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Determining Minimum Emergency Infrastructure Needs for Urban Earthquake Evacuation Centers in Surabaya

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Abstract

Urban earthquake preparedness requires evacuation centers that are not only physically available but also supported by adequate emergency infrastructure during the response phase. This study determines the minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya, Indonesia. The research used a qualitative approach through content analysis, based on in-depth interviews with stakeholders involved in disaster emergency response and supported by institutional data and literature. The findings show that emergency infrastructure required during the earthquake response phase consists of ten main components: transportation, clean water, electricity, telecommunication, sanitation and solid waste, health facilities, fire safety facilities, evacuation and shelter centers, emergency operation centers, and economic recovery facilities. The readiness assessment indicates an uneven condition. Telecommunication infrastructure had the highest readiness level, while evacuation centers, emergency operation centers, health facilities, electricity networks, and economic recovery facilities were categorized at low readiness levels. Therefore, evacuation centers require minimum support in the form of temporary shelters, field kitchens, sleeping equipment, emergency posts, logistics storage, health services, backup electricity, sanitation, and recovery facilities. This study highlights the need to strengthen evacuation centers as functional emergency infrastructure rather than merely designated shelter locations.

A. Introduction

An earthquake should first be understood as a hazard rather than a disaster. A hazard refers to a potentially damaging physical event, while a disaster occurs when that hazard interacts with exposed and vulnerable communities whose coping capacity is insufficient (UNDRR, 2017). In urban areas, this distinction is critical because the consequences of an earthquake are not determined only by the intensity of ground shaking, but also by the readiness of the city to protect residents and maintain essential services during the emergency response phase. When emergency infrastructure is inadequate, disruptions to housing, transportation, electricity, water supply, sanitation, health services, communication, and local economic activities can transform a hazardous event into a wider urban disaster. Therefore, earthquake preparedness requires more than structural mitigation and evacuation routes. It also requires minimum emergency infrastructure that can support affected populations immediately after a hazardous event occurs and prevent the emergency situation from escalating into a disaster.

The importance of preparedness and emergency response capacity has been emphasized in the global disaster risk reduction agenda. The Sendai Framework for Disaster Risk Reduction 2015–2030 highlights the need to strengthen disaster risk governance, invest in disaster risk reduction, and enhance disaster preparedness for effective response and "Build Back Better" in recovery, rehabilitation, and reconstruction (UNDRR, 2015). This perspective is relevant to urban earthquake preparedness because evacuation centers must operate as part of a wider emergency response system. They are not only places where people gather after a disaster, but also facilities that require basic services, coordination mechanisms, logistics, and protection functions.

Minimum standards are also important in humanitarian response. The Sphere Handbook has become one of the most widely recognized references for minimum standards in humanitarian assistance, including standards related to shelter, settlement, water supply, sanitation, hygiene, health, and protection (Sphere Association, 2018). Although Sphere was developed for broader humanitarian contexts, its emphasis on dignity, safety, and basic service provision is relevant for urban evacuation center planning. In earthquake-prone cities, an evacuation center that lacks clean water, sanitation, electricity, communication, health support, and logistics may not be able to protect displaced residents adequately. Thus, evacuation centers should be assessed not only by their location and capacity, but also by their minimum emergency infrastructure.

Recent studies on evacuation centers and temporary shelters further support the need to assess shelters as living environments rather than merely physical spaces. Evacuation centers are often the first temporary living spaces for disaster-affected people, and they need to provide safety, minimum living standards, continuity of care, and clear institutional responsibilities (Kako et al., 2020). Temporary shelter planning should also consider habitability, including safety, health, sociality, and comfort, because displaced residents may remain in shelters under uncertain and stressful conditions (Choi et al., 2020). Evidence from post-earthquake shelters also shows that shelter performance is affected by bedding, privacy, water, toilets, hygiene, and spatial organization (Kim et al., 2021). Therefore, minimum emergency infrastructure for evacuation centers should combine shelter, water, sanitation, health, food, logistics, and critical lifeline services, rather than treating shelter provision as a single facility-based issue (Fekete et al., 2021; Pothiawala, 2015).

