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Road Reconstruction and Redundancy Analysis on the Road Network: A Case Study of the Ateneo de Manila University Network

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Abstract

We consider studying the redundancy of roads in a given road network during emergency situations. The analysis of link redundancy is interesting especially during disaster mitigation. The roads must be reconstructed as soon as possible to achieve network connectivity. Identifying redundant links would be useful to reduce the cost and guide in prioritization of the road reconstruction during disaster. We presented a model for studying link redundancies using link reconstruction analysis. Our study compares two different techniques in road reconstruction, namely the average impact and the maximum impact road reconstruction techniques. Reconstructing redundant links in a given network reduces the overall distance of the entire network. Our proposed methodology produces similar results, but will vary based on the road network structure.

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Keywords: redundancy analysis; road reconstruction; robustness; strongly connected network; disaster mitigation

1. Introduction

Road network is a fundamental part of society. They connect different areas, cities, and people in the best possible way. Different buildings and landmarks can only be visited with the use of certain roads. Studying road networks before, during, and after disaster situation is very important to understand the reliable and robustness of the network. Especially, there is greater need to achieve network connectivity as soon as possible after the network has been destroyed due to the disaster (Immers *et.al*, 2004). At the same time, the network has to have the minimum travel cost to reach a certain destination that is solely depended on the behavior of the users (Yang & Bell, 1998).

Road networks are becoming more vulnerable to several unforeseen scenarios like disasters, accidents, and other emergency situations, which causes disruptions. This directly affects several aspects of the road network like traffic flow and network connectivity. Furthermore, recovering from such disruptions becomes more difficult overtime due to the changing demands in the network flow, which can directly affect the connectivity of the entire network, as well as the ever-increasing road reconstruction costs.

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Studying road network robustness is a relatively new research area. Different research has different definitions for robustness. Several studies been conducted to define several factors in determining robustness, to include identifying critical links, alternate routes, and network connectivity (Snelder *et.al*, 2012; Sullivan *et.al*, 2010).

However, only a few studies have been conducted in determining connectivity of the entire network after road reconstruction (Chen *et.al*, 2008; Franchin *et.al*, 2006; Jenelius, 2010). Most road network robustness research only took into account the robustness on an individual link basis without studying how each link affects the entire network. These studies also consider other elements like infrastructures, which may aid in connectivity, but is also too complicated to apply because of the usage of images, as well as the inclusion of different road network elements. Although critical links and alternate routes are identified, the network may not necessarily be robust in terms of connectivity due to the limited information it provides.

In this paper, we proposed a new concept of link redundancy analysis to be used in assessing road network robustness. We define a road link as redundant if the existence of the link does not contribute to the connectivity of the road network. The analysis of link redundancy is interesting especially during disaster mitigation when the roads must be reconstructed as soon as possible to achieve network connectivity. Identifying redundant links would be useful to reduce the cost and guide in prioritization of the road reconstruction during disaster.

The scope of this paper does not include the traffic flow of the network. The main focus of the research was performing link redundancy analysis in relation to the entire structure of the road network, without taking into account traffic flow. We also did not include in our research travel costs, in the perspective of a normal commuter.

In Section 2, we defined the terms we used in determining the robustness of a road network. Our actual methodology is found in Section 3, in which each sub-header defined the tools we used to arrive at our analysis. Section 4 discusses an analysis of the network we used to formulate our hypothesis. We applied our methodology in a case study found in Section 5. The scopes and limitations, as well as the conclusions were discussed in Sections 6 and 7, respectively.

2. Definitions and Related Works

To give better understanding of the terms we used throughout the paper, we provide here the definitions and the related works on each part.

2.1. Road Networks

A road network is a weighted directed graph $G = (V, E)$, where V represents a set of vertices (or nodes) and E represents a set of edges (or links). In a road network, the nodes represent intersections among roads, while the links represent the roads themselves. Each edge has a value that represents the distance of the link from a source node i to a destination node j. A certain landmark where the trips are generated is also represented as centroid nodes. A centroid node can either be a source, where the trips are initiated, or a sink, where the trips are terminated, or simply a basin or both source and sink. These centroid nodes are connected to the road network. The direction of each link represents the way the road is traversed. The weight of each link in the road network represents the distance of the network from one node to the next node where the link connects. Road networks are represented based on topology of the network is viewing to a map. The topology is the structure of network in the form of a graph with their respective nodes and links.

2.1.1. Adjacency and distance matrix

An adjacency matrix **A** can be used as a representation of a road network. It is an n by n matrix where n is the number of nodes in the network. The rows of an adjacency matrix represent the nodes of origin of the links, while the columns represent the nodes of destination of the links. A value of 1 is assigned to an element in the adjacency matrix to represent a link from a node to another node. The following equation shows how an adjacency matrix is constructed for road networks: