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***Research paper***

# Study on the Disaster Risk Assessment Considering Damage Status of Human Disasters and Social Disasters in South Korea

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## Abstract

With the effects of recent climate change, not only natural disasters such as typhoons, Heavy Rainfall and droughts, but also social disasters such as fires, collapse and infectious diseases are causing large-scale damage. The occurrence of such disasters affects various fields such as human life, social infrastructure, and economy, and research for disaster management is being carried out in various fields. In this study, disaster risk assessments by local governments were conducted for human and social disasters in Korea from 2006 to 2015. The disaster risk assessment was calculated on the average of four factors, listing the ranking of human losses, damage costs by natural disasters and social disasters. The damage status by disaster type was calculated as the risk and the overall disaster risk was evaluated. Disaster risk groups by local governments were analyzed as high risk group, middle risk group and low risk group. Gyeonggi-do, Gangwon-do, Jeollanam-do, Gyeongsangbuk-do and Gyeongsangnum-do were selected as dangerous local governments in the disaster. Other metropolitan cities and provinces were divided into middle risk group and low risk group. The results of this study are expected to be applicable to policies such as disaster management, reduction facilities and disaster related budget by assessing the disaster risk of each local government in the Republic of Korea

***Keywords***: *Disaster Risk Assessment, Natural Disaster, Social Disaster, Human Losses, Damage Costs*

## 1. Introduction

Disasters cause multiple damages by various effects such as climatic factors, social factors, and environmental factors. In Korea, although natural disasters such as Typhoon MaemI and Lusa occurred mainly in early 2000, social disasters such as Taean oil spill, foot-and-mouth disease and MERS occurred in late 2000. Natural disasters, human disasters, and social disasters have caused various disasters. The scale of the disaster can be confirmed by human losses and damage costs, which are representative damage factors.

Recently, due to the influence of climate change, studies have been conducted to reduce disaster damage by increasing occurrence frequency and scale of torrential rainfall and typhoon. The flood vulnerability index of climate change was selected and evaluation method was established and the vulnerability assessment was carried out for flood in natural disaster [1-3]. The most important thing for disaster vulnerability assessment is to select the appropriate indexes. In the UK and Germany, flood risk was assessed by selecting indexes for geographical information, defense capabilities, extent of damage, and flood maps in the watershed [4-6]. Flood vulnerability assessment was analyzed by using multi-criteria decision method and exponential analysis method by selecting flood area, population density, flood frequency, property damage, flood damage trend, socioeconomic Status, etc. in urban areas [7-9]. In addition, an Assessment technique for classifying the hazardous area as high risk group, middle risk group, and low risk group were selected by selecting flood vulnerability factors in urban areas [10]. It used Bayesian inference to estimate the risk of natural disasters and analyze the flood risk using channel buffering. And the insurance efficiency estimation and the differential method according to the occurrence of the disaster were suggested [11-14]. Existing vulnerability and risk studies were conducted mainly on parts of the disaster, such as flood and city, rather than on the assessment of the overall disaster. In addition, the vulnerability and risk assessment factors of disaster were mainly selected from disaster vulnerable or risky factors rather than past damage data.

In this study, we will evaluate the disaster risk by local governments considering the past disaster damage status in Korea. The disaster vulnerability factor is to take advantage of the casualties and damages of natural and social disasters from 2006 to 2015. The disaster risk is assessed to propose disaster risk groups for local governments as high risk group, middle risk group, and low risk group.

# 2. Method

## 2.1. Disaster Vulnerability Factor

Disaster in Korea is managed by 'Disaster and Safety Management Basic Law', which separates natural disaster from social disaster. Ministry of the Interior and Safety produces an annual report on the damage caused by the disaster. Natural disasters are classified into five disaster types in 'statistical yearbook of natural disaster' and social disasters are divided into 26 disaster types in the 'statistical yearbook of social disaster' and present the damage status to human losses and damage costs (Table 1).
In this study, human losses and damage costs were selected as the analysis factors to distinguish the vulnerable of disasters. As a factor that quantitatively judges the extent of vulnerability to disasters, we will use four factors as disaster vulnerability factors as human losses and damage costs of natural disasters and social disasters.