Surabaya provides an important case for discussing this issue. As one of Indonesia's major metropolitan cities, Surabaya has dense settlements, complex infrastructure networks, and strategic economic functions. At the same time, the city has potential exposure to earthquake hazards associated with the Kendeng fault system. Widodo et al. (2020) identified that Surabaya is crossed by the Surabaya and Waru segments of the Kendeng fault system, both of which have an earthquake potential of 6.5 magnitude. This condition makes earthquake preparedness an important part of urban planning and infrastructure management in Surabaya.

The urgency of this study is strengthened by the fact that evacuation centers are often treated as physical locations, while their operational requirements receive less attention. In practice, evacuation centers must be able to provide temporary accommodation, emergency command support, water and sanitation, electricity and lighting, communication, basic health services, fire safety, logistics access, and early recovery facilities. These components are not optional additions. They are minimum requirements for making evacuation centers usable and safe during the emergency phase. For dense urban areas such as Surabaya, the absence of these components can create secondary risks, including overcrowding, disease transmission, poor information flow, delayed assistance, and weak coordination.

This article therefore aims to determine minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya. It is developed from primary qualitative data collected through stakeholder-based in-depth interviews and analyzed using content analysis. Unlike studies that focus mainly on shelter location or evacuation accessibility, this article focuses on the infrastructure components required to make evacuation centers function during the earthquake emergency response phase. The contribution of this article is practical and policy-oriented. It provides a focused synthesis of emergency infrastructure needs that can support local governments, disaster management agencies, and urban planners in strengthening evacuation centers before a disaster occurs.

Based on this background, the research question addressed in this article is, RQ1: What minimum emergency infrastructure components are needed to support urban earthquake evacuation centers in Surabaya during the emergency response phase?

The article seeks to contribute to urban disaster preparedness by linking evacuation center planning with emergency infrastructure readiness. This linkage is important because the effectiveness of evacuation centers depends not only on where they are located, but also on whether they can provide essential services when normal urban systems are disrupted.

B. Method

This study used a qualitative research design to determine minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya. A qualitative approach was selected because the study aimed to identify infrastructure needs, readiness conditions, and operational requirements based on stakeholder knowledge and institutional experience in disaster emergency response. This article was developed from the author's undergraduate final project on emergency infrastructure needs for reducing the potential impacts of earthquake disaster in Surabaya. The original study used content analysis and in-depth interviews with stakeholders who had experience or institutional relevance to the emergency response phase. This article maintains the same empirical foundation, but focuses the analysis on the implications of the findings for evacuation centers.

The study area was Surabaya, Indonesia, which was selected because of its metropolitan scale, dense urban infrastructure, and potential earthquake exposure related to the Kendeng fault system. The object of analysis was emergency infrastructure required during the earthquake emergency response phase. In the original research design, emergency infrastructure was examined through three objectives: identifying emergency infrastructure needs from cities that had experienced earthquake impacts, analyzing the readiness of existing emergency infrastructure in Surabaya, and formulating emergency infrastructure needs to reduce the potential impacts of earthquake disaster in the city. The survey design used primary surveys, in-depth interviews, and content analysis to generate emergency infrastructure needs and readiness findings.

Table 1. Primary data collection method and instruments

No.	Data type	Method	Instruments
1.	Primary data	Stakeholder-based in-depth interviews	Exploring alternative emergency infrastructure needs based on lessons from earthquake-affected cities Exploring existing readiness of emergency infrastructure provision in Surabaya

Stakeholders were selected purposively because the research required information from actors with direct knowledge of disaster response, infrastructure management, and public service provision. Purposive sampling is appropriate in qualitative research when participants are selected because they possess relevant knowledge or experience for the research problem (Palinkas et al., 2015). In this study, the stakeholder groups included disaster management agencies, search and rescue actors, humanitarian organizations, urban planning agencies, public works agencies, water and sanitation-related agencies, electricity-related actors, communication agencies, health services, fire services, transportation agencies, and other institutions relevant to emergency response. This selection reflected the cross-sector character of emergency infrastructure, because evacuation centers depend not only on shelter space but also on transportation, water, electricity, communication, sanitation, health services, fire safety, logistics, and emergency coordination.

