Urban Risk Assessment Using GIS

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Key word : GIS, Risk assessment, Risk Evaluation, Urban Disaster

SUMMARY

Modern society is facing various disasters. Especially with frequent occurrence of social disasters such as chemical accident and terrorism along with existing natural disaster such as hurricane and flood, paradigm of disaster is changing. Accordingly, technology integration development for timely response and support on disaster management on disaster spatial information is required. Also, disaster response and management system that could timely respond to combination of disaster that occurs in various types and complex nature is required and on-line disaster safety management infrastructure that enables minimization of damage due to disaster is necessary. Accordingly, in this research, various types of risks inherent in metropolitan region has been analyzed in qualitative and quantitative perspective and aims to establish evaluation system that could control every spatial, social uncertainty index occurs for the event of combination disaster based on it and prepared respond system that reflects situation of the scene in real time using risk analysis. Also, in combination with GIS technology with above indexes, we have established ground for utilizing expansion on combination disaster risk technology by visualizing synergy effect that creates risk evaluation technology for each type and combination manner through development RISK-CITY system that could obtain disaster information in real time.

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1. INTRODUCTION

1.1 Necessity of the research

1.1.1 Perspective of science and technology

In modern society where various and combination of disaster occurs, combination technology development for support on disaster management on disaster spatial information and timely response is required. New concept of establishment of disaster spatial information that is related to spatial characteristics of region (vulnerable to water, coast, handling danger material, financial/medical sectors, factory sector and living type) and social characteristics (life style, living condition, traffic system and characteristics of local people), especially based on the basic spatial information that consists national spatial information, by conducting combination of disaster spatial information used for analyze of vulnerable points of disaster, improvement on disaster information management system and information sharing shall be determined. Also, related to national spatial information acquiring and sharing, system that modifies and supplements based on the national spatial information is required.

1.1.2 Perspective of policy and social

Modern society requires response and management system that timely respond to combination disaster that occurs in complex and various forms. In 'The fifth national spatial information policy fundamental plan ("13~"17)', active response regarding changed policy environment including smart phone, steep development of ICT combination technology and shift in government administration paradigm is necessary and also requires establishment of spatial information database infrastructure that systematically collects/analyze/manage relevant information for forecasting combination disaster that recently became social issue.

Also, establishment of infrastructure of real time disaster safety management for minimizing damage due to disaster is required. Due to characteristics of disaster that changes quickly, only obtaining information in precise and timely manner can minimize damage and personnel and disaster damage may be reduced by quickly respond to disaster by analyzing situation of disaster in real time from occurrence point of disaster to extinguishing point and calculating risk and estimated damaged area. Also, risk map service in various platforms in web such as operation system on smart phone enables quick report on situation in disaster area, obtaining orders from commander and timely evacuation of citizens in expected damage area.

1.1.3 Perspective of industrial and economical

By developing new spatial information database model that could replace existing spatial information that had various inherent limitation in perspective of contents and its form, it may contribute to expansion on utilization of combination as well as connection with nation's administration information and other information. Compared to two dimensional vector record that contains simple nature information such as existing recognition technology and location of material and terrain and configuration information, it includes time series change information as well as location and configuration information and develops spatial information database model that could be used while connected and integrated with other information.

1.2 National/international research and policy trend

Information of disaster and safety section in Korea is classified as 'Establishment of infrastructure' and 'Establishment of utilization service' and conducted strategically focusing on 4 main regions depending on change in national information development and technology industry. Especially, for establishment of natural disaster infrastructure using ICT, by collecting and managing disaster forecasting information, it prepared system that could respond in real time and prevent for disaster safety concern that has high probability of occurrence in the future. Especially, in the fifth national spatial information policy fundamental plan, fourth clause of seven practices, it states that 'Establish city management system that is safe from disaster and develop technology for systematic development and safety management' among conduct of R&D contents.

On the other hand, main nations such as England and Japan is expanding strategy the strategy for innovation of safety in nation level based on the ICT integration. England is conducting nation and regional disaster safety risk management that establishes resource distribution plan by analyzing factors of danger on disaster safety and prioritize danger factor according to result of evaluation. Through the task, it has its purpose on evaluating danger index of nation and prevents factors that cause danger on disaster in advance. In case of Japan, through danger map of earthquake region, it evaluated comprehensive regional danger index by analyzing forecasted earthquake region and its intensity and distance from earthquake forecasted region. Through that, it aimed to visualize pre-emptive response system for forecasting earthquake and reduction of damage. On the other hand, research is being discussed in world level as well as nation level. Especially in GDACS(Global Disaster Alert Coordination System) that aims for practical relief by alarming world disaster information in real time reports location and contents of natural disaster and location of it such as earthquake, tsunami and hurricane based on the map.(GDACS. 2014)

