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An Exploratory Study on 3D-based Building Information Management for Multi-User Fire Protection System

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Abstract: As buildings become more and more complicated, the importance of developing and managing facility management information is increasing. In a building fire situation, various information is generated and needed to be quickly shared among participants. However, the current fire response system fails to monitor the relevant information in a real time basis. This study aims to develop a system prototype for fire protection management which can quickly and accurately manage and effectively deliver the pertinent information to the target participants. The research contributes to the efficiency of fire protection endeavors by interpreting both dynamic and static fire information in an appropriate manner.

Key words: BIM, Fire response, Information management, Fire system, Visualization

1. INTRODUCTION

As technology advances, the complexity of the building gets gradually deepened. As buildings become more complex and sophisticated, the importance of operating and maintaining building information gets highlighted [1]. In particular, in the field of fire disaster management, there are concerns about the increase in rescue time due to improper management of building information. In addition, the inefficiency in fire protection and rescue has been raised [2]. Currently, there exists the importance of acquiring fire-related building information and utilizing the information about fire response in order to provide the real-time building and/or fire information for firefighting activities. However, since the building information is manually managed and kept in paper documents, it is difficult to intuitively grasp the meaningful information in a timely manner [3]. Moreover, rescuers and evacuees, who are the main subjects of the fire situation, are non-experts about the building information, so it is also a problem in achieving an easy access to this information.

In a fire situation in which various information is generated and communicated, the current fire response system is insufficient in terms of accessibility. One of the biggest problems is the low level of information usage and insignificance of information provided in routine building management activities. The building information is likely to be omitted when used, and readability and efficiency of instantaneous access is limited.

As such, it hinders the rapid acquisition and utilization of information which may induce an increase in decision-making time, and it may also lead to a decrease in fire response efficiency. In summary, it is required to improve the current building management system in relation to fire

response that can timely and accurately manage the proper information in order to maintain the built environment in a safer manner. [4]. This study, therefore, aims to develop a system prototype for fire protection management which can quickly and accurately manage and effectively deliver the pertinent information to the target participants.

2. RESEARCH BACKGROUND

A review of the previous literature relevant to the BIM-linked fire response system has been conducted in the earlier stage of this study. The summary of the contents is as follows.

2.1. Literature relevant to fire response system

Recently, there has been many research activities conducted to secure the speed of fire suppression by proposing a system that enables rapid detection of fires and initial response by alarming them [5]. In addition, a smart automatic fire extinguishing system has been proposed in an effort to combine IoT technologies. These devices can detect a fire disaster more quickly and operate sprinklers without delay by linking fire detection signal [6]. A smart fire safety system has also been proposed in predicting the path of fire and providing the optimum evacuation routes through novel algorithms. The necessity of utilizing the dynamic building and/or fire information has been emphasized in a fire response and management activities. As such, many research endeavors have been proposed to identify the real-time information that may change over time in a fire disaster circumstances [7].

2.2. Necessity to establish a database via building information model (BIM)

It is argued that a sufficient building information is not properly provided in managing building fire disaster, and the fire-related information is not updated in a timely manner [8]. The availability of information can be effectively identified throughout BIM data, so many researchers have considered BIM-based information as an important research topic. A recent research emphasizes that the type of information should be prioritized in linking the fire protection system to BIM because some information is much more important than others. For example, the fire rescuees may need an information on how to escape out of the building whilst the fire rescuers may need a data on how to suppress the fire [9]. In addition, a study has been conducted to establish an object-based system by developing a fire-based BIM library [10]. In consideration of the fire situation, previous studies have been conducted to build a 3D model that reflects the characteristics of buildings and their residents [11]. Based on this model, a recent study can provide an efficient safety management system in the event of a building fire. The optimum evacuation routes and rescue paths can be effectively identified in connection with BIM, and a digitalized fire management system can also improve the current fire protection system of buildings [12].

2.3. Preliminary findings

There are limitations of the current fire response system, so it is needed to develop a new type of system, and various studies are being conducted on it. However, existing studies have limitations in that it is insufficient to grasp the characteristics of fire-related building information and its scope is insufficient. In addition, it is not in the form of intuitively identifying and providing information. The information used in the previous studies is not considered in terms of effective information acquisition by users. Therefore, for effective fire response, it is necessary to propose a new type of fire response system that can quickly and accurately manage and deliver building information to rescuers and evacuees who are major stakeholders in the event of a building fire (see Figure 1).

