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A Study on Risk Assessment and Analysis Method of Buildings for the Development of Korean Integrated Disaster Evaluation Simulator (K-IDES) in High-Rise Buildings

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Abstract

The purpose of this study is to develop a platform tentatively named the Korean Integrated Disaster Evaluation Simulator(K-IDES) to assess building risk during disasters. In this study, the first step is an analysis of FEMA's risk management series in the USA for precedent research. Among them, FEMA IRVS is selected as the case study for the development of the K-IDES framework and through the comparative analysis of domestic building design guides, codes and special acts related to disasters. The next step is to develop a risk assessment methodology to yield quantitative results. This methodology consists of a classification system, calculation methods and grade rating. Based on it, K-IDES will establish a management system that can systematically integrate the collected information by using assessment techniques for elements except legal standards for measuring risk in response to various disasters and present a classification system of evaluation factors/ criteria for evaluation items and risk assessment methods. In the next study, and through the simulation of the selected buildings by using this risk assessment, a check-list will be verified. The final goal of this study is to build a platform to be used as an integrated risk management method against a complex disaster through expansion to other types of buildings through continuous data scaling and management systematization.

Keywords

Risk assessment method for high-rise buildings; FEMA IRVS; FEMA Risk Management

1. Introduction

1.1. Purpose and Background

Currently, the density of high-rise buildings in Korea ranks 11th in the world based on buildings that, amount to 400 in total and are more than 150m in height (under construction or completed based on The Council on Tall Buildings and Urban Habitat (CTBUH) statistics in 2018). In Seoul, it is expected that high-rise buildings will be continuously constructed due to the high-density and strengthening of the urban redevelopment plan in old districts. During disasters, the risk of property damage is amplified due to this increase in density in a larger

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scale and complexity, especially in concentrated urban areas. However, the concern of spreading the damage to the surrounding environment remains. For instance, and in the case of the 9/11 terrorist attacks in New York City, the collapse of the world trade center, surrounding buildings and explosion itself have caused damages to the surrounding environment. Loss, destruction by fire and damage of the facade and structure were caused by the collapse. In order to reduce risk and damage to high-rise buildings in urban areas, domestic studies are underway to improve the building performance against individual disasters by strengthening standards of materials and structure, equipment and evacuation procedures against fire due to recent earthquakes. However, most of these studies have focused on research and suggestions of partial improvement of evacuation-oriented buildings for individual disaster scenarios. Therefore, studies on evaluation criteria, evaluation methods, and design guidelines to reinforce buildings against various catastrophic disaster risks are insufficient. The purpose of this study is to construct a disaster risk assessment model (tentative K-IDES) for Korean high-rise buildings to reflect the domestic reality and analysis studies of the advanced cases that were conducted on Federal Emergency Management Agency (FEMA) risk assessment series in the US to manage risks and analyse it quantitatively by developing a risk assessment system against various disasters. This study aims to establish basic instructions related to risk evaluation criteria and risk assessment methods related to disasters based on comparative analysis of the domestic applicable parts of the FEMA Integrated Rapid Visual Screening (FEMA, 2011). This analysis is derived from evaluation methods from case studies of the USA FEMA risk assessment series and domestic building guidelines and codes. Among various disasters, terrorism, fire, and wind, which are likely to occur in Korea, several study scenarios were selected. This study proposes a weight setting method and an integrated risk assessment method to improve the accuracy of the risk evaluation model and analyze the results through simulations of urban high-rise buildings by applying this risk evaluation method in the next step.

1.2. Scope and Method of Research

1.2.1. Analysis of Precedent Research

In this research, through an analysis of building design guidelines related to disasters, risk assessment methods, and system construction manuals for the risk evaluation process in a building against disasters, developed by FEMA under the Department of Homeland Security since September 11 attacks, risk assessment concepts will be established. Based on FEMA IRVS, an integrated model of FEMA's six disasters published as an extension of the use of disaster risk assessment, the evaluation criteria, evaluation method and design criteria for the building's protection by disaster and utilized programs are analyzed. The contents of the analysis will be used to extract the applicable elements and methods in Korea.

1.2.2. Analysis of Domestic Building Guidelines, Codes and Evaluation Criteria Related to Disasters

In order to develop the evaluation criteria for domestic buildings, design guidelines for high-rise buildings of Seoul Metropolitan Government, anti-Terrorism Building Design Guidelines in Multi-purpose facilities of Ministry of Land, Infrastructure and Transportation, Special Act On Management of Disasters In Super High-Rise Buildings And Complex Buildings With Underground Connections, and Preliminary Disaster Impact Assessment Consultation guidelines of Ministry of Public Safety and Security are analyzed through a classification of items and comparison of the contents of provision. The reviewed results are reflected in the detailed evaluation criteria for risk assessment.

