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Comparative Evaluation on the Response of New Zealand Buildings to Natural Disasters

Zichen Li*

Auckland University of Technology, Auckland, New Zealand
375992526@qq.com
**Corresponding author*

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Abstract: With the development of science and technology, research on the response of New Zealand buildings to natural disasters is constantly improving. The exploration of building improvement in New Zealand under natural disasters and the construction and design of natural disaster assessment models based on DRI (Disaster Risk Index) are becoming increasingly important. How to reduce building risks during earthquakes is currently a key issue that urgently needs to be addressed in the entire research on building response to natural disasters in New Zealand. In this paper, based on the relevant research on the earthquake and tsunami in New Zealand, with the help of the absolute disaster level and relative disaster level calculation formula, combined with the simulation experiment, and according to the data results, the following conclusions are drawn: under the natural disasters dominated by earthquakes, New Zealand has improved its buildings in five aspects: building code, construction standards, construction levels, material use, and construction links, and based on the DRI natural disaster assessment model, the comprehensive average reduction in building risk under natural disasters was 15.5%, while the comprehensive average reduction in casualties was 11.5%. This indicates that the natural disaster assessment model based on DRI has a good practical application effect in New Zealand's construction response to natural disasters.

1. Introduction

The necessity of building prevention from natural disasters in New Zealand is constantly increasing, and peoples research and discussion on it has entered a new stage. The main objective of this article is to analyze building plans through discussions on natural disasters in New Zealand, so a comparative study of New Zealand's building response to natural disasters is very important.

There are many research theories on building response to natural disasters, mainly earthquake. Yum S G found that tunnel construction projects may cause unexpected collapse, rainstorm, earthquake and other natural disasters, and would cause huge economic and environmental losses based on various complex geological conditions. Therefore, this study conducted a multiple linear regression analysis on the impact of construction on tunnels in South Korea, in order to develop a new natural disaster risk assessment method with a focus on tunnel construction projects [1]. In order to reasonably determine the importance of various influencing factors on the overall seismic damage of buildings during earthquakes, Zhang X H studied the weight coefficients of each influencing factor using the Analytic Hierarchy Process (AHP). He detailed the impact of natural disasters such as earthquakes on building damage, aiming to improve the reinforcement and stress of building structures to cope with natural disasters. The results indicated that the AHP method is very accurate in determining the weight coefficients of various influencing factors on building seismic damage [2]. Ricardo M proposed a dynamic small-scale open economy model to explore the macroeconomic impact of building damage caused by major natural disasters. In addition to permanent damage to public and private buildings, disasters also lead to inefficiencies in the process of building reconstruction. This study used a model to analyze the debt sustainability issues caused by the need for comprehensive reconstruction of public infrastructure in the medium term [3]. In the context of a significant increase in the number of natural disaster events in recent decades, AGMP has explored the application of building nanomaterials in health and risk. Compared with traditional building materials, they have higher durability and strength. This study provides a detailed description of the relevant changes in the stability and seismic resistance of these nanomaterials to infrastructure. Experiments have shown that they have good application effects in response to natural disasters [4]. Wang Y believed that assessing the damage caused by natural disasters to buildings is crucial for coordinating rescue efforts. This study proposes a two-step solution - building positioning and damage classification. Experimental research has achieved good testing accuracy in the positioning analysis of three historical disaster events, namely the “Mexico earthquake”, “Midwest floods”, and “Palo tsunami” [5]. In order to create a high fidelity platform simulation of the impact of natural disasters on buildings, Lin S Y modeled all aspects of the disaster scene and the interaction with the building structure, and developed a platform based on the concept of distributed simulation to address this challenge. Finally, through the case study of the response of building structures and the wind induced progressive damage caused by external wind pressure, the effectiveness of the framework in responding to disaster resistance was demonstrated [6].

The combination of research on natural disasters and exploration of building response has prompted the earthquake prevention and disaster reduction department to revisit the comparative study of New Zealand’s building response to natural disasters [7-8]. The above studies have effectively discussed the damage of buildings under natural disaster earthquakes using various theoretical methods, but there is a lack of analysis on seismic reduction improvement of buildings.

The analysis of the forms of damage caused by earthquakes to buildings and the improvement of buildings in New Zealand under natural disasters is a major focus of this paper. In this article, with the help of discussions and research on absolute and relative disaster levels, combined with simulation experimental analysis, a natural disaster assessment model based on DRI is constructed. The final results show that the model has good practical application effectiveness in responding to natural disasters in New Zealand buildings.

