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Master of Science

Understanding Social Disaster Resilience Using Geographically Weighted Regression: A Case Study of Seoul Metropolitan Area

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Abstract

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Quantifying urban resilience under disaster events have been interested scholars through considerable period of time. Although many researches have tried to assess various dimensions of community resilience, it is still challenging to select significant attributes that can be used for the assessment model, especially for social resilience. This study proposes a practical assessment model of social resilience through the following steps: (1)

examining appropriate variables that are considered to be related to disaster damage, (2) analyzing the impact of spatial heterogeneity of the social attributes by using Geographically Weighted Regression (GWR) method. A Geographic Information System (GIS) software, was used for the visualization of the assessment result. Through an experimental case study on Seoul Metropolitan Area, the author proposes meaningful variables and distinguishes the relationship between disaster damage and social resilience. 5 variables including population density, vulnerable age, disability, administrative service, and multi-cultural population are determined as related proxy variables to social resilience. Significant coefficients representing the influence of each variable to social resilience is derived in positive and negative values. The study looks forward to support the decision-making process of disaster management and to improve current disaster mitigation project planning.

Keywords: Disaster management, Disaster Resilience, Social Resilience, Geographically weighted regression (GWR), Seoul.

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Chapter 1. Introduction

1.1 Research Background

Natural disasters occur suddenly, having the potential to cause great damage to individuals, families, communities. The frequency and severity of natural disaster is expected to increase, especially for extreme events that are related to climate change (IPCC, 2014).

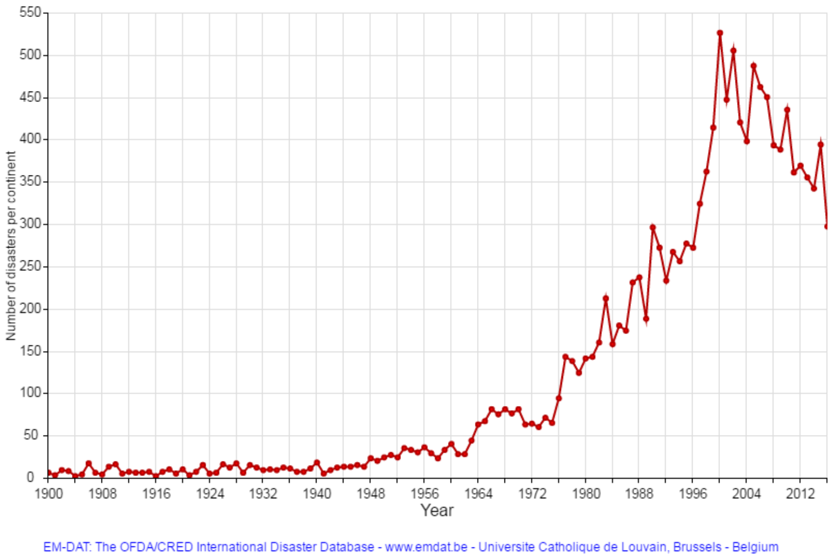

Figure 1.1 Natural Disaster Trend (International Disaster Database, 2016)

In particular, both domestically and internationally flood and storm are reported to be the major disasters around the world. These disasters are generally defined as climate-related natural disaster. Urban communities may suffer greatly from disaster losses due to their high population density and regional characteristics (Rose, 2004; Lindell et al., 2003).

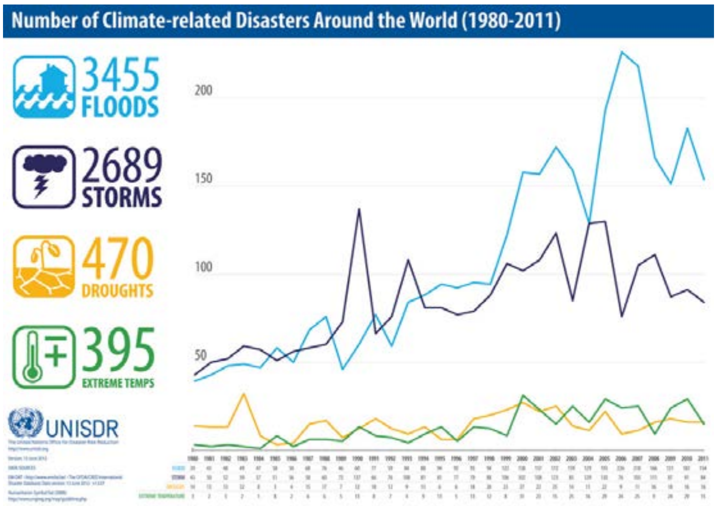

Figure 1.2 World Climate-related Disasters (UNISDR, 2012)

‘Impacted population’ is commonly used as an indicator for defining disaster losses. However, problems related to data quality arise that limit the applicability of approaches, for example, in cases of large urban cities, municipal or metropolitan government could overlook the cumulative impact on small proportions. Substantial information on residents could be lost by the exclusive approach (Mossler, 1996; Pelling and Uitto, 2001), therefore, it is necessary to develop comprehensive study on defining disaster losses.

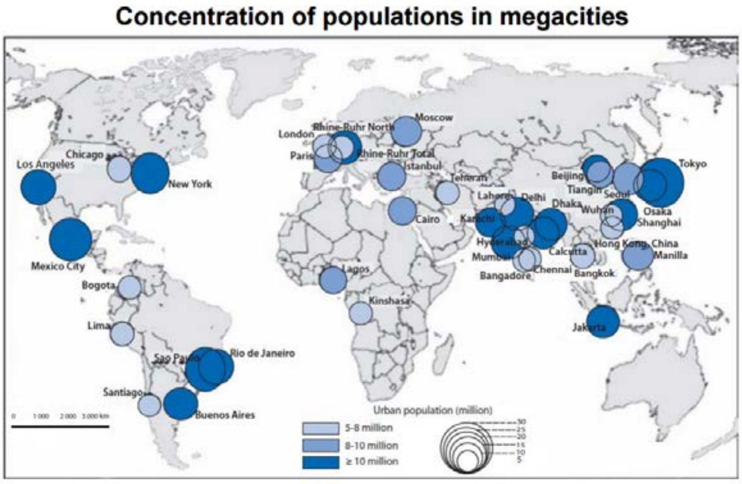

Figure 1.3 Concentration of Populations in Megacities (UN, 2002)

Recent studies have discovered that the degree of damage losses can vary depending on the vulnerability of the community (O’donnell et al., 2016). However, considerable research focused on examining components of physical and built environment related vulnerability (Mileti, 1999; Lewis, 1999). Social aspects of vulnerability are notably less considered, although the overall disaster impact is produced by interactions of the two, social and physical vulnerabilities (Cutter et al., 2003). The importance of social vulnerability was underlined by the former UN Secretary-General Kofi Annan as well, that hazards only become disasters when people’s lives and livelihoods matter (Annan, 2003). Reflecting the global attention considerably, studies on disaster resilience suggest that the social aspects must be carefully considered as well as physical aspects for comprehensive understanding.

In extension of social vulnerability, the concept of ‘disaster resilience’ has emerged recently as an important measure. As avoiding the occurrence of natural disaster is becoming more difficult, building ‘resilient city’ is getting more attention to urban communities as a common objective. Many research fields, including structural engineering, social science, and economics, are evaluating the local performance to natural disaster in terms of resilience. (Cutter et al., 2008). ‘Resilience’ has a number of definitions, but in common, it is defined as the ability to minimize the total impact of disastrous events. In urban cities, for example, the ultimate outcome of disaster can differ depending on the community resilience. Through the enhancement of resistance, robustness to extreme events, and effective recovery strategies, minimizing direct and indirect losses from hazards is possible (Bocchini et al. 2014). A number of integrative frameworks have emerged that present resilience as a useful concept in analyzing how social relations deal with stress is extensive (Matyas et al., 2012). However, still limited research has been done on social resilience, especially for urban disaster management.

Table 1.1 Theoretical and Practical Trends to Resilience

	Theoretical	**Practical**
Physical Aspects	Traditional	Mature
Social Aspects	Cutting-edge	Immature

Along with international trends, the domestic practices on disaster management are recognizing the shortage of consideration on social aspects to natural disasters. The Comprehensive Plan for Storm and Flood Damage Reduction (CPSFDR) of Korean government deficiently consider social aspects, regarding them as inferior parts. The government attempts to develop advanced analytical techniques for the effect of natural disaster, comprehensively considering regional characteristics in the context of sustainability (NEMA, 2007). Currently, due to deficient fundamental research related to sustainable development and community resilience, implementation of disaster management policy has been facing difficulties (Kim et al., 2015).

1.2 Problem Statement

The ‘resilience’ perspective in disaster, which is rapidly emerging as a dominant view in the disaster research field, assumes that a real disaster occurs when it strikes an underprivileged population. Since social aspects of a community resilience may play a major role before, during, and after a disaster, assessing social aspects is considerably important.

However, most of the study on disaster research from the past have focused mainly on physical aspects, and little research effort focused on comparing the social resilience has been done (Cutter, 2003). Risk assessments must take into account the data on vulnerability, both physical and social (De Groeve et al., 2013), however, the international community does not formulate guidelines for hazard mitigation typically focusing on the unique needs and characteristics of cities under stress (Godschalk, 2003, Birkmann, 2006).

Also, the current domestic assessment of storm and flood mitigation project planning majorly focuses on physical aspects related to disaster itself including damaged area, damaged cost, etc. Thus it is necessary to examine the regional social aspects for comprehensive understanding of overall resilience.

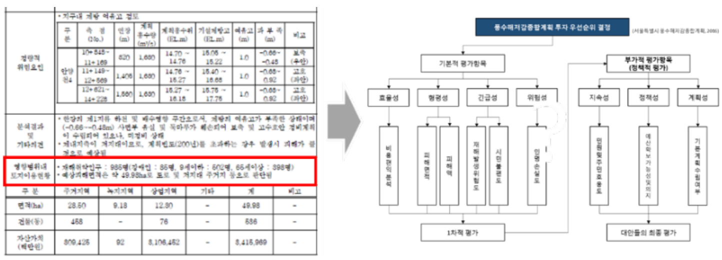

Figure 1.4 Limited Social Aspects in the Assessment Process

In particular, the current stage of social resilience study in disaster management research is limited in conceptual model building. This brings difficulties to apply social characteristics for disaster management decision making process. Therefore, developing the assessment model is necessary for more applicable implementation. The assessment model should provide practical results so that it can be discussed for actual use, as well as further development of model itself. Along with model development, assorting reasonable attributes is another important subject to be studied as there exists a diversity of opinions in the research field.

1.3 Research Objectives

The primary objective of this study is developing a disaster assessment model focusing on the social aspects in perspective of urban resilience. Instead of defining disasters fragmentally as physical occurrence, this study aims to view disaster as a result of the complex interaction between a potentially damaging physical events (e.g. floods, storms, and earth quakes) and the vulnerability of a society which are determined by human-related features.

