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Research paper doi: 10.30822/arteks.v9i1.3281

Disaster evacuation challenges in high-density urban neighborhood Kampung Code, Yogyakarta

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ARTICLE INFO

Article history:
Received January 14, 2024
Received in revised form Feb. 08, 2024
Accepted March 12, 2024
Available online April 01, 2024

Keywords:
Disaster
Evacuation
High-density Kampung

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ABSTRACT

The article discusses the challenges of disaster evacuation in the high-density urban neighborhood of Kampung Code in Yogyakarta, Indonesia. The rapid urbanization along riverbanks in the area has led to increased vulnerability to flooding and other environmental hazards. The study aims to identify the characteristics and challenges of circulation routes for supporting disaster evacuation in riverbank settlements like the Kampung Code. The research uses a mixed-methods approach, including surveys, interviews, and observations, to gather data using a town-watching approach. The article emphasizes the importance of understanding the specific characteristics of space in these areas to enhance community resilience and disaster recovery. The study occurred in Kampung Jogoyudan, one of the most populated areas along the Code River, and serves as a model for understanding and addressing evacuation challenges in other high-density urban environments.

Introduction

The ongoing global trend of urbanization and the resulting high-density living in many areas, including Kampung Kota, pose unique challenges in disaster management and evacuation procedures (Satterthwaite 2005). Urbanization along riverbanks in Indonesia has been a growing phenomenon with significant implications for options (Pramudito, Praptantya, and Nasir 2019; Fenny Aprillia, Lie, and Saputra 2020; Kusliansjah 2022). This study is about environmental sustainability and community resilience. The encroachment of urban development onto riverfront areas has been documented in studies such as the work by (Saraswati, Subiyanto, and Wijaya 2016), highlighting the challenges posed by this trend. Rapid urbanization along riverbanks often increases vulnerability to flooding, water pollution, and other environmental hazards. As Indonesia continues to experience urban expansion, understanding the specific dynamics and implications of urbanization along riverbanks is crucial for fostering resilient and sustainable urban environments (Sutopo et al. 2020). High-density urban areas are often more vulnerable to the impacts of natural disasters, and understanding the evacuation challenges in these settings is crucial for enhancing overall disaster resilience (United Nations Office for Disaster Risk Reduction (UNDRR) 2019). Like many other riverbank settlements with unique urban characteristics, Kampung along the Code River, Yogyakarta, presents specific evacuation challenges that require in-depth analysis and understanding (Birkmann, Setiadi, and Fiedler 2015). A study of riverbank populations in Yogyakarta demonstrates the capacity of local citizens to calculate and manage the risks they face (Guinness 2020).

This study aims to identify the characteristics and challenges regarding circulation routes for supporting disaster evacuation in riverbank

settlements. Investigating evacuation challenges in this area is essential for identifying opportunities to enhance community resilience and the role of social capital in disaster recovery. The findings of this research can contribute valuable insights to urban planning and policy development, aligning with the objectives of the New Urban Agenda by UN-HABITAT in creating safer and more sustainable urban spaces (UN-Habitat 2017).

The study occurred in Kampung Jogoyudan, one of the most populated areas along the Code River. This area is a high-density urban neighborhood located in Yogyakarta, Indonesia, that has experienced numerous challenges related to disaster evacuation. The rapid urbanization along riverbanks in Indonesia has significantly contributed to the vulnerability of settlements like Kampung Jogoyudan to flooding and other environmental hazards. The article highlights the importance of understanding the specific dynamics and implications of urbanization in these areas to foster resilient and sustainable urban environments. This study can serve as a model for understanding and addressing evacuation challenges in other high-density urban environments, contributing to broader knowledge of disaster resilience.

Using "Evacuation, densely populated, non-engineered settlement, Town watching" as keywords, previous research has primarily focused on discussing evacuation, cities, and housing (figure 1). However, this study aims to identify the characteristics and challenges of evacuation in high-density urban kampung settlements.

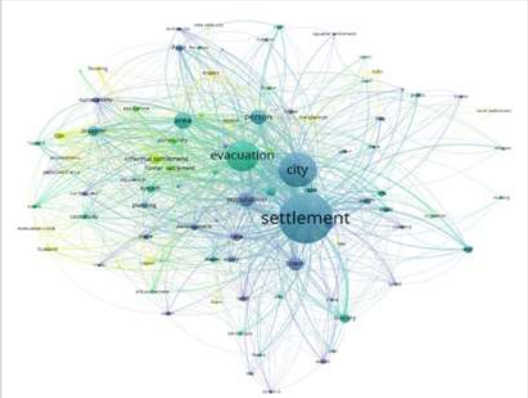

Figure 1. Vos viewer analysis on settlement, city and evacuation research

Research on high-density settlements in riverbank areas and urban resilience has become increasingly important in recent years due to the rising frequency and intensity of natural disasters. A study by Idham (2018) emphasized the significance of understanding the unique architecture as a media to deal with natural and social problem in riverbank settlement. Similarly, (Mononimbar 2018) highlighted the role of urban planning in creating resilient communities in high-density areas prone to disasters. The research by Hambati and Yengoh (2018) focused on communal mitigation efforts to support resilience in natural disasters in densely populated urban neighborhoods.

