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TAIWAN

A Probabilistic Risk Analysis for Taipei Seismic Hazards: An Application of HAZ-Taiwan with its Pre-processor and Post-processor[1]

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ABSTRACT

This paper employs probabilistic risk analysis to estimate exceedance probability curves, average annual loss (AAL) and probable maximum loss (PML) for seismic hazards. It utilizes an event-driven loss estimation model, HAZ-Taiwan, and develops its pre-processing and post-processing software modules. First, the pre-processing module establishes a set of hazard-consistent scenarios. Then, the HAZ-Taiwan model estimates hazards, vulnerabilities and economic losses for each scenario. Finally, the aggregate and occurrence exceedance probability curves for losses and their confidence intervals are simulated using the Monte Carlo simulation in the post-processing module. The methodology is then applied to analyze seismic risks in Taipei. It is found that the exceedance probability of an aggregate loss of NT$40.398 billion is 0.001. This amount of loss is approximately 2.78% of the total stock of buildings in Taipei. Its 5%-95% confidence intervals range from NT$37.41-43.12 billion. The average annual loss of buildings in Taipei is NT$1.06 billion, or approximately 0.07% of the total stock.

Keywords: probabilistic risk analysis; hazard analysis; vulnerability analysis; exceedance probability curve; HAZ-Taiwan

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1. Introduction

World-wide losses caused by natural catastrophes have increased significantly in the last ten years because of population increases, economic growth and concentration of population in hazard-prone areas (Munich Re, 2000). The same has occurred in Taiwan. Figure 1 shows the losses and casualties due to severe weather events (mainly typhoons) in the last fifty years in Taiwan. Although the numbers of casualties have been reduced over the years, the pecuniary losses have been increasing steadily. In addition, the strong earthquakes that have resulted in significant losses have struck Taiwan almost every thirty years, i.e. in 1935, 1964 and 1999. About 2,500 people lost their lives and many more were wounded as a result of the great Chi-Chi earthquake of September 21, 1999, not to mention the serious damage caused to many buildings and public facilities.

With more catastrophes expected in the future, various governments have recognized the need to have a better approach to estimate and manage the losses arising from such natural disasters. As a result, the U.S. Federal Emergency Management Agency (USFEMA) in 1997 released the first version of HAZUS, a software designed to estimate potential earthquake losses in the U.S. Following the lead taken by the U.S. with HAZUS, the National Science Council of Taiwan in 2000 developed a software that is similar to HAZUS, called HAZ-Taiwan.

Both models are deterministic and event-driven models, and can only estimate the impact of a single event, i.e. they cannot produce probabilistic loss estimates. However, in the 1990s, a few private firms, e.g., Risk Management Solutions, Inc. (RMS), Applied Insurance Research (AIR), and EQECAT, developed their own catastrophe loss assessment software that is capable of providing probabilistic loss estimates in the U.S. and other countries. They generated a series of probable disastrous events of different magnitudes to estimate the mean losses and variations in them.

In order to conduct a probabilistic seismic hazard analysis using the public-domain HAZUS model, Grossi (2000) used HAZUS with pre-processing and post-processing software modules to estimate losses to homeowners and the insurance industry in the Oakland, California region. However, more information on these calculations has not been provided due to the proprietary nature of the methodology. In addition, Grossi (2000) only considered the single maximum loss within a period, say, of one year. However, several events involving natural hazards may occur and give rise to losses in the same year. Therefore, this approach does not take into account the effect of the multi-occurrence of natural hazards and tends to underestimate the aggregate losses over the course of a year. This underestimation may be serious since governments and insurance companies may risk a high probability of insolvency simply because of this underestimation.

The purpose of this study is to make the deterministic HAZ-Taiwan model capable of producing probabilistic loss estimates for the multi-occurrence of earthquake events in Taiwan. In Section 2, we develop our pre-processing and post-processing software for HAZ-Taiwan. The pre-processor establishes a set of hazard-consistent catastrophe scenarios. Then, the HAZ-Taiwan model estimates the hazards, vulnerabilities and economic losses for each scenario. Finally, the exceedance probability curves for the mean losses and their variations are simulated using the Monte Carlo simulation in the post-processor. Not only maximum losses, but also aggregate losses, are simulated to provide a more complete picture of the natural hazard. The methodology is then applied to analyze seismic risks in Taipei. Section 3 concludes.

2. Methodology and the Taipei Case Study

The probabilistic risk analysis conducted to estimate the exceedance probability (EP) curves and losses for seismic hazards consists of three modules: the pre-processor, which is a scenario builder, the HAZ-Taiwan model, and the post-processor.

2.1 The Pre-processor: The Hazard Consistent Earthquake Scenario Builder

The first type of information that we need to estimate the probabilistic losses due to earthquakes is a list of scenario earthquakes, which can adequately represent the potential seismic sources. In order to characterize these seismic sources, we need to consider the spatial distribution and temporal distribution of earthquakes at each source. An occurrence model for earthquakes of various magnitudes is also needed. We use the stationary Poisson process to model the spatial and temporal distribution of earthquakes at a source.

1. Earthquake Spatial Distribution

Based on the geological data, tectonic structure, subduction zones and seismological information, the most representative seismogenic zoning scheme is shown in Figure 2. The seismicity around Taiwan is also shown in the figure to demonstrate the consistency between the zoning scheme and the seismicity. The earthquake occurrence rate of each sub-zone is uniformly distributed within that sub-zone according to the Poisson process assumption.

2. Earthquake Occurrence Model

The Gutenberg-Richter magnitude recurrence relation is given by

$$\log_{10} N = a - bM \tag{1}$$

where M is the magnitude, N is the number of earthquakes with magnitude $\geq M$, and parameters a and b can be evaluated from the earthquake catalog for each sub-zone. Eq. (1) is then modified into a truncated exponential model by specifying the lower and upper bounds of magnitude.