1.2.3. Development of a Risk Assessment Checklist

The checklist for the risk assessment of buildings is similar and based on the classification scheme for the first level category of risk assessment. However, the FEMA IRVS and the evaluation items for the second level category are classified according to the elements within a plan of a building. The evaluation by items is composed of the reviewed results to reflect the domestic building guidelines and building regulations related to disasters. Finally, the criteria selected for each item are the same as the FEMA IRVS' and can be carried out in five steps. However, the number of choice could range between two or five according to the purpose of the criteria.

1.2.4. Establishing a Method to Quantify the Weight and Risk by Items that Reflect the Evaluation Criteria

The risk quantification in this research is applied to the isometric scale and uses the uniform scale for each item, but is based on the method of applying weight to important items by differentiation. The weighted items are applied on the marked items as important factors to affect the building's damage against disasters in FEMA IRVS and are reflected in the prioritization of items through interviews with the advisory group in each field. The items in fire and evacuation, which are highly subject to legal standards and are difficult to check building design to reduce the risk, are suggested as an opposing way to diminish risk. Subsequently, the validation of check list for risk assessment and the simulation plan will be suggested by selecting objects for analysis in upcoming research.

2. Precedent Research

2.1. FEMA Guidelines to Protect Buildings of Various Disasters

FEMA has published multidisciplinary guidelines related to risk management to ensure safety in the event of a disaster so that it can be applied to building design and operation by disasters. In addition, special purpose buildings such as schools, hospitals, and important facilities are subdivided according to user importance. However, this study is restricted to FEMA guides related to general commercial high-rise buildings. These are divided into risk assessment, building design guides and rehabilitation of community for the purpose of the use.

Table 1. Classifications related to high-rise buildings by the FEMA guides

Hazards \ Category		Risk Assessment		Building Design Guide	Reference	Rehabilitation
Manmade Hazard	Blast	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	FEMA BIPS 04: Integrated Rapid Visual Screening of Buildings	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 459: Incremental Protection for Existing Commercial Buildings from Terrorist Attack: Providing Protection to People and Buildings	FEMA 426/BIPS 06: Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings	N/A
	Fire					
	CBR					
Natural Hazard	Seismic	FEMA P- 154: Rapid visual screening of buildings for Potential Seismic Hazards		FEMA 389:Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquakes FEMA 454:Designing for Earthquakes FEMA 543: Design Guide for Improving Critical Facility Safety from Flooding and High Winds FEMA P-749: Planning Earthquake Resistant Design Concepts FEMA P-750: NEHRP Recommended Seismic Provisions for New Buildings and Other Structures	FEMA P- 155: Rapid visual screening of buildings for Potential Seismic Hazards: Supporting Documentation	FEMA 397: Incremental Seismic Rehabilitation of Office Buildings: Providing Protection to People and Buildings FEMA 399: Incremental Seismic Rehabilitation of Retail Buildings: Providing Protection to People and Buildings FEMA 400 - Incremental Seismic Rehabilitation of Hotel and Motel Buildings FEMA P-420: Engineering Guideline for Incremental Seismic Rehabilitation
	Wind	N/A			N/A	N/A
	Flood	N/A			N/A	N/A
	Wild fire	N/A		FEMA P-737: Home Builder's Guide to Construction in Wildfire Zones	N/A	N/A
	Snow	N/A		FEMA P-957: Snow Load Safety Guide	N/A	N/A

In the case of fire, FEMA classifies fire into natural disasters and social disasters. However, a fire in the building categorizes a scenario of fire due to explosive terror and arson and presents design guides and risk assessment methods that use NFPA fire standards. In case of natural disasters, FEMA subdivides risk management guidelines for earthquakes that are likely to occur by phase. In particular, it provides step by step instructions to restore crucial facilities that affect the community after the occurrence of earthquakes.

2.2. FEMA IRVS Risk Assessment Analysis Against Disasters

The IRVS risk assessment is calculated based on an analysis of three factors: Consequence (C), Threat (T) and Vulnerability (V). The first Consequence assesses the degree of damage to a building (property) and the loss of the building's operating system due to the disaster. Second is Threat (T), which is the assessment of the degree of hazards to natural disaster, social disaster, potential events, signs, and behavioral threat factors that lead to the injury of an asset, individual or organizations. Finally, the Vulnerability (V) factor consists of assessments of the vulnerable elements of the building that can increase damage to the asset in the event of a disaster. FEMA IRVS caculates the risk level by multiplying the evaluated C, T, and V values and provides a sum. Weighting items are specified, but distinct values for the weight are not indicated in contrast to FEMA 'Rapid Visual Screening' (RVS, 2009). From a risk evaluation aspect, except for core infrastructure such as hospitals, schools, and critical facilities, it is difficult to derive differentiated results when buildings with similar uses are evaluated. Since in the case of Vulnerability, Fire, Security, and Cyber Security, evaluation items consist of qualitative analysis contents of buildings with a high error rate depending on the evaluator's subjective choices. Most evaluation items are limited to two, unlike others that must have all five or more as these evaluations reduce the sensitivity and accuracy of the risk assessment. In addition, the evaluation items with high weights of regional characteristics and environmental indicators of C and T are different from domestic high-density characteristics in urban areas, frequency and intensity of earthquakes and typhoon in Korea, and direct application of FEMA IRVS evaluation items to domestic cases' analysis are limited. Based on this research, the domestic risk assessment model is formulated for the differential comparison by deciding the criteria for evaluation target, deleting the items that are difficult to apply in IRVS and analyzing the domestic standards related to the evaluation target.

2.3. Comparison of Domestic Disaster Evaluation Standards

In order to establish standards, codes and design guidelines related to risk assessment for high-rise buildings against various disasters in Korea, nationals have not coordinated with private experts under the leadership of the government, yet design guidelines to ensure safety against disasters are continuously promoted through studies in diverse fields. The results of research is reflected in the improvement of building performance. The criteria is analyzed to construct items of the risk assessment of this study through the content analysis of the preliminary disaster impact assessment (2011), the High-rise Building Guidelines of Seoul Metropolitan Government (2009), and Anti-Terrorism Building Design Guidelines in Multi-purpose facilities of Ministry of Land, Infrastructure and Transportation. The grouping of similar items for the first classification was made by referring to items related to the architectural planning elements of buildings and the articles of IRVS. The Anti-Terrorism Building Design Guidelines in Multi-purpose facilities contains articles similar to those of FEMA RVS standards and detailed design guide contents that are not mentioned in the table below. Since the mandatory installation of the evacuation safe zone in domestic standards differs from the evacuation space design standard of the high - rise buildings in the United States according to analysed results, the developed concepts for the check list contains the criteria for the evacuation safe zone and design plan for effective evaluation but differs from the IRVS. The assessment items derived from reviewing articles are applied to the 1st sub-category and reflected on the subdivision and standardization of the assessment items for developing the K-IDES.

Table 2. Comparison of Major Related Standards by the Field of Disaster Assessment in Korea

Category	Preliminary disaster impact assessment key items	Seoul High rise building design guidelines	Key Review
Site	- Securing passage and open area in the site - Securing driveway and base space for fire engine in the site - Site entrance location planning	- Traffic line's separation between service vehicle and general vehicle - Securing the monitoring system of the public open space and eliminating visual blind spot	- Status of the road around the site - Status of the road in the site - Monitor vehicle and passenger movements
Building characteristics	- Comprehensive disaster management and safety control center planning - Public balcony (Sky park, roof garden) and staircase planning in the building	- Integrated Installation of Safety Control Room such as Disaster Prevention and Safety Room - Space planning with circulation system to pass through certain check point where	- Planning Emergency control room - Space plan to restrict passenger's movement inside the building
Envelope	- Minimal scattering methods caused by explosion of window glass or exterior finishing materials installed on the lower floors and lobby	- Finishing Materials usage for the Exterior Wall of Ground and Underground Lobby to ensure the safety in case of collision and explosion	- Low level envelope configuration and finishing material restrictions for explosion
Structure	- Seismic design and measurement installation plan	- Reflecting Wind Resistance Design - Reflecting Seismic structural design	- Seismic and wind-resistant design reflection
MEP System	- Underground flooding prevention plan - Burial status check of electricity, communication, gas, and waterworks	- Mandatory installation of evacuation elevator - Air intake/ exhaust port location	- Facility recovery plan for disaster preparedness - Planning extra facilities for the evacuation
Fire Protection	- Firefighting equipment, compartment, and smoke prevention plan - Prevention plan of ignition and combustion expansion	- Submission of Comprehensive Disaster Prevention Plan	- Plan to strengthen the performance of buildings related to fire prevention, firefighting, smoke control,
Security	- On-site security management and monitoring system - Security surveillance plan considering anti-terrorism	- Planning access/security system for major facilities	- Detail planning of security system to monitor always safety check such as CCTV
Evacuation plan	- Evacuation safety zone layout and area criteria - Structure and facility of evacuation safety zones - Evacuation facility installation plan and evacuation time	- Planning floors and location of Evacuation safety zone reflecting disaster simulation - Secure evacuation route more than two directions	- Mandatory installation of evacuation safety zones - Reinforcement of evacuation routes

3. Check List Development for Risk Assessment

3.1. K- IDES risk assessment development direction

The risk assessment method of IDES is calculated by using the concept of FEMA IRVS. In addition to it, FEMA's risk assessment method is used for other disasters based on the same formulas and concepts. In this study, the formula of FEMA risk assessment calculation, and the conceptual definition of consequences, threats, and vulnerability necessary for the quantitative evaluation of risk are applied. The evaluation criteria, evaluation items and evaluation contents are limited to the types of buildings in the high-rise buildings of more than 150m for non-residential buildings in the center of Seoul or Busan in Korea. Among the evaluation items of FEMA IRVS, the reviewing items that do not meet domestic standards, or have no relation to building characteristics, are deleted. Additionally, the evaluation items reflecting domestic standards and design guidelines such as the preliminary disaster impact assessment, the anti-terrorism design guidelines, domestic firefighting standards, and the Korea Building Code are revised or newly proposed to establish evaluation methods for the development of the Korean disaster evaluation model.

3.2. Comparison of evaluation methods between K-IDES and IRVS

Since K-IDES and FEMA IRVS are different from evaluation target types, this research attempts to limit the usable range of the evaluation method through comparing the FEMA with the IRVS. Among the evaluation areas of K-IDES, the vertical evacuation function is important for fire and evacuation, but IRVS cannot be applied to the evacuation analysis method of domestic high-rise buildings because it grasps the application of fire standards of NFPA CODE for general buildings. Thus, the contents of the evacuation section are divided into separate fields. In terms of recovery, it is difficult to specify the recovery concept and the quantitative evaluation system of the building after the disaster in Korea. Since the evaluation system of FEMA and IRVS is a qualitative assessment of a general building target, it is expected that there will be no distinguishable in its application to high-rise buildings. In this study, the evaluation items for recovery were excluded.

Table 3.

Comparing items			**K-IDES**		**IRVS**	
Evaluation target			A high-rise building in the commercial district (Nonresidential complex over 150m)		A general building which has no restriction by region and usage (Separate manuals for schools, hospitals, and important facilities)	
Category	Details		No. (%)	Remark	No. (%)	Remark
Evaluation area	Pre-field		12(11%)	Total questions: 113 * Pre-field contents are included in C, T, V * Separate classification of Evacuation in Vulnerability	18(15%)	Total questions: 120 * Pre-field contents are included in C, T, V * No separate classification system for the evacuation area for difference of concept
	Consequence		5(4%)		3(2.5%)	
	Threats		10(9%)		3(2.5%)	
	Vulnerability		98(87%)		91(76%)	
	Resilience		N/A		23(19%)	
Disaster Assessment Scenario	Man made hazards	Blast	95(84%)	Internal and external explosive attack	79(66%)	Internal and external explosive attack
		CBR	N/A		63(54%)	Internal and External release
		Fire	58(51%)	Incidental, Resulting from blast and seismic	48(40%)	Incidental, Resulting from blast and seismic
	Natural hazards	Seismic	68(60%)	Ground shaking	69(58%)	Ground shaking and failure
		Wind	37(33%)	High wind	71(59%)	Hurricane, Tornado, High wind
		Flood	N/A	N/A	51(43%)	Stillwater, Velocity Surge
Evaluation method	Weighted Item Selection		- Selection of weighted items based on IRVS weighted items and expert advice		- Selection of weighted items by assigned expects' consultation by FEMA committee	
	Weighted Value Selection		- Even division in the attribute option value by items - Using the correction value to reflect the ratio of item numbers by C, T, V		- By assigned expert consultation, weighted by items - Unequal split for the attribute option value by items	
	Risk Assessment		- Multiplying the sum values by C, T, V and deriving risk value by each disaster scenario		- Deriving risk value to apply the differentiated correction factor by multiplying the sum of C, T, V by disaster scenarios	
	Scenario Assessment by Disaster		- Applying IRVS individual risk evaluation formula		- Using the risk evaluation formula to apply the correction coefficient that varies according to the maximum and minimum values among C, T and V	
	Integrated Assessment		- Applying IRVS integrated risk evaluation formula		- Using integrated risk evaluation formula to apply the conversion coefficient after summing the risk by disaster scenario	
* C: Consequence, T: Threats, V: Vulnerability, R: Resilience IDES: Integrated Disaster Evaluation Simulator, IRVS : Integrated Rapid Visual Screening						

3.3. K-IDES Risk Measurement Methods

The K-IDES disaster risk assessment is based on IRVS's individual risk assessment and integrated risk assessment formula. K-IDES calculates the values of Consequence, Threats, and Vulnerability to sum up each item by disaster scenario, and the individual risk is calculated by using the following formula. The risk values of individual disasters exclude the interrelationships between disasters. It sums the integrated risks with the disaster risk by scenario. The risk value calculation formula derives the average risk value based on the concept of P-Norm in linear algebra.

Table 4. Individual and Integration Risk Scenarios Calculation Formula

Individual Risk Scenarios Calculation Formula		**Integration Risk Scenarios Calculation Formula**	
$R_i = \sqrt[B_i]{C_i \times T_i \times V_i}$		$R_i = \sqrt[B_i]{C_i \times T_i \times V_i}$	
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
V_i	Vulnerability rating of the i^{th} threat scenario	**n1**	power value 10
β_i	β_i value depends on αi value, α_i =Min (C_i, T_i, V_i)/Max (C_i, T_i, V_i), If $\alpha_i \leq 0.1$, β_i=4.0, If $\alpha_i \geq 0.9$, β_i=3.0, If $0.1 < \alpha_i < 0.9$, then $\beta_i = 3.875 + 1.25 * \alpha_i$	$\propto$	scaling factor 1/12

3.4. K-IDES Disaster Risk Assessment Items

The evaluation items of K-IDES comply with the evaluation classification system of FEMA IRVS, but the evaluation items are newly established in consideration of the importance of the evacuation safety zone plan derived from the high-rise building design and evaluation standards related to disasters in Korea. The purpose of evaluation between sub - items was grouped considering the correlation of similar items. K-IDES extracts the second detailed subdivision items from IRVS and the proposed items through domestic structural standards, domestic disaster related evaluation standards and guides. And then by expert's consultation on the related fields such as structure, fire, and architectural design, it specifies the detailed selection criteria of the items and contents. It carries out the evaluation process by pre-evaluation and on-site evaluation. Pre-evaluation is the process of basic information collection on the building and surrounding environment. The field evaluation consists of 113 items grouped into 9 categories in an order of Consequences, Threat and Vulnerability and 29 weighted items that are selected through IRVS and expert's consultation based on empirical knowledge. The evaluation items for the evacuation area are classified as the abatement items as they are important for securing the safety of high rise buildings. Since evaluation items are constructed while considering the impact on the buildings according to the disaster characteristics, the distribution and the number of items is different according to the disaster. In the case of a typhoon disaster, except for site, building, elevation, and evacuation plan, the correlation between it and other evaluation fields in the high-rise buildings is weak, and so it is expected to have little influence on the disaster evaluation and the final integrated disaster risk assessment.

Table 5. K- IDES Assessment Frame

Process	Division	Evaluation items	No. of Q	Man made Hazards		Natural Hazards		Weighted items	Source
				Blast	Fire	Seismic	Wind		
Pre-field data collection		Local characteristics	4	4	3	2	2	Description of applicable items in Consequence, Threats, Vulnerability	IRVS, RVS KBC regulation
		Bld. characteristics	3	3	3	2	2		
		Environment Index	5	-	-	2	3		
		Total	12	7	6	6	7		
Consequence (Community loss after disaster)		Local characteristics	3	3	2	2	2	Historic district inclusion	IRVS, RVS
		Recovery	1	1	1	1	1	-	
		Asset value	1	1	1	1	1	Asset value measurement	
		Total	5	5	4	4	4	2	
Threats (Cause potential harm factors by disaster)		Bld. characteristics	4	4	4	1	1	Building use, accessibility to building	IRVS, Korean Building Codes
		Environment Index	6	-	1	3	3	Seismic frequency, Wind frequency	
		Total	10	4	5	4	4	4	
Vulnerability (Physical feature in a building to exploitation or susceptible to hazard)	**Site Plan**	Road status around site	3	3	-	-	-	Shortest distance between adjacent roads and buildings	IRVS, RVS, Preliminary disaster impact assessment, Anti-Terrorism Building Design Guidelines, Domestic Fire Safety Code
		Road status in site	4	4	4	4	-	Distance between fire engine stop area and building	
		Limitations and control of vehicles, passengers	6	6	1	-	-	Underground access without security	
		Total	13	13	5	4	-	3	
	Architecture Plan	Building shape	6	5	2	6	6	Aspect ratio, Extrusion area	IRVS, RVS, Anti-terrorism design criteria, expert consultation
		Plan type	2	1	1	2	2	Core plan	
		Internal space plan	4	4	4	-	-	Loading dock plan	
		Parking layout	3	3	2	-	-	Major facility location in underground parking	
		Total	15	13	9	8	8	5	
	Envelope	Low level window composition	4	3	1	1	1	Ratio of window	IRVS, RVS, Seoul High rise building design guidelines
		High level window composition	2	-	2	2	2	Glass type	
		Envelope composition except window	4	3	1	4	4	Wall configuration, geometric shape of the envelope	
		Roof area configuration	2	-	-	1	2		
		Total	12	6	4	8	9	4	
	Structure	Structure system	3	3	1	2	2	Lateral transition member	IRVS, Korean Building Code, American Standard Code for Information Interchange, Expert advisory
		Structure type	10	8	1	8	4	Transfer girder support type	
		Appendage structure type	2	2	-	2	2	Internal non-support component	
		Total	15	13	2	12	8	3	
	MEP System	Mechanical, electronical, plumbing plan	9	7	1	6	3	Outside air intake, MEP's structure mounting degree	IRVS
		Total	9	7	1	6	3	2	

