

Enhancing hospital disaster resilience: Key indicator identification and framework innovation

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Globally, the intensity of disasters has significantly increased, primarily because of the effects of climate change. This trend underscores the importance of hospital resilience, given the essential functions hospitals serve in the pre-disaster preparedness, during disaster response and post-disaster recovery phase. Enhancing hospital resilience against disasters can be achieved through preparation and evaluation, leading to a healthcare system that ensures quality and patient safety. This study employed an exploratory sequential mixed-methods design, beginning with a literature review to identify potential indicators, followed by focus group discussions (FGD) with seven experts to refine and validate the framework. The findings identified key indicators and developed a framework for hospital resilience in disasters. The findings yielded eight indicators of hospital resilience, which serve as the foundation for creating an innovative framework concerning hospital resilience for disasters.

Contribution: This study contributes new insights by presenting indicators and frameworks targeting hospital resilience in disaster scenarios. The establishment of specific tools for evaluating hospital resilience in disaster contexts is crucial for enhancing the continuity of this study.

Keywords: disaster; framework; hospital; indicator; resilience.

Introduction

Disasters are events that cause significant disruption, whether caused by nature or humans, resulting in major losses to the environment and human life (Caldera & Wirasinghe 2022; Council of Australian Governments 2011). The Centre for Research on the Epidemiology of Disasters (CRED) reports that the number of disasters continues to increase every year (CRED 2023). The Disaster Data Geoportal explains that most disasters occur because of forest and land fires, and there is damage to facilities, dominated by health infrastructure (BNPB 2022). The tsunami that hit Aceh Province in 2004 was one of the largest disasters in Indonesia (Oktari et al. 2021), causing severe damage; 80% hospitals were damaged and unused (Kazancıoğlu & Erdoğan 2023). This incident emphasises the importance of learning from disasters, especially for hospitals, to increase their preparedness and resilience so as to minimise greater damage if a similar disaster occurs in the future (Mojtahedi et al. 2021).

Effective preparedness is essential for hospitals to achieve comprehensive resilience (Fallah-Aliabadi et al. 2020), enabling them to identify risks, manage threats and contribute to strengthening community resilience (Wiig et al. 2020). Preparedness forms a crucial part of disaster resilience, encompassing efforts to anticipate, respond to and recover from post-disaster challenges (Khalil et al. 2022). Global strategies for enhancing readiness and resilience against disasters have been outlined in international agreements, such as the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR). This framework aims to significantly minimise disaster-related losses, with a focus on reducing fatalities and morbidity (UNISDR 2015). One of the key objectives of the SFDRR is to emphasise the critical role of hospitals in being disaster-ready and fostering hospital resilience (UNISDR 2015). Similarly, the World Health Organization (WHO) introduced the Framework for Building Climate Resilient and Low Carbon Health Systems in 2023 (WHO 2023). This updated framework serves as a guiding tool for health facilities

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and policymakers, enabling them to develop mechanisms, plan strategies and report resilience measures in response to climate change and greenhouse gas impacts. It promotes the establishment of an integrated health security system (WHO 2023). In this context, this study tries to identify relevant indicators and develop an innovative framework that can serve as the principle for crafting regulations and comprehensive actions to enhance disaster resilience in hospitals.

Research methods and design

This research is divided into two stages according to an evidence-based research flow chart (Oktari et al. 2020).

In the first stage (development stage), the study identified indicators of hospital resilience. To obtain key indicators, this study conducted a literature review related to hospital resilience using Arksey and O'Malley's scoping review framework. This method involves five main stages: identifying research questions, searching for relevant research, selecting studies, mapping data, compiling and reporting results. Instrument searches were carried out electronically in English via PubMed, ProQuest, Elsevier, ISI Web of Science and Google Scholar, with the keywords' indicator, hospital, disaster and resilience. The research includes article publications from 2013 to 2024 based on subdiscipline, subtitle, language and type of content.

A total of 25 references, in the form of guides, instruments and scientific articles, have been arranged in a Microsoft Excel table based on title, source, author and year of publication, description and indicators. The qualitative data were analysed through mapping, deductive coding and classification based on the predetermined indicators derived from the literature review. Codes were organised into categories and themes aligned with the research objectives, enabling synthesis of the most relevant elements of hospital resilience. The results of descriptive analysis from these 25 references were used to develop hospital resilience indicators.

The researchers also practised continuous self-reflection throughout all stages of the study to minimise bias and enhance the credibility of the findings. Reflective notes and team discussions were conducted during data collection and analysis to identify and address any personal assumptions or preconceptions that might influence interpretation. Each member reviewed their analytical memos to ensure openness, dependability and confirmability of the research process.

Next, the researcher conducted a focus group discussion (FGD) with experts based on indicators obtained from the results of previously reviewed literature. The FGD was held in October 2024 via a Zoom meeting and lasted for about 2 h. A semi-structured discussion guide containing open-ended questions based on the preliminary indicators identified from the literature review was utilised. The session was led by a moderator experienced in qualitative research,

assisted by a note-taker. With participants' consent, the discussion was audio-recorded and later transcribed verbatim. The research team reviewed the transcripts for accuracy and conducted member checking with participants to ensure the credibility and validity of the collected data. This FGD aims to identify key factors that influence hospital resilience in dealing with disasters, gather perspectives from various stakeholders regarding the hospital's ability to deal with disasters and then develop recommendations for the development of the hospital resilience framework. This FGD involved seven experts, as described in Table 1 regarding the distribution of experts. Each expert was given the opportunity by the researcher to provide suggestions and recommendations in accordance with the research objectives related to disaster resilience in hospitals.

After conducting the FGD, the researchers transcribed the video recordings and qualitatively analysed the data to produce indicators that are the main keys to hospital resilience in facing disasters. Based on the results of the FGD, there were several references and reading sources recommended by experts, and it was agreed that there were eight main indicators that would represent hospital resilience in facing disasters.

In the second stage (judgement stage), the study focused on designing a framework related to hospital resilience. Theoretical saturation was ensured through iterative analysis of data obtained from both the literature review and expert FGDs. During this stage, the researchers continuously compared and refined emerging indicators until no new themes appeared, confirming data redundancy. The final framework was validated through consensus among the experts, ensuring that all relevant dimensions of hospital resilience were adequately represented and theoretically grounded. Researchers designed a framework from the indicator results obtained from the previous stage. At this stage, researchers use a conceptual framework design to develop a series of concepts and relationships from several indicators that represent this study so as to produce a framework that is integrated with the concept of hospital resilience (Grant & Osanloo 2014; Oktari & Kurniawan 2016). This study was developed based on literature studies with the aim of providing scientific information about a general framework for hospital resilience in the face of disasters. This framework outlines several indicators that represent integrating important components of hospital resilience.

TABLE 1: The distribution of experts.

Expert	Category	Institution levels	Gender	Education
1	Government	National	Female	Master
2	Government	National	Female	Master
3	Academic	Local	Male	Doctorate
4	Practitioner	National	Female	Doctorate
5	Practitioner	Local	Male	Master
6	Academic	Local	Female	Master
7	Academic	Local	Male	Doctorate
8	Practitioner	Local	Male	Professor

Ethical considerations

This study has received ethical approval from the Faculty of Medicine, Universitas Syiah Kuala in April 2024 with Ethical Approval Number: 096/ETIK-RSUDZA/2024. Researchers comply with research ethical guidelines to protect the human rights and welfare of research subjects and all parties involved, in order to minimise negative impacts that may occur during the research process.

Results

This study identified the indicators of hospital disaster resilience and innovative framework designs as a principle for developing regulations and complete follow-up to be ready and survive in the face of disasters.

Hospital disaster resilience indicator

There are eight key indicators and some sub-indicators that were obtained in this study. Key indicators of hospital resilience in facing disasters are presented in Table 2.

