PUERTO RICO SCHOOL EVACUATION TIME ESTIMATES IN CASE OF TSUNAMIS

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Abstract

This study evaluates total tsunami evacuation times for selected coastal public schools in Puerto Rico. Previously estimated travel times were expanded by incorporating earthquake strong-motion duration, occupant reaction time, and school building evacuation time to determine the Required Safe Egress Time (RSET). RSET was compared with an Available Safe Egress Time (ASET) of 20 minutes. Results show that accounting for these additional components substantially increases evacuation-time estimates, causing several schools to exceed the available time and indicating the need for additional mitigation strategies.

Introduction

Puerto Rico's location within an active tectonic region exposes the island to significant earthquake and tsunami hazards, making timely evacuation critical for vulnerable coastal communities. Previous studies have estimated tsunami evacuation times for public schools located within hazard zones, providing an important basis for assessing school vulnerability and the ability of occupants to reach safety within the available evacuation time.

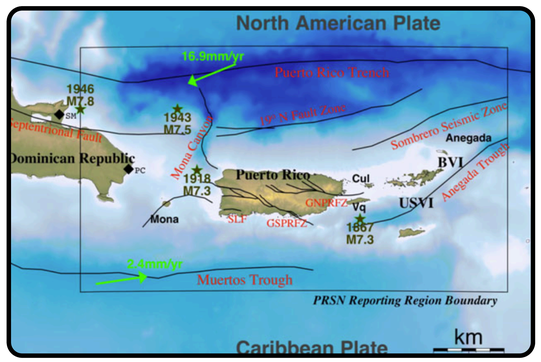


Figure 1. Tectonic setting and major seismic zones of Puerto Rico.

Region	Hazard Based on Historical Record and Earthquake Probabilities	Number of Reported Deaths
Puerto Rico and U.S. Virgin Islands	High	164

Table 1. Tsunami hazard classification for Puerto Rico and the U.S. Virgin Islands. Adapted from FEMA (2019), Table 2-1.

Motivation

Research Gap:

Previous studies estimated travel times from schools to safe locations; however, these estimates did not account for all components of the evacuation process (Torres Rodríguez & Cohen Vázquez, 2021; Stedile Zolin et al., 2023). This time gap may underestimate the total time required to reach safety and, consequently, school vulnerability to tsunami hazards.

01. Earthquake
Seismic event begins

02. Reaction
Occupants respond to event

03. School Evacuation
Classroom → Internal Assembly Point (IAP)

04. IAP Preparation
Attendance and Preparation to exit

05. Travel to Safety
IAP→ Outside Tsunami Hazard Zone

Research Gap Previously Estimated

Figure 2. Conceptual tsunami evacuation timeline and identified research gap. Adapted from Marrero-Rodríguez (2025).

Objectives

- Address gaps in current evacuation-time estimates.
- Improve evacuation-time estimates for vulnerable schools.
- Determine whether RSET exceeds ASET.
- Better assess school vulnerability to tsunami hazards.

RSET vs. ASET
Required Safe Egress Time | Available Safe Egress Time
ASET = 20 min

Methodology

Additional evacuation-time components were evaluated and incorporated with previously estimated travel times to determine the total RSET for each school.

- Jan. 7, 2020 | Mw 6.4
- Threshold: ±0.01 g

Seismic Duration = 31.25 s

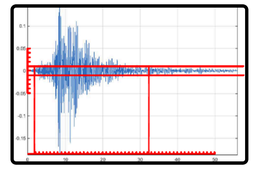


Figure 3. Strong-motion duration (±0.01 g).

- Emergency evacuation literature review (Safari et al., 2025)

Reaction Time = 60 s

Classroom-to-IAP Regression Model

→ Time (t_{CR-IAP})=0.1730 N+ 0.2367 D_{max}

N = Occupants | D_{max} = Maximum Distance to IAP

- Marrero-Rodríguez (2025)

Regression Model Validation:

Case Study: Wesleyan Academy

AutoCAD and Google Earth Pro were evaluated for remote distance measurements. Validation at Wesleyan Academy compared remote vs. field measurements and predicted vs. reported evacuation times.

✓ **Distance Measurement Validation**
%Error: 0.11%

✓ **Regression Model Validation**
Predicted Time: **3.25 min**
Observed Drill Time: **3.00 min**
%Error: 8.3%

Application to Coastal Schools:

School Population (N) → Busca Tu Escuela
Max. Distance to IAP (D_{max})→ AutoCAD, AutoCAD Pro

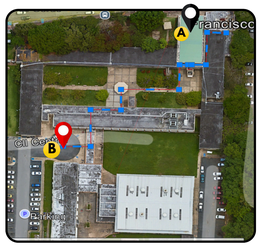


Figure 4. Route Measurement

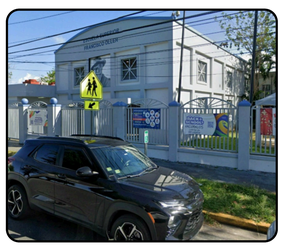


Figure 5. Route Verification

Results & Analysis

RSET = Occupant Response + Pre-Movement + Movement + Hazard Onset

Evacuation-Time Comparison & Vulnerability Assessment

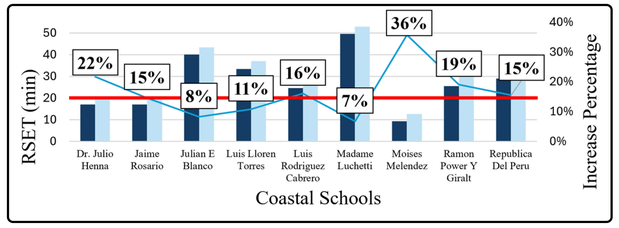


Figure 6. San Juan Evacuation Times

Current RSET Previous RSET ASET

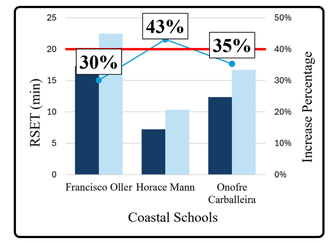


Figure 7. Cataño Evacuation Times

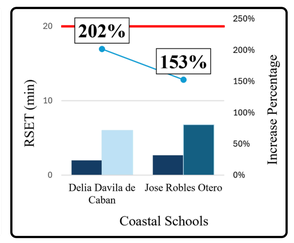


Figure 8. Toa Baja Evacuation Times

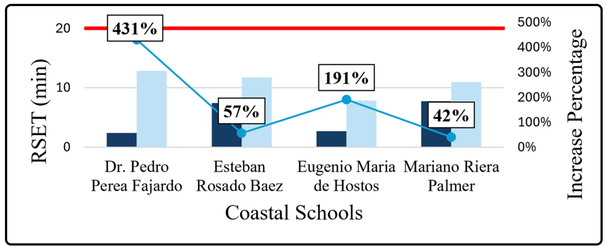


Figure 9. Mayagüez Evacuation Times

Conclusion

Including additional evacuation-time components increased RSET for all evaluated schools. Several schools that previously met the 20-minute ASET approached or exceeded the threshold, while those already exceeding it showed greater time deficits. Complete RSET estimates provide a more comprehensive assessment of tsunami vulnerability and help identify the need for additional mitigation strategies.

Acknowledgments

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LinkedIn: References: