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DEVELOPING FLOOD DISASTER MANAGEMENT SYSTEM USING BIM TECHNOLOGY (CASE STUDY AT UIJEONGBU CITY, KOREA TO DEALING WITH RESERVOIR BREAK)

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ABSTRACT :
Recently BIM (Building Information System) technology is widely used in architectural and civil engineering fields for designing and maintenance control. BIM is process involving the generation and management of digital representations of physical and functional characteristics of places. In this research, we developed the flood disaster management system using BIM technology to prepare for reservoir break or flood inundation disaster in Uijeongbu city, Korea. Hydrological and hydraulic modeling were combined with BIM technology. To overcome computational burden, resolution problem and the limit of data, concept of LOD (Level of degree) was used. City Geography Markup Language (CityGML) was used as a BIM system for standard. Hybrid method combing 1D and 2D hydrologic & hydraulic modeling was also used to reduce the computational burden. And online gaging system were equipped in the system to calibrate it. EAP (Emergency Action Plan) must be established in Korea for the reservoirs capacity over 300,000 m3 in the city by law. We suggested 3D EAP for Hongbok reservoir in in Uijeongbu city, Korea. Many important forecasted data such as flood depth, flood velocity, inundation area, escape road, damage cost can be calculated and visualized through this system in accordance with many metrological scenarios. Preemptive disaster management can possible using this system for the decision makers and citizens. This methodology can be applied for various disaster using established base BIM map system and each diffusion modeling.

KEYWORDS:
Flood disaster management system, BIM, LOD, CityGML, EAP

1. BACKGROUND AND PURPOSE

BIM (Building Information Modeling) technologies that used to revolve around the architecture sector are spreading to the civil engineering sector (Cerovsek, 2011). BIM technologies expanded 2D designs into 3D and by adding various attributes, it is now expanding to 4D, 5D and 6D. While the use of CAD and GIS was limited to the design and construction sector, BIM is utilized in various fields including design, construction, process management, maintenance, and situation control (Hardin, 2009). This paper aims at describing the advantages of using such BIM technologies in the hydraulic engineering sector, as well as cases of its application.
Until now, GIS was commonly used when expressing modeling results in the hydraulic engineering sector (Singh and Fiorentino, 2013). GIS, which was used to construct the entered data, allowed two-dimensional visual expression in expressing results, and it has many advantages compared to the past method of expression focused on floor plan (Sarhadi et al., 2012). However, with the recent development of IT technologies, it has become necessary to express even more information. To reflect the various information produced in the recently developed 2D and 3D hydraulic models, a separate expression system has become necessary, and it is judged that BIM is the technology that can best reflect such requirements. In the hydraulic engineering sector, in order to solve the problem with data resulting from the wide spatial range that the hydraulic engineering sector must cover, rather than traditional BIM technologies, it will be necessary to adopt the concept of LOD (Level of

Degree) that adjusts the level of expression and BIM standard technologies that can express open and geographical spatial information such as City Geography Markup Language (CityGML) (de Laat and van Berlo, 2011). In particular, the visualization technology and expression function of BIM technologies are judged to be useful tools that can help with the multiple decision-making of administrators and the understanding and preparation for disasters by the people.
Therefore, this study will introduce cases of applying BIM technologies in hydraulic engineering disaster prevention focusing on the "Construction of an Active Disaster Management System of Flood Control Facilities using 3D BIM Technologies" that was recently carried out as a research project of the Ministry of Public Safety and Security.

2. APPLICATION OF BIM TECHNOLOGIES IN HYDRAULIC ENGINEERING DISASTER PREVENTION

The need to construct a disaster management system using BIM technologies that can visualize hydraulic models in 3D that can simulate disaster situations has been rising in order to minimize damages by predicting damage situations and promptly responding to them in the case of disasters. In order to simulate disaster situations in advance and visualize the response plans through 3D imaging information, it is necessary to provide measurement and monitoring data, attribute information on flood control facilities, and 3D spatial information on areas expected to be damaged by floods. Thus, it is necessary to develop an active integrated disaster management system linked to disaster situation action simulation according to emergency response plans and systemized data analysis through data and monitoring on flood control facilities and BIM models constructed by using the integrated information of each element and 3D imaging information. Furthermore, the disaster management system using 3D BIM technologies can be utilized as an effective tool for situational management of flood control facilities and for reducing damages.

2.1. Development of 3D Flood Control Facility Damage Prediction System

2.1.1 Plans for Connecting Hydraulic/Floodgate Model with BIM

In order to link BIM technologies with hydraulic/floodgate models, it is necessary to construct hydraulic/floodgate models first, and the data generated through this must be interlocked with BIM technologies. A hydraulic model that combines one dimensional and two dimensional hydraulic model analyses through simulation of the collapse of the flood control facilities and precipitation-discharge model was constructed to visualize hydraulic models that can simulate disaster situations into 3D. The difference of the EAP (Emergency Action Plan) flood map using the constructed hydraulic model and the EAP flood map of the collected basin was compared and analyzed, and each flood map was shown in Figures 1 and 2.

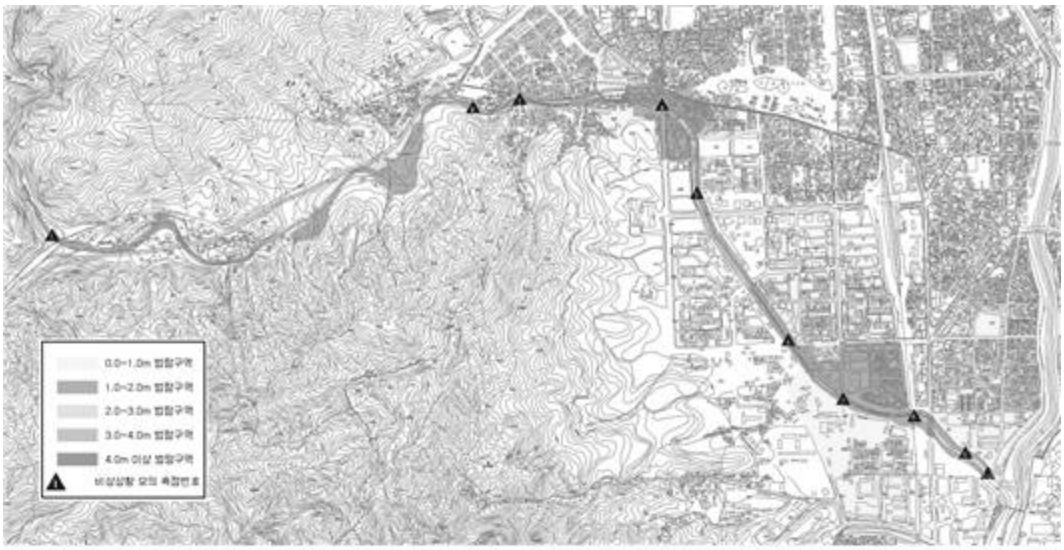

Figure 1 Flood Map of EAP Currently Used in Korea

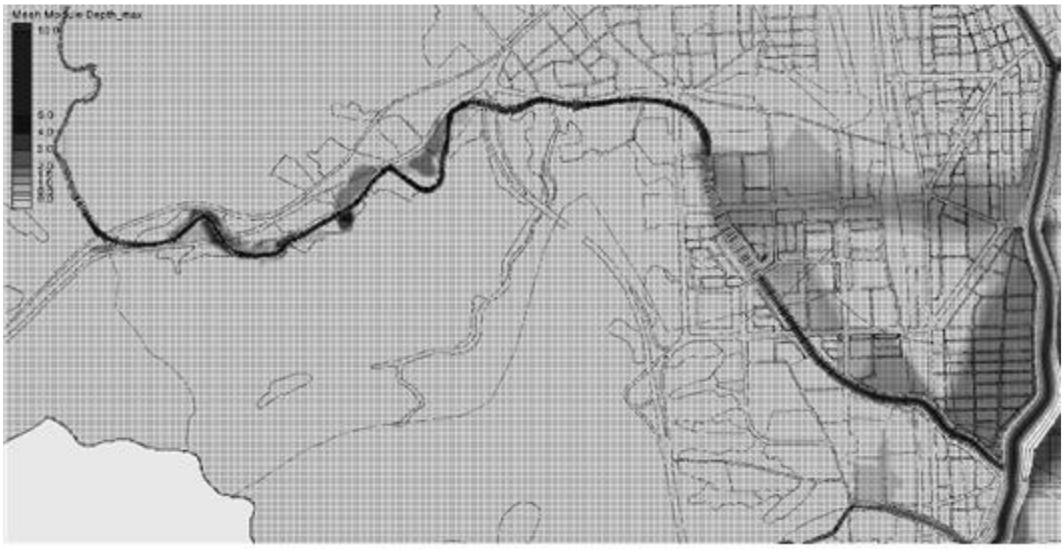

Figure 2 Flood Map of 1D/2D Combined Hydraulic Model

2.1.2 Plans to Link with the Integrated Disaster Control System of the EAP

Current EAPs were drafted according to the discretion of the technician in a 2D environment on one piece of paper when drafting the evacuation map according to the dam downstream impact assessment, and therefore it lacked systematic disaster response capacities. On the other hand, the integrated disaster management system using BIM allows the construction of prompt emergency action plans by visualizing the report and dissemination system per emergency situation stage, as well as evacuation routes through 3D rendering (Figure 3).

In order to deduce plans to link the existing EAP and integrated disaster management system, contents that could be mounted on the system among the EAP establishment guideline indices are shown in Figure 4.

