Spatiotemporal Analysis of Tsunami Vertical Evacuation:

A Case Study of the Shizuoka Metropolitan Area

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Abstract

The city of Shizuoka is the capital city of the Shizuoka prefecture is located in central Japan. The geographic position of the city gives it a special role in the area, as major transportation networks such as rail and highways that connect North and South Japan go through the city constituting it a central node in Japan's Geography. At the same time, the city directly faces the Nankai Trough, which is expected to give a major tsunamigenic earthquake every 100 to 200 years. A tsunami generated by such an earthquake could have major implications to the lives of the city's residents, even from the very first moments of the tsunami when they will need to escape. As such, there is a need to study the potential for a vertical evacuation in the city in order to provide multiple options for safe refuge in such an event.

This study has the main objective of finding vertical evacuation sites among the currently existing buildings in the city, an approach that allows fast results in the face of immediate danger, and to analyze their potential for vertical evacuation by examining how these buildings become inundated under variable tsunami scenarios, and how the city's population moves throughout them in different times of the day leaving increased or decreased volume available for evacuation. A wide range of Geographic Information System (GIS) datasets, as well as demographical and people flow movement data were used in order to (a) calculate the inundation ratio of buildings in Shizuoka City, (b) calculate the volume loss of buildings due to tsunamis based on the inundation ratio, (c) estimate the building population of the buildings in Shizuoka over 24 hours of the day and (d) introduce criteria per tsunami scenario in order to estimate how many people can be accepted in each building for evacuation based on the variable population.

The approach of this research has indicated that for four different tsunami scenarios (5m, 10m, 20m, and 34m run-up) there are 3204 potential vertical evacuation sites for the 34m scenario, 10,426 potential vertical evacuation sites for the 20m scenario, 2,046 potential vertical evacuation sites for 10m scenario, and 1643 potential vertical evacuation sites for the 5m scenario.

The analysis of the people movement over 24 hours has shown that there are discreet population distribution patterns depending on the time of the day. In the daytime, people are concentrated in the CBD for work and the other areas of the city are less populated, while in the nighttime the majority of the population is at home and distributed at the whole extent of the city. Finally, there are morning, noon and evening transit hours where great parts of the population are in transit, and outside buildings, at different locations in the city based on their transportation method. Concerning the capacity to accept people for vertical evacuation, the temporal population estimation and volume loss calculation indicate that on all four scenarios, the maximum total capacity to accept evacuees is achieved at 10am in the morning, with the 5m scenario sites allowing for 608,948 people to be accepted in the vertical evacuation sites, the 10 meter scenario allowing for 1,746,543 people to be accepted, the 20m scenario allowing for 5,764,030 people to be accepted, and the 34m scenario allowing for 1,865,315 people to be accepted. These numbers indicate that a majority of the city's population can be evacuated in potential evacuation sites that meet this study's criteria, within the tsunami flood zone of each scenario, greatly reducing the need for movement outside the tsunami flood. The approach further reveals, that this can be achieved by utilizing only existing buildings in the city without the need for additional construction. The 24h building population estimation method used allows for anticipating a building's population and capacity to accept evacuees during different times of the day allowing for temporal optimization of evacuation.

This study contributed in better understanding of how a moving population affects building population throughout the day and therefore the potential for vertical evacuation during different times of the day. The approach used in this research combines methods from different fields of Geography and GIS into a new approach that can be used in different locations that meet the data requirements, producing similar results that can be used by interested parties such as disaster planners, emergency managers and other Geographers in order to produce enhanced and optimized vertical evacuation plans.

Keywords: Building Population Estimation; GIS; Shizuoka; Tsunami; Vertical Evacuation

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