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Project Objective

Serving as critical portals of a nation's supply-chain, seaports and their associated transportation infrastructure are especially vulnerable to major disruptions from a variety of causes. The economic impacts of these disasters can be extensive well beyond the on-site operations at the port complex, through the supply-chain effects of the disruptions and/or delays of delivering imports and exports from ports to their destinations and vice versa. The objective of this project is to develop a synergetic approach linking a regional transportation model and a multi-regional computable general equilibrium (CGE) model (the TERM Model) to analyze the economic impacts of port and transportation system disruptions, as well as the effects of various resilience tactics in reducing business interruption losses. A multi-sector income distribution matrix (MSIDM) is also developed and integrated into the modeling framework to analyze the impacts of port and transportation network disruption and the effectiveness of resilience tactics across socioeconomic income groups.

Problem Statement

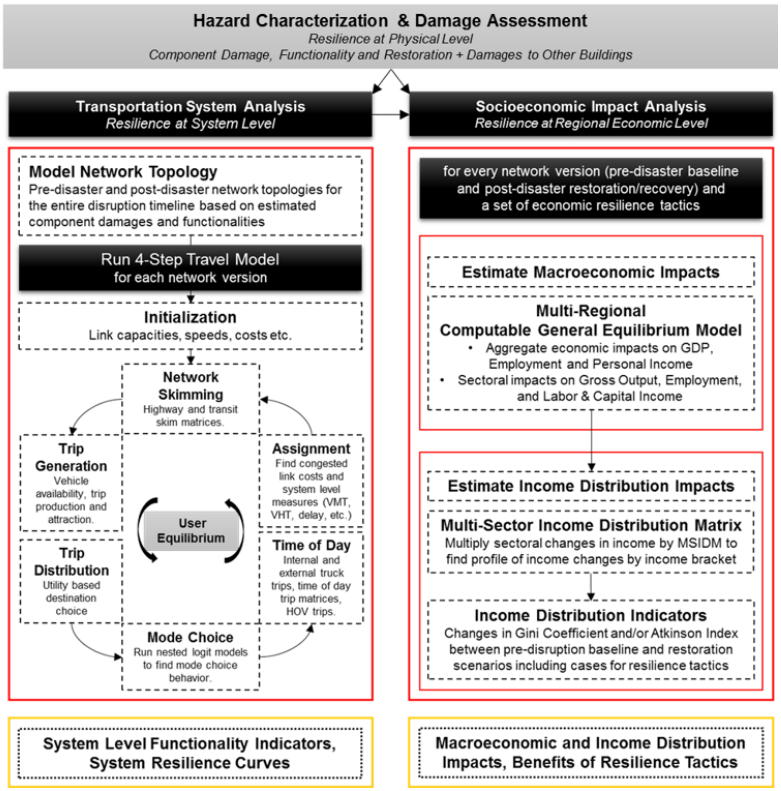
Assessment of transportation system vulnerability and resilience has gained increasing attention, especially after incidents of port closures and transportation network downtimes following major natural disasters in recent years. Many studies have estimated the impacts of transportation network disruptions in general and port disruptions in particular, and found them to be sizeable. However, most of the studies in the literature fail to incorporate the spatially distributed and networked nature of transportation infrastructures. Therefore, to achieve a comprehensive and realistic understanding of the economic impacts caused by the hazard induced disturbances in seaports, the spatial distribution and the networked nature of transportation systems and their post-event degradation has to be taken into account. Furthermore, disasters and their impacts on critical infrastructure do not affect all people in a region equally. Unfortunately, very few studies have analyzed these income distribution impacts. Moreover, no studies have examined the income distribution impacts of more than a select few resilience tactics, which have the ability to reduce regional business interruption losses.

Research Methodology

In this study, a simulated earthquake scenario that affects commodity trade flows at the Port of Los Angeles and Port of Long Beach and their associated inland highway freight transportation network is used as a case study to illustrate the working of the integrated transportation-economic impact model we developed. The transportation system analysis is implemented by adapting the regional travel demand model (RTDM) developed by the Southern California Association of Governments (SCAG). The model is used to determine the pre-disaster condition of the multi-modal transportation system (baseline) as well as its condition in post-disaster settings (e.g., day 1, 7, 30, etc. after the scenario earthquake) in terms of the changes in network functionality measured by indicators such as VHT, VMT, and time of delay. Reduced seaport capacity is estimated based on the damages of the buildings and facilities at the ports simulated using the FEMA's hazard loss estimation software -- HAZUS. The direct impacts on import and export flows through the ports are estimated by linking the damaged terminal

buildings to the main cargo categories handled by these facilities. Increase in transportation costs, reductions in imports and exports, and business interruptions caused by general building damages of the scenario earthquake are used as inputs in the TERM (multi-regional CGE) Model to estimate the macroeconomic impacts in the LA Metro region, rest of California, and rest of the country. The effectiveness of resilience tactics is evaluated by comparing the estimated economic losses before and after the incorporation of these tactics. Finally, the distributional impacts are estimated by using the TERM results on sectoral personal income changes and the MSIDM. Figure 1 displays how the various analytical models are integrated in this study.

Figure 1. Integration of Transportation and Economic Models



Results

The analysis results indicate that it takes 150 days for the ports to fully recover from the simulated disaster. The total GDP impacts stemming from port disruptions are estimated to be $1.5 billion and $9.4 billion for the LA Metro and the U.S., respectively. The impacts are reduced to $0.24 billion and $0.65 billion, respectively, after we consider various types of resilience tactics. In addition, the damage to the highway transportation system also causes a 0.53% increase in truck transportation cost within the LA Metro Region and a 0.26% increase between LA Metro Region and Rest of CA (on an annual basis). The estimated GDP losses of this are only $15 million in the LA Metro Region because of the high redundancy of the transportation network. The simulated seismic events also result in damages to the general building stock, with total GDP losses estimated to be $19.2 billion in LA Metro and $16.5 billion in the U.S. with no resilience, and $11.8 billion and $10.1 billion, respectively, after the adjustment for resilience. The lower impacts at the national level are due to the offsetting effect stemming from regional production shifts from the earthquake impacted region to other regions in the country. The combined simulation of all three types of disruptions/damages yields GDP losses of $12.1 billion for the LA Metro Region and $10.9 billion for the U.S. after we consider all the relevant resilience tactics. The loss reduction potential of resilience is 41.3% at the regional level of LA and 57.6% at the national level (Table 1).

Table 1. Real GDP Impact of the Combined Disruptions/Damages (million 2010 $ and percent reduction from pre-disaster levels)

	LA Metro	SF Metro	Rest of CA	Rest of US	US Total	Loss Reduction Potential (for LA)	Loss Reduction Potential (for US)
Base Case (no resilience)	-20,708 -3.00%	-708 -0.17%	-732 -0.15%	-3,675 -0.03%	-25,823 -0.22%		
Combined Resilience Case	-12,147 -1.76%	-10 0.00%	-143 -0.03%	1,344 0.01%	-10,956 -0.09%	41.34%	57.57%

The income distribution analyses for the LA Metro Region indicate that the income losses stemming from port disruptions are born slightly disproportionately by lower- and middle-income groups. However, the income losses stemming from transportation cost increase and general building damage are born disproportionately by middle- and higher-income groups. This can be explained by the fact that a higher proportion of capital-related income is earned by higher-income groups. Therefore, these income groups are expected to experience a higher proportion of income losses from property damage.