Through an experimental case study, the author proposes meaningful attributes and distinguishes the relationship between disaster damage and social resilience. The study can support mitigation project planning process by applying understandings of regional social aspects.

The specific objectives to achieve the primary objective are as follows:

1) Examine regional social resilience attributes that are considered to be related to disaster damage.
2) Analyze the impact of spatial heterogeneity of the social attributes on the scale of resilience.
3) Develop an assessment model by applying the selected regional social attributes.
4) Evaluate the model and discuss the result for mitigation project planning usage.

1.4 Research Scope

This study focuses on designing and developing disaster assessment model in terms of social resilience. Seoul, the capital of South Korea, has been selected as the target urban community for the case study of the model as it was reported as one of the most vulnerable city. Thus, most of the contents studied and data used in this research is based on Seoul. The author studied the current assessment method of Seoul for storm and flood mitigation planning, and used the statistical data from Seoul Open Data Plaza, Seoul Statistics, and Statistics Korea.

Although the author recognizes that it is fairly important to consider both physical and social aspects for multi-hazard assessment, this paper is limited on developing assessment model of social resilience. Further study on integration of both aspects should be developed later on.

1.5 Research Process

This paper is organized as follows. Related literature, including disaster resilience, social vulnerability and principal technologies, is reviewed in Chapter 2. Variable selection and assessment of social resilience attributes to urban storm and flood disasters is proposed in Chapter 3, and Chapter 4 describes the evaluation of the model. The paper concludes with contributions and future research opportunities of the study in Chapter 5.

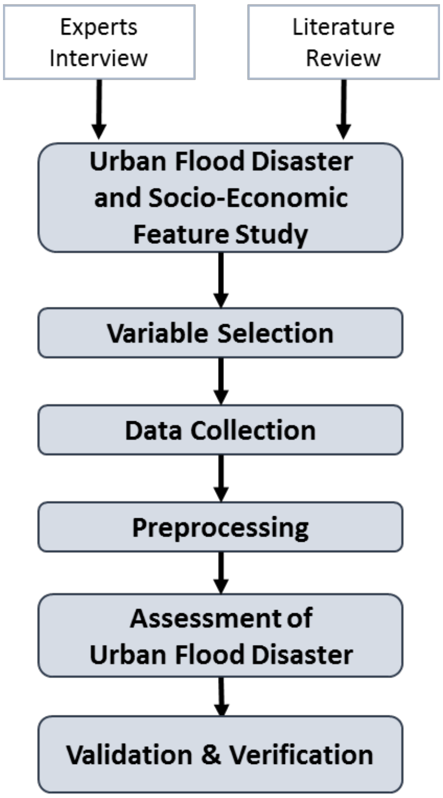

Figure 1.5 Research Process

Chapter 2. Literature Review

2.1 Disaster Resilience and Social Vulnerability

2.1.1 Disaster Resilience

The general concept of resilience emerged from several researches, ranging from environmental research to material science and engineering, psychology, sociology, and so on. As it has been studied extensively, the definition varies by researchers. Hollings (1973) and Perrings (2001) have defined resilience as the capacity to absorb stress and shock, embracing the concept of sustainability. Wildavsky (1991) defined resilience as the ability to bounce back, coping with from unanticipated dangers. Horne and Orr (1998) proposed system resilience as the ability of withstanding stresses by individuals, groups, organizations, and system as a whole. Tinch (1998) specified similar measures like stability, persistence, resistance, non-vulnerability and resilience. Rose (2004) distinguished resilience for two types, inherent resilience in normal circumstances, and adaptive resilience in crisis situations. In a broader concept, it can be defined as the ability of a system to recover from a serious shock.

Also in disaster studies, opinions on disaster resilience are diverse. Comfort (1999) defined resilience as capacity that adapts existing resources to new situations, focusing on post-disaster response. Afterward, Bruneau et al.

(2003) defined resilience as the ability of social units to mitigate hazards for earthquake disaster. They divided resilience into three aspects: ability to reduce failure probability, ability to reduce consequences from failures (e.g. lives lost, damage, and negative economic and social consequences), and ability to reduce recovery time to before-disaster level. This involves both pre-disaster measures that seek to prevent damage and losses, and post-disaster strategies that cope with minimizing disaster impacts.

Bruneau et al. (2003) illustrated the conceptual measure of resilience on seismic events.

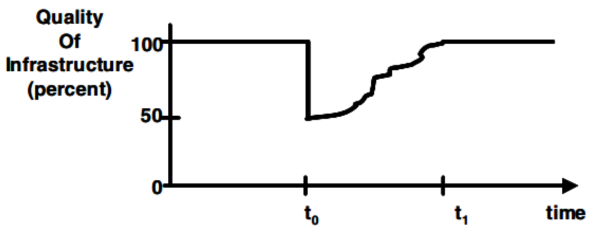

Figure 2.1 Measure of seismic resilience-conceptual definition (Bruneau et al., 2003)

$\mathrm{Q(t)}$ = Quality of Infrastructure (100%=no degradation in service, 0%=no service available)

Community loss of resilience, R, can be measured by the sized of failure. Mathematically, it can be expressed by the following equation:

$$R = \int_{t_0}^{t_1} 100 - \mathrm{Q(t)} dt$$

R = Community loss of resilience

t_0=initial time of disaster occurrence

t_1=recovered time from disaster event

Resilience can be conceptually categorized into four interrelated dimensions: technical, organizational, social, and economic.

Table 2.1 Conceptual Dimensions of Resilience, (Bruneau et al., 2003)

Dimensions	**Definitions**
Technical	the ability of physical systems to perform acceptable level from disaster forces (components and their interconnections and interactions)
Organizational	the capacity of responsible organizations involved in disaster management to make effective decisions for achieving greater resilience: robustness, redundancy, resourcefulness, and rapidity.
Social	the measures that are specifically designed to figure out communities that suffer negative consequences due to social insufficiency.
Economic	the capacity to reduce both direct and indirect economic losses resulting from disasters.

2.1.2 Social Vulnerability and Resilience

Vulnerability is the inherent characteristics of communities that create the potential for disaster losses. It is a function consisted of two values, exposure and sensitivity. Generally, it is involved in the pre-disaster stage (Cutter, 1996; Adger, 2006; Cutter, 2008). The concept evolved out form the social sciences and was introduced as a response to the purely hazard-oriented perception of disaster risk in the 1970s (Schneiderbauer et al., 2004). Afterwards, alternative paradigm of using vulnerability emerged, challenging the hazard-oriented researches. The susceptibility of people and communities exposed with their social, economic and cultural abilities to cope with the damage was studied by this approach (Hillhorst et al., 2004).

Resilience, on the other hand, is the ability of a community to respond and recover from disasters (see Chapter 2.1.1 for more detail). This includes the inherent conditions for absorbing impacts, reactions to the disaster event, and adaptive processes of rebuilding and learning after the disaster.

In this paper, both ‘vulnerability’ and ‘resilience’ are used. The aim of the research is to develop an assessment model that can support the mitigation project planning process. Since mitigation techniques and planning can increase the community resilience to disaster (Burby et al., 2000; Bruneau et al., 2003; Cutter et al., 2008), the terminology ‘resilience’ is more used in order to analyze the result in a more resilience perspective view. However, it is notable that the relationship between vulnerability and resilience is still not well defined. Still much uncertainty about what the terms vulnerability and resilience cover.

In figure 7, the relationships of such concepts are shown according to various research perspectives (Smit et al., 1999; Paton and Johnson, 2001; Burton et al., 2002; Turner et al., 2003; O’Brien et al., 2004; Adger, 2006; Birkmann, 2006; Folke, 2006; Gallopin, 2006; Manyena, 2006; Tierney and Bruneau, 2007).

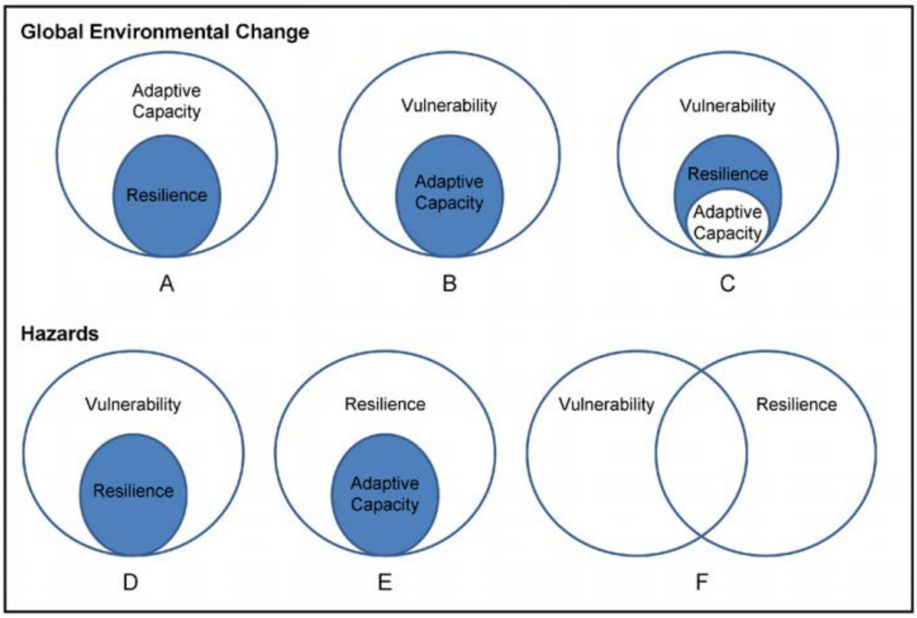

Figure 2.2 Conceptual Linkages between Vulnerability and Resilience (Cutter et al., 2008)

This study views resilience and vulnerability as a separate theme but a linked concept as Cutter et al. (2008). Thus, it is not limited to intrinsic resilience characteristics but partly involving some characteristics of vulnerability. As Cardona (2004) underlines, this research agrees with the concept of vulnerability helped to clarify the concepts of risk and disaster.

In this study, the author defines ‘vulnerability’ as a previous status or characteristic of an impacted community, whereas ‘resilience’ as an ongoing status or characteristic of an impacted community, before, during, and after a disastrous event. As this study focuses on the overall process of communities from disaster, it will use the term ‘resilience’ for the assessment analysis.

