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Analysis of Evacuation Routes Effectiveness on Dormitory Building (Case Study: Rusunawa Putri UII, Yogyakarta)

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ABSTRACT

In emergency situations, effective evacuation routes are critical to minimize losses, especially in densely populated structures like the Rusunawa Putri UII dormitory in Yogyakarta. This study aims to assess the effectiveness of these evacuation routes by investigating how factors such as route capacity, width, accessibility, and exit availability influence evacuation efficiency. Using Pathfinder simulations and field observations, the research identifies significant bottlenecks, particularly at the staircases, which lead to evacuation times exceeding safety standards. The findings offer actionable recommendations, such as widening side staircases and reducing exit clutter, to enhance resident preparedness and safety. Ultimately, this research contributes valuable insights for improving evacuation protocols in similar residential buildings and informs future design considerations in architecture and emergency management.

Keywords: dormitory, emergency, evacuation, pathfinder, residential

1. Introduction

An emergency is any sudden event that disrupts urban spaces and requires immediate action [9]. Such events can threaten lives, property, and the environment, including natural disasters (earthquakes, floods, wildfires) and human-made disasters (fires, chemical spills, terrorist attacks). Evacuation refers to quickly moving people away from dangerous areas [7]. Effective planning of evacuation routes is essential for addressing emergencies, as it assists individuals in navigating to safety more efficiently and with greater assurance.

Figure 1 Rusunawa Putri UII, Yogyakarta
Source: (DSP UII, 2023)

In densely populated buildings like Rusunawa Putri UII in Yogyakarta (Figure 1), the necessity for effective evacuation routes becomes increasingly critical due to several factors. The complexity of human behavior in emergencies complicates the evacuation process, particularly in high-density environments [2] where the unpredictable dynamics of crowds can lead to panic, an intense state of anxiety that arises during emergencies, resulting in individuals crowding in a desperate attempt to seek safety that can lead to casualties [8]. Moreover, occupants may become disoriented and unaware of their surroundings, including the actions of others and the severity of the situation. This uncertainty fosters confusion and hesitation, potentially causing bottlenecks at exit points. Therefore, designing well-planned evacuation routes can facilitate a more efficient flow of occupants toward exits, significantly reducing the risk of panic and ensuring a safe evacuation for everyone involved.

To assess the effectiveness of evacuation routes at Rusunawa Putri UII, this study employs a simulation tool called Pathfinder. This tool is designed to calculate evacuation times and optimize routes by considering factors such as walking speed and obstacles [1]. By analyzing the building layout and exit points, Pathfinder can identify potential bottlenecks or issues that may slow down the evacuation process. This research aims to explore how these factors affect the effectiveness of evacuation routes at Rusunawa Putri UII during emergencies and also to evaluate how prepared residents are for evacuation, based on the time required to evacuate under current conditions. Furthermore, this study will provide recommendations on how evacuation routes at Rusunawa Putri UII can be improved based on the results of the Pathfinder simulations.

2. Method

2.1. Literature Review

Quick and safe evacuation during emergencies especially in densely populated dormitories is essential. Therefore, evacuation time analysis should be a primary focus in building design. Existing research highlights several important parameters for evaluating the evacuation routes of a building [12]. One important parameter to consider is the capacity and width of the paths. It is crucial to ensure that evacuation routes are wide enough to prevent congestion and allow for the simultaneous evacuation of many individuals [6]. Experimental studies and numerical simulations focusing on the evacuation process in dormitories [13] analyze crowd behavior during evacuations and highlight how the width of corridors and exits significantly influences evacuation time, discovering that staircases contribute to flow stratification.

Designers must create sufficiently wide pathways following standards, such as those outlined in Article 19 of the Minister of Public Works Regulation No. 60/PRT/1992 [7]. This regulation states that stairs must have a minimum width of 120 cm, with handrails 60-80 cm high. Additionally, the height of the steps should be between 15-18 cm, and the minimum width of each step should be 30 cm. Corridors or hallways within the building should also have a minimum width of 140 cm to allow two individuals to pass through simultaneously.

