Estimating the Construction Cost of Accelerated Bridge Construction (ABC)

Final Report (Phase I)- Construction Aspect

June 30, 2016

Submitted by

Wallied Orabi, Ph.D.

Ali Mostafavidarani, Ph.D.

Mohamed Ibrahim, Ph.D. Candidate

Department of Civil and Environmental Engineering

Florida International University, Miami, Florida

Submitted to

Atorod Azizinamini

Director, ABC-UTC

June 2016

TABLE OF CONTENTS

1. INTRODUCTION

The US interstate and highway systems are integral parts of the daily lives of the American public and a crucial component of the overall U.S. economy. Nevertheless, due to the extensive use of these systems and their long serving lives, several components of these systems were subjected to a great extent of deterioration and often require emergency maintenance & rehabilitation works. One of the major components of these systems is the highway bridges. According to the U.S. Department of Transportation's 2013 status report, 25.9% of the total bridges in the United States are either considered structurally deficient or functionally obsolete; hence, requiring significant maintenance & repair works (DOT 2013). Nevertheless, these projects created a new challenge for all Departments of Transportation (DOTs) across the country as they have to try and minimize the traffic disruptions associated with them in a safe way while preserving the quality of the work and fulfilling the budgetary constraints.

In an effort to combat this new challenge, the Federal Highway Administration (FHWA) started adopting and promoting the implementation of accelerated bridge construction techniques (ABC) through the "Every Day Counts" initiative to expedite the projects' delivery and minimize their impacts on the transportation network (FHWA 2012). "ABC is [a] bridge construction [technique] that uses innovative planning, design, materials, and construction methods in a safe and cost-effective manner to reduce the onsite construction time that occurs when building new bridges or replacing and rehabilitating existing [ones]" (Culmo 2011). One of the most commonly used ABC construction methods is the prefabrication of bridge elements or systems (PBES), near or off-site, and installing them using innovative equipment & techniques (TRB 2013). Several benefits can be achieved through the use of PBES among which are: reduced onsite construction time, minimized traffic disruption, and improved work zone safety; among others (Triandafilou 2011). Hence, a number of DOTs started implementing ABC techniques and achieved positive results on a number of bridge replacement or rehabilitation projects; for example, the State Highway Bridge 86 over Mitchell Gulch in Colorado in which a new prefabricated single span bridge was installed and opened for vehicle travel after only 46 hours of weekend closure, and Belt Parkway Bridge over Ocean Parkway in New York City in which a complete replacement of the bridge was conducted using prefabricated components including piles and superstructure in 14 month with a cost savings of 8% (FHWA 2006). Nevertheless, ABC techniques are often associated with high initial costs and require capable & specialized contractors to perform them which in return deter some SHAs from taking the initiative and implementing these techniques (TRB 2013). Therefore, the need to provide decision makers with a decision making tool that has the capability to assess all the possible bridge construction alternatives became a necessity; consequently, several efforts to develop and provide such tools were conducted. In the following sections, the currently available decision making tools and guidelines concerning the decision of choosing the best bridge construction method will be explored.

2. PROBLEM STATEMENT

Accelerated Bridge Construction (ABC) methods have been successfully used by many DOTs for both planned and emergency bridge projects; however, ABC is not always the best alternative to conduct a bridge rehabilitation or maintenance project. Hence, during the project's planning phase, decision makers need to assess all the benefits & risks associated with each individual project to determine whether it warrants the use of ABC or not. Nevertheless, this decision making process is not a simple process as it involves a multi-objective process to identify the optimum strategy for the construction of bridges (Salem et al. 2013). This process involves the evaluation of both qualitative and quantitative factors, including but not limited to: construction costs, user costs, impact on traffic, quality of work, safety of motorists and construction workers and the impact on surrounding communities and businesses (Salem & Miller 2006).

One of the most important factors that the decision-makers consider when deciding on whether using ABC or not is the total construction cost of the project using these methods versus the conventional methods. However, there is a lack of tools that can help decision-makers in accurately estimating the construction cost of the ABC projects which, in some cases, might yield to an unsuitable decision. Therefore, this type of cost needs to be analyzed and estimated to support better decisions in selecting ABC versus conventional bridge construction methods. In order to address this gap in both the body of knowledge and current ABC practices, the objectives of this project are to: (1) explore the current decision-making practices and the way construction costs are calculated by the decision makers; 2) provide a parametric estimation tool for the construction cost per feet for the ABC bridges; and 3) provide a detailed cost estimation tool for the ABC construction cost. These objectives will be fulfilled through the three main tasks: 1) reviewing current ABC decision making tools; 2) develop a parametric estimation tool for the construction cost per feet; and 3) develop an ABC detailed construction cost estimation tool.

3. REVIEW OF CURRENT ABC DECISION-MAKING TOOLS

In an effort to analyze the current ABC decision criteria and the decision parameters considered by the decision makers in their decision of whether to use ABC or not, a literature review of the different decision making tools was performed. Based on this review, the current ABC decision-making tools can be grouped into three main categories: 1) qualitative tools; 2) Analytical Hierarchy Process (AHP)-based tools; and 3) DOTs' tools.

