Health Frontiers
A Multidisciplinary Journal for Health Professionals
TARQABIN NUSANTARA GROUP
Health Frontiers: A Multidisciplinary Journal for Health Professionals, Vol 2 Issue 2 2024 E-ISSN : 3024-9740

Earthquake Disaster Recovery: A Literature Review

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ABSTRACT

Earthquakes pose significant challenges as one of the most devastating natural disasters. Despite intensive efforts, deterministic prediction remains uncertain. According to statistics presented by the Centre for Research on the Epidemiology of Disasters (CRED) from 2000 to 2019, earthquakes caused the most significant damage among natural disasters, resulting in 58% of fatalities. Additionally, earthquakes rank second only to storms in terms of economic losses, averaging US$32.7 billion annually. Effective disaster recovery management is crucial following major earthquakes. This literature review aims to evaluate public knowledge of post-earthquake recovery management. Through a systematic literature review methodology, relevant articles were identified using various academic databases including Google Scholar, Scopus, and Perplexity. Inclusion criteria encompassed articles addressing recovery strategies, interventions, challenges, and best practices following earthquakes. The review highlights pre-disaster activities, risk assessment, coordination, infrastructure recovery, decision-making, and post-disaster management phases. Overall, this review provides valuable information for policymakers to address post-earthquake disaster management in designing effective and holistic post-earthquake disaster management programs.

KEYWORD

Earthquake, Natural disaster, Disaster recovery

Received: 16 July 2024
Revised: 07 October 2024
Accepted: 18 December 2024

How to cite: *Thohar,Amru Ubaidillah, et al. (2024). Earthquake Disaster Recovery: A Literature Review. Heal Front A Multidiscip J Heal Prof. 2(2): 101-109.*

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INTRODUCTION

Earthquakes are one of the worst and most devastating natural disasters. Despite intensive efforts, its deterministic prediction is still a question mark. The center for research on the epidemiology of disasters (CRED) presented natural disaster damage statistics (2000–2019) demonstrating that earthquakes caused the most devastation compared to other natural calamities, accounting for 58% of fatalities. In addition, earthquakes are second only to storms in terms of economic losses. Seismic incidents have caused an average economic loss of US $ 32.7 billion each year (EM-DAT 2021).

After a major earthquake, which caused the most extensive damage compared to other natural disasters, there is a need for recovery management. Recovery management is the arrangement of disaster mitigation efforts with an emphasis on factors that can restore the conditions of affected communities and the environment by reactivating institutions, infrastructure, and facilities in a planned, coordinated, integrated, and comprehensive manner after the disaster occurs, with its phases, namely: rehabilitation and reconstruction (BPBD NTB).

Therefore, this study aims to evaluate the public's knowledge of recovery management following an earthquake disaster. This research can provide the latest information on post-earthquake disaster management, including the steps taken for post-earthquake disaster management mitigation.

The research method employed in this study is a literature review, utilizing data collection through literature review and reading. By conducting this research, it is hoped to provide new information regarding the handling of post-earthquake disaster management. The results of this study can assist in providing useful information for policymakers to address post-earthquake disaster management in designing effective and holistic post-earthquake disaster management programs.

MATERIALS AND METHODS

This research is a literature review to determine earthquake disaster recovery. To conduct this research, a systematic approach was employed, utilizing various academic databases, including Google Scholar, Scopus, and Perplexity. The search strategy focused on identifying relevant articles using the keyword "earthquake disaster recovery." Each article's title and abstract were meticulously scrutinized to ensure alignment with the predetermined inclusion and exclusion criteria. The inclusion criteria encompassed articles that specifically addressed aspects related to the recovery phase following earthquakes, including but not limited to strategies, interventions, challenges, and best practices. Additionally, only peer-reviewed articles published in scholarly journals were considered eligible for inclusion. Conversely, articles focusing solely on seismic hazard assessment or mitigation strategies without substantial discussion on recovery were excluded from the review. Following the initial search, duplicates were removed, and the remaining articles were subjected to a thorough evaluation process. This involved a comprehensive assessment of the content's relevance and quality, with particular attention to the rigor of research methodologies and the significance of findings. Articles meeting the established criteria were selected for detailed analysis and synthesis in the literature review.

