Risk Assessment of Cultural Heritages Using Local Hazard Maps and Risk Filters

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ABSTRACT:

Cultural heritages are indispensable for understanding the history and culture of human beings. Tokyo, the capital of Japan, has more than 8,000 cultural heritages including 2,410 cultural properties designated by the national government. It is extremely important to protect and preserve these cultural heritages, which allow us to understand accurately the history and culture of Japan. Moreover, once a cultural heritage is lost, it is difficult to restore it, and it takes a tremendous amount of labor and cost even if it can be restored. Developing a risk management system is vital to protect effectively the more than 8,000 cultural heritages in Tokyo from natural hazard to enable the passing on of these valuable cultural heritages to the next generation. In this paper, an approach for the risk assessment of cultural heritages against disasters, including earthquakes, fires, floods, and landslides, is proposed. The risk assessment of cultural heritages was carried out using local hazard maps and risk filters. The danger levels against disasters were measured for each city planning district using the local hazard map to determine the danger level at the cultural heritage site. The risk filter is a value that reflects the damage characteristics of a cultural heritage, which are determined by its shape and material quality, in the risk assessment. As a result of the risk analysis, the risk level of cities is obtained.

KEYWORDS: Cultural Heritage, Database, Local Hazard Map, Risk Management System, Java, MySQL

1. INTRODUCTION

Because of the Kobe earthquake (1995), hundreds of Japan's important cultural heritages were damaged. Cultural heritages are difficult to restore if they are lost. It is very important to provide measures beforehand and to protect them adequately. Tokyo has more than 8,000 important cultural heritages including 2,410 cultural properties designated by the national government. In an urban region in particular, the rescue routes for damaged cultural heritages become severed after an earthquake because of secondary disasters such as fire, collapse of a building, and ground liquefaction [1)]. There is a potential to have more important cultural heritages damaged once a major earthquake occurs in Tokyo. It is vital to develop a risk management system for the cultural heritages and bolster disaster prevention measures for high-risk heritages.

Under the Law for the Protection of Cultural Properties, the owner, in principle, is responsible for the management and repair of their heritages and should bear the cost of repairs. Therefore, the efforts of preservation differ among owners, and there is a limit to the installation of anti-disaster measures for the cultural heritages, particularly for the heritages that are owned by an individual.

National heritages tend to be kept in warehouses of a museum, and it is considered that they are relatively safe. However in an exhibition room, they can be damaged because they are put in a defenseless state. Because of the Niigata Chuetsu earthquake (2004), earthenware pots placed on a two-dimensional seismic isolator that was installed after the Kobe earthquake fell and became damaged.

A large number of cultural heritages are scattered all over Tokyo; some of which are designated as important

cultural properties by the national and local governments. Developing a risk management system, as well as tangible disaster prevention measures, is vital to protect them effectively against natural hazards.
In this paper, we focus on an approach for developing a system to protect cultural heritages using relational database, and Java is proposed. In addition, we also discuss the risk assessment of the cultural heritages of Tokyo using local hazard maps and risk filters.

2. CULTURAL HERITAGES OF TOKYO

2.1. Classification of Cultural Heritages and Legal Grounds

Broadly speaking, cultural heritages represent all items and actions that have historic, artistic, and academic value. In Japan, under the Law for the Protection of Cultural Properties, the national government designates and selects the most important cultural heritages as "Cultural Properties". The Registration system of cultural heritages is a relatively new endeavor. It was established in 1996 on the basis of experiences following the Kobe earthquake. It enables the protection and utilization of cultural heritages more extensively. The designation, selection, and registration of cultural properties are carried out by the Ministry of Education, Culture, Sports, Science and Technology. The properties are classified according to type [2)] (Figure 1).

