

# Assessing Mosque Accessibility and Evacuation Capacity in a Dense Urban Area: Case Study of Keuramat, Banda Aceh

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## Abstract

Densely populated urban areas face high disaster risk due to limited open space, constrained evacuation routes, and insufficient emergency shelter capacity. This study evaluates the evacuation performance of two mosques in Keuramat Village, Banda Aceh, with contrasting spatial characteristics, including floor configuration, courtyard availability, and building scale. The study applies three GIS-based analyses: Euclidean buffer analysis, shelter capacity assessment, and household-to-mosque pedestrian network simulation. Results show that 743 residential buildings (96.99%) are located within a 300 m radius of a mosque, and 3,376 people (99.88%) can reach the nearest mosque within 10 minutes on foot. However, under capacity-constrained allocation, the effective accommodation level drops to only 53% of the total population. Baiturrahmah Mosque provides greater evacuation capacity (1,222 people) than Al-Ikhlas Mosque (572 people), mainly due to its larger courtyard area. These findings demonstrate that high accessibility alone does not guarantee adequate evacuation performance when shelter capacity is limited. The study highlights the need to integrate accessibility and capacity in mosque-based evacuation planning and supports the inclusion of mosques as distributed evacuation points in dense urban areas.

**Keywords:** *mosque-based evacuation; disaster risk reduction; shelter capacity; gis-based spatial analysis; urban resilience*

## Abstrak

Kawasan perkotaan yang padat penduduk menghadapi risiko bencana yang tinggi akibat keterbatasan ruang terbuka, jalur evakuasi yang sempit, dan kapasitas tempat penampungan darurat yang belum memadai. Penelitian ini mengevaluasi kinerja evakuasi pada dua masjid di Gampong Keuramat, Banda Aceh, yang memiliki karakteristik spasial berbeda, termasuk konfigurasi lantai, ketersediaan halaman, dan skala bangunan. Penelitian ini menerapkan tiga analisis berbasis *Geographic Information System* (GIS), yaitu analisis buffer Euclidean, penilaian kapasitas penampungan dan simulasi jaringan pejalan kaki dari rumah ke masjid. Hasil penelitian menunjukkan bahwa 743 bangunan hunian (96,99%) berada dalam radius 300 meter dari masjid dan 3.376 jiwa (99,88%) dapat mencapai masjid terdekat dalam waktu 10 menit dengan berjalan kaki. Namun, ketika alokasi dibatasi oleh kapasitas tampung, tingkat akomodasi efektif turun menjadi hanya 53% dari total populasi. Masjid Baiturrahmah memiliki kapasitas evakuasi yang lebih besar (1.222 orang) dibandingkan Masjid Al-Ikhlas (572 orang), terutama karena memiliki halaman yang lebih luas. Temuan ini menunjukkan bahwa aksesibilitas yang tinggi tidak selalu menjamin kinerja evakuasi yang memadai ketika kapasitas penampungan terbatas. Penelitian ini menegaskan pentingnya integrasi antara aksesibilitas dan kapasitas dalam perencanaan evakuasi berbasis masjid, serta mendukung peran masjid sebagai titik evakuasi terdistribusi di kawasan perkotaan padat.

**Kata Kunci:** *evakuasi berbasis masjid; pengurangan risiko bencana; kapasitas penampungan; analisis spasial berbasis gis; ketahanan perkotaan*

## 1. Introduction

Indonesia is highly exposed to multiple hazards because it lies within a major tectonic convergence zone and is also affected by a wide range of hydrometeorological threats, including floods, droughts, forest and land fires, extreme weather, and coastal abrasion [1]. In densely populated urban areas, these risks are often intensified by limited open space, constrained evacuation routes, and the uneven distribution of emergency facilities [2] [3]. Under such conditions, resilience-based spatial planning becomes increasingly

important to ensure that evacuation points are accessible, trusted by residents, and able to function during the early stages of disaster response.

Urban resilience literature emphasizes the importance of multifunctionality, redundancy, diversity, connectivity, and adaptive planning in improving a city's capacity to respond to shocks [2]. In this context, mosques may offer significant potential as community-based evacuation and early recovery facilities. Beyond their religious role, mosques often function as social and humanitarian spaces and are closely embedded in everyday neighbourhood life [4]. This broader role is consistent with the Islamic principle of *ta'awun* (mutual assistance). In Banda Aceh, where 103 mosques are distributed across nine sub-districts, mosques form a familiar and widely accessible layer of local urban infrastructure [5]. Their central location within residential areas, high level of community trust, and existing support facilities make them plausible candidates for neighbourhood-scale disaster response [4] [6] [7].