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RESULT AND DISCUSSION

Author (year), country	Design	Purpose	Result
Asad et al. (2023). Pakistan	Cross-sectional study	The purpose of this study is to present a methodology for a reliable seismic risk assessment considering the case of a developing country as its focus. To better prioritize and lay the groundwork for an efficient risk reduction strategy, this study intends to conduct a consolidated risk assessment covering multiple risks, including physical damage to the buildings, fatalities, economic loss, etc.	This study validates the fact that HAZUS can be utilized by developing countries that lack state-of-the-art technology and software. Moreover, results could be tailored to be more trustworthy by employing regional calibration and adjustments. Taiwan adopted an approach similar to that of HAZUS and developed HAZ-Taiwan by modifying analysis models and parameter values to account for Taiwan's unique environment and engineering practices.
Deelstra & Bristow. (2023). Canada		To demonstrate the use of a flexible modeling approach to evaluate the efficacy of Disaster Risk Reduction (DRR) strategies on critical infrastructure system resilience. Existing and novel assessment metrics are described and demonstrated through a case study of regional water, wastewater, and power systems subject to a simulated earthquake.	Results from the assessment indicate that the effectiveness of such strategies is highly dependent on the resilience of individual system components and the availability of resources to complete repairs. For some components, pre-disaster upgrades are highly effective in reducing system outage times, while others may not benefit from replacement unless they are damaged in a disaster.
Platt. (2018). Netherlands	Cross-sectional study	To try to better understand which factors may affect the speed of recovery, data from the 10 earthquake events are analysed in terms of exogenous factors, i.e. those factors that are given and are outside the control of decision-makers and planners, and endogenous factors, i.e. those factors that are amenable to decision-making.	This chapter has explored to what extent pre-existing resilience (exogenous factors) and post-event response (endogenous factors) determine the speed and quality of disaster recovery. Careful analysis of the evidence from 10 recent earthquake related disasters tentatively suggests that exogenous factors – the magnitude of the event, population dynamics, the wealth of the nation and the state of the economy – play a smaller role in determining outcomes than has hitherto been supposed. Endogenous variables, i.e. the decisions, policies and choices governments and societies make, seem to have a greater effect on recovery outcomes than has perhaps been supposed.
Ash-Shidiqqi et al. (2023). Indonesia	Case study method with a qualitative approach	To measure the impact of these disaster risk reduction efforts	The government's commitment on the significant and regional levels to involve insurance must be appreciated as a step forward because the Law on Disaster Management (UUPB) presents possibilities for insurance to be concerned in disaster management. The primary obstacle to the disaster insurance program in Indonesia is the absence of a legal umbrella that offers confirmation of payment of insurance premiums by the central and regional governments using APBN and APBD funds. Until now, the law continues to be under discussion on the Ministry of Finance, so it could be accelerated so that it could become the basis for implementing disaster insurance for each the central government and local governments.
Musdah et al. (2022). Indonesia	Qualitative approach with Gadamerian hermeneutic method	This study aims to explain the coordination of disaster management in Wajo from the perspective of the models and challenges of disaster management in Wajo	Found three meanings of coordination in disaster management in Wajo. First, coordination because of their awareness of the limitations they have. Second, coordination serves as fulfillment of the requirements of sponsorship activities. Third, coordination is an innovation to overcome problems.
Sinaga.(2013). Indonesia	Qualitative using an analytical descriptive method.	To analyse the problematic process of rehabilitation and reconstruction after the Mentawai tsunami in 2010.	The rehabilitation and reconstruction process after the Mentawai tsunami encountered various challenges such as unclear timelines for permanent housing construction, land use permit issues, complexity of the rehabilitation process, cross-sectoral coordination difficulties and late dissemination of information and limited communication facilities
Bakti et al. (2020). Indonesia	Descriptive in nature using a qualitative research method and treated with	This study aims to look at the recovery efforts undertaken by the local government through the Rehabilitation and Reconstruction process.	The results show that the efforts made by the local government are to carry out the Rehabilitation and Reconstruction that have been determined through 5 main aspects namely the Social, Economic, Infrastructure, Settlement and Cross-Sector .