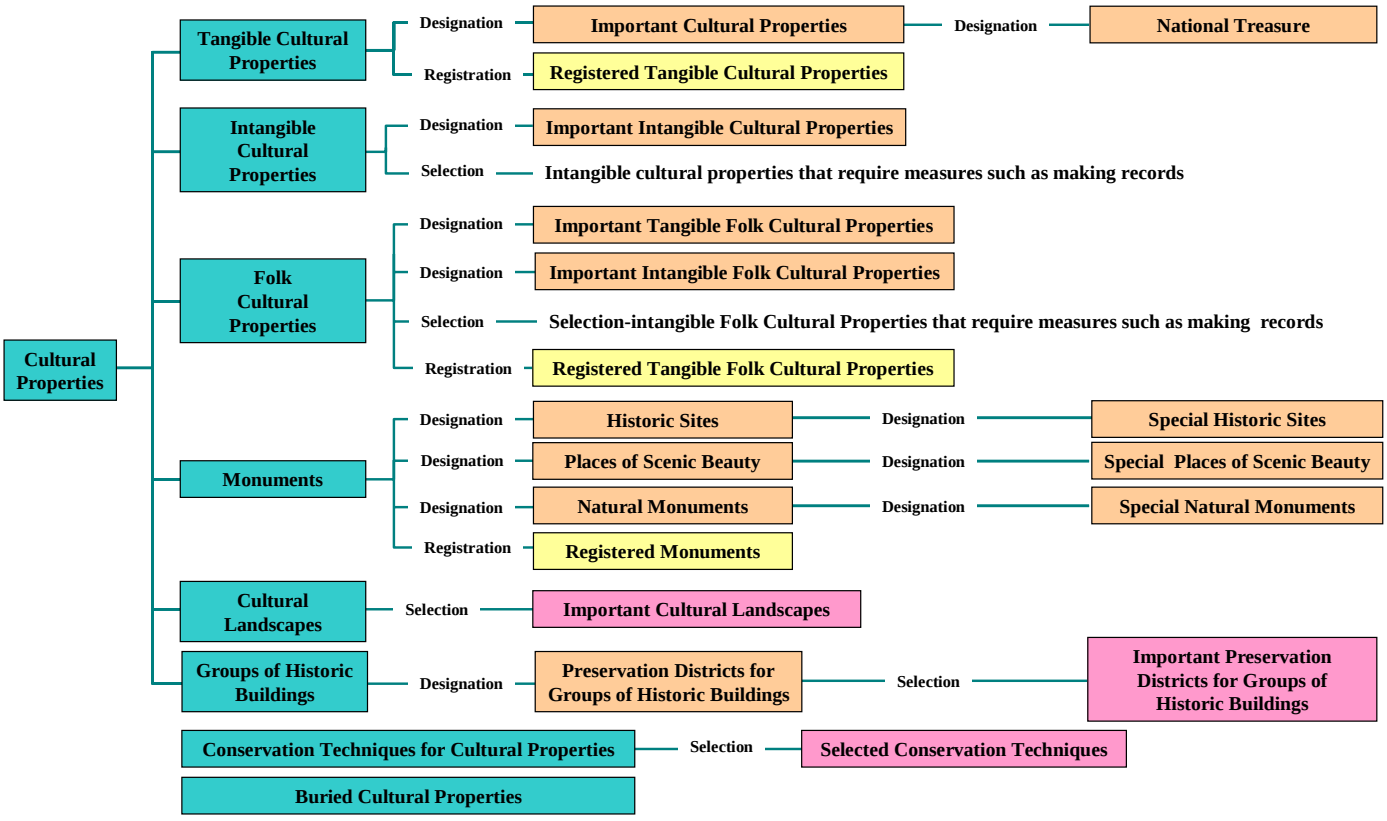


Figure 1 Classification of cultural properties by national government (Japan)

Local public entities also play a role in the designation, selection, and registration of important cultural heritages (excluding those designated by the national government). They can establish their own ordinances for the protection of cultural properties. There are some differences among local public entities although their ordinances follow the Law for the Protection of Cultural Properties. Thus, some of them do not have the registration system yet, and their classifications differ slightly from one locality to another.

2. 2. Number of Cultural Heritages

The most important cultural heritages are designated by the national government. Particularly, tangible cultural properties are called “Important Cultural Properties” and those with particularly high value are designated as “National Treasures”.

The Tokyo government also designates valuable cultural heritages excluding those designated by the national government, and then the municipalities also do the same. A designated cultural heritage is generally more valuable than a registered one. The value of a cultural heritage, however, is not a thing that is simply compared. There are 5,764 cultural properties which are designated and 3,037 cultural properties which are registered by these public entities [3] (Table 2.1). More than 500 of them are buildings. It is difficult to adopt disaster prevention measures for all these cultural properties at the same time. The establishment of a disaster prevention plan for the cultural heritages of Tokyo, which indicates the priority level of measures, is indispensable.

