Master of Science in Engineering

Web GIS-Based Flood Management System for the Architectural Heritage

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Abstract

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In recent years, flood damage is drastically increasing due to global warming, urbanization, irregular weather condition and so on. Especially, flash flood by torrential rain and locally heavy rainfall damage the architectural heritage before an appropriate measure is taken.

Multilateral efforts are put into solving the issue, however, weakness in effectively responding to the flood risk toward the cultural heritage buildings located all over the nation exists.

To solve the problem, the Cultural Heritage Administration conducted researches from 2009 to 2012. Despite efforts, however, there are difficulties in actively corresponding to the flood disaster due to unclassified research data, low accessibility to the information and so on.

To address these limitations, this research attempts to present an effective flood management system by integrating Web Geographic Information System (Web-GIS) with Relational Database Management System (RDBMS) and using real-time rainfall data.

Compared to the traditional system, suggested Web GIS based flood management system is expected to be more efficient, adaptable and flexible. Ultimately, this research aims to be more supportive tool for flood risk manager's decision making.

Keywords: Flood Risk Management System, Architectural Heritage, Web GIS, RDBMS

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Chapter 1. Introduction

This chapter presents the research objective, research scope and method. Research objective mainly explains the necessity of this study and expected results. Also, at the end of this chapter, main research process is described with research process figure.

1.1 Research Objective

Architectural heritage is constantly exposed to the external environment and can be easily damaged by external factors (The Cultural Heritage Administration, 2013). Therefore, various preservation policies for architectural heritage have been considered to prevent it from being damaged (Han, 2009).

In recent years, the occurrence of locally heavy rainfall and flood inundation has increased due to climate change and global warming. And the damage of cultural heritage has increased either. To prevent and minimize the damage, The Cultural Heritage Administration classified flood as a major factor threatening cultural heritage with the five other factors (e.g., earthquake, fire, man-made hazard, insufficient administration and biological damage). Analyzing flood risk and vulnerability of architectural heritage has to be preceded before the proper measure is taken by the related organizations for active response in flood disaster (Yoo et al., 2004).

The National Research Institute of Cultural Heritage suggested methods for evaluating flood risk of architectural heritages from 2009 and built foundation of managing flood risk of architectural heritage by applying it to the partial area (e.g., Seoul, Suwon and Buyeo). However, immediate and accurate response is not carried out due to low usability of the related information, low accessibility to the system and difficulties in securing response time.

To overcome these limitations written above, this research will classify the spatial and attribute data followed by establishment of flood management system for the architectural heritage using Web Geographic Information System which is effective in managing database and expressing the data. Based on these works, the research result is expected to effectively support the flood risk manager’s decision making by alarming flood risk of the architectural heritage before flood disaster damages the target. It means early forecasting of flood risk which is helpful in responding to the disaster situation. Also, this research aims improvement in using disaster-related information and responding to the disaster situation.

1.2 Research Scope and Process

This research mainly focuses on wooden and stone architectural heritages which are located on Seoul (near Gyeongbokgung Palace - Jongmyo Shrine), Suwon (near Suwon Stream) and Buyeo (near Qeum River). Also, the basic information is mostly based on research results which were conducted by Cultural Heritage Administration from 2009 to 2012.

To solve the problem and to accomplish the objectives written above this research should have a process and the research process is described at this lower page and illustrated as follow Figure 1-1.

1) Analyzing cultural heritage flood management system, flash flood and response time and flood risk manager's decision making
2) Selecting some applicable methods to solve the problem mentioned above.
3) Establishing the system coupled with Relational Database Management System and Web Geographic Information System based on analyzing system requirements.
4) Using usability evaluation, the effectiveness of the suggested system is verified.

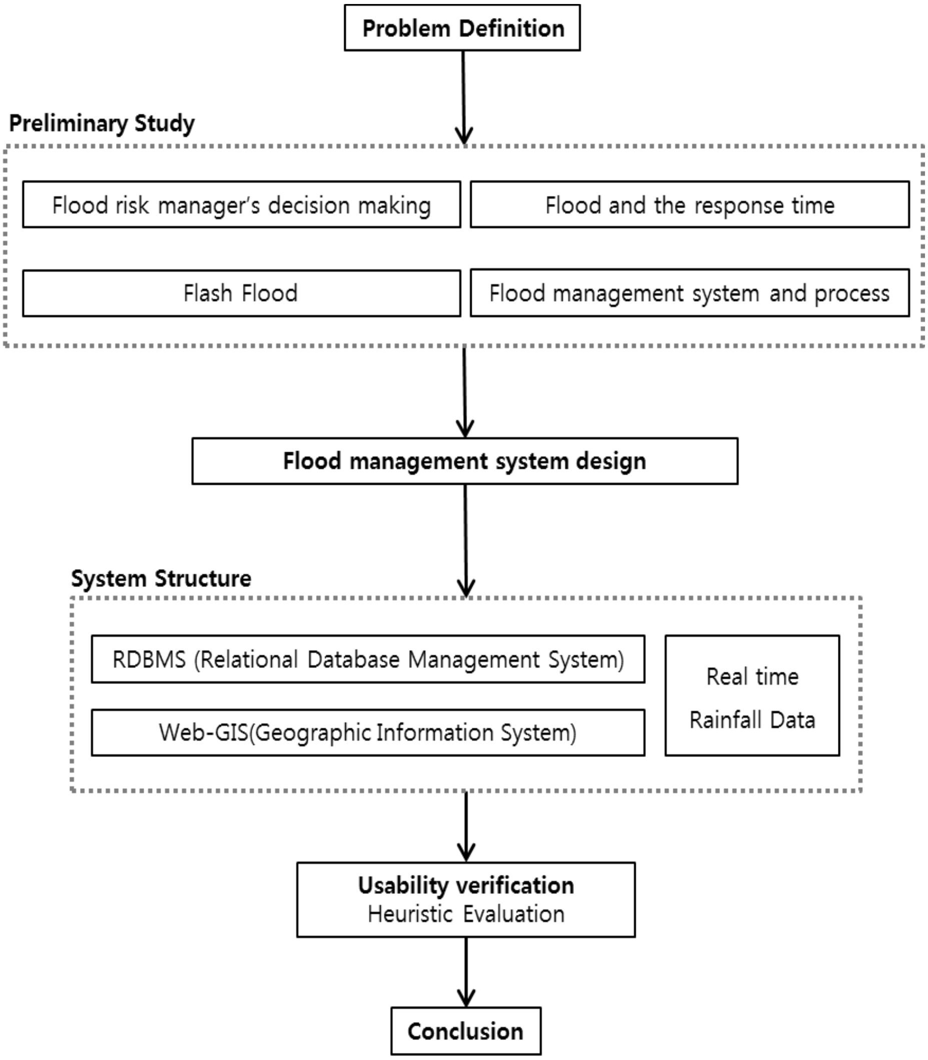

Figure 1-1. Research Process

Chapter 2. Literature Review

To solve the problem and establish the system, this chapter discusses the previous flood management system for the architectural heritage, concept of flash flood related to the response time and flood risk manager's decision making. First, the previous flood management system is understood through a literature review. Second, to verify the necessity of the system, the concept of flash flood and response time is researched through the related theory and literature review. Finally, introduce the flood risk manager's decision making which would be helpful in understanding current status of flood risk managing.

