Suggestions for Developing Integrated Risk Assessment Method for High-Rise Buildings in Korea: Based on Analysis of FEMA's IRVS

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Abstract: The purpose of this study was to develop the integrated risk assessment system for high-rise buildings reflecting the Korean Building Code and guidelines of Preliminary Disaster Inspection and Consultation Systems based on the analysis of FEMA's IRVS in US. Through reviewing various hazards' assessment factors, a classification system and methodology for evaluating risk scores in IRVS, applicable factors, limitation of systems to apply to a Korean future system and improvement to verify the assessment methodology are determined. The results of this study will be used to provide the framework and establish the practical goals for developing a Korean risk assessment system for high-rise buildings.

Keywords: Risk assessment method for high-rise buildings, FEMA IRVS, FEMA Risk management.

1. INTRODUCTION

Currently, Korea has one of the highest densities of tall buildings in the world, approximately 400 buildings of which (under construction or completed based on The Council on Tall Buildings and Urban Habitat (CTBUH) statistics in 2005) include 30-49 storied sub-high-rise buildings. Buildings of 30 to 49 stories or 120 to 200 meters are classified as sub-high-rise buildings. Focusing on Seoul and Busan (the capital of Korea and the second largest city in Korea), the development demand of more than 50 floor buildings is continuously increasing, and by 2020, these cities will have 70 buildings that have more than 50 floors. (Based on the 2017 CTBUH statistics) [17]. The increase in the demand for these high-rise buildings increases the risk to physical assets and human resources from disasters in buildings and surroundings. In order to reduce this risk, at present in Korea, to minimize the damage and rapidly restore the building functions after disaster, risk assessment methods in various areas such as design, construction, and operation of high-rise buildings are being studied. However, most of their contents are related to the evacuation area, so there is insufficient research on the quantitative analysis methods and building design guidelines for integrated risk management in various disasters. Therefore, an integrated risk assessment model is needed to derive the optimized plan for protecting the occupant safety and minimizing damage by preemptive preparation related to disaster and for securing building durability. For developing this model, 4 disasters are selected for this study, including fire, terror, earthquake, and typhoon, with regard to the possibility of occurrence in Korea. These disaster types are researched to devise an integrated disaster risk assessment model for high-rise buildings in Korea. The purpose of this study is to research applicable parts through analyzing the advanced overseas case and to apply the future model development by deriving improvements. By researching the Federal Emergency Management Agency (FEMA) building protection guidelines for disaster preparedness and the FEMA Integrated Rapid Visual Screening as a benchmark for the most systematized and advanced risk assessment system in USA, this study analyzes the basic contents, evaluation systems, and methods of risk assessment model. The results of this study will be used as the framework for constituting risk assessment model in Korea and propose the outline suggestion to develop it.

2. INTRODUCTION OF FEMA GUIDELINES RELATED TO DISASTERS

2.1. Development Status of FEMA Guidelines Related to Building Protection

In order to minimize the damage caused by explosives (blast) and biochemistry (CBR) after 9/11 terror in 2001, FEMA of the Department of Homeland Security (DHS) developed manuals for securing the protection of buildings, the management and operation of buildings, the recovery of the building's function after the disaster, and the safety of the occupants, through the collaboration with experts in the private sector [1,16]. In 2009, the FEMA 455 Handbook for Rapid

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Visual Screening of Buildings to Evaluate Terrorism Risk (RVS) system was constructed to integrate these manuals and to quantify and assess the risk of the each building element in relation to social disasters. Since then, FEMA has published manuals related to risk management as well as, design guidelines for buildings on coping with disasters other than terrorism. For integrated analysis and management of interrelated threat incidents of disaster attributes, FEMA examined six disasters (explosive terrorism, biochemical terrorism, fire, earthquake, flood and typhoon) and developed the FEMA BIPS 04 Integrated Rapid Visual Screening of Buildings, which enables the evaluation of building risk and recovery ability for general buildings, traffic facilities and tunnels where massive damage occurs in the event of disaster. Compared to the previously developed RVS, IRVS is designed to be free to download and to use web-based programs, so it can build big data about disaster related buildings. The research result is easily understood and can be practically used as the evaluation system to improve usability. IRVS also compromise comprehensive contents covering general buildings, and is designed to be used by various departments' project members (architects, engineers, facility technicians, developers, civil servants, etc.) [6, 16].