Table 2.1 Number of designated cultural properties in Tokyo

National Government

Important Cultural Property (National Treasure)	Fine and Applied Art	2,229(233)
	Building	60(1)
Historic Site (Special Historic Site)		41(2)
Places of Scenic Beauty (Special Places of Scenic Beauty)		6(2)
Natural Monument (Special Natural Monument)		13(1)
Important Intangible Cultural Property	Performing Art	37
	Craft Technique	7
Important Tangible Folk Cultural Property		8
Important Intangible Folk Cultural Property		6
Selected Conservation Technique	Holder	4
	Holding Group	8
Registered Tangible Cultural Property (Building)		211

Local Government

Tangible Cultural Property	Fine and Applied Art	1,268
	Building	203
Historic Site		302
Places of Scenic Beauty		8
Natural Monument		201
Intangible Cultural Property		62
Tangible Folk Cultural Property		332
Intangible Folk Cultural Property		172
Cultural Landscape		1
Registered Intangible Cultural Property		1,644
Registered Historic Site		380
Registered Places of Scenic Beauty		4
Registered Natural Monument		38
Registered Intangible Cultural Property		134
Registered Tangible Folk Cultural Property		514
Registered Intangible Folk Cultural Property		112

Tokyo Government

Tangible Cultural Property	Fine and Applied Art	59
	Building	265
Historic Site		334
Places of Scenic Beauty		10
Natural Monument		64
Intangible Cultural Property		8
Tangible Folk Cultural Property		17
Intangible Folk Cultural Property		48

3. DEVELOPMENT OF DATABASE SYSTEM

3. 1. Structure of Database

The lists of cultural properties are managed by each government entity. For the risk assessment of the cultural heritages of the entire Tokyo, it is necessary to gather these lists and unify them. So far, fundamental information on the national, prefectural, and municipal 4,904 cultural heritages was gathered [4) 5)], and a new

electronic database for the risk assessment of cultural heritages was developed with “MySQL”, which is one of the open-source relational database management systems. This database has 8 tables and is connected using codes (Figure 2).