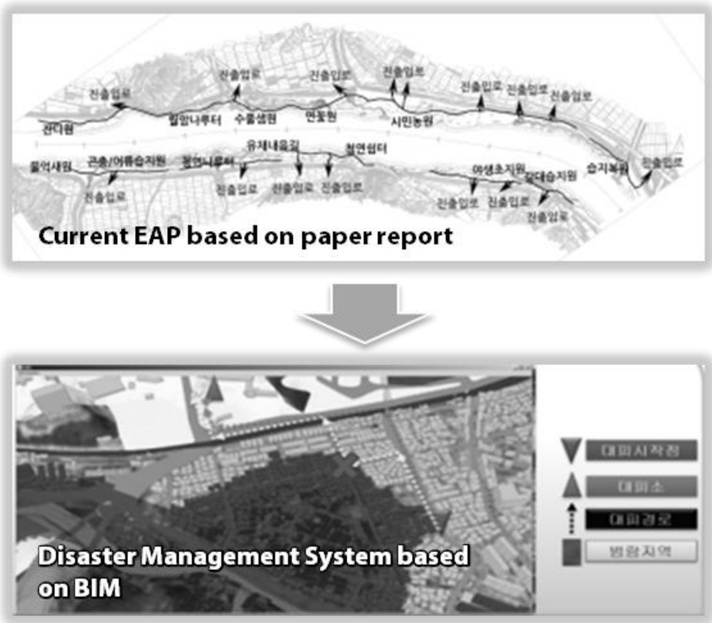

Figure 3 Improved EAP by Using BIM Technology

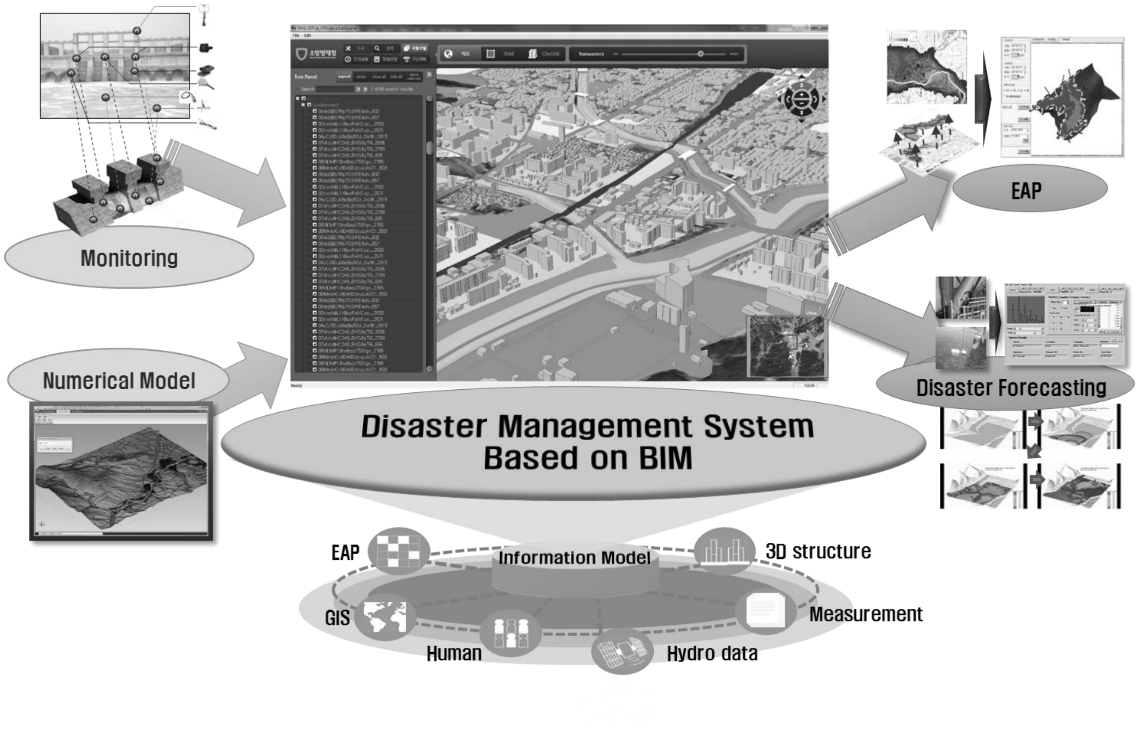

Figure 4 Integrated Disaster Management System Based on BIM

2.2. Review of Applicability of Developed Data Model for Linking Information with the Integrated Disaster Management System of the Hydraulic Model

It is possible to establish proactive action plans for disaster prevention or minimization of damages from the 3D urban information modeling perspective through simulations of realistic situations. This process can normally be divided into 'what information it will be based on', 'which method to generate the information model', and 'how to utilize it'. The issue with what information it will be based on differs according to the goal of the decision-making, and in the case of urban flooding areas, examples can be the geology of the corresponding urban area and the basic information of structures. Furthermore, hydraulic analysis data and measurement data can also be used as additional items. For the method for generating information models, reliability of linking information with other systems, continuity of information utilization, and information compatibility must be taken into consideration. Storage of information without loss or its reuse is directly connected to the utilization of the model, and therefore, the aforementioned items can be said to be subordinate to the use of information according to the final goal of preventing disaster or minimizing damages. Therefore, information must be generated and managed within a consistent frame from the planning stage up until utilizing the model.

From the perspective of information flow, the most pivotal role of the frame for linking and reusing generated information based on 3D urban information modeling can be said to be data schema (frame). Data schema determines in advance how to express which information items with which attributes using an abstract object. Data schema with the most appropriate form to apply in pre-simulation of disaster situations should be selected considering the four items of 1) 3D visualization of information models, 2) comprehensiveness for the possibility of expressing urban objects, 3) extensibility for additional user-defined information items according to the user or model producer, and 4) possibility to control internal attributes of the information model with existing software. Considering these standards, a data schema with suitable form is CityGML. The advantage of generating information models with actual data based on open-type data schema such as CityGML is that it is possible to access to saved information or data in any platform or software environment. Here, access to data goes beyond mapping of simple letters such as word search, and it includes parts on what meanings the information item has and the hierarchical relations with the items. In CityGML, information generation of meaning for information items is made up of granting functional roles on the forms of items to be expressed as shown in Figure 5, and this can apply to not only structural units, but also the detailed elements that make up the structures. An information for hierarchical relations in CityGML generates hierarchies by grouping information items according to their functional roles, and these are reflected when generating information models that include data.

