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Reframing Mosque Networks as Urban Resilience Infrastructure in Banda Aceh

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Abstract

Mosques are commonly understood as religious buildings, yet in disaster-prone Muslim cities they also function as social, spatial, and humanitarian infrastructures. This article reframes mosques as urban resilience nodes by applying Ahern's resilience capacity framework to the context of Banda Aceh, Indonesia. Located in a multi-hazard region exposed to earthquakes, tsunamis, floods, and extreme weather, Banda Aceh requires a distributed and socially trusted system of emergency facilities, particularly in dense urban areas where vacant land is limited. Drawing on an integrative literature review and contextual synthesis, this paper examines how mosque networks can contribute to five dimensions of urban resilience: multifunctionality, redundancy and modularization, biological and social diversity, multi-scale networks and capacity, and adaptive planning and design. The discussion argues that mosques have inherent resilience potential because they are spatially distributed, socially embedded, culturally trusted, and often equipped with basic support facilities. However, their actual readiness as evacuation and early recovery facilities depends on measurable factors such as pedestrian accessibility, shelter capacity, water and sanitation, electricity, inclusive access, emergency logistics, and institutional coordination. The article contributes a conceptual framework for mosque-based urban resilience planning and proposes that future disaster preparedness in Banda Aceh should move beyond identifying mosques as temporary shelters toward strengthening them as functional, networked, and adaptive resilience infrastructure.

A. Introduction

Indonesia is one of the world's most disaster-prone countries due to its location at the convergence of major tectonic plates and its exposure to both geophysical and hydrometeorological hazards. Earthquakes, tsunamis, volcanic eruptions, landslides, floods, droughts, extreme weather, coastal abrasion, and forest and land fires continue to shape the country's development challenges (BNPB, 2024). These risks are intensified by rapid urbanization, uncontrolled land use, environmental degradation, and the limited capacity of local infrastructure to respond to sudden disturbances. The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasizes that disaster risk reduction requires stronger governance, investment in resilience, preparedness for effective response, and the capacity to "build back better" during recovery and reconstruction (UNDRR, 2015). For dense urban areas, this means that disaster preparedness should not rely only on formal emergency facilities, but also on existing everyday spaces that are accessible, socially trusted, and capable of being adapted during crises.

Urban resilience has increasingly been understood not as the ability of cities to avoid all failures, but as the capacity to absorb disturbance, maintain essential functions, adapt to uncertainty, and recover through learning and transformation (Ahern, 2011; Meerow et al., 2016). Ahern (2011) argues that resilient urban systems should move from a "fail-safe" logic toward a "safe-to-fail" approach, where disturbances are anticipated and urban systems are designed to degrade gracefully rather than collapse catastrophically. Within this perspective, resilience can be strengthened through five interrelated capacities: multifunctionality, redundancy and modularization, biological and social diversity, multi-scale networks and capacity, and adaptive planning and design. These principles are highly relevant for cities exposed to multiple hazards, especially where emergency response depends on the interaction between physical infrastructure, social institutions, and community-based support systems.

Banda Aceh provides a critical context for examining this issue. The city's spatial development, collective memory, and disaster governance remain deeply shaped by the 2004 Indian Ocean tsunami. Although significant progress has been made in tsunami awareness, early warning, evacuation planning, and post-disaster reconstruction, the challenge of ensuring accessible and functional emergency spaces remains important. Dense settlements, limited vacant land, road-network constraints, and unequal distribution of public facilities can reduce the effectiveness of evacuation planning. In such contexts, the question is not only where residents should evacuate, but also whether the facilities they reach can function safely and adequately during the emergency response and early recovery phases. Minimum humanitarian standards also indicate that shelters should not be understood merely as physical spaces; they require water, sanitation, hygiene, health support, protection, safety, and basic services to preserve human dignity during crisis (Sphere Association, 2018).

Mosques are particularly relevant within this discussion. In Muslim-majority cities, mosques are not merely religious buildings. They are social, cultural, educational, and humanitarian infrastructures embedded in everyday urban life. Historically and socially, mosques have functioned as places of worship, learning, deliberation, charity distribution, social coordination, and community support (Mohit et al., 2014; Cahyadi et al., 2021). During disasters, these everyday functions may be extended into emergency roles, including temporary shelter, public information dissemination, volunteer coordination, food distribution, psychosocial support, and early recovery assistance (Cheema et al., 2014; Kotani et al., 2023). This multifunctional character aligns with the Islamic principle of ta'awun, or mutual assistance, which strengthens the social legitimacy of mosques as community support spaces during emergencies (Napsiah & Sanityastuti, 2025).

