DISRUPTION OF CRITICAL INFRASTRUCTURE DURING NATURAL DISASTERS

Emma Phillips
emma.phillips@mq.edu.au

BNHCRC PhD Scholarship Holder, PhD Candidate, Risk Frontiers, Macquarie University, NSW

Supervisors: Dr Christina Magill, Dr Felipe Dimer de Oliveira, Prof John McAneney, Risk Frontiers, Macquarie University, NSW

TO UNDERSTAND HOW COMPONENTS OF OUR BUILT ENVIRONMENT AND SOCIETY WILL FARE DURING A DISASTER, KNOWLEDGE IS FIRST NEEDED ON THE INTERCONNECTEDNESS OF NETWORK SYSTEMS AND THE ROLE EACH COMPONENT PLAYS

BACKGROUND

Lifeline networks are the infrastructure and critical services needed for everyday life. Lifeline network failure has wide reaching impacts on residents, businesses, other critical services and, in a disaster, rescue and recovery.

Currently there is limited research on the impact natural hazard events have on these systems and the flow on effects from their failure. To estimate the true impact of lifeline network disruption during a disaster there is a need to better understand network behaviour, interconnectedness and exposure to potential natural hazards.

PROJECT OBJECTIVES

This project will contribute to better understanding of the impact natural hazard shocks have on lifeline infrastructure and the implications of lifeline failure during disaster response and recovery, by:

- Utilising mathematical graph theory tools to analyse lifeline network behaviour and the impedance of services during network disruption.
- Overlaying natural hazard footprints onto network representations to simulate potential impacts of realistic disaster scenarios

RESEARCH QUESTIONS

This research will investigate:

- How lifeline networks respond to disruption and the impact of network failure
- The current exposure of lifeline networks from natural hazards
- Scenarios that could generate a potential catastrophic disruption in the future

Figure 1: Canterbury earthquake 2010. Buckling of train tracks near Rolleston, New Zealand (Source: Dr Dave Petley).

USING GRAPH THEORY TO UNDERSTAND LIFELINE NETWORK DISRUPTION

Graph theory is the study of networks represented as graphs (Figure 2). Graphs are mathematical structures consisting of nodes (vertices) and connections (edges) that are used to describe the building blocks of many physical networks and other interactions (Van Steen, 2010).

Figure 2: Example of a graph with six vertices and eleven edges.

Graph theory has been used to study critical infrastructure systems, such as power grids (Albert et al., 2004; Crucitti et al., 2004; Koç et al., 2014) and transportation networks (Angeloudis and Fisk, 2006; Derrible and Kennedy, 2010; Cardillo et al., 2013). However, the majority of research to date has focused on network topology and determining robustness to random failure and targeted attack. There is limited work on natural hazard shocks, cascading lifeline failures or dynamic flow through weighted networks.

This project will utilise graph theory to analyse flow change and impedance during network disruption. Using the Tokyo Metro as a first case study I aim to determine the most streamlined routes following track and station disruptions and, using passenger numbers, determine the magnitude of disruption and likely change in passenger loads. Figure 3, shows an example of network rerouting after a single station is removed from the network.

Figure 3: Rerouting of the shortest path (km) from Myogadani Station to Monzen-Nakacho Station after Otemachi Station was removed from the Tokyo Metro network. Original path in red, detour in yellow.

FUTURE WORK

This initial study will lead to further investigations including:

- Determining road and rail network exposure to hazardous ashfall; and implications of transport disruption for surrounding areas, following an eruption
- Applying learnings to Australian case studies, contributing to the 'Using realistic disaster scenario analysis to understand natural hazard impacts and emergency management requirements' project, as part of the BNHCRC 'Scenario and Loss Analysis' cluster

Figure 4: Mount Pinatubo eruption, 1991. DC-10 jumbo jet grounded at Cubi Point Naval Air Station (Source: U.S. Navy photograph by R. L. Rieger).

COMMENTS FROM THE END USERS

" Management of natural hazards, their impacts and their interactions in communities using structured mathematical and information system approaches is a critically important evolution of disaster management. Other sectors of industry and commerce use a variety of computational network and information modelling approaches to solve large and complex interconnected problems. These need to be applied to disasters. So the next few years will see disaster managers developing more formally adopted approaches to network, agent-based and least cost based methodologies and the research outlined in this poster will be part of the groundswell which will assist in understanding the adaption and innovation of these approaches to disasters," (NSW SES).

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