Seismic risk assessment and design of tourism buildings using probability analysis

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Abstract: The average recurrence interval of major earthquakes is approximately a century. Consequently, the existing data are insufficient for an accurate estimation of average losses. The main objective of this research is to study the disaster-prone characteristics of hotels by using modern concepts of risk management (i.e., loss exceedance probability analysis, seismic hazard analysis and so on) and then combine the relevant basic research data from domestic and foreign sources to develop a seismic risk assessment and management system suitable for the hospitality industry. The proposed seismic risk management and risk evaluation system will also provide governments, hotel asset owners, insurance companies and banks in Taiwan that have similar regional characteristics with the necessary seismic risk information to help the tourism industry effectively evaluate and manage the natural disaster risk.

Keywords: seismic risk assessment; catastrophic risk; loss exceedance probability analysis; seismic hazard analysis.


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1 Introduction

In recent years, the rapid development of tourism due to the considerable increases in the number of tourists from China has led to a significant increase in the number of hotels in Taiwan. However, earthquakes frequently occur in Taiwan because of its location on the Pacific seismic belt. Achieving a balance between the developments of tourism and ensuring the safety of the tourists has become a critical issue. In recent years, research institutions have made considerable achievements in the field of seismic risk analysis. Seismic risk analyses have become necessary for the development of asset and investment portfolios for the hospitality industry. In the past, the insurance industry used traditional empirical rules to estimate the risk of loss; however, reference data are limited.
because earthquakes are such rare events. The geographical environment of Taiwan includes an endless variety of unique and beautiful landscapes, a dynamic climate and numerous valuable natural resources for tourism. However, the geographical location of Taiwan is also the main reason for the frequent occurrence of natural disasters.

Recently, to boost the tourism industry, the Taiwanese government has actively promoted various plans to increase the number of visitors and encourage domestic travel by citizens. For the productive use of natural resources, tourism investors often build hotels at beautiful scenic spots, such as in mountainous and seafront areas. However, the hospitality industry of Taiwan is at an extremely high risk of being damaged by natural disasters such as typhoons and earthquakes and the disaster-prone characteristics of hotels crowded because of the increased numbers of tourists during holiday periods (Tsai and Chen, 2010, 2011). According to the S&P survey of economic damage in 2015, Taiwan is one of the top 10 countries most vulnerable to natural disasters, and Taiwan ranks fifth in the world in terms of the economic risk caused by natural disasters (S&P, 2015). Based on these findings, running a hospitality business in Taiwan is characterised by an extremely high risk of natural disasters.

With the rapid development of tourism, the considerable increase in the tourist population and the urgent demand for natural environmental resources, many hotels in Taiwan experience major losses due to natural disasters each year. Moreover, these incidents not only occur more frequently from year to year but also tend to become large-scale disasters. On 21 September, 1999 (local time), an earthquake with a magnitude of 7.3 on the Richter scale caused the collapse and damaged 86 hotels in Taiwan, leading to a substantial loss in revenue, equivalent to 3.3% of the gross domestic product (GDP) for that year. The earthquake on 11 March, 2010 (magnitude 9.0) in Japan caused direct losses of nearly 300 billion US dollars at that time and is still seriously affecting the economic development of tourism in Japan.

AlBattat and Som (2014) indicated that the prerequisite for hotels with a risk of disasters is the evaluation the level of the disaster. Prevention strategies depend on each hotel’s size and category. Earthquakes are natural phenomena, and existing man-made technology cannot prevent their occurrence. Practical strategies can only be implemented to reduce and even out the risks in advance to lower the possible losses and impacts on individuals, industries and the government. However, natural catastrophic risk assessment requires a large amount of data on historical disaster losses for reference.