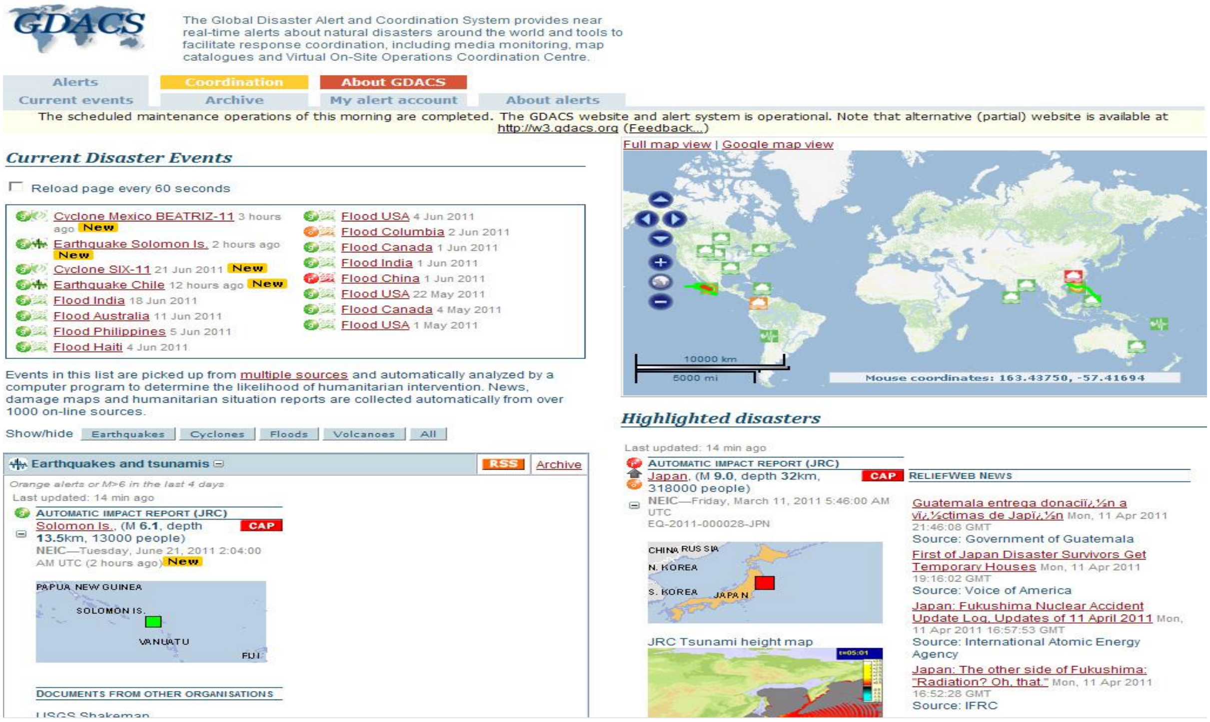

Figure 1 GDACS Web-Page

1.3 Step of research

1.3.1 Step 1: Establishment of integrated disaster spatial information model through research on list of spatial information per type of disaster

For establishment system that could control combination disaster proposed in this thesis, foundational research for constructing combination spatial information database model by analyzing spatial information and non-spatial information required in analyze per type had been conducted which includes investigation of spatial information list used per disaster type, investigation of DB model construction case of disaster spatial information for national/international and risk evaluation technology research per disaster type.

For list investigation of spatial information used per disaster type, terrain map required for analyzing disaster type, prevention of 4-CYCLE of disaster management through unification of topic, applicable sector of spatial information that may be used in preparation, response and recovery stage and utilization methods had been proposed and aims to expand timely/precisely its usefulness of spatial information regarding combination disaster by classifying stored spatial information to self-producing department and other editing storage department. Second, in case of investigation of DB model construction of national/international disaster spatial information, spatial information DB model based on GIS used for analyze software per disaster type and used for decision making in national/international mainly used in domestic. Through this, attribute granting method to scan and analyze changes (Construction scope and time) of spatial information before and after the disaster. Last, in risk evaluation technology research per disaster type based on GIS, it aimed to conduct risk evaluation technology research per comprehensive disaster type through spatial combination evaluation technology research for research investigation on qualitative/quantitative analyze algorithm of combination disaster, technology investigation using experience of expert and risk analyze matrix, technology investigation of risk index per disaster and evaluation for vulnerable point. By that, it aimed to conclude in method of constructing spatial information integrated database model based on nation to lighten nation's disaster vulnerable point.

