A Study on Disaster Prevention for High-rise Buildings through the Use of GIS and BIM

JuWon Choi\textsuperscript{1}, SunYoung Choi\textsuperscript{1}, SuengKyu Yoo\textsuperscript{2}, JuHyung Kim\textsuperscript{3}, JaeJun Kim\textsuperscript{3}

\textsuperscript{1}Master course, Department of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea, \textsuperscript{2}Ph.D. candidate, Department of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea, \textsuperscript{3}Professor, Department of Architectural Engineering, Hanyang University, Seoul, Korea

Abstract

Today, the city form is suggesting a new question on how the diverse function of a city such as habitability, mobility and information network, etc. should be developed. With the development of the construction technology industry, the architectural environment has grown and changed as much as we cannot predict. Especially, as it is difficult to secure land necessary for residence and economic living space according to rapid population increase of contemporary cities, the high-rise and deepness of urban building are being achieved more.

These building phenomena provide cutting-edge advantage of better human living environment and urban functions, whereas it is arousing doubts on the safety of structure, fire and disaster prevention at the same time. It can be said that the evaluation on utilization and expectation is insignificant in case of the field of fire fighting and disaster prevention in a special place called high-rise buildings.

The purpose of this research is to search utilization of 3-dimensional GIS, BIM in order to effectively manage building space information related to human activities in the fire-fighting and disaster prevention field of high-rise buildings.

For this, we should reflect human activity elements, ubiquitous sensor network elements, and should promote integrated standardization between GIS having geographic information of national land and district units and BIM expressing detailed information of a building unit.

Keywords: Disaster Prevention, High-rise Buildings, GIS, BIM

1. Introduction

1.1 Research Purpose and Background

With the recent magnificent development of construction technology, the high-rise is being fast spread on the ground and the deepness is being fast spread in the basement. High-rise buildings are differentiated from general medium and low buildings or small architectures in several aspects of urban context, environment, architecture and safety, etc.

Although High-rise buildings are increasing, special and exceptional items applicable to high-rise buildings are not separately clarified in the current criteria and architecture-related laws and regulations that should install safety facilities such as fire fighting facilities, etc. based on total floor area, usage and admitted personnel.

In addition, because it is made to conform to the criteria being applied to general buildings, it is not suitable for application of high-rise buildings, and there is limitation in preparation of safety measures. As facilities with composite usage coexist at one building, risk factors on fire safety also increase or are being developed complexly. In order to actively cope with these problems, a system that can effectively manage from prevention to situation treatment through rapid acquisition and analysis of risk information for disaster management is being required.

Accordingly, the purpose of this research is to search utilization of 3-dimensional GIS, BIM in order to effectively manage building space information related to human activities in the fire-fighting and disaster prevention field of high-rise buildings.
1.2 Research Scope and Method

Table 1. Existing researches related to 3D space information

<table>
<thead>
<tr>
<th>Author</th>
<th>Research Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lijuan (2006)</td>
<td>As a method integrating 3D CAD and 3D GIS, suggested a method capable of converting from VEGEGIS to AutoCAD was suggested and the layout of a program written with C++ was shown.</td>
</tr>
<tr>
<td>IvinAmri Musliman (2006)</td>
<td>3D GIS was suggested as a basis of 3D navigation, and a method that develops the current 2D GIS to 3D was suggested.</td>
</tr>
<tr>
<td>Donghoon Yang (2007)</td>
<td>Problems of efficiency in data utilization of product models by variety of data exchange standards (STEP, CIS/2, IFC, etc.) were confirmed, and a method to integrate these was suggested.</td>
</tr>
<tr>
<td>Tang-Hung Nguyen (2002)</td>
<td>Though the management of geometric data of building components is possible through CAD interface, it was classified as general building space phase information in that the space phase relationship is difficult.</td>
</tr>
<tr>
<td>Changwan Kim (2004)</td>
<td>A new 3D space modeling method including workspace partitioning algorithm, convex hulls algorithm, and coordinate transformation algorithm being applied for converting data acquired from several information acquisition places into one coordinate system was proposed.</td>
</tr>
</tbody>
</table>

2. Trend of Related Researches

2.1 General Definition of High-rise Building

Currently, the legal definition of high-rise buildings is not clarified, so it is relatively being defined according to viewpoints. The classification criteria of United States are not generally based on the number of floors or height of a building, and are suggesting three criteria that the floor space index is relatively higher than an average of the region, the machinery facility for vertical transportation is used, and that the construction method and technology different from a thing being used at a general low building are required.

2.2 Construction of Worldwide High-Rise Buildings

The height competition of high-rise buildings to be scheduled to build in the future is hot.