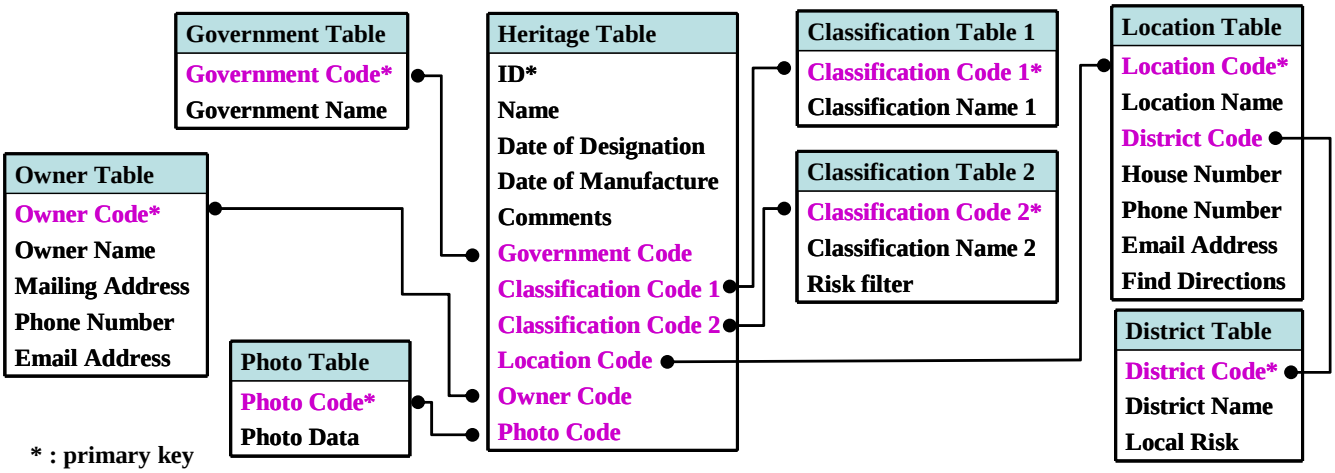


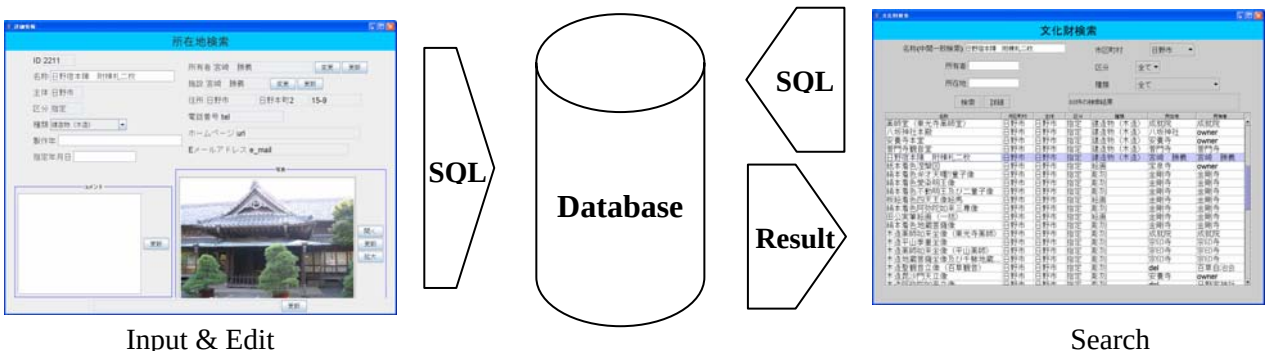
Figure 2 Structure of database

3. 2. Database Management System

Access to the database is carried out using “Structured Query Language (SQL)”, a specialized language that provides an interface to relational database systems. A management system for this database was developed using Java. This system can be used to update, delete, and request information from databases without typing SQL. The functions of the database management system are as follows (Figure 3).

- To input and edit cultural heritage information
- To input and edit heritage owner
- To input and edit heritage location
- To edit risk filter
- To edit local risk
- Some search functions

No end users are required to be aware of the complexity of the database server in terms of the daily management.



Input & Edit

Search

Figure 3 Execution screen of database management system

4. RISK ASSESSMENT OF CULTURAL HERITAGES

4. 1. Damage risk assessment using local hazard map and risk filter

A risk estimate of damage to cultural heritages requires two fundamental components.

1. A local risk that indicates vulnerability to disasters according to city planning districts.
2. A risk filter that reflects the damage characteristics of a cultural heritage, which are determined by its shape and material quality, in the risk assessment.

(a) Local risk

In this paper, the following eight local risks were measured for each district.

- Earthquake
- Liquefaction
- Landslide
- Mudflow
- Cliff failure
- Fire
- Building collapse due to earthquake
- Flood

These local risk measurements were based on local hazard maps [6) 7) 8)]. The degree of each local risk is shown in Figure 4.The fire and building collapse risks are rated on a relative scale of 0 to 5. In the measurement of the building collapse risk, specific earthquakes are not anticipated and it is measured by establishing the same condition, such as the strength of the earthquake, in all districts. The local risk information, as well as cultural heritage information, was inserted into the relational database.