1.3.2 Step 2: Analyze of risk factor for making national RISK-CITY map

Risk factors that consists foundation database for making RISK-CITY map that this research ultimately intends to develop is analyzed in this stage. Spatial information database model that is capable of integrated with disaster safety information and other information has been constructed subjecting national departments in prototype manner which consists of classification of risk factor, determination of base measure of risk map, construction of national RISK-CITY spatial information DB model in prototype manner and disaster per type risk evaluation technology research based on GIS.

First, the determination of basic measure of risk map and classification of risk factor is a stage that analyzes risk factor for evaluation of combination disaster. This includes analyzing classification method of risk factor and determination of risk map basic measurement unit for connection of disaster spatial information with literature and social information. Second, national RISK-CITY spatial information database model has been constructed in prototype manner. During this stage, spatial information regarding regional characteristics (Flood region, coastal region and factory region) and construction characteristics (Construction material, foundation of construction and height of construction) has been gathered and connected to various types of danger (Landslides, flood and earthquake) and exposure from this disaster and vulnerability and risk quantitative records associated with it. Last, through risk evaluation technology research per disaster type based on GIS, risk evaluation technology per type of disaster has been developed and conducted combination disaster risk evaluation technology research that is integrated with sensitivity and vulnerability through it.

1.3.3 Stage 3: Development of technology focusing on application on field regarding social combination disaster

Like disaster has been complicated and diversified, region too has various vulnerable points. Therefore, 'Region optimized' risk management system for securing pre-emptive response capability regarding combination disaster has been proposed. This includes risk evaluation technology research per disaster type based on GIS, pre-emptive response capability research in preparation of occurrence of combination disaster and 'Region optimized' combination disaster risk management system research. First, continuing the risk evaluation technology research per disaster type based on GIS conducted in stage 2, risk curve evaluation technology using GIS technology has been analyzed and developed annual average risk speculation technology based on it using GIS technology. Also, through pre-emptive response capability research in preparation of occurrence of combination disaster, it aimed to detect/sense combination disaster risk factor and evaluate impact on personnel and property in advance. Also, it conducted research regarding technology that prevents/eradicates proliferation of the damage on the combination disaster. Last, through propose of 'Region optimized' combination disaster risk management system, it aimed to propose optimized method that reduces combination disaster damage and relief by completing occurrence-response-recovery scenario for each type. Also, by constructing combination disaster top priority manual evaluation system, risk visualization technology called RISK-CITY has been developed.