**Table 1:** Disaster Type of Natural Disaster and Social Disaster

| Class | Count | Disaster Classification | |
|---|---|---|---|
| Natural Disaster | 6 | typhoon, | heavy rainfall, |
| | | heavy snowfall, | extreme wind |
| | | wind wave, | heat have |
| Social Disaster | 26 | forest fires, | toxic chemical spills, |
| | | large-scale water pollution, | large-scale marine pollution, |
| | | utility tunnel disaster, | dam collapse, |
| | | subway large-scale accident, | large-scale high-speed train accident, |
| | | large-scale fire at multi-use buildings, | radioactive spills from adjacent countries, |
| | | marine vessel accident, | large scale human accident at workplace, |
| | | large-scale collapse of multi-use buildings, | correctional facilities' disasters and accidents, |
| | | livestock diseases, | infectious diseases, |
| | | telecommunications, | financial computing, |
| | | nuclear safety, | power, |
| | | crude oil supply, | health care, |
| | | drinking water, | land cargo transportation, |
| | | GPS signal disturbance, | space radio disaster |

## 2.2. Disaster Risk Assessment

The analysis method of the disaster risk assessment is applied to the disaster vulnerability factors selected in Section 2.1. Disaster vulnerability factors are human losses and damage costs of natural disaster and social disaster, and the evaluation methods for each factor are shown in Eqs. (1) to (4). Disaster Risk Assessment of Vulnerability Factors is a risky area for disasters with higher rankings, and disaster-safe areas with lower rankings.

$$Natural\ Disaster\ Human\ Losses(NDHL) = \frac{Local\ governments\ of\ Natural\ Disaster\ Human\ Losses}{Total\ Natural\ Disaster\ Human\ Losses} \times 100(\%) of\ Rainking \quad (1)$$

$$Natural\ Disaster\ Damage\ Costs(NDDC) = \frac{Local\ governments\ of\ Natural\ Disaster\ Damage\ Costs}{Total\ Natural\ Disaster\ Damage\ Costs} \times 100(\%) of\ Rainking \quad (2)$$

$$Social\ Disaster\ Human\ Losses(SDHL) = \frac{Local\ governments\ of\ Social\ Disaster\ Human\ Losses}{Total\ Social\ Disaster\ Human\ Losses} \times 100(\%) of\ Rainking \quad (3)$$

$$Social\ Disaster\ Damage\ Costs(SDDC) = \frac{Local\ governments\ of\ Social\ Disaster\ Damage\ Costs}{Total\ Social\ Disaster\ Damage\ Costs} \times 100(\%) of\ Rainking \quad (4)$$

The results of the risk assessment by disaster vulnerability factor were applied to equation (5) to analyze the integrated disaster risk assessment. Disaster risk assessment has various methods for weighting the risk by each vulnerability factor. In this study, we try to apply equal weight to each factor. The disaster risk assessment factor of this study is the past disaster type. Even if the same disaster occurs, it is difficult to calculate the weight because the scale of damage varies depending on the regional characteristics. We classify the range of risk groups for the ranking of disaster risk assessment and evaluate vulnerable areas vulnerable to disaster (Table 2).

$$Disaster\ Risk(DR) = \frac{NDHS + NDDC + SDHS + SDDC}{4} \times 100(\%) of\ Rainking \quad (5)$$

**Table 2:** Risk evaluation Scope

| Risk Group | Class |
|---|---|
| High Risk Group | Rank 1 ~ Rank 1 / 3n within |
| Middle Risk Group | Rank 1 / 3n ~ Rank 2 / 3n within |
| Low Risk Group | Rank 2 / 3n ~ Rank n within |

# 3. Damage Status by Disaster Type

## 3.1. Study Area

The entire document should be in Times New Roman. The font sizes to be used are specified in Table 1. In this study, we analyse the disaster damage situation from 2005 to 2016 in Korea and evaluate the risk of disaster for local governments. The total area of the Republic of Korea is 100,339 ㎢, and it is divided into 1 special city, 7 metropolitan cities, 9 Province, total 17 categories(Fig. 1).

