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Research paper

Analysis of Vulnerable Area for Emergency Medical Services in Flood situation by using Geographic Information System

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Abstract

The influence of flooding on public health can be extremely serious. In some floods, it has been reported that the number of casualties that occurred from waterborne and water-related diseases or injuries is higher than that of drowning. Moreover, urbanization and population concentration means that more people will be exposed to flooding. Accordingly, the importance of emergency medical services for saving lives is continuously growing.
In this study, regions vulnerable to emergency medical services were suggested for Seoul, the capital city of South Korea, through analysis of the service areas of emergency medical facilities. Seoul, the capital city of South Korea, was selected as the study target region, and GIS network analysis was conducted based on the location and attributed information of 52 medical centers in Seoul which were designated as hospitals capable of providing emergency medical services. As this study is a basic study on the analysis of regions vulnerable to emergency medical services in the event of a flood caused by severe rainfall, it is expected that the results of this study will contribute to decision making that aims to minimize human injuries and improve resilience in the event of a future flood.

Keywords: *Emergency Medical Services, Flood, GIS, Vulnerable Region*

1. Introduction

The frequency and intensity of flooding are expected to increase due to severe precipitation caused by climate change [1, 2].
Urban flooding is generally divided into inland flooding and river flooding. Inland flooding occurs in urban lowlands due to the insufficient capacity of the drainage system. River flooding on the other hand is caused by the collapse of embankments or overflow.
In South Korea, flood damage is increasing because most of the rivers' midstream and upstream areas are mountainous and steep, causing runoff to take place in a very short period of time when heavy rainfall occurs.
In addition, the risk of large-scale flood damage is higher because flood runoff has increased and its travel time has been shortened as forests and grasslands capable of holding the runoff have been converted to impervious areas with concrete and asphalt, such as houses and roads, due to urbanization and industrialization.
Additionally, it seems that inland flooding occurs continuously because the facilities capable of holding flood runoff, such as drainage, storage, and underground infiltration facilities, are insufficient [3].
According to EM-DAT(Emergency Events Database), over 100 million people on average have been exposed to flood damage each year for the past three [4].
The most commonly reported flood-related injuries are sprains, lacerations, bruises, and abrasions. People are injured while trying to avoid objects swept away by rapids or collapsing buildings or structures [5]. Injuries after flooding occur when the recovery and reconstruction processes begin [4, 6, 7, 8].
In addition, overflowing sewage, wastewater, and waste become a serious threat to public health [4].
The influence of flooding on public health can be extremely serious. In some floods, it has been reported that the number of casualties that occurred from waterborne and water-related diseases or injuries is higher than that of drowning [4].
Urbanization and population concentration means that more people will be exposed to flooding [4, 5].
Accordingly, the importance of emergency medical services for saving lives is continuously growing.
In this study, regions vulnerable to emergency medical services were suggested for Seoul, the capital city of South Korea, through analysis of the service areas of emergency medical facilities.

2. Method of research

The characteristics of a flood (including the water level, duration, and contaminants of the flood) affect the scale of damages to structures and human bodies. Flood-related injuries, including sprains, lacerations, bruises, and abrasions, as well as waterborne and water-related diseases may occur immediately after a flood or during the recovery and reconstruction process.
Meanwhile, injuries and diseases are not properly monitored, and it is difficult to quantify the diseases that are caused by floods [4, 6]. It is also difficult to clearly identify the regions where emergencies have occurred due to injuries and disease. Therefore, in this study, regions with a history or high probability of flooding were set as areas where emergencies have occurred, and research was conducted under the assumption that these emergencies occurred as a result of flood damage.
Seoul, the capital city of South Korea, was selected as the study target region, and GIS network analysis was conducted based on the location and attributed information of 52 medical centers in

Seoul which were designated as hospitals capable of providing emergency medical services according to Article 3 of the Medical Law

Areas that can be reached within five to ten minutes from each emergency medical center were set as the reference points for vulnerable region analysis.