The potential role of mosques in disaster management has been documented in several contexts. In Pakistan, Cheema et al. (2014) found that mosques made distinct cultural, social, economic, psychosocial, and political contributions during the response, relief, recovery, and reconstruction phases after the 2005 earthquake. In Asia more broadly, Mohit et al. (2014) showed that mosques have supported early warning, information dissemination, evacuation, donation collection, and contingency planning. In Indonesia, Cahyadi et al. (2021) examined the use of a mosque as an emergency shelter and showed that disaster victims selected the mosque not only because of physical safety, but also because of trust, familiarity, belief, and access to basic facilities. Napsiah and Sanityastuti (2025) further demonstrated that mosque-based disaster mitigation is supported by social trust, central location, community management, and available facilities such as clean water and loudspeakers. In Japan, Kotani et al. (2021) found that mosques could serve as voluntary evacuation shelters for Muslim foreign residents, while Kotani et al. (2023) showed that mosques affected by major earthquakes functioned as relief distribution centers, temporary shelters, soup kitchens, and volunteer accommodation spaces.

Ahern's resilience capacity framework provides a useful analytical structure for this reframing. First, multifunctionality allows mosques to be read as spaces that can support worship, gathering, communication, relief distribution, and temporary shelter. Second, redundancy and modularization suggest that a distributed mosque network can reduce dependence on a single emergency facility and provide backup nodes when some facilities are damaged, overcrowded, or inaccessible. Third, biological and social diversity highlights the need to consider environmental comfort, shade, ventilation, water, sanitation, and the inclusion of children, elderly people, women, persons with disabilities, and other vulnerable groups. Fourth, multi-scale networks and capacity connect neighborhood mosques to district- and city-level disaster response systems, including local government, BPBD, health services, volunteers, and humanitarian organizations. Fifth, adaptive planning and design emphasizes that mosques should be upgraded through design, management, standard operating procedures, and periodic preparedness exercises.

This article therefore reframes Banda Aceh's mosque network as an urban resilience infrastructure. It asks how Ahern's five resilience capacities can be used to reinterpret mosques from religious buildings into functional resilience nodes, and what planning and design considerations are needed to strengthen their role in disaster preparedness. The article does not claim that all mosques are automatically ready to serve as evacuation centers. Instead, it argues that their spatial distribution, social trust, multifunctional use, and community management create a strong foundation that must be assessed and improved through measurable built-environment criteria.

The contribution of this article is threefold. First, it links mosque-based disaster studies with urban resilience theory by applying Ahern's framework to a Muslim-majority disaster-prone city. Second, it shifts the discussion from mosque-as-shelter toward mosque-as-network, emphasizing the importance of redundancy, modular capacity, and multi-scale coordination. Third, it proposes a conceptual basis for future empirical assessment of mosque-based resilience in Banda Aceh, including pedestrian accessibility, capacity estimation, emergency infrastructure readiness, inclusive design, and adaptive management. By doing so, this article supports a more integrated understanding of religious buildings as part of urban disaster preparedness and built-environment resilience.

B. Method

This article employs an integrative literature review with contextual synthesis to develop a conceptual framework for understanding mosques as urban resilience nodes in Banda Aceh. An integrative literature review was selected because the study aims to synthesize theoretical, empirical, and practice-based knowledge from multiple fields, including urban resilience, disaster risk reduction, religious infrastructure, emergency shelter planning, and built-environment studies. This approach is appropriate for an emerging interdisciplinary topic where the objective is not only to summarize existing literature, but also to generate a conceptual framework that can guide future empirical assessment and planning practice (Snyder, 2019; Torraco, 2005; Whittemore & Knafl, 2005).

The review was guided by Ahern's urban resilience capacity framework. Ahern (2011) argues that resilient urban systems should be developed through five interrelated strategies: multifunctionality, redundancy and modularization, biological and social diversity, multi-scale networks and capacity, and adaptive planning and design. These five strategies were used as the main analytical categories in this article. They provide a structured lens for examining whether mosques can be understood not only as religious buildings, but also as distributed socio-spatial infrastructure that may support evacuation, emergency response, and early recovery.

Ahern's framework was chosen because it offers a spatial and planning-oriented interpretation of urban resilience that is directly relevant to mosque-based disaster

preparedness. Its five capacities allow the study to examine mosques not only as individual buildings, but also as multifunctional, distributed, socially embedded, networked, and adaptable urban facilities. This makes the framework suitable for the Banda Aceh context, where disaster preparedness requires locally accessible and socially trusted infrastructure.

Table 1. Literature search strategy

Method	Platform	Year	Article/Document Titles
Literature Search	Google Scholar	2021	Mosque as Emergency Shelter in Natural Disaster: Responses and Challenges
		2025	Disaster Mitigation Based on Mosques: A Case Study of Community Experiences in Disaster-Prone Areas of Yogyakarta
		2021	Potential of Mosques to Serve as Evacuation Shelters for Foreign Muslims during Disasters: A Case Study in Gunma, Japan
	ScienceDirect	2023	Activities and Roles of Mosques in Japan after the Recent Major Earthquakes: A Comprehensive Study
		2023	Enhancement of Disaster Preparedness: Approaches of Place Attachment and Behavior to "Build Back Better" Mosque as Tsunami Evacuation Building in Banda Aceh City, Indonesia
		2024	Tsunami Fragility Based Characterisation of Mosques as Alternatives Tsunami Evacuation Buildings: Reconstructing Evidence from the 2004 Indian Ocean Tsunami
	Policy Documents	2015	Sendai Framework for Disaster Risk Reduction 2015–2030
		2018	The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response
		2024	Buku Data Bencana Indonesia Tahun 2023
		2024	Daftar Masjid dalam Kota Banda Aceh Tahun 2024