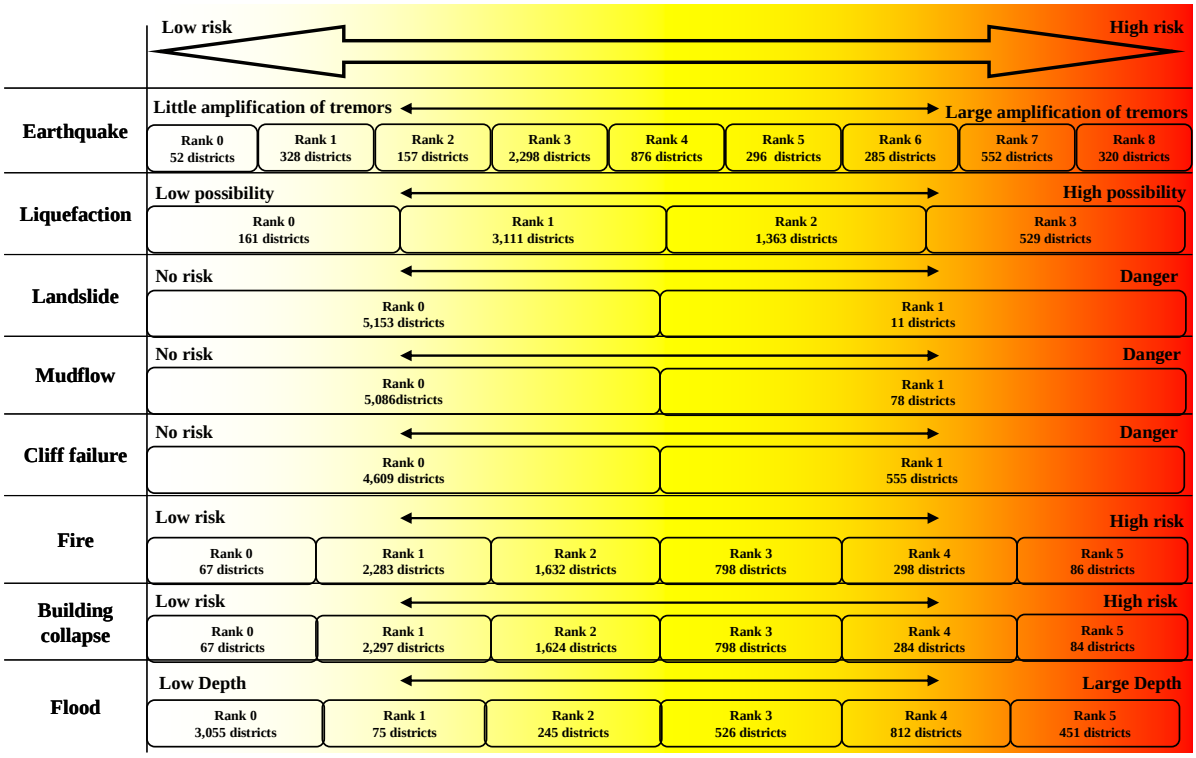


Figure 4 Degree of local risk

(b) Risk filter

Cultural heritages are of many types, such as building, picture, and others, and the damage characteristics against each hazard vary according to the type. For example, pictures drawn on paper are highly combustible

and they will be lost if they are burned. On the other hand, masonries can be considered relatively strong against a fire because they are made of stone. In this study, those damage characteristics against each hazard were reflected on by risk filters [9] (F_{ik}), which is rated on scale of 0 to 5. The rank 0 indicates that no damage is anticipated, and serious damage is expected for those with a rank of 5, which is the maximum. These can be set arbitrarily.

(c) Damage risk

In this assessment, the damage risk of a cultural heritage against natural hazards is measured on the basis of a local risk and a risk filter. The damage risk (R_{ijk}) is defined using the following formula (4.1).

$$R_{ijk} = \frac{D_{ij} \times F_{ik}}{D_{i,\max} \times F_{\max}} \tag{4.1}$$

Here, D_{ij} is a value of the local risk and F_{ik} is a value of the risk filter that considers the modality of heritage and type of hazard. $D_{i,max}$ is the maximum value of the local risk, which is assumed to be different depending on hazard (see Figure 4), and F_{max} is the maximum value of the risk filter. R_{ijk} is rated on a scale of 0 to 1.

4. 2. Damage Risk of Cultural Heritages

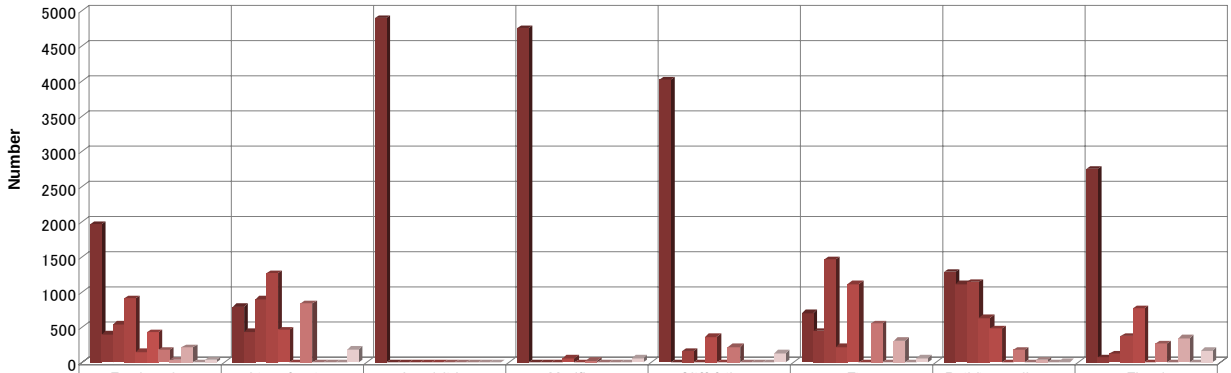
In this paper, the risk assessment was conducted on the 4,904 cultural heritages that are found in Tokyo prefecture (Figure 5). We calculated their damage risks against the eight disasters. The values of the risk filters that were used for the damage risk assessment are shown in Table 4.1.

