AN EARTHQUAKE RISK ASSESSMENT FROM THE VIEWPOINT OF ECONOMICS BY ANALYSING MACRO DATA IN KYOTO

DR. TETSUO MIZUTA

Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University
58 Komatsubara-kitamachi, Kita-ward, Kyoto-city, 603-8341 Japan

DR. HITOSHI TANIGUCHI

Graduate School of Engineering, Nagoya Institute of Technology
Gokisocho, showa-ward, Nagoya-city, 466-8555 Japan

DR. HIDEHIKO KANEGAE

School of Policy Science, Ritsumeikan University
56-1 Toujiin-kitamachi, Kita-ward, Kyoto-city, 603-8577 Japan

DR. SATOSHI OHTSUKI

Kinugasa Research institute, Ritsumeikan University
56-1 Toujiin-kitamachi, Kita-ward, Kyoto-city, 603-8577 Japan

DR. MASAHIRO SHIROTSUKI

Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University
58 Komatsubara-kitamachi, Kita-ward, Kyoto-city, 603-8341 Japan

Abstract: Kyoto has much earthquake risk, however it is a very famous sightseeing city in the world, for there are many active faults lying inside and outside of Kyoto city. Under this situation, tourism and sightseeing related industries account for about 10 percent of Kyoto city's Gross Regional Products (GRP). Estimation of human losses and Infrastructures' losses from earthquakes are shown by the city office, but it does not show economic losses. This paper estimates economic losses of tourism and sightseeing related industries from earthquakes by analyzing macro data. As a result, this paper calculates 21 Trillion JPY losses directly and indirectly in the worst case.

Keywords: Risk Assessment, Earthquake, Kyoto, Estimation, Macro Data

1. Introduction

Although Kyoto city is a very famous tourism and sightseeing places[1)], several active faults lay inside and around the city. The city holds much earthquake risk at all times. The city office made an estimation of human losses and infrastructure's losses[2)] from earthquakes. But, tourism and sightseeing related industries' losses are not shown yet. However, tourism and sightseeing related industries account for about 10 percent of city's Gross Regional Products[3)]. Only the authors estimate it with several methods[4)].

In this paper, the authors tries to re-estimation direct losses and indirect losses from earthquakes with analyzing Macro data, such as Input/Output Data[5)], City Accounts[6)] and National Stock Data named "Min-Ryoku"[7)]. The authors make use of it as basic data to realize true disaster prevention and mitigation.

This paper is a revised paper, from the one presented in the Institute of Social Safety Science's meeting held in May, 2008, in Hokkaido.

In the pre-revision paper, the authors estimated direct losses by analyzing Gross Regional Products (GRP) data. But, GRP includes both factors of "stock" and "flow" therefore adopting GRP data is not appropriate. Thus, the authors try to calculate by using national stock data and distribution index named "Min-Ryoku" for each administrative ward of Kyoto city. After estimating direct losses from these data, the authors calculate indirect losses by analyzing Input/Output data.

Through these processes, the authors try to show quantitative risk analysis.

2. Prerequisite conditions for loss estimation

2-1 Structure of I/O Data table

The Kyoto prefecture's I/O Data table is organized by 4 types of number of category; 14, 35, 92, 211. In this analysis, the authors adopted the 35-categoly table, because the 14-categoly table is too rough, while the 92-categoly and the 211-categoly tables are too complex to analyze. The authors took 13 categories as one with direct relation to tourism and sightseeing. These are agriculture, food production, fiber goods production, wooden goods production, printing, electricity and energy supply services, water and waste treatment, commerce, transportation, telecommunication and broadcasting, administrative office service, individual service, and office work supplies. The authors estimated Kyoto city's tourism and sightseeing related industries' losses from earthquakes with analyzing these 13 categories of the city's macro data.

