A Study on the Application Service for Effective Disaster Management based on BIM

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Abstract— **Recently, because of the continuous occurrence of various disasters, such as fires, earthquakes, and flooding at Korea and abroad, the periodic and systemic disaster management has become more important than ever. For effective disaster management, facilities should be managed through periodic inspection and regular maintenance on a daily, and also in an emergency, the accurate and rapid communication is essential reflecting the situation. The Building Information Modeling (BIM) technology can handle a whole building property data related the specific purpose by using the effective 3D visualization model. It can be used for various management with objects including sensors, Closed Circuit Television (CCTV), which are set in a building. Thus, this study investigates and analyzes several cases of domestic and overseas disaster management based on BIM for effective disaster response. Then, we present disaster management scenarios for daily/emergency/inspection and proposed the detailed data definitions for the application services.**

Keywords-Building Information Modeling; Disaster management; Facility management;

I. INTRODUCTION

The importance of maintenance and management has been highlighted as a systematic daily preparedness requirement, which must be performed periodically, as an emergency response. It is preferred to the introduction and construction of simple disaster facilities, as the aftermath of the recent disaster cases, such as London high-rise building fire, domestic Dongtan high-rise building complex fire, Busan tsunami, Gyeongju earthquake. The Building Information Modeling (BIM) technology manages a building not only single objects, but also it collects the entire property data of the building by using effective 3D visualization model. This makes the BIM suitable for various purposes from the planning stage of the building to its design-structure-completion stages, and even be used for building maintenance and management after the construction.

The functions of a BIM-based facility maintenance system are designed according to the management needs of a landlord or a manager for various maintenance requirements and, accordingly, the BIM data for maintenance and management are typically handled by using a BIM model designed for room lighting to room-floor-building depending on the Level of Detail (LOD). BIM model for disaster management of buildings has numerous factors to be intensively managed, such as major objects including existing extensive maintenance BIM data, essential requirements for disaster management, Mechanical Electronic Plumbing (MEP), and evacuation-related facilities depending on the use and management, or their purposes.

Particularly, the visualization of the intuitive three-dimensional model that can cope with disaster situations quickly and accurately, and the presentation of the necessary information, are the key factors. These are preferred to the spectacular and tremendous information presentation when an emergency occurs. From the viewpoint of fire control, the information, such as the internal structure of the building, the evacuation floor, the evacuation staircase, the number of floors, and the entrance are major items that allow a clear judgment in an urgent situation. Furthermore, such information can provide intuitive understanding in visualizing evacuation routes and planning based on floor structure and scenario. For this purpose, the tasks, which require building information, such as property information and 3D models, should be identified.

Thus, this study investigated and analyzed disaster Facility Management (FM) cases with BIM at domestic and overseas in Section 2. In Section 3, the facility management systems are analyzed and the utilized service and data are defined. In Section 4, BIM-based disaster management services are proposed as daily / emergency / inspection scenarios.

II. RESEARCH ANALYSIS

Recent studies on disaster management and response have suggested effective measures in terms of minimizing the spread of disasters. As the necessity of disaster management using three-dimensional data has recently emerged, various studies on pre-/post-utilization methods have been conducted. In this chapter, the domestic and overseas research trends on disaster management using BIM are examined.

Bin Wang et al. [1] reported on issues, such as fire evacuation simulation and various evacuation routes, which are mainly mentioned in the emergency management field of buildings, through BIM-based virtual environment, which is widely used in the Virtual Reality (VR) technology and game engine. Drogemuller Robin [2] presented a method to support pre-simulation of occupant behavior and building operation in regular and emergency situations by using physical virtual objects including the space of 3D BIM model. Jung-Hoon Han, et al. [3] studied the developmental

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direction of the active integrated disaster prevention system using 3D shape visualization by applying BIM technology to build situation management and response framework required for active disaster management. Byung-cheol Gong, et al. [4] developed a fire control module to solve the problems of the high-cost installation system having only the simple alarm function, and constructed a preventive system capable of performing self-diagnosis check, initial suppression, and fire-fighting information management. Geon-Hyung Lee [5] proposed the effects and utilization of BIM in terms of quality/cost/process/safety/environment when installing BIM in the fire prevention and disaster field through construction, utilization and monitoring of BIM DB. Eun-Ho Oh, et al. [6] presented a conceptual framework of real-time facility disaster management system based on spatial information by linking to BIM and sensor information model at buildings.