3. Temporal Distribution of Earthquake Source

Based on the Poisson process assumption, the average annual occurrence rate can be calculated from Eq. (1) and is adopted to represent the temporal distribution of the earthquake.

As in Table 1, a series of 342 hazard-consistent earthquake scenarios are generated and represented as (Eq_{sk}: $\overline{m}_k$, ν_{sk}, Es, Ns) to reflect the seismicity around Taiwan and to perform the earthquake loss estimation. For a scenario earthquake Eq_{sk}, $\overline{m}_k$ denotes its magnitude, (Es, Ns) are the epicenter's coordinates, and ν_{sk} is the average occurrence rate.

2.2 The HAZ-Taiwan Model: Seismic Loss Estimation of General Building Stocks

In order to evaluate the damage states/quantities and to estimate the seismic losses of general building stocks under earthquake scenarios, it is necessary to collect related databases and to calibrate analysis parameters with reasonable precision. This study uses Taipei as the pilot study region. However, once its feasibility and applicability is verified, it can be extended to apply to the whole of the Taiwan area and to estimate the exceedance probabilities of the maximum probable loss or annual average loss due to damage to general building stocks under hazard-consistent scenario earthquakes.

1. Basic Database

Besides the source parameters of the earthquake scenarios as mentioned in the previous section, the site-dependent ground motion intensities in terms of peak ground acceleration and spectral accelerations of 0.3 and 1.0 seconds, respectively, are obtained by adopting a traditional approach, that is, by using attenuation laws and site modification factors. The attenuation laws used in this study were published in Jean (2001). When seismic waves propagate from bedrock to the ground's surface, the amplification depends on the amplitudes of seismic waves, the dynamic properties of soil, and the topography at the site. A soil-type classification map is often used in determining site modification factors. However, due to the topography and basin effects, the site effects in the Taipei basin should be studied carefully.

Secondly, in order to consider the uneven settlement or lateral spreading due to soil liquefaction in the assessment of building damage, it is necessary to collect a susceptibility category map due to soil liquefaction. The liquefaction susceptibility map of Taipei and the empirical formulae used to estimate the liquefaction probability and the induced settlement are based on Yeh (2002a, b). Since the depth of ground water often varies with seasons and site conditions, it is assumed to be 1.5 meters unless more reasonable data are made available.

The building quantity statistics used in this study were obtained from the building tax data provided by the Ministry of Finance and various local governments. According to the input requirements of the Taiwan Earthquake Loss Estimation System (TELES) (Yeh, 2003a, b), which followed the HAZ-Taiwan approach and was developed by the National Center for Research on Earthquake Engineering, a building classification scheme was proposed and floor area statistics were obtained as follows. In order to efficiently estimate the state of damage that thousands of buildings subjected to strong earthquakes were in, the general building stocks were divided into 15 model building types according to their construction materials and height. These were wood (L), steel (L, M, H), light-steel (L), reinforced concrete (L, M, H), pre-cast concrete (L), reinforced masonry (L, M), un-reinforced masonry (L), and steel reinforced concrete (L, M, H). The letters L, M and H in parentheses denote low-rise, medium-rise and high-rise buildings, respectively. Depending on the year of construction and the seismic zonation, each model building type was further divided into four seismic design levels, namely, high-code, moderate-code, low-code and pre-code. The parameters in relation to the capacity and the fragility curves of each model building type and seismic design level needed to be calibrated carefully (Yeh, 2000). When buildings were subjected to strong excitations, the structural systems became nonlinear systems. Since the increase in hysteretic damping depends on the response level, an iteration method was used to find the performance point, which determined the maximum probable displacement and acceleration of a building's structural system.

To assess the economic losses arising from these general building stocks that are subjected to scenario earthquakes, the general building stocks should be classified according to their occupancy classes (usages). Since the classification scheme in relation to building usages is somewhat simplified, the specific occupancy classes used in this study follow the principles mentioned in Yeh (2003a), but contain only 13 specific occupancy classes including residential (2), commercial (5), industrial (1), agricultural (1), non-profit organizations (1), government (1), and educational (2). The numbers in parentheses represent the numbers of specific occupancy classes within the general occupancy classes. Because taxes are not paid on buildings owned by the government, the numbers in that column are all zeros in this study. To transform the damage states and quantities of model building types to those of specific occupancy classes, the mapping scheme for specific occupancy classes to model building types in each town is also obtained by analyzing the building tax data.

2. Economic Loss Estimation Model

To simplify the analysis and to avoid confusion when calibrating the associated parameters, the replacement costs of buildings contain three parts. They are the structural system, the acceleration-sensitive non-structural components, and the drift-sensitive non-structural components. It is assumed that the replacement costs of the structural systems are only related to the model building types, while the replacement costs of non-structural components are only related to the specific occupancy classes. The damage ratios in relation to the various damage states are also listed in the table. The so-called damage ratio is defined as the ratio of loss and replacement cost. The spectral displacement is used to estimate the damage-state probabilities of the structural systems and drift-sensitive non-structural components; while the spectral acceleration is used to estimate the damage-state probabilities of the acceleration-sensitive non-structural components. The parameter values in these fragility curves were obtained in part from experimental results and experiences and in part from subjective judgments. Besides referring to the total economic losses of general building stocks due to Taiwan's Chi-Chi earthquake in 1999, the replacement costs were estimated on the basis of the following rules:

a. When the building height increases, the construction cost per unit of floor area increases due to the additional costs associated with structural design, material strength, the excavation of a basement, and so on.
b. Before a building's structural systems reach the "complete damage" state, the total costs of retrofit and repair should increase as the building height increases. However, most of the damage is concentrated in the lower stories of the buildings, and hence the average retrofit and repair costs per unit floor area decrease.
c. Wood and un-reinforced masonry buildings have higher damage ratios in relation to the same damage-state, because they are not seismically designed.