	MEP System	Mechanical, electronical, plumbing plan	9	7	1	6	3	Outside air intake, MEP's structure mounting degree	IRVS
		Total	9	7	1	6	3	2	
	Fire Protection	Fire partition plan	3	3	3	3	-	Vertical, horizontal fire protection compartment appropriateness	IRVS, NFPA13, Korean Preliminary disaster impact assessment, Expert advisory
		Firefighting equipment plan	3	3	3	3	-	-	
		Smoke control plan	6	6	6	6	-	-	
		Total	12	12	12	12	-	2	
	Evacuation Plan	Horizontal evacuation plan (Evacuation route)	3	3	3	3	-	Dead-end corridor and overlapping walking length	IRVS, UK DOC, Seoul performance-based design guideline, Seoul Committee review criteria
		Vertical evacuation plan (Elevator, platform)	2	2	2	1	-	Emergency/ evacuation lift operation plan	
		Evacuation safety zone (Sunken plan)	5	5	5	5	-	Separate applied as risk reduction item	
		Total	10	10	10	9	-	2	
	Security Plan	Intra-building intrusion monitoring plan	2	2	-	-	-	-	IRVS, RVS
		Intra-building explosion threat monitoring plan	2	2	-	-	-	Internal security system efficiency	
		Out of building explosion threat monitoring plan	2	2	-	-	-	External security system efficiency	
		Total	6	6	-	-	-	2	
	Cyber Infra structure	Cyber security and emergency plan related equipment	6	6	6	1	1	Wide area, local network, wireless, satellite system efficiency in emergency	IRVS
		Total	6	6	6	1	1	1	
Total Sum (Consequnce+Threats+Vulnerability)			113	95	58	68	37	-	
Total Sum of Weighted Item			30	26	16	18	12	30	
Percentage (%)			100	84	51	60	33	27	

4. K-IDES Risk Quantification Methods

4.1. K-IDES Risk Assessment Calculation Method

Since the scoring for the quantification section of the risk assessment model developed in this study differs in the number of items among C, T, and V, the maximum value of the detail item is specified according to the ratio adjustment. The ratio is determined through the simulation together with the weighted item. K-IDES sets The minimum value at 0.1 level of the maximum value and the selection value of the detail item is determined by the isometric ratio between the intervals. According to the architectural elements affected by the disaster's specific characteristics, item distribution is interlinked and the number of questions is 2.5 times the maximum for each disaster. It is necessary to review the distribution ratio when calculating the final risk. In this study, the risk assessment by items is a process of selecting the baseline value for the final integrated risk assessment and will be used as a criterion to refine the evaluation model by analyzing the effects of individual disasters and C, T, V items through a simulation of high-rise buildings and application of the K-IDES risk assessment.

Table 6. K-IDES Assessment Frame

	Attribute options					Weight	Q-Ratio	Blast		Fire		Seismic		Wind	
	a	b	c	d	e			Min	Max	Min	Max	Min	Max	Min	Max
C	0.19	0.62	1.06	1.49	1.92	4.8	9.6%	2.419	24.19	1.498	14.976	1.4976	14.976	1.498	14.976
T	0.12	0.39	0.66	0.93	1.20	2.64	12.0%	0.874	8.736	0.994	9.936	0.677	6.768	0.677	6.768
V	0.08	0.26	0.44	0.62	0.80	1.6	78.4%	7.936	79.36	4.544	45.44	5.152	51.52	2.752	27.52
αi	αi =Min (Ci, Ti, Vi)/Max (Ci, Ti, Vi)							0.110	0.110	0.330	0.330	0.131	0.131	0.246	0.246
βi	If 0.1< αi <0.9, then βi =3.875 + 1.25* αi							4.013	4.013	4.287	4.287	4.039	4.039	4.182	4.182
Ri	$R_i = \sqrt[\beta_i]{C_i \times T_i \times V_i}$							2.019	11.294	1.562	7.824	1.512	8.326	1.278	6.665
R	$R = \alpha \sqrt[n1]{\sum_{i=1}^{n2} R_i^{n1}}$							R max: 94.8%, R min: 17.1% (R *100%)							
C: Consequence, T: Threats, V: Vulnerability (%): Ratio among number of C, T, V questions reflecting e Value															

