Tsunami evacuation building model (TEBM) in Teluk Palu (Palu Bay) area

M Bakri¹, R Awalia¹, S Mulyati¹, F Zubaidi¹, M Rusydi², A A Kasim³, R Prawita⁴

¹Department of Architecture, Faculty of Engineering, Tadulako University, Palu, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences, Tadulako University, Palu, Indonesia
³Department of Informatics, Faculty of Engineering, Tadulako University, Palu, Indonesia
⁴Study Program of Architecture, Faculty of Engineering, Tadulako University, Palu, Indonesia

Email  : embakri@gmail.com

Abstract. The research was conducted in the coastal area of Palu Bay, Lere Village. Data were collected using observation, interviews, and literature study techniques. The data were analyzed using qualitative descriptive methods and focused on the concept of the design of the tsunami evacuation building on the coast of Palu Bay. Data analysis was carried out to obtain an overview of the problems that occurred at the planning location which was analyzed with the concept of architectural design by considering the existing conditions of the site and the surrounding environment, as well as utilizing the potential of the site so that it has the potential for building functions. The conclusion obtained is based on the results of data analysis, it is necessary to have a building that can function as an evacuation container for the community when a disaster occurs in the coastal area of Palu Bay, thereby reducing the number of casualties. The benefit of this research is that it is a solution for local people to save themselves when the tsunami disaster.

Keywords: Tsunami, Evacuation, Building, Palu Bay

1. Introduction

Tsunamis are a threat of disaster for many coastal areas in Indonesia. Tsunamis are generally triggered by an earthquake in the sea which causes a vertical shift in the seabed. Tsunami threat analysis is carried out to determine the character of tsunamis that may have occurred or will occur by considering the source mechanism, location, wave propagation, tsunami wave propagation, and the height of the tsunami inundation. A tsunami is a disaster with the character of a fast-onset disaster or a type of disaster with a fast process. Tsunamis can occur from a near field location with a propagation time of fewer than 30 minutes from the source to the monitoring coastline and far-field locations with the propagation time to the monitoring shore area longer than 30 minutes or the tsunami source has a distance further than 1000 km. Tsunami threat characters tend to be site-specific. This leads to the need to analyze these threats and avoid the generalization process. The character of tsunami events in Indonesia is generally local, where the distance to the source of the tsunami is relatively close so that it only has a short time to anticipate or evacuate[1]. Tsunami disaster mitigation efforts in coastal areas require a building model that can be used as a place for community evacuation when a tsunami occurs.
One of the evacuations carried out in tsunami disaster mitigation is vertical evacuation where the community will look for upland areas. Development of evacuation structures in coastal areas that are at risk of a tsunami must pay attention to whether the buildings remain safe during the earthquake and tsunami and whether people can reach the evacuation building in a short time and find an evacuation space[2]. One of the evacuation structures developed in Japan in 2011 is the Tsunami Vertical Evacuation (TVE). The TVE structure saved many lives in the 2011 Great East Japan earthquake. The Palu Bay area as one of the areas that are at risk of having a tsunami impact in Palu City requires various tsunami disaster mitigation efforts. This study will analyze the Tsunami Evacuation Building (TEB) model which can be used as an evacuation building in the Palu Bay area. This research will focus on an evacuation building model that can be built in the Palu Bay area with a structural design that is safe for earthquakes and tsunamis as well as an easy to reach and safe location for evacuation in the Palu Bay area.

2. Methods

Evacuation, whether initiated by individuals or managed by public officials has an important role to play in saving lives from natural disasters. There are many studies to determine evacuation models such as demographic, contextual, and warning messages that influence and motivate individuals to evacuate[3]–[7]. For example, demographic attributes related to gender, ethnicity, household size, caregiver status, education level, and age. These factors have been documented to predict evacuation behavior, such as other factors such as risk perception, length of stay in an area, previous disaster experience, and trust in warning sources[8].