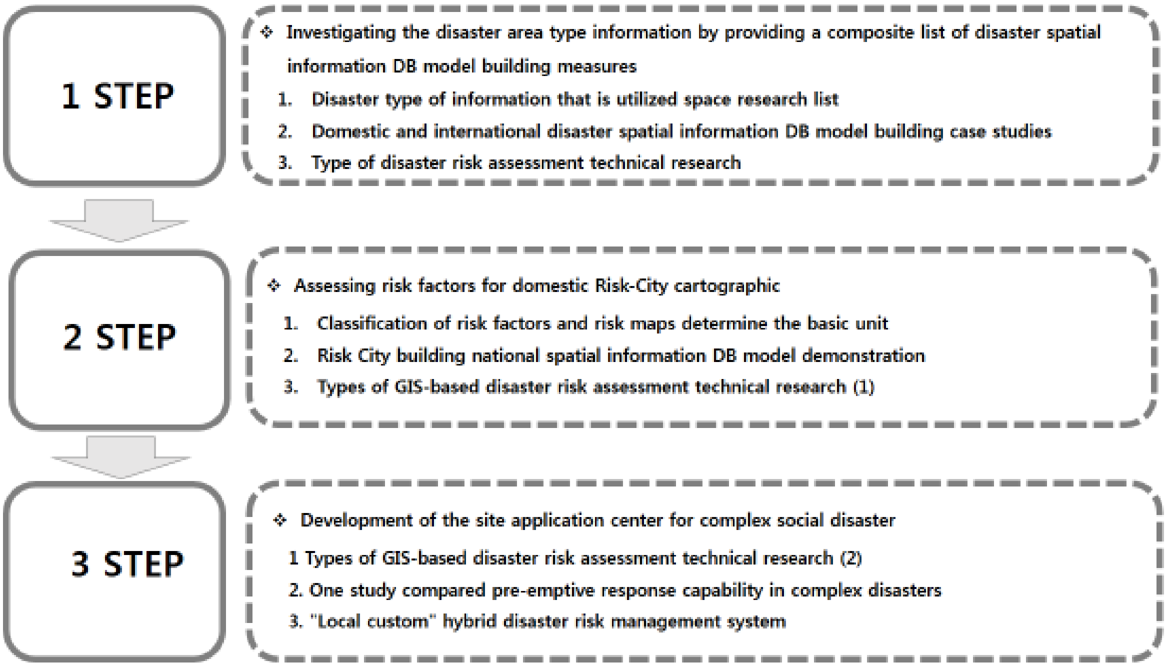

Figure 2. Research Process

1.4 Research method

1.4.1 Qualitative risk evaluation

Qualitative risk evaluation is a method that evaluates experience of experts and it is classified as words with 'Very high', 'High', 'Normal', 'Low', and 'Very low'. Number of qualitative classification may vary but generally 3~5 grades are used. For example, in area where risk is very high, 'Physical and non-physical measurement is required immediately and no more social based facility development in this region shall be permitted'. Fell (1994) defined qualitative risk evaluation that considers classification of the identical size, probability, danger, vulnerability and other specific risks. Also, guideline that has been proposed for the word to evaluate risk regarding property is mentioned in Australian Geo-mechanics Society and Landslide Risk Management. Guideline was developed by combining probability and probable results which may be applied in spatial analysis using GIS. Generally, these methods are used in national and regional level as qualitative factors may not be used depending on the size or generalization is required(Yoon et al, 2014).

These qualitative risk evaluation methods may be only applied under circumstances where risk is required to be evaluated in cheap and quick manner. These methods qualifies subjective factors included in risk evaluation procedure as much as possible and uses marking attribution that may emphasize defining wording precisely and clearly and granting weighted figure method and uses risk that could be shown in qualitative format and development within scope of result and risk.
When risk is estimated in qualitative manner, evaluation is taken on various risk factors such as railroads and roads. Results regarding each type (For example, VH, H, M, L, VL) may be classified by each level. (FEMA, 2008)

Table 1 Qualitative Risk Evaluation Matrix

Possibility	Result				
	Catastrophic	Important	Usual	Light	Minute
Almost clear	VH	VH	H	H	M
Likely	VH	H	H	M	L-M
Possible	H	H	M	L-M	VL-L
Not Likely	M-H	M	L-M	VL-L	VL
Rare	M-L	L-M	VL-L	VL	VL
Unbelievable	VL	VL	VL	VL	VL

1.4.2 Semi-quantitative risk evaluation

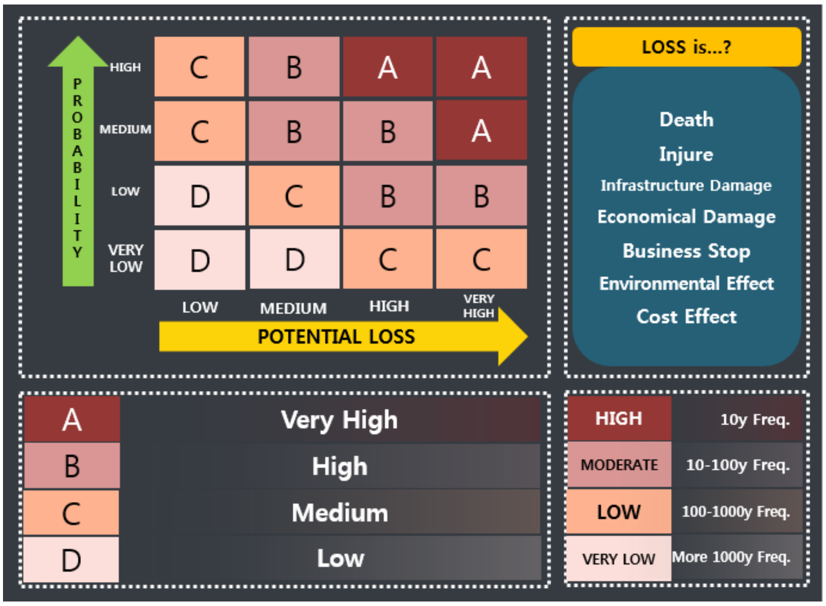

Figure 3. Risk Matrix

Unlike qualitative evaluation, semi-quantitative risk evaluation is assigning provided weighted value under certain criteria as result rather than class. Semi-quantitative estimation for risk evaluation is known to be useful under following circumstances.