In line with the findings of the study by Sajjad, Chan, and Chopra (2021) underscored the importance of considering space characteristics of space by spatial disaster resilience profiling to set up priorities of interventions. Additionally, a study by Irsyad and Hitoshi (2022) identified the need human-centered perspective in planning an effective flood emergency evacuation for informal riverbank settlements through spatial design.

To address the issues identified in Kampung Code, the study by (Prathama and Ellisa 2020) proposed innovative solutions for creating safer and more sustainable urban spaces in riverbank settlements. Similarly, a study by Rustinsyah, Prasetyo, and Adib (2021) highlighted the importance of community engagement and participation in disaster preparedness and evacuation planning in riverbank settlements.

In conclusion, the findings from recent studies on high-density settlements in riverbank areas and urban resilience provide valuable insights for urban planning and policy development to improve disaster evacuation processes and create safer environments in vulnerable urban settings.

Previous research on disaster evacuation in high-density urban neighborhoods like Kampung Code in Yogyakarta, Indonesia, has primarily focused on general challenges and strategies without delving into the specific characteristics and challenges of circulation routes in riverbank settlements. This study emphasizes the importance of understanding the specific characteristics of space in high-density urban areas to enhance community resilienc. The findings from this study, conducted in Kampung Jogoyudan, can be used as a model to address evacuation challenges in similar environments. Summary: The research focuses on identifying

public open spaces for evacuation in non-engineered settlements. The study highlights the importance of understanding space characteristics in high-density urban areas for disaster recovery. The findings serve as a model for addressing evacuation challenges in similar environments.

Methods

Kampung Jogoyudan is in the Gowongan Village, Jetis District, and part of the Kampung Kali Code. Categorized as a subzone of high-density housing in the Jetis District, Kampung Jogoyudan consists of RW 07 to RW 13. This research locus is located at RW 11 (figure 2), which is the most vulnerable area to significant impacts during floods (Tiarini 2019).

The study employs a mixed-methods approach, utilizing surveys, interviews, and observations to examine the characteristics and challenges of circulation routes that support disaster evacuation in riverbank settlements such as Kampung Jogoyudan. The research scope includes identifying the specific challenges in evacuating people from their houses and navigating the area to reach safer locations. The simulations focus on earthquake, cold lava, and flood hazards frequently experienced in this region. The study observed seven alleys (figure 2) and 43 houses using the town-watching method (table 1). The town-watching method (TWM) is a community-based disaster preparedness and response approach. It involves training and mobilizing locals to monitor their surroundings and report any signs of impending disasters or emergencies. This method relies on community members' active participation and vigilance to identify and communicate potential risks or hazards. Town watching can be particularly effective in high-density urban neighborhoods where formal emergency response systems may face challenges quickly reaching all areas. In this case, due to the limited time, the town-watching method was delivered by the architecture students of Universitas Atma Jaya Yogyakarta. Five danger principles that refer to a set of characteristics that make particular objects or materials particularly hazardous in disaster situations were utilized to evaluate the challenges of evacuation. These principles are commonly used in disaster management and emergency response to identify and address potential risks. The five principles include easy to roll, easy to move, easy to burn, easy to break and toxic material (Авитисов et al. 2019). By identifying and addressing these potential hazards, emergency management officials can take appropriate measures to mitigate risks, plan evacuation routes, and enhance community resilience in high-density urban environments like Kampung Jogoyudan. These object of studies then and additionally simulated these areas using pathfinder software to identify potential evacuation challenges during disasters. The software's limitations require simplifying the modeling of the area's angles and directions into 90 degrees.