A growing body of literature has highlighted the role of mosques during disasters. Studies in Banda Aceh show that mosques have served as places of refuge and community support during and after major events, including the 2004 tsunami [7] [8]. Other studies have shown that mosques can contribute not only to immediate sheltering but also to longer-term recovery, communication, aid distribution, and psychosocial support [4] [8]. International evidence points in a similar direction. In Japan, for example, mosques functioned as aid distribution centres, temporary shelters, and volunteer bases during major earthquakes [9]. In other Asian contexts, mosques have also supported early warning, temporary accommodation, donation management, and community coordination [10]. These findings suggest that mosques can act as trusted socio-spatial infrastructure in disaster-prone settings.

However, despite this growing interest, the current evidence base remains dominated by qualitative accounts, post-event narratives, and institution-focused case descriptions. Comparatively limited attention has been given to the quantitative evaluation of mosque performance at the neighbourhood scale, particularly in relation to two linked questions: how quickly residents can reach mosques on foot, and how many people those mosques can actually accommodate during an emergency [9] [10]. In dense urban areas, this distinction is critical. A facility may be geographically close and socially trusted, yet still perform poorly as an evacuation point if its usable capacity is insufficient.

This issue is particularly relevant in Banda Aceh, where disaster planning must respond not only to hazard exposure but also to compact settlement patterns and limited vacant land. In local practice, evacuation planning often relies on general public facilities such as village halls and other community buildings. Yet the potential of mosques as distributed evacuation points has not been systematically assessed using spatially explicit and capacity-based methods. This gap is important because mosques may strengthen village-level disaster preparedness and contribute to a broader resilience framework when their physical and locational characteristics are properly understood.

This study addresses that gap by providing a quantitative and replicable assessment of mosque performance as an evacuation and early recovery facility in a dense urban neighbourhood. Focusing on Keuramat Village, Banda Aceh, the study compares two mosques with contrasting spatial characteristics, including floor configuration, number of storeys, and the availability of outdoor courtyard space (*sahn*). The analysis integrates three components: (a) Euclidean buffer analysis to estimate micro-scale service coverage, (b) capacity assessment based on usable indoor and outdoor evacuation space, and (c) a GIS-based pedestrian network simulation to model household-to-mosque access under normal walking conditions. The analysis is further extended through capacity-constrained allocation to identify the extent to which accessibility gains are limited by shelter saturation.

Accordingly, this study aims to evaluate mosque performance as a neighbourhood-scale evacuation and early recovery facility by quantifying two key dimensions: accessibility and capacity. More specifically, it examines how quickly residents can reach the nearest mosque on foot and how many residents can be accommodated once capacity limits are applied. By combining these two dimensions, the study contributes a practical workflow for assessing trusted community facilities in dense urban areas. The findings are expected to support mosque-based disaster response planning in Banda Aceh and to inform broader discussions on the role of religious and community facilities within local contingency planning, RTRW/RDTR frameworks, and urban resilience strategies.

## 2. Material and Methods

### *Study area and research design*

This study employed a quantitative approach to produce replicable findings on mosque performance as a neighbourhood-scale evacuation and early recovery facility. The study was conducted in Keuramat Village, Banda Aceh, Indonesia, where two public mosques with contrasting spatial characteristics were

selected as case studies: Al-Ikhlâs Mosque and Baiturrahmah Mosque. The comparison focused on differences in building configuration, number of storeys, and availability of outdoor open space, particularly the *sahn* (courtyard). The analysis was organised into three stages: (a) buffer analysis to estimate effective service coverage, (b) capacity assessment to estimate indoor and outdoor evacuation capacity, and (c) pedestrian network simulation to evaluate travel time from residential buildings to the nearest mosque.

#### *Data sources and field survey*

Both primary and secondary data were used. Secondary spatial data included building footprints, road and alley networks, and administrative boundaries. Building and road network data were initially obtained from OpenStreetMap and cross-checked through field observation, while road hierarchy data were compared with the Banda Aceh City Spatial Plan (RTRW). Demographic data, including total population and household numbers, were obtained from BPS and confirmed through village-level records and local stakeholders. These datasets were used to represent evacuation demand within the study area.

Primary data were collected through field measurement and facility audits at both mosques. Indoor prayer areas and outdoor usable spaces were measured to estimate evacuation capacity. The survey also documented emergency-support facilities, including toilets, water sources, electricity, and generators. Road and alley widths along the main access routes were verified in the field to support interpretation of pedestrian accessibility. Field measurements were carried out using a laser distance meter, manual sketching, and photographic documentation. Spatial processing and modelling were performed using ArcGIS, AutoCAD, and SketchUp. ArcGIS was used for buffer mapping and network analysis, AutoCAD was used to calculate indoor and outdoor areas, and SketchUp was used for three-dimensional visualisation.

