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Research paper



Development of Bypass Evacuation Route Setting Method Considering the Flood Depth

Ji-Soo Lee[1], Yoon-Ha Lee[2*]

[1] Department of Fire Safety, Kyungil University, Gyeongsan, Korea
[2] School of Architecture, Civil, Environmental and Energy Eng. Kyungpook National University, Daegu, Korea
**Corresponding author E-mail: dldbsgk123@naver.com*

Abstract

The purpose of this study is to develop a method of setting the route by bypassing an area where evacuation is impossible due to the flooding depth in a single global scale range. Most evacuation route guidance maps developed so far have a broader range of analysis than the actual evacuation area, suggesting only a rough evacuation direction. In addition, recent map inspection showed that evacuation cannot be conducted in reality due to the fact that evacuation routes are excluded from actual evacuation routes. In order to solve this problem, this study drew out areas where physical evacuation is impossible and has developed a bypass route setting method. In addition, it applied the developed method to the flood area and verified to confirm that it is possible to provide a concrete route for each step of flooding by simulating the progress of flooding successively. In order to commercialize the results of the research in areas prone to floods in the country, it is necessary to establish a methodology to automate and construct route information.

Keywords: *Evacuation Path, Disaster Information map, Network analyst, Indirect Path, Inundation Depth*

1. Introduction

The purpose of this study is to develop a methodology for setting up a bypass route for hazardous areas as the flooding progresses in providing evacuation routes in advance for residents in areas prone to floods.

The recent studies with similar purpose of this study can be roughly divided into mapping method using spatial information and evacuation feasibility study through experiments [2]. In particular, we analyzed the problems of the disaster prevention information map provided on the web by the country in the previous study [5] and suggested improvement factors for the future. This study wishes to develop this method as a concrete methodology and to upgrade the existing disaster prevention information mapping technique.

This study provides the evacuation route in flooding situations and the spatial extent of the research is set to single district scale. This is the most realistic size for solving the problem of areas prone to floods, and it includes roads in the analysis range because it covers the size of the earth.

As a research method, the method of constructing the spatial data is to generate a polygon which is predicted to be flooded, and a prediction of the depth of the sink should be made at the same time to determine the extent to which evacuation is impossible. Then, the point where the evacuation is required is constructed from the graphic data.

For the evacuation route, a digital topographic map or shape file is processed in the form of a dataset to analyze the route from the evacuation point to the evacuation facility in order to analyze the network.

In this case, it is assumed that the figure with flood possibility is regarded as an evacuation impossible point, and a bypass route to the evacuation facility is set.

In order to verify this methodology, this study has applied 4 flooding stages in the region designated as areas prone to floods and confirmed that it is possible to provide the bypass route information in advance by stages.

2. Experimental Details

In previous studies, we examined the problems of disaster information maps currently provided by the Republic of Korea and found typical problems. In the Republic of Korea, flood experience, flood prone areas, shelter locations and rough evacuation route information are provided as shown below through the website Safety Nuri [4].

However, the results of investigation of the disaster prevention information map showed that most of the evacuation routes and shelters are passing flooded areas or they have flooded. These problems make it difficult for residents to understand the location of the evacuation facility or route. Either this or many of the other cases where evacuees were not able to access the evacuation facility due to the inundation of the evacuation route itself.

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Figure 1: Flood information map in South Korea [4]
Source: Seoul Nuri-Safety. 2017.

Therefore, in the previous research6 (Sun et.al., 2015), the concept of bypassing the flooded area was presented. However, this study proposes a method to provide realistic bypass routes by setting the area with a certain flooding depth as a control area.
Many methods for predicting flooded areas have already been developed and utilized through various software, and most of these studies7-8 are aimed at accurately quantifying the factors that cause flooding or accurately predicting flooded areas. This study, however, excluded the discussions on the precision of the flooded area or the depth of flooded area because it is a study that suggests an evacuation route by bypassing the flooded area.

In this study, for the method of predicting the flooded area and the flood depth, the TIN was generated using a digital topographical map and the flooded area by stage was converted into polygons based on the elevation.
The flooded area was transformed into graphic data using a 5m×5m grid and the flooded area was classified into 4 levels according to elevation considering the actual flooding experience as shown in Figure 2. Polygon data was created for the non evacuation area by stages based on the results of the analysis as shown in Figure2. This is because, even if the flooding progresses, a person can walk in a certain depth of water. Therefore, an area except where walking is possible even in a flooded area becomes an inaccessible area in the course of route analysis.

Previous studies on the possibility of walking according to the depth of the flood were conducted mainly through experiments. According to the study of Matsuo, K et.al., 9 the possibility of evacuation according to the flood depth and the flow velocity is defined as follows.

$$Safety = \frac{(u^2 * h)}{g} + \frac{h^2}{g} < 0.12$$

h is depth, u is flow velocity, g is gravity

In the above equation, we apply the formula for the flow velocity of 0, and in this study, it is judged that walking is possible if the water depth is less than 1.1m. Each stage of the non evacuation area was constructed with polygon data. In other words, as the flooding area is flooded as shown in the following figure 3, the building in the area is set as the area requiring evacuation and the restriction area is designated as the area where the crossing or passage is impossible.