2.2. FEMA Guides for Protecting Buildings Related to Major Disasters

In this study, for a risk assessment model for high-rise buildings in Korea, the first step is to determine the selection criteria and analyze the classifications for high-rise building design in the FEMA guides related to major disasters. The relevant FEMA guides are then classified according to their purpose as a risk assessment guide, design guideline, and reference manual for risk mitigation [16]. Classifications of guides are given in the Table **1**. In the case of fire, the FEMA guides are defined as fire caused by manmade Hazard, explosion, and earthquake, and reflect the National Fire Protection Association (NFPA) standards. In the case of natural disasters, it is possible to use the FEMA guides as general building design guidelines in the specific design for the mitigation and protection of the

Table1: Classifications Related to High-Rise Buildings by the FEMA Guides

<table>
<tr><th rowspan="2">Disaster / Category</th><th colspan="3">Manmade Hazard</th><th colspan="5">Natural Hazard</th></tr>
<tr><th>Blast</th><th>Fire</th><th>CBR</th><th>Seismic</th><th>Wind Storm</th><th>Flood</th><th>Wild Fire</th><th>Snow</th></tr>
<tr><td rowspan="2">Risk Assessment</td><td colspan="3">FEMA 452: Risk Assessment/ A How-To Guide to Mitigate Potential Terrorist Attacks Against Buildings
FEMA 455: Handbook for Rapid Visual Screening of Buildings to Evaluate Terrorism Risk</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="8">FEMA BIPS 04: Integrated Rapid Visual Screening of Buildings</td></tr>
<tr><td rowspan="2">Building Design Guide-Lines</td><td colspan="3" rowspan="2">FEMA 427: Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks
FEMA 430: Site and Urban Design for Security: Guidance Against Potential Terrorist Attacks
FEMA 453: Safe Rooms and Shelters: Protecting People Against Terrorist Attacks
FEMA 459: Incremental Protection for Existing Commercial Buildings from Terrorist Attack: Providing Protection to People and Buildings</td><td>FEMA 389: Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquakes
FEMA P-420: Engineering Guideline for Incremental Seismic Rehabilitation
FEMA 454: Designing for Earthquakes
FEMA P-749: Planning Earthquake Resistant Design Concepts
FEMA P-750: NEHRP Recommended Seismic Provisions for New Buildings and Other Structures</td><td colspan="2">FEMA 543: Design Guide for improving Critical Facility Safety from Flooding and High Winds</td><td rowspan="2">FEMA P-737: Home Builder's Guide to Constructi on in Wildfire Zones</td><td rowspan="2">FEMA P-957: Snow Load Safety Guide</td></tr>
<tr><td colspan="3">FEMA 424: Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds
FEMA 577: Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings</td></tr>
<tr><td>Manual</td><td colspan="3">FEMA 426/BIPS 06: Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings, 2nd</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

Table 2: Individual and Integration Risk Scenarios Calculation Formula

Individual Risk Scenarios Calculation Formula		Integration Risk Scenarios Calculation Formula	
$R_i = \sqrt[\beta_i]{C_i \times T_i \times V_i}$		$R = \propto \sqrt[n1]{\sum_{i=1}^{n2} R_i^{n1}}$	
Required value to calculate individual risk scenario		**Required value to integrate risk scenario**	
R_i	Risk score of the i^{th} threat scenario	R	Aggregated risk
C_i	Consequences rating of the i^{th} threat scenario	R_i	Risk score of the i^{th} threat scenario risk score
T_i	Threat rating of the i^{th} threat scenario	n2	Total number of threat scenarios * IRVS is consisted of twenties threat scenarios.
V_i	Vulnerability rating of the i^{th} threat scenario	n1	Power value 10
β_i	β_i Value depends on αi value $\alpha_i = Min(C_i, T_i, V_i)/Max(C_i, T_i, V_i)$	∝	Scaling factor 1/12

general building from fire. The risk assessment and reference manual are not separately constructed [10, 11, 12, 13, 16].

