CONSTRUCTION AND INTEGRATION OF GIS DATABASES FOR RISK ASSESSMENT OF NATIONALLY DESIGNATED CULTURAL PROPERTIES DUE TO EARTHQUAKES AND TYPHOONS IN JAPAN

Y. Futagami [a, *], M. Morii [a], T. Kumamoto [b]

[a] National Research Institute for Cultural Properties, Tokyo, 13-43, Ueno Park, Taito-ku, Tokyo 110-8713 Japan - (futa, morii)@tobunken.go.jp

[b] Department of Earth Science, Okayama University, 3-1-1, Tsushima-naka, Kita-ku, Okayama 700-8530 Japan - tkuma@cc.okayama-u.ac.jp

KEY WORDS: earthquake, typhoon, risk assessment, nationally designated cultural properties, GIS

ABSTRACT:

For protecting cultural properties from natural disasters, constant effort for comprehensive strategy including risk assessment and rescue simulation is necessary. Whether a cultural property is damaged or not by a certain natural disaster is controlled by the (1) magnitude of disaster, (2) distance between the cultural property site and the disaster source, (3) surrounding environment, and (4) vulnerability of the cultural property itself or the storage building for the case of movable property.

For these reasons, the use of geographic information system (GIS) is considered to be effective in estimating damage as precaution to cultural properties, immediate and rescue of them at the time of disasters by integrating their spatial and attribute information. In Japan, earthquakes and typhoons are two of major natural disasters, so we assessed the risk by integrating the GIS databases of cultural properties and these natural disasters.

We calculated the probabilities of occurrence of intraplate earthquakes ≥ JMA seismic intensity 5+ in 50 years, and overlaid with the GIS database of nationally designated cultural properties. 11 National Treasure buildings and 32 storage buildings of the applied arts designated as National Treasure are situated within the area of 20 % or more probabilities.

We also overlapped the track and area of several typhoons on the GIS database and showed that most of the damaged cultural properties distributed at eastern side of the track of the typhoons. These examples indicate the validation of GIS for both long- and short- period of risk assessment for cultural properties.

1. INTRODUCTION

For cultural properties, gradual change, or degradation, due to the passage of time is unavoidable. But they are sometimes damaged instantly and severely by natural disasters, such as in the case of the five-story pagoda of Muroji Temple by a typhoon in 1998 and of the collapse of Residence No. 15 in the Former Foreign Settlement in Kobe City by the 1995 Hyogoken Nambu Earthquake (Kobe Earthquake). Natural disasters can cause wide range and severe damage, so comprehensive strategy including risk assessment and rescue simulation at the time of a disaster is necessary. Whether a cultural property is damaged or not by a certain natural disaster can be decided by the relative distance of the cultural property from the place where the natural disaster occurs, terrain or surrounding environment of its location, as well as the structure of the cultural property itself or its storage building. For these reasons the use of geographic information system (GIS) is considered to be effective in estimating damage to cultural properties by integrating their spatial and attribute information. Besides, in the event of a disaster, lifesaving and maintenance of lifeline are given priority, and we cannot share much human power or budget for the rescue of cultural properties. Therefore it is necessary for us to construct an information system for the immediate and effective rescue of cultural properties at times of disasters by utilizing GIS.

After the 1995 Kobe Earthquake on January 17, 2005, the Agency for Cultural Affairs implemented various policies for reducing damage caused to cultural properties by disasters. At the time of the earthquake, the Agency did not have enough information regarding cultural properties other than nationally designated ones. Thus, they could not avoid many historical buildings to be dismantled. The system of listing cultural properties in order to promote the utilization of historical buildings by providing looser restrictions for altering the current state than are stipulated in the system of designation was therefore installed in October 1996. The Agency expected that it could obtain more information about the historical buildings through the listing of them in the national registry of cultural properties. In April 1999, the Agency set up the Guidance for the Earthquake Resistance of Important Cultural Property Buildings to indicate the methods, procedures, and notices to be followed when persons responsible for the protection of cultural properties assess the seismic capacity of buildings nationally designated as Important Cultural Properties. Furthermore, in many cases earthquake-resistant equipments or seismic isolators are settled at the time of the restoration of historical buildings. These measures, however, are for the protection of individual historical buildings, and an extensive

* FUTAGAMI Yoko futa@tobunken.go.jp Telephone: +81-3-3823-4869 Fax: +81-3-3823-4867.

disaster prevention or rescue system for cultural properties as a whole at the national level has not been launched yet.