The variables used in the analysis were derived from the emergency infrastructure framework in the original study. These variables included transportation infrastructure, clean water infrastructure, electricity infrastructure, telecommunication infrastructure, sanitation and solid waste infrastructure, health facilities, fire safety facilities, evacuation and shelter centers, emergency operation centers, and other supporting infrastructure. The survey design further detailed these variables into operational subvariables, such as transport modes, transport nodes, water treatment systems, alternative electricity sources, communication tools, sanitation tools, solid waste systems, health service equipment, fire response equipment, evacuation center facilities, and emergency operation facilities.

Data were analyzed using content analysis. Content analysis is suitable for systematically interpreting textual data, especially interview materials, by identifying categories, meanings, and patterns in relation to the research question (Krippendorff, 2019). In qualitative applications, content analysis can be used to interpret meaning from text data through coding and category development (Hsieh & Shannon, 2005). In this study, interview results were coded according to infrastructure variables and stakeholder categories. The original coding structure included codes for emergency infrastructure variables, such as clean water supply, wastewater and sanitation, solid waste generation, transportation infrastructure, electricity infrastructure, telecommunication infrastructure, health infrastructure, fire safety infrastructure, evacuation and shelter centers, emergency operation centers, service coverage, and supporting institutions.

Table 2. Analytical process

Stages	Analytical process
1.	Original infrastructure categories and interview findings were reviewed to identify components directly related to evacuation center operation
2.	Infrastructure components were grouped based on their function in the emergency response phase, including temporary shelter, basic services, health support, electricity, communication, fire safety, logistics access, emergency command, and early recovery
3.	The grouped components were synthesized into minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya

To ensure ethical use of the original data, this article does not disclose personal identifiers from the interview transcripts, such as phone numbers, email addresses, or private respondent information. Stakeholder input is presented in aggregated form according to institutional roles and infrastructure sectors. This approach is important because the purpose of the article is not to reproduce raw interview records, but to synthesize the findings into a focused standard for evacuation center preparedness. The method is therefore appropriate for answering the research question because minimum emergency infrastructure needs must be determined through cross-sector evidence, not merely through spatial location or shelter capacity analysis.

C. Results and Discussion

1. Results

The analysis identified that emergency infrastructure for earthquake response in Surabaya consists of ten main components. These components are transportation infrastructure, clean water infrastructure, electricity infrastructure, telecommunication infrastructure, sanitation and solid waste infrastructure, health facilities, fire safety facilities, evacuation and shelter centers, emergency operation centers, and economic recovery facilities. This finding indicates that earthquake emergency response requires an integrated infrastructure system. Evacuation centers cannot operate as independent shelters because their functionality depends on access, utilities, health services, communication, logistics, safety, and command systems.

Table 3. Emergency infrastructure components required during the earthquake response phase

No.	Emergency infrastructure component	Main function during emergency response
1.	Transportation infrastructure	Supports evacuation, mobility of responders, logistics distribution, and access to affected areas
2.	Clean water infrastructure	Provides water for drinking, cooking, hygiene, and emergency health needs
3.	Electricity infrastructure	Supports lighting, communication, health equipment, water systems, and shelter operation
4.	Telecommunication infrastructure	Supports information flow, coordination, warning dissemination, and emergency communication
5.	Sanitation and solid waste infrastructure	Prevents disease transmission and maintains hygiene in evacuation areas
6.	Health facilities	Provides first aid, medical treatment, referral, ambulance services, and emergency health support
7.	Fire safety facilities	Responds to secondary fire hazards and supports rescue operations
8.	Evacuation and shelter centers	Provides temporary protection and accommodation for displaced residents
9.	Emergency operation centers	Supports command, coordination, information management, logistics, and decision-making
10.	Economic recovery facilities	Supports basic supply continuity and early recovery of affected communities