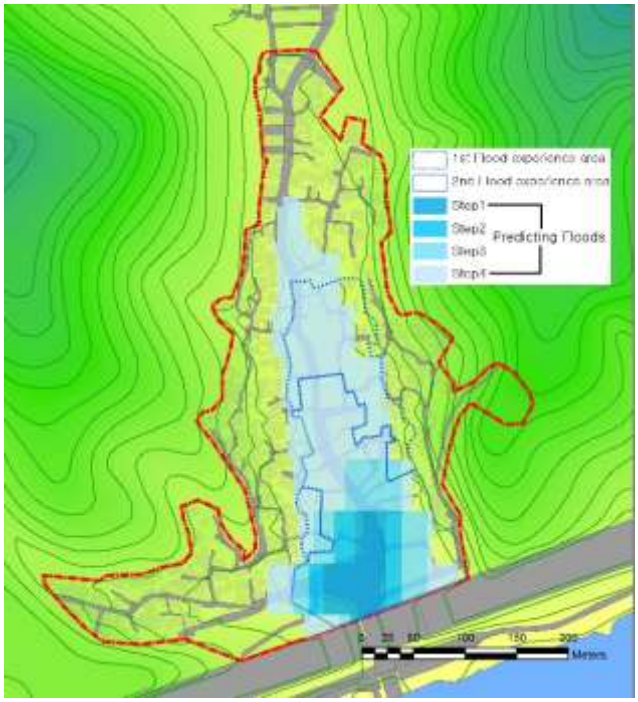


Figure 2: Classification of flooding area

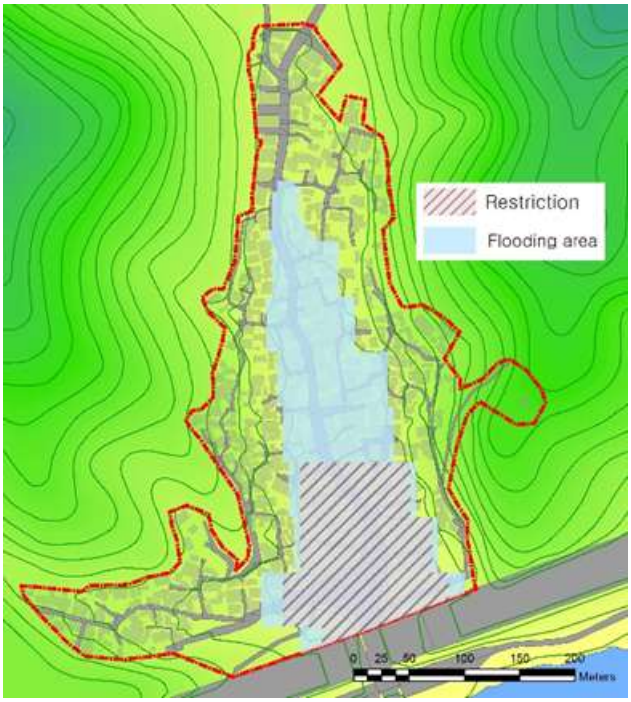


Figure 3: Evacuation restriction area

In addition, the route data necessary for the network analysis is created based on a digital topographic map and road space data, and is constructed in the form of a network dataset. In the network dataset constructed as shown below, the node point means the turning point, and all node points were set to allow the pedestrians to change or turn the route. Also, evacuation facilities and evacuation necessary points (buildings) are converted into node point data as shown in the figure below to be used for network analysis.