For the protection of cultural properties utilization of GIS is still at a preliminary stage in Japan. At the time of the 1995 Kobe Earthquake, our Institute set up a secretariat for the rescue of cultural properties at the quake-hit area to investigate the location of cultural properties and to move them away from the afflicted area. But the members of the secretariat had difficulties with their activities since they could not decide the appropriate place for settling the cultural properties, or even identify the location of each cultural property.

The need for integrating the spatial and attribute information of cultural properties has been pointed out, but the dissemination of GIS for disaster prevention and rescue of cultural properties has not been conducted. National and regional governments have constructed various databases mainly for recording information about cultural properties underground. However, the renewal of data or utilization of such databases in their routine is insufficient, and at times the construction of databases itself even becomes the objective of their work. Comprehensive databases of different cultural properties other than archaeological sites did not exist before we constructed the GIS database of nationally designated cultural properties. Moreover, the utilization of GIS database for disaster prevention or rescue of cultural properties that we are conducting is not sufficient even now. The officers in charge of the investigation of historical buildings knew the location of each nationally designated cultural property very well, so they did not feel the need for GIS database in conducting their work. But, nowadays, national policy making by utilizing GIS database is required for the construction of wide-range disaster prevention or rescue plans for cultural properties, as are guiding disaster prevention measures to the persons responsible for the protection of each cultural property.

For example, big earthquakes occurred in 2007 and 2008 in Japan. We therefore visited the quake-hit areas to investigate the damage, and the relationships between the damage and anti-seismic measures. We also interviewed the local staff working for museums or involved in the protection of cultural properties, and we were told that they had not heard about the seismic risk publicized on the web by the Earthquake Research Committee of the Headquarters for Earthquake Research Promotion that we had applied in our research on disaster prevention. They scarcely had any knowledge about the rate of seismic wave or the possibility of occurrence of indigenous earthquakes. The officers and museum staff who were in charge of the protection of cultural properties remarked that they would have been able to take actions to reduce the risk if they had been to able to get information about the seismic risk and appropriate measures for the prevention of subsequent damage through the Agency for Cultural Affairs or other appropriate organizations. They also requested that such kind of information be provided.

Thus, in this paper we will introduce our research on the application of GIS for disaster prevention of cultural properties that we have conducted since 2001. First, we will report on the construction of GIS database, targeting nationally designated cultural properties, and on the proposition of setting effective anti-seismic measures utilizing the assessment of the seismic risk of each cultural property obtained by integrating this database and GIS database of intraplate active faults. We will also introduce an example of the application of this system integrating it with the information about the seismic intensity scale to estimate the damage caused to cultural properties just after an earthquake and the verification of the adequacy of our estimation by on-site investigations. Then we will show an example of the application of the database to analyze the relationships between the route of a typhoon and locations of cultural property buildings.

2. ESTIMATION OF THE SEISMIC RISK OF NATIONAL TREASURES IN JAPAN BY USING THE GIS DATABASE

2.1 Construction of spatial database of nationally designated cultural properties

In Japan, there are several types of earthquakes classified by the mechanism of occurrence: interplate earthquakes, intraplate earthquakes, deep earthquakes and blind earthquakes. Blind earthquakes are the earthquakes for which hypocenter locations can not be specified. Interplate earthquakes, like the earthquake that occurred off Sumatra in 2004, are generated by plate movements. Interplate earthquake often cause Tsunamis. Recurrence period is around 10-100 years. The earthquake's magnitude climbs to roughly 8, and a long-period seismic wave occurs that are influential high-rise buildings. On the other hand, intraplate earthquakes, like the 1995 Kobe Earthquake, are caused by active faults and show less magnitude (7-8) than interplate earthquakes. But their hypocenter is shallow (less than 20 km) and the active faults are often located just under or near cities. Thus the effect of intraplate earthquakes to cultural properties is very serious. Besides, the short-period seismic waves of intraplate earthquakes can influence relatively small buildings like historical buildings or small museums. In these circumstances, the study of intraplate earthquakes caused by active faults is important in considering seismic countermeasures for cultural properties.

