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Economic costs of critical infrastructure failure in bi-national regions and implications for resilience building: Evidence from El Paso–Ciudad Juarez☆

Sharada Vadali [a,*], Shailesh Chandra [a], Jeff Shelton [a], Alex Valdez [a], Michael Medina [b]

[a] Texas A&M Transportation Institute, Texas A&M University, United States
[b] El Paso Metropolitan Planning Organization, United States

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ABSTRACT

Transport infrastructure of the ports-of-entry (POEs) and the Bridge of the Americas (BOTA) in the El Paso–Juarez region is important for international trade and economic vitality for both countries. This paper's contribution lies in the use of a bi-national dynamic traffic assignment model that is calibrated for the region to obtain temporal insights into daily travel effects and economic costs of an unintended disruption of the POE approach infrastructure. Travel effects and costs are evaluated for a before-and-after comparative study and changes in both daily static and dynamic travel times are considered. The model considers flow directionality, allowing the framework to isolate international flows from domestic trips for the determination of direct costs. Delays at POEs are treated exogenously since inspections are not part of the model. Simulation results show that the costs for shippers, carriers including delays at POEs could approximate $191 million in the immediate short run (in current dollars). The disruption is considered an isolated event with no impacts to additional infrastructure. Managerial actions are suggested for resilience building and suggestions are made for future research including mitigation and a network approach to resilience in assets consistent with economic dependencies.

1. Introduction

Cross-border trade with Mexico forms the backbone of economic growth of the United States (US). Freight volumes across the US–Mexico border are expected to increase by 2035 to a total of 25.5 million tons with a value of $111 billion (Cambridge Systematics, Inc., 2011). Nearly all of this volume (78% by weight, 90% by value) will be transported by truck, increasing overall volumes at the region's 22 commercial crossings (on connections to warehousing and distribution facilities) and along the region's 23 major trade corridors (primarily I-10 and US 54). Of the several existing POEs along the border, the ones located in the El Paso–Juarez region are considered to be among the most critical and important for the movement of people and freight. Laredo, El Paso and Hidalgo are among the top three trade related POEs (Bureau of Transportation Statistics; Vadali & Kang, 2013). The El Paso–Juarez international border crossings are a system of regional, statewide, and national significance. This system provides a critical link between maquiladora factories, primarily located in Ciudad Juarez, and distribution centers and consumer markets located in metropolitan El Paso, Texas, southern New Mexico, and beyond. In 2009, trucks were the predominant mode of trade through the Texas' El Paso–Juarez region POEs which accounted for 16%. In 2010, more than $71 billion moved through El Paso POEs. This represents a 50% increase in total truck related trade over 2009. Furthermore, $89.5 billion in truck trade value flowing through El Paso POEs in 2012 (Vadali & Kang, 2013). Transportation connectivity in border regions like El Paso has led to joint dependence and synergies in businesses and industries in the regional economies, not unlike other border pairs along US–Mexico or US-Canadian borders. This joint dependence is known to influence the economies of both regions and nations through several economic channels, including employment, wages, and income and production sharing relations between companies. In the US–Mexico context, the cross border travel linked to trade, tourism, recreation and work commute is known to be vital to the economic development on both sides of the border (Wilson, 2011; Villareal, 2015; Canas, Coronado, Gilmer, & Saucedo, 2011; Lee & Wilson, 2012).

According to the International Trade Administration, trade between the United States and its North American Free Trade Agreement (NAFTA) partners has soared since the agreement entered into force. It has been pointed out that accommodating the increase in freight due to trade will entail important and timely strategic planning at all existing POEs located along the borders (Brogan & Ahern, 2012). As trends in near sourcing, reverse globalization increase due to NAFTA, freight

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* Corresponding author.
E-mail address: s-vadali@ttimail.tamu.edu (S. Vadali).

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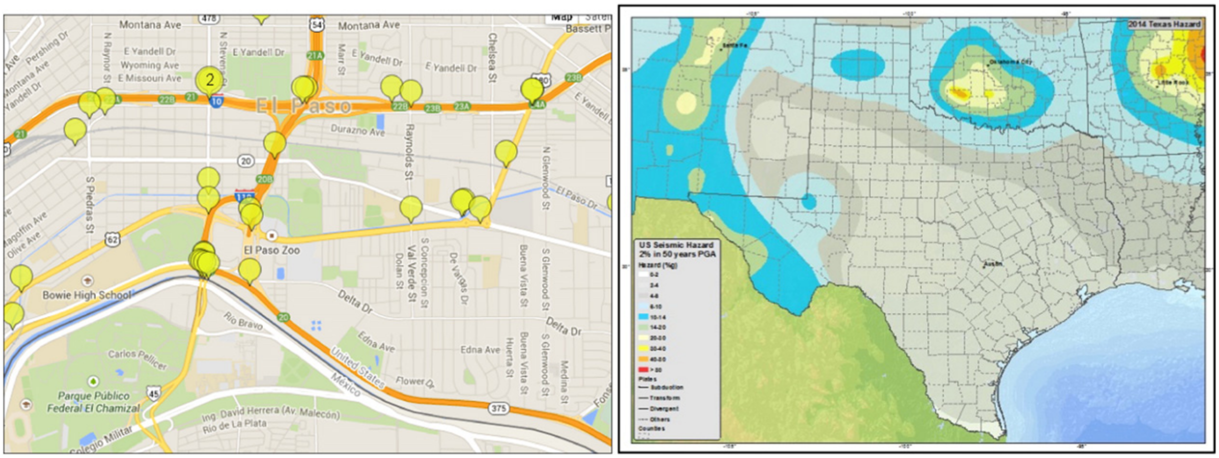

