospitals, as key elements in providing preparedness in emergency situations, must remain fully functional at the time of disasters

and major incidents (5). They are fundamental resources for successful management of disasters (6).

The vulnerability of hospitals in disasters results in instabilities in providing health care (7). Hundreds of hospitals and other health care facilities are destroyed or lose their function in natural disasters worldwide every year (8). Different studies have shown that many health care centers have been evacuated urgently due to fire, incidents related to Hydro-meteorological changes, terrorist threats, and other natural disasters (9-20).

Emergency evacuation of the hospitals is markedly different from other buildings. Transferring patients who may be in critical conditions is highly unsafe and is one of the causes for the difficulty of the process of hospital evacuation. It is crucial to move patients who require supportive services safely without any disruption in the per-

manent treatment cares that they receive (16). There are reports of mortality in emergency hospital evacuation (21). Also, 2 cases of death have been reported during hospital evacuations in Iranian hospitals in 2016.

The process of decision-making is too complex and these complications increase during crises (22). Avoidable evacuations are costly, upsetting, and unpopular, but waiting too long to leave can be devastating. Therefore, proper and fast decision-making about emergency evacuation is vital (23). Despite the essential importance of timely decision for hospital evacuation, only rare studies have been steered in this area. Besides, most studies merely concentrated on describing instances or reporting the evacuation-related experiences of health care providers and patients. The results of some studies have provided insight into decision-making by nursing home administrators to shelter in place or evacuate when a hurricane approaches.

Nevertheless, no review study has been conducted on decision-making about hospital evacuation in response to all hazards. The novelty of this systematic review was that it aimed at enhancing our knowledge of factors affecting sound and swift decision-making on emergency hospital evacuation in response to all hazards. Developing the skills and knowledge of hospital managers in decision-making during an emergency evacuation increases the safety of the patients in disasters and incidents. In fact, increasing the basic knowledge of hospital managers in this case is accounted as a new emergency. Therefore, this study aimed at determining the effective components in hospital evacuation decision-making.

2. Evidence Acquisition

2.1. Data Sources

The present study was a systematic review of publications and documents relating to defining effective factors in hospital decision-making process. The latest search was conducted in April 2016. Articles, checklists, guidelines, reference books, and relevant dissertations published during January 1, 2000 to April 15, 2016 were extracted. The searched databases were PubMed, Scopus, Proquest, Web of Science and Google Scholar. Also, we searched the Iranian databases such as SID, Iranmedex and Magiran, but we did not find any articles related to our research question. Reading the references of the included papers and using snowball method were other mechanisms for finding more articles.

2.2. Search Strategy

The search strategy was the same for all databases. To find as many articles as possible, the following terms (us-

ing Medical Subject Headings (MeSH)) were used: (health AND center) OR hospital OR "rural health center") AND (evacuation OR "Emergency Shelter*" OR "Evacuation Shelter*") OR (decision* OR intention OR resolve* OR determine* OR rule* OR "decision make*") AND (Disaster* OR Emerge*).

2.3. Selection of Articles and Documents

Two authors independently reviewed relevant documents to decrease selection bias of the included papers in the systematic review study. The titles and abstracts of the extracted articles and documents were screened to select relevant articles.

The selected publications were then read in full, and duplicates were excluded.

2.4. Inclusion Criteria

Included articles were those published in academic journals, with a main focus on decision-making during hospital evacuation, and those conducted within the scope set by the research question.

2.5. Exclusion Criteria

Excluded articles were those published prior to 2000, appeared in nonacademic journals, and those that were not related to our research question. Moreover, the articles were excluded if their full text was not available or if they were not in English.

Then, descriptive and thematic analyses were done for the included articles and the literature. Thematic analysis and categorizing the criteria were done through consulting the experts and supervisors. Finally, PRISMA checklist appraisal tool was completed for this review to decrease publication bias.

3. Results

In total, 240 articles and relevant records were identified by searching and 34 papers were included by determined criteria.

3.1. Descriptive Analysis

The largest numbers of papers were from the United States (78%), followed by Turkey (3%), Sweden (6%), and Australia (3%). Most papers (57%) were published in 2013 onwards. This has been due to the perceived need for research in this area; especially after the emergency evacuation experiences of health centers related to Katrina and Sandy hurricanes in the United States, interest in conducting research on this topic has been increased.