The readiness assessment showed an uneven condition among the ten emergency infrastructure components. Telecommunication infrastructure had the highest level of readiness. In contrast, evacuation and shelter centers, emergency operation centers, health facilities, electricity networks, and economic recovery facilities were categorized at low readiness levels. Other infrastructure components were positioned in the intermediate readiness range. This pattern shows that Surabaya had relatively strong communication infrastructure, but still required significant strengthening in components directly related to sheltering, health support, electricity, emergency command, and post-disaster recovery.

Table 4. Readiness pattern of emergency infrastructure in Surabaya

No.	Readiness category	Infrastructure component
1.	High readiness	Telecommunication infrastructure
2.	Low readiness	Evacuation and shelter centers; emergency operation centers; health facilities; electricity networks; economic recovery facilities
3.	Intermediate readiness	Transportation; clean water; sanitation and solid waste; fire safety facilities

The low readiness of evacuation and shelter centers is particularly important for this study. The findings show that evacuation centers require more than designated space. They need physical equipment and supporting facilities to accommodate displaced residents during the emergency response phase. The required components include emergency response posts, public kitchens, temporary shelters, tents, sleeping mats or mattresses, temporary housing, and transitional shelter support when needed. These components indicate that evacuation centers should be prepared as operational facilities, not only as gathering points.

More specifically, the evacuation center requirements include several equipment and service needs. The study identified the need for activity tents, evacuee tent, platoon tents, field kitchen vehicles, fuel for public kitchens, and sleeping mats or mattresses for displaced residents. These needs show that shelter planning must include both space and operational equipment. Without such equipment, evacuation centers may exist physically but remain unable to provide minimum protection and basic support for affected populations.

The findings also indicate that evacuation centers must be connected to emergency operation centers. Emergency operation infrastructure includes command center services, emergency operation control centers, emergency response posts, field command posts, logistics warehouses, and equipment warehouses. These facilities are needed to manage information, coordinate institutions, organize logistics, and support decision-making during emergency response. Without this command and coordination structure, evacuation centers may become crowded locations without clear management.