The lack of data related to earthquake events creates a major bottleneck in the assessment process (American Marsh Insurance Broker Company Limited, Taiwan branch (Guy Carpenter), 2004). Strong earthquakes often entail huge natural disaster risks. Although they have a substantial impact, the frequency of such catastrophes is low; therefore, little data can be collected on the damage (because of the less frequent occurrence or incomplete statistics), and much of the existing data were collected a long time ago. This makes it impossible to adopt the traditional insurance actuarial approach of estimating the risk by only using data on damage caused by historical events, as in the case of other general types of product insurance, that is, car insurance or fire insurance. The main underlying reason is that the historical damage data are insufficient; furthermore, the historical data do not match the present situation, because of rapid changes in the social and economic environment (Dong et al., 2002). Figure 1 shows the statistics for insurance sums and claim rates for commercial earthquake insurance and commercial fire insurance from 1998 to 2005 in Taiwan. This figure shows that the losses
related to commercial fire insurance are more stable and show less fluctuation compared with those related to earthquake insurance.

**Figure 1** Statistics for insurance sums and claim rates for commercial earthquake insurance and commercial fire insurance from 1998 to 2005 in Taiwan

The insurance loss caused by the September earthquake in 1999 resulted in the utilisation of all revenue generated from earthquake insurance fees earned by the industry over nearly 10 years. Individual insurance loss and claims due to catastrophes are not independent; these two phenomena exhibit a strong positive correlation, in contrast to the ‘law of large numbers’, the basic insurance theory upon which risk diversification is based. At the same time, the risk of a catastrophe can have a high impact on the insurance industry and the market in a short period, triggering a chain reaction of claims; both of these issues are in contrast to the long-term characteristics common in the insurance industry (Wang, 1999). Thus, the risk assessment model for natural catastrophes must integrate cross-disciplinary knowledge.

Compared with general buildings, hotel structures require more amenities (restaurants, stores, swimming pools, elevators and so on) and adequate capacity for tourist activities. Therefore, compared with general buildings, *Seismic Design Specifications and Commentary of Buildings* describes different requirements for hotels. In Taiwan, according to the regulations in *Seismic Design Specifications and Commentary of Buildings*, the important factor of hotels ($I = 1.25$) is 0.25 higher than that of general buildings ($I = 1.0$) (CPA, 2011). The current hotels in Taiwan have been built at different times; therefore, substantial differences exist in the design regulations adopted by these hotels. Many of these hotels appear to offer insufficient protection against earthquakes. An earthquake evaluation model applicable to hotels has not been developed. Hotels in Taiwan are located on the earthquake zone; hence, developing a relevant applicable evaluation model that can reduce the damage caused by earthquakes is crucial and urgent.

## 2 Assessment model for catastrophic risk

The most international well-known system is ‘HAZUS 97’ in terms of the evaluation systems which have been established by government. ‘HAZUS 97’ was authorised from ‘Federal Emergency Management Agency’ to ‘RMS’ and was released in 1997.
'HAZUS' integrates geographic systems and is able to display analysis results with maps. The purpose of its development was to be applied on earthquake salvation as well as doing financial analysis and insurance. However, when it comes to this aspect, it is not as convenient as other similar evaluation software. HAZUS released an updated version to public in 1999 related to earthquake risk evaluation module of infrastructures (e.g., bridges). In 2003, ‘EQECAT’ was authorised to do the development and successfully release HAZUS-MH (Multi-Hazard). Not only earthquakes but floods and hurricanes are also included. Taiwan imported HAZUS in 1998 and expanded it into ‘Taiwan earthquake loss estimation system (TELES)’. However, the original goal of development did not focus on insurance demands so the original construction and analysis was not suited for massive insurance computing and the calculation of risk responsibilities arrangement. In addition, it could not meet the demand of tourism industry disaster risk analysis since the accuracy was limited in counties and cities. It is required to do the earthquake disaster evaluation-related research which is focusing on tourism characteristics.

Using historical data on disasters and probability analysis, we developed a catastrophic risk assessment system for hotels in Taiwan mainly on the basis of the earthquake risk assessment framework presented by the Pacific Earthquake Engineering Research Center (PEER) in 2003, which is representative of modern risk assessment systems. The majority of the risk assessment models based on engineering theories generally share a similar assessment framework.