Although the speed of an emergency patient transport vehicle is determined by various complex factors, including road situations and signal systems, in this study it was assumed to be 60 km/h, a common speed limit in Seoul.

Table 1 : Status of utilized spatial information

Data	Source
Emergency medical facility	E-Gen (www.e-gen.or.kr)
Road information	Digital map (www.nsdi.co.kr)
River information	
Inundation trace map	Seoul Safe City (safety.seoul.go.kr)

3. Results and discussion

Seoul, the target of this study, is implementing both short- and long-term flooding safety measures including structural and non-structural measures. In the target region, however, 11,117.5 ha were flooded and 35,137 buildings were inundated or damaged between 2006 and 2015 [9].

The region was severely damaged in 2010 and 2011. The general status of Seoul, analyzed based on the inundation trace maps of 2010 and 2011 as well as digital maps provided by the national spatial data portal, is shown in the following table.

The flooded area of each district ranged from 0.00% to 9.54%, and the mean flooded area of each district was 2.68%. The surface water area of each district ranged from 0.37% to 23.91%, and the mean value was 6.07%.

Injuries or diseases caused by floods are influenced by complex factors, including the characteristics of the flood (including the size, inundation depth, and flow velocity) and various environmental conditions such as temperature and humidity. Since the main purpose of this study was to analyze the regions covered by emergency medical services, flood characteristics and other environmental conditions were not considered.

The figure below shows the distribution of 52 medical centers in Seoul which are designated as hospitals capable of providing emergency medical services.

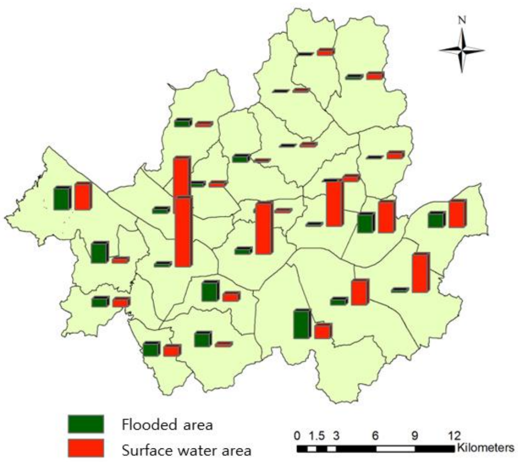

Figure 1: Distribution of medical centers in Seoul

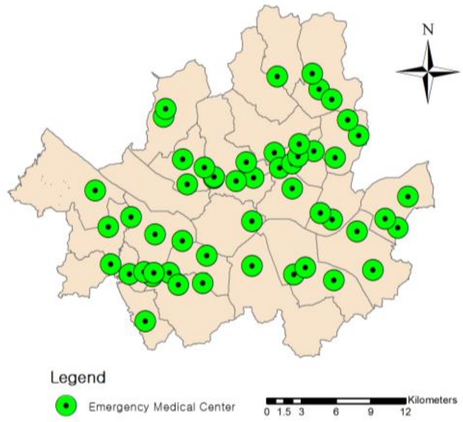

Figure 2: Distribution of medical centers in Seoul

The occurrence of inland and river flooding was assumed considering the recent and frequent occurrence of flash floods. In this case, drowning caused by rapid torrents and injuries caused by waste and floating matter may occur. Therefore, it is necessary to provide emergency treatment to patients. Network analysis was conducted using the criteria of arrival within five to ten minutes considering the emergency situation.

The results of the service area analysis based on the location and attributed information of the emergency medical centers are shown in the figures below.

As a result of superimposition based on the inundation trace maps under the assumption of inland flood occurrence, the area of the vulnerable regions outside the service area within five minutes was 59.60 ha and that outside the service area within ten minutes was 10.58 ha.