4.2. K-IDES Rating Method

K-IDES' maximum and minimum values are used to proportionally divide intervals to rate the risk as a percentage (%) which are then divided into four stages of IRVS to classify the risks. IRVS graded risk intervals are at equal intervals while the K-IDES is classified as safe for values less than 40% for risk and divided the risk into 3 intervals for values greater than 40%. Calculated scores are divided into 25%, 20% and 15% according to the risk level. This study establishes a criteria for grading based on the quantitative analysis of the degree of damage to an environmental threat and disasters level and vulnerability to the physical protection function of buildings. In the next study, the risk values derived from building simulations using K-IDES will be analyzed to verify the accuracy of the model and to examine the applicability of the settled criteria.

Table 7. K-IDES Risk Rating

No.	Rating	Definition	Range
1	Very High	There is a very high possibility of disaster and lacking capabilities physical protection against building. It has wide range of damage and serious harm in critical and major functional disruptions in the event of a disaster	85~100%
2	High	There is a high possibility of disaster and insufficient physical protection against building. It has serious damage such as loss of core function of the building in the event of a disaster.	65~85%
3	Medium	There is a possibility of disaster and capabilities of physical protection against it. It has affordable damage in the event of a disaster has the same effect as a minor disruption of building function for a considerable period.	40~65%
4	Low	There is minor risk for superior physical protection and it has negligible loss of damage	Under 40%

4.3. K-IDES Simulation Plan for Risk Evaluation Model Review

It is necessary to apply the risk evaluation model to high-rise buildings to examine the weighted items and the weight distribution of it. K-IDES sets the selection criterion for the simulation based on the items that can analyze

the influence by items in the vulnerability part of the building with minimizing the group deviation on the environmental factors. In order to verify the distribution of building vulnerability
with similar conditions as the regional characteristic related indicators of the risk assessment model, the selection of a domestic high-rise building is selected a non-residential high-rise building with a heighted of 150m or more in a commercial district with a floor area of 500% or more in Seoul and Busan as a standard. K-IDES classifies the selected targets so that they could be used as a control group by an evaluation factor for the comparison to identify moving plan of vehicles and pedestrians, applicable buildings and non-applicable buildings subject to evacuation safe zone regulations and facade composition and materials to endure the external attack. It is possible to analyze the precision of the checklist by first evaluating the characteristics of items related to the architectural planning elements such as site plan, space plan, elevation plan, and structural plan and applying them to the weight and evaluation values. For other evaluation items, due to the similarity of use of non-resident high-rise buildings, the results of the review of security plans, facilities, fire prevention plans and security plan are expected to be similar. The following table describes the characteristics of the main items selected for the simulation.

Table 8. Overviewof buildings to be evaluated by K-IDES

No.	Site Conditions					Building Characteristics			
	Population density	Building Use	FAR (%)	TFA (m2)	OLP (Thousand won/m2)	Composition of buildings	Height (m)	Structure	Separate zoning of Evacuation
A	6,340	O,H,R,M	574	805,872	42,000	One tower over mall	555	Composite	Reflect
B	4,044	O,H,M	799	630,177	10,810	Three towers over mall	338	Composite	Reflect
C	14,348	O,M	550	269,699	3,503	One tower over mall	289	Concrete	Reflect
D	4,044	O,M	926	160,732	10,810	Three towers over mall	284	Composite	Reflect
E	4,044	O,C	940	168,506	12,050	One tower + Convention	246	Composite	Reflect
F	15,449	O	848	212,615	41,900	One tower	204	Concrete	Unreflect
G	25,988	O,M	747	350,051	9,100	One tower over mall	190	Composite	Unreflect
H	7,916	O	799	219,385	38,140	One tower over mall	185	Concrete	Reflect

O: Office, H: Hotel, R: Residential, M: Mall, C: Convention
FAR: Floor Area Ratio, TFA: Total Floor AREA, OLP: Official Land Price

5. Conclusion

In USA, through collaborating with public experts, the government designs various disaster scenarios for private buildings in addition to public buildings and manage risk on them by continuously developing risk assessment system and systemizing accumulated data for the rapid recovery and reinforcement against vulnerability based on the data. In Korea, it is not sufficient to operate the integrated risk management system for responding disaster due to lack of criteria for collecting data by disaster, official acceptance to the adequacy of risk assessment and interoperability system of results. Moreover, the government has tried to reduce the high-rise building's risk against the disaster through strengthening legal standards and building performance based on the review of pre-disaster impact assessment on high-rise buildings. However, pre-disaster impact assessment and inspection of disaster facilities to reflect strengthened standards by professional workforce is also has limitation since individual subjective opinion is reflected in evaluation and cannot be quantified. In order to establish risk assessment model for high - rise buildings against four disasters: explosive terrorism, fire, seismic and wind at risk of domestic accidents.