As shown in Figure 2, in the risk assessment framework of PEER, criticality analysis is initially conducted, followed by damage analysis and finally loss risk analysis. The same risk assessment framework is mainly adopted to develop risk assessment technology, based on which an aggregate probability catastrophic risk assessment model for hotels will be developed. We hope that this model will serve as a reference for the hospitality industry to develop strategies for reducing catastrophic risks and to help the tourism industry in Taiwan to become a tourist destination despite the occurrence of frequent natural disasters.

**Figure 2  Risk assessment framework**

\[
v(DV) = \int \int \int \int \int g(DP) \, dM \, dR \, dED \, dIM \, dL
\]

*Data source: Pacific Earthquake Engineering Research Center (2003)*

The risk evaluation engine employed in this study is constructed based on the history of disaster prevention and financial insurance, which plays the most important role in the system setup. By inputting the coordinates of the evaluation tourism subject, the potential data, and the relevant evaluation parameters, the optimal location analysis and risk
evaluation mode can generate a relevant risk evaluation report, including the demand dataset by users, such as the hazard analysis of various natural disasters, loss evaluation, relevant environmental information, potential information and general information (Tsai and Chen, 2011). The employed disaster risk evaluation model is derived by reference to the architecture proposed by Hung (2009) and Naill (2011). The contents, features and theoretical basis for each hotel seismic risk assessment module are discussed below.

2.1 Stochastic event module

This module is used to create a seismic event prediction database that can fully describe the factors affecting risk exposure in Taiwan. The magnitude, location, type of focus, frequency and other information for each seismic event are recorded in the database. The seismic event prediction database is built on the foundation of the seismic focus module (Youngs et al., 1997). The geological structure of the area and information on earthquakes that have occurred in that area in Taiwan are considered. The seismic focus module is used to divide the focal areas and set the seismic activity parameters for each focal area according to the historical seismic data (Shin et al., 2013).

Based on the division of seismic focus and the setting of seismic activity parameters for each focus area, an earthquake prediction table can be created (Table 1). Data on location, magnitude and average annual frequency are recorded for each seismic event. The magnitudes of the predicted earthquakes are between 4.5 and 8. Related events can be used to simulate the impact of seismic disasters on tourist recreation areas.

<table>
<thead>
<tr>
<th>ID</th>
<th>Epicentre</th>
<th>Magnitude</th>
<th>Depth</th>
<th>Annual mean rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event 00001</td>
<td>(121.22, 24.03)</td>
<td>6.5</td>
<td>10 Km</td>
<td>0.010</td>
</tr>
<tr>
<td>Event 00002</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>0.002</td>
</tr>
<tr>
<td>Event 00003</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Event 17710</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

2.2 Hazard module

This module is used to calculate the magnitude and the location of assessment objects for each hotel after a predicted seismic event. Figure 3 presents a schematic of the hazard module. Earthquakes are phenomena in which energy released from the Earth’s crust spreads out and causes ground movement (Army, 1996). The energy and magnitude of the seismic waves decrease with distance from the epicentre. At present, these phenomena are mostly described by the surface ground motion attenuation formula (Loh, 1992). The possible earthquake hazards caused by each seismic event can be calculated using this framework and the selected ground motion attenuation formula depending on the location of the assessment object for the hotel (Figure 3).
2.3 Vulnerability module

This module is used to calculate and assess the probable average loss caused by damage to hotel buildings, damage to property or disruption of business. This module can also be used to calculate the coefficient of variation of the average loss. The assessment calculates the loss mainly based on the fragility curve for the buildings under investigation (Hwang and Huo, 1994). Figure 4 shows a fragility curve diagram for tourist hotel buildings. The fragility curve represents the possible losses from damage to the buildings caused by earthquakes of different magnitudes. The word ‘Sa’ means ‘spectral acceleration’ and the unit of it is ‘gal’. ‘Sd’ means ‘displacement spectrum’ and the unit is ‘inch’. The extent of damage can be described using the damage ratio, which is the ratio of the repair cost to the replacement cost of the building (Federal Emergency Management Agency (FEMA), 2002). Using the aforementioned seismic hazard module, the seismic magnitude and fragility curve can be obtained, based on which the average earthquake losses for the hotel buildings can be then calculated.