	the application of Nvivo 12 Plus.		
Arisanto et al. (2022). Indonesia	Qualitative research method with descriptive research type.	To explain Esri Indonesia's role as a non-state actor as well as a provider of GIS-based geospatial technology, namely ArcGIS.	Esri Indonesia's role as a non-state actor and provider of GIS-based geospatial technology, specifically ArcGIS, has contributed significantly to addressing development challenges in various sectors in Indonesia . They have helped in disseminating geospatial technology and assisting multiple stakeholders in overcoming issues caused by Covid-19 through the utilization of GIS-based geospatial technology, particularly through the Disaster Rescue Program (DRP)
Lase. (2022). Indonesia	Qualitative method with descriptive approach	To analyse the government's coordination with local governments and community participation in the health sector during natural disasters in Nias Regency.	The coordination of regional centers in natural disasters in the health sector, both health infrastructure and financing, is still very limited in terms of facilities and infrastructure and funding, while coordination is still not optimally carried out.
Mahardika et al. (2018). Indonesia	Qualitative method of descriptive type	This research is to find out how the disaster management conducted by Regional Disaster Management Agency (BPBD) Semarang City in handling the flood disaster.	The results showed that the stages of disaster management carried out BPBD Semarang City is starting from pre-disaster that there are still shortcomings that is not the formation of contingency plans, then in the stage when there is a disaster that is lack of logistics and disaster emergency personnel, and the last stage is post-disaster there are still shortcomings where the form of rehabilitation conducted BPBD there are still less appropriate target.
Pasaribu et al. (2023). Indonesia	*Literature review*	To provide an understanding and overview of Penta Helix collaboration in post-earthquake disaster management.	Research shows that the government's role is to coordinate other elements or stakeholders to contribute to the development of this collaboration
Rahman et al. (2023). Indonesia	Descriptive research with a qualitative approach	To analyze the Implementation of Lombok Earthquake Management Policy 2018 Based on Regional Regulation Number 9 of 2014 concerning Disaster Management in West Nusa Tenggara Province	The results showed: 1) the implementation of the Lombok Earthquake Management policy in 2018 West Nusa Tenggara Province based on Regional Regulation Number 9 of 2014 It has been going quite well in the context of pre-disaster and disaster emergency, but and still lacking in the context of transition to recovery or post-disaster. 2) The recommended policy implementation model is the "Implementation Reality Mecure (IRM)" model in the implementation of the 2018 Lombok earthquake management policy

Pre-Disaster Activities

Pre-disaster stage is the stage of disaster management in pre-event or pre-disaster conditions which include preparedness, early warning, and mitigation. Preparedness is a series of activities carried out to anticipate disasters through organization and through appropriate and effective steps. Building preparedness is an important element, but it is not easy to do because it involves mental attitudes and culture and discipline in the community. Early warning is a step that is needed to warn the community about disasters that will occur before events such as floods, earthquakes, tsunamis, volcanic eruptions or storms occur. Finally, disaster mitigation is a series of efforts to reduce disaster risk, both through physical development as well as awareness and improvement of the ability to face disaster threats. Disaster mitigation is an effort to prevent or reduce the impact caused by a disaster, so it is clear that mitigation is prevention before the event (Mahardika & Larasati, 2018)

Until now, no expert or institution has been able to predict when an earthquake will occur. The institution authorized to issue information on earthquake occurrence is the BMKG. Developing an emergency response plan is also an important step in preparing the community for an earthquake. Pre-disaster activities in dealing with earthquakes such as conducting drills or simulations can be useful in dealing

with rubble during an earthquake, such as ducking, head protection, holding on or by hiding under a table. Preparing fire extinguishers, standardized safety equipment and medical supplies are also necessary steps to help reduce the negative impact of an earthquake, which can cause physical damage, loss of life and loss of supplies. It is also important to build houses that are resistant to earthquake shaking with strong foundations and regular checks, and to renovate vulnerable parts of buildings to improve safety and reduce the risk of accidents. In addition, it is mandatory to pay attention to earthquake-prone areas and land-use regulations issued by the government in order to identify what risks may occur so that appropriate countermeasures can be prepared (Yanuarto et al., 2017)

Risk assessment and prioritization is the initial process to determine effective and efficient actions to reduce the risks posed by a natural disaster. Risk assessment involves identifying, analyzing and quantifying risks that cause negative impacts. In risk assessment and prioritization, the first step is to identify hazard zones that can be developed based on field surveys and secondary data. The identification of these hazard zones includes mapping fault lines, hotspots of seismic activity, and areas vulnerable to ground shaking. This allows governments, aid organizations and communities to prioritize mitigation and preparation efforts. Prioritize areas and assets based on their level of risk, taking into account factors such as potential loss of life, economic impact, disruption to essential services and community resilience. High-risk areas with dense populations, critical infrastructure or high vulnerability should be given priority for mitigation efforts. The next step is a vulnerability assessment by evaluating the vulnerability of buildings, infrastructure and critical facilities within the identified hazard zone. Construction materials, building regulations, building age and population density are factors that can be considered in the vulnerability assessment.