3. ANALYSIS OF METHODS OF RISK ASSESSMENT IN IRVS

3.1. Scoring Method of Risk Assessment in IRVS

The quantification of disaster risk assessment by IRVS is calculated by analyzing three factors. The first factor is Consequence (C), which refers to the destruction of the building (asset) due to disaster and subsequent loss of operating system, and is interpreted as an asset value for quantitative evaluation. The second factor is Threat (T), which refers to the degree of threat to potential events, signs, and actions that lead to the loss or damage of an asset, individual or organization [12]. Finally, the third factor is Vulnerability (V), which involves assessing the vulnerable elements of the building that can increase damage to the asset in the event of a disaster [12]. After calculating the C, T and V values for each scenario, the risks of individual scenarios and integrated scenarios are calculated through the equation in the Table **2**. The calculated values of C, T, and V show the risk figure results as a percentage (%). Similar to the individual disasters (explosives, biochemistry, fire, earthquake, typhoon, and flood) a level is graded as very high (70% or more), high (50% to less than 70%), moderate (less than 30% to less than 50%), and low (less than 30%) according to the risk assessment scoring criteria [12].

3.2. Scoring method of Resilience in IRVS

In the IRVS, the resilience score is calculated by measuring the quality of performance and time invested in maintaining or recovering the critical functions and operations of the building after the hazardous event. Q_i, the quality of performance, is defined as robustness, which refer to a building's

Table 3: Equation and Required Index for the Resilience Score Calculation

Equation for Resilience Score	Required Value for Calculating
$$Q_{TOTAL} = 10\left(\frac{\sum_{i=1}^{N} Q_i}{\sum_{i=1}^{N} Q_i\|_{MAX}}\right)$$	Q_{Total}: scaled quality of performance
	T_{Total}: scaled time measure
	Q_i: quality of performance (robustness)
$$T_{TOTAL} = 10\left(\frac{\sum_{i=1}^{N} T_i}{\sum_{i=1}^{N} T_i\|_{MAX}}\right)$$	*N*: upper boundary (number of characteristics with weight being summed)
	Ti : time measure (Recovery and resourcefulness)
	Q_i| Max: maximum quality of performance
RES = 100- (Q_{Total} * T_{Total}*)*	Ti| Max: maximum time measure

capability to manage its critical functions and operation [12,14,15]. Each characteristic in IRVS can affect the assessment of the quality of performance (robustness) and time measurement (resourcefulness, and/ or recovery) [12,14,15]. T_i, the time measure, is defined according to recovery and resourcefulness which involve the preparation validity and capability to reconstruct the critical functions and operations after the hazardous event.[12] Q_i |Max and T_i| Max represent the maximum weighted value of robustness, resourcefulness and recovery [12]. The equation used to calculate Q_{Total} and T_{Total} by summing Q_i *and* T_i as well as the required the index for resilience scoring are given in the Table **3**. Similar to the risk score, the computed resilience score is divided into 4 levels ranging from very high (more than 70%), high (50% or more and less than 70%), medium (30% or more and less than 50%) to low(less than 30%) [12].

3.3. Synthetical Method of Scoring Process and Categorizing the Scheme for Risk Assessment in IRVS

The method to measure the risk assessment in a building is evaluated by pre-evaluation, on-site evaluation and on line IRVS system evaluation by putting the data [11,12]. The preliminary evaluation is a collection of basic information about the building and the surrounding environment. In the order of Consequences, Threat, and Vulnerability, the field evaluation consists of 136 characteristics and 184 characteristics according to whether the criteria of the fire part are reflected in the 11 fields. Subsequent risk assessment can be used to obtain the results of the risk rating and the vulnerable elements in the survey building for the six disasters by entering the results collected from field data and investigation into the IRVS system directly. In this system, the number of items according to disasters is not evenly distributed, and six of the 17 items can be changed. However, other elements are environmental factors and cannot be changed after site determination. The data collection process and composition of IRVS are given in the Table **4**.