#### *Buffer analysis*

The first stage examined mosque service coverage using a GIS-based multiple-ring buffer with radii of 100 m, 200 m, and 300 m. These thresholds were selected to represent micro-scale walking catchments under emergency conditions. The 300 m threshold was used as a conservative limit, although Indonesian pedestrian guidelines [11] indicate that a walking distance of up to 400 m is generally acceptable. In this study, the shorter threshold was adopted to better reflect the likely needs of vulnerable users, such as older adults and young children, and to provide a stricter safety margin for rapid access during emergencies.

To avoid double counting, the buffers were processed in donut form so that each building was assigned to only one distance band. Residential buildings were then linked to the buffer zones using the spatial join function with the “have their center in” option. The output of this stage was the cumulative number of residential buildings and estimated residents served within each distance threshold.

#### *Capacity assessment*

The second stage estimated the evacuation capacity of each mosque based on usable indoor and outdoor space. Capacity was calculated using an area-per-person approach. For temporary indoor evacuation, this study adopts 1.5 m<sup>2</sup>/person within the emergency-capacity range indicated by the guide [12]. For outdoor evacuation space, a more generous standard of 2.0 m<sup>2</sup> per person was applied to account for circulation, safety, and temporary emergency use. Although other international references mention lower or higher thresholds depending on shelter duration and context, these two standards were selected as a pragmatic compromise for short-term mosque-based evacuation.

Usable indoor and outdoor areas were measured from field-based spatial modelling and then converted into estimated evacuation capacity using the following formula:

$$\text{Evacuation capacity} = \text{usable area} / \text{area standard per person}$$

Indoor and outdoor capacities were then summed to estimate the total upper-bound evacuation capacity of each mosque. The estimates should be interpreted as upper-bound values because they do not fully deduct space for circulation routes, furniture, privacy needs, storage, first aid, or other operational functions.

#### *Pedestrian network simulation*

The third stage analysed pedestrian accessibility using a service area-based network model in ArcGIS. Road and alley segments were digitised and attributed by length, width, and road type. Segment travel time was calculated from length and walking speed, while road width was incorporated as a network restriction to account for differences in route suitability for pedestrian evacuation. Thus, the model did not rely solely on geometric distance, but also considered whether available paths were sufficiently suitable for

movement within the local street network. Evacuation points were placed at the intersection between the road network and each mosque entrance. Travel time for each segment was calculated using:

$$t = d / v$$

where  $t$  is travel time,  $d$  is segment length, and  $v$  is walking speed. The walking speed was set at 2.5 km/h, following the tsunami evacuation guidance of the Cabinet Office of Japan [13], and was used as the cost attribute in the network model. The resulting service areas were mapped at 5-minute, 10-minute, and 15-minute intervals to estimate the number of residents who could reach the nearest mosque within each time threshold.

To estimate evacuation demand, the total village population was distributed across residential buildings based on the average relationship among population, households, and housing units in the study area. This produced an estimated population per residential building, which was then used to calculate cumulative demand within each service area. A second simulation incorporated mosque capacity constraints to assess how many residents could actually be accommodated once both accessibility and shelter saturation were considered.

**Table 1.** Data Source.

Data Type	Data	Source	Year
Secondary + field verification	House units (building/household distribution)	BPS [14] and verified through field observation and village officials	2024
Secondary + field verification	Road/alley network and road width classes	RTRW [18] and verified through field observation	2019
Primary	Mosque measurement (usable indoor area, number of floors, courtyard/ <i>sahn</i> area)	Direct field measurement	2025
Primary	Mosque emergency facilities	Standardized facility audit checklist and verification with mosque administrators	2025
Secondary + field verification	Population and households (residents, household counts; no data on vulnerable groups, confirmed by village officials)	BPS population data and village office records, confirmed through local stakeholders (village office)	2024
Secondary + field verification	Basemap for mapping/visual validation	Open Street Map as base layer, then adjusted through field observation	2025

Source: Compiled by the authors from field survey and secondary data, 2024–2025

### *Ethical considerations*

Fieldwork permission was obtained from relevant local authorities and mosque administrators, and participation by informants was voluntary and based on informed consent. Data collection relied on structured observation, facility audits, and field measurement. The quantitative approach was selected to ensure transparency, consistency, and methodological replicability for future studies in similar dense urban settings.

### **3. Results and Discussion**

#### *Study area context*

Keuramat Village is classified as a dense urban settlement within Banda Aceh City. The study area covers 0.488 km<sup>2</sup> and contains 766 houses, 1,067 households, and a total population of 3,380 residents. Only two public mosques serve the area: Al-Ikhlâs Mosque and Baiturrahmah Mosque. Although smaller prayer rooms are present, they were not classified as public mosques in this study because they do not function as neighbourhood-scale evacuation facilities. BPS [14] data also indicate the presence of an evacuation route, but no natural disaster early warning system or tsunami-specific early warning system.

These conditions make Keuramat a relevant case for evaluating mosque-based evacuation planning in a compact urban setting.