2.1 Flood Risk Management for Architectural Heritage

In recent days, an important development in flood management has been a shift from flood protection to flood risk management (Evers et al., 2012). It means that the management process covers the entire process from prevention to recovery and mainly focuses on advanced prevention instead of posterior measures. To manage the flood risk in the community, disaster managers have various mitigation measures available. These include analyzing vulnerability of the target, building up the hydrological model which can predict the scale of inundation and so on (Zerger and Wealands, 2004).

As described in Figure2-1, the Cultural Heritage Administration, the uppermost institution in dealing with disaster situation, categorized the way of preparing for the flood disaster into four steps (e.g., prevention, preparation, correspond and restoration).

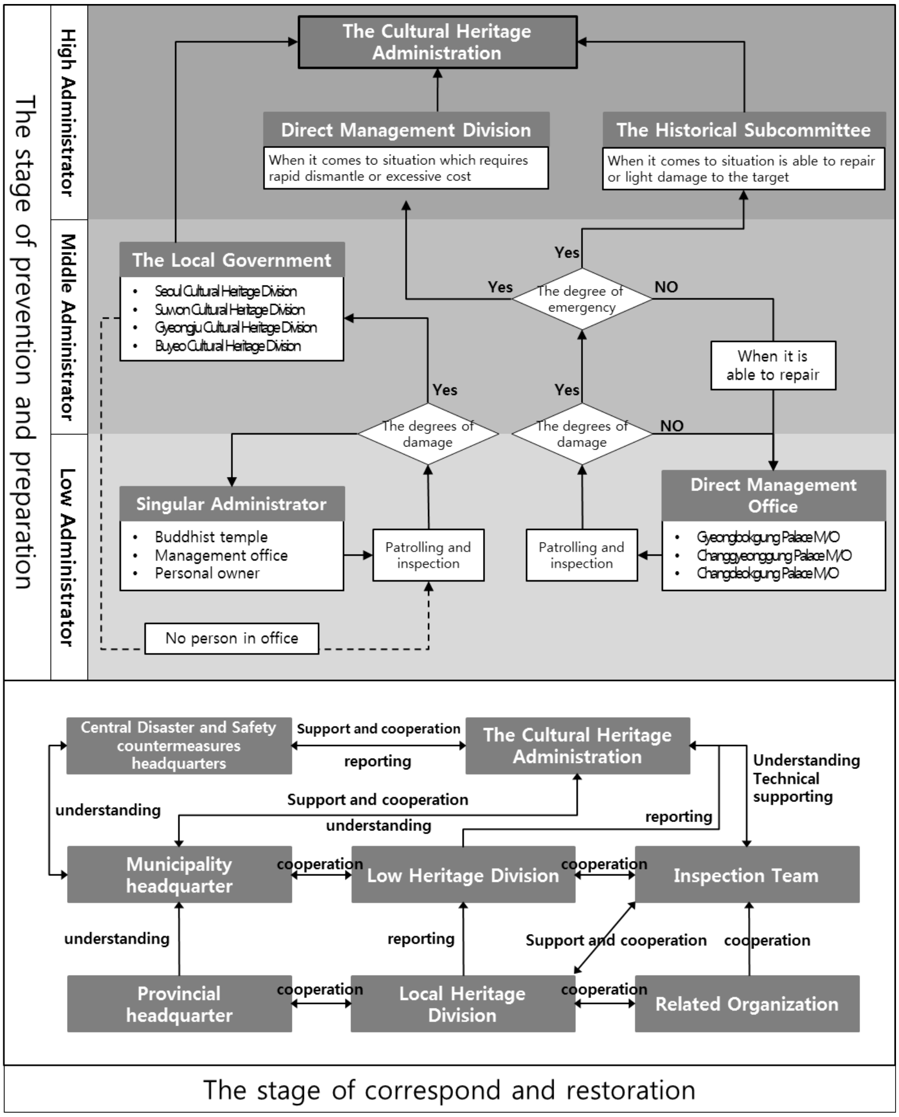

Figure 2-1. Domestic Disaster Management System for the Architectural Heritage

Firstly, they do regular patrolling and checking to preserve the architectural heritage at the stage of prevention and preparation. Also, the administration establishes countermeasures to improve a plan for preventing disasters and to reduce damage by analyzing risk factors and vulnerability of the architectural heritage.

Secondly, at the stage of correspond and restoration, the administration runs prepared plan for preventing disasters quickly and accurately based on the measure and manual written above. Also, they try to improve the preventive measures and find every ways related with emergency procedure and restoration (The Cultural Heritage Administration, 2013).

2.2 Flash Flood and Response Time

The way of prediction and damage prevention for the disaster has become difficult while the number of combined and unforeseen disaster increased significantly. Due to it, there is a need for improved disaster management system (Yoon, 2011).

Especially, flash floods are characterized by rapid spread time which occurs damage to the target before an appropriate measure is taken as described in Figure 2-2. And it makes it difficult to secure response time for taking a counter measure (Smith et al., 2014). Also, flash floods have high velocities and tremendous erosive forces which occurs fatal damage to the solid structures like architectural heritages (Plate, 2002).

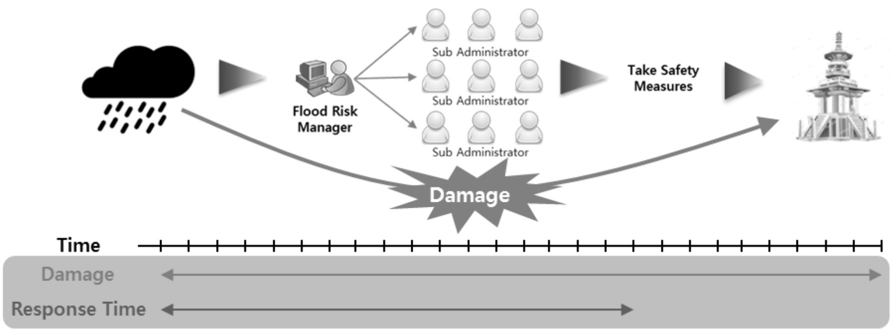

Figure 2-2. Features of the Flash Flood

Considering features of flash flood as written above, it definitely requires different response than an ordinary type of flood. And it means that rapid initial response is necessary for minimizing damage to the target by reducing response time.