2. Natural Disasters in New Zealand

2.1. Evaluation on the Occurrence of Earthquakes in New Zealand

New Zealand is located in the southwestern Pacific Ocean and is a multi-seismic country with up to 15000 earthquakes of all sizes recorded annually [9-10]. As New Zealand is located at the junction of the Pacific Plate and the Indian Ocean plate, it is the zone of plate collision and compression, and is part of the Pacific Rim volcanic Seismic zone. In the junction zone of plates, the rock stratum is usually fragile; the crust is also relatively active; the energy inside the earth is more tolerant and easy to release, so it is more prone to strong earthquakes [11-12]. According to the website of the United States Geological Survey, some historical records of earthquakes with a magnitude of 7 or above in New Zealand are shown in Figure 1:

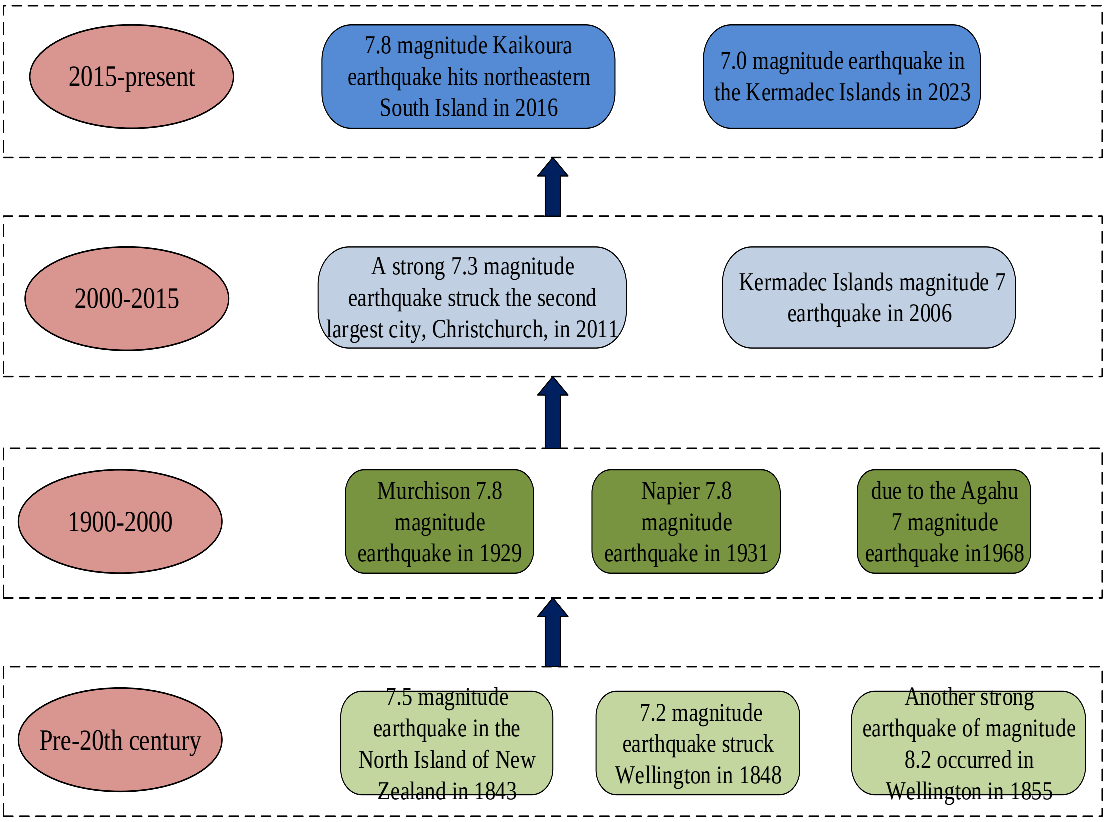

Figure 1: Partial historical records of earthquakes with a magnitude of 7 and above in New Zealand

It can be seen from the above figure that the frequency of earthquakes of magnitude 7 or above in New Zealand is relatively high during the recordable period of more than 100 years from the 20th century to the 21st century. In the high earthquake incidence area, the most dangerous big city is Wellington, the capital of New Zealand, followed by Hastings and Napier. Since 1840, more than 450 people have died in major earthquakes in New Zealand. Despite the frequent occurrence of earthquakes in New Zealand, the casualties caused by earthquakes are relatively small, thanks to New Zealand's public education and strict building regulations [13-14]. Due to the frequent occurrence of earthquakes, New Zealand has very strict requirements for building standards and has also passed legislation to ensure the quality of infrastructure construction.

