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Earthquake damage estimation systems: Literature review

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Abstract

Earthquake is an unpredictable natural phenomenon that create a vast amount of damage, affecting communities and their environment. To reduce the effects of such hazards, frameworks like building resilience have emerged. These frameworks target on increasing recovery after such disaster, by introducing new designs, technologies, and components to the building. To calculate the value of such improvements, use of loss estimation systems are essential. This paper compares and contrasts two most widely adopted loss assessment tools available, namely PACT and SLAT. Comparison of these tools mainly focuses on the consequence functions of the two methods. Recommendations are suggested to improve and complement these tools in future use.

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Keywords: Earthquakes; Cost Estimation; Time Estimation; Consequence functions; PACT; SLAT;

1. Introduction

Earthquake is a “series of vibrations on the earth’s surface caused by the generation of elastic (seismic) waves due to sudden rupture within the earth during the release of accumulated strain energy” (Shah, 2012, p. 96). Depending on the past data, GeoNet (2016) estimates that in New Zealand, an earthquake of low impact, with the magnitude of 4.0 - 4.9, occurs 1 per day in average and high impact earthquakes with magnitude above 7.0 occurs 1 per 2.5 years. These high impact earthquakes cause destruction and damages to the excessive degree (Baocai, 1996). These earthquake damages extend to economic, social, psychological and political areas, requiring rapid rehabilitation and reconstruction (Yaoxian, 1996). Globally,

United States Geological Survey (USGS) Earthquake Hazards Program (2017b) states, from the year 2000 to 2015, earthquake hazards reflected in 801,629 deaths worldwide. In the economic and monetary point of view, the 2010 – 2011 Canterbury earthquakes in New Zealand, 2010 Chilean earthquake, and 2008 Wenchuan Earthquake in China accumulated losses over NZ$ 40 billion, US$ 30 billion, and NZ$ 345 billion in damages to the communities,

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respectively (Araneda, Rudnick, Mocarquer, & Miquel, 2010; Marquis, Kim, Elwood, & Chang, 2017; Sun & Xu, 2011). In the event of such earthquakes, rapid recovery and rehabilitations are a priority. According to Yaoxian (1996), this can be achieved through the rapid recovery of economic sectors and financial resources.

Improving the recovering capabilities of organisations, buildings and communities, immediately following an extreme event like an earthquake is a key concept for rapid recovery (Bonowitz, 2009; Pampanin, 2015). Resilience-based earthquake design of buildings is one example in achieving this objective. The framework focuses on improving capabilities of buildings beyond statutory building codes (Almufti et al., 2013; Almufti & Willford, 2014). Objectives of performance-based design and low-damage are also intended to achieve this criterion. In order to achieve these objectives new and innovative technologies should be created and implemented in buildings. The value of these implementations should be calculated, compared and expressed in monetary terms, to increase wider acceptance and implementation (Pampanin, 2015).

Efficiency calculation using these methods was done at the initial levels of decision making, which is known as seismic loss estimation. Performance Assessment Calculation Tool (PACT), Seismic Performance and Loss Assessment Tool (SLAT), Seismic Performance Prediction Program (SP3), Matlab Damage and Loss Analysis (MDLA), Hazards United States for multi hazards (HAZUS-MH), loss estimation tool developed by Laboratório Nacional de Engenharia Civil (LNEC: National Laboratory for Civil Engineering) (LNECLOSS) are some of the computer tools used for seismic loss estimation (Molina, Lang, & Lindholm, 2010). In order to calculate the value addition of resilience upgrades, the tool used should have building specific seismic loss estimation. In order to use such a tool in New Zealand, it must be calibrated to regional requirements. PACT and SLAT are the probable tools utilised for this task due to its freely available nature of the information. PACT is a freeware tool built in the USA(Hamburger, Rojahn, Heintz, & Mahoney, 2012). It has a database of fragility curves and consequence functions on over 700 components. Yet, due to regional differences, the information cannot be applied directly in New Zealand. Based on PACT, SLAT (B. A. Bradley, 2009) was developed to address the needs of New Zealand earthquakes (B. Bradley, Williams, & Scarr, 2017). But, SLAT is still developing and fragility curves and consequence functions. Which are currently not developed for all the building items.

Both these tools are dependable seismic loss estimation models that can be used in component based probabilistic loss estimation model. Yet, engineers cannot use these systems on a regular basis due to weaknesses like needing significant expert knowledge (Dhakal, Pourali, & Saha, 2016). These weaknesses must be identified and solutions or circumventions must be utilised, for better use of these systems.

The primary aim of this paper is to identify the similarities, differences and shortcomings of these two tools and forward recommend actions to improve these tool for better use.

2. Methodology

In designing new components for buildings, clear and dependable estimations of their effectiveness is crucial. Currently, SLAT and PACT are the leading tools that are used for this purpose in New Zealand. Due to the unpredictability of earthquakes and its subsequent damages, these tools use probabilistic approaches to estimate the repair cost. These tools use fragility curves and consequence functions as well as Monte Carlo simulations to estimate the cost. Due to the probabilistic nature of these tools and their inheriting features, the actual loss may vary significantly from the estimate. Thus, there is a need for analysis of these tools in order identify its shortcoming and improve these systems to suit the needs of New Zealand better.

The primary method used in this research is to analyse these tools in regards its cost estimation functions. This was conducted through a literature review using published information on the tools. There is no exact literature comparing the models. Thereof, user manuals and guides published by the creators were examined and compared. Furthermore, current updates of the tools were compared. The information gained was evaluated with literature in cost estimation. Depending on the evaluation of literature and comparisons, the paper focuses on the characteristics, similarities and shortcomings of the methods. Hence, hypothetical solutions to these problems are recommended in this paper. The results of this paper will provide a foundation for a PhD research into building a Post-earthquake repair cost and downtime estimation model for New Zealand.