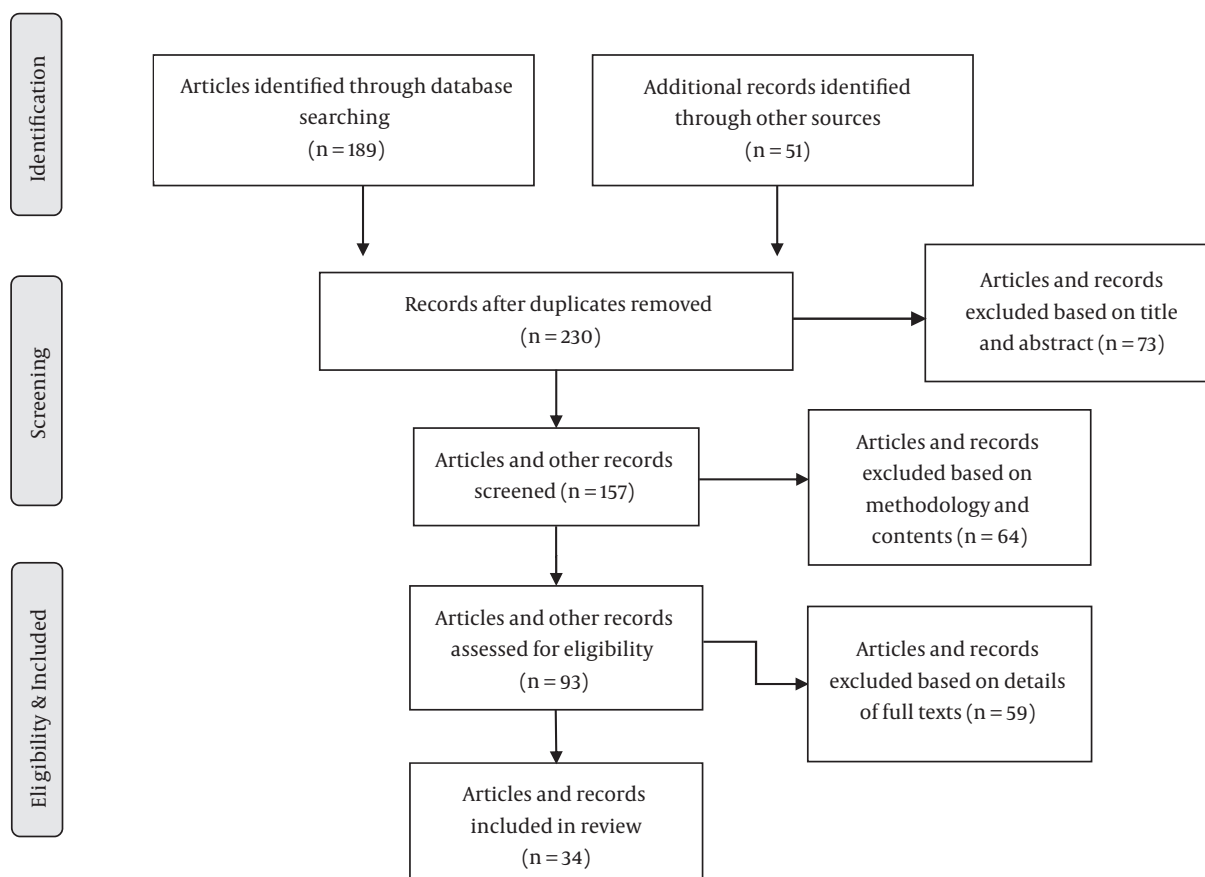


Figure 1. Flow Diagram of the Search and Selection of Papers

With respect to methodology, most of the papers (54%) were qualitative and 24% were review articles. Given that the scientific evidence in this area is partial, conducting qualitative research would be helpful. The summary of results is described in [Table 1](#).

3.2. Thematic Analysis

According to literature review and consulting with scholars and experts, the factors affecting the hospital emergency evacuation decision-making were classified into 4 general categories and 40 subcategories ([Table 2](#)).

Decision-making is a complex process, and this complexity and difficulty is due to a combination of several factors that are simultaneously involved in the decision-making situation ([22](#)). Also, decision-making is different in disasters and in critical situations; it is associated with the uncertainty of stressful and dynamic environment ([57](#)). One of the disaster features is that it occurs unexpectedly. Technical limitations make accurate forecast of the disaster difficult. Moreover, uncertainty at the time of occur-

rence and insufficient information about the severity and extent of the impact are the features of the disaster ([58](#)).

The hospital emergency evacuation planning has been considered as a subject of scientific research in the recent years ([59](#)). Most of the reviewed studies highlighted that hospital emergency evacuation decision-making or shelter in place is full of complexity and uncertainty. Unnecessary hospital emergency evacuation is costly, destructive, and unacceptable. Both options of shelter in place and hospital emergency evacuation have the potential of death, injury of patients and personnel, and intensifying treatment conditions of the patients or the injured ([25, 28, 45, 47, 48](#)).

McGlown emphasized that emergency evacuation process is sometimes dancing with danger ([45](#)). Historical record of hospital evacuation clearly reveals that uncertainty affects all aspects of emergency evacuation decision-making. Factors affecting the selection of decisions are dynamic and have an uncertain nature ([60](#)). Conducting the emergency evacuation following a disaster requires fast and correct decisions ([61](#)). The present systematic review

Table 1. Papers Analyzed for the Systematic Review of the Literature

Author	County	Year	Type	Methodology	Source of components
McGinty et al. (24)	USA	2016	Systematic review Article	Systematic review	Literature review
McGinty et al. (25)	USA	2016	Original Article	Qualitative	Semi structured interview
McGinty et al. (26)	USA	2016	Original Article	Qualitative review	Semi structured interviews
Hershey et al. (27)	USA	2016	Original Article		Literature review
Vugrin et al. (28)	USA	2015	Original Article	Case study	-
Von-maszewski et al. (29)	USA	2015	Original Article	Simulation	-
Ricci et al. (30)	USA	2015	Original Article	Qualitative	Literature review, Semi structured interviews
Hicks et al. (31)	USA	2015	Review Article	Review	Literature review
Khorram-Manesh et al. (6)	Sweden	2014	Original Article	Qualitative	interviews
Bish et al. (32)	USA	2014	Original Article	Quantitative	-
Salcedo et al. (33)	Mexico	2014	Review Article	Review	Literature review
King et al. (34)	USA	2015	Survey	Cross-sectional survey	-
Rojek et al. (7)	Australia	2013	Systematic review Article	Systematic review	Literature review
Nero et al. (35)	Sweden	2013	Original Article	Qualitative	Literature review, Risk and vulnerability analysis
Hassol et al. (36)	USA	2013	Letter to Editor	-	-
Downey et al. (37)	USA	2013	Original Article	Qualitative	Interview
Park et al. (38)	USA	2012	Report	Qualitative	Literature review, Expert Judgment
Childers et al. (39)	USA	2010	Original Article	Qualitative review	Expert panel; Literature review
Fennell (40)	USA	2009	Original Article	Qualitative and Quantitative	Conceptual framework analysis
Bagaria (41)	USA	2009	Original Article	Review	Literature review
Dosa et al. (42)	USA	2007	Original Article	Qualitative	Interview and Focus Groups
Augustine et al. (43)	USA	2005	Original Article	Case study; Simulation	Case study
Taffe et al. (44)	USA	2006	Original Article	Qualitative	Conceptual framework Analysis
McGlown (45)	USA	2001	Original Article		Literature review and Focus Groups
Milsten (46)	USA	2000	Original Article	Review	Literature review
Zaenger et al. (47)	USA	2010	Original Article	Qualitative	Literature review, structured interview

suggests improving the quality of decisions, and effective measures to achieve this are as follow: having previous experience of disaster, (30) increasing knowledge of management, (50, 57) encouraging group decision-making in emergency evacuation, (62) and being equipped with the supportive systems of decision-making (22) when the legal aspects of emergency evacuation decision-making is concerned (27, 51).

Level of risk, the most important component of threat category, was mentioned in the most reviewed literature. A linear relationship was found between the threat, decision, and consequences of emergency evacuation (63). Also, the findings demonstrated that the nature of the threat (50) was the main factor of emergency evacuation decision-making in the calculation of the risk for the safety

of the patients and the personnel (6, 7, 23, 26, 32-35, 40, 44, 45, 51, 52, 64).

Emergency evacuation order is issued according to the threat's conditions. Assessing the risk for patients and personnel is highly important, and to avoid incorrect calculation, an interdisciplinary group should estimate the potential risks for infrastructure based on reliable information (35, 44).

Collecting data and fully understanding the situation is one of the most important part of risk assessment. The findings of this study emphasized that decision-making support tools (22), information technology and computer applications (61, 65), and decision-making maps (66) increase situational awareness and provide insight for decision-makers.

Assessing hospital infrastructure empowers the decision-makers to estimate the degree of vulnerability and its potential consequences (55). This finding helps to determine that whether medical care can be continued in disasters or not. According to the decision-making instruction, self-assessment of the hospital critical infrastructure is highly important (49). Survey tool was divided into 8 parts as follow: urban water, steam, electricity, natural gas, chiller / boiler, electrical vital support equipment, IT and telecommunications, and security. Safety transfer of the patients to alternative health care centers under threat conditions is also a challenging task (36, 50, 67).

In several review papers on the lesson learned of the hospital emergency evacuation, support, equipment, human resources, information management, communications, removing patient devices, transportation, resources such as staff and intersector and interinstitutional coordination were emphasized in the success of an emergency evacuation (6, 7, 9, 23, 35, 36, 43, 46, 68, 69). The mentioned factors are prerequisites for hospital evacuation.

Another important and effective factor in emergency evacuation decision-making is political considerations (30). Disasters cause stress for an organization and its personnel, but political consequences resulting from a disaster are inevitable (57). During clinical experience and hospital management, we observed political aspects of decision-making. Berwair in 2012 presented this aspect as the blame game. Decision-makers are always blamed in case of not conducting an emergency evacuation when needed, or doing it when it was not needed. In most of the disaster situations, decision-makers are not able to accurately identify the options. They encounter a gray area between the 2 choices and this point is one of the important challenges in making decisions about hospital emergency evacuation (55).

Technical support of technology for decision-making (70) such as computer-based models (54), computer simulations (29, 71-73), computer-based role games according to the hospital emergency evacuation scenarios (74-76), decision-making support systems (77), table top exercises, and repeating them regularly (78) will be facilitating cases of the complex and difficult process of emergency evacuation decision-making.

Overall, despite using supporting tools, the responsibility to make a decision for evacuation still remains at the discretion of hospital managers. Studying and learning critical thinking skills are effective in increasing the power of initiative and creativity of managers (79, 80).

