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Transportation planning methodologies for post-disaster recovery in regional communities: the East Japan Earthquake and tsunami 2011

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ABSTRACT

Spatial planning provides tools to government authorities that support integrated response strategies as part of the disaster management but regional communities outside of the metropolitan areas often lack the necessary capacity and resources to implement these approaches. Unlike in the USA, there are no guidelines for transportation planners in coping with post-disaster situations in Japan. There is a substantive literature on institutions, concepts of urban sustainability and resilience, community engagement and travel behavioral adjustments to natural disasters and man-made disruptions to transportation supply in the emergency phase but only limited research into travel demand modeling in the recovery phase. This paper focuses on the recovery phase – and constructs conceptual and operational demand and supply models for the recovery phase to help seek options for more sustainable outcome. The methodology is applied to the city of Ishinomaki, Japan, one of the many regional communities devastated by the March, 2011 earthquake and tsunami where only limited capacity and data are available. Future hypothetical scenarios for the city are analyzed to illustrate the potential practicality of the proposed methodology with the indicators of travel performance of the scenarios in the case study area. The paper concludes with implication to planning, including the full re-location of peninsular villages, and further research needs.

1. Introduction

Integrated response strategies to disasters are needed in order to create resilient communities capable of facing risks with greater flexibility (Reis, 2013; Sapountzaki et al., 2011). This entails linking actors and policies throughout a disaster management cycle that has the following stages: (a) reconstruction and recovery, concerning the long-term activities aimed at returning an area to 'normality' after severe devastation; (b) pre-disaster or preventive planning covering activities which range from the construction of defensive engineering works to land-use planning and elaboration of evacuation plans; (c) preparedness reflecting alertness immediately before the onset of a hazard; and (d) response referring to reaction activities immediately before and after the event and (emergency) relief operations (Smith, 2001).

The problem is that, within this disaster management cycle, spatial planning (and transportation planning) is largely absent. Spatial planning 'has the tools' to guide new residential, commercial and economic development away from identified hazardous areas (Sapountzaki et al., 2011). Transportation planning is a component of spatial planning so it is hypothesized there must be a literature on decision support tools and techniques that can readily be applied to the recovery of communities devastated by natural disasters, such as earthquakes, floods, typhoons and tsunamis. The aim of this research – more broadly into planning for resilient urban development (Campanella, 2006; Ganor and Ben-lavy, 2003; Godschalk, 2003; Haigh and Amaratunga, 2010) – is to develop decision support tools for governments responsible for the reconstruction of devastated regional cities in Japan. We define in this research Japanese regional communities as being located neither in the metropolitan areas nor in the regional center areas, and have less than a population of 400,000 (MLIT, 2012).[1]

[1] In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has conducted the national transport survey in selected 70 cities and 60 towns/villages to understand the situation of transportation since 1987. The surveyed cities and towns/villages include: three metropolitan area (Tokyo, Osaka, Nagoya and their surrounding cities); regional center cities (Sapporo, Sendai, Hiroshima, Kitakyusyu and Fukuoka) and their surrounding cities; regional cities (more than 400,000 population); regional cities (less than 400,000 population); other regional cities, agricultural towns/villages (25); rural towns/villages (35). The most recent survey was conducted in 2010.

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We have identified that much of the transportation research on post-disasters is US-based, where the planning authorities are generally well resourced with strategic transportation planning tools and have professional expertise and data bases for decision support. For example, the US Federal Highway Administration/Federal Transit Administration (2007) offers a briefing book for transportation decision makers, officials, and staff. However, there are substantial resource constraints in the developing world, or in the regional cities of the developed world, that has led us to search the literature for relevant tools; in their absence, we propose a suitable methodology from first principles for post-disaster transportation planning. The existing literature has rarely explored post-disaster transportation arrangements or mid-to long-term travel behavioral responses of residents remaining after a disaster (Section 2).

Two years after the 11th March 2011 earthquake and tsunami disaster in Japan, the challenges that local governments are facing are: how to re-design the transportation system considering projected mid-term and long-term settlement and land use; and how to generate designs that enhance the preparedness for future events. To address these challenges, the classification of the stages/phases of a disaster based on a lifecycle is useful as it helps to illustrate what strategies could be considered or developed at the various stages of a disaster, and how to move into the next stage (Ritchie, 2004). In Section 3, four phases are distinguished – the pre-disaster situation; the emergency disaster phase; the temporary settlement phase; and the recovery phase – and we construct conceptual demand and supply models for the recovery phase. The research reported here focuses on planning frameworks and decision tools applied to a specific case study of Ishinomaki, Japan, which was impacted by the earthquake and tsunami (Section 4). Scenarios of future spatial distributions of population and employment are constructed and the operational models formulated are applied to estimate various standard performance indicators such as vehicle kilometers of travel. The paper concludes with the implications to spatial planning in the case study city and research more generally in the transportation field of disaster management.