In case of the previous researches analyzing flood risk of architectural heritages in Seoul, Suwon and Buyeo, they mainly focused on the result of the flood simulation model which is based on a single area.

However, it does not actively reflect the realistic situation which helps administrator's decision making. Because of this reason, this research is designed to make it possible to shorten the response time and make an early warning by comparing design rainfall data with the real time rainfall data.

2.3 Flood Risk Manager's Decision Making

The flood risk manager makes lots of decision to manage the risk of architectural heritage.

The first step is predicting and calculating the possibilities of flood inundation. To support this, a range of researches have been conducted from probabilistic statistical predictions of recurrence intervals and magnitudes (Harper, 1999) to spatially explicit two-dimensional hydrodynamic models (Hubbert and McInnes 1999). Especially in case of hydrologic model, researches coupled with remote sensing, GIS, quantitative model and time series data have been conducted to support the manager's effective decision making.

Despite these efforts and researches, however, there are some reasons why flood risk managers can't make an effective decision.

Liu (2014) argued that managers can't make a rational decision due to their tendency to depend on personal past experience in spite of the growing complexity and uncertainty in many decision situations of flood risk management.

Zerger and Wealands (2004) stated that an access to the results of models developed to support the administrator's decision making requires knowledge about modeling and special software. Because most of managers are non-expert related to the specialized knowledge, however, they have difficulties in fully understanding and using the research results.

Lien (2009) suggested the limitations of the existing systems as follow. The existing systems have difficulties in meeting the needs of the manager to access as they want to access the system at any time of the day and night with many different devices.

Chae and Woo (2006) presented that unclassified information and unstructured data type result in the difficulties in supporting effective decision making though there are various research results and data.

2.4 Summary

To protect architectural heritages from flood damage, many researches have been studied. However, there exist some limitations as follow:

1) Manager's tendency to depend on their past experience when they make a decision making in flood disaster

2) Lack of professionalism of general managers

3) Low accessibilities of the existing system

4) Unclassified and unstructured data

To solve the previously mentioned limitations, this research needs to develop system which can overcome the limitations and effectively support the administrator's decision making.

To fulfill the goal, this research follows the steps:

1) Develop Relational Database based on the previous research results of the target

2) Combine Relational Database with Web Geographic Information System

And the developed system is expected to effectively support the manager's decision making by increasing administrator's accessibility and usability to the required information and system.

Chapter 3. Database for the System

The preliminary data used for this research consists of various types of raw data. To systematically structuralize the data, this research follows the four steps: data requirements analysis, conceptual DB design, logical DB design and physical DB design as shown in Figure 3-1. The specific process and results will be presented on the next section.

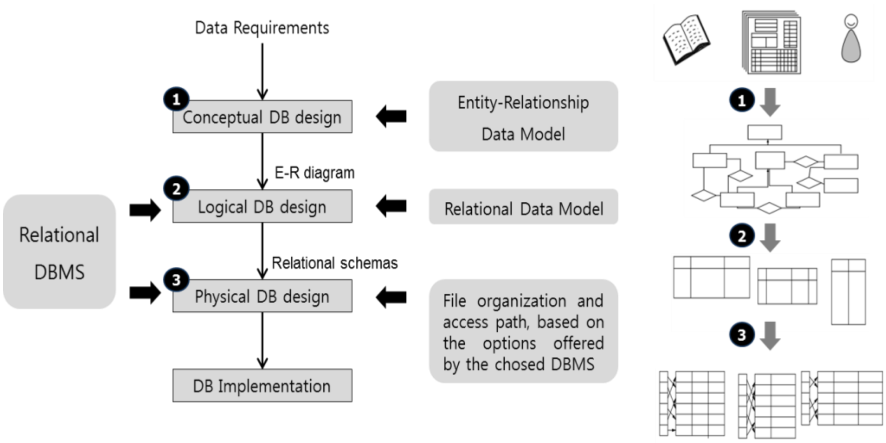

Figure 3-1. Database Process

3.1 Database Overview

Database Management System means a group of program which can classify and store the data for easily using information (Park et al., 2013). Among them, Relational Database Management System (RDBMS) has superior advantages in aspects of large size data processing, transaction and locking compared to the others (Lee and Yoo, 2010). Particularly, it has high efficiency in systematically structuralizing spatial data which takes up a considerable part of raw data (Adler, 2001). For this reason, this research aims RDBMS based system development.

Also, combining RDBMS with GIS is necessary as it provides administrator with rapid access to the required information and has high efficiency in handling tremendous amount of spatiotemporal information (Zerger and Wealands, 2004). Because of these advantages, this research aims combination of RDBMS and Web GIS.

3.2 Data Classification and DB Development

Based on the analysis of required information, service and function, the database of the research consists of six parts: cultural heritage information DB, hydrological information DB, flood risk management DB, risk assessment scenario DB, hydrological model result DB and GIS information DB. And each database consists of six tables allocated by data code for classification.

Table 3-1 shows detail contents and information of data which composes database.

Cultural heritage information table includes data related with local cultural heritage status, individual attribute data (e.g., type, name, category, height, designated day, location, administration, number, area and etc.).

Hydrological information DB contains hydrosphere status (e.g., type, length extension, level extension and etc.), topographic characteristic (e.g., distribution chart, soil map and etc.), hydraulic structure (e.g., dam, reservoir, power production facilities, facility data, waterway, general status and etc.) and so on.

Flood risk management DB covers long range plan, emergency reaction manual, structure installation manual, existing manual (e.g., master plan, river basis modifying plan) and etc.

Table 3-1. Database Components

Category	Data
Cultural Heritage Information	Local cultural heritage status Individual attribute data (Type, Name, Category, Height, Designated day, Location, Administration, Number, Area)
Hydrological Information	Hydrosphere status (Type, Length extension, level extension) Topographic characteristic (Distribution chart, Soil map, etc) Hydraulic structure (Dam, Reservoir, Power production facilities, Facility data, Waterway, General status, Etc)
Flood Risk Management	Long range plan Emergency reaction manual Structure installation manual Existing manual (Master plan, River basis modifying plan)
Risk Assessment Scenario	Flood frequency data Risk assessment rainfall data Maximum discharge capacity
Hydrological Model	Probable rainfall data(FARD) Flood discharge data(HEC-HMS) Flood stage data(HEC-RAS) Downtown flood routing model(SWMM) Real time data from the Meteorological Agency ETC
GIS Information	Coverage range 2D&3D numerical map Ground TM coordinate Water distribution networks ETC

Risk assessment scenario DB consists of data related with flood frequency data, risk assessment rainfall data, maximum discharge capacity and etc.

Hydrological model DB includes probable rainfall data (result of the Frequency Analysis of Rainfall Data), flood discharge data (result of the Hydrologic Engineering Center’s Hydrologic Modeling System), flood stage data (result of the Hydrologic Engineering Center’s River Analysis System), downtown flood routing model (result of the Storm Water Management Model), real time data from the meteorological agency and etc.

GIS information DB covers information related with coverage range, 2D and 3D numerical map, ground TM coordinate, water distribution networks and etc.

3.3 Entity Relationship Diagram Design

On the basis of the classified data, the Entity Relationship Diagram of the research is developed through the process of logical database design and physical database design. It largely consists of entity, relationship, attribute, primary key and etc.

This research developed table based on the classified table and allocated code to the each table. Although the main table consists of six parts, it can be expanded and categorized into eleven parts including administrator and system function.

For example, in case of expressing information of individual cultural heritage, the required data is showed on GIS based on Geographic Information System spatial table coupled with individual cultural heritage information table and hydrological information table. Figure 3-2 shows entity relationship diagram based on the research.

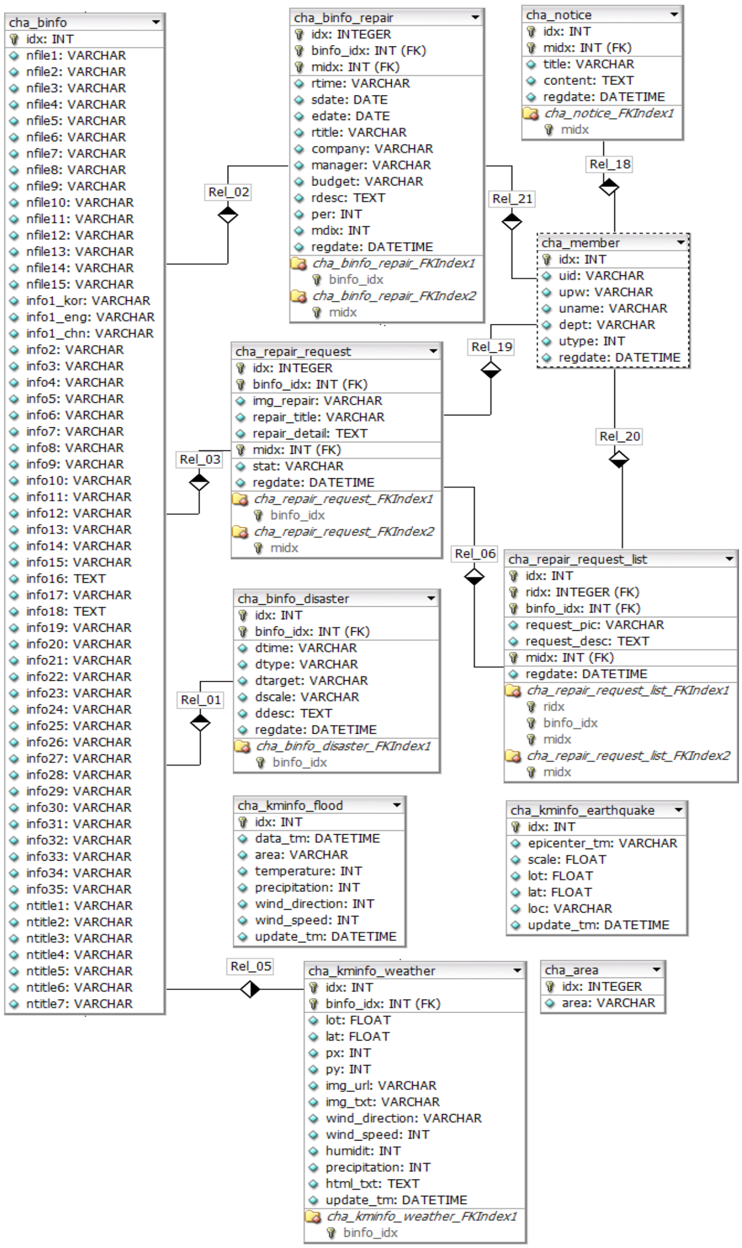

Figure 3-2. Entity Relationship Diagram for Database

3.4 Summary

This research follows four steps of designing database. Firstly, conceptual database design is performed based on analysis of data requirements. Secondly, logical database design is conducted in the form of entity relationship diagram. It aims relational data model. Lastly, physical database design process is followed for file organization and access path based on the options offered by the database management system. Through a series of process, database is implemented if the form of RDBMS.

The database is expected to be integrated with Web GIS based on real time rainfall data. Also, classified data and information would be systematically used by the favor of flood risk manager.

Chapter 4. Web Geographic Information System

The system which supports administrator's decision making in a flood disaster requires high accessibility and user oriented interface considering non-expert flood risk manager.

To solve the problem, numerous effort and researches have been conducted including integration of GIS with multidisciplinary models (Merz et al., 2010) and liaison between web service technologies and service-oriented computing (Watson, 2008). Among them, Web Geographic Information System has advantages such as convenient accessibility, data transparency, independent platform, needlessness of additional hardware and software, high efficiency in visualization and low development price. Therefore Web-GIS based environment can provide flood risk manager with the significant aid (Al-Sabhan et al., 2003).

For this, lots of systems were developed including V-World, which was firstly developed in South Korea at 2012. It has advantages like provision of extensive spatial data and free use. Especially, through V-World, flood manager can easily understanding the risk of the target by identifying related information such as location, direction, story, area and thematic map (Han, 2012). Also, no additional mash-up and processing is needed for open platform environment and easiness in developing system.

This research utilizes Open Application Programming Interface as the main server uses Web Geographic Information System.

Firstly, it calls API function. And the web site requests call to the GIS server using API key. After receiving request, the server identifies validity of the API key and suggests the required information to the user through the server. Figure 4-1 shows the process of the Web-GIS for the system.

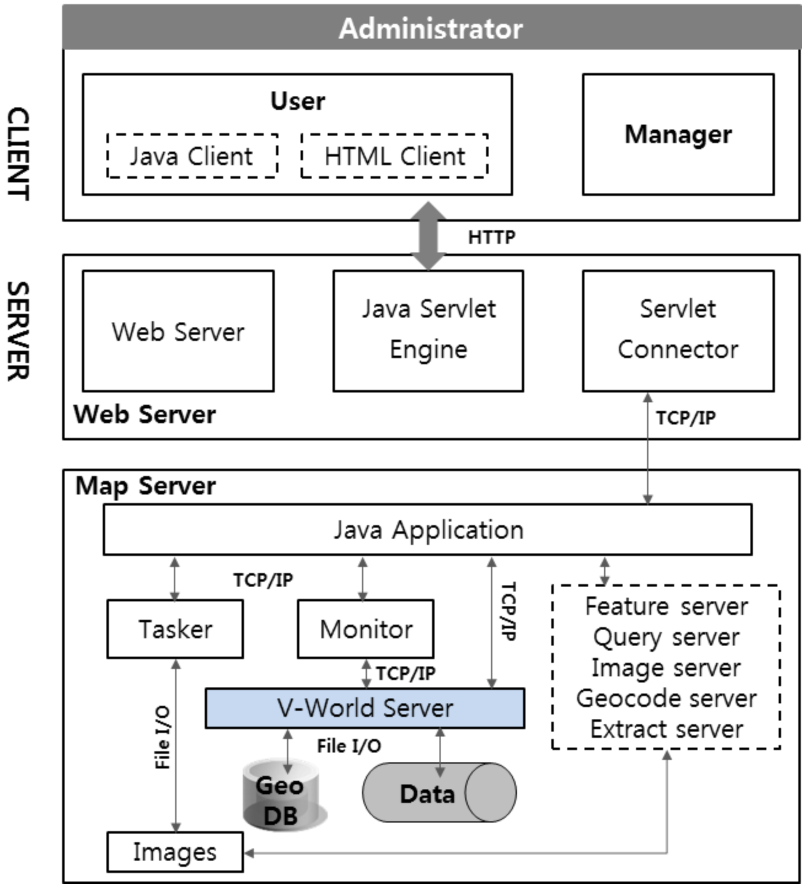

Figure 4-1. Web-GIS Process

Chapter 5. Flood Management System

In this chapter, system requirements, system structure design, system interface and function, real time expression of flood risk and provision of correspondence manual are suggested to show the process of system development. Each section describes detail contents of the system architecture. Based on the analysis of system requirements, the further process is suggested. Through a series of process system could provide administrator with great help of managing flood risk.

5.1 System Requirements

This research aims to solve difficulties in securing response time related with torrential rain and flash flood based on real time rainfall data. Also, this study aims to support the flood risk manager's decision making by use of RDBMS and Web GIS.

RDBMS could systematically classify and structuralize the unstructured data which has a format of individual model. And Web GIS has advantage in offering rapid access and easy utilization to the flood risk manager. Also lastly, based on User Interface, the administrator could easily approach to the required information and identify the result of simulated flood situation. Figure 5-1 shows the menu diagram of the system. The system menu mainly consists of two parts: section for identifying flood risk of the target in level of river basin and individual subject, menu for retrieving architectural heritage's repair and damage history.

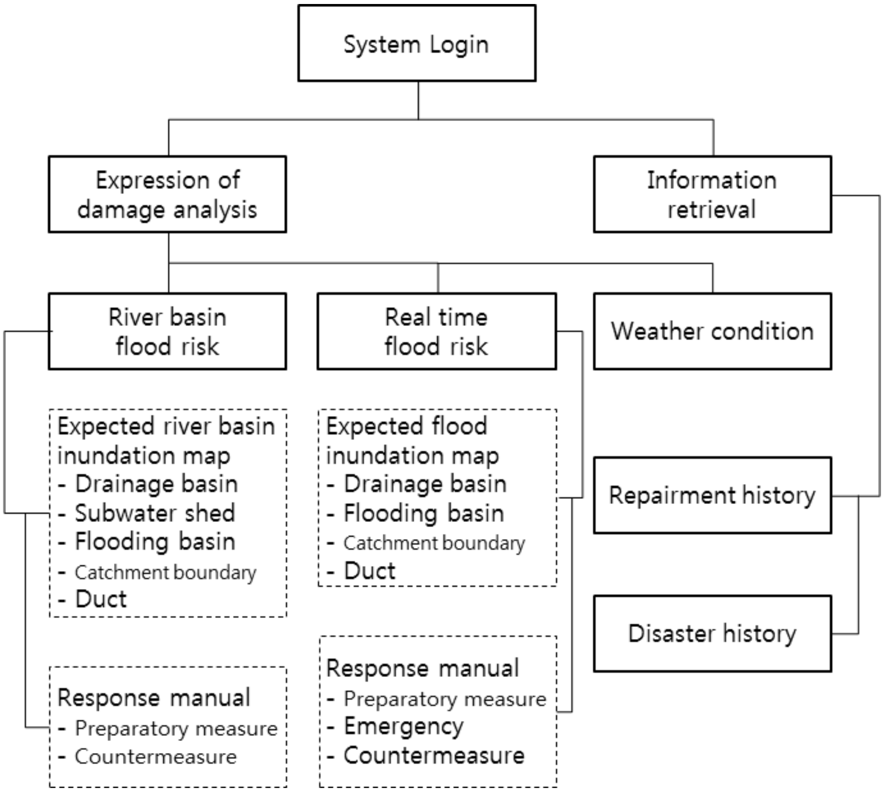

Figure 5-1. Menu Diagram

5.2 System Architecture Design

The system mainly consists of two parts. One is a Client which requires information and the other is a Server which provides data. The client has a Browser because Internet Web Browser is used when the Client inquire information from the Server. Also, there is an Apache Web Server in the Server to initiate service. And there is a MySQL server to manage information easily and external Web GIS Server to operate GIS.

When Client inquires information (HTTP Query) from Server, the Server generates information in PHP server side language or XML markup documents format. Also, the administrator can manage database using MySQL to insert, modify and delete the data in an additional database. SQL query is also used to generate information stored in database and this can be called out using PHP language. For that process, question and answer will be made in MySQL database and a user will use this to find required information and transfer to result value to MySQL server. The result is expressed by web page in PHP language. Also, Open API based required information and data reception is made in interlocking Web GIS Server. Figure 5-2 shows overall structure of the system.

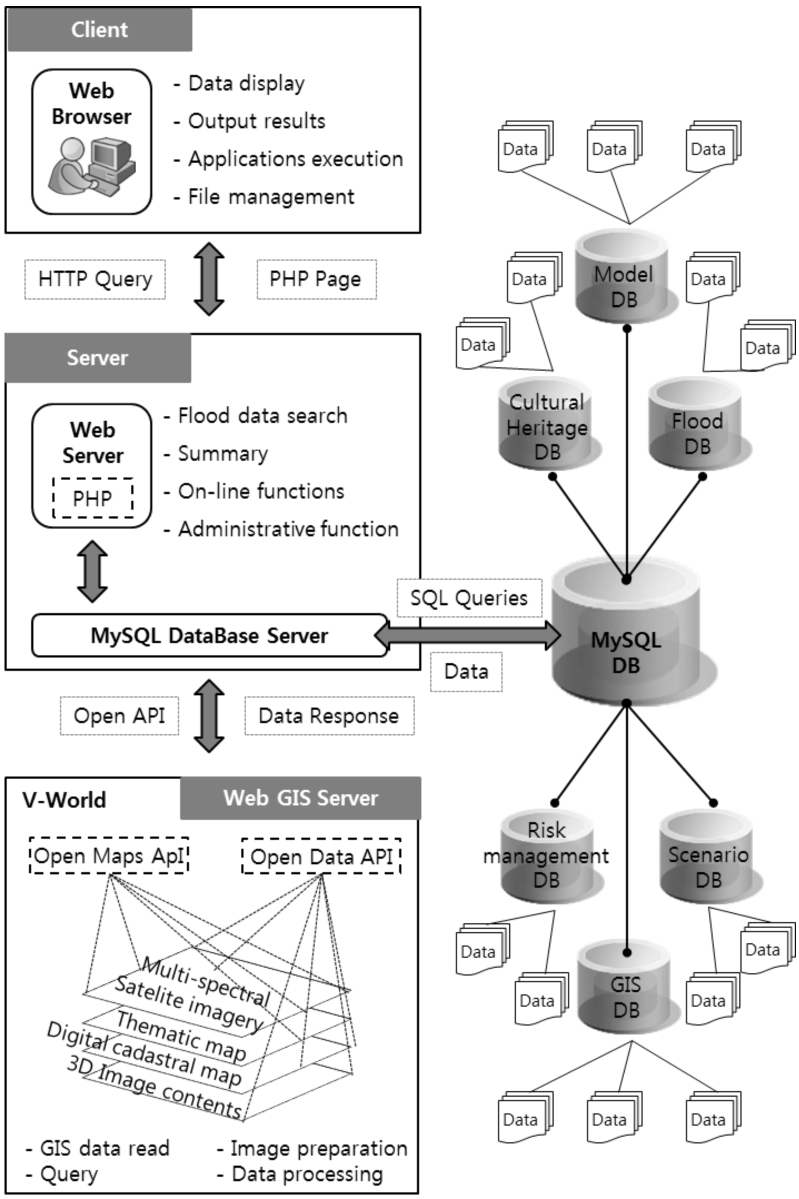

Figure 5-2. System Architecture

5.3 System Interface and Function

In the aspect of information related with disaster and hydrological model, design and capability of system interface are important to successfully improve the accessibility and usability of non-expert flood risk manager. This is because a user understands the result of the system and makes a decision based on User Interface (Power and Sharda, 2007).

The system interface follows the Figure 5-3 and required information is expressed through the Web.

The interface consists of three parts: menu section, part for setting data condition and retrieving and area for identifying information of the architectural heritage.

A part for setting data condition and retrieving provides administrator with rapid access to the information of the target.

And an area for presenting geographic information supports manager’s understanding based on high resolution Digital Elevation Model and three dimensional map.

Ultimately, by use of the system, the administrator can define in how many steps the decision making process would be completed and identify the logical process.

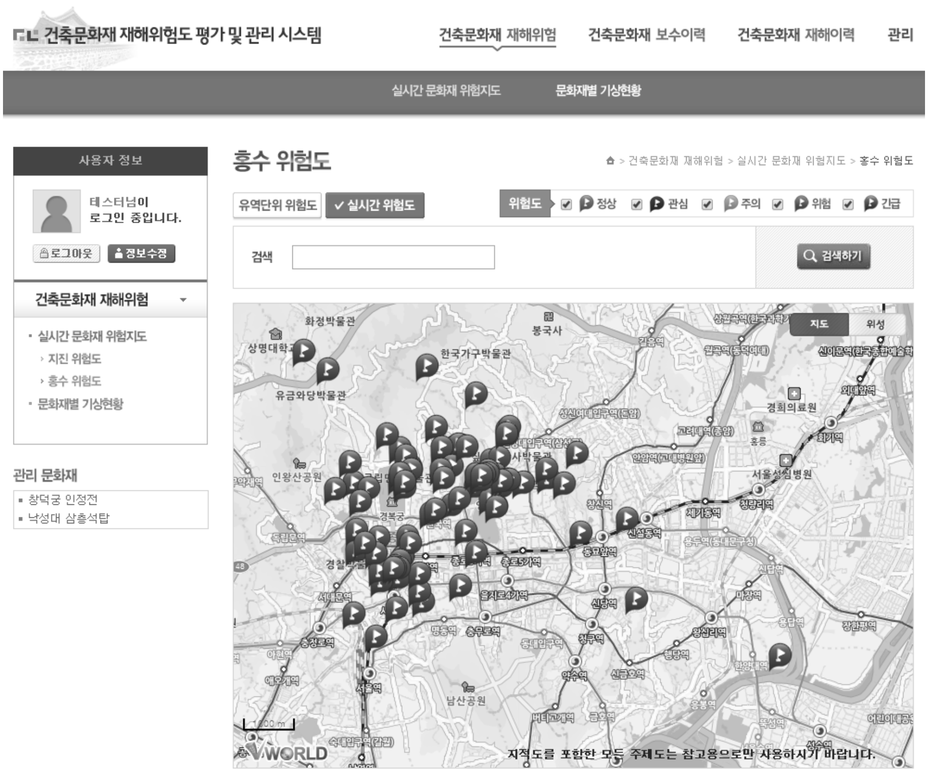

Figure 5-3. System Interface

5.4 Expression of Real Time Flood Risk

Effectively suggesting the possibility of flood inundation to the risk manager is important in a flood disastrous situation. To fulfill the goal, based on real time rainfall data, this research expresses the flood risk of the architectural heritage as shown in Figure 5-4.

The flood risk mainly consists of 2 parts: river basin flood risk which covers various architectural heritages near stream and river and real time flood risk which presents the status of singular architectural heritage.

In case of real time flood risk, the risk is categorized into five stages: low, moderate, high, very high and extreme. For river basin flood risk, the danger status has three steps: low, high and extreme.

Standard which classifies the status of river basin flood risk follows the code of the Meteorological Administration and the Cultural Heritage Administration. Purpose of the river basin flood risk is to alert risk manager to move on to the next step (real time flood risk) because it is nearly impossible to set a regular standard for dispersed heritages. In short, the river basin flood risk is a minimum standard for preserving architectural heritages against flood disaster.

In case of real time flood risk, it differs from each other for their differences in the amount of rainfall, ground and drain facilities in the place where they located. Table 5-2 shows the case of the Gyeongbokgung Palace. The figure consists of accumulated amount of rainfall and rainfall duration time which is based on the preliminary data as written in chapter 1.

Table 5-1. Legend for River Basin Flood Risk

Category	Color coding	Risk Grade	Standard
1	Blue (#0100FF)	Low	-
2	Orange (#FFBB00)	High	More than 70mm for 6hours or 110mm for 12hours
3	Red (#FF0000)	Extreme	More than 110mm for 6hours or 180mm for 12hours

Table 5-2. Legend for Real Time Flood Risk (In case of Gyeongbokgung Palace)

Category	Color coding	Risk Grade	Rainfall Duration Time (m)	The Amount of Rainfall (mm)
1	Blue (#0100FF)	Low	60	87.4
			180	184.8
2	Purple (#5F00FF)	Moderate	60	102.1
			180	222.7
3	Orange (#FFBB00)	High	60	110.5
			180	244.4
4	Red (#FF0000)	Very high	60	121.5
			180	272.9
5	Black (#000000)	Extreme	60	176.0
			180	362.6

Figure 5-4. Expression of Flood Risk

The flood risk is suggested based on the comparison of designed rainfall data per stage and expected rainfall data. When it performs, the real time rainfall data is used based on Open API format. The system get real time rainfall data of the targeted area after the Public Data Portal identifies the validation of the API Key. After the process, simulated flood inundation map and correspondence manual are presented to provide the required information. Especially, simulated flood inundation map helps manager to visually identify result of the flood inundation based on three standards: recurrence frequency, rainfall duration time and design rainfall data. Also, if a series of process completes, it is saved to the database, which is expected to use in the same or a similar situation.

5.5 Provision of Reaction Manual

As written above, the flood management process follows the steps. Firstly, flood inundation is expected to occur which can be described as flood outbreaks. Secondly the flood management system alarms the manager with the flood risk data of the architectural heritage. Lastly, once flood risk of the architectural heritage is suggested to the administrator, the risk manager should distribute the response guideline to effectively respond to the disaster.

This research provides manual for participants based on flood risk management database as shown in Figure 5-5. It consists of preparatory measure, emergency action manual and post countermeasure. Preparatory measure mainly focuses on preventive method for preserving architectural heritage against the flood disaster. Emergency action manual is used when a damage is expected to reach the target before an appropriate measure is taken. Post countermeasure is taken after flood damage harms the target. A series of manual is selected by high administrator and distributed to middle and low administrator.

The manual which covers every state of the flood disaster situation is expected to help flood risk manager to actively response to the flood inundation.

Figure 5-5. Expression of Reaction Manual

5.6 Summary

This chapter presents the detail process of developing system architecture. Firstly, analysis of system requirement is performed based on the preliminary data. The related data is utilized by use of relational database. Secondly, system architecture is designed which consists of client, server, database and web GIS server. Each part exchanges required data in the form of http query, PHP page, open API and so on. Lastly, based on previous process, system interface and function are derived which supports risk manager's decision making. Through the system, flood risk manager can easily identify the risk of the target. Also, the manager can correspond to the disaster situation based on reaction manual.

Chapter 6. System Usability Evaluation

In this chapter, overview for the usability evaluation, selection of subjects, evaluation factor and foundation and result and analysis are suggested to show the process of system usability evaluation. The process is expected to verify the usability of the proposed system.

6.1 Overview

Usability evaluation is very important process to judge usefulness and reliability of various entities such as searching engine, map of a web, application and the system. For this progress, various methods and technologies are used. The methods can be classified into GOMS(Goals, Operators, Methods, Selection) Model, Heuristic Evaluation and Usability Test (Chang et al., 2005). Especially, Heuristic Evaluation is the mostly used way of evaluating usability because of it’s high efficiencies in time and cost (Kim, 2013). For this reason, this research applies Heuristic Evaluation to identify the usability from group of flood risk manager.

6.2 Selection of Subjects

Nielsen and Molich (1990) recommended that the number of people attending the research should be 3 to 7 to get the proper result saying that 5 member can carry out 80% of the problem as shown in Figure 6-1.

In this research, 6 subjects (1 in the Cultural Heritage Administration, 1 in the National Emergency Management Agency, 2 in the Management Office, 2 in the Local Cultural Heritage Division) were selected.

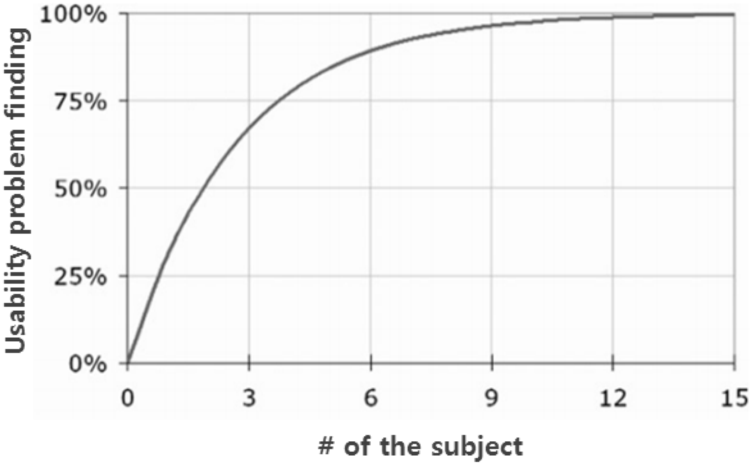

Figure 6-1. Proportion of Usability problems found by subjects of size 1 to 15

6.3 Evaluation Factor

Experts put basis on constant evaluating standard or guideline for Usability Evaluation. Therefore, core evaluating factors were derived from the literature review and applied to the questionnaire.

Considering specificity of flood disaster, eight major factors (system accessibility, convenience, findability, usefulness, availability, aesthetics, interaction & feedback and satisfiability) were presented based on 10 clauses of user interface evaluation suggested by Nielsen and Molich (1990).

Based on the work, the survey consists of 25questions according to Likert 5-point scale measurement.

6.4 Result and Analysis

Table 6-1 and Table 6-2 show the result of the Heuristic Evaluation. The existing system has 2.33point at accessibility, 2.67point at convenience, 2.50point at findability, 2.17point at availability, 1.83point at aesthetics, 2.67point at interaction&feedback and 2.83point at satifiability. In conclusion, it has 2.44average point.

On the other hand, the suggested system has 3.50point at accessibility, 3.33point at convenience, 3.50point at findability, 3.67point at usefulness, 3.33point at availability, 2.50point at aesthetics, 3.50point at interaction&feedback and 3.33point at satifiability.

In short, the existing system has the lowest point at aesthetics and the highest point at satisfiability. Also, it has low points at availability and accessibility, which means that the system does not effectively support risk manager's decision making in a flood disaster situation.

Meanwhile, the proposed system has the highest point at usefulness and the lowest point at aesthetics.

Table 6-1. Results of the Existing System

Existing System							
Evaluation Factors	**Experts**						**Average**
	A	**B**	**C**	**D**	**E**	**F**	
Accessibility	3	2	1	3	2	3	2.33
Convenience	2	3	3	2	4	2	2.67
Findability	2	5	1	2	2	3	2.50
Usefulness	3	4	3	2	2	1	2.50
Availability	2	3	3	2	1	2	2.17
Aesthetics	3	1	1	2	1	3	1.83
Interaction & Feedback	2	2	3	3	4	2	2.67
Satisfiability	3	3	4	2	2	3	2.83
Total							2.44

Table 6-2. Results of the Proposed System

Proposed System							
Evaluation Factors	**Experts**						**Average**
	A	**B**	**C**	**D**	**E**	**F**	
Accessibility	3	4	4	4	3	3	3.50
Convenience	2	3	5	3	3	4	3.33
Findability	3	4	4	3	3	4	3.50
Usefulness	4	3	5	3	4	3	3.67
Availability	3	3	4	4	3	3	3.33
Aesthetics	3	3	2	2	3	2	2.50
Interaction & Feedback	4	4	3	3	3	4	3.50
Satisfiability	3	3	4	3	4	3	3.33
Total							3.33

Figure 6-2 is a normalized diagram comparing each factor of usability evaluation. Score of usefulness, accessibility and availability is relatively high. It means that flood risk manager's accessibility is increased through the suggested system and usefulness and availability are improved by enhanced tool which helps manager's decision making.