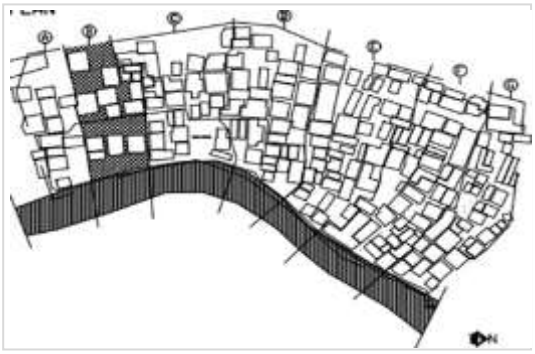

Figure 2. Observed area in Kampung Jogoyudan

The findings of this research aim to provide valuable insights for urban planning and policy development, ultimately aiming to create safer and more sustainable urban spaces in high-density areas prone to natural disasters.

Table 1. Number of observed research objects

Research objects	Number	TWM	Simulation
Alley	7	•	•
Houses	38	•	-

Results and discussion

In the results and discussion section, the data collected in the study conducted in Kampung Jogoyudan is analyzed and interpreted. This section will explore the characteristics of the housing layout and alleys and the challenges they pose to evacuation in this area.

Characteristics and challenges of evacuation inside the house

The characteristics of houses were identified based on the number of occupants, area, adequacy of living space per family member, circulation within the house, and the characteristics of the five dangers in each room. According to the survey, the average home in the surveyed area is occupied by 1-11 people, with an average of 4-5 people per family. Approximately 32% of the houses in Kampung Jogoyudan have an area below the standard adequacy of living space based on SNI 03-1733-2004, which is 9 square meters per person. Fortunately, more than 84% of the houses have more than one exit that can support evacuation during disasters (figure 3).

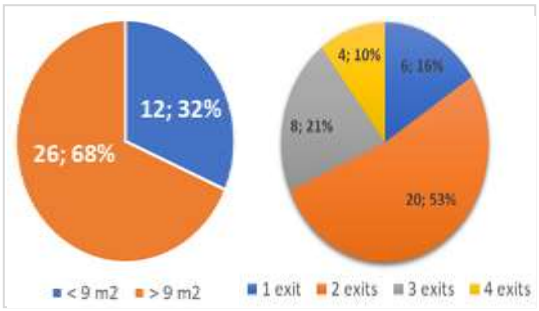

Figure 3. Living space sufficiency (left) and number of exits in the Kampung Jogoyudan area

In the case of Kampung Jogoyudan, this space insufficiency is addressed by dividing the space with stand-alone furniture such as cabinets or temporary dividers (curtains, screens, multiplex, etc.) to create privacy and needed spaces (figure 4 left). Additionally, the community utilizes multi-functional spaces, typically using the living room as a dining area and bedroom at night with changes in furniture layout (figure 4 right). Furniture in multi-functional spaces usually has a greater quantity and is placed on top of other furniture to support space effectiveness (figure 5). Due to limited space, items are not uncommon to be placed along circulation space (figure 6). In addition to the limited living space, this area also has limited parking spaces outside buildings. For security reasons, corridors and indoor circulation areas are often used as parking spaces for motorcycles and bicycles (figure 7).

Figure 4. Utilisation of stand-alone furniture (left) in the multipurpose room (right)

Figure 5. Stacked things on the top of furniture in a multipurpose room

Insufficient living space has a significant impact on quality of life. People living in areas with inadequate living space face challenges such as high population density, poor air quality, lack of access to open spaces, poor housing quality, and higher risk of disasters.

Figure 6. Things in the circulation spaces

Figure 7. Vehicles parking in the house circulation or multipurpose room

The evaluation was conducted on the arrangement of furniture inside the house. Based on the total number of hazards in the surveyed houses, it shows that the most danger is caused by objects that are easily rolled. Most easily rolled objects are caused by stacking items placed on top of furniture, resulting in a vertical arrangement configuration. This configuration naturally increases the chances of furniture toppling during an earthquake. Vertical or stacked furniture arrangements can be found in almost all types of rooms. Multipurpose rooms have a higher risk compared to other rooms (figure 8).

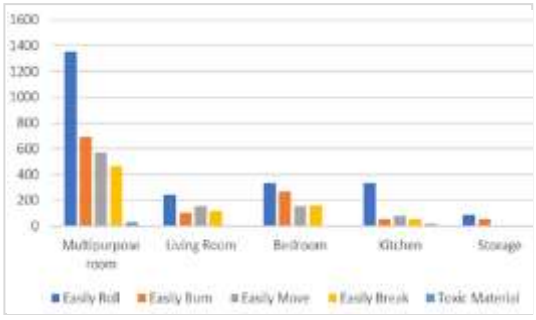

Figure 8. Number of 5 dangers by room function

Analysis of space adequacy in providing temporary shelter during the earthquake is conducted by comparing the safe area coverage of 5 dangers to the total room area. Objects and furniture are simulated to have been affected by the five dangers during the earthquake. It shows that the room with the lowest percentage of safe space is the multipurpose room (figure 9). This finding is consistent with the finding in figure 8. This can imply that greater the number of 5 Dangers objects tends to decrease the presence of safe space for temporary shelter during the earthquake.