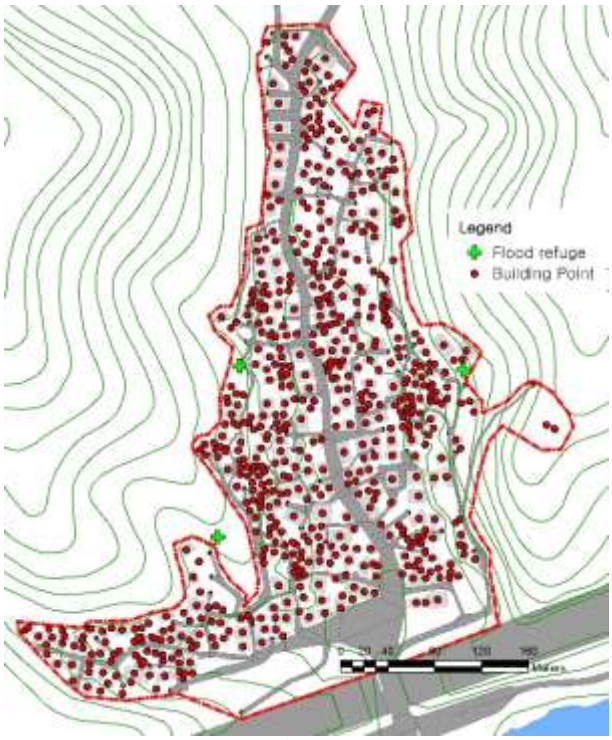


Figure 4: Flood refuge & evacuation point data

3. Results

The data and methodology constructed in the previous study3 were applied to the study areas which are designated as areas prone to floods in Daegu, Republic of Korea1. The area of the site is about 110,000 ㎡, which experienced flooding for two years in a row. In the first flood, about 23,000 ㎡, and in the second flood, about 35,000 ㎡ flooded. Considering that the minimum elevation of the site is about 25m and the flood has progressed to about 31m above in the past, the scenario of 4 flooding in 2m units was set. Therefore, the flooding of the first step was inundated in the 25m area, and there was no area where walking was impossible in the first stage. The second step was set 27m, the third step 29m, and the fourth stage 31m.
An analysis was carried out on the assumption that evacuation is possible up to a depth of 1.1m in each step.

The Arc GIS 10.2 network analyst was used and the data needed for the analysis consisted of the evacuation points, the location of the evacuation facility, the flooded area and the flood depth, and the network dataset.

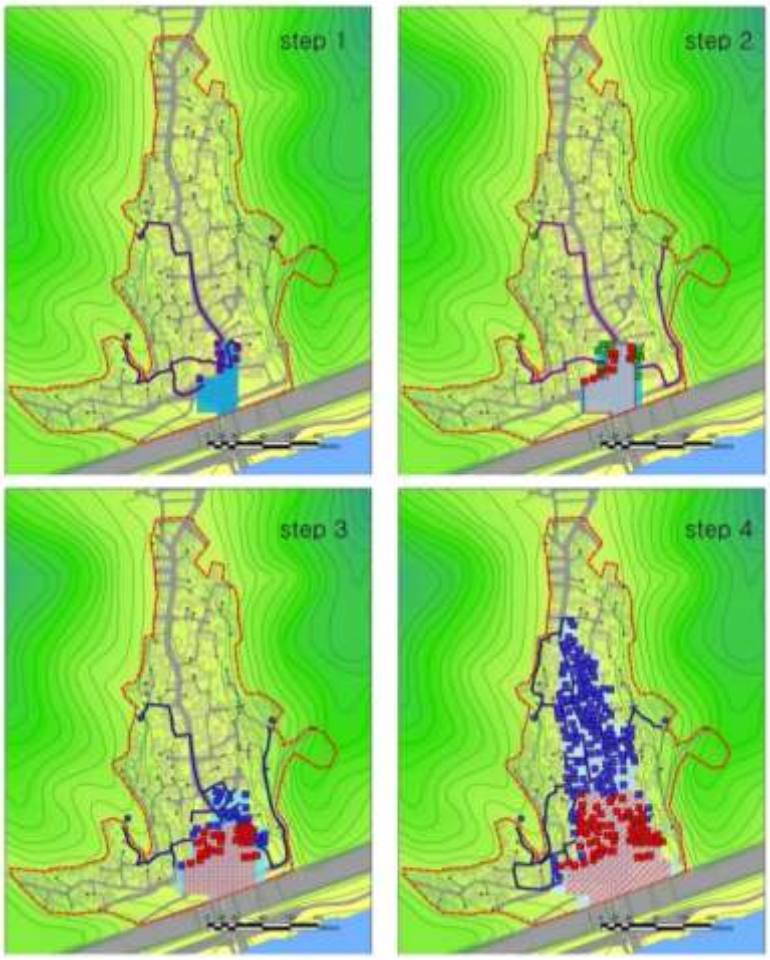


Figure 5: Results of bypass routes analysis by stage in floods

For evacuation points, the node points of the buildings located in the flooded areas of each stage are used, and the location of the evacuation facility was also converted into node point data. The fastest route from each evacuation point to the evacuation facility was searched, and the routes were searched by excluding the passage from the flooded areas where evacuation is impossible. The results of this analysis are as follows. As a result of applying to the study area, it was confirmed that step 1 evacuates freely and finds the fastest route if there is no area over 1.1m in depth. However, for steps 2 to 4, there are cases where bypass routes are designated due to the designation of an area where evacuation is not

possible and occasionally, the evacuation facility is approached by bypassing a considerable distance.
However, due to the limitation of the program that must select the shortest path in the process of setting the path, it may not be feasible in reality to choose the shortest path possible for walking in a flooded area. However, in this study, it is possible to compensate for the limit of the existing evacuation route information because it can provide information by excluding a path that cannot be walked due to flooding in many evacuation points.

4. Conclusions

In this study, a 1.1 m depth, which is generally considered to be impossible to evacuate, was set to be a non-evacuation area, but it is also necessary to consider the age and the people with impaired walking ability. In addition, considering the movement mode of people with impaired walking ability, the area where the evacuation becomes difficult due to the slope of the site should also be discussed.
However, the existing disaster prevention information map only set the outline direction to the evacuation point, but this study is meaningful that it was possible to present a concrete route. In addition, although the disaster prevention map provided by the Republic of Korea is considerably advanced compared to other countries, the previous studies have problems with providing a route to cross the flooded area. However this study solved it by providing a concrete methodology.

Acknowledgement

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