The use of geospatial technology and vulnerability modeling to identify areas vulnerable to earthquakes and estimate their potential impacts is recommended as a tool for geographic mapping and analysis. Geospatial technology has developed very rapidly and is utilized to produce geospatial information by various parties in various mapping interests such as disaster events, natural resources, economic growth, agriculture and so on. Geospatial information directly informs the user to know the objects in an area and their activities (Arisanto & Pratiwi, 2022). By using accurate and up-to-date data, governments, aid organizations and communities can take more effective preventive measures to reduce risks and minimize losses after an earthquake.

Disasters are complex problems and require coordination between many parties in post-earthquake disaster recovery efforts. Government agencies play an important role in facilitating a rapid and coordinated response after an earthquake. These government agencies include: the Regional Disaster Management Agency (BPBD), the Regional Development Planning Agency (Bappeda), the Department of Public Works and Public Housing (PUPR), the Department of Housing and Settlements, the Department of Community and Village Empowerment, the Meteorology, Climatology and Geophysics Agency (BMKG), the Department of Environment and Natural Resources (DLHSDA), the Finance Agency, the Department of Agriculture, the Department of Food Security, the Social Service, Regional Research and Development Agency (Balitbangda), Education and Culture Office (Disdikbud), Public Health Office, Hospitals/Puskesmas, Civil Service Police Unit (Satpol PP), National Search and Rescue

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Agency (Basarnas), Department of Transportation, Office of Communication and Informatics (Kominfo), Manpower and Transmigration Service (Disnakertrans), Indonesian National Armed Forces (TNI), and Indonesian National Police (Polri). In addition to government agencies, private institutions, non-governmental organizations (NGOs), media, and universities are expected to be involved in coordinating disaster management (Musdah et al., 2022).

Good coordination also enables proper allocation of resources and efficient deployment of assistance to those in need. In addition, coordination also plays an important role in building the capacity of local communities to deal with earthquakes. Research by a disaster research institute found that training and capacity-building programs supported by multiple stakeholders can improve community preparedness in the face of disasters and strengthen social networks needed to support post-earthquake recovery efforts.

The preparation of development plans by the central and local governments such as the preparation of disaster management is important. Basically, the central and local governments should already have standard procedures or operational guidelines to cope with disasters through strong cooperation (Lase, 2022). The central government is responsible for making development plans for local governments according to identification and evaluation.

Rehabilitation and reconstruction together lead to long-term recovery that considers physical and non-physical factors of the disaster-exposed area. Based on Law No. 24 of 2007 concerning Disaster Management, rehabilitation is the repair and restoration of all aspects of public or community services to an adequate level in post-disaster areas with the main target of normalizing or running reasonably all aspects of government and community life in post-disaster areas. Article 57 states that rehabilitation in post-disaster areas is carried out through activities: environmental improvement of disaster areas; repair of public infrastructure and facilities; provision of assistance to repair community houses; social and psychological recovery; health services; reconciliation and conflict resolution; social, economic and cultural recovery; restoration of security and order; restoration of government functions; and restoration of public service functions.

Based on Law No. 24 of 2007 concerning Disaster Management, reconstruction is the rebuilding of all infrastructure and facilities, institutions in post-disaster areas, both at the government and community levels with the main target of the growth and development of economic, social and cultural activities, the establishment of law and order, and the rise of community participation in all aspects of community life in post-disaster areas. Urgent strategic development is needed, especially in the health sector affected by the earthquake, namely health infrastructure including the provision of clean water and its management, renovation of health centers, drainage, improving the quality of maternal and child health, improving the quality of services and networks at health centers, allocating budgets to poor people receiving public health insurance, building class D regional public hospitals, and rehabilitation at health centers.

The decision-making process in post-disaster situations is of utmost importance because it requires smart, systematic and effective decisions. The government has the responsibility to declare a state of

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emergency from before the disaster, during the disaster and after the disaster. There is a need for collaboration, where this form of government simultaneously involves various stakeholders in a forum with government officials to make joint decisions.