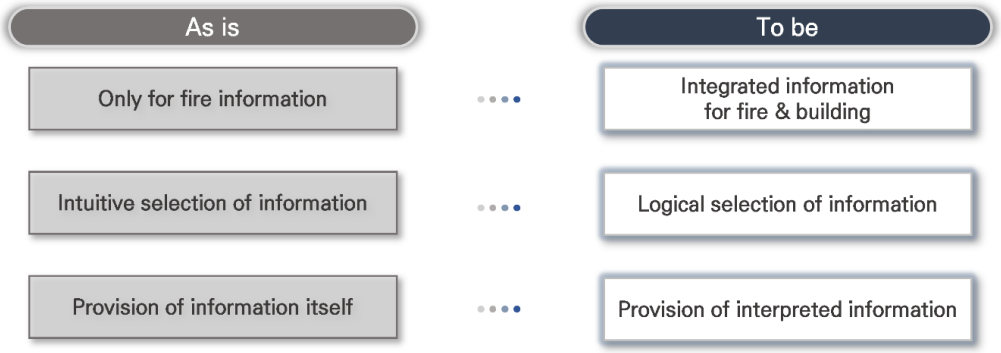

Figure 1. Comparative analysis between current (as-is) and new (to-be) fire information system

3. RESEARCH METHODOLOGY

3.1. Research objective

The purpose of this study is to propose an effective fire response system by overcoming the limitations of the current fire response system. The existing system, in terms of information exchange, is limited in utilizing and sharing the whole set of relevant information. The lack of sharing information could hinder the timely use of the right information in the response process, causing confusion in fire response. Therefore, this study seeks to propose a new framework for 3D/BIM-linked visualization by integrating the information models that can share and use for closely related to fires subjects; evacuees, managers and rescuers. The key content is to provide a ready-to-use information through a single visualization model in a timely accessible form. It could be used as a meaningful and reliable information when responding to fires, and it is expected that the ability to cope with unexpected situations can be improved by quickly sharing information.

3.2. Research methodology

The research steps of this study is shown in Figure 2.

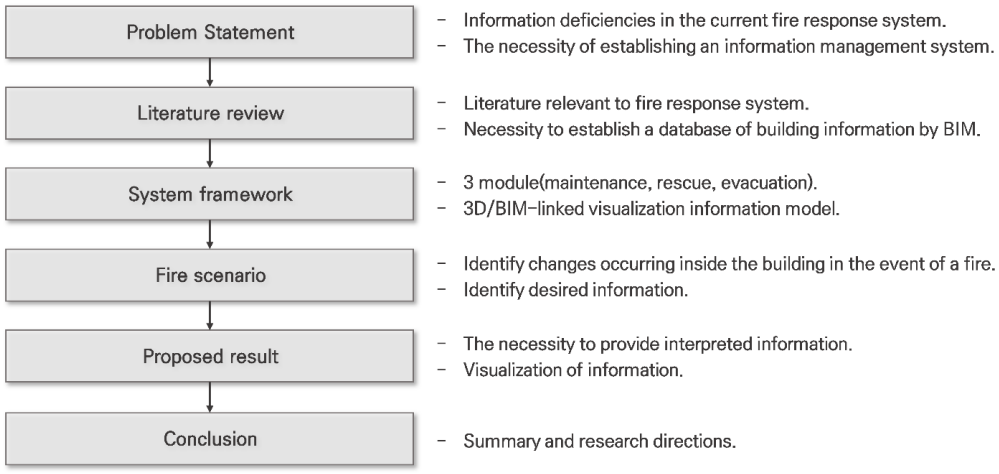

Figure 2. Research methodology

Once identifying deficiencies in the information management aspect of the current fire response system, the current status of research related to the fire response system and the possibility of BIM utilization have been investigated through a rigorous literature review. The system framework then

has been developed by utilizing the concept of three modules, maintenance, rescue, and evacuation. Throughout the generation of a fire scenario, the authors could investigate the system effectiveness in application of the proposed framework. Finally, the study suggests some pilot visualization screens of the proposed system when the system is operated.

