

# Analyzing the Crowd Evacuation Pattern of a Large Densely Populated Building

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## Abstract

Understanding crowd evacuation behavior is of utmost importance for large buildings in order to achieve efficient crowd monitoring and management. This paper presents the simulation and analysis of crowd evacuation pattern for a large building called Al Masjid An Nabawi, widely known as ‘the Haram,’ in Madinah, Saudi Arabia. Legion Evac software is employed to simulate the crowd evacuation. During simulation, Legion computes various metrics that holistically reflect the crowd evacuation pattern, which captures the crowd evacuation behavior. We analyze the magnitude and temporal variations with respect to the general evacuation patterns (GEP) of the building. The magnitude is analyzed using the *t*-test, which is a hypothesis testing method. However, the temporal variations are analyzed using cross-correlation analysis. The GEP captures the general crowd evacuation behavior (across all sections) of the building by aggregating the evacuation patterns of each section of the building. The crowd evacuation simulation resulted in an evacuation time of 21 min to evacuate a population of approximately 170,000. The analysis of evacuation patterns shows that the evacuation pattern of different sections of the building differs significantly in magnitude, but has significant temporal similarity with respect to GEP. Finally, insights are derived from the analysis results, which aid in efficient crowd monitoring and management.

**Keywords:** Crowd evacuation; Simulation; Legion Evac; Crowd evacuation behavior; Cross-correlation analysis; Evacuation patterns