The analysis was conducted in four stages:

1. The article identified the core concepts and assumptions within Ahern's resilience capacity framework;
2. The selected literature on mosque-based disaster response was reviewed to identify recurring roles of mosques during emergencies, including sheltering, information dissemination, aid distribution, volunteer coordination, psychosocial support, and early recovery;

3. These recurring mosque functions were coded and mapped onto Ahern's five resilience capacities;
4. The resulting conceptual categories were applied to the Banda Aceh context to develop a mosque-based urban resilience framework.

Banda Aceh was selected as the contextual case because it represents a disaster-prone Muslim-majority city with strong historical memory of the 2004 Indian Ocean tsunami and a dense network of mosques embedded in everyday urban life. According to the official list issued by Dinas Syariat Islam Kota Banda Aceh (2024), the city had 120 mosques distributed across its urban area. This condition makes Banda Aceh suitable for developing a conceptual argument about mosques as a distributed layer of resilience infrastructure. However, this article does not conduct a full empirical audit of all mosques in Banda Aceh. Instead, it develops a conceptual and planning-oriented framework that can guide future empirical assessment.

To avoid overgeneralization, this article distinguishes between inherent resilience potential and operational resilience readiness. Inherent resilience potential refers to characteristics that mosques already possess, such as social trust, daily use, neighborhood presence, religious legitimacy, spatial distribution, and community management. Operational resilience readiness refers to measurable conditions required for emergency use, including accessibility, shelter capacity, water and sanitation, electricity, communication, inclusive access, logistics, health support, and institutional coordination. This distinction is important because a mosque may have strong social legitimacy but weak emergency infrastructure. Conversely, a mosque may have good physical capacity but limited coordination mechanisms.

The analytical process uses Ahern's five resilience capacities to interpret mosque-based urban resilience in the Banda Aceh context. Based on this analytical mapping, the article proposes a conceptual framework that does not treat mosques as isolated buildings. Instead, it interprets them as a network of potential resilience nodes that should be assessed across spatial, physical, infrastructural, social, and institutional dimensions.

This methodological approach has several limitations. First, because the article uses an integrative literature review rather than a systematic review, it does not claim to provide an exhaustive account of all studies on mosques and disaster management. Second, the Banda Aceh discussion is contextual and conceptual, not a complete citywide empirical audit. Third, the use of Ahern's framework provides a strong analytical structure, but other resilience frameworks may produce different emphases. These limitations are acknowledged to clarify the scope of the article and to position the proposed framework as a basis for future empirical research rather than as a final assessment of all mosques in Banda Aceh.

C. Results and Discussion

Mosques are often classified in urban planning as religious facilities. While this classification is formally correct, it does not fully capture their broader role in Muslim-majority cities. In everyday life, mosques function as places of worship, education, social gathering, public communication, charity distribution, and community deliberation. These functions make mosques part of the social infrastructure of the city. During disasters, this social infrastructure can be activated for emergency response.

The concept of social infrastructure is important in resilience planning because disaster response is not delivered only through physical systems. Roads, buildings, water networks, and communication systems matter, but so do trust, familiarity, local leadership, and community cooperation. Aldrich and Meyer (2015) argue that social capital plays a critical role in community resilience because it shapes how people exchange information, mobilize support, and recover after disruption. Berkes and Ross (2013) also emphasize that community resilience depends on social networks, local knowledge, leadership, and the capacity to self-organize. Mosques are relevant because they combine physical space with social organization.

In Banda Aceh, mosques are deeply embedded in the daily rhythm of urban life. Residents are familiar with their locations, their management structures, and their social meanings. This familiarity can reduce uncertainty during emergency situations. When people are afraid, displaced, or separated from formal information channels, familiar places may become important points of orientation. This explains why mosques are often perceived not only as religious spaces, but also as places of safety and protection during disasters (Cahyadi et al., 2021; Kotani et al., 2021).

Table 2. Mapping Ahern's resilience capacities to mosque-based urban resilience

Ahern's resilience capacity	Interpretation for mosque network	Banda Aceh relevance
Multifunc-tionality	Mosques function beyond worship, including gathering, education, charity, public communication, relief distribution, temporary shelter, and psychosocial support.	Mosques are embedded in daily urban life and may be activated during emergency response (Cahyadi et al., 2021; Cheema et al., 2014; Mohit et al., 2014; Napsiah & Sanityastuti, 2025).
Redundancy and modulariza-tion	Multiple mosques can operate as distributed backup nodes if some facilities are damaged, overcrowded, or inaccessible.	The officially recorded network of 120 mosques provides a potential decentralized emergency system (Dinas Syariat Islam Kota Banda Aceh, 2024).
Biological and social diversity	Mosque compounds can support varied users and environmental needs through shade, ventilation, courtyards, water, sanitation, and inclusive access.	Disaster users include children, women, elderly residents, persons with disabilities, and people with medical needs (Sphere Association, 2018; UNDRR, 2015).
Multi-scale networks	Mosques can connect household, neighborhood, district, and city-	Neighborhood mosques can serve immediate response, while larger

Ahern's resilience capacity	Interpretation for mosque network	Banda Aceh relevance
and capacity	level preparedness systems.	mosques can support logistics or coordination (Cheema et al., 2014; Kotani et al., 2023; Mohit et al., 2014; Napsiah & Sanityastuti, 2025).
Adaptive planning and design	Mosques can be gradually upgraded through design, management, SOPs, drills, and facility improvement.	Banda Aceh's disaster memory and changing urban risks require facilities that can adapt over time (UNDRR, 2015; BNPB, 2024).

However, reframing mosques as resilience nodes requires a shift in analytical perspective. A mosque should not be evaluated only by its symbolic role or community trust. It must also be assessed according to whether it can perform emergency functions. A resilience node must be accessible, usable, adequate in capacity, safe, inclusive, and connected to wider response systems. This means that the mosque's disaster role depends on both its social legitimacy and its built-environment performance.

Thus, the central argument of this article is that mosques in Banda Aceh should not be treated only as individual evacuation points. They should be reframed as a network of urban resilience nodes. This network has the potential to support disaster preparedness because it is distributed, familiar, socially trusted, and already used in everyday life. Yet its actual effectiveness depends on systematic planning, design upgrading, infrastructure readiness, and institutional coordination.

1. Multifunctionality: From Worship Space to Emergency Support Space

Multifunctionality is one of the most visible resilience capacities of mosques. Ahern (2011) argues that multifunctional urban systems can support resilience because they allow spaces and infrastructures to serve different needs under changing conditions. In ordinary times, a mosque primarily supports worship and religious activities. However, its spatial and social functions are rarely limited to worship alone. Many mosques also host Qur'anic education, public lectures, community meetings, donation collection, dispute mediation, and social assistance.

During disasters, these existing functions can be transformed into emergency support activities. The main prayer hall can serve as temporary shelter. The veranda and courtyard can become assembly areas. Ablution facilities can support hygiene needs. Loudspeakers can be used for public announcements. Mosque committees can help coordinate volunteers. Donation networks can support the collection and distribution of food, clothing, medicine, and other relief items. These functions have been reported in different disaster contexts, including Indonesia, Pakistan, Bangladesh, Afghanistan, and Japan (Cahyadi et al., 2021; Cheema et al., 2014; Kotani et al., 2023; Mohit et al., 2014).

This multifunctional capacity is especially relevant for dense urban areas. In compact cities, vacant land for emergency shelter may be limited. Building new specialized evacuation facilities may require significant land, budget, and time. In contrast, mosques already exist as daily-use facilities distributed across neighborhoods. Strengthening mosques for emergency roles may therefore be more feasible than relying entirely on new infrastructure. This does not mean that mosques should replace formal emergency facilities. Rather, they can complement formal systems by providing neighborhood-level first response capacity.

In Banda Aceh, mosque-based emergency planning can be organized across village, district, and city levels. This layered classification allows mosque functions to be matched with their spatial scale, accessibility, capacity, available facilities, management readiness, and position within the wider urban emergency response system.

Table 3. Proposed mosque roles across village, district, and city levels in Banda Aceh

Spatial level	Mosque type / scale	Planning considerations
Village level	Smaller neighborhood mosques located close to residents	Prioritize walking accessibility, visibility, route safety, basic communication, small-scale first aid, and simple emergency layout
District level	Larger mosques serving several surrounding neighborhoods	Assess shelter capacity, water and sanitation, electricity, shaded areas, women/family zones, storage space, and access for emergency vehicles
City level	Major mosques with wider symbolic, spatial, and institutional reach	Link mosque management with BPBD, city government, health services, humanitarian organizations, media channels, and formal disaster response protocols

Yet multifunctionality also creates challenges. Emergency use may conflict with religious activities, privacy needs, gender arrangements, or cleanliness requirements. For example, using a prayer hall as sleeping space requires clear rules regarding zoning, footwear, sanitation, and gender-sensitive arrangements. The needs of women, children, older people, and persons with disabilities must also be considered. Without planning, multifunctionality can produce disorder rather than resilience.

Therefore, mosque multifunctionality must be supported by spatial and operational planning. Each mosque should have a basic emergency layout indicating assembly zones, temporary resting areas, logistics storage, women and family areas, medical support points, sanitation access, and circulation routes. This type of planning can preserve religious functions while enabling emergency support when needed.