4. DEVELOPMENT OF SYSTEM FRAMEWORK

4.1. Overview of System Framework

The purpose of this study is to establish a system framework for a 3D/BIM-linked visualization by integrating building objects with fire information. The core of the system framework is to develop a comprehensive visualization information model that enable users to communicate and provide real-time information with high accessibility to three main stakeholders in occurrence of a fire disaster. Therefore, the model should be expressed by integrating building information and fire information simultaneously. The consideration of each function is required to be used effectively according to the characteristics of the main subjects of the fire disaster in this model.

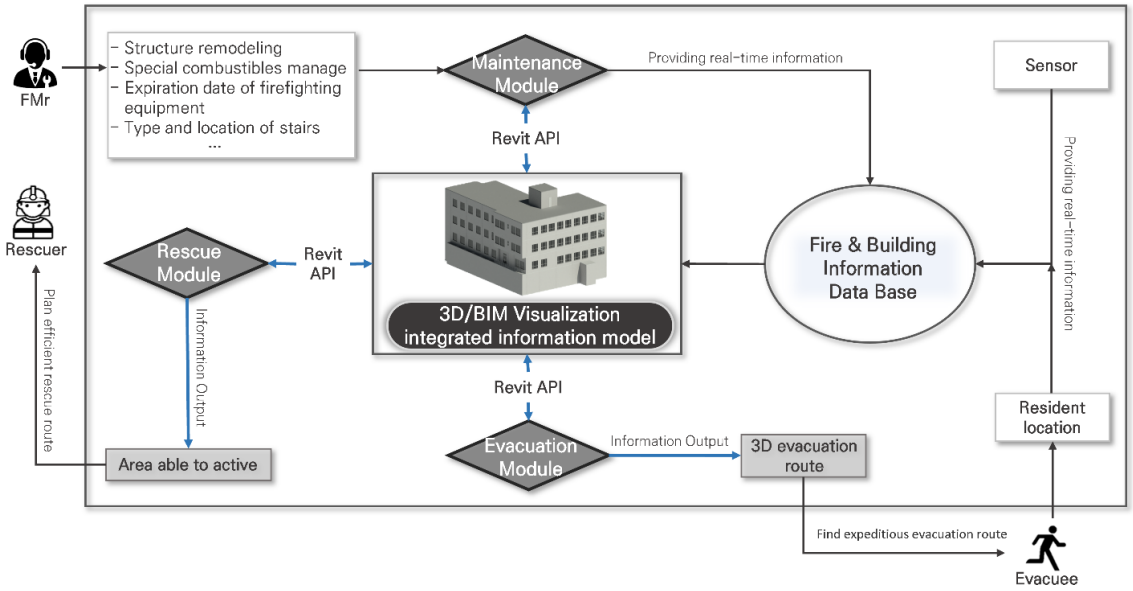

Figure 3. System framework

The system framework for the content is shown in Figure 3. The system is operated based on three modules, maintenance, rescue, and evacuation ones, focusing on the 3D/BIM visualization with an integrated information model. As seen in Figure 2, the fire database is constructed with the information generated by facility manager (FMr), evacuees and sensors installed in the building. Thereafter, the information in the database is visualized and expressed in an appropriate format in a 3D/BIM model. The 3D/BIM visualizes the most significant information (i.e., smoke, temperature, door/window, wall, stairway, etc.) with an easy-to-use function as an information medium. In the event of a building fire, the 3D information model can be promptly provided to rescuers and evacuees who are main users of the information, and it is expected to support effective rescue and evacuation of the building.

4.2. Scenario Analysis

This study focuses on developing a visualization system framework that compensates for the deficiencies of the current fire response system in terms of information, communication and utilization. Therefore, it is required to understand what information is shared and needed within a

series of process of fire response. In consideration of the purpose which delivers meaningful information, the authors re-establish three main participants in a building fire disaster, including rescuers and evacuees, who are commonly recognized as main subjects, in addition to facility managers who operate and manage building information. Based on the understanding of the communication network of these subjects, the following scenario has been generated as shown in Figure 4. This scenario is obtained from various materials including fire protection manuals, previous literature, and fire accident reports.