2.2. Evaluation on Tsunami in New Zealand

Tsunami refers to destructive waves caused by submarine earthquake, volcanic eruption, undersea landslide or meteorological changes. In New Zealand, a country adjacent to the sea and prone to earthquakes, there are countless tsunamis caused by earthquakes. Among New Zealand's natural disasters, the frequency of earthquakes ranks first, while the tsunami is the one that causes the greatest damage to people's lives and housing properties [15-16]. The hazards associated with the New Zealand earthquake and subsequent tsunamis are shown in Figure 2:

7.1 magnitude earthquake in
Wellington, North Island, New Zealand

New Zealand's Kermadec Islands
7.2 magnitude earthquake

North Island Wellington earthquake
triggered a 40 cm tsunami wave

Local tsunami caused by
earthquake in Madhek Islands

Figure 2: New Zealand earthquake and subsequent tsunami situation

In summary, the 7.1 magnitude earthquake in Wellington, North Island, New Zealand caused a 40 centimeter tsunami wave that completely submerged the city’s basic buildings and caused permanent damage to buildings and other facilities. The 7.2 magnitude earthquake in the Madek Islands also triggered a local tsunami in the city center, rapidly devouring other infrastructure such as roads and buildings [17-18]. When designing buildings in New Zealand, it is not only necessary to consider the impact of natural disasters such as earthquakes, but also the impact of natural disasters such as tsunamis. Therefore, comparative research on the response of New Zealand buildings to natural disasters is of great significance.

3. Evaluation of New Zealand’s Building Response to Natural Disasters

3.1. Building Improvements in New Zealand under Natural Disasters

Due to the natural disasters in New Zealand, such as earthquakes, tsunamis, volcanic eruptions, hurricanes, and landslides, earthquakes and tsunamis have the greatest and most frequent damage to people, property, and buildings. Therefore, this article mainly discusses the comparative study of New Zealand’s building response to earthquakes and tsunamis as natural disasters [19-20]. Firstly, based on the relevant research and image descriptions of earthquakes in New Zealand mentioned above, the forms of damage caused to buildings during earthquakes are analyzed, and the conclusions are shown in Table 1:

Table 1: Forms of damage to buildings caused by earthquakes

Form	Explanation
Severe damage not easy to repair	The houses collapsed in the worst-hit areas are basically rural self-built houses
Moderate damage	The structural design was unreasonable, and the construction of frame structures did not meet the design strength by cutting corners.
Slightly damaged or intact	Newly repaired residential communities and some public facilities, structural design and construction quality qualified

This article continues to discuss the plans for New Zealand's buildings to cope with earthquakes. If frequent major earthquakes are not prevented, they may cause a large number of house collapses, economic losses, and casualties, which may lead to subsequent tsunami disasters. The improvement of New Zealand buildings under natural disasters caused by earthquakes is shown in Table 2:

Table 2: New Zealand building improvement measures under earthquake natural disasters

Category	Brief description
Building Code	There are detailed provisions for designers and design drawings, and the drawings should be sent to professional departments for review
Construction Standards	Special rubber mats are used for seismic isolation of the foundation, and seismic isolation and damping devices are set on some large buildings and bridges
Construction Level	Strengthen the construction around the window and door openings, and do a good job according to the documents and seismic requirements.
Material Use	Structural columns around the windows and doors, etc.
Construction links	Basically, low-rise and multi-storey residential houses are made of light construction with wooden frames and large glass, which are light in weight and high in strength.

It can be seen from the table that when New Zealand buildings respond to earthquakes, they are mainly improved from five aspects, namely, building code, construction standards, construction levels, material use and construction links. In addition, in terms of seismic fortification, it is strictly in accordance with the 8 degree fortification standard for earthquake stricken areas in New Zealand. Reinforced masonry is used, and structural columns and seismic joints are set up at door and window openings and corners. Building materials must be strictly inspected and qualified before being used on the construction site [21].

After discussing the comparative study of earthquake response in New Zealand buildings, this paper would continue to analyze the impact of the tsunami on New Zealand buildings. The harm of tsunamis to buildings mainly comes from waves. The direct impact of waves does not cause much damage to general residential buildings, but has a significant destructive effect on simple houses and weak foundations. Therefore, strengthening building foundations is the core measure to prevent tsunamis. After the first wave of high water level inundation and surge impact damage in the tsunami, its huge impulse would carry some solid floating objects generated by damaged buildings forward together. At this time, the combined effects of floating object impact and other destructive forces are stronger. Therefore, the main measures to prevent tsunamis are to preset the structural state of buildings, determine the load of Haixiao buildings, and analyze and design tsunami resistant structures.