In addition to width, it is vital to ensure that evacuation routes are accessible from all areas of the building. This means that evacuation pathways must be obstacle-free so that all occupants can quickly reach the exits [4]. Any obstacles can slow down the flow of people, which is dangerous in emergency situations. The number and location of exits are also important to prevent crowding at a single point. By ensuring that exits are adequately distributed throughout the building, designers can help maintain a smooth flow during evacuations [5], particularly in densely populated dormitories, which can exacerbate congestion issues.

The distance to exits must also be considered to ensure it remains within a reasonable range, as excessively long distances can slow evacuation time and increase the risk of injury for occupants attempting to escape [5]. Furthermore, it is crucial to keep evacuation routes in good condition; these paths should be free from hazards such as broken stairs or blocked hallways to function effectively during emergencies [5]. Another important aspect is designing evacuation routes that are accessible to all occupants, including those with disabilities. Providing features such as ramps, handrails, and designated safe areas is essential to ensure that everyone can evacuate safely, taking into account the diverse needs of building occupants [4].

In addition to ensuring accessibility for all occupants, another equally important factor is the speed of evacuation itself. Guidelines from the SFPE (Society of Fire Protection Engineers) recommend an optimal and safe evacuation time for building occupants of 2.5 minutes or 150 seconds [11]. Research indicates that many deaths occur not from fire or smoke but rather due to mass panic and people trampling each other during evacuations [10]. Under normal conditions, individuals typically walk at a comfortable speed of about 1.34 m/s, with a standard deviation of around 0.26 m/s [3]. However, in panic situations, this speed can dramatically increase to more than 1.5 m/s. This spike in speed can significantly affect flow and safety in crowded environments, underscoring the importance of well-planned evacuation routes to ensure safe movement during emergencies.

2.2. Research Objective

This study aims to examine how well current evacuation routes work for safely and quickly evacuating people during emergencies in dormitories. Using Pathfinder simulation, the study will look at how people move during evacuations and find any problems in the routes. The goal is to give practical advice to decision-makers on how to improve evacuation plans and safety measures, making sure people stay safe during emergencies.

2.3. Scope

The study will focus on assessing the effectiveness of existing evacuation plans for the dormitory. Key factors to be considered in this assessment include the building layout, accessibility, occupant familiarity with the environment, and potential obstacles that may hinder evacuation. To facilitate this analysis and generate meaningful recommendations, the Pathfinder simulation will be employed as a modeling and identification tool. By leveraging this advanced simulation software, the study aims to provide a comprehensive evaluation of the evacuation routes and their effectiveness in ensuring the safety of the occupants during emergencies.

2.4. Research Methods

The Rusunawa Putri UII dormitory in Yogyakarta (Figure 2) was selected for this research due to its five-story design, which relies exclusively on staircases for vertical transportation. This choice allows for a focused examination of the specific challenges residents might face during emergencies. Initial data collection involved gathering information online and consulting with a friend residing in the dormitory to build a foundational understanding of the building's layout.

Figure 2 Location Rusunawa Putri UII, Yogyakarta
Source: (Google Maps, 2024)

A direct observation was conducted on June 5, 2024, where detailed measurements of key areas, including staircases and corridors, were taken. This on-site visit ensured that the collected data accurately reflected the actual conditions of the building. After gathering this information, various data points were compiled, including architectural floor plans, occupancy distribution, and details about occupant types. With this data, a 3D digital model of the dormitory was created for analysis.

The 3D model was utilized in Pathfinder software to simulate evacuation scenarios, with parameters set to reflect real-life conditions. This allowed for the calculation of evacuation times and identification of potential bottlenecks. The analysis of the simulation results revealed important metrics, such as total evacuation times and areas of congestion. Based on the simulation results were used to evaluate whether the existing evacuation routes and staircases meet safety standards and to understand how occupants would move during an emergency situation.

