MPC-463

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Project Title:
Rehabilitation Project Selection and Scheduling in Transportation Networks

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Utah State University

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Research Needs:
Road infrastructure in the U.S. is aging rapidly as many roads are approaching or exceeding their design life. As a result, transportation agencies need to allocate more resources to maintenance and rehabilitation (M&R) activities. The National Highway System (NHS) spent 48.5 percent of its total capital spending in 2008 in system rehabilitation, the highest percentage since 2000 (FHWA, 2010). On the other hand, stringent budgets provide insufficient funding to support all needed M&R projects. Decision makers have to prioritize and select projects based on their tangible benefits to the transportation system. Meanwhile, traffic congestion across the country has been on the rise over the past 30 years by every measure (TTI, 2012). The problem is further exacerbated by an increasing number of M&R projects performed on already-congested roads. Work zones are estimated to account for nearly 24% of non-recurring delay on freeways (USDOE, 2002). Hence, M&R project selection and scheduling not only are essential to restore and maintain a reasonable level of service on existing roads but also have profound impact on congestion mitigation.

Highway project selection and scheduling are traditionally treated as two separate problems in the literature. The benefit-cost analysis (BCA) is a common approach adopted by transportation agencies to assist in project selection when an agency is operating under budget constraints. In particular, the benefit-cost ratio (BCR) is often used as the primary BCA measure to identify a collection of projects among competing ones that yields the highest ratio of benefits to costs (e.g., FHWA, 2003; Li and Kaini, 2007). When transportation projects involve multiple stakeholders with conflicting interests, decision makers have to make trade-offs among multiple objectives. Instead of the single-objective BCA, multi-objective optimization problems are often formulated to address the conflicting requirements of different objectives (e.g., Fwa et al., 2000; Orabi and EI-Rayes, 2012; Wu et al., 2012). When it comes to project scheduling, transportation agencies are often faced with the need to perform multiple work zone projects concurrently because of the increasing number of required M&R activities. Work zones may cause excessive congestion and delays to motorists, especially when multiple projects are under construction simultaneously in close proximity to one another. Most existing studies, however, focus on quantifying the impact of work zone delays at the individual project level (e.g., FHWA, 2006). Few studies have been done to strategically schedule multiple M&R projects in a transportation network to mitigate their impacts on traffic. Qiu (1997) assumes the impacts of different projects are independent and does not consider travelers' response to multiple concurrent projects. Chang et al. (2001) uses a simplified setting of work zone scheduling, which greatly limits the number of possible schedules. Zheng et al. (2013) uses an approximation approach to estimate travelers' route choice behavior and the Genetic Algorithm adopted has limited capability in handling large-scale problems in terms of the number of projects and network size.

In summary, it is critical to investigate how to select and schedule M&R projects in a way that can maximize their benefit or effectiveness while minimizing the traffic impacts of work zones across project development phases. There is a pressing need to develop an integrated framework for simultaneous selection and scheduling of multiple M&R projects at the network level.

Research Objectives:

This proposed project is to develop a systems approach for selecting and scheduling M&R projects simultaneously. The proposed modeling framework will accomplish the following two objectives:

1. Explicitly capture the impacts of the presence of multiple M&R projects on travelers' route choice behavior.
2. Strategically select and schedule M&R projects in a transportation network over a finite planning horizon to maximize social benefit.

Research Methods:

In the proposed research, we will formulate the project selection and scheduling problem in a mathematical modeling framework. Given candidate projects and associated project parameters, e.g., project type, cost, duration, improvement and capacity reduction during construction, transportation agencies want to choose a limited number of projects subject to budget constraints and determine the optimal sequence of implementing those selected projects within a finite planning horizon. The modeling framework will adopt a bi-level programing structure, whose upper-level problem represents the selection of M&R projects and their corresponding construction schedules, while the lower-level problem captures travelers' spontaneous response to the choice and schedule of multiple M&R projects made in the upper level.

