Transportation planning for Emergency: The role of Transportation to the *resilience* of populations

Guy Keren[1], Carlo Giacomo Prato[2], Daniel Felsenstein[1]

[1] Department of Geography at the Hebrew University of Jerusalem
[2] School of Civil Engineering, Faculty of Engineering, Architecture and Information Technology, The University of Queensland

Abstract

Escape is sometimes the most effective solution to save lives in a disaster. In this study, we estimate the role of the transportation system in the overall resilience of populations to disasters, as part of a Dynamic Integrated Model for Disaster Management and Socio-Economic Analysis (DIM^{2}SEA). This study investigates variables that affect the probability of the population to escape and aid to be delivered by using Agents Based Modeling that simulates the behavior of individuals in an emergency scenario. For each agent, we calculate a scenario-based escape route, considering relevant route choice behavior. By aggregation, we get the overall evacuation simulation flow of the region.

The ability of populations in cities to cope with unanticipated disasters is an issue high on the urban agenda(UNISDR 2012; Masterson et al. 2014): over the last few decades cities have been subjected to ever-increasing disastrous events resulting in casualties and extensive property damage. Given the magnitude of the potential catastrophes and the expanding availability of data, tools and knowledge, increasing multi-disciplinary effort is being focused on mediating the hazards facing cities and bolstering their resilience. In our scope, we ask: What is the role of the transportation system to the resilience attributes of the population? What are the necessary conditions/attributes for accessibility in relevant scenarios? Where are the most fragile people in terms of accessibility to vital sites? Which evacuation solutions could be "optimal"?

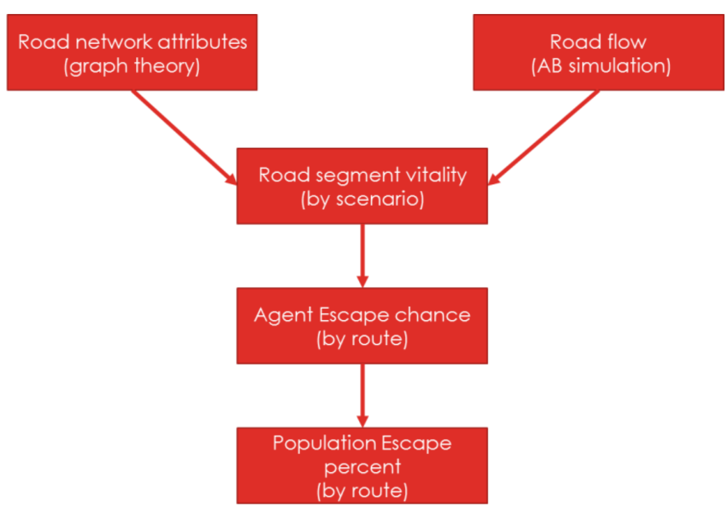
The ideal of 'resilience' in urban planning is a concept lacking universal definition and acceptance. In our study, *Resilience* of population is the percent of survived people; unharmed or escaped. The *Resilience* of the transportation system is the percentage of its elements (roads, cars etc.) functioning. Its contribution to overall *Resilience* is in its relevance to the population needs. To evaluate resilience as an attribute, we refer to *Mobility* as "'the ease with which a person can move through space"(Martens 2012, 5), An increase in mobility means a person could travel longer distances and/or more frequently (Martens 2012; Sager 2008). We also refer to *Accessibility*, it is the ability of people to access necessary or desired activities by different transportation modes. (Blumenberg and Ong 2001) When we are talking about *Vital* street/intersection/sites we refer to those places that lead to a *safe* destination or are safe, graded by alternatives from the origin, weighted by population. *Safe* destination is unharmed by the disaster.

As part of DIM^{2}SEA we propose a data disaggregation algorithm to build individual socio-economic profiles from census tract data. The allocation of the census data into households and

discrete individuals allow for the analysis of the urban and socio-economic dynamic. The outcome of simulation scenarios provides a large amount of data at multidimensional levels in the urban environment. This information is considered as synthetic big data needed to be process for scenario analysis and for Descriptive simulation of escape routing. Thus, we use Agent Based Modeling for the attributes of the population: Agents are Individuals, constructed from CBS data, defined by their mobility ability\mode.

To estimate the attributes of the roads network we use graph theory: Nodes are intersections and sites, Edges are available roads ranked by function. We calculate "Betweenness Centrality" to find bottleneck (Brandes 2001), and "Degree Centrality" to find connectivity (Diestel 2010). But, to distinguish roads by their importance, the network needs to be weighted by population - The AB model is used for proper population distribution. Agents defined by their mobility, go as Markov chain from street segment to the next. They are governed by route choice model relevant to their attributes: *i.e.* Residents will try the shortest path to safety, but Visitors may try the "popular path" to safety (through main or congested roads). The route choice model is calibrated by surveys.

Based on this simulation, we evaluate the accessibility of each building in the city in any scenario of roadblocks (and for each type of mobility), predict the congestion on the roads, assess the service area of aid, and give a weighted survivability score to the overall transportation system ability to cope with the disaster and contribution to the resilience of the population. *i.e.* we have for each building an estimated duration of travel time for an ambulance from its station, to the building and to the nearest hospital. This method concepts are demonstrated on the neighborhood in the city of Haifa, Israel.



***Key words*:** Agent based simulation; emergency transportation; route choice in emergency.

Reference

Blumenberg, E., and P. Ong. 2001. "CARS, BUSES, AND JOBS: WELFARE PARTICIPANTS AND EMPLOYMENT ACCESS IN LOS ANGELES." *Transportation Research Record*, no. 1756. https://trid.trb.org/view.aspx?id=695867.

Brandes, Ulrik. 2001. "A Faster Algorithm for Betweenness Centrality." *Journal of Mathematical Sociology* 25 (2): 163–177.

Diestel, Reinhard. 2010. *Graph Theory*. Graduate Texts in Mathematics. Springer-Verlag Berlin Heidelberg. http://www.springer.com/gp/book/9783642142789.

Masterson, J.H., W.G. Peacock, S.S. Van Zandt, H. Grover, L.F. Schwarz, and J.T. Cooper. 2014. *Planning for Community Resilience: A Handbook for Reducing Vulnerability to Disasters*. Washington, DC: Island Press.

Martens, Karel. 2012. "Justice in Transport as Justice in Accessibility: Applying Walzer's 'Spheres of Justice' to the Transport Sector." *Transportation* 39 (6): 1035–53. doi:10.1007/s11116-012-9388-7.

Sager, Tore. 2008. "Hypermobility and the Forecast-Free Planning of Society." *Spaces of Mobility: Essays on the Planning, Ethics, Engineering and Religion of Human Motion*, 31.

UNISDR, (United Nations International Strategy for Disaster Reduction). 2012. *How to Make Cities More Resilient – A Handbook for Local Government Leaders*. Geneva: United Nations. http://www.unisdr.org/files/26462_handbookfinalonlineversion.pdf.