3.2. Construction of Natural Disaster Assessment Model Based on DRI

Using data sources released by the New Zealand Bureau of Statistics, this article determines that the New Zealand Disaster Risk Index (DRI) is mainly composed of earthquakes, tsunamis, volcanic eruptions, and hurricanes. Based on research on natural disasters such as earthquakes and tsunamis in New Zealand, combined with measures for building improvement under natural disasters and analysis of the forms of damage caused by earthquakes, the natural disaster assessment model is divided into building risk module, personnel injury module, and economic loss module. Therefore, the construction of a natural disaster assessment model based on DRI is shown in Figure 3:

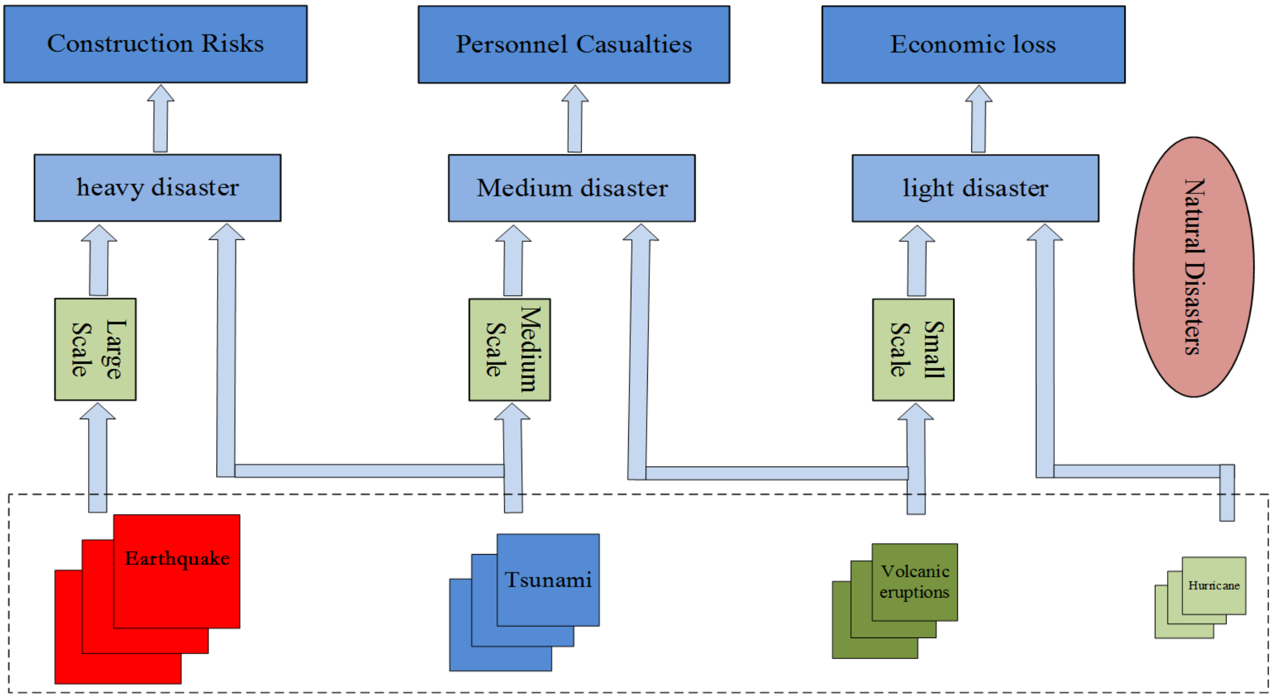

Figure 3: DRI based natural disaster assessment model

When analyzing the comparative study of New Zealand's building response to natural disasters, the calculation of absolute and relative disaster levels is an important step in verifying the research results. According to the natural disaster assessment model designed above, the absolute disaster level calculation is shown in Formula 1:

$$D_a = \frac{1}{n}\sum_{i=1}^{n} \lg N_i \tag{1}$$

Among them, Ni represents the actual housing situation statistics of the i-th indicator, and n represents the number of indicators. The relative disaster level calculation is shown in Formula 2:

$$D_r = (P_1 + P_2 + 2P_3)/3 \tag{2}$$

Among them, P1 represents the percentage of the affected population in the total population; P2 represents the percentage of the affected area in the total planting area, and P3 represents the percentage of direct economic losses in the sliding average of the total industrial and agricultural output value.