2.4 Financial analysis module

This module is primarily used to calculate the losses suffered by hospitality properties (the insurant), insurance companies, reinsurance companies and the government under different financial viewpoints, when insurance and reinsurance certificates are taken into account.

The formula for calculation of the insurance loss for general product insurance certificates is as follows:

\[ Y(l) = \min[\max(l - d, 0), c - d], \]

where \( l \) implies the losses caused by the earthquake; \( d \) implies the deductible amount; and \( c \) implies the amount insured. The aforementioned formula shows that, when the loss is less than the deductible amount, the loss is totally borne by the insurant, and the underwriting loss is equal to 0. However, when the loss is greater than the deductible amount, but less than the amount insured, the underwriting loss is equal to the loss
amount after the deductible amount is deducted, that is, \( l - d \), and when the loss surpasses the amount insured, the underwriting loss is equal to the difference between the amount insured and the deductible amount, that is, \( c - d \).

After an insurance policy has been issued to a hotel, the seismic event prediction module can be used to predict the probability of a specific seismic event, and the hazard module can be used to calculate the extent of the hazard given the locations of hotel buildings.

**Figure 4** Fragility curve for tourist hotel buildings

Subsequently, the vulnerability curve for the hotel buildings can be prepared and the vulnerability module can be used to calculate the possible loss for hotel buildings. Finally, taking into account the conditions of the policy (e.g., the amount of the deductible and the amount insured), the total losses or insured losses possibly caused by each event can be calculated. A seismic event loss table similar to that shown in Table 2 can be established, in which the event code, the annual frequency, the average loss
caused and the corresponding coefficient of variation will be recorded. Figure 5 outlines the overall simulation method and elucidates the process for establishing the loss-surpass-probability curve.

<table>
<thead>
<tr>
<th>Event ID</th>
<th>Mean occur. rate ($\lambda$)</th>
<th>Mean loss ($L$)</th>
<th>COV ($cv$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#0001</td>
<td>0.00445</td>
<td>2,560,000</td>
<td>2.32</td>
</tr>
<tr>
<td>#0002</td>
<td>0.00600</td>
<td>4,340,000</td>
<td>1.86</td>
</tr>
<tr>
<td>#0003</td>
<td>0.00353</td>
<td>9,023,000</td>
<td>2.04</td>
</tr>
<tr>
<td>#0004</td>
<td>0.00387</td>
<td>6,870,000</td>
<td>1.22</td>
</tr>
<tr>
<td>#0005</td>
<td>0.00485</td>
<td>3,650,000</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Seismic risk assessment for hotels applies risk analysis methods to the relevant estimates of hazards and fragility. The historical data for seismic disasters (magnitude, depth and so on) are utilised to analyse the seismic potential of events with different return periods, magnitudes and depths. An established seismic loss-surpass-probability curve can be used to estimate possible losses for hotel buildings after seismic events of different magnitudes, based on which the annual maximum seismic loss and total expected loss can be predicted and can serve as references for seismic hazard prevention planning by tourism operators.

3 Case study

3.1 Information on the hotel examined in this study

The hotel selected for the case study is located in Hualien City in eastern Taiwan (as shown in Figure 6). It is situated on the southern side of Meilun Mountain, near the Meilun Active Fault, the major earthquake fault running under the city. Founded in October 1976, the hotel covers over 1000 m$^2$ and has 11 floors aboveground and
two floors underground (all made of reinforced concrete). It features 270 guest rooms, a sauna, an open-air spa pool, Chinese and Western restaurants, a banquet room that can accommodate more than 50 people, a multifunctional conference room, and a parking area for 50 cars. The hotel is a 10-min drive from the airport and the railway station. Convenience was a crucial factor when considering the location of the hotel. As indicated by the historical disaster survey questionnaire and data, both the Hualien earthquake on 15 November, 1986, and the earthquake on 21 September 1999 caused extensive damage to the hotel.