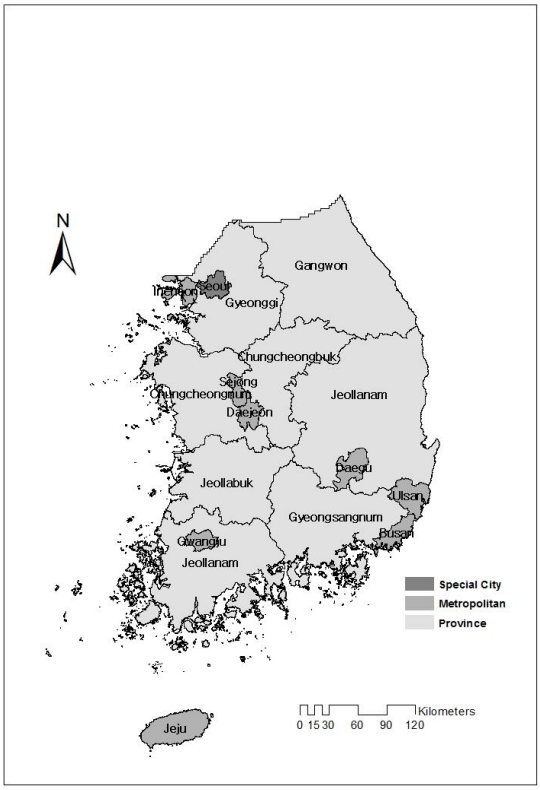



**Fig. 1:** The Study Area in South Korea

## 3.2. Damage Status of Natural Disaster

The natural disasters in the Republic of Korea are presented in the annual 'statistical yearbook of natural disaster' by the Ministry of the Interior and Safety. This study analyzes the human losses and damage costs of natural disaster from 2006 to 2015 in Korea. The damages caused by natural disasters in Korea for the past 10 years were 218 human losses and 5,252 billion damage costs (Fig. 2).

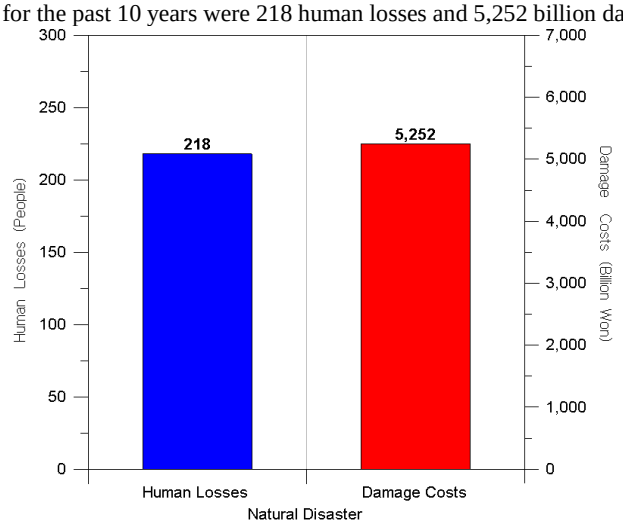



**Fig. 2:** Human Losses and Damage Costs of Natural Disaster

According to local governments, the damage caused by natural disasters was 59 people in Gyeonggi-do and 1,623 billion in Gangwon-do, the most in 10 years (Table 3). Damages status by local governments include 8 local governments in special cities and metropolitan cities, 44 people for human losses and damage costs for 318 billion won. The provinces included 9 local governments, 174 people for human losses and 493.5 billion won for damage costs. The damage of natural disaster occurred about 4.0 times in human losses and 15.5 times

in damage costs in provinces than in special cities and metropolitan cities. Considering the current damages from natural disasters, it is believed that areas with high population density and regional development are safer in disaster than areas without such areas.

**Table 3:** Damage Status of Natural Disaster

| local governments | Human Losses (People) | Damage Costs (billion won) |
|---|---|---|
| Seoul-si | 27 | 61 |
| Busan-si | 6 | 160 |
| Daegu-si | 0 | 1 |
| Incheon-si | 6 | 28 |
| Gwangju-si | 1 | 23 |
| Daejeon-si | 1 | 6 |
| Ulsan-si | 3 | 38 |
| Sejong-si | 0 | 1 |
| Gyeonggi-do | 59 | 612 |
| Gangwon-do | 44 | 1,623 |
| Chungcheongbuk-do | 4 | 185 |
| Chungcheongnum-do | 7 | 327 |
| Jeollabuk-do | 13 | 325 |
| Jeollanam-do | 12 | 753 |
| Gyeongsangbuk-do | 12 | 303 |
| Gyeongsangnum-do | 10 | 648 |
| Jeju-do | 13 | 159 |

Note) Ministry of the Interior and Safety. Disaster Year Book in 2015, 1rd ed.; Ministry of the Interior and Safety: Seoul, Korea, 2016

### 3.3. Damage Status of Social Disaster

The social disasters in the Republic of Korea are presented in the annual 'statistical yearbook of Social disaster ' by the Ministry of the Interior and Safety. This study analyzes the human losses and damage costs of social disaster from 2006 to 2015 in Korea. The damages caused by social disasters in Korea for the past 10 years were 872 human losses and 2,371 billion damage costs (Fig. 3).

