



# Vulnerability of Schools in Puerto Rico to Tsunami Events

## Case Studies: Loíza, Mayaguez, and Toa Baja



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### Abstract

This research extends the vulnerability analysis of schools to the municipalities of Loíza, Mayaguez, and Toa Baja. The analysis is performed based on their evacuation time to reach a safe zone in a tsunami-like event. This was achieved by identifying the schools in the hazard zone, assembly points, evacuation routes, determining the evacuation times, and evaluating the routes conditions by virtual inspection. The finding of this study show that the majority of the schools in these towns, with exception of five, fail to meet a 20-minute threshold of evacuation time, with Loíza posing as the most critical out of the three towns. Additionally, all three towns showed poor condition of the pedestrian evacuation routes infrastructure, unbalanced number of primary services, and lack of signage. The study presents some recommendations to improve their condition.

### Introduction

Tsunamis have the potential to cause devastating damage to coastal regions worldwide, and Puerto Rico is no exception. PRSN (n.d.) as well as FEMA (2018) warns that Puerto Rico has a high potential for tsunami-generating events due to their proximity to earthquake-prone regions and underwater landslides, such as the Puerto Rican Trench.

Assessing the vulnerability of schools in Puerto Rico during tsunami events is crucial, given that schools are not only educational institutions but also serve as shelters and voting centers. Previous research by Pacheco-Crosetti et al. (2021) assessed the conditions of evacuation routes and evacuation times for public and private schools in San Juan and Cataño. This study assess the cities of Toa Baja, Mayaguez, and Loíza by determining the evacuation times to reach the nearest assembly point using the guidelines provided by the Pedestrian Evacuation Analyst (2014).

### Objective and Scope

Extend the previous vulnerability analysis of schools (Torres, Cohen, 2021) to the towns of Loíza, Mayaguez, and Toa Baja.

Locate schools, assembly sites, evacuation routes, primary services, and evaluate evacuation time and route condition.

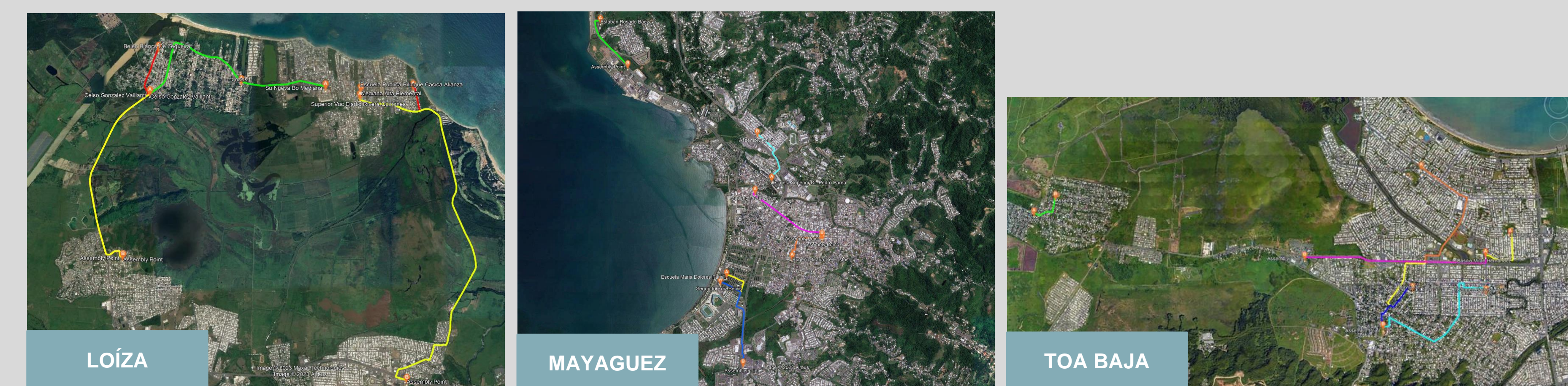
Analyze the evacuation routes and times for schools in the hazard zone of these cities.

Identify obstacles that could delay evacuation and recommend improvements to the existing evacuation routes education, as well as identify alternative safe zones to minimize potential losses in the case of a tsunami event.