Fig. 1. Functionally obsolete bridges in the impact area and U.S. Geological Survey (USGS) earthquake hard map for Texas.
Sources: National Bridge Inventory (2013) data and US Geological Survey (2014).

volumes will rise with near international partners, and in particular, with emerging countries like Mexico in vital manufacturing value chains (Torres, 2013). This increasing realization about the interdependence of the national and global transportation supply chains between the two nations, where one transportation network is an integral part of a "flat" global transportation network, brings up questions as to the effects of any kind of disruption in the context of global chains and bi-national linkages. Disruptions to critical networks and nodes both within the U.S. and globally have the potential to impact not just the supply chain but overall freight movement and have repercussions on the commerce and the economy. The magnitude of these effects in cross-border city pairs where trade leads to joint economic dependence can be significant and that this aspect is addressed in this paper. Federal Highway Administration (FHWA) documents several case studies and examples of recent studies in this area (FHWA (Federal Highway Administration)).

Disruptions can be approximated by several performance metrics based on the context including but not limited to, travel time measures (Cascetta, 2001), percent of population receiving essential services as a humanitarian dimension (Sbizonuka et al., 2003), or economic costs (Rose, 2009). Resilience is the ability of the network to internalize minor perturbations and have built in flexibility to recover from large disruptions. Network resilience is directly linked to the economic space within which transactions occur; hence it is only natural that a disruption will impact economic resilience. The higher sectoral dependence and international linkages can result in higher costs and spillovers. As an extreme example, the Japanese Tsunami affected not only Japan, but also Toyota production in the United States. It is in this context, that transportation management solutions via resilience planning assume importance. This is due because goods/freight movement is a private sector function and the affected community is also partly private industry that is linked to the economic base of the region. On the other hand, the provision of infrastructure is largely a public sector undertaking.

This paper has three objectives. The first objective lies in the assessment of disruption related travel effects (travel time and volumes) in the context of cross border international trade and other freight flows that occur in the region (international bi-directional US–Mexico/Mexico–US as well as internal truck flows to the US side). Fig. 1 shows the distribution of functionally obsolete bridges in and around this area[1] based on the bridge inventory data for El Paso. It also shows the most current seismic hazard map provided by USGS for West Texas.

[1] Functionally obsolete means that the design of a bridge is not suitable for its current use, such as lack of safety shoulders or the inability to handle current traffic volume, speed, size, or weight. Bridges — A report card for America's infrastructure. http://www.infrastructurereportcard.org/. The inventory data identifies bridge ownership as well as whether it is structurally deficient or functional obsolete.

Most of the bridges show-cased are state owned. Five of them are federal bridges at the POE. While this paper does not statistically determine the hazard rate, both the maps suggest that disruption anywhere is certainly a possibility. BOTA is used as a case example. This POE and the associated approach transport infrastructure are considered to be a critical portion of the bi-national transportation network connecting both the US and Mexico markets in the region. The disruption was modeled at a critical interchange in the vicinity of the POE using a model developed and calibrated for the bi-national region. The dynamic traffic assignment (DTA) model was developed for the bi-national network using an open source tool (Dynus-T; Chiu et al., 2012) and was used as a test bed for a simulation of the temporal trend of travel effects before-and-after the disruption (both on traffic volumes and travel times). Since disruptions can vary in severity, the simulation assumed that it was large enough to warrant port closure.

A second objective of this paper is to use the travel effects to identify and estimate the direct first order economic costs (non-administrative) accruing to the private sector and the community at large. The third objective of this paper is to utilize the results to suggest some transportation and non-transportation actions that agencies can consider knowing that the effects of major disruptions can cascade and be costly. Specific transportation mitigation strategies are not the subject of this study and are left for future research as also the use of input–output or Computable General Equilibrium (CGE) models for addressing the magnitude and spread of cascading effects. This paper contributes to the literature by demonstrating how a specially calibrated DTA model for the entire network can provide insights into the spread of a disruption impact across the network. It differs from the other studies in that it strives to use the analysis to inform public agencies about the magnitude and extent of direct costs to suggest the implications for resilience planning in integrated border-pairs, other strategies and suggestions for future research. Past studies have addressed impacts resulting from infrastructure disruptions; however, not specifically in the context of bi-national trade between the US and Mexico. Few, if any, have used DTA models to explore economic costs as the literature review suggests.

The remaining sections of this paper are organized as follows. The next section presents a literature review on the following themes: i) disruption traffic impact assessment literature and use of DTA models; ii) economic costs and resilience linked to disruptions; iii) propagation of disruption effects in supply chains and iv) transportation disruption and economic impact studies; v) the DTA model and its use in traffic mitigation and finally, vi) general role of resilience strategies. Section 3 discusses the model for the case study region and also presents the framework for analyzing direct costs to carriers and shippers from the model. Section 4 analyzes the results. Section 5 presents a discussion on potential implications of this study on transportation