ABC-UTC 2015

Progress Report

This document provides the problem statement, objective and scope of the project, followed by list of tasks and their status

A. PROJECT TITLE: An Integrated Project- to Enterprise-Level Decision Making Framework for Prioritization of Accelerated Bridge Construction

B. START & END DATE: 1/1/2016-12/31/2017

C. PI & Co-PI(s): Alice Alipour and Douglas Gransberg

D. PROPOSAL ABSTRACT: (Not to exceed 300 words)

Accelerated Bridge Construction (ABC) techniques have a great potential to minimize the traffic disruptions during the bridge repairs/replacements, promote traffic and worker safety, and also improve the overall quality of the built bridges. Despite the major advances in design and construction of ABC techniques, transportation agencies are still hesitant about using ABC techniques majorly due to perceived risks during construction and higher initial costs. Furthermore, the current decision process used to prioritize the candidate bridges for this type of construction techniques are solely based on the annual daily average traffic (AADT) and/ or the experience of the decision makers.

Extensive research has been conducted to ensure the structural integrity of the bridges using ABC. This is in addition to the developments in advancing the construction techniques to increase constructability and decreasing the time. However, to date, the overwhelming majority of the research has been in the structures field with little, if any, research devoted to constructability. SHRP2 and TRB research has proven that projects with a high degree of constructability are both faster and safer to build, which reinforces

the aim of ABC. Dr. Gransberg was a member of the national task force that developed and published the FHWA ABC manual. Based on his experience, a decision tool for ABC project selection is needed that ***accounts for project-specific constructability of viable ABC design alternatives.*** Additionally, an enterprise-level decision model is required to provide the necessary justifications for the use of ABC techniques on ***an enterprise/network basis rather than project basis***. This project aims to develop a decision-making algorithm that brings together the project-level decision process that involves the choice of optimized construction techniques together with the enterprise-level process that implements regional prioritization schemes considering indirect costs (such as drivers' delay, economic impact, opportunity losses, economic growth, environmental foot print, and social investments) in addition to the direct costs associated with implementation of the ABC techniques. The contribution Is in two main areas: i) choice of construction technique based on factors such as constructability and time of construction and ii) prioritization of the candidate bridges using a combination of direct and indirect costs accrued during the construction project. The idea behind the proposed framework is to ensure the success of ABC projects by selecting the right bridge and decreasing the down time associated with the construction by selecting the right construction technique.

E. DESCRIPTION OF RESEARCH PROJECT (Section not to exceed 6 pages.)

E.1. PROBLEM STATEMENT (Include project objectives)

Reduction of road closure times, traffic disruption and user costs, in addition to improvements in construction quality utilizing prefabricated elements, are all attractive qualities of the implementation of ABC techniques that encourage the transportation agencies to use the technique for repair and replacement projects. However, despite the extensive developments in effective design and construction of the ABC bridges, there are limited guidelines in planning phases for selection of the candidate bridges and the appropriate construction technique. A cursory review of the literature shows that there are two major decision strategies for prioritization of the bridges for ABC: the Analytic hierarchy process (AHP) and the two-stage decision making tool followed by the Iowa DOT that integrated AHP in the second stage of the decision making process. These decision processes use readily available data from NBI (such as AADT, out-of-distance travel, and daily user costs) to qualitatively rate the bridges, then if a bridge is considered as a candidate for the ABC, the AHP method is used to qualitatively compare the options based on factors such as construction schedule, direct and indirect costs, and site constraints. The assessment criteria in many cases are subjective in nature and not detailed enough. Furthermore, the considered algorithm fails to capture the effects of the bridge downtime on the long term functionality of the network and the communities it serves. This highlights the need for a holistic decision making algorithm that integrates the project-level parameters (such as the project completion time, site conditions, availability of specific resources, etc.) into an enterprise-level asset management framework (such as the effect of project in the region, accessibility and connectivity to critical facilities, the economic growth of the region, social return on investment, etc.). This is in addition to the need for a holistic framework that would be readily available in case of emergency conditions when there are multiple bridges affected by a regional natural hazard that would require immediate prioritization based on such factors as importance to the connectivity and accessibility of the network.

The main objectives of the proposed project are as two folds: Development of i) an enterprise-level decision making framework by simulating the transportation network of the region under consideration, definition of the performance measures, identification of critical facilities, social effects, economic impact to business/industrial districts in the region for prioritization and ranking of the ABC bridge candidates, and ii) a matrix-based project-level decision framework consisting of important indices (such as time, cost, or safety) that affect the outcome of the project in terms of time and constructability. The final outcome of the two tiers will be a holistic decision making framework that not only considers the project level factors in choice of ABC techniques but also goes beyond the physical borders of a specific project and considers the regional effects that a specific bridge could have in the everyday life and long term growth of the region.

E.2. CONTRIBUTION TO EXPANDING USE OF ABC IN PRACTICE

Accelerated bridge construction technology, initially reserved for routes with large AADT's and/or critical thoroughfares, has significantly improved and increased in popularity. As a result, the benefits and economics of these techniques have gained traction in nearly all avenues of bridge replacement. However, one area of ABC technology in need of additional research is the development of a holistic decision making framework that can consider different aspects of the effects that such techniques could have in the overall growth of the region they are implemented in. These details will allow the ABC product, which is already of high quality and constructed under exceptional quality control, to further extend to applications that otherwise were not considered in traditional implementations of this technique.

E.3. RESEARCH APPROACH AND METHODS

To develop a holistic decision making framework for selecting the candidates for ABC techniques, a multi-level optimization scheme that covers from project- to enterprise-levels is required. The research here will have specific focus on the operational applications (such as the use of ABC for repair and replacement of deficient or obsolete bridges) as well as extreme event applications (specifically when a large number of bridges are affected by regional hazards such as floods, hazards, and hurricanes). To achieve the goals of the project, three major steps will be taken: i) A multi-level decision making framework covering scales from project- to enterprise-level will be developed, ii) the framework will be implemented for the state of Iowa bridges as a test-bed and its effectiveness in operational conditions will be evaluated, and iii) the application of framework will be extended for use as a decision making tool for post-event emergency response to an extreme event affecting a region.

E.4. DESCRIPTION OF TASKS TO BE COMPLETED IN RESEARCH PROJECT

The proposed research will develop a holistic decision making framework for use in selection of candidate bridges for ABC in addition to the suitable techniques for each project. The following tasks will be performed to achieve the project goals:

Task 1- Literature review:

The project will start with a thorough literature review on: i) the available ABC decision making techniques such as those used by Iowa DOT or Utah DOT, the AHP developed by Oregon State University, WMU's/MIDOT tool, and others, highlighting the benefits and shortcomings of each technique, ii) review of the data and experiences from previous successful implementations of ABC as part of the *Every Day Counts* initiative projects conducted by MoDOT, and iii) review of available articles on application of ABC for

repair/replacement of bridges, increasing economic growth of the region through unconventional investments [4] and also applications to increase restoration speed, and consequently resilience of the system, after major regionally distributed extreme events [2 and 5].

October 1 - December 31, 2016 Report: The literature review has been broken to two main parts: i) addressing the developments in the construction techniques applied in ABC and ii) enterprise level benefits of ABC technologies considering components such as social benefits and impact to the regional economy. The first part is 70% complete and second part of 100% complete.

Task 2- Network-level planning framework for ranking and prioritization:

At this stage a transportation network of the case-study area will be developed. Upon the formation of the network's model using the graph theory, a risk-based approach will be used to estimate the likelihood of the bridge closures (partial or full) due to repair or replacement in operational conditions or the risk of closures due to extreme event conditions. The likelihood of repair/replacement will be estimated based on the inspection reports and NBI data. The risk due to extreme conditions will be calculated based on probability of the occurrence of the event in addition to the vulnerability of the network to such events.

To establish the network-level planning framework, it is essential to identify appropriate performance measures capable of comparing different states of the network before and after closures. Among various measures proposed to date, three measures of flow capacity, travel time, and network connectivity are proven to be the most appropriate ones. The flow capacity can be directly used to quantify the extent of change in the network right after closure (both partial and full). The travel time is a more holistic functionality measure that can estimate the level of performance of the network using more micro-level traffic data. The network connectivity can be defined as the ability to get from one node to another one. The connectivity measure is mostly suitable to ensure access to critical facilities while bridge is closed for repair. The proposed project takes advantage of all the three functionality measures to provide a comprehensive understanding of the state of resilience of the networks.

A comprehensive ranking scheme will be used to pin point the best bridge candidates. This ranking scheme will consider different aspects such as connectivity between different points of the network and accessibility to critical facilities (hospitals, fire stations, police departments), the effect of the downtime of the project on drivers' delay, length of detours, opportunity loss/gain, the economic impact to the local economy (such as businesses, industry, or agriculture), social effects, and even environmental foot print due to longer detours during construction. The prioritization framework will recursively communicate with the project-level data (Task 3) through a two-stage stochastic process to ensure an optimal prioritization scheme.

October 1 - December 31, 2016 Report: The network of five counties of the MoDOT network has been generated and used for the analyses conducted in a submitted TRB paper. There is a lack of data availability for all the counties so the team is overlaying the available data from different sources and data packages to come up with the most representative network model of the state. At the same time, a network of the Iowa network is under development.

Task 3 - Project-level framework for best construction method approach:

There are different construction techniques within the ABC that could be used depending on a number of parameters such as costs, availability of resources, the available time, possibility of full or partial closure, etc. that needs to be accommodated in a holistic decision making framework. For this purpose in this task a matrix-based approach will be implemented that lists different factors and weighs them based on different performance measures from construction standpoint (such as time, cost, durability, constructability, and safety). These parameters will then feed into the prioritization scheme established in the network model (Task 2) to highlight the best ABC technique to be used in that site.

> October 1 - December 31, 2016 Report: A matrix of different construction techniques, their duration, and constructability has been developed. The characteristics of different bridges and applicability of different construction techniques will be mapped in the next stage

Task 4 - Application to the test-bed and comparison with previous ABC projects:

After the development of the two-level decision making framework, it will be applied to a test-bed study (i.e. Iowa transportation network) and the results will be compared with the previous decision tool. Also the data from some extensive ABC projects such as the MoDOT "Safe and Sound" project, which delivered 802 rural bridge replacements in a single contract and set the standard for maximizing constructability in the ABC process, will be compared and the effects of such projects on the economic growth of the region will be evaluated.

> October 1 - December 31, 2016 Report: N/A

Task 5 - Final report:

A final report will be developed that documents the entire project with an accompanying

October 1 - December 31, 2016 Report: N/A

manual to use the framework.

E.5. EXPECTED RESULTS AND SPECIFIC DELIVERABLES

The primary deliverable will be a holistic decision making framework using quantifiable measures.

October 1 - December 31, 2016 Report: A presentation was made to the TRB Standing Committee on Transportation Programming and Investment Decision-Making (ADA50):

Barutha, P., Zhang, N., Alipour, A., Miller, C., and Gransberg, D. "Social Return on Investment as a Metric to Prioritize Use of Accelerated Bridge Construction in Rural Regions,"

E.6. TIMELINE (GANTT CHART)

	Year 1												Year 2											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task 1	■	■	■	■																				
Task 2				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Task 3				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Task 4																		■	■	■	■	■	■	■
Task 5																							■	■

F. DISCUSSION OF PERTINENT COMPLETED AND IN PROGRESS RESEARCH. FOR PROJECTS CO-FUNDED BY OTHER SOURCES, COPY OF THE CO-FUNDED PROPOSAL SHOULD BE ATTACHED AS AN APPENDIX.

Not applicable.

G. DESCRIBE THE PLAN FOR COOPERATING WITH OTHER ABC-UTC CONSOURTIUM UNIVERSITY MEMBERS

As part of this work, the research team will form a Technical Advisory Committee (TAC) to oversee and guide the work. Each of the other ABC-UTC consortium members will be asked to nominate a member to serve on the TAC. The TAC for this project shall meet at least once per quarter (to be scheduled in advance) such that the research team can provide regular and timely updates on project status, problems, and results. The team at ISU has also identified colleagues in Construction Engineering and Transportation Engineering that would be able to collaborate with on different aspects of this project. At the network-level studies, the PI: Alice Alipour, has developed network models of transportation systems in major metropolitan areas in the US and can apply the same procedure to generate the transportation network of the case study region consisting of all the bridges in the rural, secondary, and artery routes at one tier, combined with traffic analysis zones (TAZs) to simulate the traffic distribution at different O-D points in the second tier, and the economic aspects of the study region in addition to critical facilities at the third tier. The unique background of PI in both Structural Engineering and Transportation network modelling will provide the opportunity to integrate not only the transportation models but also more representative models of the bridge structures in the network-level studies. The FIU transportation engineering will be integrating the spreadsheets for their transportation models with the PI’s network model. In the

Construction Engineering, the Co-PI: Doug Gransberg, has access to the data from MoDOT “Safe and Sound” project, which delivered 802 rural bridge replacements using ABC and will utilize stochastic models to generate the decision making process at the project-level. The Construction Engineering at FIU will combine the two-tiered field data they have access to: (50 projects from Oregon DOT and 17 projects with detailed cost data) to contribute to the stochastic model developed by the Co-PI. To ensure a streamlined collaboration, monthly web meetings will be scheduled where the two-teams will share their progress and findings.

H. KEY WORDS

ABC, Decision making, prioritization, economic growth, social investment, direct and indirect costs

I. LITERATURES CITIED

1. Accelerated Bridge Construction: Experience in Design, Fabrication, and Erection of Prefabricated Bridge Elements and Systems, FHWA, Pub. No. HIF-12-013, November 11, 2011.

2. Furtado, M.N. and Alipour, A. (2014), Cost Assessment of Highway Bridge Network Subjected to Extreme Seismic Events, Transportation Research Record: Journal of the Transportation Research Board, No. 2459, pp. 29-36.

3. Iowa Department of Transportation. ABC Policy Development, Mid-continent Transportation Research Symposium, Structures/Construction session 2D, August 15, 2013.

4. Miller, M.C., Rueda, J.A., and Gransberg, D.D. (2015), Applying Social Return on Investment to Risk-Based Transportation Asset Management Plans in Low-Volume Bridges, Transportation Research Record: Journal of the Transportation Research Board, No. 2473, pp. 75-82.

5. Testa, A.C., Furtado, M.N. and Alipour, A. (2015), Resilience of Coastal Transportation Networks Faced with Extreme Climatic Events, Transportation Research Record: Journal of the Transportation Research Board, No. 2532, pp. 29-36.

J. STAFFING PLAN (Should correspond with budget)

This work will be conducted by Dr. Alice Alipour and Dr. Doug Gransberg.