This study revealed the lack of similar documenting tools for reporting hospital evacuation cases. Also, there was no database for registry of the mentioned cases. We have a similar situation in Iran, and thus providing such

database helps the researchers to analyze and disseminate the lessons learned to promote decision-making skills during hospital evacuations.

3.3. Limitations

Only English articles were included in the literature review of this article. Also, access to some documents of international organizations was impossible.

4. Conclusions

Fast decision-making and reasoning play an important role in effective management of disasters. Appropriate decision-making plays a key role in reducing the intensity of negative consequences of the disaster. The current review showed that different variables affect the process of hospital emergency evacuation decision-making. However, due to the complexity, uncertainty, and inadequacy of information in an emergency situation, quantifying the concept of decision-making is difficult. It is hoped that the outcome of this study contribute to the development of a decision-making tool to facilitate hospital emergency evacuation in cases of disaster and emergency in Iran.

Footnote

Funding Statement: The authors received no specific funding for this work. The authors declare that no competing interests exist.

References

1. The international bank for reconstruction and development . *Natural disasters in the middle east and north africa: A regional overview*. Washington DC: The World Bank; 2014. Available from: <http://www.worldbank.org/en/region/mena/publication/natural-disasters-in-the-middle-east-and-north-africa..>
2. Neumayer E, Plumper T, Barthel F. The political economy of natural disaster damage. *Glob Environ Change*. 2014;**24**:8-19.
3. Shojaie P. Hospitals preparation in disasters: Security. *J Health Adm*. 2007;**10**(28):65-70.
4. Khankeh H . *Disaster Hospital Preparedness: National Plan*. 2nd ed. Tehran: Iran: University of Medical Sciences, Rehabilitation and Welfare; 2012.
5. Iserson K. Hospital evacuation: A new method. *South Med J*. 2013;**106**(1).
6. Khorram-Manesh A, Angthong C, Pangama A, Sulannakrarn S, Burivong R, Jarayabhand R, et al. Hospital evacuation; learning from the past? Flooding of bangkok 2011. *Br J Med Med Res*. 2014;**4**(1):395.
7. Rojek A, Little M. Review article: evacuating hospitals in Australia: what lessons can we learn from the world literature?. *Emerg Med Australas*. 2013;**25**(6):496-502. doi: [10.1111/1742-6723.12160](https://doi.org/10.1111/1742-6723.12160). [PubMed: [24224553](https://pubmed.ncbi.nlm.nih.gov/24224553/)].
8. Ardalan A, Kandi M, Talebian MT, Khankeh H, Masoumi G, Mohammadi R, et al. Hospitals safety from disasters in I.R.iran: the results from assessment of 224 hospitals. *PLoS Curr*. 2014;**6**. doi: [10.1371/currents.dis.8297b528bd45975bc6291804747ee5db](https://doi.org/10.1371/currents.dis.8297b528bd45975bc6291804747ee5db). [PubMed: [24596661](https://pubmed.ncbi.nlm.nih.gov/24596661/)].

Table 2. Effective Determinants and Components of Decision- making on Hospital Emergency Evacuation

Determinates	Components	Citation
Threat	Geographical situation (31, 48, 49)	Hicks (2015), Goestehius (2014), Zane (2010)
	Hospital size (31)	Hicks (2015)
	Disaster type (40, 45, 50)	Mcglown (2001), Fennell (2009), Glick (2012)
	Disaster severity (35, 45, 51)	Mcglown (2001), Nero (2013), Koeing (2016)
	Level of risk (7, 32, 33, 40, 44, 45, 50-52)	Mcglown (2001), Rojek (2013), Bish (2014), Fennell (2009), Salcedow (2014), Toffe (2005), Koieng (2016), Rega (2009), Glick (2012)
	Duration (38, 49, 51)	Park (2012), Zane (2010), Koeing (2016)
	Potential patients casualties (23, 38, 44)	Park (2012), Toffee (2005), Aidini (2012)
	Potential structural impacts (31, 33, 37, 46)	Milsten (2000), Hicks (2015), Downey (2013), Scalcedow (2014)
	Loss of electricity (36, 45, 47, 49)	Mcglawn (2001), Zane (2010), Hassol (2013), Zanges (2010),
	Loss of Water (45-47, 49)	Mcglown (2001), Zane (2010), Zaneger (2010), Milsten (2000)
Hospital infrastructure consequences	Loss of heating packages (HVAC) (45-47, 49)	Mcglown (2001), Zane (2010), Zaneger (2010), Milsten (2000)
	Loss of generators (45, 53)	Mcglown (2001), Bflower (2013)
	Loss of gas (47, 49)	Zane (2010), Zaneger (2010)
	Boilers/Chillers (49)	Zane (2010)
External factors	Community awareness (37)	Downey (2013)
	Physical Access (36, 44, 47, 49)	Toffee (2005), Zane (2010), Hassol (2013), Zaneger (2010)
	Transportation (36, 39, 41, 42, 44, 49, 53, 54)	Toffee (2005), Bflower (2013), Zane (2010), Hassol (2013), Childers (2010) Voyer (2016) Dosa (2007) Bagaria (2009)
	Traffic condition (6, 14, 49)	Zane (2010), Khorammanesh (2014),
	Secutiry (38, 47, 49, 51)	Zane (2010), Park (2012), Koieng (2016), Zaneger (2010)
	Destination Capability (23, 38, 49)	Park (2012), Aidini (2012), Zane (2010)
	Political Pressure (23, 30, 37)	Ricci (2015), Downey (2013), Aidini (2012)
	National resilliency (23)	Aidini (2012)
	Coordination with Authorities (7, 23, 47)	Aidini (2012), Zaneger (2010), Rojek (2013)
	Information management (23, 43, 51)	Aidini (2012), Voyer (2016) Augustine (2005)