1. Early screening stage to check danger and risk
2. When pre-determined level of risk is not adequate for the time and effort
3. Where receiving of numerical value is limited

Semi-quantitative method considers various factors that affect risk. Scores and setting scope for each factor may be used when evaluating scope of unstable (Danger) and loss or advantages and disadvantages of the damage. Matrix priority of danger and result is used to get determined value of the risk, which is created by combining scope of dangers and scope of series of results. Final risk value classifies with the given qualitative result and prioritizes them in order. Risk estimation may be conducted separately for loss of life and economical loss.

Semi-quantitative method may be applied to cover large area (Spatial or GIS based). In some cases, selecting scoring system for specific region can result in dilemma. This method may apply size of analysis or level to certain extent but it may be appropriate to use it for middle size. Semi-quantitative method in these days may use spatial multi-standard method effectively running in GIS where standardization, granting weighted value and integration of data in single tool. Semi-quantitative method has been reviewed in 2 methods in this paper.

1. Spatial Multi-Criteria Evaluation
2. Risk index

First, Spatial Multi-Criteria Evaluation (SMCE) is very important frame for evaluation of vulnerability and danger.(Castellanos. E, 2007) Figure.4 suggests case where SMCE was used to determine risk index on landslides in Cuba. In this case, risk index was determined by combining danger index and vulnerability index. Danger index is made using relevant index map related to stimulating factors and environmental factors and vulnerability index is made using index of 4 groups. In this research, in order to use it on national level, 43 of vulnerability index for the first time was determined. However, due to the fact that not every information may be gained and high relevancy between various indexes chosen in the early stage, total number of indexes has been limited to 5 main indexes including housing and traffic condition (Physical vulnerability index), population (Social vulnerability index), production (Economical vulnerability index) and protection region (Environmental vulnerability index).

These indexes have been determined based on polygon related to political-administrative region and most of them are at the level of local government. Each index is processed, analyzed and standardized according to its contribution to danger and vulnerability. Indexes determine weighted value using direct, and multiple comparison, prioritization and this weighted value has been combined in order to gain final risk index map. (HAZUS, 2004)

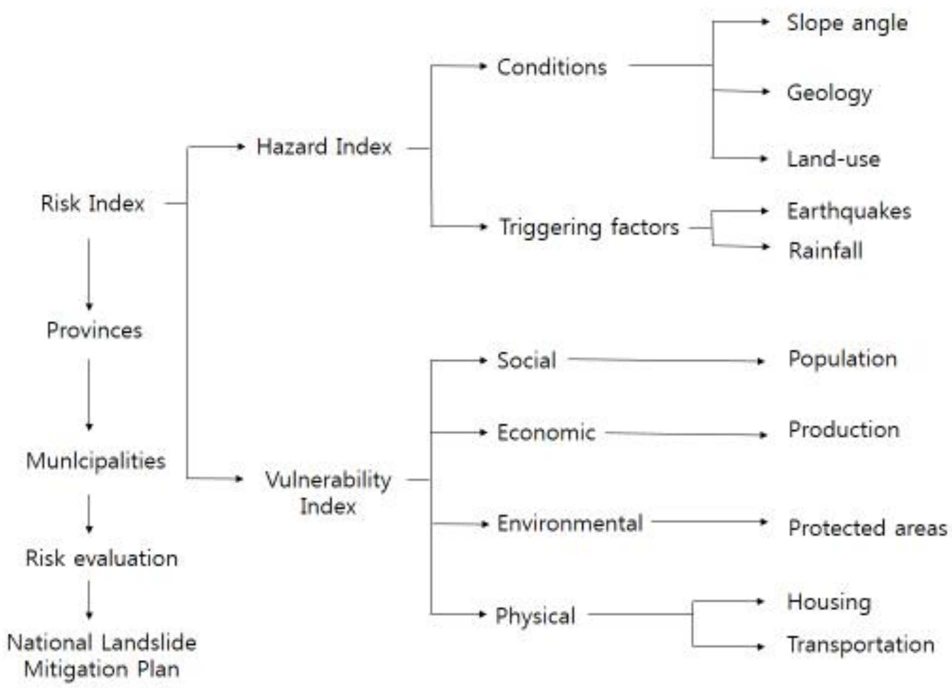

Figure 4. Example of Spatial Multi-Criteria Evaluation

Second, determination method regarding risk index shall be explained. Among disaster risk index, DRI disaster risk index is typical. Disaster risk index is index that could measure nation's physical exposure and comparative vulnerable points. DRI may estimate average risk regarding casualty per nation due to large scale disaster elated to earthquake, tropical cyclone and food based on the data from 1980 to 2000. DRI has correlation with casualty risk and confirms various social-economic-environmental variables that could provide causing process of disaster risk. In DRI, nation's index per danger type depending on the physical exposure level, comparative vulnerability and risk is decided.