Table 2. Construction Trend of Worldwide High-Rise Buildings

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction Trend</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>-82: Texas Commerce Tower(75 floors, 305m)-89: Bank of China Tower(70 floors, 310m)-90: The Center(80 floors, 350m)</td>
<td>- Revitalization(2nd active period)- centered on Asia such as China and Hong Kong- Occurrence of the most fire accidents</td>
</tr>
<tr>
<td>1990</td>
<td>-90: Library Tower(73 floors, 310m)-92: Center Plaza(78 floors, 374m)-96: Shenzhen Avic Plaza Building(69 floors, 325m)-97: Sky Central Plaza(80 floors, 322m)-98: T&amp;C Building(85 floors, 348m)- Baiyoke Tower II(90 floors, 320m)</td>
<td></td>
</tr>
</tbody>
</table>
- Most hyper buildings with more than 100th floor were constructed in Asia.

2000
- 01: Telecom Malaysia New HQ Building (170 floors, 310m)
- 03: Two International Finance Center (88 floors, 415m)
- 04: Taipei 101 (101 floors, 509m)
- 07: Union Square Phase 7 (102 floors, 474m)
- 08: Asia Plaza (103 floors, 431m)
- 09: 1776 Freedom Tower (73 floors, 606m)
- 10: Dalian International Trade Center (78 floors, 420m)
- 12: Complex Federation (87 floors, 345m)

2010
- 10: Tower of Russia (125 floors, 649m)
- 12: Freedom Tower (73 floors, 541m)


3.1 Fire Characteristics of High Rise Buildings

If we prepare measures to secure performance as safe residence and economic activity space according to the high-rise trend of buildings, the most important thing is to analyze fire characteristics of high-rise buildings and to establish measures suitable for it. Because high-rise buildings have an important role in verticality itself, it should reflect technological expression as well as symbolism of the country and city. Fire characteristics of high-rise buildings is that evacuation is difficult and fire suppression by the outside fire brigade is almost impossible due to its unique vertical structure. Until now, when analyzing fire characteristics occurred at high-rise buildings.

<table>
<thead>
<tr>
<th>Accident Types</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Unpreparedness of fire detection and fire extinguishing measures of closed space</td>
<td>- Early discovery is difficult in case of fire propagation due to unpreparedness of early-response fire-extinguishing equipment measures(high possibility of large accident generation)</td>
</tr>
<tr>
<td>- Unpreparedness of evacuation paths and evacuation space measures</td>
<td>- Unpreparedness of related current laws and regulations(difficulty of efficient evacuation)</td>
</tr>
<tr>
<td>- Early loss of power supply systems</td>
<td>- Generation of large casualties are generated and fire suppression time is consumed much due to power loss generation in the early fire generation period of time</td>
</tr>
<tr>
<td>- Non-operation of fire doors</td>
<td>- Problem of automatic locking device</td>
</tr>
<tr>
<td>- Unpreparedness of life saving measures such as old and feeble persons, the disabled and children, etc.</td>
<td>- Unpreparedness of building’s refuge facilities or refuge area facilities for old and feeble persons, the disabled</td>
</tr>
<tr>
<td>- Fire caused by terror</td>
<td>- No legal criterion</td>
</tr>
<tr>
<td>- Unpreparedness of supply systems of fire extinguishing water source</td>
<td>- Problem of water supply by external fire extinguishing equipment</td>
</tr>
<tr>
<td>- Fire propagation to the window</td>
<td>- No separate laws and regulations (Fire propagation threat on overall building still exists.)</td>
</tr>
</tbody>
</table>
3.2 Backwardness of Fire Response System

Advanced countries are performing a task such as fire suppression, etc. through construction of on-site dispatch systems, and grasp the current situation of buildings and respond to it at a computer of a situation room by securing fire information obtained through preventive activities on special buildings according to some fire departments and regional fire headquarters.

In addition, after establishing tabletop exercise for practical fire suppression training and local virtual fire training plan, it is executing more than one time per year, but the fire suppression standardization is insufficient because the system of cooperation systems among district fire department, 119 safety center and nearby fire department which are dispatched according to scale and usage of a building and fire situation is not scientifically constructed.

4. Scalability of BIM and GIS

4.1 Characteristics of BIM and GIS

BIM (Building Information Modeling) is generating a digital database for cooperation in the architecture, structure, facility and construction field, etc., and is operated.

The change occurred in one field through a common database can be reflected to other related field, and the data is managed and information is renewed and preserved.

On the other hand, because GIS deals with geographic information, its appearance or external space of around a building in case of a building, and has a table form of attribute data related to each phase element as phase structure consisting of a point, line and surface.

This GIS is being utilized to the geographic space field, urban planning, traffic planning, facility planning, environmental management, resources management and disaster management, etc.

Accordingly, if a virtual city is constructed by integrating building information being modeled at BIM into GIS, the business such as architectural planning and design, complex planning and design, urban landscape analysis and urban planning, space information-oriented drawing management and facility management, security management, disaster management, etc. are improved, so a lot of costs can be saved efficiently.