2.2 Disaster Mitigation Project Planning

One of the main strategy to deal with climate-related disasters like flood and storm is to implement mitigation plans. Disaster mitigation measures are those that eliminate or reduce the impacts and risks of hazards through proactive measures taken before an emergency or disaster occurs. The emphasis on mitigation and prevention stages have increasingly grown as they take action before a disaster for loss reduction (Rose, 2004; Mileti, 1999). Along with mitigation, community gain ability to cushion or reduce loss through regional resilience (Rose, 2004). As such, mitigation projects are highly influential to disaster management strategy in terms of resilience. Local governments recognize the responsibility to protect the safety and welfare of their citizens from natural disasters. Proactive mitigation policies help reduce risk and create more disaster-resilient communities (FEMA, 2013). However, due to lack of budget and administrative efficiency, not all community can be supported by new mitigation plans. Hence, the need of proper examination and analysis method for mitigation implementation will continue to increase, in order to support equitable mitigation project selection decision-making.

The Korean government implements 3 major management plans for flood and storm management. To ensure that the flood disaster policy vision is consistently maintained, Seoul checked its disaster prevention system every time there was a major flood (in 1984, 1987, 1990, 1998, and 2001) and came up with mid-term to long-term countermeasures to supplement the existing system.

Table 2.2 Mitigation Management Plans for Urban Cities in Korea

River Management Plan	**Sewerage Management Plan**	**Storm and Flood Damage Reduction Plan**
Quantitative	Quantitative	Qualitative
10 years	20 years	10 years (5 year modification)
MOLIT (Ministry of Land, Infrastructure and Transport)	ME (Ministry of Environment)	MPSS (Ministry of Public Safety and Security)

2.3 Social Resilience Assessments

Although many research primarily focused on natural hazards and their quantification, a paradigm shift has been required towards the identification and assessment of various vulnerabilities of social resilience (Maskrey, 1993; Lavell, 1996; Bogardi et al., 2004; Birkmann, 2006). Recent studies view disaster as a result of the complex interaction between a potentially damaging physical event and the vulnerability of society (Birkmann, 2006). In this perspective, natural disasters can be understood as "un-natural disasters" (Cardona, 1993; van Ginkel, 2005).

The UN declaration from the World Conference on Disaster Reduction, "Hyogo Framework for Action 2005-2015" pointed out that:

The starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken on the basis of knowledge (UN, 2005).

It stresses out the need of developing indicators of vulnerability:

Develop systems of indicators of disaster risk and vulnerability at national *and sub-national scales that will enable decision-makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to decision makers, the public and populations at risk (UN, 2005).*

Through appropriate assessment model for community resilience, three important contributions can be derived. First, disaster managers can determine the need for external assistance by using the information. Second, disaster impacts can be identified specifically by the segments of regional disproportionableness (e.g., low-income, households, ethnic minorities, or specific types of business). Third, administrative planners can develop mitigation project plans concentrating on both efficiency and equality.

In order to expand research from hazard-oriented view to human-oriented view, identifying various attributes and testing relevant indicators with well-made assessment model is necessary (UN, 2005; Birkmann 2005; Brauch, 2005). The Hyogo Framework for Action underlines three major aspects that should considered while assessing the impact on disaster: social, economic, and environmental conditions. The declaration emphasizes the necessity to develop methods and indicator which can be used in policy and decision-making processes.

The paradox that we aim to measure social resilience, yet we cannot define it precisely makes it complicated to sort relative indicators. However, as various disciplines have developed their own definitions and pre-analytic visions of meanings, the author over viewed 10 assessment models on vulnerability and sorted out indicators in the view of social resilience.

1) The Risk Vulnerability Assessment Tool (RVAT) was developed by the National Oceanic and Atmospheric Administration (NOAA). It is a tool that helps identify people, property, and resources that are at risk of injury, damage, or loss from hazardous incidents or natural hazards (Coletti et al., 2013). The model consists of variables such as age, ethnic inequality, poverty, etc.

2) The European Spatial Planning Observation Network (EPSON) project published a risk assessment based on historical tsunami events and seismic hazard. The map classifies coastal areas in Europe according to the probability of a tsunami occurrence. It was set up to support policy development and to build a European scientific community in the field of territorial development (De Groeve et al., 2013). The model consists of variables such as population density, age, education, regional affordability, etc.

3) The Flood Vulnerability Index (FVI) is an index for assessing vulnerability to flood disasters that can be applied at the river basin level. The main objective of FVI is to be useful as versatile applications for policy-making on flood disasters by governmental decision makers (Hara et al., 2009). The model consists of variables such as population density, age, poverty, etc.

4) The Baseline Resilience Indicators for Communities (BRIC) is an empirically-based resilience metric that was developed to compute

related indicators for use in a policy context. (Cutter et al., 2014). It is based on the Disaster Resilience of Place (DROP) model that defines a set of indicators that measure exclusively the antecedent conditions within communities. The model provides conceptualization for understanding and measuring community-level resilience to natural hazards. The model consists of variables such as age, foreigner, disability, etc.

5) The United States Agency for International Development (USAID) has adapted a resilience domain framework and identified a number of potential indicators under each domain. The framework makes use of existing indicators and data already collected in surveys, adding in a limited set of additional measures. USAID defines resilience as "the ability of people, households, communities, countries and systems (social, economic, ecological) to mitigate, adapt to, recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth". The key points of this model are that resilience is not an outcome, but a capacity that influences outcomes, and should be measured at multiple levels. The model consists of variables such as age, education, social assistance, etc.

6) The DRLA/UEH model was developed by Disaster Resilience Leadership Academy (DRLA) in partnership with the State University of Haiti (UEH). The framework was created to evaluate the large scale humanitarian assistance that occurred in response to the Haiti

earthquake. It measures the connection between an event, humanitarian assistance and resilience. It measures seven resilience dimensions: wealth, debt and credit, coping behaviors, human capital protection and security, community networks, and psychosocial status. The model consists of variables such as education, social assistance, crime/security, etc.

7) The FAO resilience framework looks at the root causes of household vulnerability instead of trying to predict how well households will cope with future crisis or disasters. FAO defines resilience as “the ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner”. The factors considered in the model are combined intro an index which gives an overall quantitative ‘resilience score’. The score shows where investments need to be made to further build resilience. The aim of the model is to provide information for decision makers to objectively target their actions and measure their results over time. The model consists of variables such as education, social assistance, health access, etc.

8) The National Emergency Management Agency (NEMA) of South Korea published assessment on regional safety from disasters (NEMA, 2008). Including the NEMA assessment, domestic studies of disaster vulnerability assessment had limitations in variables (Park et al., 2006; Lee et al., 2007; NEMA, 2008). However, although most of the

indicators are focused on the physical aspects of the geology and hazard, some measures are related to community characteristics, opening its potential to consideration of social resilience. The models generally consist of variables such as population density and disability, etc.

Table 2.3 Variable List

No.	Category	Variable	RVAT	EPSON	FVI	BRIC	USAID	DRLA/UEH	FAO	NEMA	Park et al. (2006)	Lee et al. (2007)
1		Population Density		●	●					●	●	●
2		Age	●	●	●	●	●					
3		Ethnic Inequality	●									
4	**Human**	Foreigner				●						
5		Disability				●				●		
6		Poor	●									
7		Education		●		●	●	●	●			
8		Social Assistance				●	●	●	●			
9		Political Power				●						
10	**Social**	Crime/Security				●		●	●			
11		Health Access							●			
12		Population Wellness				●						
13		Migration						●				
14		Housing Asset					●	●	●		●	●
15		Income		●			●		●			
16	**Economic**	Homeownership				●	●					
17		Employment				●	●		●			
18		Female Labor Participation					●					
19		Business Environment				●						
20		Admitistrative Work									●	
21	**Administrative**	Regional Affordability		●							●	
22		Shleter Capacity				●		●				

From the comprehensive study of the existing research models of resilience assessment, relative indicators to measure social resilience has been chosen. Although previous studies provide various indicators that can have relationship with disaster resilience, still it is hard to understand the actual influence or significance of the indicators to resilience. Discussion on these indicators continues in Chapter 3.1 for their reflection to the analysis model.

2.4 Geographically Weighted Regression (GWR)

Geographically weighted regression (GWR) is a technique of spatial analysis which captures the variation of spatial data to analyze the relationship of points in space (Brunsdon et al., 1996).

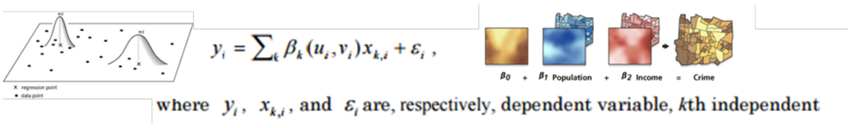

Figure 2.3 Concept of Geographically Weighted Regression

The topological, geometric, or geographic property information can be used for geographically weighted regression analysis. Through the analysis, spatial dependency of each variables derive information of spatial relationship. The variables can be sorted into independent and dependent type. The relationship between the two types of variables provides information of the spatial heterogeneity. Thus, estimated parameters can be generated for each spatial point through geographically weighted regression technique (Fotheringham et al., 1998).

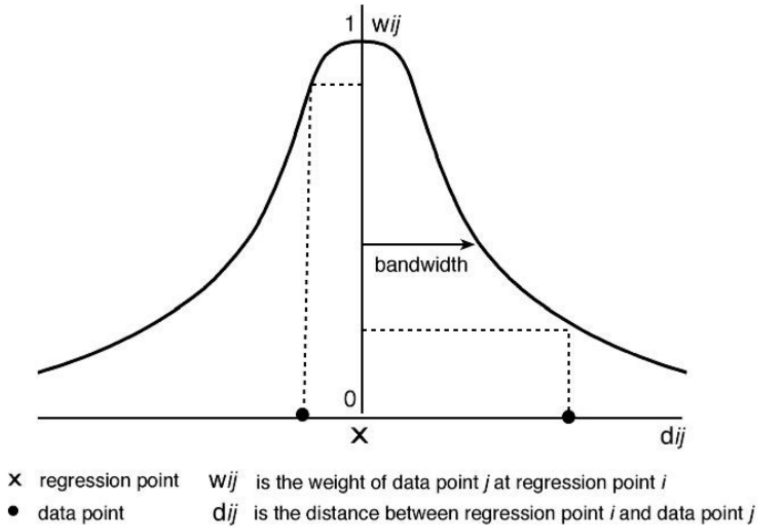

Figure 2.4 Typical Spatial Weighting Function

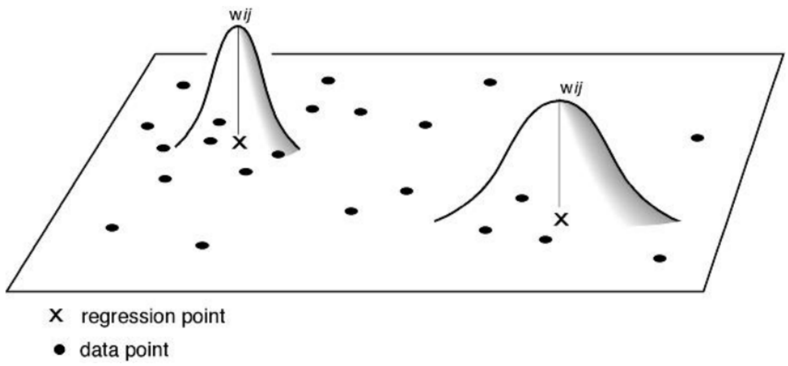

Figure 2.5 Spatially Adaptive Weighting Scheme

The GWR4 software used in this study was developed and programmed by Professor Tomoki Nakaya of the Department of Geography, Ritsumeikan University, Kyoto, Japan.