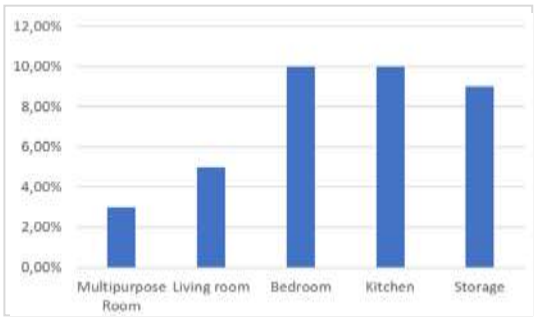

Figure 9. Average area of safe place by the room function

Character and challenges of evacuation in the allies

The circulation characteristics discussion consists of the physical attributes of circulation, corridor and Walkway width analysis, and the placement characteristics of furniture in the walkway area. Circulation in Kampung Jogoyudan can be classified into two types, which are vertical circulation and horizontal circulation. Based on their services, circulation can be divided into two types of services: walkways and corridors (figure 10). Walkways are usually more open, have more natural light, and typically serve only one side of the building. Meanwhile, corridors are narrower, more enclosed, and serve two sides. The corridor circulation stretches horizontally along the river at the bottom and the road at the top. Corridor circulation dominates the east-west direction, connecting the upper and lower walkway circulation of the area. Vertical corridor circulation usually consists of ramps or stairs to accommodate the unique extreme land contours in riverbank areas (figure 11 and figure 12). The vertical and horizontal circulation placement in the observation area can be seen in figure 13. This study observed 183 segments of flat circulation roads, 38 stairs, and 38 vertical circulation ramps. Corridor and circulation width measurements were also conducted in this study.

According to the Guidelines for Natural Disaster Evacuation Routes from Tsunamis, (Kementrian Pekerjaan Umum dan Perumahan Rakyat 2023), the minimum evacuation route width is 3.5 meters. However, the corridor and walkway widths in the road segments are dominated by circulation with widths of 0.6-1.8 meters. Only 7 out of 276 road segments, or 2.54% of the circulations, meet evacuation standards (figure 14). This condition is exacerbated by furniture placement in the circulation path (figure 15). The limited space inside buildings and the lack of parking allows residents to use the already narrow circulation areas as extended rooms from the indoor space. This results in a reduction in the effective area that can be used for circulation. Residents often use circulation routes to dry clothes, shops/stores, motorcycle parking, fish ponds, and greening.