4. Simulation Experiment Results

After completing the design of the natural disaster assessment model for DRI, experiments were conducted using simulation experiments to test the actual effectiveness of the model in responding to natural disasters in New Zealand buildings [22].

In this experiment, six different urban parameters in New Zealand are selected as experimental samples, which are Wellington A, Hastings B, Napier C, Kemadek D, Kaikōura E and Murchison F in the order of earthquake frequency from small to large, and are used as data sets for training and testing. The Monte Carlo method was used to test and analyze the data for 400 rounds in a certain period of time, and the building risks and casualties of six cities under the natural disaster assessment model and the traditional scheme were obtained. The comparison results of the natural disaster assessment model based on DRI are shown in Figure 4:

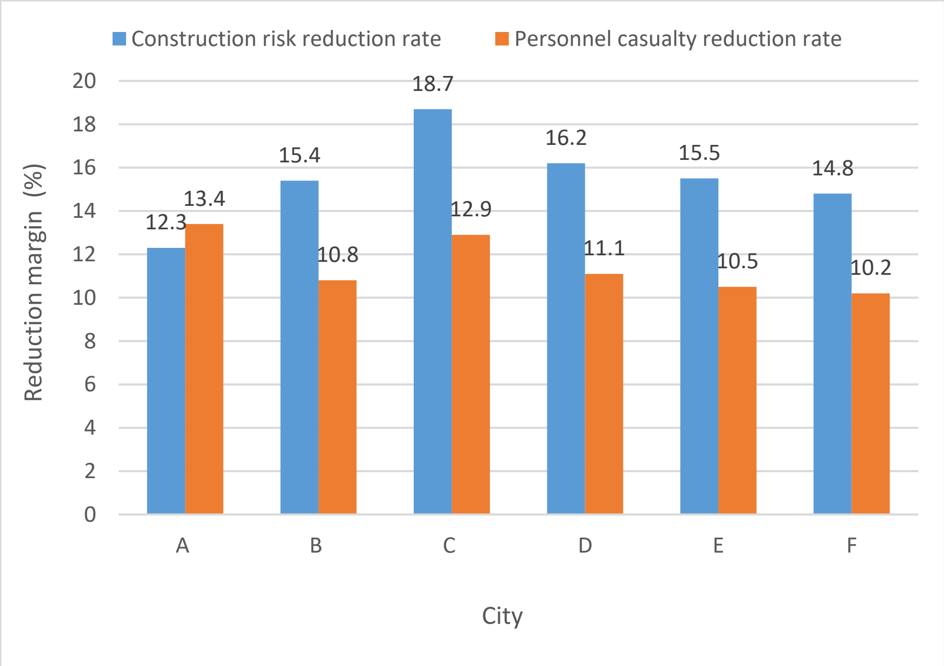

Figure 4: Improvement of building risk and casualty after applying the improved model

Among them, the blue column represents the reduction of building risk using the DRI-based natural disaster assessment model, while the orange column represents the reduction of casualties using the DRI-based natural disaster assessment model. It can be seen that the construction risk reduction using the natural disaster assessment model in Napier City C was the most significant, with a reduction of 18.7% and a comprehensive average reduction of 15.5%. At the same time, the casualties reduction using the natural disaster assessment model in Wellington A was the most significant, with a reduction of 13.4% and a comprehensive average reduction of 11.5%. This indicates that the use of DRI-based natural disaster assessment models has practical application effects in New Zealand's construction response to natural disasters.

5. Conclusions

Against the backdrop of increasingly rapid research on natural disasters, a natural disaster assessment model based on DRI can be widely applied to the assessment and analysis of natural disaster buildings in various cities in New Zealand. This article is based on research on earthquakes and tsunamis in New Zealand. By studying the forms of damage caused to buildings and the impact of natural disasters on New Zealand buildings, a natural disaster assessment model based on DRI is constructed and simulated. It is concluded that the model has good practical application effects in responding to natural disasters in New Zealand buildings. This article aims to provide a DRI-based natural disaster assessment model for the comparative study of New Zealand's construction response to natural disasters through theoretical and empirical research. Due to the limited selection of sample variables for New Zealand cities and the incomplete analysis of absolute and relative disaster level calculation formulas, there are still many shortcomings in the comparative study of New Zealand's building response to natural disasters. Further improvement and improvement would be made in future research.

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