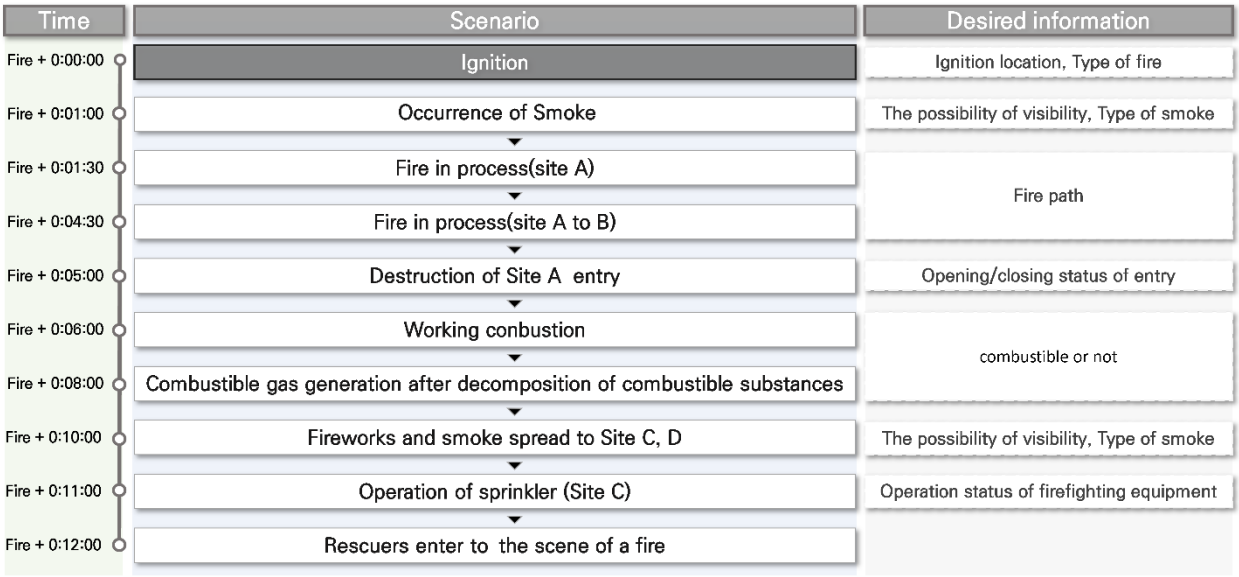

Figure 4. Virtual fire scenario

By making virtual fire scenario, the authors can identify changes occurring in the building and desired information that be required from the changes. It can be seen that there are various situations that can hinder the activities of rescuers and evacuees, such as combustion, generation of combustible gas, and change of fire path. Therefore, it is necessary to provide an appropriate information to grasp and overcome that situation. It is verified that the desired information is generated and used by the three main fire subjects, so it can be understood that the information is necessary for responding to the fire effectively. Therefore, the necessity and validity of extracting meaningful desired information through scenario creation is considered to be effectively simulated.

4.3. Verification Strategy

To verify the applicability of the system, the authors have chosen a real case project and conducted a scenario-based simulation. A 3D BIM model has been created to visualize the case project. At the time of this writing, the authors are testing the functions of the system by assuming there is a fire inside of the building. The method of testing the system can be divided into two aspects: rescue and evacuation. Rescue performance is conducted as a functional evaluation through the preparation of a questionnaire. It can be evaluated in terms of the improvement of rescue ability when distributing the visualization model from the hands-on workers.

From the perspective of evacuation, it can be evaluated by conducting an experiment on the evacuation situation. The experiment is divided into two groups. One is provided with the visualization model and the other group is given the existing 2D drawings. Later, the two groups are requested to provide a feedback in terms of information accessibility and thus, the validity of the system can be successfully evaluated in terms of the robustness of the system.

4.3. Proposed System Result

The main purpose of this study is to provide an appropriate 3D/BIM information system by interpreting the relevant information in the event of a building fire. When information is properly interpreted, the system can minimize the error of an individual's decision-making by considering various rescue and evacuation routes which are, otherwise, randomly selected by the individuals. Therefore, one-sided information flow should be avoided. But rather a comprehensive information system should be provided with a certain detail level of information. As such, an immediate decision-making can be obtained by real-time information flow in dynamic circumstances.

The proposed system could provide a multi-dimensional information of an internal situation of the building (entry, door/winder, staircase, flame, temperature, etc.) to the fire fighters in the event of a building fire. For evacuees, at the same time, an evacuation guidance in a simple and easy form is suggested to support rapid evacuation. An example is shown in Figure 5.

