UTC Project Information – National Transportation Center @ Maryland (NTC@Maryland)	
Project Title	Methods for Improving the Reliability of Transportation Systems
University	University of Maryland, NC State University
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PI(s) and Co-PI(s) Photo(s) Image should be 80width x 120height pixels. Allowed file types: **png gif jpg jpeg**.	
Funding Source(s) and Amounts Provided (by each agency or organization)	UMD: $120,000 NCSU: $67,347
Total Project Cost	$187,347
Agency ID or Contract Number	DTRT13-G-UTC30
Start and End Dates	8/1/16 – 8/31/17
Project Image (for website) Should be 233width x 155height pixels. Allowed file types: **png gif jpg jpeg**.	
Brief Description of Research Project	Reliability in transportation systems is a measure of predictability and consistency in departure and arrival times. It may be measured as the probability of arriving (or possibly departing) within a specified time span (or "window"), the variance of arrival, departure or service times, or the generalized cost of the variability. Reliability is one of the key aspects of service quality and system performance to be considered in planning, designing

	and operating transportation systems. The reliability of transportation systems may be improved in various ways involving overall system design, the detailed design of facilities and vehicles, maintenance of facilities and equipment, routing, scheduling, traffic management, terminal operations, control of vehicle movements, provisions for reserves or slack in various system components, and preparations for contingencies. While seeking to develop general methods applicable to various kinds of transportation systems, the objective of the proposed study is to improve freight transportation reliability in road networks. Furthermore, this study will focus on three important aspects of transportation system reliability, namely (1) the development and maintenance of reliable networks, (2) real-time vehicle dispatching decisions, and (3) resulting resource requirements, especially fleet sizes. In analyzing the development and maintenance of transportation networks, we will develop methods for evaluating candidate projects or alternatives based on their reliability effects, in addition to various effectiveness measures, including infrastructure costs, user costs and benefits, environmental impacts and some external economic impacts. The two major improvements over conventional methods for transportation investment planning and scheduling will be (a) their explicit consideration of reliability measures jointly with other effectiveness measures in the evaluation and optimization processes and (b) their consideration of quantifiable interrelations among alternatives. Interrelated alternatives are those whose benefits and/or costs depend on which other alternatives are implemented at what times. Consideration of interrelations is very important for transportation networks because changes in network components shift traffic and thus affect the benefits of improvements to other components. Temporary interruptions in resource availability for maintenance purposes may also shift traffic and their effects depend crucially on whether the closed elements are in parallel or in series. The costs, budgets and other resources available for various alternatives may also be interrelated. The currently available analysis methods are relatively well suited for dealing with mutually exclusive alternatives or independent alternatives but quite inadequate for dealing with realistic numbers and complexities of interrelated alternatives. By extending methods already developed by our team (Tao &Schonfeld 2005, 2006, 2007, Wang & Schonfeld 2005, 2008, 2012, Shayanfar & Schonfeld 2015, Yang et al 2015) we expect to develop methods

	that not only evaluate interrelated alternatives appropriately, but also optimize the selection, sequencing and scheduling of those alternatives, subject to constraints on reliability, continuity, budgets, various resources, implementation times, fairness and other factors.
Describe Implementation of Research Outcomes (or why not implemented) May Place Any Photos Here	In analyzing real-time control decisions we will focus on vehicle dispatching decisions at transfer terminals (such as ports or rail yards) and their effects on the propagation of delays in freight transportation networks and on fleet size requirements. Such dispatching decisions should be based on tradeoffs among various factors including vehicle availability and operating costs, probabilities and costs of missed connections, delay costs to freight already on-board vehicles or waiting downstream, priorities among vehicles and shipments, cost vs. transfer time tradeoffs at terminals, the costs of speeding up en-route vehicles and possibly skipping some stops, and the expected cascading effects of dispatching delays on missed connections and delays at downstream terminals. The decisions depend heavily on the reliability and timeliness of information about delays, expected vehicle arrival times, and the characteristics of freight that must transfer to other vehicles. While we can rely to a considerable extent on methods previously developed by our team (Lee & Schonfeld 1991, 1994, Ting & Schonfeld 2005, Chen & Schonfeld 2010, 2011, Markovic & Schonfeld 2013, Markovic et al 2014, 2015) as well as methods developed by other researchers, we expect to develop new analytic and simulation methods to deal with delay propagation, vehicle and freight priorities, transfer processes within terminals, and possible correlations or other relations among vehicle arrivals and departures due to traffic conditions, weather, and limited capacities of system components. We will especially seek to quantify the effects of the magnitude and distribution of slack times in schedules on delay attenuation or propagation, especially in cases where individual late vehicles can delay many others, thus causing cascading or “chain reaction” delays.
Impacts/Benefits of Implementation (actual, not anticipated)	Project has not begun yet, so no impacts have been realized.

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