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A GIS-based earthquake damage assessment and settlement methodology

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ABSTRACT

Earthquakes have a greater effect on society than most people think. These effects range from structural damages to economic impacts and fatalities. An earthquake only lasts for a few seconds and the aftershocks may continue for days, but the damage does continue for years. Residential site safety and earthquake damage assessment studies play a crucial role in developing reliable rehabilitation and development programs, improving preparedness and mitigating losses in urbanized areas. The extremely densely populated metropolis of Tehran, which totals of 7,768,561 for 22 districts (according to the 2006 population census), coupled with the fragility of houses and infrastructure, highlight the necessity of a reliable earthquake damage assessment based on essential datasets, such as building resistance attributes, building population, soil structures, streets network and hazardous facilities. This paper presents a GIS-based model for earthquake loss estimation for a district in Tehran, Iran. Damages to buildings were calculated only for the ground shaking effect of one of the region's most active faults, the Mosha Fault in a likely earthquake scenario. Earthquake intensity for each building location was estimated based on attenuation relation and the ratio of damage was obtained from customized fragility curves. Human casualties and street blockages caused by collapsed buildings were taken into account in this study, as well. Finally, accessibility verification found locations without clear passages for temporary settlements by buildings via open streets. The model was validated using the 2003 Bam earthquake damages. The proposed model enables the decision-makers to make more reliable decisions based on various spatial datasets before and after an earthquake occurs. The results of the earthquake application showed total losses as follows: structural damages reaching 64% of the building stock, a death rate of 33% of all the residents, a severe injury rate reaching 27% of the population and street closures upwards of 22% due to building collapse.

1. Introduction

Metropolises are specifically vulnerable to earthquakes due to the high density of buildings, infrastructure and people [1]. Highly populated cities that are unprepared for such emergencies contain many potential victims and invite high fatalities during unavoidable disasters [2–4]. Although rare in Tehran metropolis, earthquakes are one of the most destructive natural hazards, so assessing the damage they cause is of great importance [5]. Disaster management and mitigation are not easy tasks and require resources and analyses to design effective and appropriate strategies to reduce vulnerability [6,7]. This complexity dictates the use of an integrated earthquake damage assessment methodology. The design of geographic information systems (GIS) supports spatial decision-making based on multiple georeferenced datasets and it thereby makes possible natural disaster risk assessment for vulnerability reduction [8–10]. For the purpose of this paper, the GIS data layers of the study area include the dwelling unit inventory, statistical information about buildings, streets, the positions of hazardous facilities (e.g., gas stations), active faults and soil characteristics. The collected data were corrected and converted to shape files and geodatabases. The information such as distances of buildings to the Mosha Fault and street widths were extracted from primary layers. We used ArcGIS toolbox functions to analyze the data layers and present final damages. This study highlighted the usefulness of GIS for the input, management, manipulation, analysis and visualization of spatially referenced data.

Although residential regions are at risk because of multiple hazards caused by earthquakes, including landslides, surface fault rupture, tsunami, liquefication, fire and flood as well as the release of hazardous materials, ground shaking is the principal cause of earthquake damage and loss [13,15,8]. The primary objective of this study is to develop earthquake loss scenarios in terms of building and street damages and casualties. Damage to buildings was calculated only from the ground shaking effect of an earthquake.

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