2. Redundancy and Modularization: Mosque Networks as Distributed Backup Systems

Redundancy and modularization are essential for resilience because they reduce dependence on single facilities or centralized systems. Ahern (2011) argues that resilient urban systems require multiple components that can perform similar functions, so that if one component fails, others can compensate. In disaster response, this principle is highly important. Roads may be blocked, electricity may fail, communication may be disrupted, and official shelters may become overcrowded or inaccessible.

Mosque networks offer a strong basis for redundancy. If Banda Aceh has 120 mosques distributed across its urban area, then these facilities may form a decentralized network of possible emergency nodes. This distribution can reduce reliance on one or two large shelters. If a mosque is damaged, full, or difficult to reach, nearby mosques may serve as alternatives. This is particularly important during sudden-onset hazards such as earthquakes, when people may need to move quickly to the nearest safe and familiar location.

Modularization is also relevant because each mosque can function as a semi-independent community unit. Mosque committees, local volunteers, and surrounding residents may be able to organize immediate support before external assistance arrives. In the first hours after a disaster, centralized response may be delayed. A modular mosque-based system can help bridge this gap by enabling local action at the neighborhood scale.

However, redundancy should not be assumed from numbers alone. A city may have many mosques, but the network may still be weak if several mosques are located in high-risk zones, lack capacity, lack access, or have poor emergency facilities. A redundant system must be mapped and classified. Mosques should be assessed according to hazard exposure, structural condition, service radius, pedestrian access, usable area, water supply, sanitation, electricity, and management capacity.

Table 4. Distribution of Mosques, Population, and Spatial Service Load by Sub-district in Banda Aceh.

Sub-district	Mosques	Area (km^2)	Density (mosques /km^2)	Population	Density (people/ km^2)	Population per mosque
Baiturrahman	23	4.54	5.07	32,506	7,161	1,413
Kuta Alam	25	10.05	2.49	42,691	4,249	1,708
Meuraxa	14	7.26	1.93	27,090	3,733	1,935
Syiah Kuala	19	14.24	1.33	34,247	2,405	1,803
Jaya Baru	7	3.78	1.85	27,157	7,184	3,880
Banda Raya	8	4.79	1.67	26,607	5,556	3,326
Kuta Raja	8	5.21	1.54	14,928	2,865	1,866
Ulee Kareng	9	6.15	1.46	28,610	4,652	3,179
Lueng Bata	7	5.34	1.31	25,702	4,812	3,672
Total/average	120	61.36	1.96	259,538	4,230	2,163

Source: Author's calculation based on Dinas Syariat Islam Kota Banda Aceh (2024) and BPS Kota Banda Aceh (2024).

Table 4 shows that Banda Aceh's mosque network is spatially distributed across all nine sub-districts, but its service load varies considerably when population and area are considered. Kuta Alam has the highest number of mosques, with 25 mosques, followed by Baiturrahman with 23 mosques and Syiah Kuala with 19 mosques. However, Baiturrahman records the highest mosque density, with approximately 5.07 mosques per km². When population is considered, Baiturrahman also has the lowest population burden per mosque, with about 1,413 people per mosque. In contrast, Jaya Baru, Lueng Bata, Banda Raya, and Ulee Kareng show higher population burdens per mosque, ranging from approximately 3,179 to 3,880 people per mosque. These differences suggest that the resilience potential of Banda Aceh's mosque network should not be assessed only by the total number of mosques, but also by spatial density, population density, and population service load. Sub-districts with higher population burdens per mosque may require more detailed accessibility, capacity, and emergency infrastructure assessment before mosques can be designated as functional evacuation or resilience nodes.

This suggests the need for role differentiation within the mosque network. Not all mosques need to perform the same emergency function. Some may be designated as short-term assembly points. Others may serve as temporary shelters, logistics nodes, emergency kitchens, health-support points, or coordination centers. This modular classification would make the network more realistic and operational. It would also help local government and mosque administrators prioritize upgrades based on actual needs and capacities.

In practical terms, redundancy and modularization can support a citywide mosque-based preparedness map. Such a map would identify which mosque serves which neighborhood, how many people it can accommodate, what facilities are available, which routes are safest, and what backup mosque should be used if the nearest mosque is unavailable. This type of mapping would move mosque-based disaster planning from informal practice toward evidence-based urban resilience planning.

3. Biological and Social Diversity: Inclusive and Climate-Responsive Mosque Environments

In urban resilience theory, diversity increases the ability of systems to respond to different disturbances because it provides multiple functions, actors, resources, and response pathways (Ahern, 2011; Berkes & Ross, 2013). In mosque-based resilience planning, social diversity is particularly important because mosques serve communities with varied demographic, physical, cultural, and emergency needs. At the same time, biological or environmental diversity can be interpreted through the quality of mosque compounds as climate-responsive micro-environments.

Socially, mosques are not used by a single type of user. They are visited by children, adults, older people, students, traders, workers, local residents, and visitors.