3. Result and Discussion

The dormitory is in Krawitan, Umbulmartani, on UII's Main Campus along Kaliurang Street. It covers approximately 1,280 square meters and measures 62 by 20 meters, equipped with three staircases—one main staircase centrally located and two smaller side staircases at either end. However, it lacks accessibility features such as elevators and ramps, indicating that it does not meet the critical parameter for accommodating individuals with disabilities. This initial observation aligns with the research aim to evaluate the effectiveness of evacuation routes during emergencies, especially for residents with varying needs.

Figure 3 (a) Ground Floor Plan; (b) Second-Fifth Floor Plan
Source: (Direct Observation, 2024)

This five-story dormitory houses hundreds of female students and features various amenities, including bedrooms, shared bathrooms, study rooms, classrooms, kitchens, and communal spaces. It also facilitates campus religious activities for newcomers and provides temporary accommodations for international students. The ground floor (Figure 3a) serves as a meeting room and classrooms, while the upper floors (Figure 3b) contain 4x5 meter bedrooms, each shared by two residents. With 24 rooms per floor, the upper levels can accommodate a total of 192 students, along with two guards and two staff members, bringing the total occupancy to around 200 people.

From the second to the fifth floors, some corridors (Figure 4) encircle the building, measuring 150 cm in width and bordered by 80 cm high railing walls. From this condition, it can be seen that the existing corridor dimensions already meet the standards set by the Ministry of Public Works Regulation [7], which requires corridors to have a minimum width of 140 cm.

Figure 4 Second-Fourth Floor Corridor
Source: (Direct Observation, 2024)

The building features a main entrance located on the south side (Figure 5a), which includes a double-leaf door that is 1.3 meters wide. On the north side (Figure 5b), there is a smaller single-leaf exit door. Additionally, there are side exits (Figure 5c) on both the right and left, each equipped with a double-leaf door of the same size as the main entrance. The south exit is the most accessible due to its strategic placement and width, while the other three doors are less accessible due to cluttered surroundings that may obstruct users, particularly in an emergency.

Figure 5 (a) South Entrance; (b) North Entrance; (c) Side Exit
Source: (Direct Observation, 2024)

The building includes three staircases, with the main staircase (Figure 6a) positioned centrally and aligned with the exit, providing the best access due to its larger dimensions. This staircase consists of 18 steps, featuring a riser height of 20 cm and a tread width of 28 cm, with an overall width of 140 cm. In contrast, the side staircases (Figure 6b) are narrower at 100 cm, which does not comply with standard requirements specifying a minimum width of 120 cm, a riser height between 15-18 cm, and a minimum tread depth of 30 cm. The inadequate design of the side staircases underscores the necessity for careful planning and design, as staircases are vital for safe evacuation in multi-story buildings [6].

Figure 6 (a) Main Stairs; (b) Side Stairs
Source: (Direct Observation, 2024)

Based on the collected data, which includes the estimated population of 200 occupants, floor plan configuration, staircase sizes, corridor widths, and other essential factors, an analysis was conducted using Pathfinder. The results (Figure 7a) indicate a clear preference for the main staircase over the side ones, shown by the fewer purple lines leading to the side stairs and the notable congestion at the main staircase. The simulations revealed that evacuating 200 occupants took 190 seconds, or 3 minutes and 10 seconds (Figure 7b), surpassing the optimal evacuation time of 2.5 minutes established by SFPE standards [11].