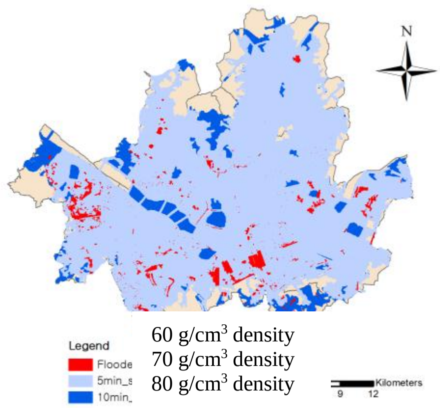

Figure 3: The results of the service area analysis (based on inun-dation trace maps)

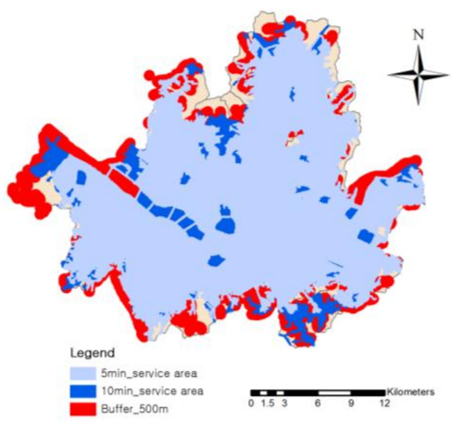

Figure 4: The results of the service area analysis (based on 500 m buffer zones)

Table 2: Service area of emergency medical facilities

Category	Area (ha)	Ratio (%)
Total area of Seoul	60,524.03	100%
Inundation trace (2010, 2011) area	1,819.03	3.01%
Area of surface water	3,855.59	6.37%
Area of buffer for surface water (500m)	31,932.33	52.76%
Emergency medical facility service area (within 5 minutes)	46,539.17	76.89%
Emergency medical facility service area (within 10 minutes)	51,759.79	85.52%

Superimposition of the results of the buffer zone for surface water under the assumption of river flood occurrence showed that the area of the vulnerable regions outside the service area within five minutes was 9,248.76 ha and that outside the service area within ten minutes was 5,413.25 ha.

Table 3: Results of derived vulnerable regions

Category		Area of vulnerable regions (ha)	Ratio (%)
Inland flooding (based on inundation trace maps)	Within 5 min.	59.60	0.10
	Within 10 min.	10.58	0.02
River flooding (based on 500 m buffer zones)	Within 5 min.	9,248.76	15.28
	Within 10 min.	5,413.25	8.94

4. Conclusion

In this study, regions with the possibility of flooding were divided into two: those with the possibility of inland flooding, and those with the possibility of river flooding. This was based on the inundation trace map and surface water status data. In addition, network analysis was conducted using the location information of emergency medical facilities, and areas vulnerable to emergency medical transport in the target region were analyzed.

As a result, it was found that in the event of an inland flood, providing emergency patient transport within five to ten minutes would be impossible in 0.02 to 0.10% of the entire area of Seoul.

It was also found that in the event of a river flood, emergency patient transport within five to ten minutes would be difficult in 8.94-15.25% of the entire area.

This study has limitations in that it could not conduct analysis in an environment that is close to the actual environment in which patient transport vehicles are operated. Therefore, it fails at reflecting real conditions, such as lanes and traffic congestion, in the network analysis process.

Such limitations need to be supplemented in the future by using big data such as the dispatch statuses of emergency vehicles. In addition, as this study did not consider the primary patient transport, i.e., the travel distance and time from the paramedics to the location of the patients, in future it is necessary to conduct a study on the entire patient transport process from the location of the patient to the emergency medical facility.

Finally, it is necessary to supplement the process of predicting the influence range of inland and river flooding and of estimating the degree of risk.

As this study is a basic study on the analysis of regions vulnerable to emergency medical services in the event of a flood caused by severe rainfall, it is expected that the results of this study will contribute to decision making that aims to minimize human injuries and improve resilience in the event of a future flood.

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