Based on a study conducted during the Lombok earthquake in 2018, decision-making related to the implementation of disaster management programs was not measurable and directed due to insufficient managerial and technical disaster skills. The government should prepare the community to become a Tim Siaga Bencana Desa (TSBD) or Relawan Kampung Siaga Bencana (RKSB) in the context of disaster management from responsive to preventive, as outlined in Perda Provinsi NTB No. 9 Tahun 2014. In the event of a disaster, they can quickly make decisions to search for and evacuate victims, provide education on disaster management efforts, and evaluate the impact and needs of the community without waiting for direction from the center or local government (Rahman et al., 2023)

Decision-making systems enable the use of information technology to make quick and accurate decisions. Decision-making systems can store past data, manage it, and use it as part of decision-making. This decision-making system for earthquake natural disaster management is an EGovernment application consisting of software, hardware, and technology that helps make decisions by providing information to help make decisions. By using web technology to create EGovernment, the system can be accessed online from anywhere and anytime with transparency and convenience. To run the decision-making system for earthquake countermeasures, we can use :

1) Client programming such as HTML, Javascript or Jscript, Code Style Sheet, and Java Applet.

2) Server programming such as ASP, PHP, JSP, coldfusion or CGI.

3) Database can use MySQL, Oracle, SqlServer, or postgrace.

The Decision-Making System for natural disaster management Earthquakes will receive warnings according to the output of the BMKG's earthquake prediction early warning system. Warnings will be given by the BMKG based on high-risk earthquakes, those with a high Richter scale or earthquakes that will hit strategic and populated locations. Based on BMKG earthquake predictions, the Decision-Making System for Earthquake Natural Disaster Management will obtain data from the history of earthquakes in Indonesia and internationally and make comparisons. Based on this information and the comparison, the Decision-Making System for Earthquake Natural Disaster Management will provide a prediction of the status and level of the disaster. The Decision-Making System for Earthquake Natural Disaster Management can help predict important things such as how many national health workers are needed, how many estimated injuries and deaths based on past data, how many national volunteers are needed, how many tents are needed, which and nearby food sources are accessible, how many sanitation centres should be built and much more (Hendric, 2009)

Post-disaster management is a set of policies, administrative decisions and operational actions related to the different stages of a natural disaster. In this regard, disaster management cannot be seen as one event at a time; rather, it can be seen as the various stages of a natural disaster, each of which requires actions to reduce the impact of the disaster. Disaster risk management is integrated through the recovery,

rehabilitation and development processes, utilising existing opportunities and enhancing capabilities during the recovery phase to reduce disaster risks in the short, medium and long term. It also integrates post-disaster reconstruction with sustainable economic and social development in affected areas.

Recovery is a series of activities aimed at restoring the condition of the community and environment affected by the disaster by reactivating institutional infrastructure and facilities through normalisation efforts. Rehabilitation is the restoration and improvement of all aspects of public services in post-disaster areas with the main objective of normalisation or good management of aspects of government and community life as before the disaster. Some activities related to rehabilitation and rehabilitation include: 1) Improvement of the disaster area environment, 2) Repair of public infrastructure and facilities, 3) Providing assistance to repair the houses of affected communities, 4) Socio-psychological recovery, 5) Health services, 6) Reconciliation and conflict resolution, 7) Socio-economic cultural recovery, and 8) Restoration of public service functions. Reconstruction is the rebuilding of all infrastructure and facilities as well as institutions in post-disaster areas with the main objective of developing and expanding economic, social, cultural activities, maintaining order, and increasing the role of the community in all aspects of life. Assistance for rehabilitation and reconstruction in disaster areas includes: 1) Integrated infrastructure development, drinking water, sanitation, drainage and waste management in Huntara and Huntap areas, 2) Rehabilitation of industries affected by natural disasters, 3) Restoration of people's markets in underdeveloped areas, border areas and areas prone to natural disasters, and 4) Assistance in the restoration of buildings/materials affected by disasters (Pasaribu et al., 2023)

CONCLUSION

Emphasising the importance of preparation, coordination, risk assessment and stakeholder engagement in effective disaster recovery management after an earthquake, the need for standardised procedures, infrastructure restoration and decision-making systems to minimise the negative impacts of earthquakes on communities. The findings of this study provide valuable insights for policymakers to design and implement a comprehensive disaster management programme that prioritises pre-disaster activities and involves various stakeholders in post-disaster recovery efforts. Overall, there is a need for a well-coordinated approach in disaster management to enhance resilience and facilitate efficient recovery after an earthquake.

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