The values of movable furniture, equipment, and business inventory in buildings are assumed to be proportional to floor area. Since the damage-state of a building's contents is related to acceleration, the fragility parameters are similar to those of acceleration-sensitive non-structural components. Even if the structural system has been completely damaged, it is assumed that part of the building's contents can still be used or sold. Thus, the damage ratio in relation to the building's contents in a completely damaged state is assumed to be 0.5 in this study. The estimation of the economic loss in relation to the building's structural system, non-structural components and contents follow an approach similar to that of Yeh (2003a). According to the parameter values and simple mathematical operations, the total replacement cost of general building stocks in Taipei is about NT$14,500 billion.

In our study, we calculated the expected losses arising from the building's structural systems, non-structural components and contents due to scenario earthquakes. The standard deviations caused by the uncertainties surrounding the damage-states were also calculated. The expected loss and the standard deviation are denoted by μ and σ, respectively, and expressed as Eqs. (2) and (3), respectively. In these equations, k denotes the different types of losses including losses due to damage to the structural systems, the acceleration-sensitive or drift-sensitive non-structural components, and the buildings' contents.

$$\mu_k = \sum_{ds=2}^{5} RC_{k,ds} P_{k,ds} \tag{2}$$

$$\sigma_k{}^2 = \left[\sum_{ds=2}^{5} RC_{k,ds}{}^2 \cdot P_{k,ds} \right] - \mu_k{}^2 \tag{3}$$

The variation coefficient of economic losses in relation to general building stocks subjected to a scenario earthquake is defined as

$$COV = \frac{\left(\sum_{k=1}^{4} \sigma_k{}^2 \right)^{1/2}}{\sum_{k=1}^{4} \mu_k} \tag{4}$$

By using the loss estimation model and the associated parameter values as inputs in HAZ-Taiwan/TELES, the economic losses in relation to general building stocks in Taipei due to scenario earthquakes generated by the pre-processor were obtained and are presented in Table 1. In Table 1, EXPLOSS represents the loss due to damages to structural systems, non-structural components and contents, TOTAL is the sum of EXPLOSS, relocation expenses and income losses, COV is the variation coefficient due to the uncertainty surrounding the damage-state, and EXPO is the total exposure of general building stocks in Taipei.

2.3 Post-processor: EP maker

The purpose of the probabilistic risk analysis methodology is to estimate the mean and its variation in relation to regional earthquake losses. The foundation of the methodology is the loss exceedance probability (EP) curve. The y-axis of the EP curve represents the probability of exceedance and the x-axis the measure of risk. The probability of exceedance is the probability that the measure of risk will be exceeded for a given period of time. Typically, the period of time is one year and the measure of risk is the economic loss. With a mean EP curve, we can easily calculate the expected annual loss as the area under the mean EP curve. We can also easily find the worst-case loss by reading the loss associated with a given low annual probability of exceedance from the EP curve.

The output of the pre-processor and the HAZ-Taiwan model is an event loss table (ELT) as in Table 1. An ELT depicts the annual rate of occurrence (λ_j), the expected loss ($\overline{L_j}$), and the standard deviation of the loss (σ_{L_j}) for every event generated in the pre-processor (Hazard Consistent Earthquake Scenario Builder). There are a total of J events in the ELT, i.e. j=1, …, J.

There are two kinds of EP curve. The traditional EP curve, called the occurrence loss exceedance probability (OEP) curve in Dong (2001), is defined as:

$$F(L > l_k) = F(\max(L_1, L_2, ..., L_n) > l_k) = 1 - P(L < l_k) \tag{5}$$

where $P(L < l_k)$ denotes the cumulative probability function for the loss l_k. An OEP is the exceedance probability of the maximum loss in a period, regardless of how many occurrences (n) there are. However, since every event in the ELT is independent, more than one event causing losses may occur in a given period of time and the aggregate losses may be prohibitive. Thus, Dong (2001) defined a new EP curve, referred to as the aggregate loss exceedance probability (AEP) curve, as

$$F(L > l_k) = F(L_1 + L_2 + ... + L_n > l_k) = 1 - P(L < l_k) \tag{6}$$

Thus, an AEP is the exceedance probability of the aggregate loss in a period.

Dong (2001) has derived equations for both EPs. First, he discretizes all event losses into increments of Δl. Therefore, a random loss L can have only discrete values, l_k, that are multiples of the increment, i.e.

$$l_k = k \cdot \Delta l, \qquad k = 1, ..., K$$

For any event j with the expected loss l_j, the probability that the loss will be equal to $l_k = k \cdot \Delta l$, is denoted as

$$p_{j,k} = P(L_j = k \cdot \Delta l)$$

Then the mean rate for the loss value l_k (=$k\Delta l$) is as follows:

$$\overline{\lambda_k} = \sum_{j=1}^{J} \overline{\lambda_j} \cdot p_{j,k}$$

Note that the rate $\overline{\lambda_k}$ is no longer a rate for a particular event, but the summation of all events with the loss exactly equal to l_k. Let $\overline{\lambda} = \sum_k \overline{\lambda_k}$. Then, an OEP is equal to:

$$F(L \geq l_k) = 1 - P(L < l_k) = 1 - e^{-\sum_{i \geq k} \overline{\lambda_i}} \tag{7}$$

and an AEP is

$$F(L \geq l_k) = 1 - P\left(L < l_k\right) = 1 - (e^{-\bar{\lambda}} + \sum_{n=1}^{\infty} \frac{e^{-\bar{\lambda}} \cdot \bar{\lambda}^n}{n!} P^{n^*}\left(L < l_k\right)) \quad (8)$$

where $P^{n^*}\left(L < l_k\right)$ is the n^th^ convolution of P evaluated at the loss l_k.