During disasters, this diversity becomes more complex. Evacuees may include women, children, older adults, persons with disabilities, pregnant women, people with chronic illness, and people experiencing psychological distress. Therefore, a mosque that functions as an evacuation node must be evaluated according to its ability to serve different social groups, not only according to its total floor area.

This point is important because social trust does not automatically produce inclusive shelter performance. A mosque may be socially welcoming but physically difficult to access for wheelchair users. It may have large prayer space but insufficient toilets for women and children. It may have a courtyard but limited shade. It may have loudspeakers but no clear information system for vulnerable groups. Humanitarian standards emphasize that emergency shelters should protect dignity, safety, accessibility, health, and the specific needs of affected populations (Sphere Association, 2018). Therefore, mosque-based resilience requires inclusive design and operational planning.

The concept of social capital also helps explain why mosques can become important support spaces during disasters. Aldrich and Meyer (2015) argue that social networks influence survival, evacuation, assistance, and recovery. Mosques can strengthen bonding social capital among local residents because they are embedded in neighborhood life. They may also support bridging social capital by connecting different community groups and linking social capital by connecting residents with institutions, donors, local government, and humanitarian actors. Previous studies have shown that mosques may support disaster communication, volunteer coordination, donation distribution, psychosocial support, and recovery activities because of this social embeddedness (Cheema et al., 2014; Kotani et al., 2023; Mohit et al., 2014).

In the Banda Aceh context, this social dimension is particularly relevant. Mosques are part of everyday religious and communal life. Residents are familiar with mosque locations, prayer schedules, management structures, and community leaders. This familiarity may reduce uncertainty during emergencies. However, the disaster role of mosques should be expanded beyond general community trust toward a more inclusive resilience model. Mosque committees and local disaster institutions need to consider how different user groups would access, occupy, and use mosque facilities during evacuation and early recovery.

Biological and environmental diversity can also support mosque-based resilience. Mosque compounds often include courtyards, trees, shaded verandas, water facilities, and open-air spaces. These elements may improve thermal comfort, ventilation, drainage, and outdoor usability during emergencies. In tropical climates, shelter performance is strongly affected by heat, humidity, ventilation, crowding, water access, and sanitation. A mosque that has shaded outdoor space and natural ventilation may perform better as a short-term evacuation facility than an enclosed building with poor airflow.

This suggests that mosque resilience should be assessed not only through building structure, but also through the quality of its surrounding landscape. Trees, permeable surfaces, drainage channels, shaded waiting areas, and open courtyards can reduce heat

stress and support safer temporary occupation. These elements are consistent with the broader resilience principle that urban systems should integrate ecological and social functions rather than treating built infrastructure as separate from environmental performance (Ahern, 2011; Meerow et al., 2016).

Therefore, the diversity dimension produces two planning implications. First, mosque-based resilience must include social inclusiveness, especially for vulnerable groups. Second, mosque upgrading should include climate-responsive environmental design. These two aspects are connected. A mosque that is socially trusted but physically uncomfortable may not function well during prolonged emergency use. Conversely, a mosque with good environmental quality but weak social coordination may also fail to support effective response.

4. Multi-Scale Networks and Capacity: From Neighborhood Mosques to Citywide Preparedness

Urban resilience depends on the interaction of different spatial and institutional scales, from households and neighborhoods to districts, cities, and wider regional systems (Ahern, 2011; Cutter et al., 2008; Meerow et al., 2016). In disaster response, no single scale is sufficient. Households need immediate access to safe places. Neighborhoods need gathering points and local coordination. City governments need information, logistics, emergency command, and service continuity. Mosque networks can potentially connect these scales.

At the household scale, residents need nearby and familiar locations that can be reached quickly during an emergency. In dense neighborhoods, mosque proximity may be important because residents may not have time or ability to move to distant formal shelters. At the neighborhood scale, mosques can function as first assembly points, information centers, volunteer bases, and temporary support spaces. At the district scale, larger mosques may serve as coordination or logistics nodes. At the city scale, a mosque network can be integrated with local government, BPBD, health services, public works, humanitarian organizations, and community volunteers.

This multi-scale logic shifts the interpretation of mosques from isolated buildings to a connected infrastructure system. A single mosque may have limited capacity, but a coordinated network of mosques can distribute functions. Some mosques may serve primarily as short-term gathering points. Others may support temporary shelter, emergency kitchens, health posts, or logistics storage. Major mosques may support wider coordination and relief distribution. This type of role differentiation is consistent with Ahern's principle that resilient systems require capacity across multiple scales rather than dependence on a single centralized facility (Ahern, 2011).

Capacity is the critical issue in this network approach. Accessibility alone does not guarantee resilience. This issue has been empirically demonstrated in Keuramat Village, Banda Aceh. Shah et al. (2026) showed that mosque-based evacuation planning can perform very well in terms of pedestrian accessibility but still remain limited by shelter

capacity. Although almost all residents in the study area could reach the nearest mosque within 10 minutes on foot, the capacity-constrained allocation showed that only about 53% of the population could be effectively accommodated. This finding is important for mosque-based resilience planning because it reveals a gap between spatial reach and functional performance. A mosque network may appear adequate when assessed through distance or travel time, but it may become insufficient when usable space, courtyard capacity, and building scale are included in the analysis.