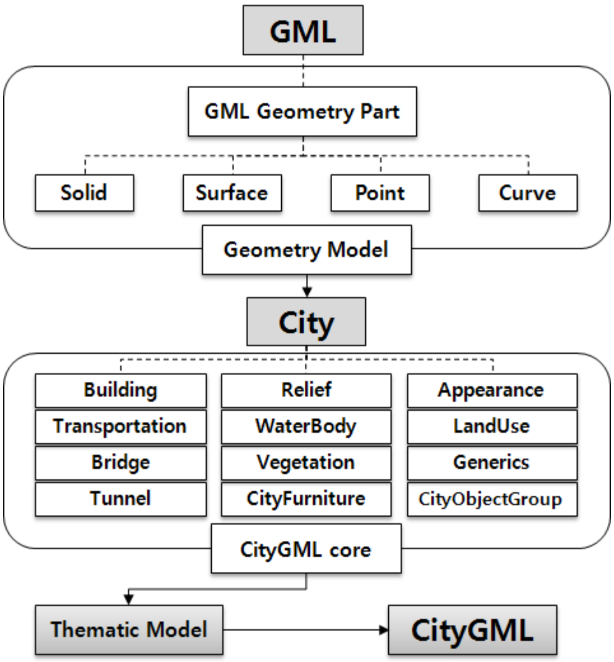

Figure 5 Hierarchical relations in CityGML

Results sought to obtain related to the use of 3D urban information models and through simulation of disaster situations must reflect elements from the perspective of data schema, and when generating information models, a space inside or outside of the model that can save the results must be provided. When assuming that urban flooding occurred, some examples related to the predicted human and property losses can be the population by age group, proportion of the disabled, price index, and building property value. Calculation of predicted human and property loss in floods can reflect these results as theories that can be appropriately expressed in the information model. Input information for calculating the result values can be directly extracted from the 3D urban information model and the output information can generate result values in the storage space that was pre-designated to link with the urban information model.

Figure 6 displays parts of the CityGML-based 3D urban information model generated by reflecting the necessary items. Geographical models can play a central role for managing the location information of all structures, and in relation to this, they may have regional or global coordinate information. Furthermore, they can have information related to functions that may be possessed by geography such as administrative information and geological information. Street models can include imaging information related to the streets, connection information per point related to street networks, and administrative information related to street names. Street models can utilize location information to utilize function-related information that includes geographical models, and it can directly control administrative information in specific locations for flooded roads by presuming floods. When calculating predicted human/property losses, facilities that should be given the most importance from the perspective of the residents are most probably buildings. Attributes that can be included in such building model are population per building or household, demographics (children, seniors, disabled, etc.) that can affect evacuation, and data needed to calculate property damages (building structure, year of assessing property value, price index, etc.).

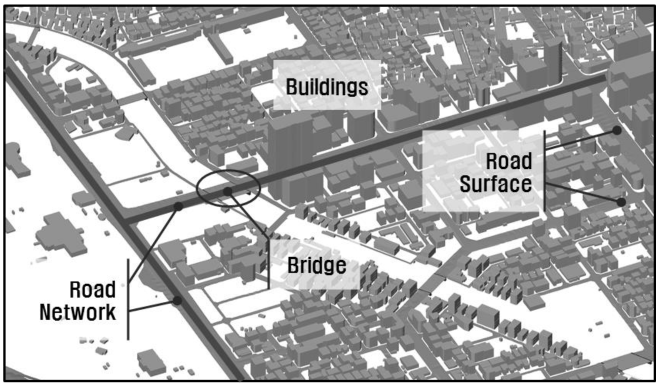

Figure 6 3D Urban Information Model Based on CityGML

It is possible to use information generated during 3D urban information modeling to make simulations when deducing result values through various combinations for supporting decision-making. In the event of urban flooding due to destruction of levees, 1) position of buildings (GPS coordinates), building height, building area, etc., which are elements for location/formative aspects, 2) building name, building structure, building stories, administrative regions, population, percentage of disabled, etc., which are elements for functional meaning information, and when the predicted damage results have been deduced, 3) expected number of deaths, expected number of persons stranded, amount of losses for buildings, which are damage result deducing elements can be used as questioning elements to deduce location information for decision-making. For example, administrative unit information of buildings can be deduced in the order of the highest number of stranded persons to determine priorities for rescue teams. Also, property damage information can be deduced in the order of the highest number of expected deaths to review the correlation between human loss and property loss.