Although previous studies have focused on disaster management systems using 3D visualization and location information of sensors for facility disaster management, BIM data were used for conceptual simulation or simple visualization in the prevention aspect. Thus, this study analyzes various existing domestic disaster management cases and suggests maintenance services and utilization scenarios capable of effective response using BIM for effective facility disaster management.

III. OVERVIEW OF BIM-BASED FACILITY DISASTER MANAGEMENT

A. Multi-Disaster Definition

Among various natural and social disasters, the study defined the earthquake, fire, and flooding that had recently gained much attention in Korea as the subjects of complex disasters. The number of earthquakes in Korea, including the Gyeongju earthquake (magnitude 5.8) on September 12, 2016, has been increasing. These earthquakes caused huge casualties and economic losses over a wide range of areas, resulting in national disasters, including paralysis of the national nervous network. In addition, major fires in the past 3 years and the Busan tsunami have required improvement of existing systems and development of new technologies. This study develops an integrated disaster data platform utilizing 3D BIM data with experts in earthquake, fire and flooding fields to build a digital twin-type facility disaster management system that can be effectively addressed. It is intended to be established of response strategy for multi-disaster, and advanced disaster response system centered around the integrated control tower.

B. Facility Management System Analysis and Function Definition

This study investigated and analyzed domestic and overseas facility management systems to define BIM infrastructure disaster management functions. The BIM-based facility disaster management proposed in this study should be able to manage the overall facility and to respond to needs through an integrated system in case of an emergency. In this case, the management system should receive the data from real-time/non-real-time sensors, recognize the situation, confirm the more accurate situation with Closed Circuit Television (CCTV), and respond to the situation through use of the proper firefighting facilities, which are all required for effective disaster management system.

Typically, the facility management system consists of basic information inquiry, energy usage inquiry, space management, facility management, maintenance, and event alarms [7]. In case of a disaster, the monitoring system is constructed based on the detection of the initial situation using CCTV [8]. This is the level at which managers use the primary CCTV equipment to judge and respond to the situation. A more specialized system is composed of functions, such as notification of sensor data and real-time monitoring data based on spatial information about the location of occurrence, by linking to sensors and system for detecting the initial situation [9].

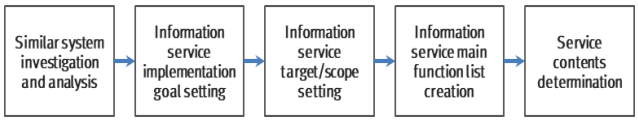

Figure 1. Process of facility disaster management service derivation

Through a BIM-based facility management service derivation process, as shown in Figure 1, this study categorized main functions to be proposed by using the BIM data among various similar services obtained from the above examples, in terms of 1) facility information management area, 2) 3D visualization area, and 3) disaster management area.

- FM- A single system was formed by the division of functional units, such as space management, energy management, cost management, etc.
- 3D visualization - 3D model object control method differs by each system. / 2D/3D conversion mode is required depending on the function. / There are various ways to represent attribute information, such as pop-ups and tooltips.
- Disaster Control - Visual effect methods of notifying the disaster occurrence space are diverse (the whole space, icon utilization, etc.) / Real-time notification board is provided to control facilities

C. Utilized Services and Data Definition

This study limited the utilized service target to high-rise and complex facilities that are easier to manage within the environment, as well as to information management of facility disaster management system. Furthermore, a consultation meeting was held with numerous related experts, such as the actual high-rise apartment managers, FM managers at major domestic complex facilities and trade centers, as well as experts from the disaster safety industry and academia. As a result, space management and the disaster-related facility management were finally selected by primarily organizing common management functions in terms of facility disaster management.