2-2 Assumed 9-types of earthquake

The Kyoto city office is worrying about occurrence of earthquakes and showed expected losses in each 11 administrative ward as "Expected Losses Estimation Report, the third edition" in 2005. Expected earthquakes' name, volume of magnitude and range of tremor are shown below.

1) Hanaore fault quake: M7.5 and 5+ to maximum 7
2) Momoyama fault quake: M6.6 and 5- to maximum 7
3) Ujigawa fault quake: M6.5 and 5- to 6+
4) Katagihara fault quake: M6.6 and 5- to maximum 7
5) Koumyouji fault quake: M6.3 and 4 to 6-
6) Arima fault quake: M7.2 and 5- to 6+
7) Oubaku fault quake: M6.5 and 4- to maximum 7
8) Biwako-seigan fault quake: M7.7 and 5- to 6+
9) Nankai-Tounankai trough quake: M8.6 and 5- to 6

2-3 Details of equations

To estimate lost values from earthquakes, we set an equation with two parameters; the percentage of houses and buildings burned downed and the percentage of broken houses and buildings. Then, we estimated direct lost values in each quake types and each administrative ward, and sum all values as total losses of Kyoto city's tourist and sightseeing related industries. Although the authors noticed that "rumor's negative effect" is not to be neglected, we did not include it in whole city's losses. It is because the authors treated stable data as parameter for calculation, while "rumor's negative effect" is not easy to grasp. Thus we did not include it in this equation.

Finally, the authors showed total estimated lost values as one year's damage.

2-4 National Wealth and "Min-Ryoku" as stock data

National wealth means net assets; whole real assets and financial assets minus debts. The authors estimated Kyoto city's stock data by multiplying its distributional rate to national data. The Kyoto city's distributional rate is set by using "Min-Ryoku" index. Min-Ryoku means autonomy's index. Min-Ryoku shows totally 100,000 points all sums. We adopted this value as Kyoto city's percentage of national assets.

Net national stock asset is 2501.5 Trillion JPY[8)], while Kyoto city's 11 administrative ward's amount of stocks are shown in Table-1.

Table-1: Min-Ryoku index and the amounts of stock in each administrative ward

(Stock's unit: Trillion JPY)

Name of ward	Index	Amount of stock
Kita	77.5	1.9387
Kamigyou	60.6	1.5160
Sakyou	105.7	2.6442
Nakagyou	106.4	2.6617
Higashiyama	40.6	1.0156
Shimogyou	89.2	2.2314
Minami	88.4	2.2114
Ukyou	126.0	3.1520
Fushimi	176.3	4.4103
Yamashina	76.8	1.9212
Nishikyou	87.6	2.1914
Total in the city	1035.3	25.8941

3. Results of calculation for direct losses and indirect losses from earthquakes

3-1 Results of estimation of direct losses

An equation that we adopt to estimate direct losses based on prerequisite conditions is shown as eq. (1).

$$Dt = \sum_{n=1}^{11} \{ (Df_w + Dh_w) \times AS_w \} \qquad (1)$$

In this equation, "Dt" means lost value, "Df" is the percentage of houses and buildings burn downed, "Dh" is the percentage of broken houses and buildings, "AS" is Amount of Stock Data of Kyoto city, and the attached small letter "w" means each administrative ward.

The authors defined each parameter as these.

1) the percentage of houses and buildings burn downed is set as 20% and each building has 1.5 households[9]. The rates of fire prevention and the numbers of houses are based burn downed on "Kyoto city's earthquake loss estimation report".

2) the percentage of broken houses and buildings is calculated as:

(the percentage of houses completely destroyed) + 1/2 × (the percentage of houses half destroyed) [10]

3) the amount of stock of each ward is shown in Table-1, and in this equation, we treated them as fixed numbers.

The authors estimated direct losses in each ward from 9 types of earthquake. These are shown in Table-2.