FEMA IRVS in USA and domestic risk evaluation criteria of buildings in case of disasters were analyzed. Based on this research, the risk assessment concept aims to establish a management system that can systematically integrate the collected information by using assessment techniques for elements in response to various disasters. It presents a classification system of evaluation factors, criteria for evaluation items and risk assessment methods. The results of the study create a basis for establishing the criterion of risk assessment methods to establish the Korean risk assessment model. In the next study, the developed model will be verified. Subsequent studies will increase the evaluation model's precision by refining the criterion for disaster-related evaluation items and incorporating it into the risk assessment quantification. The final goal of this study is to develop a platform for building an integrated risk assessment system for disasters that can be utilized in systems developed from the beginning of the design considering domestic reality. This platform is expected to be used as integrated risk management against a complex disaster by expanding to infrastructures and other types of buildings through continuous data scaling and management systematization.

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7. Reference

1. Lee, K. (2009). Basic Research for Preventing Terrorism in multipurpose building. National Intelligence Service Counter terrorism research summary; 6.

2. Kang, K. Y., Lim, D. H., Kim, J. S., & Lee, K. H. (2012). A Study on the Architectural Design Guidelines of Super High Rise Buildings for Terrorism - Focused on the 1st and 2nd Layers Defense. *Korea Crisis Management Nonjip [Crisisonomy],6*(4), 191-216. Retrieved December, from https://www.earticle.net/Article/A154512.

3. Kang, K.Y., Park, B.J. and Lee, K.H. (2011) A study on the vulnerability assessment of high-rise buildings in Korea. Journal of the Architectural Institute of Korea (Planning & Design), 27 (11), pp.125-133

4. Choi J. W., Kang K. Y., Jang J. B., Lee K. H., Choi I. C. (2012) A study on a risk assessment model of bomb attack for high-rise buildings based on the analytic hierarchy process. Korean Review of Crisis & Emergency management, 8 (1), pp.127-139.

5. Kang, K., & Lee, K. (2014). Vulnerability Assessment Model for Cost Efficient Anti-terrorism Design of Super High-Rise Buildings. *Journal of Asian Architecture and Building Engineering,13*(2), 413-420. doi:10.3130/jaabe.13.413

6. Yu, Y. S., Yoon, S. W., & Ju, Y. K. (2012). Risk Assessment of Tall Buildings in Korea by comparative study of Modified RVS and IRVS system. *Journal of the Korean Association for Spatial Structures*, *12*(4), 91-98.

7. Ministry of Government Legislation. (2015). *Special Act on Management of Disasters in Super High Rise Buildings and Complex Buildings with Underground Connections.*[PDF]. Korea.

8. Ministry of Public Safety and Security. (2014). *Preliminary Disaster Impact Assessment Consultation guidelines.*

9. Seoul Metropolitan Government (2009) Design guidelines of high rise buildings. Seoul: Seoul Metropolitan Government.

10. Ministry of Land, Infrastructure and Transportation. (2010). *Anti-Terrorism Building Design Guidelines in Multi-purpose Facilities*.

11. Ministry of Land, Infrastructure and Transportation. (2017). *Regulations on standards for the structure of evacuation and fire prevention in buildings*.

12. FEMA (2005) FEMA 452. Risk assessment: a how-to guide to mitigate potential terrorist attacks against buildings. Washington, D.C.: DHS

13. FEMA (2009) FEMA 455. Handbook for rapid visual screening of buildings to evaluate terrorism risks. Washington, D.C.: DHS

14. Department of Homeland Security. Federal Emergency Management Agency (FEMA). (2011). *FEMA BIPS 04: Integrated Rapid Visual Screening of Buildings.*(Rep.).

15. FEMA (2011) FEMA 426/BIPS 06. Reference Manual To Mitigate Potential Terrorist Attacks Against Buildings 2^{nd}.

16. The Council on Tall Buildings and Urban Habitat (CTBUH). (n.d.). Retrieved from http://regions.ctbuh.org /south-korea/seoul