Figure 6 Hotel (case study) location map

3.2 Results of the probability seismic risk module

In this study, we performed an assessment of the aforementioned hotel and collected the data shown in Table 3.
Table 3  Basic data for natural disaster risk assessment for an urban tourist hotel

<table>
<thead>
<tr>
<th>Item</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total value of the buildings</td>
<td>USD2,500,000</td>
</tr>
<tr>
<td>Total value of the building contents</td>
<td>USD350,000</td>
</tr>
<tr>
<td>Annual turnover</td>
<td>USD2,800,000</td>
</tr>
<tr>
<td>Building type</td>
<td>Made of reinforced concrete</td>
</tr>
<tr>
<td>Number of floors</td>
<td>11 floors</td>
</tr>
<tr>
<td>Usage type</td>
<td>Commercial usage</td>
</tr>
<tr>
<td>Year built</td>
<td>1976</td>
</tr>
</tbody>
</table>

For privacy considerations, the values and turnover in the above table are approximations only.

The models, basic data and assumed information used in the analysis are briefly introduced in Table 4.

Table 4  Basic data and information used in the case analysis

<table>
<thead>
<tr>
<th>Location</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Hualien city</td>
</tr>
<tr>
<td>Coordinates</td>
<td>Longitude: 121.38; Latitude: 24.01</td>
</tr>
<tr>
<td>Ground type</td>
<td>The first type</td>
</tr>
<tr>
<td>Effective semi-diameter of the seismic source</td>
<td>250 km</td>
</tr>
<tr>
<td>Predicted earthquake eruption mode</td>
<td>Poisson mode</td>
</tr>
<tr>
<td>Energy release mode</td>
<td>Fault rupture mode</td>
</tr>
<tr>
<td>Surface ground motion attenuation formula</td>
<td>Campbell’s formula (doubling the standard variation of the upper and lower boundaries)</td>
</tr>
</tbody>
</table>

Utilising the seismic risk assessment module developed by our institute, the exceedance probability was calculated, and the seismic risk of the hotel was then assessed to obtain the surface ground acceleration peak value curve for the hotel’s location, as shown in Figure 7. From this figure, it can be seen that the peak ground acceleration (PGA) value for the hotel buildings (namely, an exceedance probability of 10% in 50 years) is ~0.32, which is consistent with the standard value, that is, a 475-year return period according to the aseismic standard. Given different seismic risks, the system cumulative simulation analysis (as shown in Figure 8) yields various damage probability distributions for these hotel buildings. The probability that hotel buildings will suffer light to moderate damage is high.

Assume that the owner of this tourist hotel wishes to buy insurance to disperse the earthquake risk, and the insured amount is 80% of the total value of the buildings (ignoring digits after the decimal point). The insured amount would be USD 2,500,000. Pursuant to current earthquake insurance regulations in Taiwan, and given that this hotel is located in the Fourth District and is A-level building, the deductible amount to be borne by the insurant should be at least 1%. If the deductible amount is increased from 1% to 10%, the premiums should be reduced accordingly. Therefore, the building owner must consider the amount of the deductible when purchasing seismic insurance.
Figure 7  Seismic damage curve for all seismic foci: probability of surpassing the PGA

![Figure 7](image1.png)

Figure 8  Distribution of the seismic response and probability of damage to hotel buildings

![Figure 8](image2.png)

After using the seismic risk assessment module to find the exceedance probability of a specific case, we compared the building’s seismic risk cost with possible loss. Figure 9 shows the annual seismic insurance premiums, annual deductible amount, the risk cost after the purchase of seismic insurance, the annual average loss and the probable maximum loss (PML). The seismic risk cost is a sum of the annual seismic insurance premium and annual average deductible amount. The average loss for buildings is correlated with the annual average deductible amount. It can be inferred from this figure that under different deductibles, the cost of seismic risk insurance remains lower than the average loss for buildings. When buying seismic insurance, building owners should choose the most economic deductible amount, namely 1%.

