PEER "Research Nuggets"

Title: A Granular Framework for Modeling the Capacity Loss and Recovery of Regional Transportation Networks under Seismic Hazards: A Case Study on the Port of Los Angeles

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Motivation: First, previous bridge modeling studies under seismic hazards have largely used assumptions to group bridges into classes to simplify analysis and have not utilized satellite images or other newer sources of data to make more individualized models. Second, previous traffic models have largely had to make a choice between (a) macrosimulation/static models or microsimulation/dynamic models, and relatedly, (b) large networks or small networks. This has led to studies that either focus on a regional perspective without much insight on local effects or vice-versa. Third, while there have been a few studies that looked into the socio-economic impact of earthquakes to the transportation system and its users, they largely also suffer from the choice between regional or local impacts and are at times proprietary and inaccessible. Lastly, there is a gap in studies that address all the aforementioned issues in a singular framework.

Objectives: The goal of this report is to provide a synthesis approach that: (1) factors in the different structural and seismic characteristics of individual bridges across the region using an efficient image-based structure-and-site-specific fragility generation method, combined with (2) a large-scale/regional, agent-based semi-dynamic traffic simulation that can then lead to (3) disaggregate cost, resilience, and economic impact assessments attributable to individual system components/aspects, all in all, to extract highly granular information that can guide the formulation of resilience assessments and preparation plans with both local and regional perspectives taken into account.

Methodology: A four-part framework is adopted to facilitate the inclusion of highly granular infrastructure seismic performance in this study where focus is given to the latter three steps.

1. *Bridge model generation and damage assessment*: This consists of: (1) identifying tentative bridge locations for a region from National Bridge Inventory and refining this location information using an OpenStreetMap and routing APIs, (2) downloading all street-level imagery associated with each detected bridge, (3) reconstructing 3-D bridge geometry for each bridge using the downloaded imagery, (4) populating these geometric shells with structural information using class statistics to develop nonlinear bridge models, and (5) calculating bridge fragility functions using the developed nonlinear models and component damage thresholds available in the existing literature.
2. *Transportation network analysis*: An open-source agent-based semi-dynamic traffic assignment model is used to capture the effects of bridge damage on the traffic network performance at a large geographic scale.

3. *Economic impact estimation*: The economic cost of damages in a transportation network is estimated by splitting it into two components: direct costs (amount of resources needed to repair the damaged road components in the network) and indirect costs (costs due to delay to travelers or lost demand/unfulfilled trips). By nature of the transportation network analysis, these costs can be further broken down temporally and spatially.

Results: The framework was applied to a hypothetical M7.4 earthquake scenario near the Port of Los Angeles. After verifying that simulation outputs are comparable to real-life metrics such as mean commute time and average distance traveled, it is found that: (1) there are spatially disproportionate impacts to the port area as opposed to the region at large with as much as 62% of the total indirect cost coming from the port area and with 15% of all trips in the port area being unfulfilled, (2) lost demand, which is a proxy indicator for the degradation of road network connectivity, is a bigger cost component than delays, and (3) computed total cost can be used to compare with federal and state budgets to assess how appropriate they are relative to projected costs. Figure 1 shows the cost estimate breakdown from the conducted case study.

Conclusions: The presented framework can come up with hierarchies of cost, as well as numerical estimates, that can be broken down between direct cost to repair or replacement of roads as opposed to socio-economic cost to the transportation system and its users. This can further be broken down spatially, for example between the port area and non-port areas, to focus on areas of interest. This can also be further broken down into car trips and truck trips because of the agent-based nature of our traffic model. With access to more data, these costs can be further broken down based on trip activity, demographics (such as age, sex, race), and more to analyze whether certain areas, groups, or sectors are affected differently compared to others or compared to the whole, and by extension, decision-makers are able to make more informed policy choices. This model can only be improved with more granular information for bridges, roads, and trips.

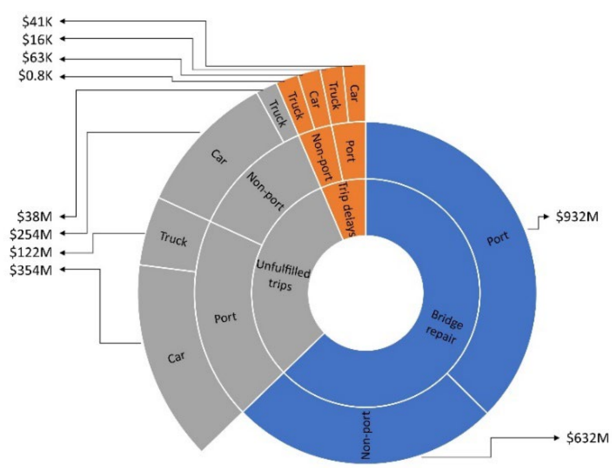

Figure 1. Cost estimate breakdown visualization.

Keywords: Earthquake, recovery, economic, infrastructure, resilience, transportation