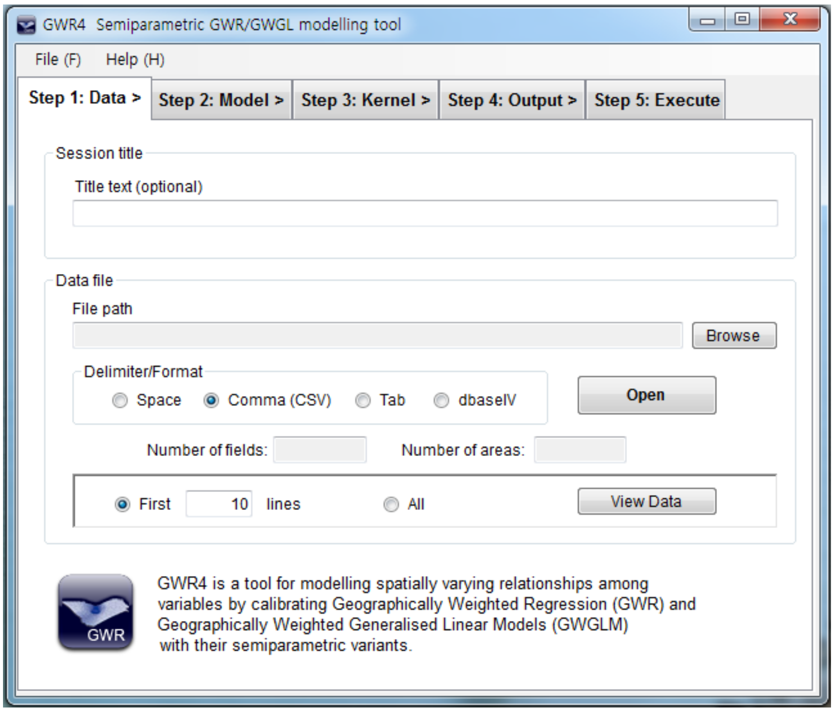

Figure 2.6 GWR4 - a modelling software for GWR method

GWR4 software provides features for model fitting including conventional Gaussian models and generalized linear models such as geographically weighted Poisson and logistic regression models.

As the software also provides ordinary least square (OLS) model results, it is useful to compare both the results of GWR and OLS. In addition, ordinary least squares (OLS) is a method estimating parameters in a linear regression model. It uses the method to minimize the sum of squares of the difference between observation and prediction of variables. The method provides minimum variance estimation, under the assumption that errors are normally distributed.

2.5 Visualization/Geographic Information System (GIS)

To provide better understanding of assessment results, geographic information systems (GIS) tool was used for data visualization. GIS has strong connection to spatial analysis, for example, the geographic data from spatial analysis can be easily managed through GIS platforms. This includes computing distance or connectivity of spatial data, and distributing both raw data and analysis results for visualization.

There exists various GIS packages that includes analytical tools, and often they offer software development kits (SDKs) or programming languages for further development of one's own analysis. In this study, Quantum-GIS (QGIS) is used for visualization. QGIS is an open source software that provides analytical tools for spatial data. By importing the raw data and assessment result data to the software, it was possible to represent the data on a spatial distribution format. Thus, easier understanding and decision making can be done through visualization.

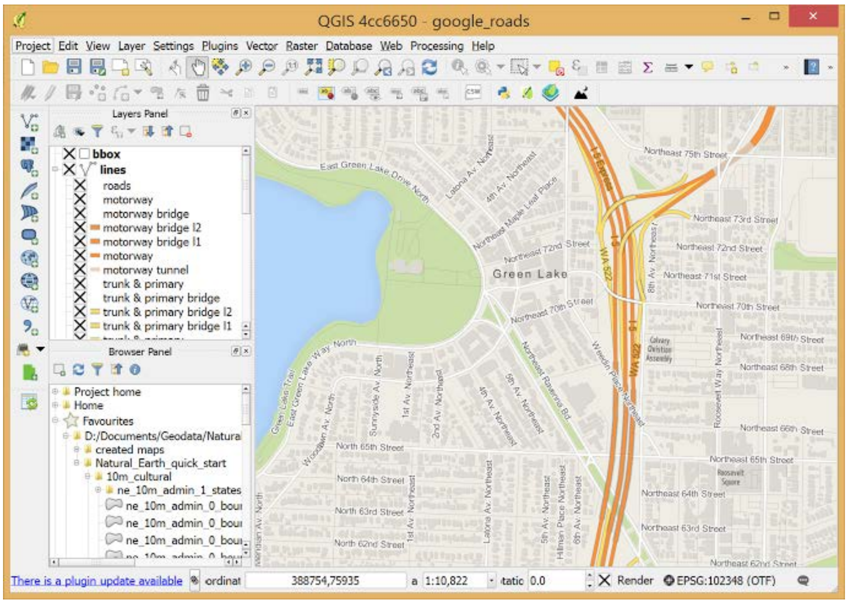

Figure 2.8 Quantum Geographical Information System (QGIS)

Chapter 3. Assessment Model Development

The primary objective of this study is developing a disaster assessment model focusing on the social aspects in perspective of urban resilience. Instead of defining disasters fragmentally as physical occurrence, this study aims to view disaster as a result of the complex interaction between a potentially damaging physical events (e.g. floods, storms, and earth quakes) and the vulnerability of a society which are determined by human-related features.

Through an experimental case study, the author proposes meaningful attributes and distinguishes the relationship between disaster damage and social resilience. The study can support mitigation project planning process by applying understandings of regional social aspects.

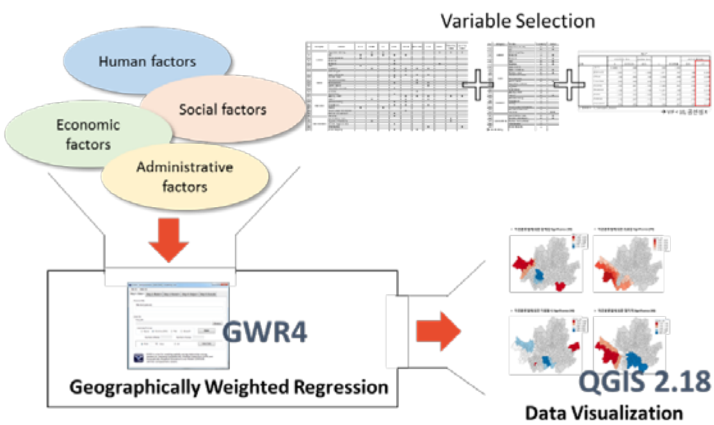

Figure 3.1 Process of Research Methodology

3.1 Variable Selection

To measure the spatial heterogeneity of regional social resilience, selecting appropriate and applicable variable needs to be done as first step. Since there exist numerous social resilience attributes related to storm and flood disaster, the selection process was carefully studied. The author reviewed literatures related to disaster/hazard assessment tools and models and specifically focused on common set of social resilience and vulnerability related attributes that those assessment tools and models include. 10 related research models were studied above in Chapter 2.3.

Table 4 in Chapter 2.3 shows the variable list studied by corresponding literatures. 22 variables are sorted from the 10 related research models. The variables are grouped into 4 categories: human, community, economic, and administrative.

For performing geographically weighted regression (GWR) analysis, correlation analysis and multicollinearity analysis was carried out

To examine the correlation between disaster damage status and social resilience variables, experimental data must be collected. The data from Seoul has been used for the reference of experimental data, as it is the area of interest for the main analysis later on. A total of 13 out of 29 variables are figured out to be significantly important according to the result of survey by relevant experts. The correlation analysis was done using these 13 proxy variables.

Table 3.1 Variables sorted out by Survey

No.	Category	Variable	Survey Result	Selection (Above 4)
1	Human	Population Density	6.514	○
2		Age	5.371	○
3		Ethnic Inequality	4.771	○
4		Foreigner	3.829	
5		Disability	5.086	○
6		Poor	4.429	○
7		Education	3.114	
8	Community	Social Assistance	3.800	
9		Political Power	3.486	
10		Crime/Security	4.057	○
11		Health Access	5.314	○
12		Population Wellness	4.657	○
13		Migration	4.714	○
14	Economic	Hosing Asset	3.714	
15		Income	3.800	
16		Homeownership	3.743	
17		Employment	3.600	
18		Female Participation	3.457	
19		Business Environment	4.371	○
20	Administrative	Administrative Work	5.429	○
21		Regional Affordability	5.429	○
22		Shelter Capacity	5.886	○

A total of 5 out of 13 variables are identified to have significant correlation with the inundated areas from 2010 flood and typhoon damage of Seoul. The Pearson correlation was checked during this analysis, and variables that have p-value less than 0.05 was selected. Data were analyzed using correlation analysis through IBM SPSS Statistics 22.0 version.

Table 3.2 Result of Correlation Analysis

	Pearson 상관	유의확률(양측)	N
N_DamageH_2010	1		423
Population Density	**.113***	.020	423
Age	**.105***	.031	423
Disability	**.100***	.039	423
Poor	-.005	.916	423
Health Access	-.021	.667	423
Admitistrative Work	**.152****	.002	423
Shleter Capacity	.010	.845	423
Ethnic Inequality	**.266****	.000	423
Regional Affordability	-.043	.381	423
Migration	.028	.560	423
Crime	.010	.845	423
Health	-.033	.500	423
Business Environment	.063	.197	423

*. 상관관계가 0.05 수준에서 유의합니다(양측).

**. 상관관계가 0.01 수준에서 유의합니다(양측).

Then, the 13 variables were examined to see the multicollinearity between the variables. The variance inflation factor (VIF) was used to assess multicollinearity. Table 3.2 shows the result of the multicollinearity test. Generally, if the VIF result is less than 10, it can be assumed that there exists no multicollinearity. While multicollinearity does exit, VIF scores of less than

10 suggest that it will not significantly influence the stability of the parameter estimates (Diel-man, 1991).

The result is shown in Table 3.3. VIF score ranged between 1.096 and 3.357. Thus, all the 5 variables can be used for the regression model. Data were analyzed using the VIF test model of regression analysis through IBM SPSS Statistics 22.0 version.