Most seismogenic faults in Japan are cataloged and listed in a GIS database. In 1991, Active Faults of Japan [New Edition] was published. Digital Active Fault Map of Japan in 2002 can visualize the information of active faults on PCs. The data can be converted to the format for utilizing on GIS software. Therefore, we considered that if we construct a database on cultural properties and integrate it with the database of seismogenic faults on GIS, we can describe the seismic risk of each cultural property quantitatively.

According to the law for the Protection of Cultural Properties, national government considers to have high value for special national protection as Important Cultural Properties among the tangible cultural properties. National Treasures are Important Cultural Properties that have particularly high value. First we targeted tangible cultural properties that are designated as National Treasures. There are 209 architectures (253 buildings), 850 arts and crafts (155 paintings, 123 sculptures, 252 craftworks, 280 archival materials, 39 archaeological objects and 1 historical object) as of January 1, 2002. A GIS database on the location of National Treasures was constructed following the procedure as shown below.

We put primary data of cultural properties into the database. We chose name, number of buildings, type, structure, roofing, age, owner and date of designation as category of architectural cultural property from *Journey to National Treasures* (Kodansha, 2001) and Online Retrieval System for Nationally designated Cultural Properties (Agency for Cultural Affairs, 2002), and put these data by using Microsoft Access. For arts and crafts, we chose name, material, type, age, storage place, address and date of designation from the book (Kodansha, 2001) and put the data into the database.

We then searched the exact addresses of architectural properties and storages of arts and crafts by using the book (Kodansha, 2001), the System (Agency for Cultural Affairs, 2002) and

Digital Telephone Directory 2002 Industry-classified Version (Nippon Software Service, 2002), and put these data to the primary information of the database.
Finally we got latitude and longitude of the location by using Digital Atlas Z IV (Zenrin, 2001) and other software, and websites of digital maps for obtaining the spatial data of the cultural properties at the scale of 1:25000. The scale is the same as the topographical map developed by the Geographical Survey Institute. In case of National Treasure buildings, if the location of each building can be noticed we put the exact location to the database. If we cannot identify the place of a building because there does not exist large-scale maps or only the name of a cultural property is shown on a map, we consider the location of a National Treasure as the center of the area of a cultural property. If there are several designated buildings at the same address, the major building represents the location. Arts and crafts were classified in their owners and put their spatial information to the database because there are organizations that have multiple cultural properties.
Thus, by showing the location of each cultural property in latitude and longitude, we can link the data with other spatial databases and use for analyses on GIS. We used ArcView GIS by ESRI as GIS software. Then we also put the information of the buildings designated as Important Cultural Properties and storage buildings of arts and crafts in our GIS database.