2.3. Configuration of BIM-based Integrated Disaster Management System and System Verification through Test-Bed Execution

2.3.1 Description of Integrated Disaster Management System

The BIM-based integrated disaster management system constructs a 3D information model (including forms and attributes for the geography and facilities) for a region and conducts simulations on various situations as a decision-making support system that can assist in preparing for disasters. In this study, flood models made through precise hydraulic calculations were applied to develop disaster prevention work in the event of floods. Because information on flood situations are depicted intuitively in this system, it can be used as a tool for persons in charge of the disaster prevention operations can easily identify the situation and to prepare plans such as deciding safety evacuation routes fitting to each situation. This system was developed for persons engaged in disaster prevention operations, but it can be improved so that even the general public can utilize it considering the level of disclosure of information in the future. Also, it can be further developed into a common disaster management system that can help make appropriate decisions through simulations on various situations by applying different disasters in addition to flooding.

2.3.2 Configuration of Integrated Disaster Management System

The functions of the integrated disaster management system are divided into five areas.

1) Measurement: 3D coordinates included in the 3D map can be used to measure distance and area for accurately than 2D maps. This can be used to more accurately calculate the evacuation distance or area of damage.

2) Search: The search function of this system includes not only general map search functions, but also various BIM attribute information fitting to user demands. This means that if accurate information is provided to the BIM model, in addition to general search such as searches for major facilities, it will also be possible to search a variety of information such as the structural features of a structure, current number of people, and also search the number of senior citizens inside of a facility by floor.

3) Geographical Model: The geographical model function supports decision-making through the integrate disaster management system via visual effects, and it can express facilities on a 3D map or visually express the depth, speed or direction of a specific position offered through hydraulic analyses.

Simulation: This function allows users to select hydraulic analysis results and express it on the system to select and simulate damage situations for specific regions by case. Each disaster situation includes the water level, direction and speed information of each point according to the passage of time, and the simulation results can be identified intuitively.
4) Rescue Plans: The integrated disaster management system offers functions for users to register evacuation locations and evacuation routes proposed by the EAP, as well as functions to automatically calculate evacuation routes based on networks. The network-based evacuation route automatic calculation function grants nodes to street intersections, evacuation centers and evacuation start locations based on the streets to automatically calculate the shortest evacuation routes that detour areas of flooding.

2.3.3 Application to Test-bed

The integrated disaster management system developed in this study was applied in River A and River B basins located in Gyeonggi-do as its test-bed for verification. Through this, the process for generating BIM-based geographical and facility models was concretized and various information to judge the situation was made to be easily identified through visualization and informationization of disaster situations. Furthermore, safe evacuation routes were calculated depending on the progress of the situation, and it was confirmed that it was possible to take necessary actions according to the situation. Such results were compared and analyzed with actual damage situations that occurred in the past, and through this, the applicability of this system was verified.

3. CONCLUSION AND FUTURE RIPPLE EFFECTS

Flood control facilities are major social infrastructure. It is one of the most fundamental infrastructures for the safety and welfare of countries and people, and it plays an essential role in developing regions and improving the quality of life. Maintenance of flood control facilities, which are the public properties of the nation, can have a direct impact on the safety of a region. Furthermore, it destruction to do disasters can not only cause human and capital losses to the respective area, but also create massive social and economical damages to other nearby areas, thus making it essential to continuously manage and maintain the facilities during its lifecycle. At this point of time with the recent rise in awareness for disasters throughout society, as well as the heightened interest and need for studies on the management of flood control facilities, by integrating 3D disaster management systems utilizing BIM technologies in the flood control facility management systems under the central and local governments, it will be possible to more efficiently manage the flood control facilities around the nation. Furthermore, it is judged that it will be possible to construct a system that can minimize damages resulting from disasters.
The 3D disaster management standard information model using BIM can provide damage response simulations in the case of disasters, making it possible to be applied to various social infrastructures in addition to flood control facilities. Moreover, the 3D disaster management system through BIM can be useful in establishing flood control facility system project plans based on provincial dams and reservoirs around the nation. Such system has the advantage that it is not limited to only flood control facilities, but can also be applied for preparing for other disasters such as tsunamis and earthquakes. In addition, 3D video information of the geographical model can be linked with structure information for configuring virtual simulations during design and construction of structures. As a representative system that converge IT technologies and construction technologies, this can have a huge impact on creating jobs for specialized personnel with knowledge on 3D-based construction informationization.

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