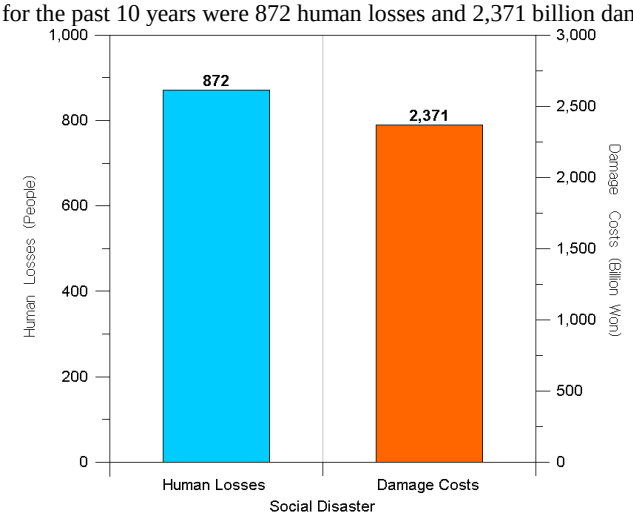



**Fig.3:** Human Losses and Damage Costs of Social Disaster

According to local governments, the damage caused by social disasters was 339 people in Jeollanam-do and 1,079 billion in Gyeonggi-do, the most in 10 years (Table 4). Damages status by local governments include 8 local governments in special cities and metropolitan cities, 214 people for human losses and damage costs for 97 billion won. The provinces included 9 local governments, 658 people for human losses and 2,276 billion won for damage costs. The damage of social disaster occurred about 3.1 times in human losses and 23.5 times in damage costs in provinces than in special cities and metropolitan cities. Considering the current damages from social disasters, it is believed that areas with high population density and regional development are safer in disaster than areas without such areas.

**Table 3:** Damage Status of Social Disaster

| local governments | Human Losses (People) | Damage Costs (billion won) |
|---|---|---|
| Seoul-si | 62 | 3 |
| Busan-si | 93 | 2 |
| Daegu-si | 7 | 15 |
| Incheon-si | 23 | 63 |
| Gwangju-si | 8 | 0 |
| Daejeon-si | 10 | 2 |
| Ulsan-si | 11 | 4 |
| Sejong-si | 0 | 8 |
| Gyeonggi-do | 140 | 1,079 |
| Gangwon-do | 17 | 235 |
| Chungcheongbuk-do | 15 | 157 |
| Chungcheongnum-do | 14 | 354 |
| Jeollabuk-do | 15 | 0 |

| | | |
|---|---|---|
| Jeollanam-do | 339 | 9 |
| Gyeongsangbuk-do | 54 | 418 |
| Gyeongsangnum-do | 41 | 24 |
| Jeju-do | 23 | 0 |

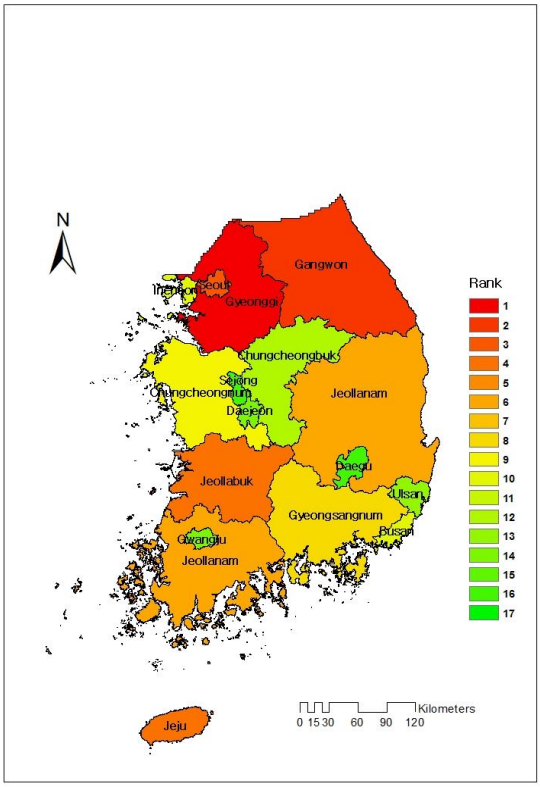
Note) Ministry of the Interior and Safety. Disaster Year Book in 2015, 1rd ed.; Ministry of the Interior and Safety: Seoul, Korea, 2016