Table 3.3 Result of Multicollinearity Analysis

모형		비표준화 계수		표준화 계수	t	유의확률	공선성 통계량	
		B	표준오차	베타			공차	VIF
1	(상수)	-62.904	39.210		-1.604	.109		
	Population Density	.000	.000	.054	1.092	.275	.912	1.096
	Age	-.002	.006	-.021	-.244	.807	.298	3.357
	Disability	-.012	.019	-.052	-.610	.542	.309	3.238
	Admitistrative Work	5.494	3.070	.126	1.790	.074	.444	2.255
	Ethnic Inequality	.526	.114	.236	4.620	.000	.845	1.183

In response to our first research question, it is clear that a common set of social resilience indicators can be applied to examine the variability in resilience among Seoul region. The proxy variables are population density, age, social assistance, political power and administrative work. These variables came out to be representing the social resilience measures.

3.2 Data Collection

3.2.1 Case Study Area: Seoul

Lloyd's City Risk Index 2015-2025 analyzed the potential impact on the economic output of 301 of the world's major cities from 18 manmade and natural threats. Seoul was evaluated to hold the third rank out of 301 cities for (all threats and) wind storm. The expected economic loss is $103.50 billion dollars, 2.27% of the total sum of all cities. Thus, Seoul is considered as one of the top vulnerable cities that has to deal with disaster, especially for wind storms.

Located at the heart of the Korean Peninsula, Seoul has always been an important strategic point throughout the centuries in terms of defense and the economy. Nearly 24 million of the population is settled around the capital city, Seoul. This metropolitan area of Seoul, Seoul Capital Area(SCA), is located in the north-west of South Korea. It is ranked as the 4th largest metropolitan area in the world, forming the cultural, commercial, financial, industrial, and residential center of South Korea. The Hangang (River) flows horizontally across Seoul, dividing the city into two sections lying north and south of the river. There are 25 autonomous districts and 423 administrative "dong" units in Seoul. The city covers 0.28% of the entire peninsula (or 0.61% of South Korea), and spans an area 30.30 km north-to-south and 34.78 km west-to-east (Seoul Metropolitan Government Website, 2016).

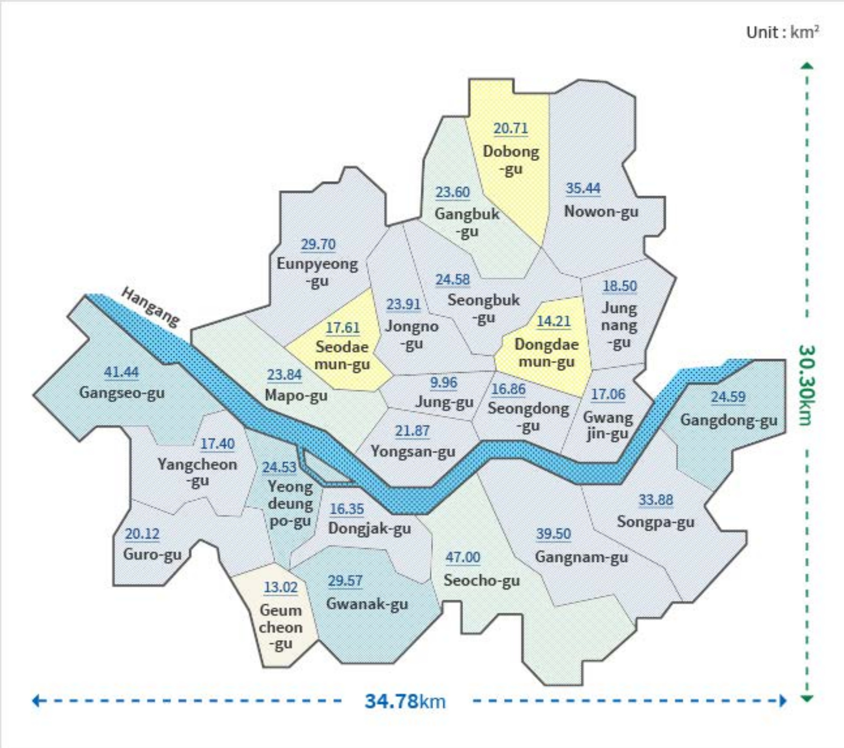

Figure 3.2 Distribution of the Districts of Seoul

(Seoul Metropolitan Government Website, 2016)

Seoul is a city with an intense concentration of political, economic and other urban functions. Its population is dense, and its buildings and underground networks are intricately structured. Flooding in such a city would result in considerable loss as well as prohibitive costs and restoration time. In Korea, two thirds of the annual rainfall is typically concentrated during the wet season from June to September, usually in the form of monsoons, typhoons or torrential rains.

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Temperature	-0.9	1.0	6.3	13.3	18.9	23.6	25.8	26.3	22.4	15.5	8.9	5.0	13.8
Rainfall	13.0	16.2	7.2	31.0	63.0	98.1	207.9	172.8	88.1	52.2	41.5	17.9	808

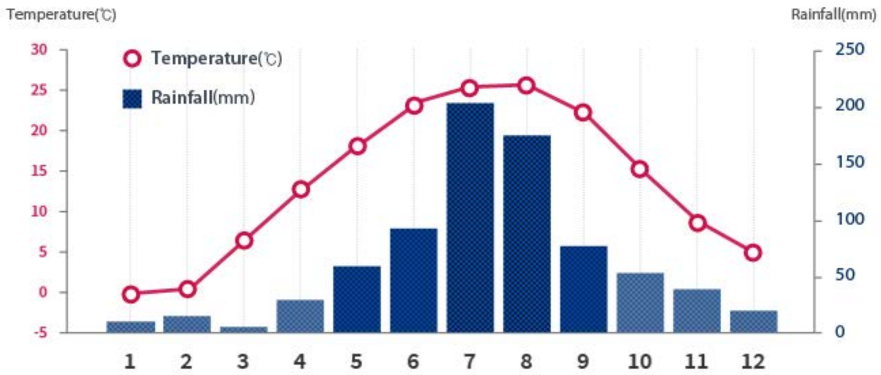

Figure 3.3 Average Temperature and Rainfall of Seoul

(Seoul Metropolitan Government Website, 2016)

3.2.2 Data Source

By addressing the departments of Seoul Metropolitan Government, the data of 5 proxy variables for regression analysis was collected. The flood damaged data (inundated area information) was collected through each district offices, thus it is possible that the total data can differ from the whole data that government syntagmatically collected. Most of the districts only stored flood damage data of 2010 and 2011, 2 major years that huge storm and heavy rainfalls hit Seoul.

Table 3.4 Details of Proxy variables

	Variable	Mean	Std. Deviation	N	Year
Y	Inundated Record	47.34	109.32	423	2010
X	Population Density	24928.70	12384.70	423	2014
	Disability	943.03	480.48	423	2014
	Age (under 5, over 65)	3859.92	1512.13	423	2014
	Administrative Work	15.87	2.51	423	2014
	Ethnic Inequality	53.44	49.00	423	2014

Figure 3.4 shows the distribution of inundated records of Seoul. This data represents the damaged areas from storm and flood disaster. It is important to note that the records had been made through reports of the residents. The study assumes that social aspects of impacted area may have influence to the damage reports which can be related to social resilience further on. Thus, inundated record used in this study represents the social resilience of the certain community.

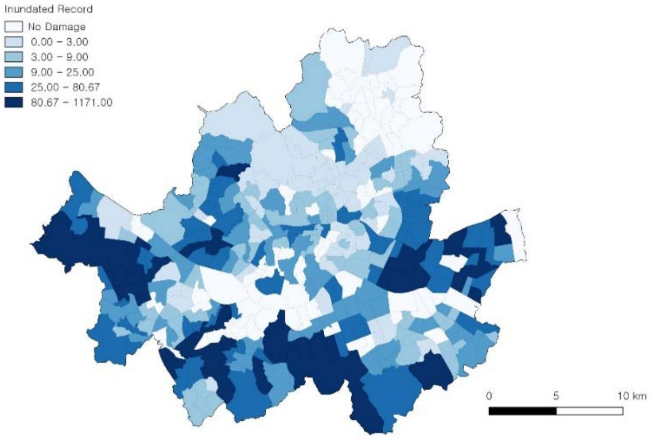

Figure 3.4 Distribution of Inundated Record

Figure 3.5 shows the distribution of population density of Seoul. This data is used for estimating the influence of population density on social resilience through assessment analysis.

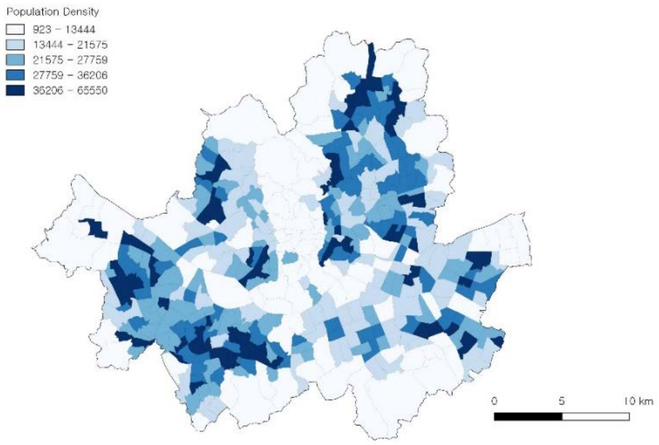

Figure 3.5 Distribution of Population Density

Figure 3.6 shows the distribution of vulnerable age population (age under 5 and over 65) of Seoul. This data is used for estimating the influence of vulnerable population by age on social resilience through assessment analysis.

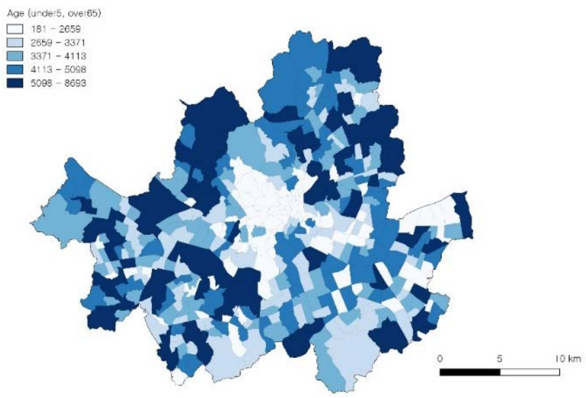

Figure 3.6 Distribution of Vulnerable Population by Age

Figure 3.7 shows the distribution of disabled population of Seoul. This data is used for estimating the influence of disabled population on social resilience through assessment analysis.