6

Bagaria (2009)

9. Squillace N. *Hospital evacuations: Historical precedence and modern preparedness*. Wright State University - Main Campus; 2010.
10. Carey MG. Smoked out: emergency evacuation of an ICU. *Am J Nurs*. 2007;**107**(9):54-7. doi: [10.1097/01.NAJ.0000287511.31006.bd](https://doi.org/10.1097/01.NAJ.0000287511.31006.bd). [PubMed: [17721151](https://pubmed.ncbi.nlm.nih.gov/17721151/)].
11. Hogan C. Responding to a fire at a pediatric hospital. *AORN J*. 2002;**75**(4):793-800. [PubMed: [11963673](https://pubmed.ncbi.nlm.nih.gov/11963673/)].
12. Thomas J, Lackey N. How to evacuate a psychiatric hospital: a Hurricane Katrina success story. *J Psychosoc Nurs Ment Health Serv*. 2008;**46**(1):35-40. [PubMed: [18251350](https://pubmed.ncbi.nlm.nih.gov/18251350/)].
13. Bernard M, Mathews PR. Evacuation of a maternal-newborn area during Hurricane Katrina. *MCN Am J Matern Child Nurs*. 2008;**33**(4):213-23. doi: [10.1097/01.NMC.0000326075.03999.1i](https://doi.org/10.1097/01.NMC.0000326075.03999.1i). [PubMed: [18664902](https://pubmed.ncbi.nlm.nih.gov/18664902/)].
14. Barnett J, Dennis-Rouse M, Martinez V. Wildfire disaster leads to facilities evacuation. *Orthop Nurs*. 2009;**28**(1):17-20. doi: [10.1097/01.NOR.0000345849.32424.0a](https://doi.org/10.1097/01.NOR.0000345849.32424.0a). [PubMed: [19190472](https://pubmed.ncbi.nlm.nih.gov/19190472/)].
15. Tanigawa K, Hosoi Y, Hirohashi N, Iwasaki Y, Kamiya K. Loss of life after evacuation: lessons learned from the Fukushima accident. *Lancet*. 2012;**379**(9819):889-91. doi: [10.1016/S0140-6736\(12\)60384-5](https://doi.org/10.1016/S0140-6736(12)60384-5). [PubMed: [22405787](https://pubmed.ncbi.nlm.nih.gov/22405787/)].
16. Organization WH. *Safe hospitals in emergencies and disasters: Structural, non-structural and functional indicators*. World Health Organization; 2010. Available from: http://www.wpro.who.int/emergencies_disasters/documents/SafeHospitalsinEmergenciesandDisastersweboptimized.pdf.
17. Nates JL. Combined external and internal hospital disaster: impact and response in a Houston trauma center intensive care unit. *Crit Care Med*. 2004;**32**(3):686-90. [PubMed: [15090948](https://pubmed.ncbi.nlm.nih.gov/15090948/)].
18. Yanagawa Y, Miyawaki H, Shimada J, Morino K, Satoh E, Ohtomo Y, et al. Medical evacuation of patients to other hospitals due to the Fukushima I nuclear accidents. *Prehosp Disaster Med*. 2011;**26**(5):391-3. doi: [10.1017/S1049023X11006418](https://doi.org/10.1017/S1049023X11006418). [PubMed: [22067474](https://pubmed.ncbi.nlm.nih.gov/22067474/)].
19. Perrin K. A first for this century: closing and reopening of a children's hospital during a disaster. *Pediatrics*. 2006;**117**(5 Pt 3):S381-5. doi: [10.1542/peds.2006-0099H](https://doi.org/10.1542/peds.2006-0099H). [PubMed: [16735269](https://pubmed.ncbi.nlm.nih.gov/16735269/)].
20. Verni C. A hospital system's response to a hurricane offers lessons, including the need for mandatory interfacility drills. *Health Aff (Millwood)*. 2012;**31**(8):1814-21. doi: [10.1377/hlthaff.2012.0154](https://doi.org/10.1377/hlthaff.2012.0154). [PubMed: [22869660](https://pubmed.ncbi.nlm.nih.gov/22869660/)].
21. Cocanour CS, Allen SJ, Mazabob J, Sparks JW, Fischer CP, Romans J, et al. Lessons learned from the evacuation of an urban teaching hospital. *Arch Surg*. 2002;**137**(10):1141-5. [PubMed: [12361420](https://pubmed.ncbi.nlm.nih.gov/12361420/)].
22. Olmez M, Lindemann U. Managing attribute complexity for user-centered decision support systems. *Procedia Comput Sci*. 2014;**28**:130-7.
23. Adini B, Laor D, Cohen R, Israeli A. Decision to evacuate a hospital during an emergency: the safe way or the leader's way?. *J Public Health Policy*. 2012;**33**(2):257-68. doi: [10.1057/jphp.2012.2](https://doi.org/10.1057/jphp.2012.2). [PubMed: [22318408](https://pubmed.ncbi.nlm.nih.gov/22318408/)].
24. McGinty MD, Burke TA, Barnett DJ, Smith KC, Resnick B, Rutkow L. Hospital Evacuation and Shelter-in-Place: Who Is Responsible for Decision-Making?. *Disaster Med Public Health Prep*. 2016;**10**(3):320-4. doi: [10.1017/dmp.2016.86](https://doi.org/10.1017/dmp.2016.86). [PubMed: [27198183](https://pubmed.ncbi.nlm.nih.gov/27198183/)].
25. McGinty MD, Burke TA, Resnick BA, Smith KC, Barnett DJ, Rutkow L. Legal Preparedness for Hurricane Sandy: Authority to Order Hospital Evacuation or Shelter-in-Place in the Mid-Atlantic Region. *Health Secur*. 2016;**14**(2):78-85. doi: [10.1089/hs.2015.0068](https://doi.org/10.1089/hs.2015.0068). [PubMed: [27081887](https://pubmed.ncbi.nlm.nih.gov/27081887/)].
26. McGinty MD, Burke TA, Resnick B, Barnett DJ, Smith KC, Rutkow L. Decision Processes and Determinants of Hospital Evacuation and Shelter-in-Place During Hurricane Sandy. *J Public Health Manag Pract*. 2017;**23**(1):29-36. doi: [10.1097/PHH.0000000000000404](https://doi.org/10.1097/PHH.0000000000000404). [PubMed: [26910873](https://pubmed.ncbi.nlm.nih.gov/26910873/)].
27. Hershey TB, Van Nostrand E, Sood RK, Potter M. Legal Considerations for Health Care Practitioners After Superstorm Sandy. *Disas-*