Because this building was built in 1976 based on the design standards for 1974, it was necessary to understand the difference between structural reinforcement and seismic loss. It was assumed that improvements were made to the original design to meet the design standards for 2000. Comparisons were made between the building’s seismic risk cost and seismic loss by using the 1982 and 2011 standards, as shown in Figures 9 and 10, respectively. From the figures, by adopting the 1982 assessment standards, the seismic risk cost for insurance would be lower than the average loss for buildings; therefore,
purchasing seismic insurance would be the optimal choice for the building owners, and the most economic deductible amount would be 1%. By adopting the 2011 standards, with different deductible conditions, the seismic risk cost for insurance would be higher than the average loss for buildings. Therefore, the optimal option for the building owner would be to choose a risk self-retention method or to collect their own disaster reserves.

If the owners decide to buy seismic risk insurance, the most economic deductible amount would still be 1%.

3.3 Seismic risk management strategies

Based on the risk analysis results for this hotel, this study developed three natural disaster risk management strategies:


With risk self-retention and self-reduction measures, hotel owners should prepare their own risk management strategies, such as creating their own disaster reserves and
implementing natural disaster prevention measures. The seismic risk cost will be higher than the annual average loss and may even approach the PML after reinforcement of the hotel structure. In this case, a risk self-retention strategy can be adopted. If hotel owners choose only risk self-retention as their risk management strategy, they should consider reserving a higher ratio of disaster reserves to manage unexpected events. The recommended minimum amount should be at least equal to the annual loss, as assessed by the hotel’s exceedance probability plus USD 60,000. Moreover, it is recommended that a certain percentage of funds should be used as disaster reserves; these funds are spent on projects to lower disaster risk, such as establishing an earthquake disaster response team, developing earthquake protection plans, studying and planning outdoor refuge and evacuation mechanisms, improving the allocation and locations of machinery and facilities (electromechanical equipment, banquet facilities, restaurant facilities, car parking, and entertainment and leisure facilities), and finally providing disaster prevention training to personnel.

The hotel in this case study was built in 1976 based on the aseismic design standards for 1974 and was damaged by earthquakes in 1986 and 1999. Therefore, this study recommends that the hotel should adopt measures to improve the earthquake resistance capacity of the hotel building and to reduce the possible seismic hazard risk. Based on the aggregate probability assessment result, if the hotel had adopted the latest aseismic design standards (2011), the annual average loss would have been lowered from USD 20,000 before the reinforcement to USD 8000 after the reinforcement (Table 5).

Table 5 Annual seismic loss and reinforcement effects for international urban tourist hotels

<table>
<thead>
<tr>
<th>Nominal construction cost for hotel buildings (USD10,000)</th>
<th>Average annual loss (USD)</th>
<th>Average annual aseismic loss: reinforcement (USD)</th>
<th>Average annual reinforcement effects (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>20,000</td>
<td>8000</td>
<td>12,000</td>
</tr>
</tbody>
</table>

From an economic perspective, if the cost of aseismic reinforcement of the hotel buildings is lower than the difference between the seismic loss before and after the reinforcement, then this can be seen as one of the most economical and most effective methods. If the amount for aseismic reinforcement for the hotel is less than USD 200,000 (in other words, the average annual reinforcement cost over 20 years will be less than USD 10,000 per year), the reinforcement of the hotel building can be regarded as effective.

Through the execution of the abovementioned disaster reserve saving mechanism, aseismic reinforcement and various preventive measures, the natural disaster risk to the hotel building can be reduced.

Strategy B Partial self-retention and catastrophe insurance.

According to the above disaster risk analysis results, the hotel’s earthquake disaster risk can also be reduced through the purchase of catastrophe insurance and partial self-retention. This insurance strategy focuses on seismic risk insurance and additional earthquake insurance. The seismic risk cost after aseismic reinforcement will be higher than the annual loss amount. Even though risk-risk retention is adopted as the risk strategy, the hotel should still purchase additional earthquake insurance in combination
with the seismic risk insurance to ensure loss prevention and reduce possible risk. The most economical deductible amount for the former is 1%.

【Strategy C】Partial self-retention and catastrophe insurance and industry coinsurance.