Although it is not difficult to calculate the OEPs according to Eq. (7), very large numbers of calculations are required to evaluate the AEPs according to Eq. (8). In order to solve the calculation problem, we write a Monte Carlo simulation program to generate the exceedance probability curves for aggregate and maximum losses and their variation using the information in an ELT.[2] The simulation program consists of the following steps:

1. To generate the mean EPs:

(1) Use a simplified version of the output of the pre-processor and the HAZUS model as in the case of the Event-Loss Table (ELT) in Table 2.

(2) By assuming that each event follows an independent Poisson process, generate the rate of occurrence (R_j) using the Poisson (λ_j), $0<R_j<\infty$, rounded to integers in the first simulation. Then calculate the simulated losses (SL_j) which are equal to (R_j) times the expected loss ($\overline{L_j}$).

(3) Calculate the maximum loss, $L_o = Max\left(\overline{L_1}, \overline{L_2}, ..., \overline{L_n} \mid R_j \geq 1, j = 1, ..., n\right)$.

(4) Calculate the aggregate loss, $L_A = (SL_1 + SL_2 + ... + SL_n \mid R_j \geq 1, j = 1, ..., n)$.

(5) Repeat the above steps M times, say, M=10,000. Thus, the probability of the occurrence of L_o and L_A generated in every simulation is $1/M$.

(6) Order the L_o (and L_A) generated in the M simulation in descending order. Then, $F\left(L \geq l_k\right)$=k/M. l_k is k^{th} L_o or L_A. The first simulation has successfully generated the mean exceedance probability curve for both OEP and AEP. With a mean EP curve, we can easily calculate the expected annual loss because it is the area under the mean EP curve. We can also easily find the worst-case loss by reading the loss associated with a chosen low annual probability of exceedance from the EP curve.

2. To generate the confidence interval for the EPs:

(1) For each event in the ELT, use the cumulative Beta distribution β (*a, b, p, q*) to generate the losses (L_j). The Beta distribution has four parameters: *a, b, p,* and *q*.

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[2] The program is written in SAS.

of which a=0, since a is the lower bound of the losses, b=X (total exposure), since b is the upper bound of the losses, and p and q can be calculated from the mean loss ($\overline{L_j}$) and standard deviation ($\sigma^2_{L_j}$) using Eqs. (8) and (9) (Johnson and Kotz, 1970, p. 44).

$$p+q=((\overline{L_j}-a)/(b-a))(1-(\overline{L_j}-a)/(b-a))/(\sigma^2_{L_j}/(b-a)^2)-1 \quad (8)$$

$$p=((\overline{L_j}-a)/(b-a))^2(1-(\overline{L_j}-a)/(b-a))(\sigma^2_{L_j}/(b-a)^2)^{-1}-((\overline{L_j}-a)/(b-a)) \quad (9)$$

Based on the above, we first generate a random number p_j using the uniform distribution. $0<p_j<1$. Then we generate L_j, given p_j and β (a, b, p, q). This process is repeated for all events in the table and results in a new ELT.

(2) Follow the simulation procedure in the first simulation, in order to obtain another OEP (and AEP) curve.

(3) Repeat the above procedure N times, for example, N=1,000. We can then produce N curves of the two kinds of EP. The 5%-95% and 85%-15% confidence intervals can be obtained from the N curves of EP.

2.4 Taipei Case Study

The above methodology is then applied to analyze seismic risks in Taipei. First, we obtain the event loss table (ELT) for 342 scenario earthquakes in Taipei (Table 1) by using the pre-processor and the HAZ-Taiwan model. We then apply the Monte Carlo simulation methodology in the post-processor with M=10,000 and N=1,000.

The results of the case study are presented in Figures 3-7 and Tables 3-4. Figures 3 and 4 depict, respectively, the simulated mean aggregate loss exceedance probability curve (L_{AEP}) and the simulated mean occurrence loss exceedance probability curve (L_{OEP}). Figure 5 is a portion of the mean and its confidence intervals of the simulated aggregate loss exceedance probability curve (L_{AEP}), and Figure 6 is that of L_{OEP}. L_{AEP} and L_{OEP} are combined together in Figure 7 to show that, given an exceedance probability, the aggregate loss would always be greater than the occurrence loss as expected.

Tables 3 and 4 show the values of those losses. It is found that the exceedance probability of an aggregate loss of NT$40.398 billion is 0.001. This amount of the loss is approximately 2.78% of the total stock of buildings in Taipei. The respective 5%-95% confidence intervals range from NT$37.41-43.12 billion. The average annual loss of buildings in Taipei is NT$1.06 billion. Given an exceedance probability, the difference between the aggregate loss and the occurrence loss ranges from 0.1%-13%.

3. Conclusion

This paper uses probabilistic risk analysis to estimate exceedance probability curves, average annual loss (AAL) and probable maximum loss (PML) for seismic hazards. It utilizes an event-driven loss estimation model, HAZ-Taiwan, and develops its pre-processing and post-processing software modules. First, the pre-processing module establishes a set of hazard-consistent catastrophe scenarios. Then, the HAZ-Taiwan model estimates hazards, vulnerabilities and economic losses for each scenario. Finally, the aggregate and occurrence exceedance probability curves for losses and their confidence intervals are simulated using Monte Carlo simulation in the post-processing module.