# 4. Disaster Risk Assessment

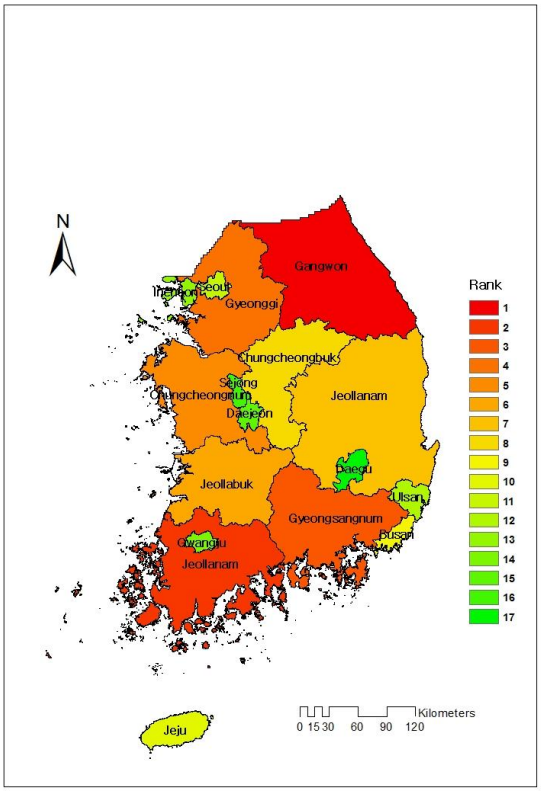
## 4.1. Risk assessment by disaster

We conducted a risk assessment for human losses and damage costs of natural disasters and social disasters in Korea from 2006 to 2015. Risk assessment methods for disaster vulnerability factors include eq. (1) to eq. (4) were applied. The results of the risk assessment of vulnerability factors by local governments are shown in Fig. 4.

The risk assessment of human losses and damage costs by disaster ranked the degree of vulnerability to disasters by local governments (Table 5). The human losses of hazardous local govern




(a)

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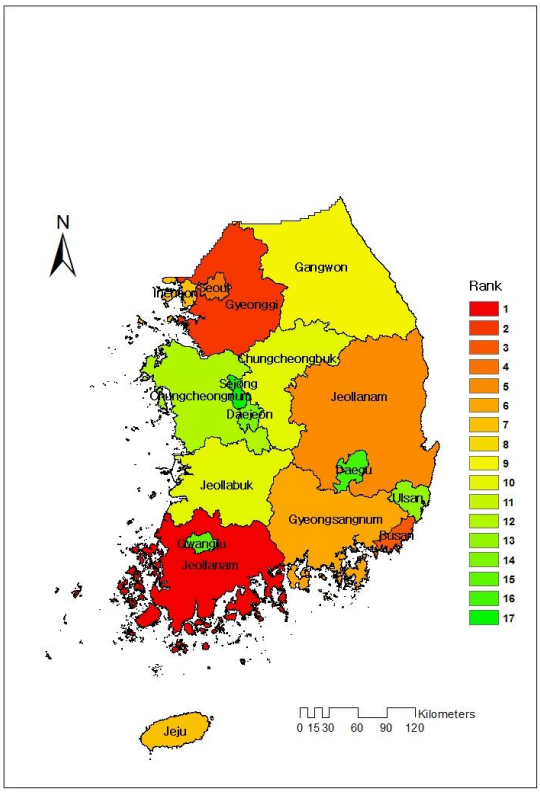


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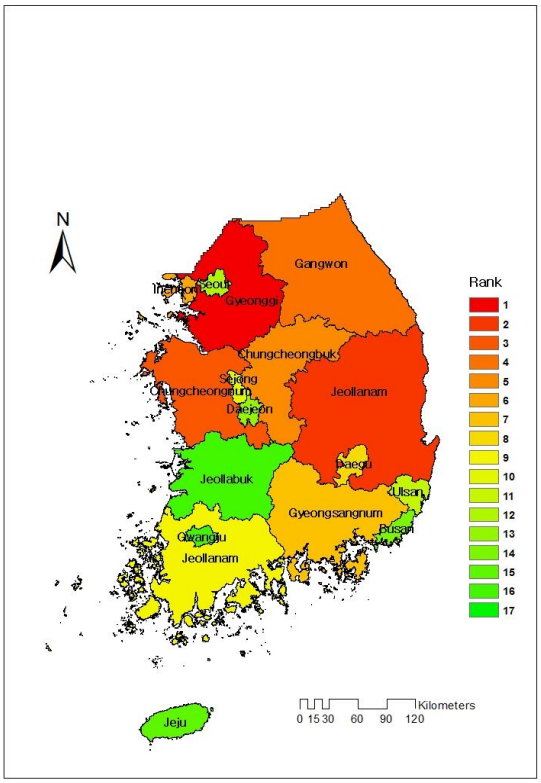



(d)

**Fig. 4**: Risk assessment of human losses and damage costs by disaster: (a) Natural Disaster Human Losses; (b) Natural Disaster Damage Costs; (c) Social Disaster Human Losses; (d) Social Disaster Damage Costs

ments due to natural disasters and social disasters are Gyeonggi-do, Seoul-si, Gangwon-do, Busan-si and the damage costs are Gyeonggi-do, Gangwon-do, Jeollanam-do, Gyeongsangbuk-do, Chungcheongnum-do, Gyeongsangnum-do. The hazardous local governments of human losses and damage costs of natural disasters was Gyeonggi-do, Gangwon-do, Seoul-si, Jeju-do and Daegu-si, Sejong-si, Gwangju-si, Daejeon-si was selected as a safe local government. The hazardous local governments of human losses and damage costs of social disasters was Jeollanam-do, Gyeonggi-do, Busan-si, Seoul-si and Gwangju-si, Jeollabuk-do, Jeju-do, Busan-si was selected as a safe local government.