According to previous analysis results for various disaster types, the hotel can effectively reduce part of the natural disaster risk by combining the aseismic reinforcement strategy with the purchase of catastrophe insurance. However, because the total hotel assets amount to nearly USD 2.68 million, the insurance rate may be lower than the expected amount only if the insurance purchasing strategy is adopted, and the insurance amount may be insufficient. In this case, in addition to saving reserves for floods, and purchasing additional earthquake and flood insurance to partially cover the possible loss, some coinsurance system, possibly established by the tourism industry association, would be a favourable choice for transferring disaster risk. Therefore, participating in industry coinsurance through the Hualien Hospitality Association would be recommended to bridge the insurance loss gap. The following measures would effectively reduce the risk of direct loss and of business disruption caused by natural disasters: possessing over USD 60,000 in disaster reserves, drawing upon a percentage of disaster reserves to spend on aseismic reinforcement measures (satisfying the 2014 aseismic design standards would be recommended), and improving weak aseismic items (e.g., establishing a natural disaster response team, transferring facilities to safer locations and so on), as well as purchasing suitable catastrophe insurance and participating in industry coinsurance organisations. According to the aforementioned recommendations, Strategy C seems to be a more favourable choice for hotel disaster risk management. However, a self-help coinsurance system for hospitality industry has not yet been established in Taiwan. This study therefore suggests that hotel owners should choose Strategy B as their natural disaster risk management strategy, the detailed implementation of which is shown in Table 6.

<table>
<thead>
<tr>
<th>Disaster risk items</th>
<th>Suggested strategies</th>
<th>Suggested implementation methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic disaster risk</td>
<td>• Purchase catastrophe insurance</td>
<td>1. Purchase fire insurance plus seismic insurance: with the insured amount being USD 2,500,000 and the deductible amount being 1%</td>
</tr>
<tr>
<td></td>
<td>• Aseismic reinforcement strategies</td>
<td>2. Reinforce the hotel structure to meet the 2014 aseismic design standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Reinforce the furniture inside the buildings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Sign an open contract</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Establish a special earthquake response team and make aseismic plans</td>
</tr>
</tbody>
</table>

4 Systems benefits and restrictions

Situating at Pacific seismic belt, earthquakes occur in Taiwan frequently. How to do tourism development and disaster prevention simultaneously is always the purpose for
Taiwan government and citizens paying effort to. This research utilised the method ‘using probability analysis’ which created the earthquake evaluation system of tourism buildings and is supposed to generate five categories:

1. distribution of the seismic response and probability of damage to hotel buildings
2. annual seismic insurance premiums
3. annual deductible amount
4. the risk cost after the purchase of seismic insurance
5. the annual average loss and the PML.

Associated disaster evaluation information will be helpful for practitioners of tourism industry.

The natural disasters that tourism buildings face include floods, slopeland, tsunami, etc. This research focuses on severe tourism industry loss in Taiwan, and other disaster categories are not included. The first research restriction is the reason causing the interruption of tourism industry. In addition to the damage on buildings, the loss caused by vital lines (roads, electricity, water…) disruption is also included. The second restriction, loss evaluation, is out of the range of this research since it is in professional field.

5 Conclusions and recommendations

At present, many hotels are located in areas exposed to frequent natural disasters, which puts the hospitality industry at high risk. The risk assessment data and the characteristics that lead to natural disaster-related risk for the hospitality industry were studied. Statistical analysis was conducted to develop a seismic disaster risk assessment and management system suitable for the hotel industry. It is hoped that this study will draw the attention of academics on tourism research and encourage them to conduct additional studies to establish an integrated catastrophic risk assessment framework for the tourism industry as a whole, thereby reducing the catastrophic risks posed to the tourism industry. The findings and prediction modules are expected to provide the government with references for public tourism planning, the construction and reinforcement of roads, and establishment of flood control facilities. The data can be also used as references by the tourism industry for overall disaster strategy planning and by the insurance and banking industry when planning catastrophe insurance, catastrophe bonds, industry coinsurance systems and low-rate loans for the tourism industry. Additional studies may elaborate the seismic disaster risk assessment modules, and expand the application of these analytical results to other risk assessment modules (such as composite disaster or man-made disaster risk assessment modules).

Acknowledgements

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