On the other hand, IDB index system uses indexes regarding benchmarking nations for various periods of time for mutual comparison between nation in systematic and quantitative manner. Each index is related to it and has various factors measured in empiricism way. Factors are chosen after consideration of various factors such as nation compensation, soundness of data, and direct connectedness to the events that measures the index and quality. Disaster Deficit Index, Local Disaster Index, Prevalent Vulnerability Index, Risk Management Index or major factors that shows vulnerability of combination index has been reflected and shows that in many nations, their risk management ability has been enhanced.

IDB index system has been constructed to be able to measure index in national level using collected information from existing nation and international database. It may only be used in local level but it is constructed for comparison between nations or semi-nations. This provides enough information that nation is vulnerable depending on the danger that has impact on it.

1.4.3 Quantitative risk evaluation

Quantitative risk evaluation has its purpose on quantify risk according to following formula.

$$R_S = P_T \times P_L \times \text{V} \times \text{A}$$

P_T is temporal occurrence probability of specific danger scenario that has given occurrence period in selected region. $P_L$is spatial or location occurrence probability of specific danger scenario that has given occurrence period while affecting factors of risk in selected region. V is danger scenario and A is quantified amount of evaluated specific type of risk factor. Amount may be quantified in various methods and it is important to show the risk in quantified manner by the method that quantified amount. For example, amount may be displayed in numerical form such as number of buildings, number of population. Also, factor of risk may be quantified by using economical terms.

In this quantitative risk evaluation method, combination effects in perspective of loss for every possible scenario that could occur are calculated. There are many approach methods and they are similar in certain way but difference is observed as well. This includes method that could calculated danger or calculates vulnerability result. Resolution may be found among method that combines dangers like probability of vulnerability. Regarding other various danger scenarios, these results construct time occurrence probability of danger cases of the graph. Through that, by intersecting curves called risk curve and calculate area under the curve shall result in total risk. This procedure in multiple danger risk evaluation is conducted regarding all types of danger and it shall be conducted carefully to evaluate mutual relationship between dangers. As risk is regulated to annual risk, risk curve as standard to evaluate multiple danger risk and reduction of disaster risk shall be used.

If risk curve regarding certain type of danger has been calculated, conversion it into AAL which is annual estimated loss that averages for long period of time is important. In calculation, AAL is summation of accident loss and accident occurrence probability regarding every probable accident in loss model. Total annual risk is total area under the danger curve. X-axis of danger curve indicates loss and Y-axis indicates annual occurrence probability. Dots in the curve represents occurrence period that performed analysis and related loss. There are 2 ‘Graphical’ methods that could calculate total area under the curve.

1. Triangle and rectangle method

By connecting two dots in the curve on the bottom of the curve area by straight line and divide them into triangles and calculate difference in loss between two scenarios as difference in X-axis. Y-axis of the two scenarios is difference in probability. Remaining areas under to curve is comprised of rectangles as explained in Figure 5.