- ter Med Public Health Prep. 2016;**10**(3):518-24. doi: [10.1017/dmp.2016.33](https://doi.org/10.1017/dmp.2016.33). [PubMed: [27021812](https://pubmed.ncbi.nlm.nih.gov/27021812/)].
28. Vugrin ED, Verzi SJ, Finley PD, Turnquist MA, Griffin AR, Ricci KA, et al. Modeling Evacuation of a Hospital without Electric Power. *Prehosp Disaster Med.* 2015;**30**(3):279-87. doi: [10.1017/S1049023X15000230](https://doi.org/10.1017/S1049023X15000230). [PubMed: [25868416](https://pubmed.ncbi.nlm.nih.gov/25868416/)].
 29. Von-Maszewski M, Botz G. 952: Planned evacuation of an icu as preparation for disaster management. *Crit Care Med.* 2015;**43**(12):239.
 30. Ricci KA, Griffin AR, Heslin KC, Kranke D, Dobalian A. Evacuate or Shelter-in-place? The Role of Corporate Memory and Political Environment in Hospital-evacuation Decision Making. *Prehosp Disaster Med.* 2015;**30**(3):233-8. doi: [10.1017/S1049023X15000229](https://doi.org/10.1017/S1049023X15000229). [PubMed: [25783663](https://pubmed.ncbi.nlm.nih.gov/25783663/)].
 31. Hicks J, Glick R. A meta-analysis of hospital evacuations: overcoming barriers to effective planning. *J Healthc Risk Manag.* 2015;**34**(3):26-36. doi: [10.1002/jhrm.21162](https://doi.org/10.1002/jhrm.21162). [PubMed: [25630283](https://pubmed.ncbi.nlm.nih.gov/25630283/)].
 32. Bish DR, Agca E, Glick R. Decision support for hospital evacuation and emergency response. *Ann Oper Res.* 2014;**221**(1):89-106.
 33. Salcedo VV, Lopez AM. General evacuation measures in disaster situations for hospitalized mental patients. Literature review and suggestions. *Salud Ment (Mex).* 2014;**37**:343-8.
 34. King MA, Dorfman MV, Einav S, Niven AS, Kisson N, Grissom CK. Evacuation of Intensive Care Units During Disaster: Learning From the Hurricane Sandy Experience. *Disaster Med Public Health Prep.* 2016;**10**(1):20-7. doi: [10.1017/dmp.2015.94](https://doi.org/10.1017/dmp.2015.94). [PubMed: [26311514](https://pubmed.ncbi.nlm.nih.gov/26311514/)].
 35. Nero C, Ortenwall P, Khorram-Manesh A. Hospital evacuation: Planning, assessment, performance and evaluation. *J Emerg Disaster Med.* 2013;**2**:1.
 36. Hassol A, Biddinger P, Zane R. Hospital evacuation decisions in emergency situations. *J Am Med Assoc.* 2013;**309**(15):1585-6.
 37. Downey EL, Andress K, Schultz CH. External factors impacting hospital evacuations caused by Hurricane Rita: the role of situational awareness. *Prehosp Disaster Med.* 2013;**28**(3):264-71. doi: [10.1017/S1049023X13000125](https://doi.org/10.1017/S1049023X13000125). [PubMed: [23688660](https://pubmed.ncbi.nlm.nih.gov/23688660/)].
 38. Park YS, Abramson DM, Levin K. *Assessing the reliability and validity of the evacuation support decision tool.* New York: National Center for Disaster Preparedness; 2012.
 39. Childers A, Taaffe KM. Healthcare facility evacuations: Lessons learned, research activity, and the need for engineering contributions. *J Healthc Eng.* 2010;**1**(1):125-40.
 40. Fennell J. *A decision making framework for hurricane evacuation and sheltering.* Louisiana: Louisiana State University; 2009.
 41. Bagaria J, Heggie C, Abrahams J, Murray V. Evacuation and sheltering of hospitals in emergencies: a review of international experience. *Prehosp Disaster Med.* 2009;**24**(5):461-7. [PubMed: [20066652](https://pubmed.ncbi.nlm.nih.gov/20066652/)].
 42. Dosa DM, Grossman N, Wetle T, Mor V. To evacuate or not to evacuate: lessons learned from Louisiana nursing home administrators following Hurricanes Katrina and Rita. *J Am Med Dir Assoc.* 2007;**8**(3):142-9. doi: [10.1016/j.jamda.2006.11.004](https://doi.org/10.1016/j.jamda.2006.11.004). [PubMed: [17349942](https://pubmed.ncbi.nlm.nih.gov/17349942/)].
 43. Augustine J, Schoettmer JT. Evacuation of a rural community hospital: lessons learned from an unplanned event. *Disaster Manag Response.* 2005;**3**(3):68-72. doi: [10.1016/j.dmr.2005.05.005](https://doi.org/10.1016/j.dmr.2005.05.005). [PubMed: [15986026](https://pubmed.ncbi.nlm.nih.gov/15986026/)].
 44. Taaffe KM, Kohl R, Kimbler DL, editors. Hospital evacuation: Issues and complexities. *Winter Simulation Conference.* 2005.
 45. McGlown KJ. Evacuation of health care facilities: A new twist to a classic model. *Natur Hazard Rev.* 2001;**2**(2):90-9.
 46. Milsten A. Hospital responses to acute-onset disasters: a review. *Prehosp Disaster Med.* 2000;**15**(1):32-45. [PubMed: [11066840](https://pubmed.ncbi.nlm.nih.gov/11066840/)].
 47. Zaenger D, Efrat N, Riccio RR, Sanders K. Shelter-in-place versus evacuation decision making: A systematic approach for healthcare facilities. *Risk Hazard Crisis Public Policy.* 2010;**1**(3):19-33.