**Table 5:** Risk Assessment by Disaster

| Local Governments | Natural Disaster | | Social Disaster | |
|---|---|---|---|---|
| | Ranking of Human Losses | Ranking of Damage Costs | Ranking of Human Losses | Ranking of Damage Costs |
| Seoul-si | 3 | 11 | 4 | 12 |
| Busan-si | 10 | 9 | 3 | 14 |
| Daegu-si | 16 | 17 | 16 | 8 |
| Incheon-si | 10 | 13 | 7 | 6 |
| Gwangju-si | 14 | 14 | 15 | 16 |
| Daejeon-si | 14 | 15 | 14 | 13 |
| Ulsan-si | 13 | 12 | 13 | 11 |
| Sejong-si | 16 | 16 | 17 | 10 |
| Gyeonggi-do | 1 | 4 | 2 | 1 |
| Gangwon-do | 2 | 1 | 9 | 4 |
| Chungcheongbuk-do | 12 | 8 | 10 | 5 |
| Chungcheongnum-do | 9 | 5 | 12 | 3 |
| Jeollabuk-do | 4 | 6 | 10 | 16 |
| Jeollanam-do | 6 | 2 | 1 | 9 |
| Gyeongsangbuk-do | 6 | 7 | 5 | 2 |
| Gyeongsangnum-do | 8 | 3 | 6 | 7 |
| Jeju-do | 4 | 10 | 7 | 15 |

In addition, natural disasters are proportional to the risk of human losses, such as Gyeonggi-do, Gangwon-do, while social disasters are inversely proportional to risk, such as Jeollanam-do or Busan-si. As a result, it was confirmed that the damage status caused by natural disasters and social disasters in the event of disasters has different characteristics.

### 4.2. Disaster Risk according to Disaster Risk Group Assessment

The comprehensive disaster risk assessment by local governments in Korea is calculated by applying Equation (5) to the disaster risk analysis results by disaster in Section 4.1. As a result, the most vulnerable local governments are Gyeonggi-do and the most secure local governments are Daegu-si (Fig. 5).

The results of the disaster risk by local governments in the the comprehensive disaster risk assessment were relatively safe for special city and metropolitan where population density was high, local governments had high budgets and infrastructure was located (Table 6). Not only in Gyeonggi-do, where disaster risk is at the top, but also in other provinces, some si-gun-gu were developed as major cities. However, Gyeonggi-do was selected as the most dangerous local governments after evaluating the whole of Gyeonggi-do.

In the past, the risk assessment by disaster was carried out considering the disaster damage status of the Republic of Korea. The disaster risk groups are classified into high risk group, middle risk group and low risk group. The high risk group is ranked 1th to 5th, middle risk group is ranked 6th to 10th, and low risk group is ranked 11th to 17th. The results of the comprehensive disaster risk groups by local governments were evaluated as Gyeonggi-do, Gangwon-do, Jeollanam-do, Gyeongsangbuk-do, Chungcheongnum-do in the high risk group, Gyeongsangnum-do, Seoul-si, Busan-si, Jeollabuk-do, Chungcheongbuk-do in the middle risk group and Jeju-do, Incheon-si, Ulsan-si, Gwangju-si, Daejeon-si, Daegu-si, Sejong-si in the low risk group (Fig. 6).

In order to be evaluated as a high-risk group in a comprehensive disaster risk group, two or more high-risk groups should be evaluated in the disaster risk group. To be assessed as a low-risk group in a comprehensive disaster-risk group, two or more low-risk groups or one low-risk group and two intermediate-risk groups should be evaluated in the disaster risk group. The other disaster risk groups in the disaster damage status are evaluated as moderate risk groups (Table 7).

