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Analysing impacts of natural disasters on logistics activities: flood risks and petroleum fuels in Queensland, Australia

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Abstract

Natural hazards cause much damage to lives, assets, and the economy as a whole. The functional discontinuity of businesses impacted by a natural disaster has a direct impact on affected community's quality of live. In regional and remote communities petroleum fuels are an essential commodity, particularly in post-disaster situations, given the supply chains of many other commodities are dependent on fuel supply. The aim of this study was to develop a framework and use it to analyse petroleum supply to communities affected by flooding across Queensland, Australia. The intent was to assist industry partners in identifying vulnerable localities and to development methods for application to other commodities. The approach focused on both the demand and supply side and used socio-spatial datasets, transport and commodity data. A multi-agent model was developed to represent the situation of petroleum fuel supply chain before and after a disaster event. The results identify both the broad sweep of vulnerable locations in key regions in Queensland as well as particular issues for communities in Cape York in far north Queensland. The approach proved viable, despite the limitations of publically available commodity datasets in Australia, and should therefore be of assistance to policy makers elsewhere seeking to identify system vulnerabilities and increase resilience.

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1. Introduction

The frequency and intensity of natural disasters has been increasing in recent years (Whybark et al, 2010). Disasters such as typhoons, floods and earthquakes create damage to lives, assets, and the economy as a whole. Businesses struggle to recover in the aftermath. Australia is a particularly disaster-prone country where floods, bushfires, storms, earthquakes, and landslides often occur. The 2010-11 flooding events in Queensland were the worst in recent Australian history (Department of Agriculture, Fisheries, and Forestry, 2012). The floods strongly impacted to the economy as a whole with IBISWorld downgrading the country's GDP by 0.3 percent solely as a result of flooding (IBISWorld, 2011). Disruption was caused to all transport modes including road, rail, air, and sea. According to the major report on the floods' impacts (Department of Agriculture, Fisheries, and Forestry, 2012), at its peak 155 major roads were flooded and damaged. This caused severe disruption to supply chains preventing numerous cities and towns from being resupplied. Shortages of essential items occurred and, in the worst case, petroleum fuels had to be barged in to the city of Townsville and emergency food drops by helicopter were required to numerous localities. The report suggested the major impacts of the floods on supply chains were due to the disruptions of transport routes, warehousing and manufacturing facilities, and also to production. Identifying vulnerabilities in such systems, and building resilience, can help alleviate problems in future.

Petroleum fuels are a critical commodity in regional areas of nations such as Australia. Fuel is required not only for people to access work, education and the goods and services they need in daily life, it is also essential to carrying goods by road or rail. The supply chains of all other commodities are dependent on petroleum fuel supply. Fuels are also essential for heavy equipment needed for repair and restoration of transport networks and other infrastructures, and for the generation of electricity in communities where electrical grids are knocked out by a disaster. As such, many nations use countermeasures to prepare for petroleum shortages, storing additional capacity in strategically placed reserves. Local media reporting through recent floods in Australia shows how customers have had to wait many days for fuel until roads are reopened (News.com.au, 2011) and how limited remaining supplies had to be triaged in other locations for emergency services and other priority vehicles when floods have struck (Whitsundaycoastguardian, 2013).

Vulnerability analysis of critical infrastructures is used to identify possible effects in advance of disasters. Vulnerability may be defined as the degree to which a system is susceptible to adverse effects. It is a similar but somewhat different concept to resilience, which incorporates a network or a community's capacity to deal with and bounce back from a disaster. The critical infrastructures considered are often lifeline systems including transportation, energy, information and telecommunication, and drinking and underground water systems (Kroger, 2011). In disaster logistics research, vulnerability analysis is used to identify vulnerable nodes and links in a transport network, so to assist planners to retrofit or manage future hazards. Two broad approaches are used: i) qualitative analysis, often focused on learning from past events to discern how to better manage risk in future; and ii) quantitative analysis, using transport and commodity data, and modelling both supply and demand, to identify vulnerabilities, and simulate and forecast impacts under various disaster scenarios. We focus on quantitative approaches in this paper.

There is great diversity in the literature on quantitative vulnerability assessments for transport networks, given the many elements of both road networks and supply chains that are vulnerable to disasters, at different scales. But much of the work seeks to harness what may be termed 'accessibility-based network vulnerability analysis' (Taylor, 2008). Chang and Nojima (2001) evaluated the transportation network performance in the 1995 Kobe Earthquake in terms of transport accessibility. Sohn (2006) proposed an accessibility approach to evaluate the significance of highway links under flood damage. He derived an accessibility score based on distance and traffic volume, suggesting highway links having a high percentage of accessibility loss will have higher significance. Taylor et al. (2006) considered the socio-economic impacts of network degradation due to the change in the level of accessibility for the analysis of vulnerability of a road network. Their framework used a number of indices including generalized travel cost, the Hansen integral accessibility index, and an Australian remoteness index, highlighting how other socio-spatial datasets can be employed in vulnerability analysis. Others have focused on failure at the link level. Taylor

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