4. ANALYSIS OF THE APPLICATION PLAN FOR THE DEVELOPMENT OF DISASTER RISK ASSESSMENT MODEL FOR HIGH-RISE BUILDINGS IN KOREA

4.1. Development Status of Disaster Risk Assessment Model for Domestic High-Rise Buildings

Currently, for the study on disaster risk assessment for high-rise buildings in Korea, in a case studied by Lee KH *et al*. (2011), a risk assessment model based on the Analytic Hierarchy Process (AHP) method is proposed by selecting the evaluation items related to the architectural design among the guidelines suggested by the US Federal Emergency Management Agency (FEMA), the US Department of Defense (DoD), CPNI (Centre for the Protection of National Infrastructure) and NaCTSO (National Counter-Terrorism Security Office) of the British Terrorism Office [3,4]. In addition, the study uses the results of the previous prevention design studies related to terrorism in Korea based on the three lines of defense defined by the building and the site boundary [1,2,3]. Subsequently, Choi JW *et al*. (2012) extended the AHP method to derive a risk assessment model of explosive terrorism for high-rise buildings considering the interrelationship between the evaluation items [4]. In addition, case studies have been performed of risk assessment, using only structure analysis, to protect against natural disasters such as earthquake and typhoon using IRVS in domestic high-rise buildings. However, architectural studies on the development of an integrated disaster risk assessment model, that reflects the domestic standards; Korean building codes and new regulations in Special act on Management of Disasters in Super High-Rise Buildings and Complex Buildings With Underground Connections cited 2012 [8] are insufficient [7]. In addition, since domestic studies have been carried out in the private sectors, in terms of securing the substantial demand and collecting data on the credible disasters and the major building, the practical application of platform research is limited in terms of securing big data of the buildings in preparation for the various disasters. In addition, various experts are needed to participate in the building from development to operation, to develop and apply the risk assessment models, as in the case of the IRVS developed by private experts working on the government plan in the United States. The risk assessment models are focused on the practical use for multiple types' users and the result invented by private experts has been evaluated as the benchmark project in terms of systematization of risk management related to various disasters. In the case of the US Federal Emergency Management Agency (FEMA) under Homeland Security, the developments of the Risk Management Series were carried out by private experts such as the URS Group (design and engineering consulting), Weidlinger Associates (structure consulting) and Raytheon Utd Inc (security consulting) in collaboration with the National Institute of Building Sciences [12]. It is also necessary to consider

Table 4: IRVS Data Collection Process and Composition to Evaluate Risk Assessment for the Selected Disasters

Division / Process	Evaluation Fields	Key Evaluation Characteristics	Weighted Characteristics	Number of Question	Manmade Hazards			Natural Hazards		
					Blast	CBR	Fire	Seismic	Windstorm	Flood
Pre-Field Data Collection	Building, site, circumstance, geographical characteristics and etc.	- Occupancy rate - Building usage - Construction cost per square feet, - Structure type - Ambient density of Target, - Targetability - Identification of geographical features related to earthquakes, floods, and typhoon	- Targetability (PF-5.1)*, - Density of target in Zone 1,2,3 (PF-6.1 ~6.3)*, - Soil Type (PF-17)* - Structure type (PF-18)*	18	10	10	10	10	9	8
Consequences Assessment	1. Asset Value	- Characteristics and density type of buildings - Ability to recover critical building function or operating organization after a disaster -As the result of the impact of physical loss, Evaluation by building asset value	N/A	3	3	3	3	3	3	3
Threats Assessment	2.Threats factors	- Population density around the site - Visibility and symbolic value of buildings - Assessing threats that could lead to property loss or damage through accessibility analysis of buildings	- Building Accessibility (2.3)*	3	3	3	3	-	-	-
Vulnerability Assessment	3.Site plan	- Vehicle approach distance, perimeter boundary, visibility, underground structure, topography, foundation, emergency exit, surrounding structures, etc. vulnerability assessment within and outside the site	- Topography: Slope (3.7)* - significant assets location: degree of exposure to high wind (3.13.1)* - Significant assets location: degree of exposure to flood (3.13.2)*	15	8	4	10	8	8	8
	4.Architecture plan	- Height and form of building - Evaluation of vulnerability to vehicle access, parking lot, interior space planning, etc.	- Degree of reinforcement of building accessories (parapet, chimney, building decoration) (4.9)*	14	11	5	6	10	10	6
	5.Enclosure	- Vulnerability assessment of building envelope related to elevation form, material and roof form	- Percentage of overall elevation contrast window (5.2)*	12	6	2	0	8	12	2
	6.Structure	- Vulnerability assessment of building structure type, column spacing, number of members, height, support type, roof span, etc.	- Transition beam type (6.5)*, - Earthquake design/ readjustment (6.9)*	13	8	-	1	10	10	4
	7.MEP System	- Vulnerability assessment of machinery and electric facilities inside and outside buildings	- Location of major outside air intake (7.1)*	11	5	3	3	6	4	4
	8a.Fire Protection (General)	- Vulnerability assessment to general fire protection facilities, standards compliance, fire fighting training, etc.	- Facility upgrade to the current fire prevention law and government fire standards (8.1a)*	10	-	-	10	-	-	-
	8b.Fire Protection (Standard)	- Vulnerability assessment of fire protection system based on evaluation items reflecting government firefighting standards	- Facility upgrade to the current fire prevention law and government fire standards (8.1b)*	56	-	-	56	-	-	-
	9.Security	- Vulnerability assessment related to the number of security monitoring systems for internal and external bombs and biochemical terrorism and system efficiency	N/A	10	6	4	-	-	-	-