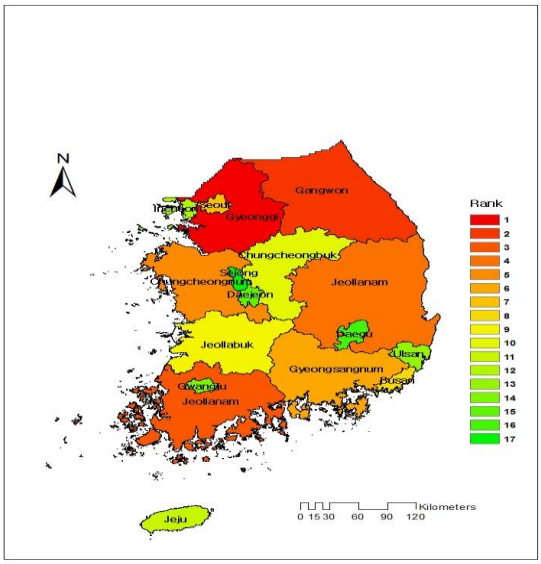
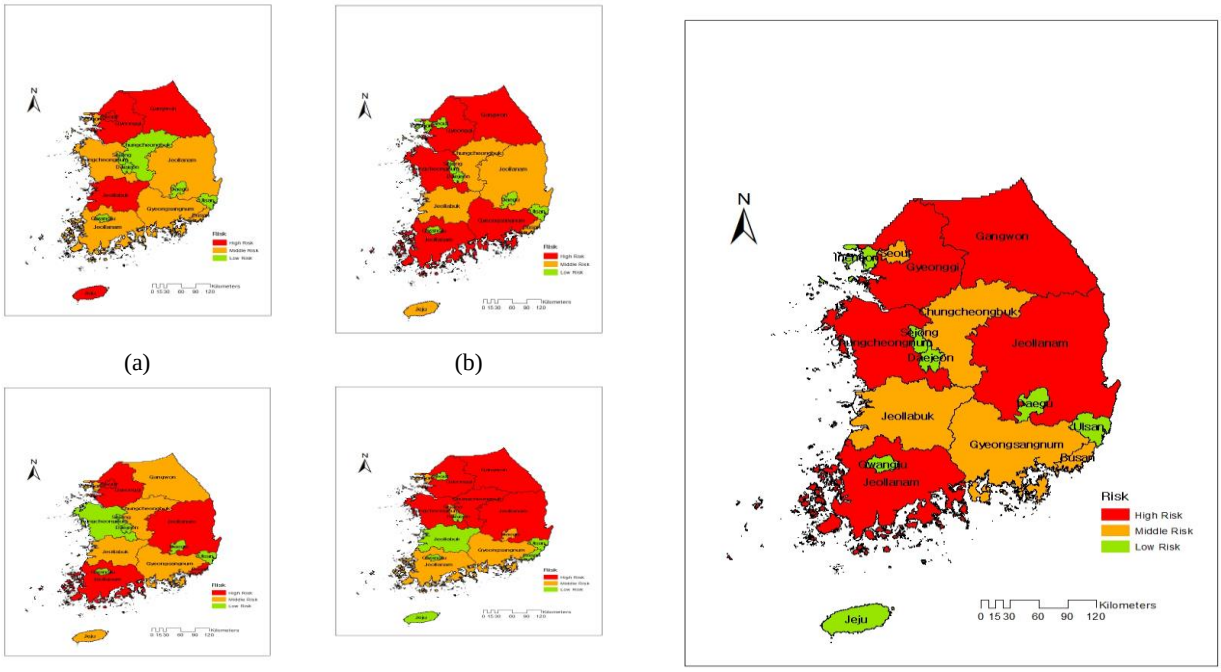



**Fig. 5:** Comprehensive Disaster Risk Assessment Considering Disaster Status

**Table 6:** Comprehensive Disaster Risk Assessment

| Local Governments | Ranking of Damage Costs |
|---|---|
| Seoul-si | 3 |
| Busan-si | 10 |
| Daegu-si | 16 |
| Incheon-si | 10 |
| Gwangju-si | 14 |
| Daejeon-si | 14 |
| Ulsan-si | 13 |
| Sejong-si | 16 |
| Gyeonggi-do | 1 |
| Gangwon-do | 2 |
| Chungcheongbuk-do | 12 |
| Chungcheongnum-do | 9 |
| Jeollabuk-do | 4 |
| Jeollanam-do | 6 |
| Gyeongsangbuk-do | 6 |
| Gyeongsangnum-do | 8 |
| Jeju-do | 4 |




(a) (b) (c) (d) (b)

**Fig. 6**: Disaster Risk Group Assessment considering Disaster Damage Status: (a) Risk Group of Natural Disaster Human Losses; (b) Risk Group of Natural Disaster Damage Costs; (c) Risk Group of Social Disaster Human Losses; (d) Risk Group of Social Disaster Damage Costs; (e) Comprehensive Disaster Risk