A mosque may be close to many households, but its usable space may be insufficient. A mosque may have strong symbolic value, but its toilets, water supply, electricity, and ventilation may not support large numbers of evacuees. This distinction is important because disaster planning often identifies evacuation points based on location, while underestimating capacity constraints and functional requirements.

For Banda Aceh, this approach has strong planning relevance. The reported presence of 120 mosques across the city suggests a potentially rich network of community facilities. However, the resilience value of this network depends on spatial distribution, catchment areas, capacity balance, hazard exposure, and operational readiness.

Such classification would also help avoid unrealistic expectations. Not every mosque needs to become a full evacuation center. Smaller mosques may only be suitable for short-term assembly and information dissemination. Larger mosques with courtyards, multiple floors, water facilities, and stronger access may support temporary shelter or logistics. This differentiated network approach is more realistic than assuming that all mosques perform the same role.

The multi-scale perspective also emphasizes governance. Mosque committees cannot work alone. Their emergency role should be linked with village officials, sub-district authorities, BPBD, health offices, public works agencies, social services, and local volunteer groups. The Sendai Framework emphasizes the importance of disaster risk governance and coordination across institutions and scales (UNDRR, 2015). Mosque-based resilience will be stronger if it is embedded in formal preparedness plans while preserving its community-based character.

5. Adaptive Planning and Design: Upgrading Mosques for Future Risks

Ahern (2011) argues that resilient urban systems should not be static. They must be capable of learning, adjusting, and improving in response to uncertainty. This principle is central for mosque-based resilience because disaster risks, urban density, climate conditions, and community needs continue to change. Mosques that are adequate today may become insufficient in the future if population density increases, hazards intensify, or infrastructure systems become more fragile.

Future-oriented planning is important because resilience depends not only on present conditions, but also on the capacity to anticipate change. Although future disasters cannot be predicted precisely, planners can estimate possible shifts in population density, hazard exposure, land use, climate stress, and infrastructure demand. For

mosque-based resilience, this means that mosque capacity, accessibility, water and sanitation, electricity, and management readiness should be assessed against both current and future emergency needs. This anticipatory approach helps prevent mosques from becoming inadequate as urban risks and community demands increase over time.

Adaptive planning begins with recognizing that mosques have both everyday and emergency functions. Disaster preparedness should not disrupt their primary religious role. Instead, emergency functions should be integrated into mosque design, management, and maintenance in ways that remain compatible with worship and community activities. This can be achieved through low-cost and incremental interventions.

At the building level, adaptive design may include improving access routes, providing ramps, increasing ventilation, ensuring emergency lighting, preparing backup electricity, improving toilets and ablution areas, and identifying safe zones within and around the mosque. At the site level, adaptive design may include improving courtyards, adding shaded areas, securing open spaces for assembly, improving drainage, and ensuring access for ambulances or emergency vehicles. At the operational level, adaptation may include preparing emergency layouts, evacuation signage, basic logistics storage, first-aid kits, water storage, contact lists, and standard operating procedures.

Mosque committees can also play an adaptive governance role. They can coordinate with local government, BPBD, youth groups, women's groups, health volunteers, and neighborhood leaders. Regular drills can test whether the mosque can function during emergencies. Community education can be integrated into religious gatherings, Friday sermons, youth activities, and social programs. In this way, preparedness becomes part of everyday community life rather than a separate technical program.

Adaptive planning also requires evidence. Before upgrading mosques, planners need data on location, hazard exposure, building condition, usable capacity, toilets, water availability, electricity backup, accessibility, surrounding population, and management readiness. This data can support prioritization. Mosques with high accessibility but low capacity may require backup facilities. Mosques with large courtyards but poor sanitation may need infrastructure upgrading. Mosques in hazard-prone locations may be unsuitable for shelter but still useful as information points before evacuation.

In Banda Aceh, adaptive mosque planning should also consider the city's disaster memory and future uncertainty. The 2004 tsunami created a strong awareness of hazard risk, but preparedness can decline over time if not institutionalized. Mosques can help maintain community memory and preparedness because they are used regularly and are socially respected. This gives them a unique advantage over facilities that are used only during emergency drills. More broadly, social infrastructure in disaster-prone cities should integrate resilience capacity into everyday buildings, sites, and management systems, so that schools, community halls, health facilities, markets, and religious buildings can support emergency communication, temporary gathering, basic services, and early recovery when needed.

However, adaptive design must avoid overburdening mosques. A mosque is not a substitute for comprehensive disaster management. It cannot replace early warning systems, formal shelters, resilient roads, hospitals, logistics networks, or government coordination. Its role is complementary. The goal is to strengthen mosques as part of a broader urban resilience system, not to shift the entire responsibility of disaster response to religious institutions.