The methodology is applied to analyze seismic risks in Taipei. It is found that the exceedance probability of an aggregate loss of NT$40.398 billion is 0.001. This amount of loss is approximately 2.78% of the total stock of buildings in Taipei. The corresponding 5%-95% confidence intervals range from NT$37.41-43.12 billion. The average annual loss (AAL) of buildings in Taipei is NT$1.06 billion.

The invaluable information provided by this probabilistic risk analysis would be very useful for both the government and the insurance industry as they plan ahead for the worst possible earthquake that may occur in Taipei in the future.

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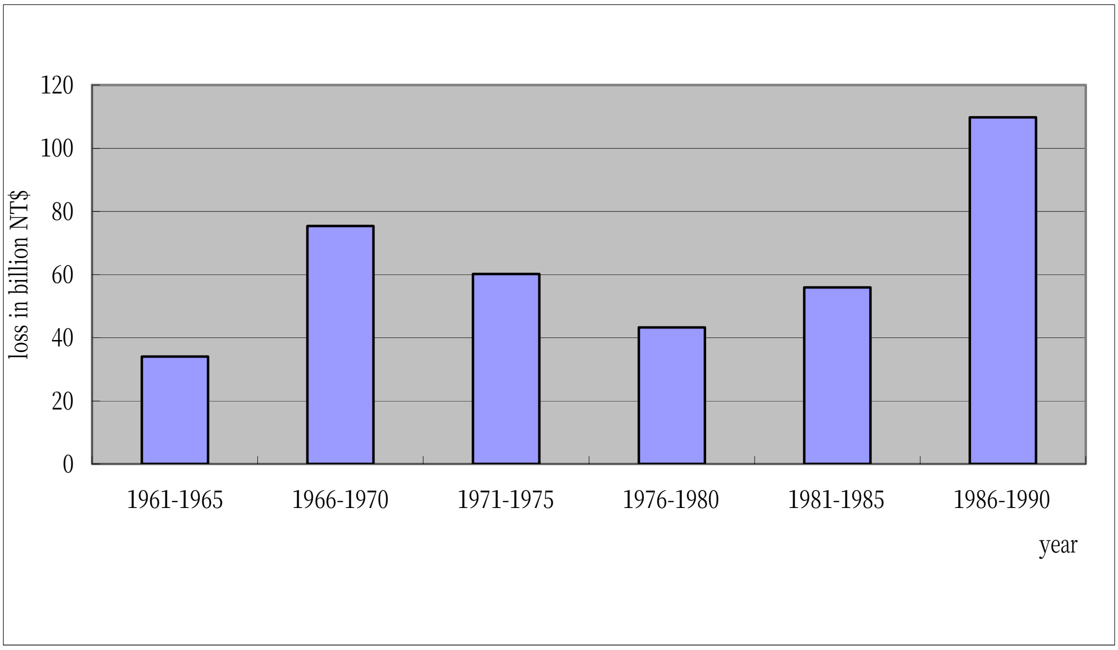

Figure 1 Loss Caused by Severe Weather in Taiwan
Source: Central Weather Bureau

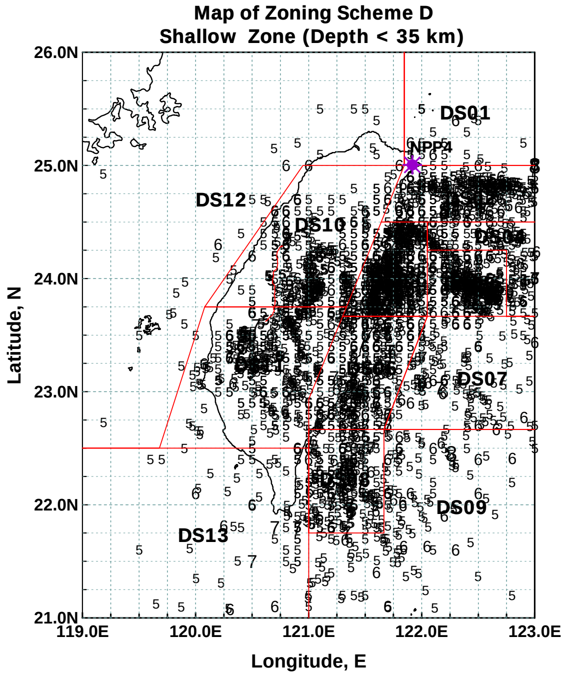

Figure 2. Comparison of zoning scheme and epicenters of earthquakes with $M_L \geq 4.5$