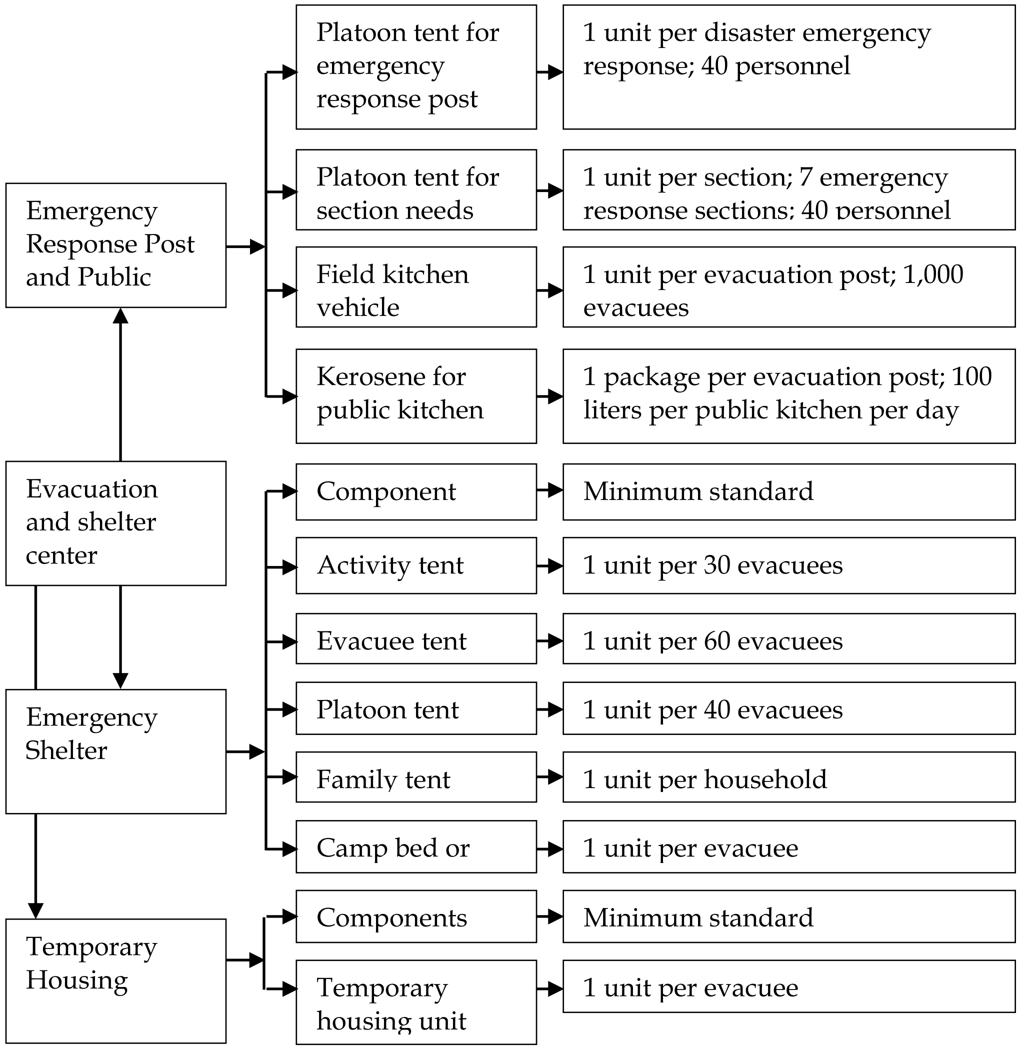

Figure 1. Readiness flow diagram for evacuation and shelter centers

Health infrastructure is another critical requirement. The study identified the need for field hospitals, health service vehicles, mobile clinics, home care services, medical personnel, medicines, medical equipment, transport ambulances, and emergency ambulances. These components are important because earthquake-affected populations may include injured residents, older people, children, pregnant women, and people with chronic illnesses. Therefore, evacuation centers should not be separated from health support and referral systems.

Electricity infrastructure was also categorized as a low-readiness component. The required components include generators, emergency lighting, portable solar cells, vehicle batteries or alternative power sources, diesel, and fuel. Electricity is essential for shelter lighting, communication equipment, health services, public kitchens, water pumping, and security. In the context of evacuation centers, backup electricity should be treated as a minimum requirement because the main electricity network may be disrupted after an earthquake.

Economic recovery facilities were also identified as a low-readiness component. The findings indicate the need for emergency markets to support the supply of basic needs after disaster. This component is relevant because evacuation centers do not only serve immediate shelter needs. They also become places where affected residents seek food, information, basic goods, and assistance during the transition from emergency response to early recovery.

Based on these findings, the minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya can be summarized into five groups: shelter and accommodation support, basic service support, health and safety support, emergency command support, and early recovery support.

Table 5. Minimum emergency infrastructure needs for urban earthquake evacuation centers

No.	Minimum need group	Required components
1.	Shelter and accommodation support	Emergency response post, temporary shelter, activity tents, evacuee tent, platoon tents, family tents, sleeping mats or mattresses, temporary housing
2.	Basic service support	Clean water, sanitation, solid waste management, backup electricity, emergency lighting, fuel, public kitchen
3.	Health and safety support	First aid, medical personnel, medicines, medical equipment, ambulances, field health services, fire safety equipment
4.	Emergency command support	Command center, emergency operation control center, field command post, logistics warehouse, equipment warehouse, communication tools
5.	Early recovery support	Emergency market, basic goods distribution, livelihood support, coordination with recovery-related agencies

The results show that minimum emergency infrastructure needs for evacuation centers must be understood as a package. Shelter equipment, water, sanitation, electricity, health, communication, logistics, command, and early recovery support are interconnected. If one component is unavailable, the function of the evacuation center may be weakened. For example, a shelter with adequate tents but without sanitation can create public health risks. A shelter with good communication but without logistics storage may face delays in aid distribution. A shelter with access roads but without command support may experience weak coordination.

2. Discussion

The findings confirm that urban earthquake evacuation centers should be planned as part of an emergency infrastructure system. In Surabaya, the required infrastructure components are not limited to shelter facilities, but also include water, electricity, communication, sanitation, health services, fire safety, transportation, command systems, and economic recovery facilities. This means that evacuation center preparedness should be evaluated based on operational capacity, not only location availability.

The low readiness of evacuation and shelter centers, emergency operation centers, health facilities, electricity networks, and economic recovery facilities indicates that the most critical gaps are located in service-supporting infrastructure. This is important because these components directly affect the ability of evacuation centers to receive and support affected residents. A designated evacuation center may exist, but it may not function well if it lacks tents, public kitchens, lighting, health services, sanitation, command posts, and logistics support.

This finding is consistent with the broader argument that evacuation planning cannot stop at accessibility and capacity. Shah et al. (2026), for example, showed that high spatial accessibility to mosque-based evacuation facilities in Banda Aceh did not automatically solve capacity problems. In the Surabaya case, this article extends the issue further by showing that evacuation centers also require minimum emergency infrastructure to function during the response phase. Thus, evacuation center planning should combine three dimensions: accessibility, capacity, and infrastructure readiness.

The findings also show the importance of cross-sector coordination. No single institution can provide all components required for evacuation center operation. Transportation agencies are needed for mobility and access. Water and sanitation agencies are needed for basic services. Electricity providers are needed for backup power. Health offices and hospitals are needed for medical response. Fire services are needed for secondary hazard response. Disaster management agencies are needed for command and coordination. Economic and trade-related agencies are needed for emergency markets and supply continuity. Therefore, minimum infrastructure needs should also clarify institutional responsibilities.

The need for cross-sector coordination is also consistent with critical infrastructure and humanitarian logistics literature. Resilient infrastructure systems are expected to continue providing essential services during and after shocks, including transportation, energy, water, sanitation, and communication (Hallegatte et al., 2019; OECD, 2019). Community resilience planning also requires buildings and infrastructure systems to be considered together because emergency response depends on the ability of multiple systems to recover and support community functions (NIST, 2016). In evacuation centers, this interdependency becomes visible through the need for logistics, clean water, sanitation, health services, and emergency supply chains. Emergency logistics is a critical component of disaster response because relief items, medical support, and basic goods must reach affected populations quickly (Jiang & Yuan, 2019). Water and sanitation are also essential because inadequate access to clean water and toilet hygiene can increase health risks in post-disaster shelters (Akaishi et al., 2021; Ersel, 2015).

The results have practical implications for urban disaster preparedness in Surabaya and other Indonesian cities. Local governments should not only list evacuation center locations, but also audit their minimum infrastructure readiness. Each potential evacuation center should be assessed based on the availability of accommodation equipment, water, sanitation, electricity, communication, health support, fire safety, logistics access, and command linkage. This assessment can help identify which facilities are ready, which require upgrading, and which should only be used as temporary gathering points.

The study also suggests that preparedness investment should prioritize low-readiness components. In the Surabaya case, this means improving evacuation and shelter centers, emergency operation centers, health support, backup electricity, and early recovery facilities. These components are essential because they determine whether evacuation centers can support displaced residents after an earthquake. Strengthening them before disaster occurs can reduce delays during the emergency response phase.

Studies on emergency shelter planning have commonly used location-allocation, multi-criteria, and hierarchical planning approaches to determine shelter locations, service coverage, and allocation of evacuees (Li et al., 2017; Shi et al., 2019; Xu et al., 2016; Zhao et al., 2017). These studies are important because shelter location and accessibility influence whether affected residents can reach safe places during the emergency phase. However, spatial optimization alone does not fully explain whether a shelter can operate effectively after residents arrive. For this reason, evacuation center planning also requires an assessment of service readiness, including water, sanitation, electricity, communication, health support, logistics, and command coordination.

