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Evaluating the significance of highway network links under the flood damage: An accessibility approach

Jungyul Sohn *

Department of Earth Sciences, University of Memphis, 229 Johnson Hall, Memphis, TN 38152, United States
National Center for Smart Growth Research and Education, University of Maryland, 1112 Preinkert Fieldhouse, College Park, MD 20742, United States

Abstract

This paper conducts an analysis to assess the significance of highway network links in Maryland under flood damage. An accessibility index is derived to incorporate the distance-decay effect and the volume of traffic influence on the transportation network. The accessibility level of individual counties and the state as a whole is checked before and after the hypothetical disruption of individual links within the floodplain. The results indicate that critical links identified based on the distance-only and the distance-traffic volume criteria appear to be different, implying that the priority of retrofit might also vary depending on what criterion to choose. The percentage loss of accessibility due to the disruption of a link is generally greater in the latter. However, distance-only consideration results in a more prominent spatial distribution pattern of links in percentage loss induced. Some links remain significant in both cases. Especially if the disruption of a certain link does not have an alternative solution (for example, if the link is the only way in and out of a certain county) and if counties connected by the link are low accessibility counties, the two criteria may produce a similar outcome.

Keywords: Highway network disruption; Flood; Accessibility; Maryland; Distance; Traffic volume

1. Introduction

There seems to be a consensus that natural hazards or disasters have a huge impact on human society in many respects. While different types of natural hazards are associated with different time spans of impact and varying levels of damage, the consequence of a disaster is devastating in many cases. A number of studies rooted in physical environment have focused on understanding the mechanism of the disaster and the immediate physical damage. However, there have been only a small number of works devoted to exploring the potential impact of the disaster on society, and, the retrofit and restoration strategy against the disaster, even if the number has increased in the 1990s among disciplines such as geography, regional science, urban planning, and transportation studies. One major reason for the lack of studies is related to the difficulty of interdisciplinary

* Tel.: +1 901 678 4579; fax: +1 901 678 2178.
E-mail address: jsohn@memphis.edu

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approaches. For example, to assess an economic impact of a disaster, a researcher has to derive a way to convert the physical damage from the disaster into some other measure showing the damage on society. This is not a trivial task. Various assessment frameworks have to be developed related to different types of natural disasters as well as different types of impacts to be assessed in order to derive a proper methodology to convert the physical damage into the social damage.

Flood may not be a natural disaster that imposes as spectacular damages as earthquakes or hurricanes do. However, flood is likely to occur more often than many other types of disasters since even man-made disasters (e.g. collapse of a dam) as well as different types of precipitation (heavy rain, snow, and hurricane) might be a potential trigger of the flood. In this respect, it is hard to determine which type of disaster is more harmful than others in a general context. While not a lot of actions can be taken to get rid of natural disasters themselves, there are some ways to relieve the damage from disasters, such as pre-disaster measures (retrofit) and post-disaster measures (restoration). If those measures are efficiently implemented, the damage can be greatly reduced. Such efficiency is often related to budget constraints on retrofit and restoration. For example, when the transportation network has to be retrofitted, all the links with the risk of potential disruption can be retrofitted at the same time if there is no budget constraint. If there is a budget constraint, however, not every link can be retrofitted all at once. Rather, a certain type of priority has to be established among those links in the retrofit process in order for the result of the retrofit to be more effective.

As an attempt to investigate the probable impact of flood on society, this paper examines the highway network system in Maryland. More specifically, this paper attempts to establish a priority of retrofit among the links on the state highway network based on the knowledge on the potential disruption led by flood. An accessibility index is used as the major criterion to determine how significant individual links are. GIS highway network database is used to calculate the accessibility index as well as to measure the road distance between counties in the state. Solutions calculated based on the distance-only and the distance-traffic volume criteria are presented and compared. Section 2 reviews previous efforts devoted in this area. Section 3 introduces the analysis framework of the paper. Section 4 reports the results of an empirical analysis. Section 5 concludes the paper.

2. Literature review

While it is not difficult to find a research devoted to flood in general, the number of research is relatively small if the focus is on something more than the physical characteristic of flood and on the corresponding implications in regional planning. This type of study is usually interdisciplinary since the study needs to consider approaches from physical and social sciences. The review here is limited only to those interdisciplinary literatures.

One of the concerns related to flood from a planning perspective is the size of damage it causes. Different studies have measured the level of damage with different methodologies. Using a China example, Renyi and Nan (2002) calculated flood area with GIS techniques. Flood damage in their study was estimated using the overlay operation of different land use patterns. The damage was measured as the ratio of flood area to the total area by each land use. They concluded that while their method was succinct and inexpensive, the result showed a satisfactory performance. Lekuthai and Vongvisessomjai (2001) focused more on assessing the economic damage of flood. They divided the total damage into tangible and intangible ones. The tangible damage was the direct function of flood depth and duration. To quantify the intangible damage in monetary terms, they used anxiety–productivity and income interrelationship approach. Based on the estimation results from the Bangkok data, they have found that a substantial portion of damage was made from the intangible one.

Nicholas et al. (2001) attempted to establish a conceptual model to work through the flood damage estimation process on the UK properties. According to the authors, it was very difficult to find the single optimal repair strategy due to a large variation in assessment. In their standardized assessment, flood damage was a function of flood characteristics and building characteristics. Damage was measured as the flood damage repair index. Wurbs et al. (2001) introduced uncertainties in the estimation of average annual damage of flood. In the study on College Station, TX, they adopted Hydrologic Engineering Center (HEC) simulation models of the US Army Corps of Engineers. They suggested that stochastic approach is more reasonable for implementing risk-based analyses since these types of analyses are associated with various aspects of uncertainty.