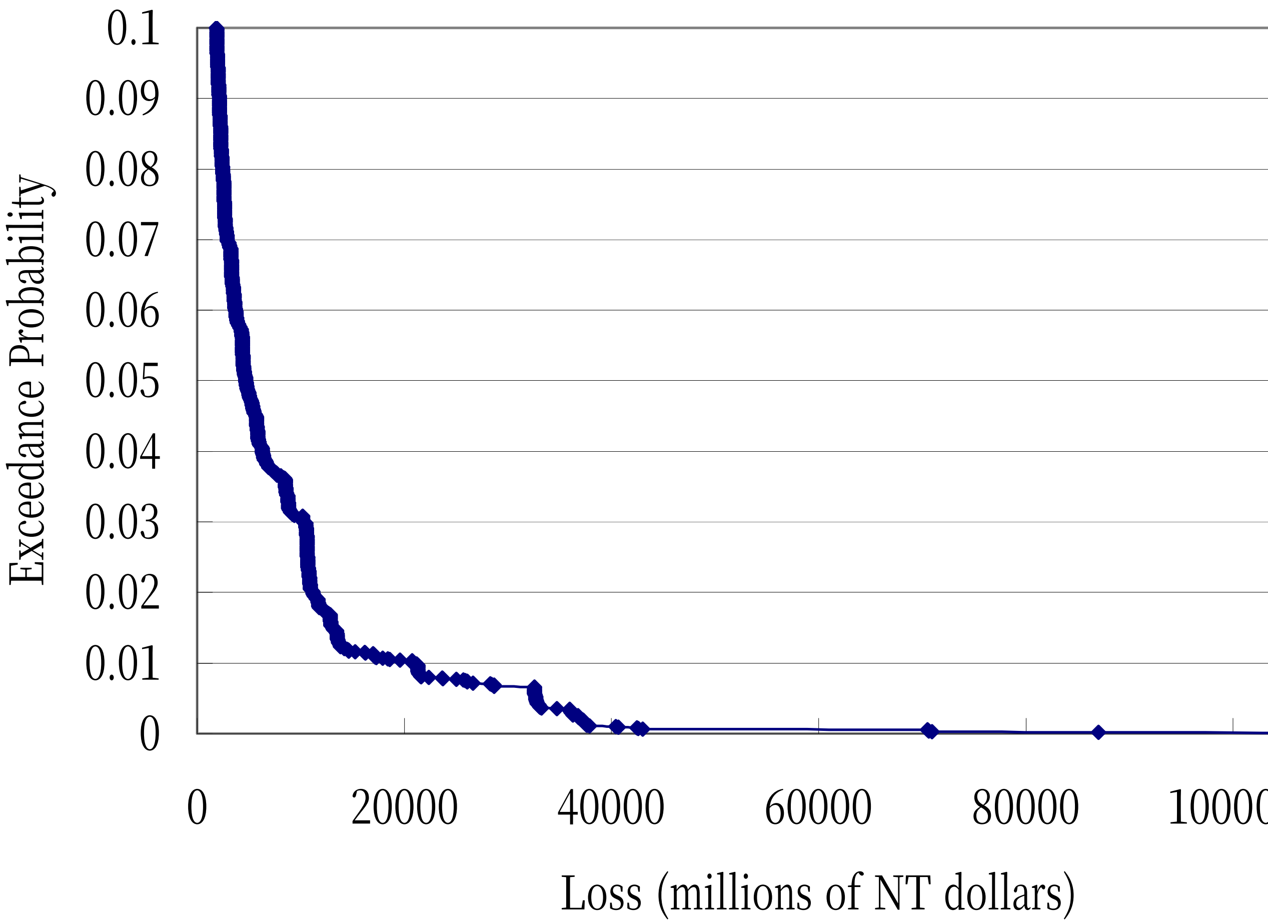

Figure 3 Aggregate Loss Exceedance Probability Curve (L_{AEP})

Loss (millions of
NT dollars)