Framework

This framework outlines several indicators that represent integrating important components of hospital disaster resilience. This framework was developed through modifications from various sources and scientific literature. In the inner core section, which is the core part of the framework modified from the Sendai Framework 2015–2030. This inner core part consists of understanding, strengthening, enriching and rebuilding. Then, the outer core is the second layer of the framework, modified from the Scientific Meeting attended by researchers in 2023 in Australia by P.H. Barners (Barners 2010). This outer core section consists of identify, plan, implement and study. Next, the final layer of this framework is the coat section obtained from the results of a systematic review of various scientific literature, which is the first part of this research process. This layer is a key indicator of hospital resilience, which consists of information and technology, training and research, governance, workforce, financing, infrastructure, service and business continuity. When linked, these three layers not only provide key indicators but also define how a hospital is resilient to disasters. This framework is arranged in a scheme as depicted in Figure 1.

Discussion

The primary indicators of hospital resilience are crucial elements for assessing the preparedness and capability of hospitals to face disasters (Fleming et al. 2022; Haghghat et al. 2024; Zhong et al. 2015). These indicators encompass various critical aspects, such as information technology, training and research, governance, workforce, financing, infrastructure, services and business continuity. Together, these aspects form a comprehensive resilience framework aimed at helping hospitals identify, measure and enhance their resilience.

As a basis for systematic evaluation, resilience indicators enable hospitals to assess their readiness through measurable parameters (Husaini et al. 2023; Sari et al. 2023). For instance, the infrastructure indicator evaluates the facility's ability to withstand disasters, such as earthquakes, floods or fires (Laily 2020; Sunindijo, Lestari & Wijaya 2019; WHO 2015). Meanwhile, the financing indicator ensures adequate budget allocation for risk mitigation, supports robust financial strategies and ensures efficient resource management (Heidaranlu et al. 2015; WHO 2024). The service indicator focuses on the hospital's capacity to handle patient surges caused by disasters (Fleming et al. 2022; Heidaranlu et al. 2015; WHO 2017), while the business continuity indicator ensures that core hospital functions remain operational despite major disruptions (Heidaranlu et al. 2015). Additionally, training and research indicators, as well as information technology, contribute to enhancing hospital adaptability to emergency situations. Simulation-based training, for example, provides healthcare personnel with practical experience in responding to disasters effectively. Good governance ensures the presence of well-directed risk mitigation policies, while workforce indicators assess staff competency to respond to challenges in a more organised manner. Post-disaster, the infrastructure indicator supports reconstruction processes with a 'build back better' principle, ensuring improvements that strengthen the facility's resilience for the future (UNISDR 2015).

The four core elements, or the inner core, serve as the primary foundation for building hospital resilience. The first element, understanding, emphasises the importance of in-depth comprehension of risks through the identification of threats, vulnerabilities, capacities and opportunities. This understanding supports data-driven planning, the development of information technology, training and research to prepare hospitals for various risks. The second element, strengthening, focuses on capacity building to ensure service continuity even under high-pressure conditions, with an emphasis on governance and a competent workforce. The enriching element aims to enhance hospital flexibility through innovation and collaboration, enabling the hospital to dynamically adapt to unforeseen circumstances. This element focuses on financing and infrastructure. Meanwhile, the final element, rebuilding, highlights the hospital's ability to recover with the 'build back better' principle, ensuring long-term resilience and maximising capacity to face future risks (UNISDR 2015). To support the implementation of the inner core elements, the outer core framework is designed as a systematic guide. This process involves risk identification, strategic planning, targeted implementation and data-driven evaluation. Through this approach, hospitals can strengthen risk understanding, capacity and infrastructure, maintain service continuity and rebuild effectively after disasters.

This framework provides an evidence-based foundation for hospitals and policymakers to measure resilience, develop regulations related to risk mitigation and create a safe environment (Oktari & Kurniawan 2016;

TABLE 2: Hospital disaster resilience indicator.