Overall, the findings support the need for minimum emergency infrastructure provision for urban earthquake evacuation centers. Such provision can help local governments move from a location-based shelter approach toward an operational preparedness approach. In this approach, an evacuation center is not considered ready simply because it has space. It is considered ready when it has the minimum infrastructure required to protect residents, support basic services, coordinate response, and connect affected populations to recovery assistance.

D. Conclusion

This study determined minimum emergency infrastructure needs for urban earthquake evacuation centers in Surabaya based on stakeholder-based qualitative data and content analysis. The findings show that evacuation centers cannot be understood merely as physical shelter locations. They must be supported by an integrated emergency infrastructure system that enables temporary accommodation, basic services, health response, safety, coordination, logistics, and early recovery. In the Surabaya case, ten emergency infrastructure components were identified as necessary during the earthquake response phase: transportation, clean water, electricity, telecommunication, sanitation and solid waste, health facilities, fire safety facilities, evacuation and shelter centers, emergency operation centers, and economic recovery facilities.

The readiness pattern indicates that emergency infrastructure preparedness in Surabaya was uneven. Telecommunication infrastructure showed the highest readiness, while evacuation and shelter centers, emergency operation centers, health facilities, electricity networks, and economic recovery facilities were categorized at low readiness levels. This condition suggests that the most urgent preparedness gaps are located in infrastructure components directly related to shelter operation, health support, emergency coordination, backup power, and early recovery. Therefore, strengthening evacuation centers requires more than identifying safe locations; it requires a minimum package of infrastructure, equipment, services, and institutional support.

The minimum emergency infrastructure identified in this study includes: temporary shelters, tents, sleeping mats or mattresses, field kitchens, fuel, clean water, sanitation, solid waste management, backup electricity, emergency lighting, communication tools, first aid and health services, ambulances, fire safety equipment, logistics storage, emergency response posts, field command posts, and emergency market support. These components should be prepared as a connected package because the weakness of one component can reduce the functionality of the entire evacuation center. For example, adequate shelter space without sanitation can create public health risks, while good communication without logistics and command support may not lead to effective response.

The main contribution of this study is the focused translation of city-scale emergency infrastructure needs into minimum requirements for urban earthquake evacuation centers. This contribution is practical for local governments and disaster management agencies because it provides a basis for auditing evacuation center readiness, prioritizing preparedness investment, and clarifying cross-sector responsibilities. It also contributes to urban disaster preparedness studies by emphasizing that evacuation center readiness should be assessed through three connected dimensions: accessibility, capacity, and emergency infrastructure support.

For policy and planning, the findings imply that Surabaya and other earthquake-prone cities should develop evacuation center readiness standards before disaster occurs. Local governments should not only list potential evacuation centers, but also evaluate whether each facility has minimum shelter equipment, water and sanitation, electricity backup, communication tools, health support, fire safety, logistics access, and links to emergency operation systems. These standards can be integrated into contingency plans, spatial planning documents, annual budgeting, public facility management, and disaster preparedness simulations.

This study has limitations. The findings are based on qualitative data collected in Surabaya in 2019, and infrastructure conditions may have changed over time. The study also focuses on emergency infrastructure needs and does not include structural safety assessment, real-time evacuation simulation, or updated spatial analysis of population distribution and shelter accessibility. Future research should combine the minimum infrastructure framework with building safety assessment, GIS-based evacuation modeling, service capacity analysis, and updated institutional readiness data. Such integration would allow urban evacuation centers to be evaluated more comprehensively as functional emergency facilities in earthquake-prone cities.

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Declaration of Competing Interest

The author declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI

During the preparation of this manuscript, the author used ChatGPT to assist with language refinement. After using this tool, the author reviewed, revised, and edited the content as needed and takes full responsibility for the content of the manuscript.

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