Table-2: Direct lost values in each ward (Unit: Trillion JPY in a year)

Name of quake /Name of ward	Hanaore	Momoyama	Ujigawa	Katagihara	Koumyouji	Arima	Oubaku	Biwako-seigan	Nankai
Kita	0.28	0.52	0.15	0.14	0.08	0.18	0.05	0.17	0.08
Kamigyou	0.39	0.04	0.02	0.01	0.00	0.02	0.00	0.29	0.01
Sakyou	0.40	0.03	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Nakagyou	1.13	0.20	0.06	0.04	0.01	0.11	0.01	0.38	0.02
Higashiyama	0.24	0.17	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Yamashina	0.56	1.17	0.10	0.01	0.00	0.01	0.39	0.16	0.01
Shimogyou	2.51	1.09	0.12	0.04	0.02	0.18	0.05	0.44	0.02
Minami	0.78	0.40	0.04	0.06	0.01	0.29	0.01	0.06	0.02
Ukyou	0.09	0.01	0.01	0.10	0.01	0.03	0.00	0.03	0.00
Nishikyou	0.02	0.00	0.00	0.17	0.03	0.06	0.00	0.00	0.00
Fushimi	0.23	0.20	0.14	0.01	0.00	0.03	0.06	0.00	0.01
Total in the city	6.64	3.83	0.65	0.59	0.17	0.92	0.58	1.65	0.17
Ranking	1st	2nd	5th	6th	9th	4th	7th	3rd	8th

We found that Hanaore fault earthquake will cause the most serious damage to Kyoto city. Especially, Shimogyou ward which is located in the center of the city and has many department stores, several kinds of shops and hotels, will be the most damaged area. The authors show estimation of direct losses from Hanaore earthquake in Figure-1.

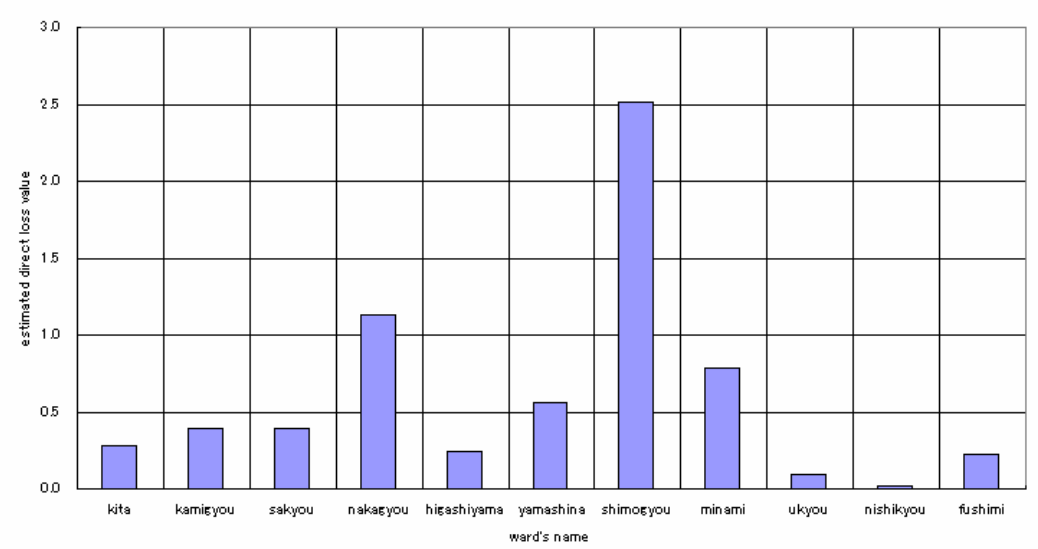

Figure-1: Estimated direct losses from Hanaore earthquake in each ward
(The unit of vertical axis unit is Trillion JPY)

3-2 Results of estimation of indirect losses

As the next step, the authors estimated indirect losses which are affected by direct losses. We defined indirect losses as decrease of the amount of production and restriction of service compared to un-damaged situation.