2.2 Estimation of the seismic hazard of National Treasures in Japan

We assessed the seismic hazard rate of National Treasures based on the calculation of the seismic movement of each National Treasure by integrating the database on the location of National Treasures with the seismogenic fault system database (Kumamoto, 1999). For this purpose, first we calculated the distance from each National Treasure to all seismogenic faults in the database on GIS. We then calculated the estimated magnitude of an earthquake from each seismogenic fault by using the relationship between magnitude and length of seismogenic fault system (Matsuda, 1975) and the empirical relationship between the length of seismogenic fault system and the average slip rate (Wesnousky et. al., 1984). We then calculated the peak ground acceleration (*PGA*, unit is gravity acceleration (g)) estimated at the location of National Treasures, considering the surface geology, when seismogenic fault systems produce earthquakes. For the estimation of the seismic movement of National Treasures, we gave the values of magnitude and distance to empirical equation (Fukushima and Tanaka, 1991) concerning diminution of seismic waves by distance. The range of peak ground acceleration estimated at the location of National Treasures is 0 to 0.89 gal.
To calculate the probabilities of earthquake occurrence, this time we adopted the random earthquake recurrence hypothesis (Poisson process) for the assessment of earthquakes that occur from active faults. Conditional probability is better for understanding the seismic risk, but it is difficult to know the elapsed time of the activity of each active fault. We use historical records, trench investigations for getting such information of earthquakes, but shallow soil is often cultivated and we hardly detect the evidence of recent earthquakes. Even in Japan we have many historic records about earthquakes, and the oldest record is said as 6 centuries A.D., but it is only 1400 years ago, that is old enough to know the recurrence period of the activity.
Then the "Map of the Probability of *PGA* during Any 50-year Period in 10 %" was made covering the entire country. By using this method we calculated the probabilities of occurrence of earthquakes with JMA seismic intensity scale of 5+ (approx. Modified Mercalli Scale IX (NIED, 2000)) during any 50-year period at the location of each National Treasure (figure 1).

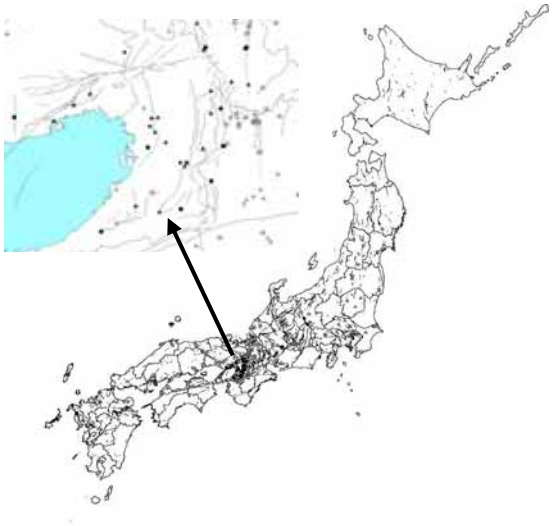

Figure 1 Map showing the National Treasures with ≥20 % probabilities of *PGA* during any 50-year period in black

The result of calculation based on the method of seismic assessment shows that there are 11 National Treasure buildings with ≥20 % probabilities of *PGA* during any 50-year period. Among these National Treasures, the estimated *PGA* is maximum at Matsumoto-jo Castle in Nagano Prefecture. The reason is that East Matsumoto Basin Fault of the Itoigawa-Shizuoka Tectonic Line (ISTL) series is located at a distance of 2 km from Matsumoto-jo Castle. According to a record of historic earthquakes of the ISTL, the last earthquake occurred about 1200 years ago, in 841 AD (or 762 AD). In contrast, the interval of activity of the fault is estimated as 1000 years by trench investigation of active faults (Headquarters for Earthquake Research Promotion, 2002). There are 32 storages of National Treasure arts and crafts that have ≥20 % probabilities of *PGA* during any 50-year period. Two of them, located in Shizuoka and Yamanashi Prefectures, show the highest rate of probability, maximum probability being over 30 %. They are located near Fujigawa Fault System. According to the "Outline of assessment of active faults that have been investigated until now" by the Headquarters for Earthquake Research Promotion, this fault system continues to the interplate fault in Suruga Bay and its average velocity of displacement is 7 m in 1000 years, which is maximum among the active faults in Japan. Most of the National Treasures with probabilities ≥20 %, however, are located in 4 prefectures in the Kinki region where the densities of both active faults and cultural properties are high. Intensive measures should be taken promptly to protect cultural properties in this area from damage caused by inevitable future earthquakes.