Code	Theme	Sub-indicator	Reference
IT	Information and technology	IT.1 Supporting health facilities in digital technology	Sari et al. (2023)
		IT.2 Updating the information system related to digital health technology	Sari et al. (2023), WHO (2022)
		IT.3 Effective information systems (data information flow, mechanisms, available hard (phone and wi-fi) and soft (press, community and NGOs) infrastructure communication, as well as marketing and branding related to disasters	European Union (2020), Sari et al. (2023)
		IT.4 Systems for providing disaster warnings based on technology such as artificial intelligence (AI) or big data	BNPB (2024)
TR	Training & research	TR.1 Existence of Research and Development related to climate change	WHO (2023)
		TR.2 Planning and implementation of staff education development and based on competence and authority	Fleming et al. (2022), Haghighat, Mousavi and Jahadi Naeini (2024), Jafari Nodoushan et al. (2022), Sari et al. (2023), WHO (2022)
		TR.3 Planning and implementing research for staff	Fleming et al. (2022), WHO (2017, 2022)
GV	Governance	GV.1 Leadership involvement in carrying out scheduled monitoring and evaluation related to disasters (ability to read situations, give feedback, excellent leadership, visionary, effective communication, transparency, creativity and innovation), as well as supporting the availability of facilities related to disaster management	WHO (2015, 2023), Zhong et al. (2015), European Union (2020), Gupta, Mathur and Dewan (2021); Fleming et al. (2022); Sari et al. (2023), Haghighat et al. (2024)
		GV.2 Collaboration with vendors related to accelerating digital transformation change (21), local agencies related to disaster management, national and international agencies, collaboration with other hospitals, participation of Pentahelix Collaboration (Government, Academics, Business Actors, Society and Media) in strengthening disaster literacy	European Union (2020), Sari et al. (2023), Haghighat et al. (2024), WHO (2024)
WF	Workforce	WF.1 Availability of human resources who have the capacity for digital health technology, alternative human resources in disaster situations, certified knowledge and skills, conformity with manpower patterns and government policies, especially related to disasters	Fleming et al. (2022), Sari et al. (2023), WHO (2020a, 2023)
		WF.2 Regular evaluation of Staff Satisfaction (motivation, support and welfare)	Fleming et al. (2022)
		WF.3 HR procedures according to policies and legislation (recruitment, orientation and evaluation)	Fleming et al. (2022); Jafari Nodoushan et al. (2022)
		WF.4 Availability of supporting facilities and staff health and safety programmes related to disasters	WHO (2017, 2024), Gupta et al. (2021), Fleming et al. (2022), Jafari Nodoushan et al. (2022)
FC	Financing	FC.1 Having a financial management (budget) to be ready to face disasters and other emergency situations and having financial reports	Fleming et al. (2022), Karamagi et al. (2022), Kementerian Kesehatan (2024), Kementerian Kesehatan RI (2023); Sari et al. (2023), WHO (2017, 2020, 2021, 2024)
		FC.2 Financial flexibility, especially regarding disaster and emergency management, from the Hospital Owner, based on the prepared budget	Sari et al. (2023)
		FC.3 Funding and financing related to climate change	WHO (2023)
IF	Infrastructure	IF.1 Hospital's ability to redesign rooms during a disaster	Sari et al. (2023), WHO (2024)
		IF.2 Disaster-friendly supporting infrastructure	Gupta et al. (2021), Sari et al. (2023), WHO (2024)
		IF.3 Location of disaster-friendly hospitals (drainage, access points, evacuation areas, helicopter routes)	Gupta et al. (2021)
		IF.4 Availability of building infrastructure services such as architecture, physical infrastructure, critical systems, equipment and supplies) (non-structural safety) that are disaster friendly	Gupta et al. (2021) WHO (2015, 2023, 2024)
		IF.5 Readiness in providing emergency shelter, temporary shelter and temporary housing during a disaster (covered/semi-covered spaces)	Gupta et al. (2021), WHO (2022a, 2024)
		IF.6 Structural safety	WHO (2015, 2024)
SV	Service	SV.1 Service quality indicators	WHO (2017), Fleming et al. (2022)
		SV.2 Availability of main services in disaster and emergency conditions, such as medical and non-medical services; availability of main supporting services in disaster conditions (lab, radiology, nutrition, medical gas); infection prevention and control services; management of zoonotic event, suspected, diagnostic and therapeutic services (prevention, promotion, treatment, rehabilitation and palliative care), community health promotion services and resilience and continuity of essential health services (community tool)	Gupta et al. (2021), Karamagi et al. (2022), UNDRR (2020), WHO (2017, 2020, 2022, 2024)
		SV.3 Management of chemical event and radiation emergency controllers	Karamagi et al. (2022)
		SV.4 Availability of logistical support	Gupta et al. (2021); Haghighat et al. (2024), WHO (2020, 2024)
		SV.5 Assessment of health risk, GHG emissions and progress tracking; disease surveillance and early warning	WHO (2022, 2023)
		SV.6 Responsible for community services (ensuring community health and welfare, utilisation of health services and monitoring risk factors and threats to health, management of public health emergencies, promoting prevention and early detection of diseases, both communicable and non-communicable diseases, and ensuring quality and access to health services)	WHO (2022, 2024)
		SV.7 Having a disaster plan or disaster scenario (policies, programmes, procedures and reports)	WHO (2015,2024), Zhong et al. (2015), UNDRR (2020), Sari et al. (2023)
		SV.8 Having a disaster management team (control, command and coordination)	WHO (2015, 2021, 2024), Gupta et al. (2021), Sari et al. (2023)
		SV.9 Post-disaster management capabilities (recovery, evaluation, adaptation) (4) (5) and emergency response (concept of responsible health system, operational concept, incident management system)	Jafari Nodoushan et al. (2022), WHO (2015, 2021, 2024), Zhong et al. (2015)
		SV.10 Deactivation and post-emergency response	WHO (2021, 2024)
		SV.11 Hospital readiness analysis, REMAP analysis (resource mapping and impact analysis on health security investment)	WHO (2019, 2020)
		SV.12 Inherent system resilience (awareness, diversity, self-regulation, mobilisation and transformation)	Karamagi et al. (2022), Sari et al. (2023)
BC	Business continuity	BC.1 Business continuity programme	Heidarlanlu et al. (2015)