To estimate indirect losses, the authors must get an interim input value, firstly. To get an interim input value, we multiply direct losses by interim input ratio. In addition, the authors can get prefectural demand value by multiplying an interim input value by self-sufficient ratio, in generally. The Kyoto prefectural I/O Data table shows three categories: the Primary industry, the Secondary industry and the Tertiary industry. The authors followed these methods and calculated prefectural product demand values in each industrial categories. Its equation is shown as eq. (2).

$$Ii_c = Di_c \times Ir_c \qquad (2)$$

In this equation, "Ii" means interim input value in each industry, "Di" is interim input values of direct effect in each industry, "Ir" is the percentage of an interim input index in each industry, and the attached small letter "c" means each industries' name.

The authors calculated in each three type of industries. For example, in a case of Hanaore earthquake, we calculated like eq. (2)-1.

The interim input value of direct effect in each industry ＝ 6.64 Tri. JPY × 0.3609 (input index of the Primary industry) ＋ 6.64 Tri. JPY × 0.5758 (input index of the Secondary industry) ＋ 6.64 Tri. JPY × 0.3237 (input index of the Tertiary industry) ＝ 8.37 Tri. JPY (2)-1

At the same time, the authors calculated them about the rest of 8 types of earthquakes.

Furthermore, we tried to get prefectural product demand values. Calculation methods are written before. Finally, the authors want to know real indirect lost values by multiplying demand values with inversed matrix index, and sum all. These methods are general ones and we followed them as usually.

In a Table-3, the authors showed results of estimation indirect losses in each industry and in each earthquake type.

Table-3: Indirect lost values in each industry and in each earthquake type

(Unit: Trillion JPY in a year)

Name of quake / Name of industry	Hanaore	Momoyama	Ujigawa	Katagihara	Koumyouji	Arima	Oubaku	Biwako -seigan	Nankai
Primary	0.49	0.28	0.05	0.04	0.01	0.07	0.04	0.12	0.01
Secondary	4.57	2.63	0.44	0.41	0.12	0.63	0.40	1.14	0.12
Tertiary	10.06	5.80	0.98	0.90	0.25	1.39	0.88	2.50	0.26
Total	15.12	8.72	1.47	1.35	0.38	2.09	1.33	3.76	0.40
Ranking	1st	2nd	5th	6th	9th	4th	7th	3rd	8th

The authors found that Hanaore earthquake will also cause the most severe damage from the viewpoint of indirect losses. But, estimated lost value ranking is different from direct lost value ranking, slightly. Damage will occur mainly in the Tertiary industry which includes hotels, shops and service suppliers.

3-3 Total estimated lost values of tourism and sightseeing related industries

The authors tried to estimate total lost values of tourism and sightseeing related industries in Kyoto city from the viewpoint of macro economics with analyzing several macro data. Final results of estimation are shown in Table-4 and Figure-2.

Table-4: Estimated total lost values in each earthquake type

(Unit: Trillion JPY in a year)

Name of quake / damage classification	Hanaore	Momoyama	Ujigawa	Katagihara	Koumyouji	Arima	Oubaku	Biwako -seigan	Nankai
Direct loss	6.64	3.82	0.64	0.59	0.16	0.91	0.58	1.65	0.17
Indirect loss	15.12	8.71	1.47	1.34	0.38	2.09	1.32	3.67	0.39
Total loss	21.76	12.53	2.11	1.93	0.54	3.00	1.90	5.32	0.56
Ranking	1st	2nd	5th	6th	9th	4th	7th	3rd	8th