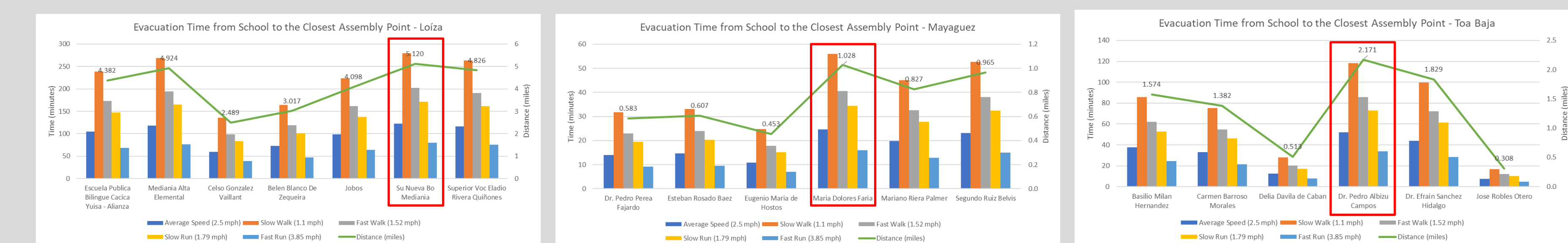
### Methodology

#### 1 Identify Schools, Assembly Points, Evacuation Routes, and Primary Services

City	School	Number of Students (2021)	Number of Teachers (2021)	In the Hazard Zone?
Loíza	Escuela Publica Bilingue Cecilia Yusa - Allanca	34	5	Yes
	Mediana Alta Elemental	354	29	Yes
	Guillermo Rosado De Ayala	189	40	No
	Celia Gonzalez Vallant	308	22	Yes
	Belem Blanco De Zaqueira	365	31	Yes
	Isidro	270	21	Yes
	Su Nueva Bo Mediana	298	22	Yes
	Superior Voc. Eladio Rivera Quiñones	498	34	Yes
	<b>Total</b>	<b>2716</b>	<b>298</b>	<b>8</b>
	<b>Total in the THZ</b>	<b>2127</b>	<b>164</b>	<b>7</b>



#### 2 Determine Evacuation Times



#### 3 Evaluate Routes Conditions by Virtual Inspection



City	Number of Emergency Services							
	In Town				In a 5km Radius			
	Police Stations	Hospitals and EMS	Fire Stations	Total	Police Stations	Hospitals and EMS	Fire Stations	Total
Loíza	1	1	1	3	3	3	3	9
Mayaguez	1	21	1	23	2	21	3	26
Toa Baja	1	2	1	4	3	13	3	19

### 4 Conclusion and Recommendations

The majority of schools located in the evaluated areas (16/21, 76%) fail to meet the threshold of 20 minutes for evacuation. For instance, in Loíza, at average speed, the evacuation times ranged from 55 minutes to 125 minutes.

Also, there was noticed poor road conditions, lack of necessary infrastructure, and urban furniture/hazards that can cause delays during evacuation.

The study recommends analyzing the possibility of using schools as vertical evacuation sites or constructing new vertical evacuation buildings for those schools. Loíza should be given priority.

Improve the evacuation routes by reallocating urban furniture, improving signage, and adding sidewalks where they are nonexistent. Prioritizing pedestrian safety is essential to ensuring that they can evacuate the area safely and quickly in the event of a disaster, as an integral part of a resilience improvement analysis.

### 5 Ongoing Work

Assessment of the existing assembly sites

Identification of alternative safe zones/assembly sites

Identification of buildings that may serve as vertical evacuation shelters

### Main References

Torres Rodríguez, V. A., & Cohen Viquez, J. A. (2021, September 17). Vulnerability of schools in Puerto Rico to tsunami events. PRCR Principal. Retrieved April 23, 2023, from <https://prcrepository.org/xmlui/handle/20.500.12475/1166>

Disidier, O. M., Luis, F., & Soto, J. C. (2022). Anuario Estadístico del Sistema Educativo Instituto de Estadísticas. Retrieved November 15, 2022, from <http://www.estadisticas.pr>

(2018). Guidelines for Design of Structures for Vertical Evacuation from Tsunamis. FEMA. [https://www.fema.gov/sites/default/files/2020-08/fema\\_eartquakes\\_guidelines-for-design-of-structures-for-vertical-evacuation-from-tsunamis-fema-p-646.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_eartquakes_guidelines-for-design-of-structures-for-vertical-evacuation-from-tsunamis-fema-p-646.pdf)

Jones, J.M., Ng, P., Wood, N.J., 2014. The pedestrian evacuation analyst—Geographic information systems software for modeling hazard evacuation potential: U.S. Geological Survey Techniques and Methods, book 11, chap. C9, 25 p., <http://dx.doi.org/10.3133/tm11C9>

(n.d.). TSUNAMI PROGRAM. PRSN. Retrieved April 23, 2023, from <https://redsisica.uprm.edu/english/tsunami/>

### Acknowledgements

- Undergraduate Research Program for Honor and Outstanding Students (URP-HS) for the opportunity of performing this research
- Dr. Gustavo E. Pacheco and Dr. Héctor J. Cruzado for their mentorship