Table 4. Features of BIM and GIS

<table>
<thead>
<tr>
<th>Division</th>
<th>BIM</th>
<th>GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expression target</td>
<td>Internal space of building</td>
<td>Building appearance and external space</td>
</tr>
<tr>
<td>Expression elements</td>
<td>No phase structure, has detailed information such as drawing’s plane, material and form, etc.</td>
<td>Has phase structure, linkage with attribute data except space object of a point, line and surface</td>
</tr>
<tr>
<td>Using field</td>
<td>Architectural design, indoor space analysis, volume calculation, construction and maintenance</td>
<td>Geographic space field (topography, land register), urban planning, traffic planning, facility planning, environmental management, resources management and disaster management</td>
</tr>
<tr>
<td>Commercial program</td>
<td>Graphisoft ArchiCAD, Autodesk Revit, Bentley Architecture, Gehry Technologies Digital Project</td>
<td>ESRI ArcGIS</td>
</tr>
</tbody>
</table>
4.2 Standardization of linkage between BIM and GIS

CityGML is a GIS standard that is legislated at the open GIS consortium which is a private standard council organized for geographic information standardization. The CityGML standard is a model for expressing 3D urban objects, and started since 2002, and the version 1.0 was legislated in 2008. The model expressed at the CityGML includes digital terrain model, site information (building, bridge, tunnel, etc.), transportation facilities such as a river and road, etc. and urban sculpture, etc. The CityGML is facilitating fusion between GIS standard and BIM standard. Currently, Europe and United States are trying for construction of a ubiquitous urban environment in various fields through linkage with IFC which is OGC standard and open BIM standard.

The most important concept in the linkage between GIS and BIM is LOD (Level of Detail) defining a level of expressing spatial information. The LOD algorithm is an expression method that can effectively show analysis results of spatial information in the 3D visualization to users in a form of virtual reality, the LOD algorithm expresses a close place, namely, a place seen well to observers in detail, and expresses a remote place or a place where is not seen well in less detail, so that it provides a function visualizing in 3 dimension quickly and efficiently.

Though the 3D work regulation was made based on CityGML, the internal information of a building cannot be reflected because LOD was reduced to 4 stages. In the viewpoints of international standard, it is necessary to establish because it is the flow to be contrary to the trend that CityGML is integrated into the IFC model. The following improvement is necessary for integration between GIS and BIM like the integrated model of CityGML and IFC.

First, human activities should be reflected to the integrated model. The major purpose handling the 3D indoor space information is just effective distribution of people using the inside of a building, and namely, is for quick evacuation and rescue in case of emergency situation generation like a fire. Space elements capable of supervising and management of movement of human beings should be added. The phase relationship such as movement inside a building and optimal evacuation pathway, etc., should be considered and reflected.

Second, the ubiquitous sensor network information like CCTV should be added. In order to effectively manage movement activities of human beings, it should be managed through a network by arranging the ubiquitous sensors like CCTV, infrared sensors and RFID at the right places. Through this, movement activities of human beings are monitored, and the phase relation is strengthened and can be utilized for simulation. The elements of ubiquitous sensor's rearrangement inside a building, addition and monitoring system should be added to the integrated model.

Third, the development of computer graphics technology like virtual reality and augmented reality should be reflected by expanding the integrated model of BIM and GIS. Computer graphics are defining X3D Geospatial as a standard item by introducing a concept of recent geographic information. X3D Geospatial is a thing that the previous GeoVRML was improved, and is a standard model seeking integration between computer graphics and geographic information system. Standardization integrating the facilities monitoring field into human activities that are partially progressed by being divided into the existing computer graphics, geographic information and architectural field is necessary.

5. Conclusion

This thesis has arranged the status and fire characteristics of high-rise buildings, and studied a concept of GIS and BIM integration of the disaster prevention system related to high-rise buildings.

It can be said that the fire among elements threatening life safety of internal space of a building has high generation probability. Accordingly, the whole measures for securing of fire safety at high-rise buildings, where many personnel are dense, should be considered very importantly and most primarily. Currently, the system related to disaster prevention of high-rise buildings is being written according to various institutions, and a method capable of utilizing this comprehensively is insufficient. The respective institution has to standardize information with big commonness, and separate information should be constructed by considering characteristics of disaster, and further, it means that construction of an intelligent disaster prevention system is necessary.

It can be seen that the integration between BIM and GIS according to technical development in indoor spatial information is an essential evolution stage. If GIS having geographic information of a national land and district unit is integrated into BIM expressing detailed information of a building unit, the information of regional and urban unit based on the geographic space could be effectively managed and analyzed. In addition, the birth of fusion and composite services based on a new disaster location can be expected by uniting building information and geographic information.
ACKNOWLEDGMENT

This research was supported by a grant (code No.06ChumdaneunghapE01) from Virtualmighty Program by Ministry of Construction and Transportation of the Korean Government (MOEHRD)(R05-2004-000-10591-0)

References

Choi Hee-Jig (2011) A Study on the Improvements of Fire Management Systems for fire prevention of high-rise buildings, Master’s thesis majored in urban fire prevention, Graduate School of Construction Industry, Kyonggi University.)