Figure 10. Corridors (left) and walkway (right type of circulation

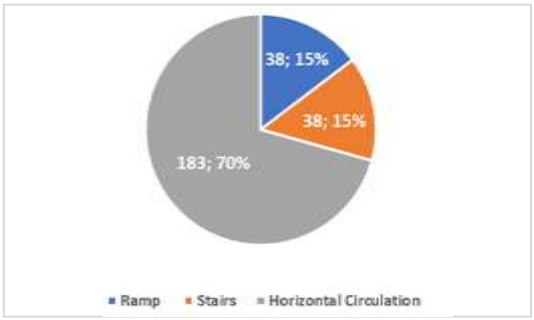

Figure 11. Percentage type of circulation

Figure 12. Ramp (left) and stairs (right) in Kmapung Jogoyudan

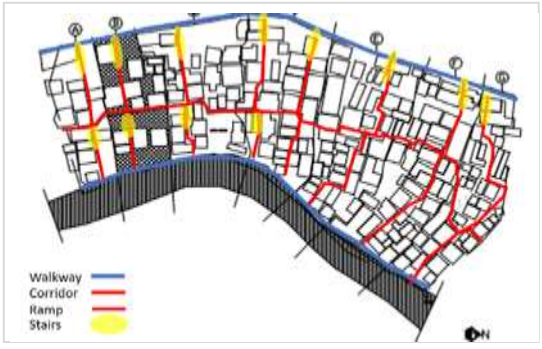

Figure 13. Placement of horizontal and vertical circulation

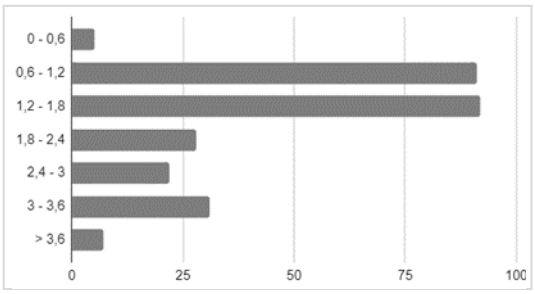

Figure 14. Goods and its five dangers characteristics in circulation space

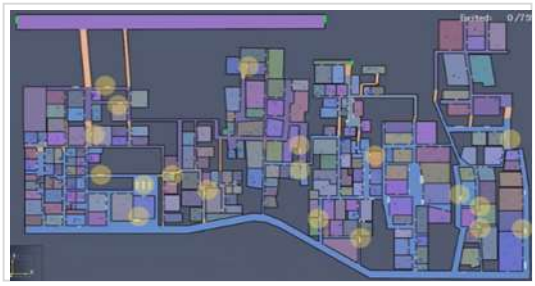

Figure 15. Mapping five dangers objects along the circulation routes

Analysis using a pathfinder was also conducted to determine the locations of mass accumulation during evacuation. This simulation used earthquake hazards followed by cold lava floods. Based on interviews, cold lava floods have occurred at a height of one meter, so according to (Rahayu and Anita 2013) the safe height for evacuation places is approximately 4.5 meters above the riverbank. The evacuation modeling is directed towards higher locations, specifically on the western (upper) part of the river. Based on the simulation results, mass accumulation occurs on the stairs in the upper part. Meanwhile, the stairs near the disaster source are still relatively smooth and passable. Density is also visible in the circulation intersections and turns that have a width of less than 2 meters (figure 16 and figure 17).

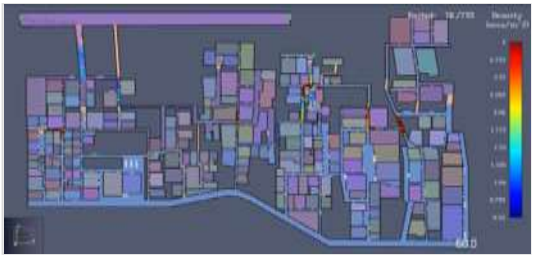

Figure 16. Pathfinder simulation of Kampung Jogoyudan

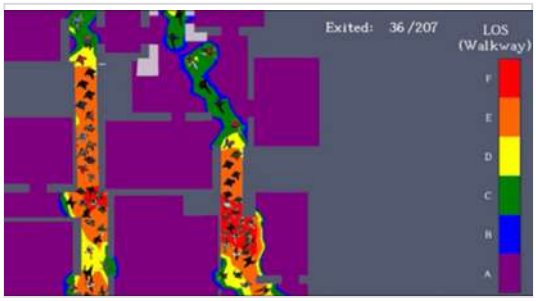

Figure 17. Evacuation challenges at the stairs

The text discusses the analysis and interpretation of data collected in a study conducted in Kampung Jogoyudan. The characteristics and challenges of evacuation inside houses and in the alleys are explored.

Regarding evacuation inside houses, the characteristics of houses were identified based on factors such as the number of occupants, living space per family member, and circulation within the house. This research clarify that approximately 32% of the houses have an area below the standard adequacy of living space. However, more than 84% of the houses have more than one exit, which supports evacuation during disasters.

The study also evaluated the arrangement of furniture inside the houses. It found that the most significant danger is caused by objects that are easily rolled, which is often due to stacking items on top of furniture. Multipurpose rooms have a higher risk compared to other rooms.

In terms of evacuation in the alleys, the circulation characteristics were analyzed. The circulation in Kampung Jogoyudan can be classified into vertical and horizontal circulation. Corridors and walkways serve as the circulation routes. However, the corridor and walkway widths in the area are mostly below the minimum evacuation route width. Furniture placement in the circulation paths further reduces the effective area for circulation. Additionally, residents often use the circulation routes for purposes other than evacuation, such as drying clothes, parking motorcycles, and setting up shops.

This research also highlights the presence of objects in the circulation areas that can hinder evacuation and cause secondary hazards, such as fires. Fragile objects from windows and glass doors along the circulation routes also pose a risk. The mapping of the five danger principles shows that these hazards can be found throughout the observation area. Simulation modeling was conducted to determine the locations of mass accumulation during evacuation. The results indicated that mass accumulation occurs on stairs and in narrow circulation intersections and turns.

In summary, the text provides an analysis of the characteristics and challenges of evacuation inside houses and in the alleys of Kampung Jogoyudan. It highlights issues such as insufficient living space, furniture arrangements, narrow circulation routes, and the presence of objects that hinder evacuation and pose secondary hazards.

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Author(s) contribution

Khaerunnisa contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Katarina Evelyn Koncuru contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Mikhellon Kwa contribute to methodology, supervision, and validation.