2.3 Necessity of estimation of damage caused by earthquakes and future aspects

We made an assessment of the probabilistic seismic hazard caused to all National Treasures by intraplate active faults with uniform conditions throughout Japan. No studies have ever tried to estimate the seismic risk of cultural properties. The significance of the assessment throughout the country with uniform conditions is that it provides useful information to the

national government in considering seismic countermeasures for nationally designated cultural properties.
It is ideal to provide the best aseismic measures to every cultural property. But, considering the limited budget, we must consider the most effective use of the budget for the protection of cultural properties. By using the results of our study we can suggest to government staff concrete cultural property protection policies, such as deciding the area of priority for antiseismic measures or installing adequate antiseismic facility for each cultural property based on the estimated values of peak ground acceleration.
On March 23, 2005, the Earthquake Research Committee of the Headquarters for Earthquake Research Promotion released the National Seismic Hazard Maps for Japan. Among these maps, the Probabilistic Seismic Hazard Map shows the ground motion prediction for a certain period for each 1 km (now 250 m) throughout Japan. Two types of maps are distributed by the committee. Probabilistic approach is useful for national government officers who are responsible for allocating adequate budget for protecting each cultural property. On the other hand, the deterministic approach to the peak ground motion of each place and simulation of time domain waveform (strong ground motion) of future earthquakes is important especially for the responsible persons for protecting each cultural property such as the owners or municipality officers.

3. APPLICATION OF THE GIS DATABASE TO THE ASSESSMENT OF DAMAGE OF CULTURAL PROPERTIES AT TIMES OF EARTHQUAKES AND TYPHOONS

Based on the GIS database mentioned above, our Institute constructed a system on the disaster prevention of cultural properties. This is a database on historical buildings among the nationally designated cultural properties. The database is integrated with information concerning natural disasters, such as past typhoons and/or earthquakes, and digital national information, such as landform, ground and active faults, in order to estimate the damage caused to cultural properties by natural disasters and to obtain information concerning damaged cultural properties when natural disasters occur. We can also analyze statistically the fragility of each cultural property by inputting the cause, extent, part and shape of its damage.
This disaster prevention system for cultural properties is constructed for national and regional governments that are responsible for the protection of cultural properties. This system enables them to input and show the history of damage and restoration for their daily maintenance work. Thus the system, by showing the history of damage by past disasters, enables analysis on the possibility of damage to cultural properties that may be caused by future disasters by considering the timeline.

3.1 Prediction of damage to cultural properties in case of earthquakes

Information about cultural properties damaged by disasters is transmitted from cities/towns/villages to prefectures, and then to the Agency for Cultural Affairs. But the more the damage of the area is severer, the more the information flow becomes slower. So, if we can integrate the information about the location of cultural properties and earthquakes, we can predict the existence of damaged cultural properties with limited information obtained just after disasters and take appropriate actions before we get information from municipalities.

Thus, to estimate the usability of the disaster prevention system of cultural properties we targeted the 2007 Noto Earthquake and the 2007 Niigataken Chuetsu-Oki Earthquake to predict the damage to cultural properties by using the information disseminated just after these earthquakes. We overlapped the distribution data of JMA seismic intensity scale of each city/town/village with the existing system to specify the cultural properties located in the municipalities that showed high value of seismic waves.

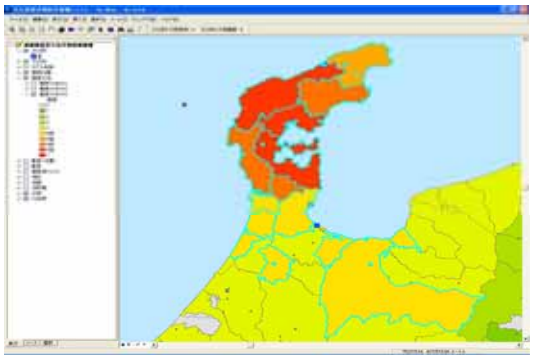

Figure 2 Map showing the estimation of damaged cultural properties at the time of the 2007 Noto Earthquake. Light blue dots are nationally designated cultural properties with ≥ JMA seismic intensity scale 5- and assumed as damaged.