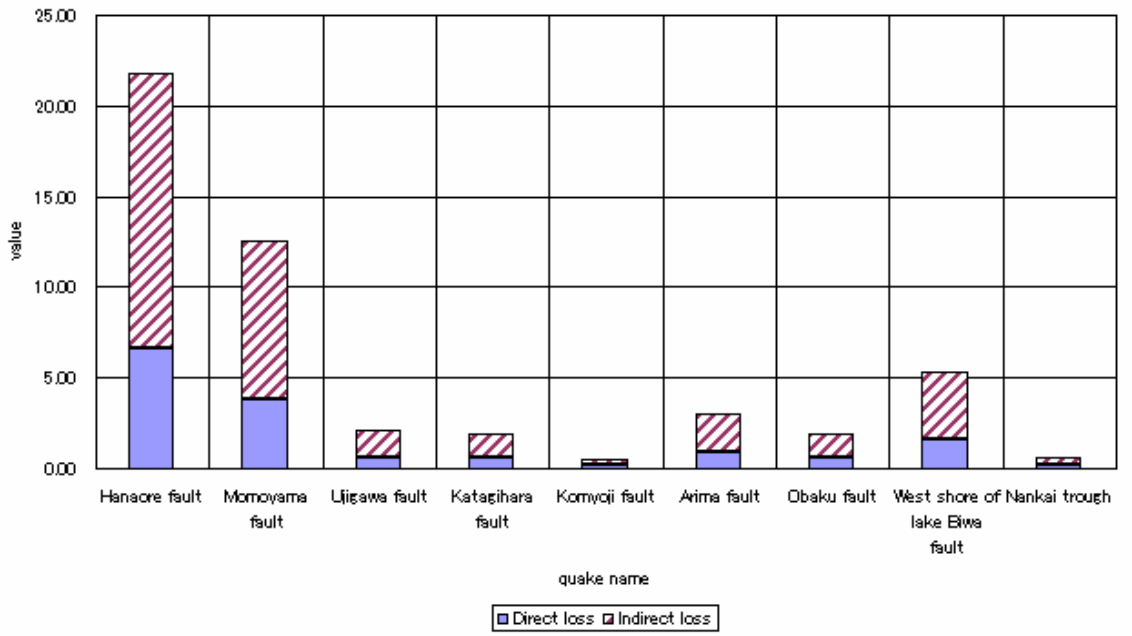

Figure-2: Estimated total lost values in each earthquake type
(The unit of vertical axis unit is Trillion JPY)

The authors found that the worst case; Hanaore fault earthquake will occur and 21 Trillion JPY loss will be caused only in Kyoto city. This value is 3.5 times higher than city's Gross Regional Products; 6 Trillion JPY in a year. If we see a comparison between direct losses and indirect losses, each indirect lost value will be 2-3 times higher than each direct lost value. This number is a little higher than other previous cases, because the Tertiary industry dominantly composes Kyoto city's whole industry.

Biwako-seigan fault lies on next to Hanaore fault. Thus, if one fault moves, there is a chance that the others move simultaneously. In this case, it is easy to imagine that more severe damage will be caused by two earthquakes. But, in this paper, the authors tried to estimate lost values made by one earthquake. We will challenge to estimate other loss caused by multi-quakes for the next research.

4. Conclusions and future challenges

Officially, Kobe earthquake caused 10 Trillion JPY losses as direct losses, while it is said that indirect losses were 3-7 Trillion JPY. In our research, the authors estimated direct and indirect losses from big earthquakes. As a result, estimated total losses are about 21 Trillion JPY in the worst case. We think these values are higher than other cases already happened in Japan. The authors must upgrade accuracy and try again.

But, this is the first trial to disclose earthquake disaster risk from the viewpoint of economics. Especially, loss estimations in each administrative ward are very useful. It will play an important roll to consider disaster prevention

measures and priorities with mixing this originally estimated result and Kyoto city's estimation results.

This main object of research was to make a risk assessment. The authors could grasp how risk in Kyoto is with analyzing several macro data. As future challenges, the authors think that we must improve accuracy of estimation method firstly, and must show mitigation measures and its effectiveness analysis as risk mitigation, secondly.

Estimations in this research are based on a short term scale and without any preparation for disaster. Thus, the authors must simulate with various conditions with a long term scale. We will try to estimate investment effect for disaster prevention and mitigation with using this simulation.