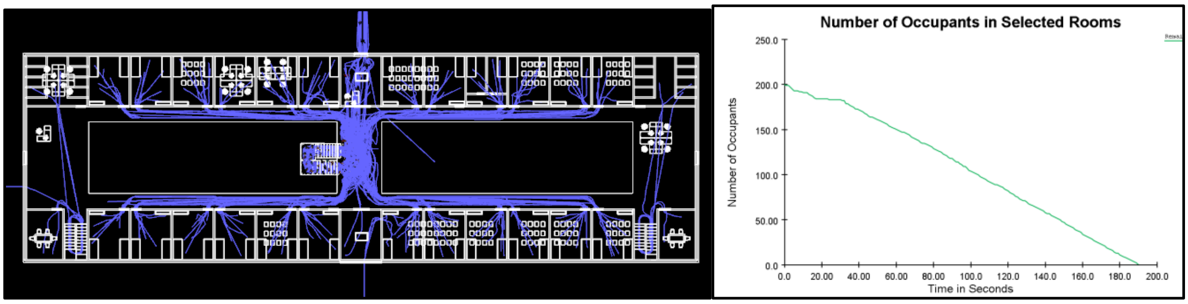

Figure 7 (a) Congestion of Users at The Main Staircase; (b) Pathfinder Analysis Result
Source: (Pathfinder Simulation, 2024)

The simulation revealed several challenges that affect both the efficiency and safety of evacuation in the Rusunawa Putri UII dormitory. A major bottleneck was identified at the central staircase, which most occupants favored due to its larger size and convenient access to the main exit. To enhance the evacuation routes at the dormitory, it is recommended to widen the side staircases (Figure 8) to better accommodate a greater number of people simultaneously. This modification would reduce the reliance on the central staircase, thereby alleviating congestion and significantly improving evacuation flow. However, these enhancements may necessitate the restructuring of surrounding areas to ensure effective implementation.

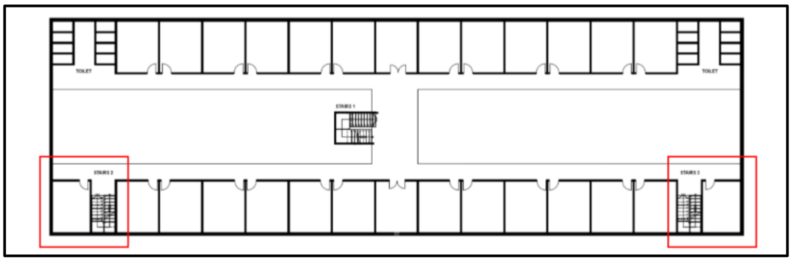

Figure 8 Areas that can be improved
Source: (Author, 2024)

The plan includes expanding the side staircase, initially 100 cm wide, to match the 140 cm width of the central staircase (Figure 9). This adjustment aims to enhance both accessibility and ease of movement within the building. Furthermore, the riser height will be adjusted to 18 cm, and the tread depth will be ensured at 30 cm to comply with existing safety standards.

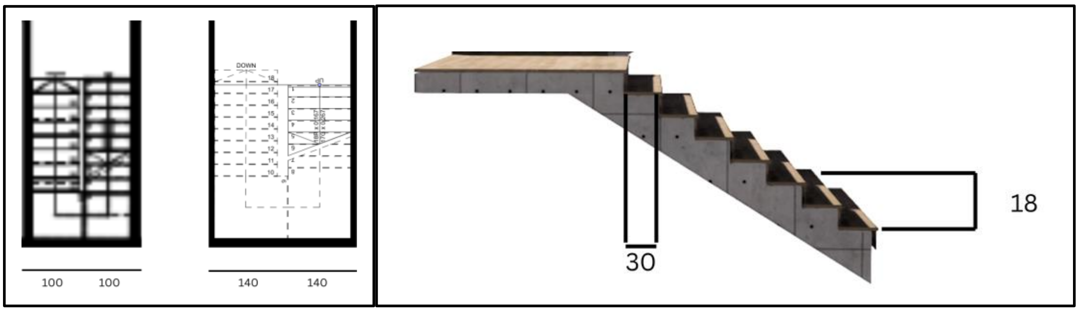

Figure 9 Illustration of Recommendation Staircases Size
Source: (Author, 2024)

With these modifications, Pathfinder simulations indicate that evacuating 200 occupants from the Rusunawa Putri UII building now only requires 82 seconds, or 1 minute and 22 seconds (Figure 10b). This marks a substantial improvement from the previous conditions, ensuring efficient compliance with safety standards and fostering a more effective evacuation process for residents during emergencies.