2. A review of research on decision support tools on post-disaster transport provision

2.1. Travel demand

There is extensive research on the behavioral adjustments that urban travelers make in response to transportation disruptions, irrespective of whether caused by natural or man-made events. This literature includes travel behavioral responses to network disruptions caused by public transit strikes; bridge closures; special events, such as the Summer Olympic and the Winter Olympic Games; and earthquakes, floods and tsunamis. Most of these studies are largely descriptive of behavioral change – usually with statistics typically based on a change of traffic flows on highways and time of day of travel before and after the event. One of the most recent studies is by Zhu et al. (2010) who analyzed the adjustments to traveler's decisions following the collapse of the I-35 W bridge over the Mississippi River in Minneapolis in 2007 with a view to better understand the short-term traffic dynamics and behavioral reactions to major transportation network disruptions. This study follows a line of travel behavior research in North America prompted by natural disasters, or infrastructure repair and maintenance, such as the 1989 Loma Prieta earthquake in San Francisco (Ardekani, 1992), the 1994 Northridge earthquake, Los Angeles (Deakin, 1997; Guiliano and Golob, 1998), the traffic management operations during the I-195 Providence River Bridge Repair Project (Devine et al., 1992), and the 14-month closure for repair of the Centre Street Bridge in downtown Calgary, Canada (Hunt et al., 2002).

Zhu and Levinson (2008) identify short-term travel behavioral changes immediately after a network disruption as:

– Change in the normal routes followed by drivers of vehicles because of road, and ramp closures or congestion caused by traffic re-allocating over non-effected routes.
– Adjustment in travel-time departure to avoid as much congestion as possible.
– Consolidation of trip purposes and, or, less frequent travel.
– Switch to alternative transport modes; and
– Share travel duties among family members.

There has been less emphasis on modeling behavior with the notable exception of Osaragi (2012) and Holguin-Veras et al. (2003), who conducted a stated-preference experiment on New York residents six months after the September 11th terrorist attacks on the Twin Tower Buildings on lower Manhattan. They attempted to determine the process people use to decide whether to make an inter-city trip by airplane, train or automobile. Stated preference data were used to calibrate behavioral mode-choice models based on Random Utility Theory. Osaragi (2012) constructed several models that describe decision-making and behavior of individuals in a large city attempting to reach home on foot in the wake of a major earthquake. Probability models were calibrated using data taken from questionnaire surveys and person-trip surveys conducted in the Tokyo Metropolitan area. This simulation of the movement of individuals having decided to return home on foot was then applied to determine the spatio-temporal distribution of those who might be exposed to city fires that are ignited during earthquakes.

Suarez et al. (2005) applied the traditional four-step transportation model calibrated for Boston, Massachusetts, with a set of plausible assumptions to test the impacts of severe flooding scenarios. Assumptions include: a flooded road implies that the link is rendered useless, and therefore its capacity was set equal to zero; no trips were generated from flooded residential areas; commuting trips that have as destination a flooded industrial or commercial area were canceled from the data base; and shopping trips that have as destination a flooded area were redirected to the closest commercial area. By comparing the transportation model run that incorporates these changes with the run under non-flooded conditions, a number of performance indicators were obtained. These include: the number of trips canceled due to flooding of the origin or destination; the number of trips canceled due to inability to go from origin to destination; the difference in vehicle miles traveled (VMT) and the difference in vehicle hours traveled (VHT), which is an economic impact based on the additional network delay that can be allocated a cost using the monetary value of time appropriate for the study area. Despite the efforts in understanding the transportation demand and travel behavioral responses after the unexpected disruption of a transportation network, the authors located no literature that analyzes the transition in transportation demand and behavior, within the disaster management. The recent work by Chang et al. (2012) examined the dynamics of urban disaster risk of 35 years in Metro Vancouver and its link with casualties and transportation risk. However, the analysis was focused on the transportation disruption during the emergency phase, by the loss of a bridge.

2.2. Transport supply

Studies of behavioral travel demand change is accompanied by quantification of damage to transportation supply. In most of the published studies of disruptions to the transportation system,