Both Al-Ikhlash and Baiturrahmah Mosque are active for Maulid, Qurban, Praying times, Friday praying, Ied prayer, Baitul Mal, Pengajian Tuesday night, Nuzulul Quran, and TPA for children in Keuramat Village.

*Buffer-based service coverage*

The first analysis examined service coverage using Euclidean buffer distances of 100 m, 200 m, and 300 m from the two mosques. The results show that only 175 residential buildings (22.84%) fall within the 100-m radius. Coverage increases to 536 buildings (69.97%) within 200 m and to 743 buildings (96.99%) within 300 m. Only 23 houses (3.01%) remain outside the 300-m threshold.

These results indicate that the spatial distribution of the two mosques provides broad geometric coverage across the settlement. The 300-m threshold captures almost the entire residential area, suggesting that mosque locations are favourable for rapid access under a simplified distance-based assumption. At the same time, the remaining uncovered houses indicate that some peripheral pockets may still require improved access or complementary evacuation points.

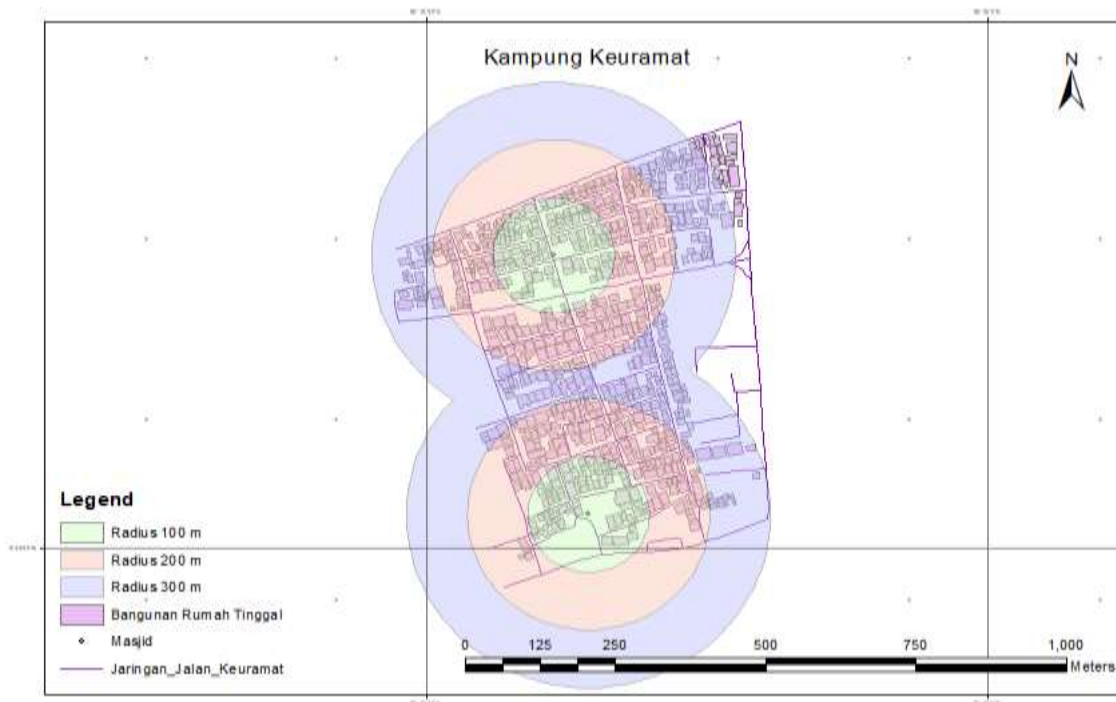


**Figure 1.** Al-Ikhlash (left) and Baiturrahmah (right) Mosques.  
 Source: Author’s field documentation, 2025

**Table 2.** Disaster preparedness of Keuramat Village [14].

Number	Metrics	Value
1	Natural disaster early warning system	No
2	Tsunami special early warning system	No
3	Disaster evacuation route	Yes
4	Construction, maintenance, or normalization of: rivers, canals, embankments, ditches, drainage, reservoirs, beaches, etc.	Yes