On the left side in Figure 5, it demonstrates the internal condition of the building through a variety of colors. For example, the red-colored area indicates the most dangerous zone because of high temperature and/or toxic gas. Likewise, the yellow-colored area indicates less hazardous zone. The right side depicts an example of a 3D evacuation guidance. The evacuation route is indicated using arrows. Through these symbols, rescuers and evacuees can easily identify the optimum route that is easy to rescue people and evacuate out of the building.

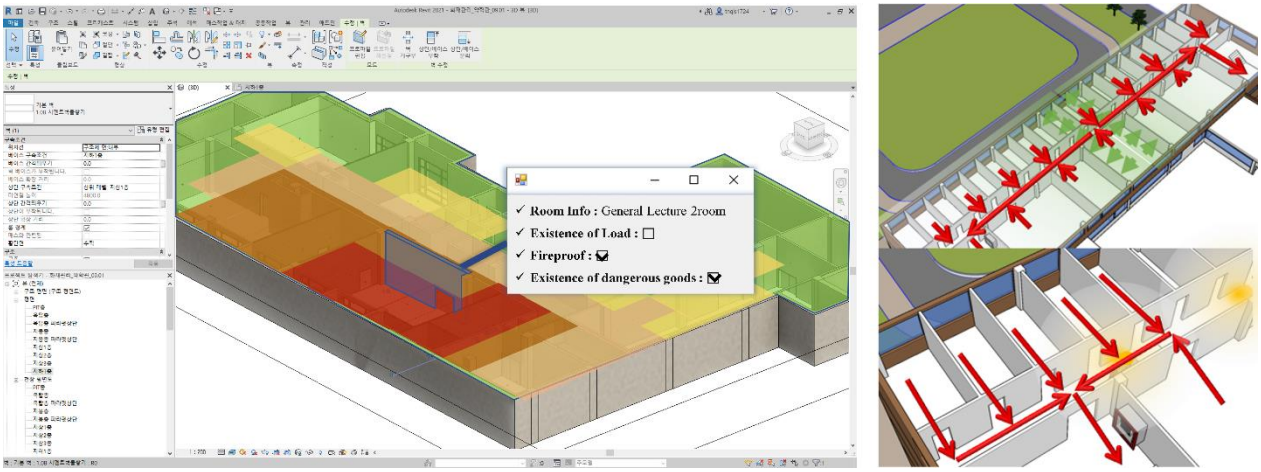

Figure 5. Proposed result

5. CONCLUSION

In this study, a 3D/BIM-based fire information management system has been proposed in relation to fire protection endeavors. Accordingly, a fire scenario has been developed to identify the contents and type of information for three major stakeholders (i.e., facility manager, fire rescuee and fire rescuer). Through this application, the proposed system has verified that the identified information can been effectively used and shared in the event of a building fire. Furthermore, it has been determined that it is beneficial to develop an 3D/BIM-based fire response and protection system.

It is plausible that the proposed 3D-based information system integrates building elements with fire information which is required in real time basis. The system framework improves the insufficiency in sharing and utilizing the fire-related information. A 3D/BIM-based fire information system prioritize, visualize and monitor the relevant data in a timely manner in the predetermined building fire database. A plan to effectively provide an integrated information system has also been proposed. Although the proposed algorithm is developed based on the desktop

operation system, a mobile application can be more powerful. The mobile system can expedite the accessibility of the data in a more rapid way. Once the system is tested and secured in terms of reliability, the proposed algorithm can further be implemented into a mobile operation system.

This study has identified the limitation of the current fire protection system, which simply focuses on the fire situation without reflecting the characteristics of the building information. It has been considered that the rescuer's and evacuee's lack of understanding of the building, and it results from the lack of tools to quickly deliver and manage information of the changing circumstances.

This study is intended to establish a system framework of the building fire protection by enabling the fire response by increasing the accessibility of the relevant information. Through this, it is expected that the desired information in the event of a fire can be used in a timely manner. As a result, the proposed system prototype can provide the meaningful information to rescuers and evacuees, and it is believed that it can contribute to the speed and reliability of information by shortening the time for fire response. However, this study requires a practical application of the proposed system framework and evaluates the results. Therefore, it is required to realize the research findings and to recognize the benefits of its application.

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