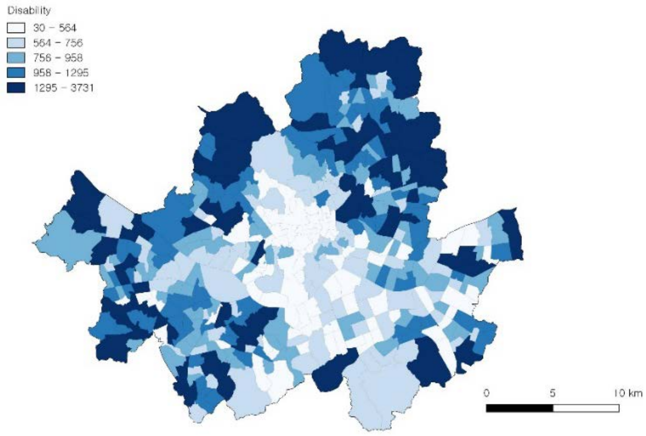

Figure 3.7 Distribution of Disabled Population

Figure 3.8 shows the distribution of administrative service of Seoul. This data is used for estimating the influence of administrative service on social resilience through assessment analysis.

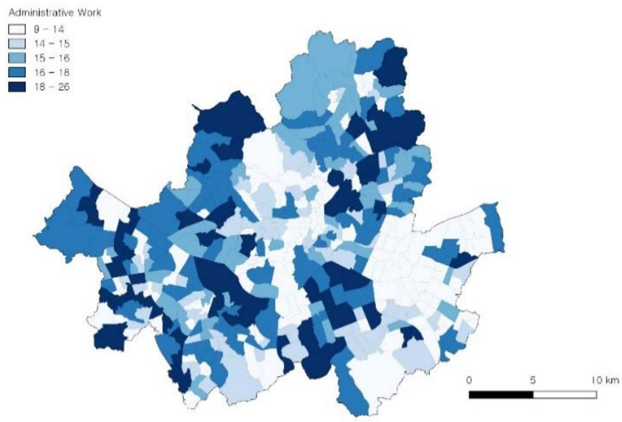

Figure 3.8 Distribution of Administrative Officers

Figure 3.9 shows the distribution of multi-cultural residents of Seoul. This data is used for estimating the influence of multi-cultural residents on social resilience through assessment analysis.

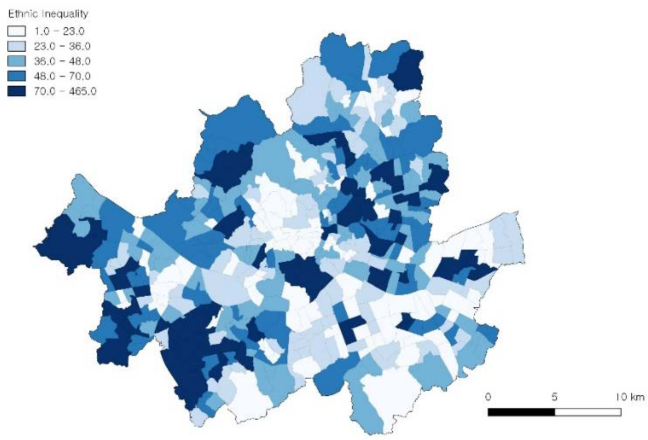

Figure 3.9 Distribution of Multi-Cultural Residents

3.2.3 Data preprocessing

Since the collected data for 5 variables were organized based on 2 types of standards, administrative divisions (423 sub-districts; dong) and legislative divisions (467 districts), data pre-processing was necessary. As the GIS map is based on administrative divisions of 2014 which has 423 sub-districts, all the data has been reorganized to administrative divisions.

CODE	X	Y	District	Dong	N_Damag	Populatio	Age	Disability	Poor	Health Ac	Admitistra	Shleter Ca	Ethnic Ine	Regional A	Migration	Crime	Health	Business E
1101053	126.9701	37.57414	종로구	사직동	-0.38728	-1.34776	-1.19863	-1.27797	-0.80692	-0.21851	-0.34838	3.377178	-0.74864	1.25123	-0.06071	-0.25388	-0.68113	0.886214
1101054	126.9811	37.58788	종로구	삼청동	-0.43301	-1.83579	-2.06723	-1.6859	-0.90903	-0.45276	-2.33976	-0.67084	-0.96813	1.25123	-0.55448	-1.49594	-0.84593	-0.6341
1101055	126.9626	37.59675	종로구	부암동	-0.41472	-1.60889	-1.21611	-1.19888	-0.81033	-0.45107	-1.14493	-1.27805	-0.62118	1.25123	-0.1266	-0.0324	-1.07781	-0.75017
1101056	126.9693	37.61404	종로구	평창동	-0.42387	-1.83449	-0.23538	-0.72227	-0.75246	-0.43085	-0.74665	-1.07564	-0.25383	1.25123	-0.04425	1.45847	-0.51987	-0.68053
1101057	126.9588	37.57771	종로구	무악동	-0.42387	-0.11875	-1.51701	-1.28005	-0.74225	1.967258	-1.54321	-0.67084	-0.86609	1.25123	-0.26028	-0.55915	-1.22889	-0.73344
1101058	126.9642	37.57101	종로구	교남동	-0.33239	-0.85821	-1.90851	-1.4528	-0.74906	-0.43591	-1.14493	-0.67084	-0.86609	1.25123	-0.61607	-1.18163	-1.47324	-0.87758
1101060	126.9866	37.58276	종로구	가회동	-0.37813	-1.23319	-1.87479	-1.55061	-0.90563	-0.41905	-1.54321	-1.07564	-0.82527	1.25123	-0.30141	-1.14381	-1.47859	-0.65515
1101061	126.9898	37.5751	종로구	종로1·2·3·4	-0.37813	-1.70685	-1.30841	-1.12604	0.615775	0.105059	0.44818	5.80599	-0.58037	1.25123	0.166748	-0.4732	-1.17816	7.639076
1101063	127.0044	37.57288	종로구	종로5·6가	-0.28666	-1.19613	-1.7908	-1.34457	-0.62653	-0.11908	-0.34838	0.138762	-0.62118	1.25123	-0.22045	-0.98909	-1.28177	3.147786
1101064	127.003	37.5795	종로구	이화동	-0.43301	-1.04893	-1.60629	-1.28213	-0.71162	6.758416	-1.14493	1.353168	-0.47832	1.25123	0.013766	-0.40226	-1.19412	-0.32582
1101067	127.0138	37.57242	종로구	창신1동	-0.36898	-0.16429	-1.73723	-1.30086	-0.15003	-0.3449	-0.74665	-0.46844	0.011483	1.25123	-0.14381	-0.80307	-1.38346	0.25833
1101068	127.0102	37.57598	종로구	창신2동	-0.36898	1.499862	-1.39202	-0.83258	-0.37126	-0.47804	-0.34838	-0.67084	0.297204	1.25123	-0.60295	-0.04054	-0.84458	-0.57849
1101069	127.0132	37.57893	종로구	창신3동	-0.36898	0.827581	-1.67771	-1.21553	-0.75587	-0.37524	-1.94149	-0.87324	-0.662	1.25123	-0.35111	-0.62321	-1.21533	-0.89
1101070	127.0169	37.57728	종로구	숭인1동	-0.39642	0.566775	-1.74818	-1.33416	-0.60951	-0.44096	-1.54321	-1.27805	-0.51914	1.25123	-0.29398	-0.75766	-1.40189	-0.74693
1101071	127.0204	37.57451	종로구	숭인2동	-0.39642	0.312106	-1.39996	-0.99283	-0.26916	-0.46961	-1.14493	-0.26604	-0.11097	1.25123	0.196012	-0.26366	-1.15686	-0.02943
1101072	126.9704	37.58462	종로구	청운효자동	-0.3141	-1.55819	-0.84879	-0.75765	-0.65036	-0.42579	-0.34838	-0.46844	-0.68241	1.25123	-0.1569	0.53145	-1.16826	-0.48617
1101073	126.9977	37.58735	종로구	혜화동	-0.35069	-0.59756	-0.61299	-0.68689	-0.60611	-0.42579	-0.34838	0.948366	-0.49873	1.25123	-0.12707	1.464984	0.167815	-0.08558

Figure 3.10 Data preprocessing by sub-divisions

Also, before performing regression analysis, all data were standardized to avoid the errors caused by unit size difference of each variable. Table 3.5 provides details of the standardization information of proxy variables.

Table 3.5 Standardized Proxy variables

	Variable	Mean	Std. Deviation	N	Year
Y	Inundated Record	-0.0000177	1.000	423	2010
X	Population Density	-3.46	1.000	423	2014
	Disability	6.45	1.000	423	2014
	Age (under 5, over 65)	1.31	1.000	423	2014
	Administrative Work	0.00187	1.000	423	2014
	Ethnic Inequality	-0.0000540	1.000	423	2014

In addition, the geographically weighted regression analysis requires coordinates of every data points. In this study, the UTM-K(GRS-80) coordinate system has been used considering the GIS shape file projection of QGIS.

3.3 Geographically Weighted Regression (GWR) Analysis

Using the geographically weighted regression analysis by GWR4 program, the following result was derived.

The equation for regression model is:

$$y_i = \beta_0(i) + \beta_1(i)\, x_{1i} + \beta_2(i)\, x_{2i} + \cdots \beta n\, (i)\, x_{ni} + \varepsilon_i$$

with the estimator:

$$\beta'(i) = (X^T W(i)\, X)^{-1} X^T W(i) Y$$

where W(i) is a matrix of weights specific is a matrix of weights specific to location i such that observations to location i such that observations nearer to i are given greater weight nearer to i are given greater weight than observations further away.

In the figures, the regions that are in positive relation with damage status have been colored in green. The regions that are in negative relation, on the other hand, have been colored in red. Not significant areas (confidence interval 90%) are colored in grey. Classes are sorted by Jenks natural break. The negative and positive signs have been reflected for the coloring. Areas with positive coefficients are colored in greener colors, whereas negative coefficient areas are colored in reddish colors.

Figure 3.11 shows the distribution of coefficients of population density that are highly significant.

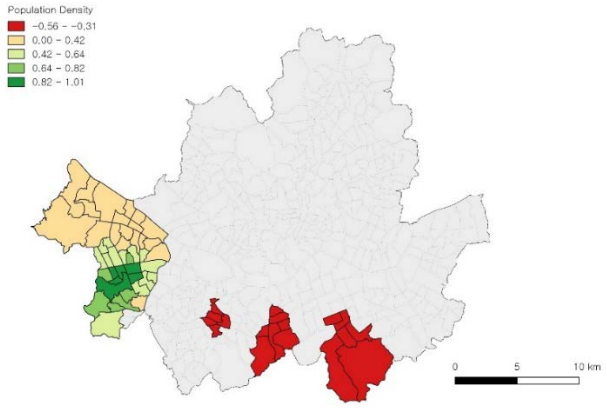

Figure 3.11 Distribution of Significant Coefficient for Population Density

As a result, 70% of areas with significant coefficients show positive influence between inundated records and population density (see Figure 3.12).