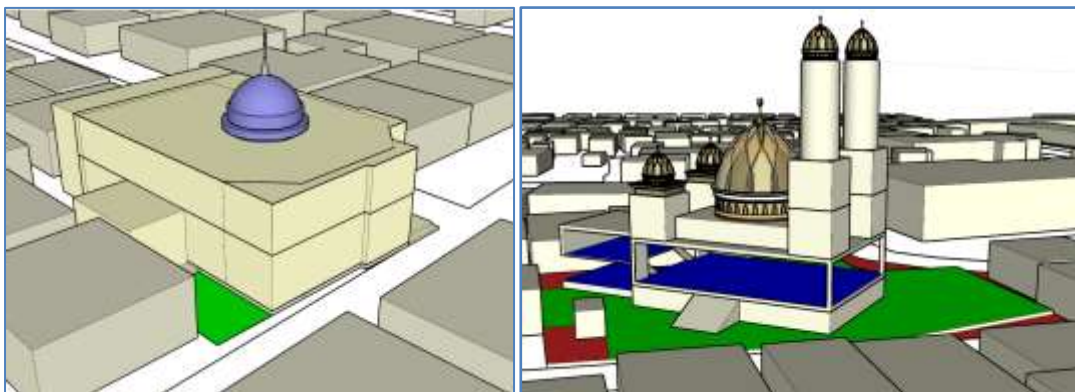
Source: BPS 2024



**Figure 2.** Buffer analysis of 100 m, 200 m and 300 m.  
Source: ArcGIS analysis, 2025

### *Evacuation capacity of the mosques*

Indoor space capacity was estimated based on the UNICEF Philippines [12], which stipulates a minimum standard of 1.5 m<sup>2</sup> per person for temporary shelter within buildings. Outdoor space capacity was calculated based on the 2 m<sup>2</sup> per person requirement after taking into account circulation, security, and the placement of emergency tents. Evacuation capacity was estimated using a standard area-per-person formula: Capacity = Area/Standard.



**Figure 3.** 3D model of Al-Ikhlash (left) and Baiturrahmah (right) mosques  
Source: SketchUp model, 2025

Total evacuation capacity was obtained by summing indoor and outdoor capacity, in accordance with the integrated evacuation planning principles recommended by UNICEF Philippines [12], to ensure that prayer rooms and open spaces around mosques can be optimally utilized in an emergency. In this study, the calculation is based on usable floor and courtyard areas and does not explicitly allocate space for circulation routes, fixed furniture, operational buffers, or functional zones. As a result, the estimates should be interpreted as an upper-bound capacity. Future research should develop a more detailed space-programming and zoning approach for emergency operations. That includes separating areas for circulation, food preparation/kitchen, prayer activities, women and children, older adults and people with disabilities, temporary clinics/first aid, storage, and coordination so that capacity can be managed safely and equitably during disasters.

Table 3. Mosque capacity.

Number	Mosque	Indoor area	Outdoor area	Indoor evacuation	Outdoor evacuation	Totals
1	Al-Ikhlas	818 m <sup>2</sup>	54 m <sup>2</sup>	545 people	27 people	572 people
2	Baiturrahmah	673 m <sup>2</sup>	1,548 m <sup>2</sup>	448 people	774 people	1,222 people

Source: Field measurement and author calculation, 2025.

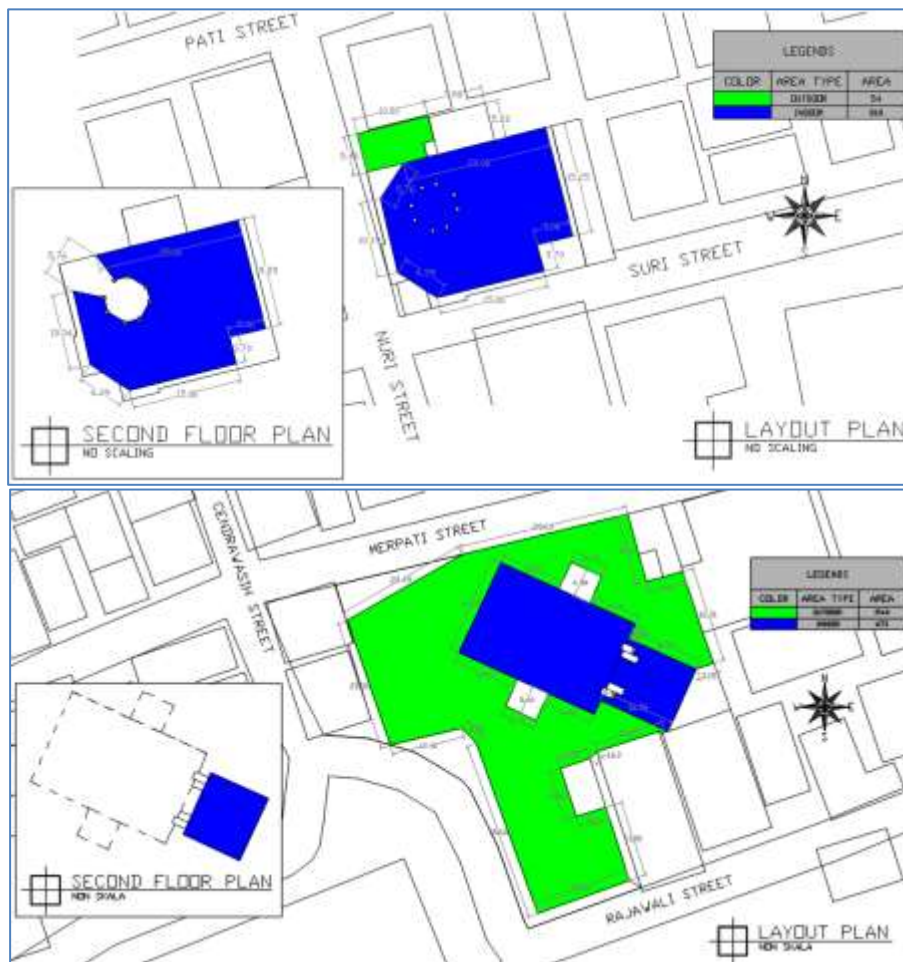


Figure 4. Analysis result of Al-Ikhlas (top) and Baiturrahmah (bottom) mosque

Source: AutoCAD analysis, 2025.