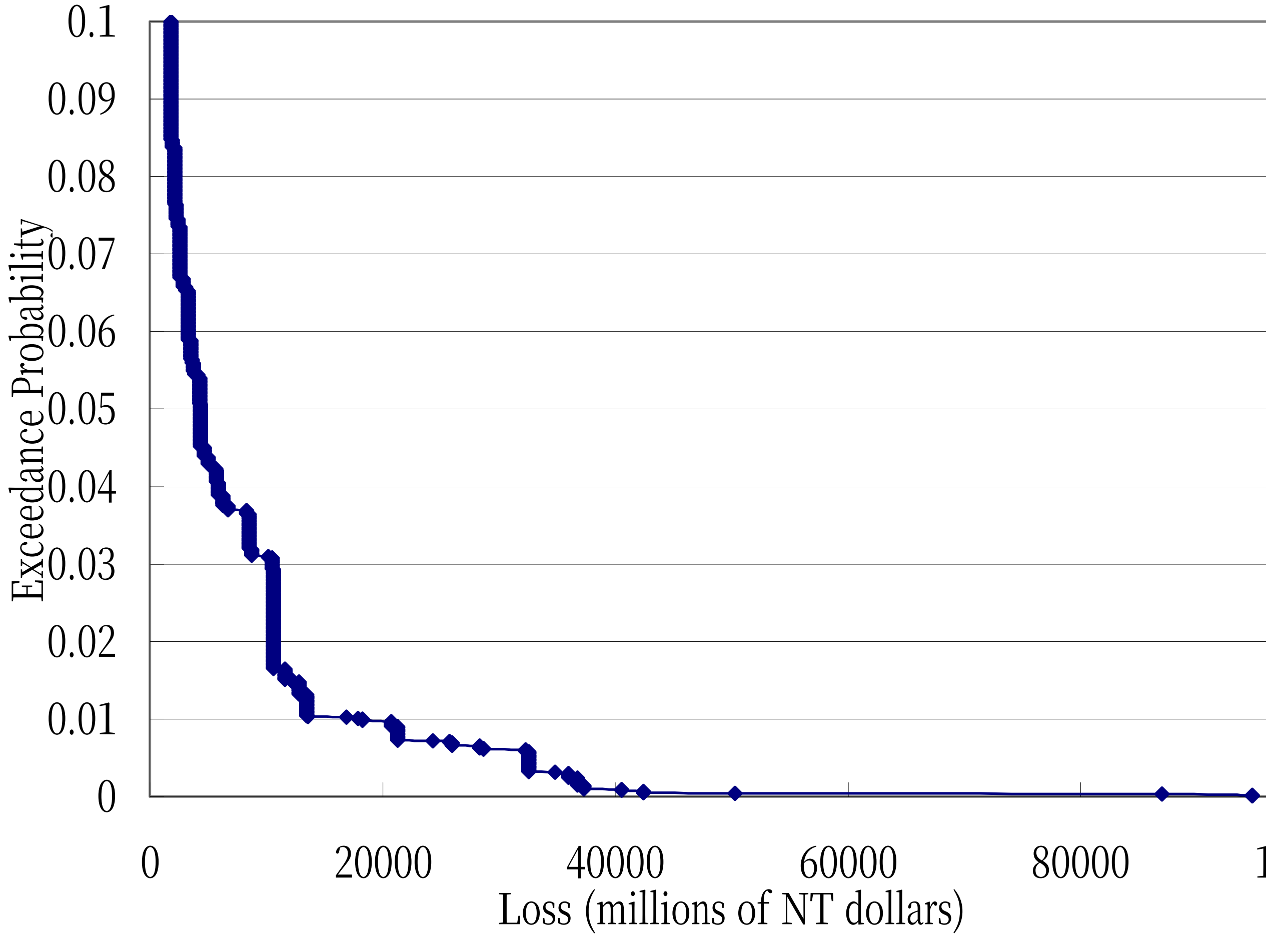

Figure 4　Occurrence Loss Exceedance Probability Curve (L_{OEP})

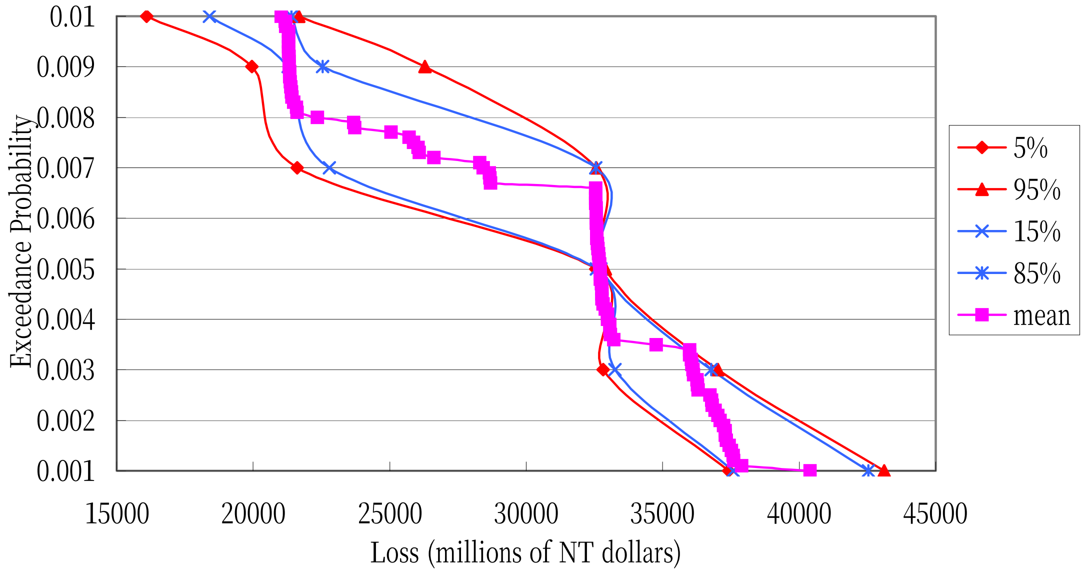

Figure 5 Aggregate Loss Exceedance Probability Curves (Mean and Confidence Intervals)

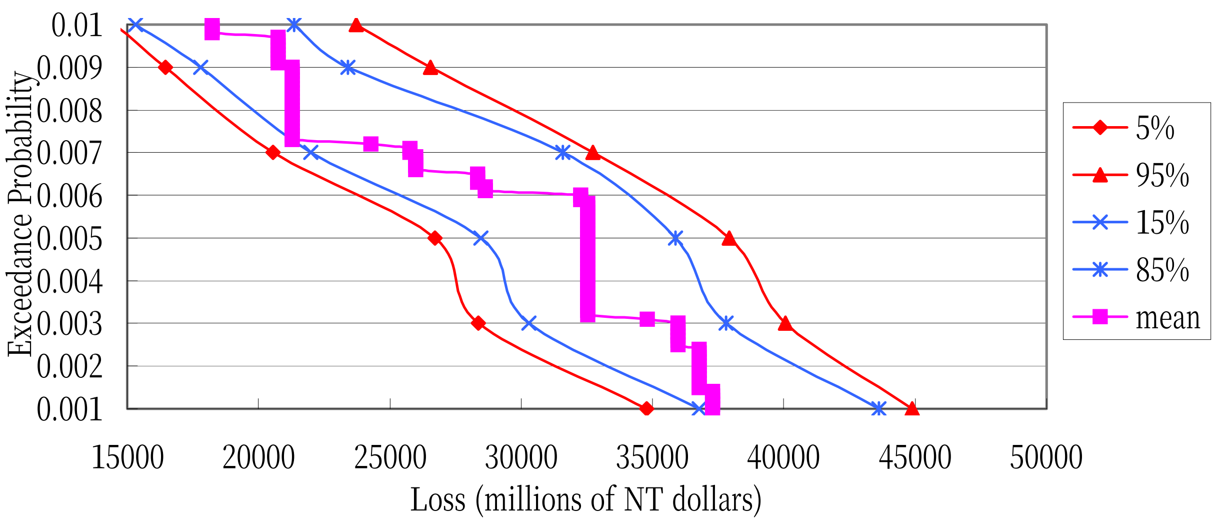

Figure 6 Occurrence Loss Exceedance Probability Curves (Mean and Confidence Intervals)