	10.Cyber Infrastructure	- Vulnerability assessment of IT infrastructure such as cyber security plan, efficiency of staff training program related to IT equipment, plan to receive important information in emergency, spare power supply source, etc.	N/A	6	6	1	4	1	1	1
	11.Continuity (Resilience rating)	-Recovery assessment (normal conditions except for special buildings) so that the building's functions and the operating system can be operated normally after a disaster.	N/A	23	23	23	23	23	23	23
Total (In case of application of general fire protection, 8a)				136	89	58	73	79	80	59
				%	65	43	54	58	59	43
Total (In case of application of fire protection to add fire standards, 8b)				184	89	58	119	79	80	59
				%	48	32	65	43	43	32

*Numbers and characters in weighted characteristics are the same as the evaluation characteristics number in FEMA BIPS 04: Integrated Rapid Visual Screening of Buildings.

the usability of results, which means that as the private and public collaborative working model, Homeland Security can conduct a Pilot Test on the risk assessment model and make it practical for use by all participants.

4.2. Limitation of FEMA IRVS Application in Korea

FEMA's IRVS is composed of simple evaluation items (height, structure, window ratio, etc.), applicable to general buildings, and has no subdivided items such as elevation materials, height, building structure, building shape, security systems, and unique facilities that reflect the specific characteristics of high-rise buildings. Therefore, if the IRVS system is used to assess the risk for similar types of high-rise buildings, it is difficult to differentiate the results. In addition, the evaluation items of Consequence (C) and threat (T) among the IRVS risk assessment are irrevocably fixed as the stationary elements at the time of site selection. Also, because no weighting and classification system exist for the fixed and variable elements, applying the IRVS system to improve the vulnerable parts of the building through the risk assessment in the building design phase or the existing building is limited. In addition, the assessment items of construction, equipment, security, and IT infrastructures related to the possible quantitative evaluation of the building data in the vulnerability (V) evaluation item mainly focus on terrorism and fire, which are manufactured hazards, while the proportion of the assessment items of the earthquakes and typhoons, which are natural hazards, is low. Therefore, the reliability of the evaluation result according to the disaster is reduced.