Note: Please see the full reference list of this article, Husaini, B.A., Sugiarto, S., Rahman, S. & Oktari, R.S., 2025, 'Enhancing hospital disaster resilience: Key indicator identification and framework innovation', *Jambá: Journal of Disaster Risk Studies* 17(1), a1954. <https://doi.org/10.4102/jamba.v17i1.1954>, for more information.

GHG, Greenhouse Gas; NGO, non-governmental organisation.



FIGURE 1: Spider framework for hospital disaster resilience.

Zhong et al. 2014). By fostering effective coordination, clear internal and external communication and protection for patients, staff and hospital assets, this framework serves as a guideline for establishing a resilient, adaptive and highly durable healthcare system for the future.

Conclusion

The increasing frequency and intensity of disasters globally, which is becoming increasingly concerning, require hospitals not only to be prepared for disasters but also to adapt, maximise their capacities and endure emergency situations and disasters, whose impacts are difficult to predict. This study develops key hospital resilience indicators with a framework that provides a solid foundation to support hospitals in addressing these challenges. Indicators such as information technology, training, governance, workforce, financing, infrastructure, services and business continuity play a significant role in ensuring that hospitals can withstand, adapt and recover post-disaster. The framework integrates these elements into a systematic and mutually reinforcing structure, creating a comprehensive and sustainable resilience framework.

This study specifically focuses on hospital resilience in the context of disaster. Further study involving all healthcare facilities is highly recommended to ensure the preparedness and resilience of the healthcare system as a whole in facing disasters. Additionally, continuous efforts are needed to develop practical instruments that can serve as input for policymakers. These instruments are expected to contribute to the preparation of policy briefs that assist governments in strengthening hospital resilience in the face of disasters.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRedit authorship contribution

Brury A. Husaini: Conceptualisation, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. Sugiarto Sugiarto: Data curation, Formal analysis, Investigation, Supervision. Safrizal Rahman: Data curation, Resources, Investigation, Supervision. Rina S. Oktari: Data curation, Resources, Supervision Visualisation. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

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Data availability

The data that supports the findings of this study are available from the corresponding author, Sugiarto Sugiarto upon reasonable request.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings and content.

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