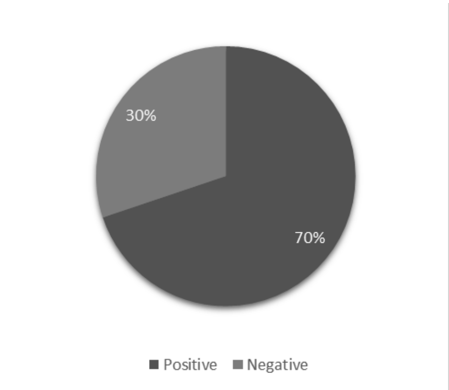

Figure 3.12 Proportion of Population Density Coefficients by Signs

Positive sign represents that area with more population density causes more inundated records, which leads to the idea of less resilient community. Thus, these areas in green should be recognized during decision making process for better resource distribution.

Figure 3.13 shows the distribution of coefficients of vulnerable age population that are highly significant.

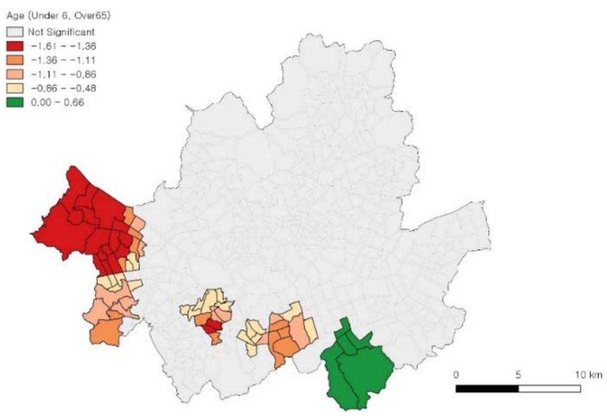

Figure 3.13 Significant Coefficient of Vulnerable Age (under 5, over 65)

As a result, 8% of areas with significant coefficients show positive influence between inundated records and vulnerable age (see Figure 3.14).

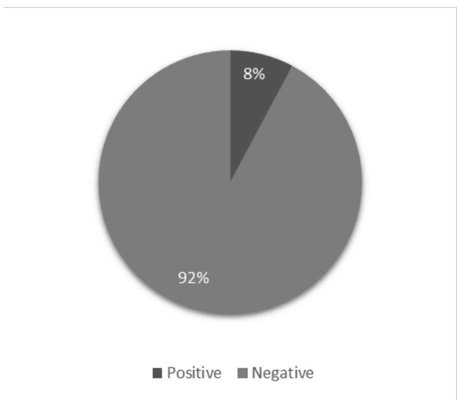

Figure 3.14 Proportion of Vulnerable Age Population Coefficients by Signs

Positive sign represents that area with more population at vulnerable age causes more inundated records, which leads to the idea of less resilient community. However, the result shows that only 8% of areas with significant coefficients have positive sign, whereas most of the areas have negative sign. Negative signs mean less vulnerable age population causes more inundated records. Comprehensive study should be done later on for figuring out the reason for this negative relationship. Nevertheless, areas in greener color (positive relationship) should be recognized after all.

Figure 3.15 shows the distribution of coefficients of disabled population that are highly significant.

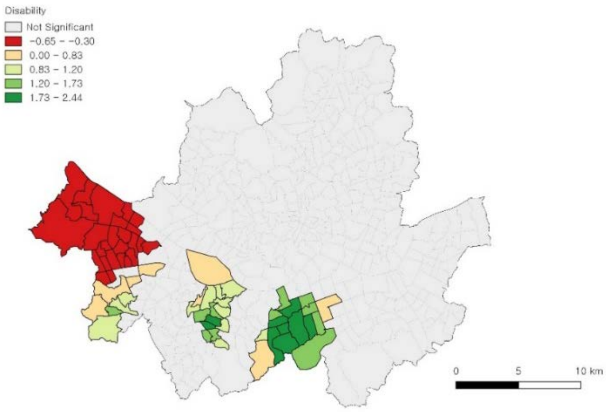

Figure 3.15 Significant Coefficient of Disabled Population

As a result, 95% of areas with significant coefficients show positive influence between inundated records and disabled population (see Figure 3.16).

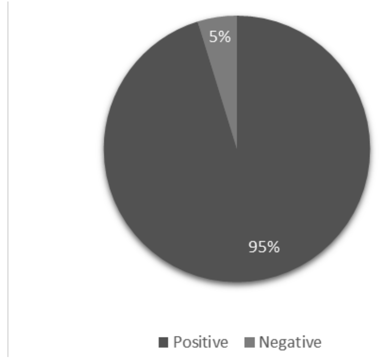

Figure 3.16 Proportion of Disabled Population Coefficients by Signs

Positive sign represents that area with more disabled population causes more inundated records, which leads to the idea of less resilient community. Thus, these areas in green should be recognized during decision making process for better resource distribution, especially considering the handicapped population.

Figure 3.17 shows the distribution of coefficients of administrative service that are highly significant.

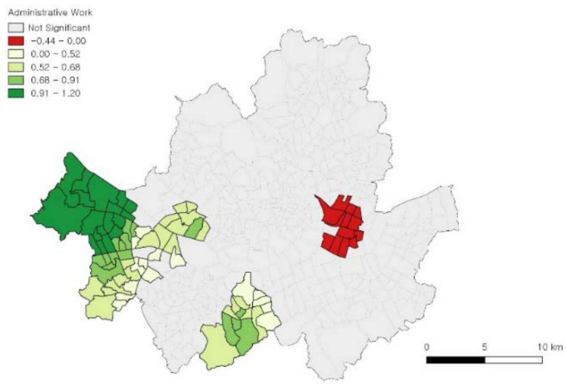

Figure 3.17 Significant Coefficient of Administrative Work

As a result, 85% of areas with significant coefficients show positive influence between inundated records and administrative work (see Figure 3.18).

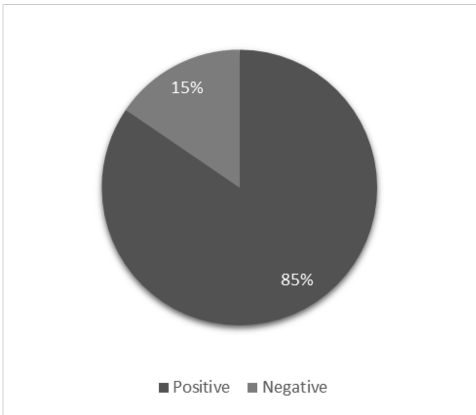

Figure 3.18 Proportion of Administrative Work Coefficients by Signs

Positive sign represents that area with more administrative service causes more inundated records. Here, the author proposes to read the result carefully since more administrative service does not directly influence more damage to a community. On the contrary, more administrative service should influence for building more resilient community. Hence, to understand the result, it can be assumed that the more active work by community administrative officers, the more damage records may be collected which reflects the result. Furthermore, investigation on administrative work related to disaster events should consider such kind of assumption later on for comprehensive understanding.

Figure 3.19 shows the distribution of coefficients of multi-cultural population that are highly significant.

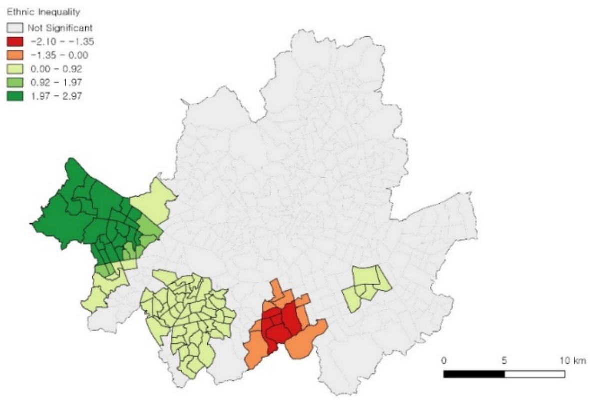

Figure 3.19 Significant Coefficient of Multi-Cultural Population

As a result, 86% of areas with significant coefficients show positive influence between inundated records and multi-cultural population (see Figure 3.20).

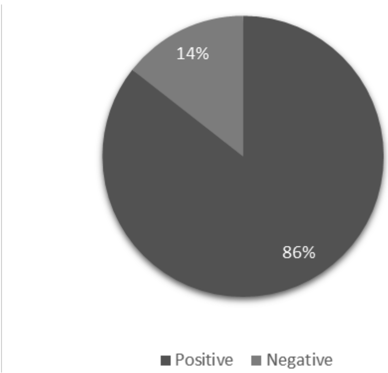

Figure 3.20 Proportion of Multi-Cultural Population Coefficients by Signs

Positive sign represents that area with more multi-cultural population causes more inundated records, which leads to the idea of less resilient community. Recently, residents of multi-cultural family have been major focus in Korea. It is widely known that a large portion of foreign population through international marriage struggles in diverse situations, and disaster resilience consists a part. Thus, these areas in green should be recognized during decision making process for better resource distribution, especially considering the ethnic inequality of the community.

Figure 3.21 shows the distribution of local R^2 value. Local R^2 values range between 0 and 1, indicating how well the geographically weighted regression model fits the observed y value. The higher value means that the local model is performing greatly, whereas the lower value means that the model is performing weakly. These poorly performing areas might indicate the existence of missing variables that explains the regression model better.

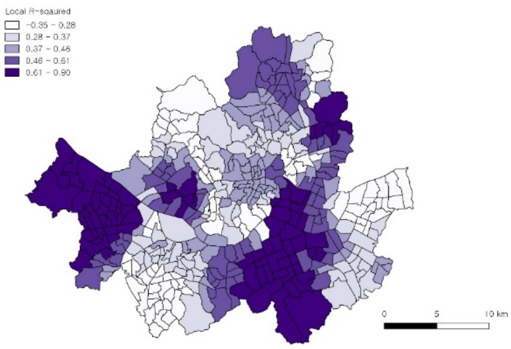

Figure 3.21 Distribution of Local $\mathbf{R^2}$

Figure 3.22 shows the distribution of standard deviations of residuals. It represents the remaining variability that can possibly unexplained by the assessment model. Also, locations are visualized where the assessment model miss predicted (over or under) the value of dependent variable.

Figure 3.22 Distribution of Standard Residuals

Chapter 4. Assessment Model Evaluation

4.1 Verification

4.1.1 Quantitative Verification

By comparing the fit of the OLS and GWR models. Here, the OLS model will be referred as the global model and the GWR model as the local model.

The AICc is used as a measure of assessing the model fitness. The corrected Akaike's Information Criterion (AICc) is information-based criteria that assess model fit. The AICc is computed from a measure of the divergence between the observed and fitted values, and a measure of the complexity of the model.