The space management work is performed to improve the efficiency in using each space of the facility. To improve the

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efficiency, it is necessary to analyze the BIM-based spatial condition and establish the space allocation standard. To analyze the actual condition of a space, the functional requirements include computerization of drawings, standardization of space (use classification, organization classification, and location classification), and area aggregation by space. The space management system can provide accurate results for this analysis. The space management in the disaster management system is primarily aimed at intuitively recognizing and identifying the situations in a timely and appropriate manner by using 3D BIM data in case of an emergency; thus, it is essential to focus on core fundamental functions in space management.

TABLE I. SAMPLE OF FIRE FIGHTING FACILITY PART OF THE DATA DEFINITION AND BIM LINKAGE INFORMATION

Level 1	Level 2	Level 3	BIM data
Fire-fighting facility basic data management	Facility type management	Fire-fighting facility type	Object
	Detailed facility type management	Detailed fire-fighting type	Object
	Facility name management	Fire-fighting facility name	Object
	Location management	location information	Object/ Space
Fire-fighting facility location info. management	Fire-fighting facility Installation location management	Location info. by building	Object/ Space
		Location info. by floor	Object/ Space
		Location info.by fire-fighting facility	Object/ Space
Fire-fighting facility monitoring	Fire-fighting facility Installation status management	Status info. by building	Object/ Building
		Status info. by floor	Object/ Floor
		Status info. by fire-fighting facility	Object/ Space
	Daily monitoring	Fire-fighting facility operation	Object/ Space
		Fire-fighting facility status observation	Object/ Space
		Fire-fighting facility operation history	Object/ Space
	Disaster situation monitoring	Fire-fighting facility operation	Object/ Space
		Fire-fighting facility status observation	Object/ Space
		Fire-fighting facility operation history	Object/ Space
		Location display for situation occurred	Object/ Space

Disaster-related facility management is the task of monitoring the building status in a comprehensive manner by managing the information of each facility constituting the building. Thus, the management of the systematic facility information in a regular manner should be able to respond to emergency situations immediately. The information handled in facility management mainly includes basic data, such as type of each facility, installation date, location information, and management information. This study created a facility management list and service data for sensors, CCTV, and fire-fighting facilities. Table 1 is a fire fighting facility part of the detailed data definition for disaster management service.

IV. BIM-BASED DISASTER MANAGEMENT SERVICE

Based on the utilized services and data for facility disaster management previously created, the BIM-based service for daily monitoring / disaster response service operated in the event of a disaster / facility inspection service for disaster were defined as follows, respectively.

A. Daily Monitoring

The daily scenarios of BIM-based facility disaster management focus on the basic information and static data checking of the site including the building. Daily monitoring can inquire basic information on BIM-based building situation, construction information, auxiliary facilities, and floor information on the building site. In Figure 2, CCTV monitoring can analyze the timely symptoms, which looks like the disaster, and inform the suspected area with 3D building and location information. Particularly, in the case of a dangerous area or space, it is possible to construct a floor plan separately for the use as an emergency evacuation route and related danger area notification through a space-based management as shown in Figure 3.

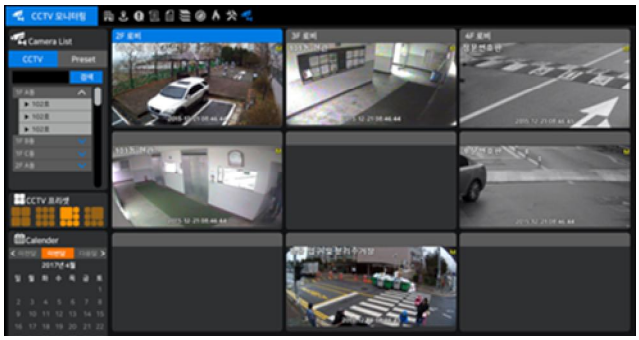

Figure 2. CCTV management

Figure 3. Space management for cautious spaces

B. Disaster Response

The corresponding scenario consists of major functions for rapid disaster identification and response, in the event of