Based on field measurements, the Baiturrahmah Mosque has an indoor area of 673 m<sup>2</sup> and an outdoor area of 1,548 m<sup>2</sup>. With a standard of 1.5 m<sup>2</sup> per person for indoor evacuation and 2.0 m<sup>2</sup> per person for outdoor evacuation, the mosque's evacuation capacity is estimated at 1,222 people. Meanwhile, the Al-Ikhlâs Mosque has an indoor area of 818 m<sup>2</sup> and a significantly smaller outdoor area of 54 m<sup>2</sup>, resulting in an estimated evacuation capacity of 572 people.

Adding the capacities of both mosques together, the total evacuation capacity in the study area is 1,794 people. Comparing this capacity to the population in each buffer zone shows that: (a) Within a 100-meter radius, the capacity is sufficient (ratio 2.32) because the number of residents served (772 people) is smaller than the total capacity. (b) At a radius of 200 meters and 300 meters, capacity begins to decrease significantly (ratios of 0.75 and 0.54), indicating the borderline of adequacy based on the mosque's capacity. (c) At a radius of more than 300 meters, capacity is only able to accommodate 53% of the total population (ratio of 0.53), indicating the borderline of adequacy of the evacuation area for all residents of Keuramat Village. These results indicate that the availability of evacuation space around the mosque is relatively adequate for nearby residents. However, the combined capacity of both mosques is insufficient to accommodate the entire village population.

**Table 4.** Capacity adequacy relative to population.

Number	Radius	Cumulative population	Total capacity	Ratio
1	100 meters	772	1,794	2.32
2	200 meters	2,365	1,794	0.75
3	300 meters	3,278	1,794	0.54
4	More than 300 meters	3,380	1,794	0.53

Source: Calculated by the author based on population data and mosque capacity assessment, 2025

**Table 5.** Identification of evacuation site infrastructure.

Number	Infrastructure	Al-Ikhlâs	Baiturrahmah
1	Capacity (people)	572	1,222
2	WC	Yes	Yes
3	Well water	Yes	Yes
4	Electrical installations	Yes	Yes
5	City water installations	Yes	Yes
6	Generator	Yes	Yes
7	Handy talky	No	No
8	Megaphone	No	No
9	Loudspeaker	Yes	Yes
10	Gong	No	No

Source: Field survey and verification with mosque administrators, 2025

The comparison between the two mosques also highlights the importance of outdoor open space. In this case, the larger outdoor courtyard space (*sahn*) at Baiturrahmah substantially increases its evacuation capacity, despite its smaller indoor area.

*Pedestrian network accessibility*

Network analysis reveals that the service radius is not always uniform. Geographically close residents (for example, within 200–300 meters in a straight line) may not be able to reach the mosque more quickly because of obstacles such as narrow roads, dense settlement patterns, or limited infrastructure. Conversely, residents who are farther away in Euclidean distance but have good access to main roads can reach the mosque more quickly. Network analysis demonstrates that a mosque as a disaster evacuation centre must be assessed not only by its geographic location but also by its connectivity to the road network. In this study, travel time and road functionality were based on 2.5 km/h under normal pedestrian conditions [13], excluding debris, strong winds, rain, and flooded roads, even during disasters. Future research should incorporate disruption scenarios to provide more realistic accessibility estimates and support more robust evacuation planning decisions.