The upper-level problem determines the selection and implementation schedule of M&R projects to maximize social benefit. The project selection and scheduling decision will be modeled as binary decision variables. Constraints for the upper-level problem will include budget/resource constraints and other constraints dealing with practical considerations of project selection and scheduling. For example, the construction of a project cannot be broken into separate sessions, i.e., a project must be scheduled in consecutive months. The lower-level problem essentially is a multi-period traffic assignment problem. It depicts travelers' route choice in response to travel delays induced by work zones scheduled in a specific time period, e.g., a month, and the lower-level problem also ensures user equilibrium in all time periods within the planning horizon. In modeling travelers' route choice behavior, it is noted that travelers may not depend solely on travel time to make their route choices but pavement surface roughness also directly affects the ride quality experienced by travelers (Yin et al., 2008). Therefore, we assume that travelers base their route choices on a generalized route travel cost, which is the sum of generalized costs associated with links that the route comprises. Although the formulation is expected to be complex and thus difficult to solve, we plan to adopt the active set approach (Zhang et al., 2009) to solve it efficiently, given its track record of solving problems of similar structure, e.g., Wu et al. (2011).

We also plan to conduct a case study in Utah's Wasatch Front region, which comprises Davis, Morgan, Salt Lake, Tooele, and Weber Counties and is home to almost eighty percent of Utah's residents. We will contact the Wasatch Front Regional Council (WFRC), the designated Metropolitan Planning Organization (MPO) of the region, to obtain their Transportation Improvement Program (TIP) and project implementation schedules. Since M&R projects in most TIPs are given, we will apply the proposed methodology to schedule multiple projects over the planning horizon, and compare our results with the existing project schedules developed by WFRC. We will also use the proposed model to provide decision support for WFRC on their future project selection and scheduling.

Expected Outcomes:
The project is expected to produce an integrated modeling framework for simultaneous selection and scheduling of multiple M&R projects at the network level. The research findings will not only have theoretical significance, but also have a wide range of applications in highway maintenance and asset management. The end product will be useful to the Utah Department of Transportation (UDOT), WFRC and other transportation agencies in developing TIPs and project implementation schedules. The results of this study will be presented at conferences, published in professional journals.

Relevance to Strategic Goals:
The proposed project contributes to two goals of MPC, i.e., state of good repair and economic competitiveness. The proposed research studies the M&R project selection and scheduling problem, which is a common one that transportation agencies have to deal with in maintaining road infrastructure in a state of good repair. Poor road conditions impose costs on travelers in the form of increased vehicle operating costs, delays and crashes resulting from substandard pavement conditions. Keeping road infrastructure in a reasonably good shape is essential to sustaining existing transportation services, as well as to supporting economic competitiveness. The proposed project provides decision makers a tool to identify the most cost-effective projects to improve road conditions, while minimizing the negative impacts of implementing those projects through strategic scheduling.

Educational Benefits:
One graduate student will be involved in the research and receive training in transportation network modeling, optimization, and transportation asset management. The research results will provide fresh materials and case studies to expand the transportation curricula at USU.

Work Plan:
The proposed research will be carried out in a period of 18 months with the following schedule:

Tasks	Durations
Literature Review We will conduct a thorough literature review on M&R project selection and scheduling.	2 months
Multi-Period Network Equilibrium Model We will develop a multi-period network equilibrium model that captures travelers' route choice in response to selected projects and their corresponding schedules.	2 months
Optimal Project Selection and Scheduling Problem We will formulate the M&R project selection and scheduling problem as a bi-level programing model.	4 months
Solving Project Selection and Scheduling Problem We plan to apply a modified active set approach (Zhang et. al, 2009) to solve the model. Other approaches identified in the literature review will also be applied and compared.	4 months
Case Study We will conduct a case study in Wasatch Front, UT.	4 months
Report Writing	2 months

Project Cost:
Total Project Costs: $61,419
MPC Funds Requested: $31,419
Matching Funds: $30,000 Source of Matching Funds: Faculty Salary

TRB Keywords:
Maintenance and Repair, Rehabilitation, Pavement Management, Project Management, Network Analysis, Schedules and Scheduling

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