a disaster, to automatically transition from an existing daily system to a disaster response system. 3D BIM data can be used to intuitively access disaster-detected areas, and the integrated disaster management manager can make quick decisions by using the notification from the nearby CCTV and sensors in the target area. Furthermore, as shown in Figure 4, it is possible to provide detailed and clear information to the firefighting team by recognizing spread of additional disaster through floor- and space-based disaster detection, as well as by using the BIM data on building structure, materials, and facility location related to a disaster. Thus, it is further possible to recognize the initial situation.

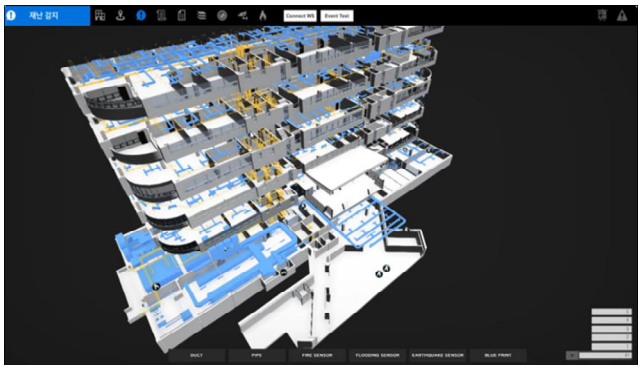

Figure 4. Confirmation of BIM-based disaster facilities

C. *Facility Inspection*

Inspection scenarios have the function for inspection of various facilities including sensors, CCTV, and fire-fighting facilities for disaster preparedness.

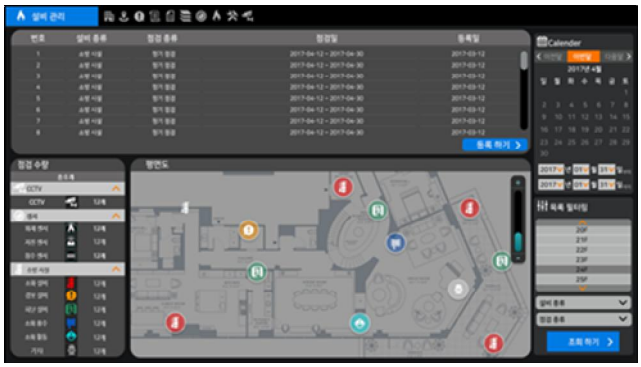

Figure 5. Facility inspection related to disaster

As shown in Figure 5, the facility maintenance team can use the facility location information within the BIM model to establish the plans for daily and periodic inspections, and can manage the detailed inspection history by filtering the inspections by equipment type, inspection date, and floor unit. Sensors can inquire abnormal signals and disaster information history depending on real-time/non-real-time inspection cycle.

V. CONCLUSION

This study investigated and analyzed domestic and overseas disasters cases, and identified the problems regarding these cases to derive facility disaster management scenarios. The study summarized the requirements for effective disaster management through numerous consultation meetings with facilities FM personnel of major high-rise and complex facilities. Based on these consultations, this study defined the disaster-related services and data using the system, along with the necessity for a 3D data-based system for an effective disaster management. This study further presented the purpose-specific scenarios for daily/disaster/inspection situations.

The calamity and disaster field particularly requires quick situation judgment and visualization to intuitively foresee various possibilities. In this regard, the integrated management system can prevent disasters and seek early suppression through daily preparedness as well as emergency response. Future studies will integrate this system with AR/VR technology, which is recently gaining popularity, to build various contents, such as mobile-based facility inspection and management, fire-fighting training simulation, and operation support.

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