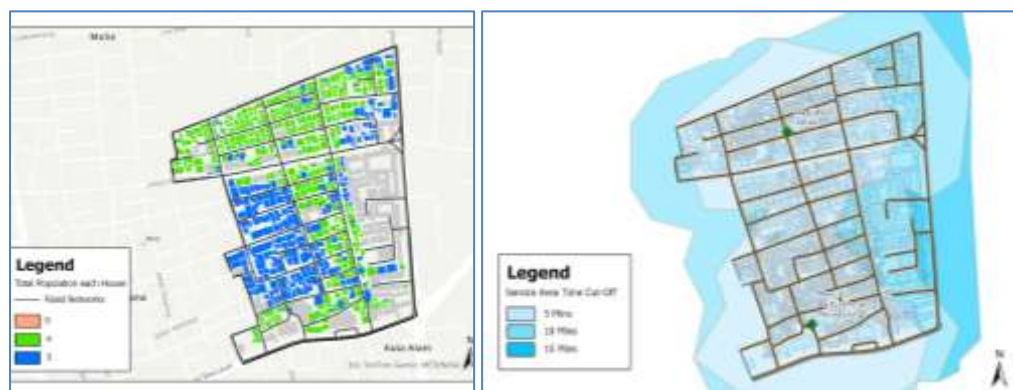
The total number of residences was 766, with a population of 3,380. Because household occupancy data were unavailable at the building level, evacuation demand was approximated by assigning four persons to 450 houses and five persons to 316 houses, based on the aggregate population-to-building ratio. The third analysis used a service area-based pedestrian network model to estimate accessibility under normal walking conditions while incorporating width-related route restrictions in the street network. The results show that within 5 minutes, 2,716 people (80.36%) or 616 houses can reach the nearest mosque. Within 10 minutes, coverage increases to 3,376 people (99.88%) or 765 houses. Within 15 minutes, the full village population is covered.

**Table 6.** Network analysis calculation data.

Number	Value	Formula	Value
1	People per household	Population/Number of households	3.16776
2	Household per house	Number of households/Number of buildings	1.39295
3	Population per building	Households per house x People per household	4.4125

Source: An analysis of the number of house occupants [19]

These findings indicate that the two mosques occupy highly accessible positions within the local street network. They also show that network-based accessibility is shaped not only by straight-line distance, but also by route structure and the suitability of available paths. Thus, residents who are geographically close to a mosque are not always the fastest to reach it, while others located farther away may still have efficient access through more suitable routes.



**Figure 5.** Total population and service area time cut-off.

Source: ArcGIS analysis, 2025.

Table 7. Service area.

Number	Service area	Total population	Cumulative population	Number of houses	Cumulative number of houses	Percentage
1	5 minutes	2,716	2,716	616	616	80.36
2	10 minutes	660	3,376	149	765	99.88
3	15 minutes	4	3,380	1	766	100.00

Source: Calculated by the author based on ArcGIS network analysis, 2025

### Capacity-constrained accessibility

A different pattern emerges when pedestrian accessibility is assessed together with mosque capacity limits. Under the 5-minute scenario, only 1,092 people can be accommodated, leaving 2,288 people (67.6%) unaccommodated. Under the 10-minute scenario, the number accommodated increases to 1,794 people, but 1,586 people (46.9%) still remain outside available capacity. The corresponding accommodated shares are 32.30% at 5 minutes and 53.07% at 10 minutes.



Figure 6. 5-minute and 10-minute evacuation scenario  
Source: ArcGIS analysis, 2025

These results show that accessibility alone provides an incomplete picture of evacuation performance. Although most residents can reach a mosque quickly, the available shelter capacity is insufficient for the full population. In Keuramat, the primary limitation is therefore not the spatial reach of the mosque network, but the mismatch between high accessibility and limited accommodation capacity. This is the central empirical finding of the study.

The results show that mosques in dense urban settlements can perform strongly as neighbourhood-scale evacuation destinations in terms of accessibility, while still facing serious limitations as collective shelters. In Keuramat Village, nearly all residents can reach one of the two mosques within 10 minutes under normal walking conditions. This confirms the importance of mosques as familiar, trusted, and spatially embedded community facilities. However, once shelter capacity is taken into account, the apparent strength of the system declines substantially. The combined capacity of both mosques can accommodate only about 53% of the village population, showing that high accessibility does not automatically translate into adequate evacuation performance.

This distinction is important because much of the existing literature has emphasised the social, cultural, and institutional roles of mosques during disasters, including their functions as shelters, aid distribution centres, and coordination hubs. The present study supports that literature, but adds a quantitative spatial dimension. Rather than asking only whether mosques can support evacuation, this study evaluates how well they perform when assessed through both walking access and accommodation limits. In this case, the answer is mixed: the mosque network performs strongly as an accessible first destination, but less strongly as a sufficient shelter system for the entire neighbourhood.

**Table 8.** Simulation calculation data.

Number	Evacuation location	Evacuation duration 1 (5 minutes)	Evacuation duration 2 (10 minutes)
1	Al-Ikhlas (Caps: 572)	572	572
2	Baiturrahmah (Caps: 1,222)	520	1,222
3	Not evacuated	2,288	1,586
4	Evacuated percentage	32.30%	53.07%

Source: Calculated by the author based on ArcGIS network analysis, 2025

The comparison between Al-Ikhlas and Baiturrahmah Mosques also highlights the strategic importance of outdoor open space. Although Al-Ikhlas has a larger indoor area, its extremely limited courtyard reduces its overall evacuation usefulness. By contrast, the large outdoor courtyard space (*sahn*) at Baiturrahmah substantially increases total shelter capacity. This suggests that mosque-based disaster planning should not focus only on the prayer hall, but also on the quantity and usability of outdoor space. In dense urban contexts where indoor expansion is difficult, the courtyard may be one of the most practical spatial resources for increasing short-term evacuation capacity.