Figure 2 shows the estimation at the time of the 2007 Noto Earthquake. We settled the JMA seismic intensity scale 5- (approx. Modified Mercalli Scale VIII (NIED, 2000)) as threshold and assumed the cultural properties damaged within the area that show this rate or higher. By using this system, we could input the seismic information obtained from the Japan Meteorological Agency (JMA) and extract the cultural properties in a very short period.
This time, to evaluate the effectiveness of our disaster prevention system for cultural properties, we compared between our estimation and the information about damaged cultural properties obtained from the Agency for Cultural Affairs and from our field investigations. Since we found that there is only one damaged cultural property outside the area where damage was expected, so it can be concluded that our hypothesis was reasonable. Moreover, this cultural property is located near the border of the area and we could have considered it as damaged had we looked at the search result of the area of JMA seismic intensity scale 5+ shown in the map.
Showing the value of the JMA seismic intensity scale of each municipality is useful for the responsible persons who work for local governments, but the ground motion varies with the ground of each place and the motion of each building varies depending on the height or characteristic vibration period. So, for more precise estimation of damage it is necessary to show the value of the JMA seismic intensity scale of each seismometer and make detailed investigation of the characteristics of each cultural property. It is also necessary to improve the system to integrate automatically the seismometer's data to the GIS database of cultural properties.

3.2 Analysis of spatial relationships between the route of a typhoon and cultural properties

As mentioned above, not only earthquakes but typhoons are also major natural disasters in Japan. Based on the recent meteorological statistics, every year 25 typhoons form, 9.3 of them approach and 2.5 make landfall on Japan on average.

Typhoons bring heavy rains, wind storms and storm surges. They also cause floods, debris flows, landslides and some other disasters.

The approach and landfall of typhoons may cause severe damage against cultural properties. For example, storms blow away roof tiles of cultural property buildings and floods cause inundation above floor level of them. In addition, some buildings have been severely destroyed by landslides or the wind-toppled trees. In particular, buildings in coastal area, such as Itsukushima shrine, are prone to be collapsed by storm surge (Figure 3). Typhoons cause serious damage not only cultural property buildings but also arts and crafts stored in museums and archives. In particular, many historical records have been swamped and damaged by floods.

Figure 3 Itsukushima shrine, floorboards were damaged by storm surge (Typhoon 0418)

So, we analyzed the relationships between the routes of past typhoons and the damage of cultural properties caused by the typhoons by our system on the disaster prevention of cultural properties. This system is expected to enable us to make statistical approach about the damage of cultural properties, and predict the damage by future typhoons. The locations of the center and radius of storm area of each typhoon were recorded and visualized in the database. We also put the data on the damage of cultural property buildings based on the press releases issued by the Agency of Cultural Affairs.

Figure 4 shows the distribution of the trajectory and damaged cultural property buildings by the landfall of the Typhoon 9918. In this system, we classified their damage into six grades with checkboxes to classify the damaged parts and the causes of the damage. This figure indicates that 16 buildings were damaged by landfall of the typhoon, and 13 of them were severely damaged as classified "collapse". The figure also indicates that most of the damaged buildings were distributed at the eastern side of the path. We detected that heavy rain and storm of the area was stronger than the opposite side and the storm surge was subject to become severer by the effect of wind drift. The damage of the cultural property buildings by typhoons is mainly caused by their strong wind and floods, so strong relationships between the route of the typhoons and the distribution of the damaged buildings was revealed. But we also experienced the heavy rains or strong wind caused severe damage to cultural property buildings from distance of the route of the typhoons like the example of Typhoon 0908. We will conduct further study for the estimation of damage more precisely by utilizing

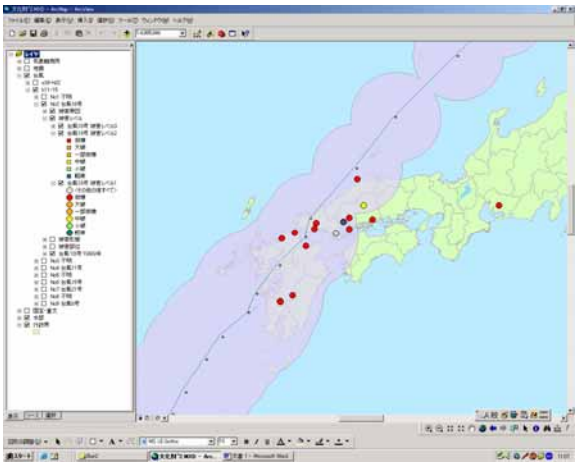

Figure 4 Distribution of damaged cultural property buildings by landfall of the Typhoon 9918

detailed spatial information like the hazard maps at regional or local levels.