Figure 5 Number and classification of cultural heritages for the assessment

Table 4.1 Value of the risk filter

i	k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Classification of cultural heritage	Painting	Sculpture	Applied art	Callography	Classical book	Ancient manuscript	Archaeological artifact	Historical material	Building	Intangible cultural property	Intangible folk cultural property	Tangible folk cultural property	Historic site	Place of scenic beauty	Natural monument	Conservation technique for cultural property	Buried cultural property	Local collection	Sword	Ancient manuscript made of stone	Tangible folk cultural property made of stone	Tangible folk cultural property Sculpture	Wooden building	Tomb	Stone sculpture
1	Earthquake	3	5	5	2	2	2	5	2	0	0	0	3	0	0	0	0	0	5	3	5	5	5	0	5	5
2	Liquefaction	3	5	5	2	2	2	5	2	5	0	0	3	5	5	0	0	5	5	3	5	5	5	5	5	5
3	Landslide	2	3	2	2	2	2	2	2	5	0	0	3	5	5	0	0	5	2	2	5	5	3	5	3	3
4	Mudflow	2	3	2	2	2	2	2	2	5	0	0	3	5	5	0	0	1	2	2	5	5	3	5	3	3
5	Cliff failure	2	3	2	2	2	2	2	2	5	0	0	3	1	1	0	0	1	2	2	5	5	3	5	5	3
6	Fire	5	5	5	5	5	5	5	5	4	0	0	5	3	3	0	0	1	5	4	1	1	5	5	1	1
7	Building collapse	2	3	2	2	2	2	2	2	5	0	0	3	3	3	0	0	1	2	2	5	5	3	5	4	3
8	Flood	5	3	3	5	5	5	3	5	3	0	0	3	2	2	0	0	1	5	3	1	1	3	3	1	1

All the heritages were categorized by damage risk against each disaster (Figure 6). This rank indicates the heritages that preferentially require disaster prevention measures. We will investigate the conservation state in detail particularly for the heritages whose damage risk is ranked 1 in the future.



	Earthquake	Liquefaction	Landslide	Mudflow	Cliff failure	Fire	Building collapse	Flood
0	1963	798	4892	4746	4013	709	1287	2752
0.1	407	439	0	0	0	445	1118	77
0.2	545	902	0	0	158	1467	1147	129
0.3	917	1266	0	0	0	224	637	377
0.4	155	470	6	64	370	1118	482	773
0.5	427	0	0	0	0	0	0	0
0.6	185	836	3	30	226	558	177	274
0.7	44	0	0	0	0	0	0	0
0.8	217	0	0	0	0	316	42	348
0.9	0	0	0	0	0	0	0	0
1	44	193	3	64	137	67	14	174

Figure 6 Damage risk of cultural heritages in Tokyo

The numbers of high-risk cultural heritages in each city are shown in Figure 7. A significant number of cultural heritages exposed to five hazards except landslide, mudflow and cliff failure are found in Koto-ku. This is because Koto-ku has more cultural heritages than other cities and has many high-risk areas. The cultural heritages that have high risks against landslide disasters were found more in the western part of Tokyo.
Nitenn-mon, one of the Important Cultural Properties designated by the national government and located at Asakusa Shrine, which is a famous sightseeing spot in Tokyo, is found to have a high risk against liquefaction.