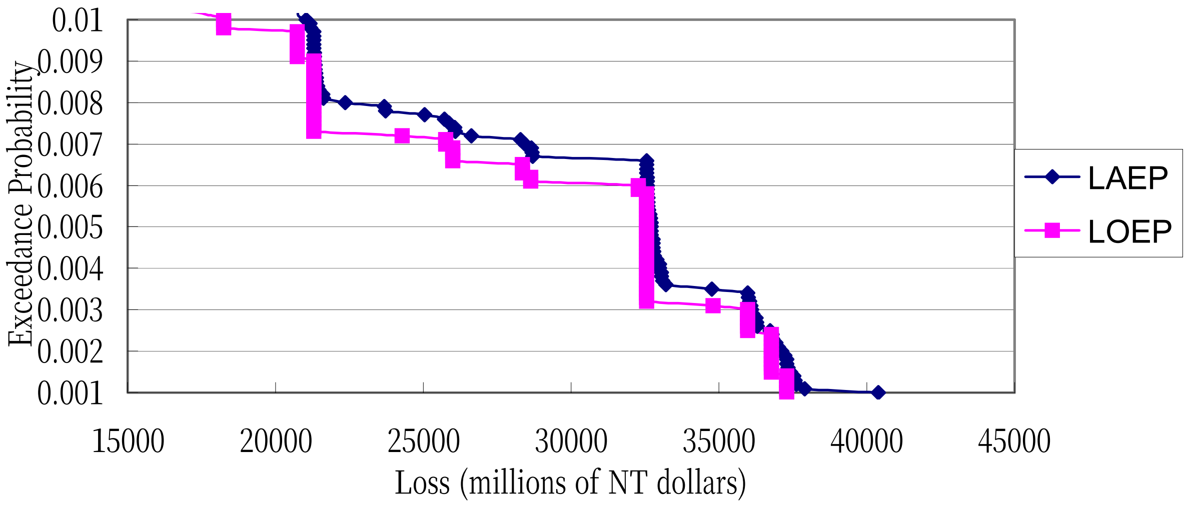

Figure 7 Comparison of L_{AEP} and L_{OEP} Curves

Table 1 Scenario Earthquake Events and their Economic Losses in terms of General Building Stocks (Partial)

EVENT_ID	MAGNITUDE	EPIC_X	EPIC_Y	DEPTH	RECUR_RATE	TOTAL	EXPLOSS	COV	EXPO (NT$$10^6$)
s01ch_575	5.75	363215.45	2807800.20	10000.0	0.00165	19.079	19.028	1.21116	1453131.327
s01ch_625	6.25	363215.45	2807800.20	10000.0	0.00104	201.606	195.539	0.50533	1453131.327
s01ch_675	6.75	363215.45	2807800.20	10000.0	0.00065	1601.470	1451.168	0.28103	1453131.327
s01ch_725	7.25	363215.45	2807800.20	10000.0	0.00041	10187.030	8328.536	0.17646	1453131.327
s01ch_763	7.63	363215.45	2807800.20	10000.0	0.00015	33264.350	25756.040	0.12187	1453131.327
s01dh_575	5.75	388377.24	2808035.49	10000.0	0.00248	3.208	3.208	2.61721	1453131.327
s01dh_625	6.25	388377.24	2808035.49	10000.0	0.00156	47.142	46.731	0.85479	1453131.327
s01dh_675	6.75	388377.24	2808035.49	10000.0	0.00098	440.361	417.873	0.40050	1453131.327
s01dh_725	7.25	388377.24	2808035.49	10000.0	0.00061	3280.200	2858.837	0.23785	1453131.327
s01dh_763	7.63	388377.24	2808035.49	10000.0	0.00022	13304.210	10615.565	0.16472	1453131.327

Table 2　Event Loss Table (ELT)

Event ID (1)	Annual rate of occurrence (2)	Expected loss (3)	Standard deviation of loss (4)	Total exposure (5)
1	λ_1	$\overline{L}_1$	σ_{L_1}	X_1
2	λ_2	$\overline{L}_2$	σ_{L_2}	X_2
:	:	:	:	:
j	λ_j	$\overline{L}_j$	σ_{L_j}	X_j
:	:	:	:	:
J	λ_J	$\overline{L}_J$	σ_{L_J}	X_J

Table 3 L_{AEP} and its 90% Confidence Interval

Loss / EP	5%		Mean		95%	
	loss (NT$$10^6$)	Loss/Total exposure (%)	Loss (NT$$10^6$)	Loss/Total exposure (%)	Loss (NT$$10^6$)	Loss/Total exposure (%)
0.001	37412	2.57%	40398.15	2.78%	43116.89	2.97%
0.003	32820.03	2.26%	36105.6	2.48%	37025.16	2.55%
0.005	32547.81	2.24%	32706.79	2.25%	32902.57	2.26%
0.007	21611.52	1.49%	28433.06	1.96%	32578.67	2.24%
0.009	19956.88	1.37%	21318.57	1.47%	26289.03	1.81%
0.01	16092.61	1.11%	21038.73	1.45%	21665.14	1.49%

Table 4 L_{OEP} and its 90% Confidence Interval

Loss / EP	5%		Mean		95%	
	Loss (NT$$10^6$)	Loss/total exposure (%)	Loss (NT$$10^6$)	Loss/Total exposure (%)	Loss (NT$$10^6$)	Loss/Total exposure (%)
0.001	34771.61	2.39%	37294.3	2.57%	44880.82	3.09%
0.003	28361.39	1.95%	35976.43	2.48%	40071.24	2.76%
0.005	26704.54	1.84%	32543.63	2.24%	37921.8	2.61%
0.007	20541.98	1.41%	25756.04	1.77%	32735.74	2.25%
0.009	16453.13	1.13%	21294.64	1.47%	26550.65	1.83%
0.01	14548.05	1.00%	18238.12	1.26%	23728.33	1.63%

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