4.3. Limitations of Preliminary Disaster Impact Assessment Consultation in Korea

In Korea, the government's risk assessment scheme related to the disasters about high-rise and underground linkage complex buildings has been established to reflect the guidance compliance from the early stages of building design through the review of the Preliminary Disaster Impact Assessment Consultation. Preliminary Disaster Impact Assessment Consultation is a review process for protecting occupant's safety from disasters and analyzing the risk factors related to building design related to disasters by a expert committee appointed by the government as one of building permit process for the high-rise buildings' construction [8,9]. The current Korean system has limited communication channels, with government departments that can change the evaluation methods of the risk assessment for the integrated disaster or suggest a direct improvement plan in the private sector. It is also difficult to select such a risk assessment model developed by the private sector as a government official model and to review the practical application of the development model through the pilot test with the aim of establishing a big data center for disaster related building information in the future by the public sector.[8,9] However, in the preliminary disaster impact assessment consultation system, guidelines for practitioners are insufficient to mitigate the risks of buildings and review provisions to reflect risk scenarios according to the disaster. An architectural plan for enhancing the risk management of buildings against disasters is necessary to review the decisions made on architectural contents in terms of the appropriateness of the installation of the safe zone and the evacuation inducement plan in the emergency. However, it is still essential to supplement the detailed provisions related to the architectural guidelines based on the disaster attributes that can preemptively prevent action not as a countermeasure after the occurrence. Also, in the evaluation method, it is difficult for the committee to derive an objective indicator of the evaluation. They thus require the supplementation of architectural guidelines and evaluation methods through the quantitative analysis. Since the process of reflecting and reviewing the opinions of the architects and the committee members after the consultation has not been computerized, as an improvement measure for the data accumulation and usability of evaluation cases, a web-based electronic system needs to be established and activated.

4.4. Suggested Development Plan of the Korean Integrated Risk Assessment System

The assessment items of the disaster evaluation system of domestic buildings in the future recognize the limit of IRVS and consider the main items of the domestic standard and prior disaster impact assessment. This study will be developed to revise the

Table 5: Proposed Korean Integrated Disaster Risk Assessment Category with Comparison of IRVS and Preliminary Disaster Impact Assessment

<table>
<tr><th colspan="2">US IRVS Risk Assessment Category</th><th>Korean Preliminary Disaster Impact Assessment ITEMS</th><th colspan="2">Korean Type Risk Assessment Category</th><th>Key Items</th><th>Fixed*</th></tr>
<tr><td colspan="2">Pre-field data Collection</td><td>N/A</td><td colspan="2">Pre-field data Collection</td><td>- Environmental condition evaluation-(geographical index, zoning, building purpose, asset value, etc)</td><td>O*</td></tr>
<tr><td colspan="2">Consequences /Threats Rating</td><td>N/A</td><td colspan="2">Consequences /Threats checking</td><td>- Same as pre-field data collection items</td><td>O</td></tr>
<tr><td rowspan="9">Vulnerability Rating</td><td>Site plan</td><td>- Site layout plan to prevent terrorism and vehicle intrusion</td><td rowspan="8">Vulnerability Rating</td><td>Site plan</td><td>- Road conditions, vehicle and passenger restrictions and Control, ground condition</td><td>△*</td></tr>
<tr><td>Architecture plan</td><td>- Spatial structure and layout planning
- Comprehensive disaster management and safety control center planning
- Evacuation safety zone arrangement and area standard</td><td>Architecture plan</td><td>- Space configuration, building type, sub-structure type</td><td>X*</td></tr>
<tr><td>Enclosure</td><td>- Minimal scattering methods caused by explosion of window glass or exterior finishing materials installed on the lower floors and lobby</td><td>Enclosure</td><td>- Window ratio, glass type, connection, wall material, rooftop composition, etc.</td><td>X</td></tr>
<tr><td>Structure</td><td>- Seismic design and measurement installation plan</td><td>Structure</td><td>- Structural features
- Seismic and fire resistant structural plan</td><td>△</td></tr>
<tr><td>MEP System</td><td>- Underground flooding prevention plan
- Building Counter Terrorism Design Plan (Including CCTV installation)</td><td>Fire and evacuation safety plan</td><td>- Arrangement of evacuation safe area and facility standard
- Fire protection standard and facility planning</td><td>O</td></tr>
<tr><td>Fire Protection</td><td>- Firefighting equipment, compartment and smoke prevention plan
- Prevention plan of ignition and combustion expansion
- Extra plan prescribed by Presidential Decree</td><td>MEP System</td><td>- Mechanical, electrical and plumbing plan for protecting critical function of buildings</td><td>X</td></tr>
<tr><td>Security Vulnerabilities</td><td>- On-site security management and monitoring system
- Security surveillance plan</td><td>Security plan</td><td>- CCTV, internal and external security system installation plan</td><td>X</td></tr>
<tr><td>Cyber Infrastructure</td><td>- Burial status check of electricity, communication, gas and waterworks</td><td>Cyber Infrastructure</td><td>- Cyber security plan
- Efficiency of cyber security operation</td><td>X</td></tr>
<tr><td>Resiliency</td><td>N/A</td><td colspan="2">Resiliency</td><td>- Power, system-level planning for building continuity recovery</td><td>X</td></tr>
<tr><td colspan="2">Extra</td><td>- Evacuation plan and time control
- Disaster and Safety Management Plan</td><td colspan="4">* Fixed: Environmental conditions such as surrounding building density, land use, road conditions when determining the site and legal standards to be adhered to during designing building.
* O: Most items are fixed conditions during planning phase.
△: Some items are changeable conditions during planning phase.
X: Most items are changeable conditions during planning phase.</td></tr>
</table>