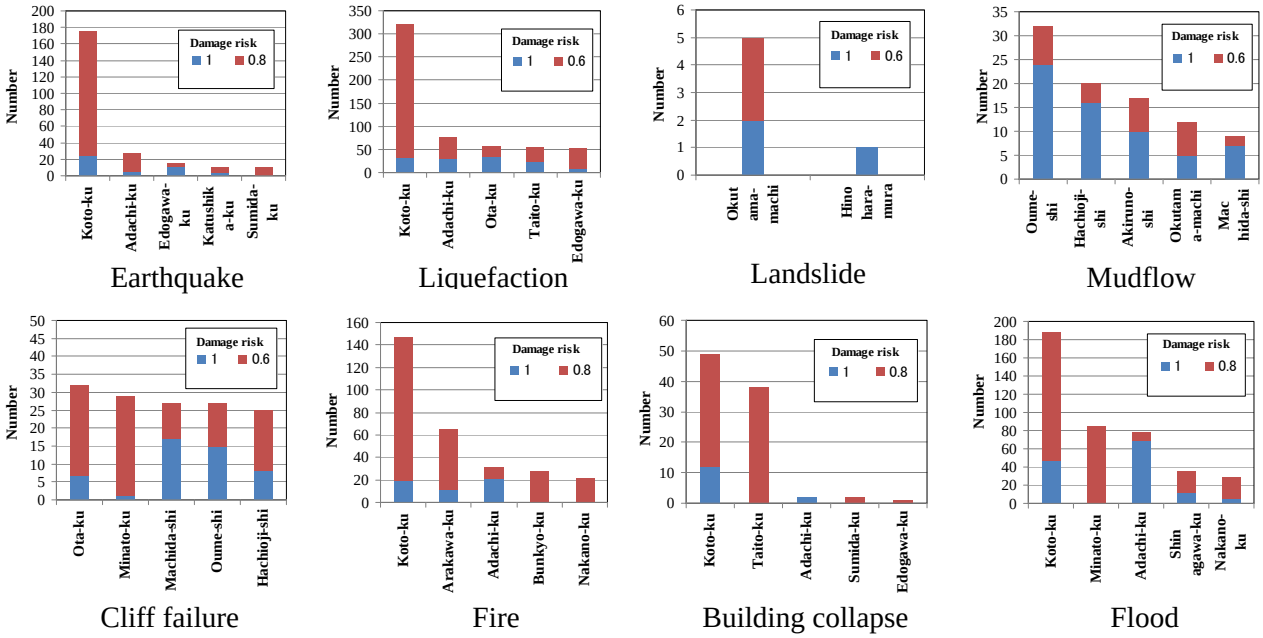


Figure 7 Number of high-risk cultural heritages in each city

5. SUPPORT SYSTEM FOR ESTABLISHING DISASTER MITIGATION PLAN

In this system, the damage risk assessment was integrated with the heritage database that can be used easily. The actual contents of this system are as follows (Figure 8).

- Cultural heritage database
- Local risk database
- Database management system
- Damage risk analysis system

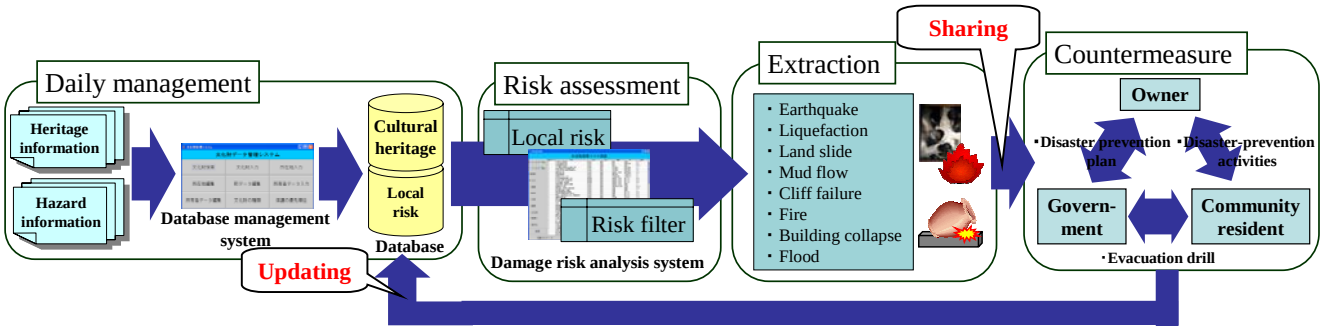


Figure 8 Support system for establishing disaster mitigation plan

6. CONCLUSIONS

A database of cultural heritages and local risks was developed. Moreover, a support system prototype for a disaster mitigation plan was produced experimentally. From the results of the damage risk assessment of cultural heritages, the damage characteristics of cultural heritages at the city level have been determined.

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