For decreasing indirect losses from earthquakes, the authors must understand risk perception of affected people. Nowadays, rumors' negative effect cannot be ignored in the damaged areas and their vicinity areas. To know what and how rumors' negative effect is, the authors are preparing for questionnaire survey and interview in earthquake damaged areas. With these studies, we will show not only hard measures but also soft measures for disaster prevention and mitigation.

Acknowledgement:

This thesis is an achievement of "Establishment of academic principles for the protection of cultural heritage and artistic works from natural disasters". This project is supported by the Ministry of Education, Culture, Sports, Science and Technology.

In this paper, Mr. Yusuke TOYODA, Master Course Student of Graduateschool of Policy Science, Ritsumeikan University helped us for translating from Japanese to English and proofreading.

References (all are in Japanese)

1) "Kyoto City's Sightseeing Annual Report of 2006", Kyoto City Office, Travel Agent, 2007

2) "Expected Loss Estimation Report, the third edition", Kyoto City Fire Department, 2005

3) "Tourists' Consuming Effect Analysis of Kyoto City", Kyoto City Office, Travel Agent, 2005

4) For example, "An experimental estimation of economic damage of sightseeing related industries from big earthquakes in historical city, Kyoto" (Bi-annual Workshop 'Watch disasters vol.6', The Disaster Prevention Research Institute of Kyoto University, Feb. /2008)

5) "Kyoto's Input/Output Data", Kyoto prefectural office, statistical division, 2005. In this report, data of Year 2000 is the latest. While, Kyoto city office has not make any I/O Data table.

6) "City Accounts", Kyoto city office, division of information and statistics, 2005

7) "Min-Ryoku", Asahi Shinbun, 2007

8) "National Accounts and Stock Data of 2006", Cabinet office, the institute of economics, 2008

9) "The story of tremble No.5 -Damages of Housings and Buildings-", Masayuki TAKEMURA, Seismological Society of Japan, 2002, No.29

10) "Loss Estimation Report of Tokyo", Tokyo metropolitan government, department of disaster prevention and rescue, 2006

Authors:

Tetsuo MIZUTA

Post Doctoral Researcher, Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University, Kyoto, Japan. He graduated from Faculty of Agriculture in Gifu University in 1991, and Faculty of Law in Chuo University in 1998. He studied Risk Management in the Graduate School of Policy Science, got a Ph.D. from Ritsumeikan University in 2004. His present study themes are risk assessment, economic analysis and less-loss mitigation planning.

Hitoshi TANIGUCHI

Professor, Graduate School of Engineering, Nagoya Institute of Technology, Aichi, Japan. He graduated from Aichi Institute of Technology in 1973. Hokkaido University granted him Doctor Degree in 1989. His majors are earthquake engineering and urban safety planning. He worked for the United Nations Centre for Regional Development (UNCRD), the Institute of Physical and Chemical Research of Japan and etc.

Hidehiko KANEGAE

Professor, Faculty of Policy Science, Ritsumeikan University, Kyoto, Japan. He graduated from Graduate School of Engineering, Tokyo Institute of Technology in 1994 and got a Ph.D. in Engineering. His majors are Planning Theory and Digital Planning. He worked for UNCRD, Tokyo Institute of Technology, Asian Institute of Technology and etc.

Satoshi OHTSUKI

Post Doctoral Researcher, Kinugasa Research institute, Ritsumeikan University, Kyoto, Japan. He graduated from the Graduate School of Policy Science, got a Ph.D. from Ritsumeikan University in 2004. His present study theme is participatory city planning.

Masahiro SHIROTSUKI

Post Doctoral Researcher, Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University, Kyoto, Japan. He graduated from the Graduate School of Policy Science, got a Ph.D. from Ritsumeikan University in 2008. His present study theme is psychology and human behaviour in a disaster.