Chapter 18
Assessing a Vulnerability Index for Healthcare Service Facilities:
A Logistics Perspective

Alvaro Talavera
Universidad del Pacífico, Peru

Michelle Rodríguez
Universidad del Pacífico, Peru

Andrés Regal
Universidad del Pacífico, Peru

ABSTRACT

The rapid growth of cities in the 21st century along with the congestion of road infrastructure and high population density makes urban spaces highly vulnerable to disasters. After a disaster occurs, health services infrastructure is critical to support medical operations for injured patients. This chapter presents a methodology for evaluating the vulnerability of health services infrastructure from a logistics perspective, based on several layers of information such as population density, road congestion, and hospital location. The methodology uses computational and business intelligence techniques such as fuzzy inference systems, geographic information systems, graph theory, and visualization. The purpose of this methodology is to generate a unique score of vulnerability that identifies each health services facility, providing decision makers with the analytical framework of a spatial multicriteria analysis to evaluate their options for facing a disaster.

INTRODUCTION

Mainly urban areas have absorbed the accelerated increase in the world's population in the past four decades. By 2050, the world's population will reach 10 billion inhabitants, of which about 66% is projected to be urban (United Nations Department of Economic and Social Affairs, 2014). As fragile socioeconomic systems, cities are highly vulnerable to the impacts of environmental hazards, creating

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the premises for various disasters (Parker & Mitchell, 1995). In the context of an explosive increase in value of the damage caused by natural disasters, the need for evaluating and visualizing the vulnerability of urban areas becomes a necessity for helping practitioners and stakeholders in their decision-making processes (Armas, 2012).

Disasters such as the 2001 U.S. terrorist attacks, Hurricane Katrina, and the 2008 Chengdu earthquake have highlighted the need for improved public health and medical disaster response capabilities (Brandeau, McCoy, Hupert, Holty, & Bravata, 2009). Healthcare systems play a critical role in recovering and mitigating the effects of natural disasters and deliberate attacks (Arboleda, Abraham, Richard, & Lubitz, 2009).

While natural and human-hazard events will occur, the capabilities for coping with the effects of an event developed by a system or a nation will not be perceived as responsive to a major disaster (Kovács & Spens, 2007). An evaluation of the risks and a defined contingency plan for a quick response are crucial.

In this response, healthcare facilities become an important part of the support infrastructure. Furthermore, assessing the vulnerability of healthcare facilities is an important part of a contingency plan to mitigate the impacts of disasters in the population. Thywissen (2006) defines vulnerability as a dynamic and inner feature specific to any system, which usually becomes visible during a disaster. As Armas (2012) states, the need to define and measure vulnerability is necessary for a better understanding of the factors that determine when hazards become disasters.

Vulnerability assessment with respect to natural hazards is a complex process. Several works had taken different approaches to construct a vulnerability index to numerous hazards. U.M.K. Eidsvig et al. (2014) focused on landslide vulnerability for several European regions, they proposed an index using an additive model where each dimension was assigned with a weight based on its importance during a disaster. To compute this index, dimensions such as vulnerable elements, preparedness and recovery were analyzed. Since the scale of the calculated index is relative, a single score becomes difficult to interpreted. It was necessary to apply this model to different regions; from which the results form a base to interpret the single score. A more recent work, Zin Zin et al (2016), assesses earthquake vulnerability based on georeferenced land use conditions, population and building density. They used analytic hierarchy process (AHP) to set level of influence on pairwise comparisons of variables. Similarly, Lorenzo C. et at. (2017) evaluated both social (mortality, resources, poverty, population density) and physical (economical, infrastructure, social loss) attributes. They combined AHP to define weight priority for each attribute and fuzzy logic to build a final vulnerability score. On the other hand, Reza A. et al. (2018) proposed a systematic approach to measure the risk value of landslides through different factors. They applied a mamdani fuzzy inference system to build three factors: vulnerability, consequence and a likelihood index. Then a final risk value was calculated by a Takagi-Sugeno fuzzy system, using the previous indices as inputs. Fuzzy models are among the most powerful techniques in handling the inherent uncertainty (Reza Azimi et al, 2018).

In this chapter, a methodology to evaluate the vulnerability of healthcare facilities using Fuzzy Inference Systems (FIS) is presented. For this evaluation, multiple georeferenced layers of information may be used (such as population density or road connectivity) as inputs to the FIS, which in turn possesses a set of rules to process and merge available information into a unique score. The main advantage of this methodology is the expert's input. By evaluating changes in the rule-base, a quick and efficient facility scoring may be presented to decision makers in order to motivate data driven public policy for healthcare facilities.