 48. Nguyen MM, McCracken CJ, Milner ES, Goetschius DJ, Weiner AT, Long MK, et al. Gamma-tubulin controls neuronal microtubule polarity independently of Golgi outposts. *Mol Biol Cell.* 2014;**25**(13):2039-50. doi: [10.1091/mbc.E13-09-0515](https://doi.org/10.1091/mbc.E13-09-0515). [PubMed: [24807906](https://pubmed.ncbi.nlm.nih.gov/24807906/)].
 49. Zane R, Biddinger P, Hassol A, Rich T, Gerber J, DeAngelis J. *Hospital evacuation decision guide.* Agency for Healthcare Research and Quality, US Department of Health and Human Services; 2010. p. 1-55.
 50. Glick R, Bish DR, Agca E. Optimization-based decision support to assist in logistics planning for hospital evacuations. *J Emerg Manag.* 2013;**11**(4):261-70. [PubMed: [24303770](https://pubmed.ncbi.nlm.nih.gov/24303770/)].
 51. Koenig KL. *Koenig and schultz's disaster medicine: Comprehensive principles and practices.* Cambridge University Press; 2016.
 52. Rega PP, Locher G, Shank H, Contreras K, Bork CE. Considerations for the vertical evacuation of hospitalized patients under emergency conditions. *Am J Disaster Med.* 2010;**5**(4):237-46. [PubMed: [20879506](https://pubmed.ncbi.nlm.nih.gov/20879506/)].
 53. Bellflower RA. *How nursing home administrators make the decision to shelter-in-place or evacuate.* CAPELLA; 2013.
 54. Voyer J, Dean MD, Pickles CB. Hospital evacuation in disasters: Uncovering the systemic leverage using system dynamics. *Int J Emerg Manag.* 2016;**12**(2):152-67.
 55. Berwari A. *The simultaneous evacuation of a midwestern community's multiple healthcare facilities during a major flood event: A study in decision-making and implementation.* Fargo, North Dakota: North Dakota state university; 2012.
 56. Kim J, Oh SS. Confidence, knowledge, and compliance with emergency evacuation. *J Risk Res.* 2015;**18**(1):111-26.
 57. Huder RC. *Disaster operations and decision making.* Hoboken, New Jersey: John Wiley Sons; 2013.
 58. Yu L, Lai KK. A distance-based group decision-making methodology for multi-person multi-criteria emergency decision support. *Decis Support Syst.* 2011;**51**(2):307-15.
 59. Poppenborg J, Knust S. Modeling and optimizing the evacuation of hospitals based on the MRCPS with resource transfers. 2014:1-32. *Eur J Comput Optim.* 2014.
 60. Cova TJ, Dennison PE, Drews FA. Modeling evacuate versus shelter-in-place decisions in wildfires. *Sustain J.* 2011;**3**(10):1662-87.
 61. Moulik S, Misra S, Obaidat MS. Smart-vac: Big data-based decision making for emergency evacuation. *IEEE Cloud Comput.* 2015;**2**(3):58-65.
 62. Levy JK, Taji K. Group decision support for hazards planning and emergency management: A group analytic network process (GANP) approach. *Math Comput Modelling.* 2007;**46**(7):906-17.
 63. Kolen B, Helsloot I. Decision-making and evacuation planning for flood risk management in the Netherlands. *Disasters.* 2014;**38**(3):610-35. doi: [10.1111/disa.12059](https://doi.org/10.1111/disa.12059). [PubMed: [24905713](https://pubmed.ncbi.nlm.nih.gov/24905713/)].
 64. McGinty MD. *Evacuate or shelter-in-place? Decision-making for hospitals during hurricane sandy.* Baltimore, Maryland: Maryland Johns Hopkins University; 2015.
 65. Little RG, Manzanares T, Wallace WA. Factors influencing the selection of decision support systems for emergency management: An empirical analysis of current use and user preferences. *J Conting Crisis Manag.* 2015;**23**(4):266-74.
 66. Comes T, Hiete M, Wijngaards N, Schultmann F. Decision maps: A framework for multi-criteria decision support under severe uncertainty. *Decis Support Syst.* 2011;**52**(1):108-18.
 67. Zoraster RM, Amara R, Fruhwirth K. Transportation resource requirements for hospital evacuation. *Am J Disaster Med.* 2010;**6**(3):173-86. doi: [10.1002/jemt.1060140310](https://doi.org/10.1002/jemt.1060140310). [PubMed: [2187066](https://pubmed.ncbi.nlm.nih.gov/2187066/)].
 68. Sorensen B, Zane R, Wante B. Hospital emergency response checklist: An all-hazards tool for hospital administrators and emergency managers 2011. *World Health Organ.* 2013.
 69. Kaliamoorthy I, Reddy MS, Rajakumar A, Varghese J, Pandey S, Pillai B, et al. Safe emergency evacuation of a Tertiary Care Hospital during the "once in a century" floods in Chennai, India. *Indian J Crit Care Med.* 2016;**20**(2):104-8. doi: [10.4103/0972-5229.175933](https://doi.org/10.4103/0972-5229.175933). [PubMed: [27076711](https://pubmed.ncbi.nlm.nih.gov/27076711/)].
 70. Simonovic SP. *Systems approach to management of disasters: Methods and applications.* John Wiley Sons; 2011.
 71. Beroggi G. Organizational decision making in crisis management. *Organizing Emergency Management strategies for the transport sector with*