AICc can be defined as follows:

$$\mathrm{AICc} = -2\mathrm{LogLikelihood} + 2\mathrm{k} + 2\mathrm{k}(\mathrm{k}+1)/(\mathrm{n}-\mathrm{k}-1)$$

where k is the number of estimated parameters in the model and n is the number of observations in the data set. This value can be used to compare various models for the same data set to determine the best-fitting model. The model having the smallest value, as discussed in Akaike (1974), is usually the preferred model.

The value has been decreased from 1178.13 to 1082.39 and the difference is about 96. Our preferred measure of model fit is the AICc, the global model's value is 1178.13, and the local model's value is 1082.39 – the difference of 95.74 is strong evidence of an improvement in the fit of the model to the data.

The global r-squared value is 0.08 and the local r-squared value is 0.61 which suggests that there has been some improvement in model performance.

Table 4.1 Results of OLS and GWR analysis

		Global, OLS (n=423)			Local, GWR (n=423)	
No.	**Factor**	**Coeffient**	**Standard Error**	**t(Est/SE)**	**Mean**	**STD**
F1	Population Density	0.053692	0.049164	1.092099	0.026827	0.224991
F2	Age	-0.021019	0.086033	-0.244309	-0.225634	0.418252
F3	Disability	-0.051511	0.084489	-0.609677	0.104271	0.478789
F4	Administrative Work	0.126175	0.070503	1.789640	0.162197	0.314466
F5	Ethnic	0.235967	0.051080	4.619520	0.266412	0.671134
R^2		0.080632			0.612329	
AICc		1178.129394			1082.389580	

4.1.2 Qualitative Verification

To verify the result of variable significance, survey results have been used to compare with the analysis result. The survey results came out that the most important feature is the population density, and the following variables are administrative work, age, disability, and ethnic inequality. However, the GWR model examined the most important feature is the ethnic inequality, and the following variables are age, administrative work, disability, and population. In addition, the OLS model also examined the most important variable as the ethnic inequality, followed by administrative work, population density, disability, and age.

Table 4.2 Qualitative Verification with Survey Results

Variable	Survey Result	OLS Model	GWR Model
Population Density	6.514 (1)	0.053 (3)	0.027 (5)
Age (under 5, over 65)	5.429 (2)	0.021 (5)	0.226 (2)
Disability	5.371 (3)	0.052 (4)	0.104 (4)
Administrative Work	5.086 (4)	0.126 (2)	0.162 (3)
Ethnic Inequality	4.771 (5)	0.236 (1)	0.266 (1)

( ) = Rank

4.2 Validation

To confirm the model development and results, review from field experts has been done for validation. Research objectives and model development was introduced, and the assessment results were shown to the experts for the review.

First of all, they agreed the concept of quantifying each related variables' influence by each community for social resilience. At current stage, physical aspects, for example, road runoff and drainage system capacity for storm and flood disaster, are majorly considered for decision making and project planning. Recently, attempts to invite social aspects for the decision making process have been made. However, it has limitations since social aspects are reflected through survey results or insufficient information. Thus, the developed model in this study could gain affirmative answer. It may get more attention if it can involve more related variables both from open source data and survey results.

Closely looking into the results, comments on the locations with significant coefficients have been made. Historically, during the 70-80s' Seoul development plans, inhabitants living without permission after the Korean War were displace to public land. At the time most of the public land were lowlands, located beside the Han River. Since the lowlands usually acted as retarding basin for storm or flood evert, the land value could not form high price. This could possibly have relationship with the characteristics of population living now days. Thus, the variables seems to have significant relationship to the social resilience during storm and flood disaster.

Additionally, reviews on the use of the model and further development was made. Since the objective of disaster management is to repair and support every community, it is important notice that the model should not focus on prioritizing communities but to customize disaster management plans by using the variable influence results.

Chapter 5. Conclusion

5.1 Summary

The study proposes a practical assessment model of social resilience through examining appropriate variables that are considered to be related to disaster damage, and analyzing the impact of spatial heterogeneity of the social attributes by using Geographically Weighted Regression (GWR) method. Through an experimental case study on Seoul Metropolitan Area, the author suggests meaningful variables and distinguishes the relationship between disaster damage and social resilience.

Firstly, the research examined social resilience attributes that are considered to be related to disaster damage. 13 variables out of 22 set of variables were suggested to be significant to flood and storm disaster losses. Through the correlation and multicollinearity test, 5 variables (population density, vulnerable age, disabled population, administrative work, and multi-cultural population) were selected as the final variables for the analysis method. Secondly, the spatial heterogeneity was measured on the scale of social resilience by GWR analysis. The result data has been visualized by GIS platform using QGIS software. Thirdly, an assessment model using the selected social resilience variables was developed, using geographically weighted regression (GWR) method. The signal of coefficients (positive/negative) has been discussed for analyzing the relationship between social resilience and each variables. Finally, evaluation of the develop model was done for through verification and validation. The verification process involves both quantitative and qualitative methods, and validation was done by field experts' review. They conclude that the developed assessment model has significant potential and meanings, yet more challenges should be solved such as looking for missing explanatory variables, combining both physical and social aspects of resilience, and so on.

5.2 Contributions and Future Study

The study provides additional insight into the urban resilience in a comprehensive manner using open source software and public databases. The author believes that this study could expand and strengthen our research initiatives to enhance our understanding of resilience by estimating practical influence of each variables to social resilience. It may provide information for the development of more effective policies to protect diverse population groups from disasters, while recognizing the unique risks that underrepresented groups confront. Figure 5.1 shows the assigned mitigation project costs and damage amount of each districts in Seoul. Although complaints on the fact that some districts receive way more budget for mitigation projects than others are raising, the current assessment process does not provide sufficient explanation. The study could support this kind of equity-related residential complaints by using the result of social resilience information.

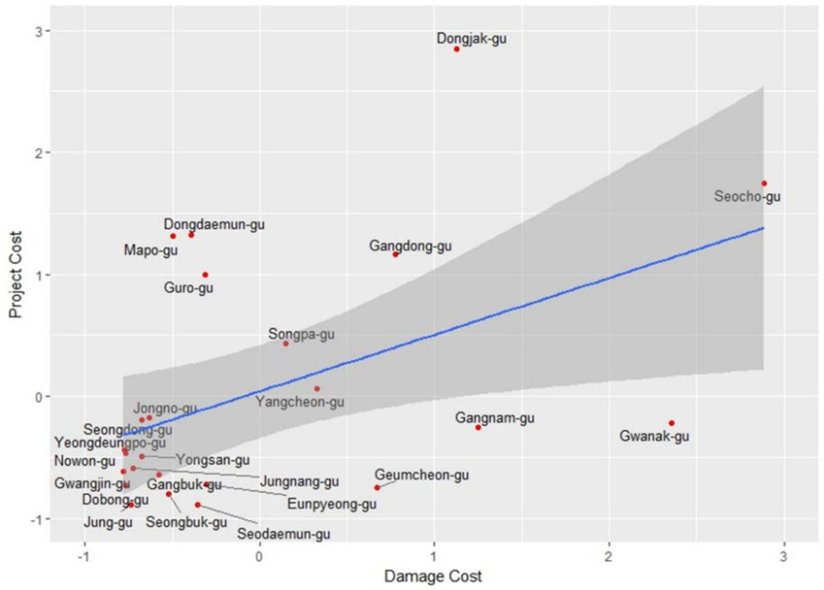

Figure 5.1 Mitigation Project – Disaster Damage Distribution in Korea

Furthermore, the study can support governments and decision-makers to develop and implement policy that moves from a reactive response to a more proactive approach focusing on preparedness. As the previous related studies emphasized the importance of social resilience and suggested conceptual models for resilience assessment, this study provides practical values for social resilience. Although the assessment model has limitation on the fact that it considered one side of resilience, the social aspects, the model can be further developed through combination of multi-aspects, considering both physical and social resilience. Through examining both sides of resilience, more comprehensive analysis can be done for better understanding of disaster resilience.

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초 록

전 세계적으로 재난재해 발생 빈도는 증가하고 있는 추세이며, 인구와 인프라가 밀집한 도시지역을 중심으로 그 피해 또한 확대되고 있다. 최근 재난재해 관련 연구들은 이러한 재난상황에 대해 복원력 증진을 통한 대응책 마련을 제시하고 있다. 이는 재난재해 및 파급효과의 불확실성 증가에 대한 대안으로, 피해 예측과 구분된 복원력 개념의 도입 및 활용의 필요성 증대를 의미한다. 하지만 복원력 개념에 대한 논의는 과거부터 지속적으로 이루어진 데 반해 정량화 방법에 대한 연구는 주로 구조물의 피해 등 물리적 복원력을 중심으로 수행되었다. 따라서 복원력 평가에서 공간 변인에 대한 포괄적인 이해를 위해서는 물리적 요소뿐만 아니라 지역의 사회적 요소를 고려할 필요가 있다. 본 연구는 지역별 사회적 요소와 사회적 재난복원력의 관계를 확인하고, 이를 기반으로 지역단위 사회적 복원력에 대한 해석을 수행하는 모델을 제시하고자 한다. 이러한 연구 목적을 달성하기 위해 다음과 같은 세부목표를 설정하였다. 첫째, 재난에 대한 사회적 재난복원력과 지역의 사회적 요소에 대한 연구동향과 데이터를 기반으로 한 관계성을 확인한다. 둘째, 사회적 재난복원력에 대한 각 지역별 사회적 요소의 영향력을 도출한다. 셋째, 지역별 사회적 영향력을 기반으로 한 모델을 도출하고 결과를 분석한다. 넷째, 향후 발전적인 재난관리 대책 마련에 도입 될 수 있는 방향성을 제시한다. 이러한 연구 수행을 위해 본 연구는 선행연구 문헌고찰과 설문조사를 통하여 사회적 요소에 대한 리스트를 작성하고, 오픈

소스 데이터 등 실제 지역의 데이터를 활용하여 관계성을 확인하였다. 그 결과 인구 밀도, 취약 연령층, 장애 인구 등 총 다섯 가지 인자에 대해 유의미한 상관관계가 있음이 확인되었다. 또한 공간가중회귀를 활용하여 해당 인자들과 사회적 복원력을 대변하는 피해 상황 자료를 분석한 결과, 행정동 기준의 지역별 회귀계수가 산출되었다. 본 연구는 사회적 인자의 영향력에 대한 정령화를 통해 사회적 복원력에 대한 이해의 증진과 효과성을 제고하고, 나아가 물리적 복원력과의 복합적인 해석의 기반을 마련하고자 하였다. 이를 통해 지역 맞춤형 저감사업계획 등 도시 재난재해 관리 역량 강화를 기대한다.

주요어: 도시재난, 풍수해, 사회적 복원력, 공간가중회귀, GIS

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