The tsunami vertical evacuation strategy is designed to provide safe protection in tsunami-stricken areas by offering a sufficient height above the maximum water level. In the event of a tsunami near the field, vertical evacuation can be an alternative protective measure against horizontal evacuation [9]. Safe heights can be provided in artificially raised open ground or towers specially designed for evacuation. Research related to the construction of a vertical evacuation building for Tsunami Vertical Evacuation (TVE) Building has been carried out in various countries with the potential for a tsunami, one of which is Japan. The Japanese government has led an initiative in the preparation of vertical evacuation guidelines for the construction and management of tsunami vertical evacuation buildings (TVEB), in early 1982 in Kesennuma City, Japan [10]. Tsunamis present interesting challenges for evacuation planners with a range of evacuation characteristics. Local earthquakes can create tsunami waves that arrive within tens of minutes of an earthquake occurring, are preceded by significant ground shaking that alter the evacuation landscape, and represent a significant threat to life safety. As a result, emergency evacuations usually emphasize individually initiated pedestrian-based evacuations. This research has shown that individuals at risk have used vehicles to evacuate during the local tsunami disaster. To achieve the research objectives, data processing and analysis was carried out in four stages.

The first stage is editing, namely checking/checking the completeness and correctness of the data that has been obtained either from the results of observations, interviews, questionnaires, and documentation techniques. The second stage is data reduction, including the allowance for considered data less related to research, so the remaining data can be compiled in a simpler form. The third stage is the grouping of primary and secondary data and then comparatively analyzed to determine the function of the data further, whether as a concept support or as a conceptualization. The final step is data analysis using macro and micro analysis methods. The flow of data processing techniques in this study can be seen in Figure 1.
Data analysis that has been collected during the study was carried out by using macro and microanalysis methods. The macro analysis includes site analysis of sun and wind, circulation, noise, view, and outdoor layout. Meanwhile, macro data analysis includes architectural design approaches, namely the function of space, the activity of actors, space requirements, the amount of space, the pattern of space organization, structure, and utility as well as the image of the building, namely the shape of the building. The synthesis stage interprets and concludes the results of the analysis that lead to the right concept and design as an architectural solution with an effective structural system. The analytical steps to produce a Tsunami evacuation building model can be seen in Figure 2.

![Figure 1. Proposed method for building the Tsunami Evacuation Building Model (TEBM)](image)

3. Result and Discussion
Selection of site locations for the planning of Tsunami Evacuation Buildings. On the coast of Palu Bay, an alternative location was planned based on the potential and problems that have occurred around the site. The first alternative, the site is located in the East Palu District, West Besusu Village, Raden Saleh street, Hotel Palu Golden, the location description can be seen in Figure 3.
The potential at the location has the potential to support the function of the building as an evacuation building, a short distance from the position around the coast, a densely populated environment, and provincial road access. The second alternative, the chosen location is in the area of the State Islamic Institute (IAIN) Palu, precisely located between Diponegoro Street and Squid Street. This location is the right location to build a tsunami evacuation building on the Pesisi Teluk Palu, because looking at the description of the location and considering the incident that occurred on September 28, 2018, which resulted in many casualties around the location. The second alternative location can be seen in Figure 4.

The concept of a site zoning system in a tsunami evacuation building aims to organize and create space groups according to the activities of the building so that there are no errors in the arrangement between the zones and the creation of harmonious functions of existing facilities on the site. In this zoning site, the potential and site conditions in the area greatly influence the zoning results so as to produce a good layout that supports the overall function.

Based on the existing criteria, the zoning system on the site is divided into:
a. Zone of impact
The affected zone is the area or place that is affected by the tsunami in the vicinity of the site and how to handle it.

b. Zone of Tsunami Evacuation
The evacuation zone is the main object in the site that involves all the people who come during a tsunami emergency.

c. Zone countermeasures plan
This zone includes a disaster mitigation zone using green zone safety systems and breakwaters. The green zone is a plant that can prevent coastal abrasion and tsunamis and can withstand the crashing of seawater along the coast which is positioned inside the building while the breakwater is a pile of certain formations made of Benton rebates positioned outside the site on the seafront. Zone mapping can be seen in Figure 5.

