

UTC Project Information	
Project Title	MPC 464 – Development of Network-Based Measures and Computational Methods for Evaluating the Redundancy of Transportation Networks
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Project Duration	October 1, 2013 - July 31, 2018
Brief Description of Research Project	<p>Natural and man-made disasters encountered in the past decade (e.g., the 9/11 terrorist attacks in 2001, the London Bombing in 2005, Hurricanes Katrina and Rita in 2005, Minneapolis' 35W bridge collapse in 2007, Christchurch, New Zealand's earthquake in February 2011, Japan's devastating earthquake/tsunami in March 2011, and the Superstorm Sandy in 2012) have repeatedly emphasized the importance of transportation networks and the need for government agencies and communities to make this system more resilient. Recently, various conceptual and/or computational frameworks have been proposed to analyze resiliency (e.g., Chang and Nojima (2001), Victoria Transport Policy Institute (2005), Tierney and Bruneau (2007), Heaslip et al. (2010), and Croope and McNeil (2011) for a general transportation network resiliency evaluation framework, Caplice et al. (2008), Adams and Toledo-Durán (2011), and Miller-Hooks et al. (2012) for a freight system resiliency evaluation framework, and Faturechi and Miller-Hooks (2013) for a general civil infrastructure system).</p> <p>The Multidisciplinary Center for Earthquake Engineering (MCEER) provided the four "Rs" concept to characterize resiliency: robustness, redundancy, resourcefulness, and rapidity (Bruneau et al., 2003). In their definitions, robustness refers to "strength, or the ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function"; redundancy refers to "the extent to which elements, systems, or other units of analysis exist that are substitutable, i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of function"; resourcefulness refers to "the capacity to identify</p>

	<p>problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other unit of analysis”; and rapidity refers to “the capacity to meet priorities and achieve goals in a timely manner in order to contain losses and avoid future disruption”.</p> <p>The Federal Highway Administration (FHWA, 2006) defined redundancy as the ability to utilize backup systems for critical parts of the system that fail. They emphasized that it is extremely important to consider redundancy in the development of a process or plan for emergency response and recovery. One of the pre-disaster planning strategies is to improve network resiliency by adding redundancy to create more alternatives for travelers or by hardening the existing infrastructures to withstand disruptions. Despite a growing body of research on resiliency, there is no formal mathematical definition of transportation network redundancy, and few researchers have concretely developed quantitative network-based measures and computation methods to assess the redundancy of real transportation networks.</p> <p>The objectives of this research proposal are twofold: (1) to develop network-based measures for systematically characterizing the redundancy of transportation networks, and (2) to develop computational methods for evaluating the network-based redundancy measures. The proposed research on network redundancy can be considered as a critical component in assessing network resiliency and also designing a more resilient transportation network against disruptions.</p> <p>Research Objectives: Redundancy is vital for transportation networks to provide options to users and planners during disastrous events. This research proposal will develop network-based redundancy measures and computation methods for evaluating the redundancy of transportation networks. Specifically, the objectives include the followings:</p> <ol style="list-style-type: none"> 1. Develop network-based measures for characterizing the redundancy of transportation networks. 2. Develop computational methods for evaluating the network-based redundancy measures. 3. Collect data from different sources to develop a case study for evaluating the redundancy of a real transportation network.
<p>Describe Implementation of Research Outcomes (or why not implemented)</p> <p>Place Any Photos Here</p>	<p>The application of the developed computation methods revealed that the two measures have different characterizations on network redundancy from different perspectives. Two sets of numerical examples were provided. The simple network example demonstrated the necessity of having the two dimensions together for systematically characterizing transportation network redundancy. The Winnipeg network demonstrated the applicability of the computational methods as well as the importance of considering the requirement of not-too-long</p>

	routes in the travel alternative diversity measure.
Impacts/Benefits of Implementation (actual, not anticipated)	The two network-based measures and the computational methods developed in this study can help governments and communities evaluate the resiliency of transportation systems. The two measures (travel alternative diversity and network spare capacity) can complement each other by providing meaningful information to travelers and by helping planners enhance network redundancy in their infrastructure investment decisions. A well-designed future network with alternative travel modes could significantly increase the network spare capacity to accommodate a substantial demand increase.
Web Links <ul style="list-style-type: none"> • Reports • Project Website 	http://www.ugpti.org/resources/reports/details.php?id=880