classification of the functional elements according to building type and the method of reflecting the non-changeable factor, which is the environmental characteristic, through weight adjustment and the readjustment of evaluation items [3,4,5]. First, to develop the Korean risk assessment model, among the evaluation items of the existing IRVS system, the domestic regulations and items applicable to the high-rise buildings are selected and the classification of the eight areas of IRVS is examined (site, building characteristics, building envelope, building structure, building facility, fire protection system, security, and IT infrastructure). The evaluation items focusing on domestic high-rise buildings based on the Preliminary Disaster Impact Assessment items are then selected through the difference analysis and comparative review with IRVS evaluation items, an integrated risk assessment system will be developed for Korean high-rise buildings by classifying the common review items and the characteristics according to the disaster and by establishing measures for weight control [3,4,5]. At the same time, the future model for developing the integrated risk assessment system will be considered to assess the necessity of the resilience of the buildings after the disaster that was not mentioned in RVS for terrorism, which was the basis of IRVS development. By deriving the results from the study, the main category for the potential integrated disaster risk assessment to be developed is classified and proposed in Table **5**. In this study, the key items for the suggested risk assessment of Korean type are limited to be classified integratedly excluding the relevance by the correlations between disasters or the characteristics of individual disasters.

CONCLUSION

Currently, in Korea, the evaluation of high-rise buildings against disasters consists of the necessary items for the preliminary disaster impact consultation, and is mainly composed of contents related to the evacuation and refuge plan [8,9]. Therefore, as the evaluation items are limited, and the pre-disaster assessment and disaster facilities are also assessed only by professional personnel, subjective opinions of the individual expert are reflected in the evaluation, with the disadvantage of not being able to be quantified. In the United States, where the preparedness system against the disaster is the most advanced, in contrast to the IRVS, an integrated disaster evaluation system for the buildings was developed under a government initiative to actively collect big data for the disaster preparedness according to the various types of buildings. Due to the inadequacy of the data collection criteria and methods of the risk assessment related to the disaster and the lack of an interoperability system of results, in Korea, the integrated management system for systematic management and utilization is insufficient [7,8,9,16]. In this paper, firstly through analysis of the possibility and the limitations of IRVS derived from the present research, this study is used as a basic comparison guideline for establishing a direction for the development of the domestic system and for reflecting domestic environmental factors, standards, and regulations. Secondly, the objective and quantified evaluation criteria of the integrated risk assessment system for high-rise buildings with high exposure to disaster risk are provided. Finally, the study goal is to propose a platform for building a web-based disaster risk assessment system to improve the usability of various experts so that the risk assessment items developed through this study can be systemized and utilized from the initial design stage. But this study has the limitation that the scope of the evaluation items are extensive to cover the various building characteristics related to disasters and for the actual detailed evaluation, it is difficult to reflect the interrelated affect between disasters on the vulnerability evaluation. So for the completive risk assessment, based on this study, future study will be developed for the methodology of quantitatively analysis related to the interrelation between disasters. In the point of the utilization, it will be possible to construct a big data center for the disaster preparedness of high-rise buildings through continuous data accumulation, to improve the accuracy of evaluation according to the disaster type and to use the target architecture for future platform construction with infrastructure and other types of buildings. Also, this study will be used as a case study to expand the platform of the integrated risk assessment systems against a complex disaster for the infrastructure and other types of buildings.