![Zone of Impact Zone of Tsunami Evacuation Zone of Countermeasures](image)

**Figure 5. Zone Mapping of TEBM**

To obtain a building design that is following the function of the tsunami evacuation building, adjustments to the shape concept are made by transforming the formations of triangles, circles, squares and iconic natural forms that are used as shapes that are under their main function and are generally attractive to the eye. The transformation model can be seen in Figure 6.

![Model Transformation of TEBM](image)

**Figure 6. Model Transformation of TEBM**

The square shape has added shapes on the right and left sides which can be seen to resemble the shape of a ship, because this building functions as an evacuation building, the function of this building adapts to the shape of the building so that the merging of the two transformations of the square and the shape of the boat produces a simple and iconic design. The shape of the tsunami evacuation building can be seen in Figure 7.
4. Conclusion
The Tsunami Evacuation Building on the Teluk Palu (Palu Bay) is realized with a micro and macro analysis approach that plans based on the analysis and synthesis of problems for human needs and utilizes all information obtained from sources, media, and so on to produce designs. Apart from its main function as an evacuation site, this building can also be a place for educational education about disasters. The concept of shape by transforming triangles, circles, squares, and iconic natural shapes.

References
[1] M. R. Amri et al., *Risiko Bencana Indonesia*. 2006.
[2] J. W. McCaughey, I. Mundir, P. Daly, S. Mahdi, and A. Patt, “Trust and distrust of tsunami vertical evacuation buildings: Extending protection motivation theory to examine choices under social influence,” *Int. J. Disaster Risk Reduct.*, vol. 24, no. June, pp. 462–473, 2017, doi: 10.1016/j.ijdrr.2017.06.016.
[3] J. LIM, M. LIM, and M. PIANTANAKULCHAI, “Factors Affecting Flood Evacuation Decision and Its Implication to Transportation Planning,” *J. East. Asia Soc. Transp. Stud.*, vol. 10, pp. 163–177, 2013, doi: 10.11175/easts.10.163.
[4] D. Sun, J. E. Kang, R. Batta, and Y. Song, “Optimization of evacuation warnings prior to a hurricane disaster,” *Sustain.*, vol. 9, no. 11, pp. 1–29, 2017, doi: 10.3390/su9112152.
[5] S. Lamb, D. Walton, K. Mora, and J. Thomas, “Effect of authoritative information and message characteristics on evacuation and shadow evacuation in a simulated flood event,” *Nat. Hazards Rev.*, vol. 13, no. 4, pp. 272–282, 2012, doi: 10.1061/(ASCE)NH.1527-6996.0000070.
[6] W. Soviana and H. A. Rani, “Study of alternative building for tsunami evacuation in Kuta Alam sub-district Banda Aceh,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 674, no. 1, 2019, doi: 10.1088/1757-899X/674/1/012021.
[7] K. Penuel and M. Statler, “Evacuation Planning,” *Encycl. Disaster Reli.*, 2014, doi: 10.4135/9781412994064.n76.
[8] N. Wood, J. Jones, J. Peters, and K. Richards, “Pedestrian evacuation modeling to reduce vehicle use for distant tsunami evacuations in Hawai’i,” *Int. J. Disaster Risk Reduct.*, vol. 28, no. November 2017, pp. 271–283, 2018, doi: 10.1016/j.ijdrr.2018.03.009.
[9] A. Mostafizi, H. Wang, D. Cox, and S. Dong, “An agent-based vertical evacuation model for a near-field tsunami: Choice behavior, logical shelter locations, and life safety,” *Int. J. Disaster Risk Reduct.*, vol. 34, no. December 2018, pp. 467–479, 2019, doi: 10.1016/j.ijdrr.2018.12.018.
[10] S. Fraser, G. S. Leonard, H. Murakami, and I. Matsuo, “Tsunami Vertical Evacuation Buildings – Lessons for International Preparedness Following the 2011 Great East Japan Tsunami,” *J. Disaster Res.*, vol. 7, no. October 2011, p. 12, 2012.

Acknowledgement
This work supported and funding by DIPA BLU Fakultas Teknik Universitas Tadulako in scheme Penelitian Unggulan in 2020 (Grant No. 647.i/UN28.2/PL/2020)