- the use of innovative IT systems. 2011.
72. Chen W, Guinet A, Ruiz A. Modeling and simulation of a hospital evacuation before a forecasted flood. *Oper Res Health Care*. 2015;**4**:36–43.
 73. Marshall DA, Burgos-Liz L, IJzerman MJ, Osgood ND, Padula WV, Higgashi MK, et al. Applying dynamic simulation modeling methods in health care delivery research—the simulate checklist: Report of the ispor simulation modeling emerging good practices task force. *Value Health*. 2015;**18**(1):5–16.
 74. Silva JF, Almeida JE, Rossetti RJ, Coelho AL. A serious game for evacuation training. *Serious Games and Applications for Health (SeGAH)*, IEEE 2nd International Conference on. Vilamoura, Portugal. IEEE; 2013.
 75. Silva JF, Almeida JE, Rossetti RJ, Coelho AL. Gamifying evacuation drills. *8th Iberian Conference on Information Systems and Technologies (CISTI)*. Lisboa, Portugal. IEEE; 2013.
 76. Campbell B, Weaver C. Rim Sim response hospital evacuation: Improving situation awareness and insight through serious games play and analysis. *Int J Info Systems Crisis Respon Manage*. 2011;**3**(3):1–15.
 77. Yaqoob L, Ahmed Khan N, Subhan F. An overview of existing decision support systems for disasters management. *Sci Int (Lahore)*. 2014;**26**:1765–76.
 78. Rinne T, Tillander K, Gronberg P. Data collection and analysis of evacuation situations. *Valtion Teknillinen Tutkimuskeskus*. 2010.
 79. Yurtseven MK, Buchanan WW. Complexity decision making and general systems theory: An educational perspective. *Soc*. 2016;**6**(2):77–95.
 80. Sun B, Ma W, Zhao H. An approach to emergency decision making based on decision-theoretic rough set over two universes. *Soft Comput*. 2015:1–12.