This adaptive approach produces a practical planning agenda. Banda Aceh can begin with a mosque resilience audit, followed by classification of mosque roles, minimum facility upgrading, community training, integration with local disaster plans, and periodic evaluation. This would translate Ahern's theoretical framework into a concrete planning process.

D. Conclusion

Based on the synthesis above, mosque-based urban resilience can be understood as the interaction between four operational dimensions: accessibility, capacity, emergency infrastructure readiness, and social-institutional coordination.

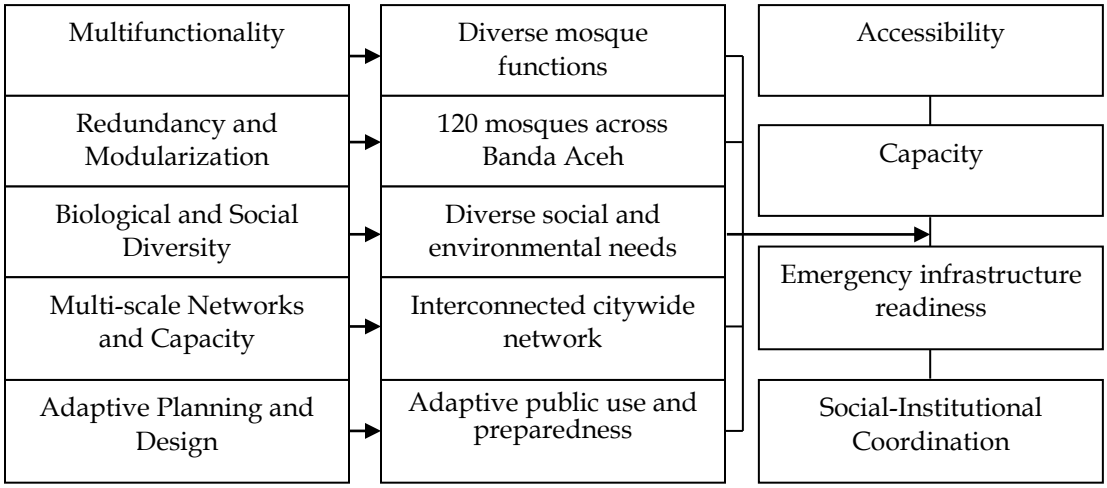

Figure 1. Conceptual framework for mosque-based urban resilience in Banda Aceh based on Ahern's resilience capacity framework

The distinction between accessibility and capacity is particularly important. In mosque-based evacuation planning, high accessibility can create a false sense of preparedness if shelter capacity is not calculated. Shah et al. (2026) demonstrated this problem in Keuramat, Banda Aceh, where pedestrian access to nearby mosques was almost universal, but effective accommodation declined sharply after capacity constraints were applied. Therefore, the proposed framework treats accessibility and capacity as separate but interdependent dimensions. A mosque is not fully resilient

simply because it is close to residents; it must also be able to accommodate them safely and support emergency functions.

Table 5. Proposed indicators for mosque resilience audit

Dimension	Key indicators	Output
Spatial accessibility	Distance, walking time, road connectivity, route safety, visibility, route barriers	Service area map and walking-time classification
Shelter capacity	Prayer hall area, veranda, courtyard, upper floors, safe density, structural condition	Capacity estimate and capacity gap
Emergency infrastructure	Water, sanitation, electricity, lighting, communication, first aid, logistics storage, ventilation, waste management	Emergency readiness score
Inclusiveness	Ramps, accessible toilets, women/family areas, elderly access, child-friendly space, privacy	Inclusive shelter readiness rating
Social-institutional coordination	Mosque committee, village officials, BPBD linkage, volunteers, SOP, communication chain, drills	Coordination readiness profile
Environmental comfort	Shade, trees, airflow, drainage, heat exposure, courtyard usability	Climate-responsive shelter assessment
Network role	Assembly point, temporary shelter, logistics node, emergency kitchen, health post, coordination node	Mosque role classification

This framework also distinguishes between potential and readiness. The potential of mosques comes from their distribution, familiarity, trust, and multifunctional use. Readiness depends on measurable conditions and institutional arrangements. Therefore, a mosque-based resilience strategy should not simply declare mosques as evacuation centers. It should audit, classify, upgrade, and connect them within a broader urban disaster preparedness system.

For Banda Aceh, the framework suggests a five-step planning process:

1. Map the mosque network across the city and identify surrounding population catchments;
2. Assess pedestrian accessibility using actual road networks and walking-time thresholds;
3. Estimate shelter and assembly capacity based on usable indoor and outdoor areas;
4. Audit emergency infrastructure readiness, including water, sanitation, electricity, communication, health support, and inclusive access;
5. Classify mosque roles within a multi-scale emergency system, from neighborhood assembly points to city-level logistics and coordination nodes.

This framework can support future empirical research and local planning practice. It can also be adapted to other Muslim-majority cities where mosques are widely distributed and socially trusted, but where their emergency readiness has not yet been systematically assessed.

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Declaration of Competing Interest

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

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