The network analysis further demonstrates that route suitability matters. Because road width was incorporated as a restriction in the pedestrian model, accessibility was shaped not only by segment length and walking speed, but also by whether available routes were sufficiently suitable within the local network. This makes the analysis more realistic than a purely geometric or unconstrained network model. It also explains why residents located close to a mosque in straight-line terms may not always have the fastest access, while others farther away may reach the mosque more efficiently through more suitable routes. For evacuation planning in compact urban areas, this means that location and capacity should not be treated as competing priorities. Accessibility determines whether residents can arrive quickly, whereas capacity determines whether the destination can function effectively after arrival. A robust evacuation system requires both.

This finding is particularly relevant because previous studies have shown that mosques can function as temporary shelters and aid distribution centres during disasters [9] [15]. A broader systematic review also indicates that religious institutions can play important roles in disaster risk management through communication, coordination, and community trust [16]. In this context, rapid access to mosques becomes an important indicator of neighbourhood-level disaster preparedness, especially in dense urban areas where trusted community facilities may support early evacuation and initial response.

From a planning perspective, the findings suggest that mosques can serve as distributed first-stage evacuation points in dense urban neighbourhoods, but should not be treated as stand-alone final shelters unless their capacity is expanded or supplemented. In Keuramat, this may involve integrating additional open spaces, community facilities, or secondary shelters into a wider local evacuation network. The results also support the inclusion of mosques in local contingency planning, not only because they are accessible and trusted, but because their performance can now be evaluated using measurable spatial criteria.

Several limitations remain. The model represents normal pedestrian movement and does not incorporate hazard-induced disruption such as debris, flooding, panic congestion, wind, or blocked links. Capacity estimates are also upper-bound values because they are based on usable area and do not fully deduct space for circulation, privacy, storage, first aid, WASH, or vulnerable groups. In addition, the study covers only two mosques in one urban village, so the findings should not be generalised without caution.

Even so, the workflow offers a practical basis for broader studies at sub-district or city scale, especially in Banda Aceh, where mosque networks are dense and socially significant.

#### 4. Conclusion

This study evaluated mosque performance as a neighbourhood-scale evacuation and early recovery facility in Keuramat Village, Banda Aceh, by integrating buffer analysis, capacity assessment, and pedestrian network simulation. The results show that the two mosques are highly accessible in spatial terms: 96.99% of residential buildings are located within 300 m of a mosque, 80.36% of residents can reach one within 5 minutes, and 99.88% within 10 minutes under normal walking conditions. However, their combined evacuation capacity is only 1,794 people, equivalent to approximately 53% of the total village population. These findings indicate that the mosque system performs strongly in terms of accessibility, but remains limited in terms of total accommodation capacity.

The main contribution of this study is to demonstrate that accessibility and capacity must be assessed together in evaluating evacuation performance. A mosque may be strategically located and socially trusted, yet still be insufficient as an evacuation facility if its usable shelter area is limited. In Keuramat, the principal constraint is not whether residents can reach a mosque quickly, but whether the mosques can accommodate them once they arrive. The study also shows that outdoor open space, especially the *sahn* (courtyard), plays a critical role in increasing temporary evacuation capacity.

Religious institutions are often well integrated within local communities and can support disaster risk reduction and post-disaster recovery through trust, social embeddedness, and community coordination [16] [17]. In this context, the present findings support the inclusion of mosques as distributed first-stage evacuation points in Banda Aceh's urban disaster system. This is also consistent with evidence from Japan, where mosques have functioned as temporary shelters, relief distribution centres, and community support spaces during major disasters [9]. At the same time, mosque-based evacuation planning should remain aligned with wider city evacuation routes and complementary shelter facilities so that rapid access is matched by effective and safe accommodation capacity.

From a planning perspective, the findings support the inclusion of mosques as distributed first-stage evacuation points in dense urban areas. At the same time, mosque-based evacuation planning should be strengthened through improvements in usable outdoor space, pedestrian access, emergency-support facilities, and integration with complementary shelters and formal contingency frameworks such as RTRW, RDTR, and BPBD planning instruments. Future research should test this workflow in other neighbourhoods, incorporate disrupted-network scenarios, and refine capacity estimates by considering operational zoning, vulnerable groups, and emergency-support functions in greater detail.

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#### 6. Abbreviations

<i>BPS</i>	Statistics Indonesia (Badan Pusat Statistik)
<i>GIS</i>	Geographic Information System
<i>OSM</i>	OpenStreetMap
<i>RTRW</i>	Regional Spatial Plan (Rencana Tata Ruang Wilayah)

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