**Table 7:** Comprehensive Disaster Risk Groups Assessment

| Local Governments | Risk Group | | | | |
|---|---|---|---|---|---|
| | Natural Disaster of Human Losses | Natural Disaster of Human Losses | Social Disaster of Human Losses | Social Disaster of Human Losses | Comprehensive |
| Seoul-si | High | Low | High | Low | Middle |
| Busan-si | Middle | Middle | High | Low | Middle |
| Daegu-si | Low | Low | Low | Middle | Low |
| Incheon-si | Middle | Low | Middle | Middle | Low |
| Gwangju-si | Low | Low | Low | Low | Low |
| Daejeon-si | Low | Low | Low | Low | Low |
| Ulsan-si | Low | Low | Low | Low | Low |
| Sejong-si | Low | Low | Low | Middle | Low |
| Gyeonggi-do | High | High | High | High | High |
| Gangwon-do | High | High | Middle | High | High |
| Chungcheongbuk-do | Low | Middle | Middle | High | Middle |
| Chungcheongnum-do | Middle | High | Low | High | High |
| Jeollabuk-do | High | Middle | Middle | Low | Middle |
| Jeollanam-do | Middle | High | High | Middle | High |
| Gyeongsangbuk-do | Middle | Middle | High | High | High |
| Gyeongsangnum-do | Middle | High | Middle | Middle | Middle |
| Jeju-do | High | Middle | Middle | Low | Low |

## 5. Discussion

In this study, we assessed the disaster risks of the local governments for human losses and damage costs of natural disaster and social disaster in Korea. In addition, disaster risk groups of the local governments were classified into high risk group, middle low risk group and low risk group, and regions vulnerable to disaster were selected. In the case of disaster risk assessment conducted at home and abroad, vulnerability was analyzed by selecting indicators such as extent of damage, property damage, frequency of flood occurrence, and socioeconomic level [4-9].

In this study, we assessed disaster risk assessment and disaster risk group considering only disaster damage status. The human losses of natural disasters and social disasters in the Republic of Korea were 1,090 people and damage costs amounted to 7,623 billion won. The results of the disaster risk assessment were analyzed as 5 high risk groups, 5 middle risk groups and 7 low risk groups. It is estimated that special city and metropolitan where the urban development and population are concentrated is safer than provinces due to the risk group of the disaster in Korea.

As a result of this study, it can be seen that the disaster risk of local governments is different from disaster reduction facility or disaster management due to budget, population, etc. A more precise outcome is expected if disaster risk assessment is carried out considering budget and reduction facilities by local governments in the future.

## 6. Conclusion

In this study, we analyzed the damage status caused by natural disasters and social disasters in Korea from 2006 to 2015. One special city, seven metropolitan, and nine provinces. A total of 17 by local governments were selected as study area in Korea. The disaster risk and the disaster risk group were assessed using the damage status by disaster.

The damage status in the last decade of natural disasters has resulted in 218 people of human losses and 5,252 billion Damage Costs. As a result of the assessment of the risk of natural disasters, human Losses was analyzed for high risk in Gyeonggi-do, Gangwon-do, and Damage Costs in Gangwon-do and Jeollanam-do. The damage status in the last decade of social disasters has resulted in 872 people of human losses and 2,371 billion Damage Costs. As a result of the assessment of the risk of social disasters, human Losses was analyzed for high risk in Jeollanam-do, Gyeonggi-do and Damage Costs in Gyeonggi-do and Gyeongsangbuk-do.

The Comprehensive disaster risk group assessment is the result of the risk assessment by Human Losses and Damage Costs per disaster. The Comprehensive disaster risk groups are classified into high risk group, middle risk group and low risk group. The high risk group is ranked 1th to 5th, middle risk group is ranked 6th to 10th, and low risk group is ranked 11th to 17th. The results of the comprehensive disaster risk groups by local governments were evaluated as Gyeonggi-do, Gangwon-do, Jeollanam-do, Gyeongsangbuk-do, Chungcheongnum-do in the high risk group and Jeju-do, Incheon-si, Ulsan-si, Gwangju-si, Daejeon-si, Daegu-si, Sejong-si in the low risk group.

As a result of the comprehensive disaster risk group assessment, metropolitan excluding the Seoul-si were analyzed as low-risk and province as moderate. Among local governments in South Korea, the special city and metropolitan was able to confirm that it was safer in disaster than province. The results of this study are expected to be applicable to policies such as disaster management, reduction facilities and disaster related budget by assessing the disaster risk of each local government in the Republic of Korea. Future studies will apply the disaster risk assessment of this study to 229 local governments in Korea.

## Acknowledgement

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