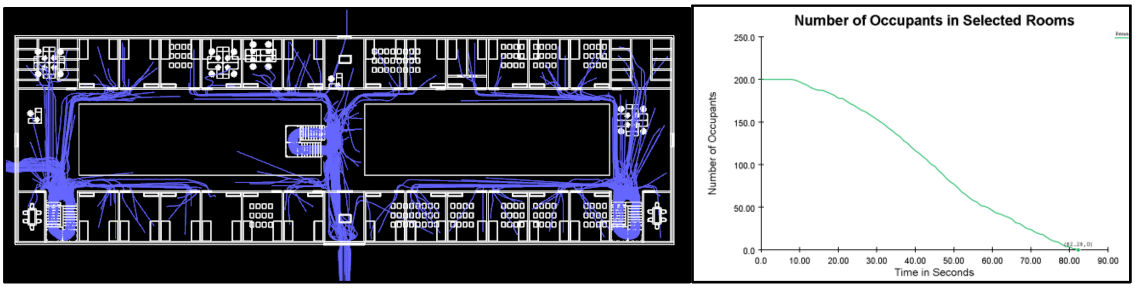

Figure 10 (a) Pathfinder Simulation Result; (b) Pathfinder Analysis Result
Source: (Pathfinder Simulation, 2024)

The simulation results indicate that the effectiveness of evacuation routes at Rusunawa Putri UII is significantly influenced by the current design, particularly the bottleneck at the central staircase, which hinders efficient evacuation. Additionally, the findings reveal that residents are inadequately prepared for swift evacuation under existing conditions, as evidenced by evacuation times exceeding recommended standards. These insights not only highlight areas for improvement but also provide actionable recommendations to enhance evacuation preparedness and overall safety during emergencies.

These findings align with existing literature, which emphasizes that bottlenecks and inadequate egress routes are prevalent issues in emergency evacuations. Studies, such as those by Lei, et al. (2019) [6], highlight that timely evacuation relies heavily on well-designed pathways. By providing actionable recommendations, this research not only enhances safety protocols at Rusunawa Putri UII but also contributes to broader discussions in the fields of architecture and emergency management. Ultimately, the insights gained can guide future designs of dormitory buildings, ensuring they better support efficient evacuation and occupant safety.

4. Conclusion

The simulations clearly reveal that the evacuation routes at Rusunawa Putri UII are inadequate due to several critical factors, such as route capacity, width, accessibility, the number of exits, and their distances. The narrow and isolated positioning of the side staircases exacerbates accessibility issues, particularly since they do not comply with standard dimensions. Consequently, it is evident that Rusunawa Putri UII is ill-equipped to handle emergencies effectively.

To directly address the research question concerning improvements to evacuation routes and resident preparedness, specific recommendations are crucial. Key enhancements include widening the side staircases to accommodate a greater number of individuals, modifying staircase dimensions to meet safety regulations, and minimizing clutter around exits. Implementing these adjustments will significantly improve the dormitory's capacity to manage emergencies efficiently and safely. Adopting a proactive approach to safety standards in building design is essential to prevent extensive renovations and ensure user safety during emergencies.

To build upon this research, further investigations could focus on implementing the recommended improvements and evaluating their effectiveness through controlled evacuation drills at Rusunawa Putri UII. Assessing how modifications, such as widening staircases and minimizing exit clutter, affect evacuation flow and reduce bottlenecks will be crucial. Additionally, exploring the impact of various emergency scenarios on evacuation efficiency and resident preparedness could yield valuable insights. Long-term studies aimed at understanding residents' retention of evacuation procedures may also enhance safety training and preparedness initiatives within dormitory settings.

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6. Conflict of Interest

The authors declare that there are no conflicts of interest related to the preparation, publication, or content of this manuscript.

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