

# Chapter 19

## Resilience of Urban Infrastructure in Latin American Cities

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### ABSTRACT

*Resilience is the capacity of a society or infrastructure to resist, adapt, and recover after being impacted by an extreme event. In this chapter, the authors focus on measuring how much the road infrastructure is able to withstand the appearance of extreme events. An extreme event will be represented by an intentional (e.g., perpetrated attacks) or unintentional (e.g., as result of climate extreme event) damage on the routes or intersections of the road network within a city. To do this, the authors measure the primary characteristics of urban networks in order to understand their morphology (i.e., the way in which they were constructed). Then, they evaluated the resistance capacity of different points of the road networks with three types of attacks: random, directed, and localized. The first results of this study show the fragility of some roads and intersections before the appearance of extreme phenomena. These results can be exploited by those in charge of public management and then converted into policies.*

### INTRODUCTION

A Japanese proverb defines resilience as “build again, but better”. Resilience covers a group of capacities that an individual, a society or an infrastructure must have to continue functioning under adverse conditions or after an extreme event (Flemming & Ledogar, 2010). Currently, governments, environmental associations and society are concern about the adverse effects of a severe environmental event. This nega-

DOI: 10.4018/978-1-5225-8160-4.ch019

tive effect can alter the resilience of infrastructure in three different ways. First, when the infrastructure does not fully recover its original state, becoming less resilient. Second, when the infrastructure recovers its original state, without altering its resilience. Third, when the infrastructure exceeds its original state, becoming more resistant to face future events. From the previous categorization, it is evident that the first state is the most worrisome. Therefore, state-of-the-art research is focused on this state (*i.e.*, first state).

Resilience is closely linked to vulnerability or fragility. Thus, it is necessary to quantify the risk factors for reducing vulnerability opportunely (Smokowski, 1998). In this context, the present study focuses on the vulnerability analysis of road networks in urban areas, notably, in densely populated cities like Lima-Peru and Quito-Ecuador. We have represented the road networks of both cities using graph models to compare their morphology and other properties. Then, we have analyzed the resilience of the road networks by simulating closure of roads and intersections. Finally, we have measured how the closure of roads and intersections makes it more difficult for people to reach health infrastructure such as hospitals.

The present chapter is organized as follows. Section 2 introduces the essential background and state-of-the-art. Section 3 explains the theoretical framework of our approach. Section 4 presents the methodology we have followed, while Section 5 describes our case study in two Latin American capitals. Finally, Sections 6 and 7 indicate some solutions, recommendations and future works, respectively.

## **BACKGROUND**

Resilience is a concept of positive connotation. This term was used a hundred years ago as an indicator that allowed measuring the invulnerability or invincibility of infants, as an individual entity, as part of a family, or collectively or culturally (Glantz & Johnson, 2002). Later, other works in the literature reference to resilience as the possibility of intervention, prevention and positive adaptation to recover the vulnerabilities of individuals at risk. Other works related to resilience focuses on how to correct the vulnerability of a society and its infrastructure. For example, (McLellan et al., 2012) and (Eldosouky et al., 2017) assess the risk of global warming affecting critical infrastructures. (Meyer et al., 2018) (Godschalk, 2003) and (Kao et al., 2017) analyze repeated disturbances and focus on assessing the possibility of failure of a system facing a disaster. Also, Duijnhoven et al. (2014) and Marchant & Stevens (2017) conceive resilience as the capacity for mitigation, adaptation and recovery of a social or environmental structure affected by extreme climate changes.

In developed countries, resilience is used as an instrument to measure society's risk face to an adverse phenomenon, to prevent or intercept threats before they appear.

In the United States, there are organizations such as The National Academy of Sciences NAS, and the U.S. Global Change Research Program. These organisms offer a framework to analyze extreme events caused by a climatic phenomenon. They propose a sequence of systematized steps to discover and to document climate hazards. Then, they propose viable actions to reduce risks. These steps include measuring the initial damage caused, monitoring the recovery process, and assessing the existence of irreparable permanent damage. However, it is also possible to restore the initial state and improve the conditions to face similar disturbing events in the future.

On the other hand, the European Union and the European Commission (EC), in their document, Joint Communication to the European Parliament and the Council evokes the term resilience as a means of prevision. The idea is to make the population aware of natural disasters and how they can impact the vulnerability of society, especially in the poorest countries. The fragile components they consider are

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