REFERENCE

[1] Lee KH. Basic Research for Preventing Terrorism in multipurpose building. National Intelligence Service Counter terrorism research summary 2009; 6.

[2] Kang KY, Lim DH, Kim JS and Lee KH. A Study on the Development of Architectural Design Guidelines of Super High- Rise Buildings for Protecting from Terrorism- Focused on the 1st and 2nd Layers of Defense. Crisisonomy 2010; 6(4): 191-216. http://www.cemtp.re.kr

[3] Kang KY, Park BJ and Lee KH. Study on the Vulnerability Assessment of High- Rise Building in Korea for Protecting from Vehicle Bomb Attack. Architectural Institute of Korea Architectural Research 2011; 27(11): 125-33. http://journal.auric.kr/jaik

[4] Choi JW, Kang KY, Jang JB, Lee KH and Choi IC. A Risk Assessment Model of Potential Bomb Attacks against High-Rise Buildings based on the Analytic Hierarchy Process. Crisisonomy 2012; 8(1): 127-39. http://www.cemtp.re.kr

[5] Kang KY and Lee KH. Vulnerability Assessment Model for Cost Efficient Anti-terrorism Design of Super High-Rise Buildings. JAABE 2014; 13(2): 413-20. https://doi.org/10.3130/jaabe.13.413

[6] Su YY, Yoon SW and Ju YK. Risk Assessment of Tall Buildings in Korea by comparative Modified RVS and IRVS. Journal of Korean Association for Spatial Structures 2012; 12(4): 91-8. http://www.kasss.or.kr/index.html

[7] Visibility window Research Division. Disaster Risk Assessment for Urban Disaster Reduction. Report. The Seoul Institution; c2009 [cited 2009 Nov 18]. Available from: https://www.si.re.kr/node/24480.

[8] Special Act on Management of Disasters in Super High-Rise Buildings and Complex Buildings with Underground Connections. c2015 [cited 2012 Mar 9]. Available from: Ministry of Government Legislation.

[9] Preliminary Disaster Impact Assessment Consultation guidelines. c2014 [cited 2014 Dec 8]. Available from: Ministry of Public Safety and Security.

[10] Department of Homeland Security. FEMA 452- Risk Assessment: A How-To Guide to Mitigate Potential Terrorist Attacks Against Buildings. c2005. Available from: https://www.fema.gov/media-library/collections/3.

[11] Department of Homeland Security. FEMA 455: Handbook for Rapid Visual Screening of Buildings to Evaluate Terrorism Risks. c2009. Available from: https://www.fema.gov/media-library/collections/3.

[12] Department of Homeland Security. FEMA BIPS 04: Integrated Rapid Visual Screening of Buildings. c2011. Available from: https://www.fema.gov/media-library/collections/3.

[13] Department of Homeland Security. FEMA 426 BIPS 06: Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings, 2nd. c2011. Available from: https://www.fema.gov/media-library/ collections/3.

[14] National Infrastructure Advisory Council. A Framework for Establishing Critical Infrastructure Resilience Goals Final Report and Recommendations by the Council. c2010 [cited 2010 Oct 19]. Available from: https://www.dhs.gov/xlibrary/assets/niac/niac-a-framework-for-establishing-critical-infrastructure-resilience-goals-2010-10-19.pdf

[15] National Infrastructure Advisory Council. Critical Infrastructure Resilience Final Report and Recommendations. c2009 [cite2009Sep8]. Available from: https://www.dhs.gov/xlibrary/assets/niac/niac_critical_infrastructure_ resilience.pdf

[16] Department of Homeland Security. Federal Emergency Management Agency (FEMA). Available from: https://www.fema.gov/resource-document- library.

[17] The Council on Tall Buildings and Urban Habitat (CTBUH). Available from: http://regions.ctbuh.org/ south-korea/seoul.

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