4. CONCLUSIONS AND FUTURE ASPECTS

It is concluded that the GIS database of cultural properties can be utilized for risk assessment and estimation of damage to cultural properties from natural disasters. This time, we chose earthquakes and typhoons as our subjects of research since they are the most serious natural disaster in Japan. Once the GIS database is constructed, we can integrate the information to different natural hazards, such as floods or eruption of volcanoes, in order to reduce damage to cultural properties. We have not yet constructed a national-scale comprehensive hazard map of cultural properties but have taken Kamakura City in Kanagawa Prefecture as an example and integrated the GIS database with hazard maps and topographic map.

GIS database of cultural properties will be incorporated with the inventory of nationally designated cultural properties of the Agency for Cultural Affairs to utilize as a tool for the planning and implementation of management plans for cultural properties, as well as for the damage estimation of cultural properties from various hazards. For this purpose, we are improving the database including its items and user interface with the cooperation of the Agency.

5. REFERENCES

Agency for Cultural Affairs, 2002. Online Retrieval System for Nationally designated Cultural Properties. http://www.bunka.go.jp/ (accessed 2002). (In Japanese)

Doki, K., 1999. Naze bunkazai wo jishinsaigai kara mamorou to shite irunoka (Why do we try to protect cultural properties from seismic hazards?) In: *Jishin ha chikai (Earthquakes will occur soon)*, Adthree Publishing Co.Ltd., Tokyo, Japan, pp. 10-17. (In Japanese)

Doki, K., 2000. Bunkazai wo jishin saigai kara mamoru (Protect cultural properties from seismic hazards). *SEISMO*, Tokyo, Japan, November 2001, pp. 6-9 (in Japanese)

Fukushima, Y. and Tanaka, T., 1991. A new attenuation relation for peak horizontal acceleration of strong earthquake ground motion in Japan. *Shimizu. Tech. Res. Bull.*, 10, pp. 1-11.

Futagami, Y. and Kumamoto, T., 2002. Seismic Assessment of the risks that intraplate earthquakes pose for the National Treasures of Japan - Constructing a GIS database of National Treasures that is integrated with an active fault database. *Archaeology and Natural Science*, 44, pp. 45-75. (In Japanese with English abstract)

Futagami, Y., 2009. An approach to disaster prevention and rescue of cultural properties by using GIS in Japan - example of the National Research Institute for Cultural Properties, Tokyo -. In: *Expert Meeting on Cultural Heritage in Asia and the Pacific - Restoration and conservation of immovable heritage damaged by natural disasters* - , National Research Institute for Cultural Properties, Tokyo, and Fine Arts Department, Ministry of Culture, Thailand, Bangkok, pp. 109-120.

Headquarters for Earthquake Research Promotion, 2001. Chokiteki na jishin hassei kakuritsu no hyoka shuhou ni tsuite (Regarding methods for evaluating long-term probability of earthquake occurrence). Long-term Probability Assessment Group, Earthquake Research Committee, the Headquarters for Earthquake Research Promotion, Ministry of Education ,Culture, Sports, Science and Technology, 46p. (In Japanese)

Headquarters for Earthquake Research Promotion, 2002. Outline of assessment of active faults that have been investigated until now. http://www.jishin.go.jp/main/chousa/hyoka.htm (accessed 2002) (in Japanese)

Kodansha Ltd., 2001. *Kokuho no tabi -Nihon no bi, Nihon no kokoro- (Journey to National Treasures -Japanese beauty, Japanese spirit-).* Kodansha Ltd., 446p. (In Japanese)

Kumamoto, T., 1999. Seismic Hazard Maps of Japan and Computational Differences in Models and Parameters. *Geographical review of Japan*, Ser. B, 72, pp. 135-161.