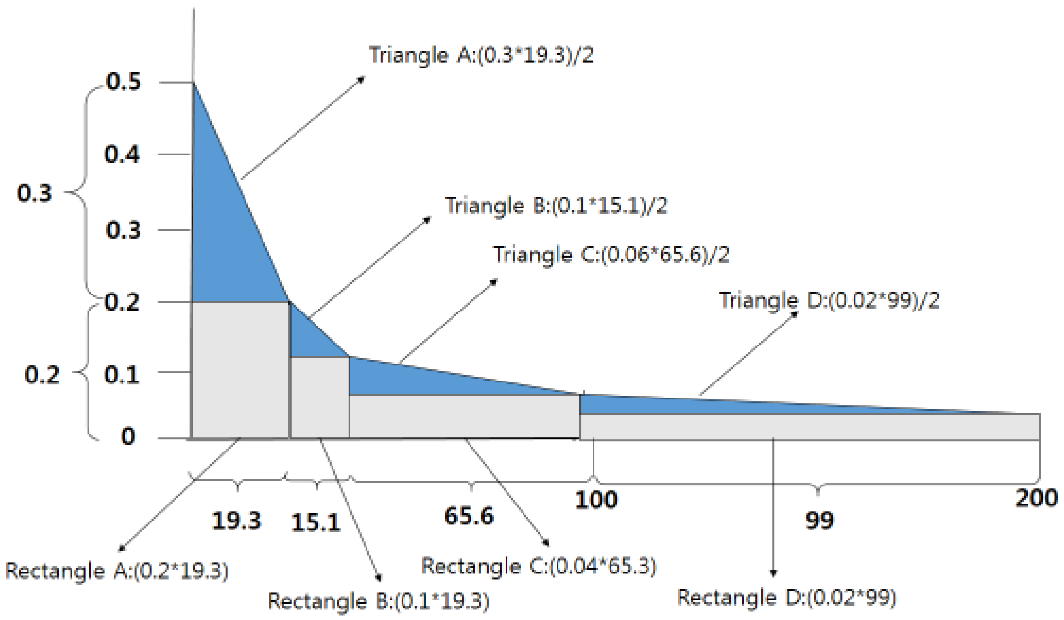

Figure 5. Method of Triangle and Rectangle

2. Simplified rectangle method

This method calculates bottom area of the curve by simplifying graph to rectangles. Mark Y-axis of the curve as difference in consecutive scenarios and mark X-axis as average loss between consecutive losses. Also, graph may be represented as function and this function may be applied in calculation of area under the curve.

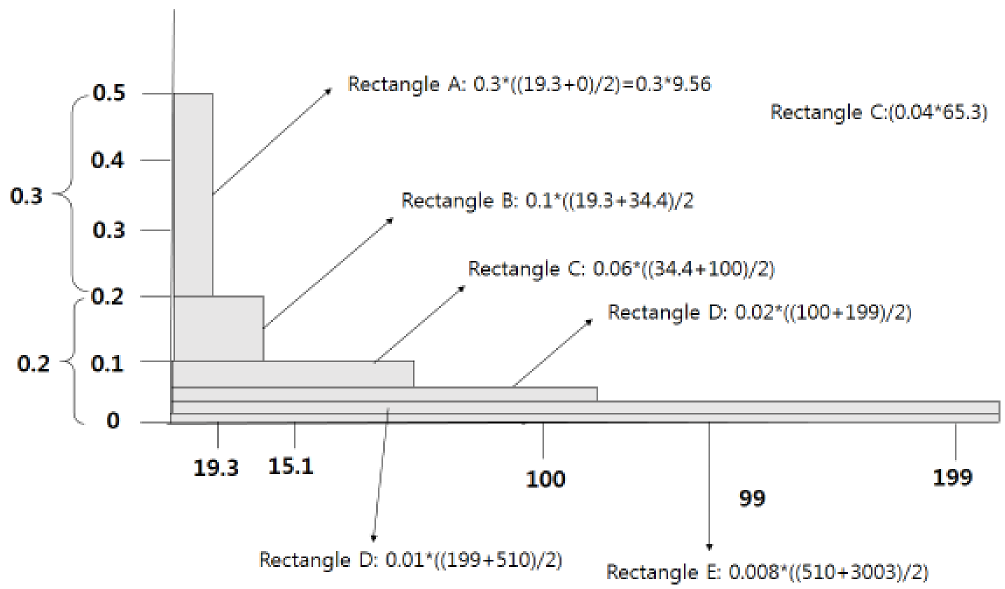

Figure 6. Method of Rectangle

1.4.4 Risk evaluation method for social disaster

Compared to existing natural disaster (Hurricane and flood) where mathematical model exists, social disaster such as fire, explosive and exposure of harmful substances are difficult to be evaluated for its timing, scope and size. Therefore, this research had conducted research that defines weighted value by focusing on danger material and fire vulnerable places within local society. During the process, risk evaluation method applied has been determined to be applied in RISK-CITY that would consider less important factors such as wind direction and humidity in disaster occurrence time as multiple danger risk evaluation method.

2. Result of the research

2.1 Final outcome of the research

2.1.1 Reform of national spatial information listing classification system

Spatial information stored in central department, city government, basic local community, public department and agent department in Korea is approximately 90,000, however, it is true that use of the spatial information is low due to absence of listing of information required in disaster management. Also, type of disaster that occurs frequently in domestic (Flood, landslide) is partially provided however, spatial information list regarding social disaster occurring due to recent change of climate and complex and diversified of disaster is still weak. Therefore, as accomplishment of research, it aims to construct integral system for mutual utilization by reconstructing classification system of national spatial information listing.

2.1.2 Reclassification of listing information regarding spatial information useable for each type of disaster

Characteristics of main disaster occurred recently is that it affects other types of natural or social disaster after occurrence of natural disaster or it shows tendency of Multi-Hazard which causes more than 2 natural disasters spontaneously. In order for constructed spatial information to be used in disaster sector, classification of spatial information per disaster type is required. In this research, by investigating spatial information that can be used in disaster section, it aimed to conduct work that lists per disaster type. Also, by distinguishing spatial information list per disaster type and basic information and detail Meta-information and completed spatial information list that provides and creates it internally in utilization system (Total of 329).