Also, overall preference point is 3.33 which is higher than 2.44 of the existing system. It means that the suggested system is superior to the existing system. However, considering that score of convenience and aesthetics, additional supplement is required.

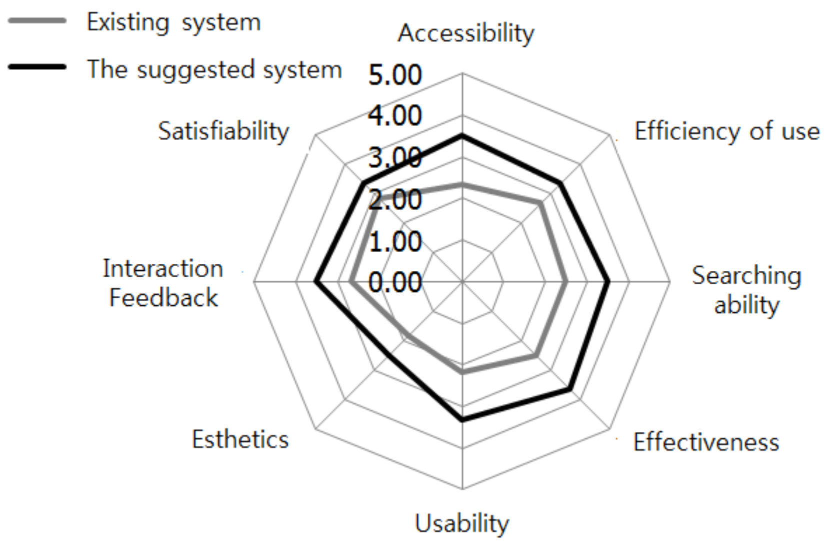

Figure 6-2. Comparison of Heuristic Evaluation Factors

Chapter 7. Conclusion

7.1 Research Results

In flood disaster situation, various ways of preserving the value of architectural heritage have been conducted by the Cultural Heritage Administration and related organization. However, with the growth of torrential rain and flash flood, flood damage to the architectural heritage has increased due to difficulties in securing response time. It means that damage to the architectural heritage occurs before an appropriate measure is taken. Therefore, there is a need to develop new type of decision supporting system which can shorten response time.

As stated in chapter 6, through the heuristic evaluation, the proposed system got higher score in every sector. Firstly, superiority in findability means that the manager has high efficiency in finding required information or data. Consequently, Relation Database Management System successfully classified unstructured data and helped administrator to find necessary information. Secondly, superiority in accessibility, availability and satisfaction means that it effectively supports the flood risk manager's decision making. Lastly, superiority in usefulness means that it efficiently respond to the flash flood disaster. Synthetically, the proposed system is an effective tool for supporting administrator's decision making and responding to the flash flood disaster.

7.2 Contributions

Though there was an effort to solve the problem by the Cultural Heritage Administration for 4 years, it is hard for non-expert flood risk manager to make an effective decision due to unstructured research data and low accessibility.

To overcome the limitation, this research suggests Web GIS based flood risk management system which cap help flood risk manager's decision making. Firstly, preliminary data is classified and structuralized by use of Relational Database Management System. Secondly, integration with Web GIS is processed for improvement in accessing data and providing availability to the non-expert flood risk manager. Lastly, using rainfall data, simulated flood inundation map and scenario, response time is expected to shorten.

In conclusion, the proposed system is expected to solve the previous problems of managing architectural heritage against the flood disaster and effectively support the flood risk manager's decision making with the use of real time rainfall data.

7.3 Limitations and Future Researches

Though there were numerous efforts and researches to effectively respond to the flood disaster including this study, it is hardly ever possible to offer perfect protection against flood disaster and no technical solution to flooding is absolutely safe because there are risks such as failure of technical systems and rare flood which exceeds the design flood.

Therefore, the future research would progress to the way for actively reflecting rapidly changing weather condition and effectively managing flood risk manager’s decision making.

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국 문 초 록

홍수 재난상황에 대해 건축문화재의 가치를 보존하기 위해 문화재청과 유관기관들을 중심으로 안전관리가 시행되어 왔다. 그러나 최근 늘어나고 있는 국지성 폭우로 인해 돌발홍수가 증가하고 있고 이는 의사결정자가 적절한 대처를 내리기 전에 문화재에 상당한 피해를 발생시키고 있다. 따라서 대응시간을 단축시킬 수 있는 새로운 형태의 의사결정 지원 시스템이 요구된다.

이를 위해 국립문화재 연구소는 4년에 걸쳐 건축문화재 홍수위험도 관리의 기초를 마련하였는데 대부분의 데이터와 자료들이 비 구조화된 형태로 존재하며 접근성이 낮고 이를 활용하는 관리자가 해당 정보에 대해 비전문가이기에 효율적인 의사결정이 이뤄지지 않는다는 한계점이 존재한다.

이에 본 연구에서는 홍수 재난상황에서의 건축문화재 관리자들의 의사결정을 도울 수 있는 Web GIS 기반의 건축문화재 홍수위험관리 시스템을 제안하였다. 이를 위해 관계형 데이터베이스를 도입하여 기초 자료들을 분류하고 구조화 시켰으며 Web GIS와의 결합을 통해 자료에 대한 관리자의 접근성 및 비전문가의 활용성을 증진시켰다. 또한 실시간 강우 자료를 활용하여 의사결정자에게 침수예상지도 및 시나리오를 제공함에 따라 의사결정의 시간 단축을 통한 대응시간의 확보가 이루어질 수

있도록 하였다.

하지만 홍수에 대한 어떠한 기술적인 해답도 완벽한 안전을 보장해주지는 않으며 시스템이 기획한대로 작동하더라도 모든 경우의 홍수 상황에 대해 안전을 제공해줄 수는 없다. 시스템 상의 기술적인 문제점이 항상 존재하며 설계 강수량을 초과하는 상황이 발생되기 때문이다. 따라서 향후 급변하는 기상상황을 능동적으로 반영할 수 있으며 관리자의 의사결정을 보다 효과적으로 관리할 수 있는 모델 및 시스템에 대한 연구가 필요하다.

주요어: 건축문화재 홍수위험관리 시스템, 웹 지리정보시스템, 관계형 데이터베이스 시스템, 건축문화재

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