Matsuda, T., 1975. Magnitude and recurrence interval of earthquakes from a fault. *Jour. Seismol. Soc. Japan*, 28, pp. 369-383. (In Japanese with English abstract)

Matsuda, T. 1990. Seismic zoning map of Japanese islands, with maximum magnitudes derived from active fault data. *Bull. Earthq. Res. Inst.*, 65, pp. 289-319. (In Japanese with English abstract)

Morii, M. and Aoki, S., 2007. Bunka-zai no kyohuu higai (Damages by wind storm against cultural properties). In: *Handbook for wind engineering - structure, disaster prevention, environment and energy* - , Asakura Publishing Co. Ltd., pp.233-234. (In Japanese)

National Research Institute for Earth Science and Disaster Prevention (NIED), 2000. Kishocho no keisoku shindo oyobi atarashii shindo kaikyu (JMA instrumental seismic intensity and the new intensity scale). http://www.k-net.bosai.go.jp/gk/publication/I-8.2.1.html (accessed 29 Aug 2009). (In Japanese)

National Research Institute for Earth Science and Disaster Prevention (NIED), 2009. http://www.bosai.go.jp/ (accessed 18 Aug 2009)

Nozawa Corporation, 2002. Kuni Shitei Juuyou Bunkazai Kyu Kobe Kyoryuchi Juugobankan (Nationally designated Important Cultural Property Residence No. 15 in the Former Foreign Settlement in Kobe). http://www.nozawa-kobe.co.jp/15ban/15ban01.html (accessed 18 Aug 2009) (in Japanese)

Odagiri, S. and Shimazaki, K., 2001. Correspondence of a historical earthquake to a seismogenic fault. *J. Seismol. Soc. Japan*, 54, pp.47-61 (in Japanese with English abstract)

Oike, K., 1999. Jishin ha motto chikai (Earthquake will occur very soon). In: *Jishin ha chikai (Earthquake will occur soon)*, Adthree Publishing Co.,Ltd., Tokyo, Japan, pp. 109-120. (In Japanese)

Takamura, K., 2005. Itsukusima-jinja to taihuu higai (Typhoon damages of the buildings of Itsukushima shrine). In: *Report of the 1st conference of disaster prevention plan for cultural properties*, National Research Institute for Cultural Properties, Tokyo, pp. 41-52. (In Japanese)

Research Group for Active Faults of Japan, 1991. *Shinpen Nihon no Katsudanso (Active faults in Japan: sheet maps and inventories (2nd edition)).* University of Tokyo Press, Tokyo, Japan, 437p. (In Japanese with English abstract)

Sangawa, A.., 2001. *Jishin - namazu no katsudoushi (Earthquake-history of activities of catfish-).* Taikosha Ltd., Chiba, Japan, 173p. (in Japanese)

Wesnousky, S.G., Scholz, C.H., Shimazaki, K., and Matsuda, T., 1984. Integration of geological and seismological data for the analysis of seismic risk: a case study of Japan. *Bull. Seism. Soc. Am.*, 74, pp. 687-708.

Usami, T., 1996. *Shinpen nihon higai jishin souran (Materials for comprehensive list of destructive earthquakes in Japan) [Revised edition 416-1995].* University of Tokyo Press, Tokyo, Japan, 493p. (In Japanese)

YAMADA, M., 1998. Hanshin Awaji Daishinsai to bunkazai no fukkyu -genjo to kadai- (Hanshin Awaji Big Earthquake and recovery of cultural properties from the earthquake -current situation and problems-). *Gekkan Bunkazai (Cultural Property Monthly)*, 390, Tokyo, Japan, pp. 4-12. (In Japanese)

Zenkoku Bijutsukan Kaigi (Japanese Council of Art Museums), 1995. *Hanshin Daishinsai bijutsukan hakubutsukan sogo chousa hokoku I (Comprehensive investigation of museums damaged by Great Hanshin Earthquake: report I).* Zenkoku Bijutsukan Kaigi, Okayama, Japan, 147p. (In Japanese)