2.1.3 Establishment of expansion of combination disaster risk technology through RISK-CITY for construction of spatial information database model.

By planning new database model that is capable of integration with information and developing combination disaster risk evaluation model, risk evaluation technology in local government level in perspective of academic/technology has been aimed for improvement. Compared to existing level where information on building regarding local characteristics and construction characteristics could not be connected and integrated with combination disaster risk evaluation, this research constructed data to be able to provide time series information that considers time changes when estimating disaster occurring probability in disaster section. With support of disaster control information from Korea NDMS (National Disaster Management System), past occurrence listing information has been categorized to analyze frequency of disaster occurrence and size per disaster type. Based on the above database, RISK-CITY system has been developed and constructed evaluation system that is capable of controlling every spatial/social unstable analysis index occurring in the event of multiple disaster. During the process, qualitative method using risk matrix, semi-quantitative method that uses index and spatial multi criteria evaluation and qualitative method using probability approach method has been applied.

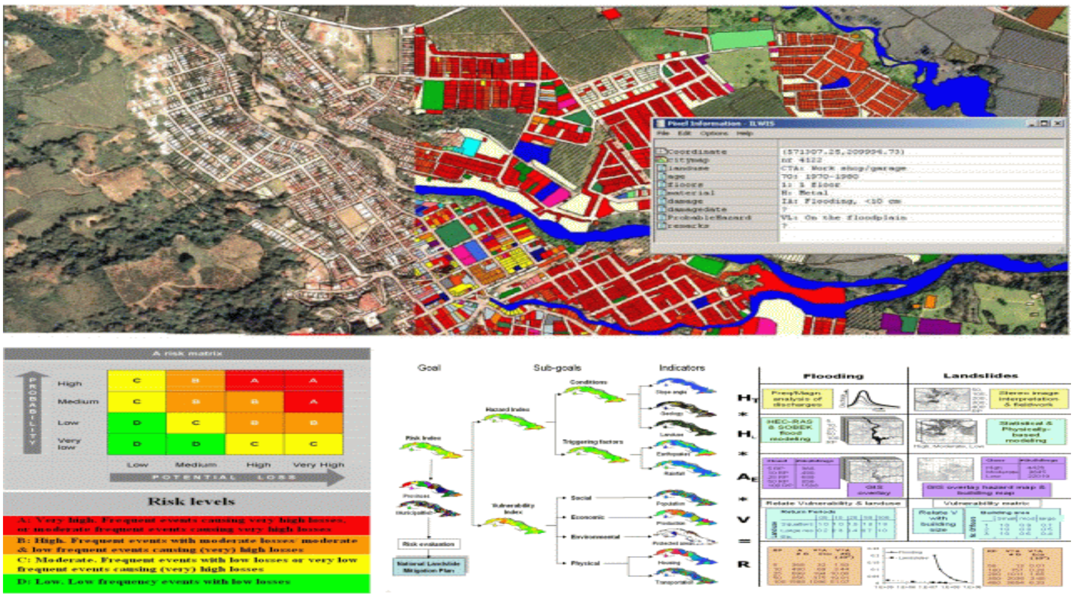

Figure 7 Complexed Disaster Risk Assessment Method (RISK-CITY)

3. Conclusion

In this paper, we conducted a study on urban risk management using GIS and the contents are as follows

1. Disaster mechanism analysis and real-time predictive technology about social disaster
2. Disaster monitoring and risk assessment technology about social disaster
3. Disaster Response technology and public protection technology about social disaster

Unlike the natural disaster, Disaster of modern society is becoming complex and diverse. So, the process of disaster study also changes in accordance with the mechanisms. Especially, in addition to the approach of past engineering method, adding the humanities and social concept also should be regarded. So if we study an in-depth study about decision-making process, it would be better study subject about comprehensive risk assessment.

REFERENCES

Yoon. H. S., Cho. J.M., Choi. H. J., Hwang. J. S., 2014, disaster risk evaluation, Moonwoondang, p443-482

Castellanos. A., Van. W. C. J., 2007, Qualitative landslide susceptibility assessment by multicriteria analysis: a case study from san Antonio del sur, Guantanamo, Cuba, Geomorphology

FEMA, 2008, Mitigation Planning : How to suides, Federal emergency management agency.

HAZUS, 2004, Multi-hazard loss Estimation methodology, FEMA, USA

GDACS, 2014, Global disaster alert and coordination system: timely information for the, emergency response and humanitarian communities.

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