3.1. Qualitative Tools:

3.1.1. FHWA Framework:

In an effort of assist decision makers, FHWA developed a decision making manual entitled "Framework for Prefabricated Bridge Elements and Systems Decision Making" that provides frameworks and guidelines for decision makers when exploring the use of ABC for their individual projects (FHWA 2005). This framework is presented in three formats, namely: a flowchart, a matrix, and a set of considerations, which can either be used separately or in conjunction with each other. These three formats will be explored in details in the following sections.

3.1.2. FHWA Flowchart:

The flowchart developed by FHWA aims at assisting decision makers in determining whether the use of a prefabricated bridge is suitable for their project or not. As seen in figure (1), the flowchart starts with questions about the major factors that trigger the use of PBES; namely: if the bridge has high average daily traffic, whether this bridge is an emergency replacement or not, whether it is on an evacuation route or not, if the project requires peak hour lane closures & detours, and if the construction of the bridge is on the critical path of the whole project's schedule. If the answers to all of these questions are "no", then the decision maker should only consider PBES if it justifiably improve safety and/or if its construction cost is less than that of the conventional construction; otherwise, they should use conventional construction. On the other hand, if the answer to any one of the above five questions is "yes", then the decision maker should consider PBES after examining the bridge's need for rapid construction, and its safety & costs impacts as discussed above.

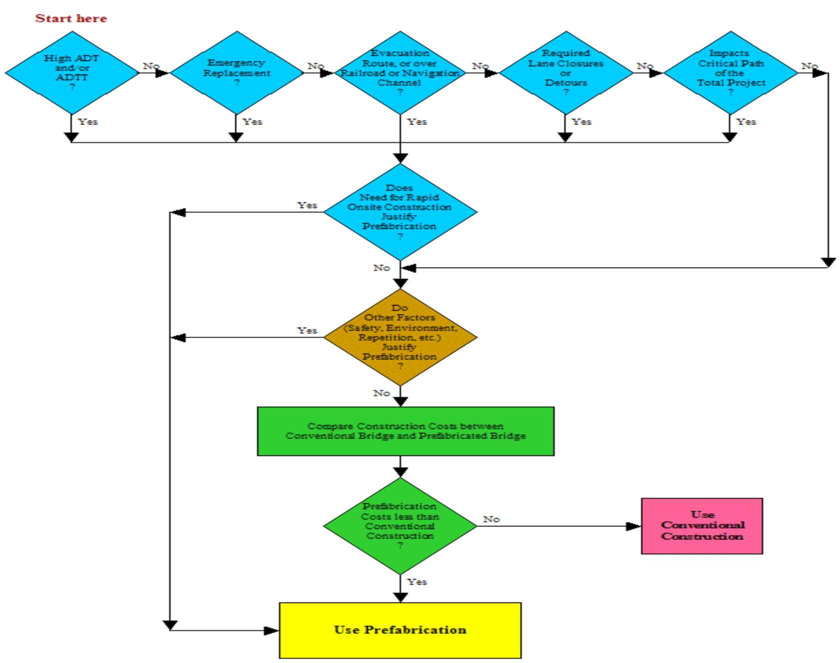


Fig. 1: Flowchart for PBES Decision Making

Although the flowchart helps in determining the suitability of PBES to an individual project, it only assesses this suitability in a qualitative way without an in-depth analysis of the factors considered.

3.1.3. FHWA Matrix:

The FHWA's matrix form is shown in table (1). With the use of this tool, decision makers answer a set of 21 questions related to their project with a simple "yes", "no" or "maybe" answer, and if the majority of the answers is "yes", then the project should be constructed using PBES; although a one or two "yes" answers may warrant the use of PBES depending on each project's nature. This tool provides more detailed analysis than the flowchart as it examines more factors that impact the project's construction such as its impact on local businesses, its impact on the surrounding environment, and the nature of the bridge's design, among others. In spite of this increased level of details, the matrix tool assesses the suitability of PBES in a qualitative rather than a quantitative way which makes it subject to judgment and a certain degree of uncertainty.

Table 1: FHWA PBES Decision Making Matrix

Question	**Yes**	**Maybe**	**No**
Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?			
Is this project an emergency bridge replacement?			
Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?			
Will the bridge construction impact traffic in terms of requiring lane closures or detours?			
Will the bridge construction impact the critical path of the total project?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Does the local weather limit the time of year when cast-in-place construction is practical?			
Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?			
Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise)?			
Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon			
If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?			
Can this bridge be designed with multiple similar spans?			
Does the location of the bridge site create problems for delivery of ready-mix concrete?			
Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?			
Are delay-related user costs a concern to the agency?			
Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?			
Can the owner agency provide the necessary staffing to effectively administer the project?			
Can the bridge be grouped with other bridges for economy of scale?			
Will the design be used on a broader scale in a geographic area?			
Totals:			

3.1.4. FHWA Set of Considerations:

The third form of the PBES decision making tools developed by FHWA is a set of considerations in the form of questions and their detailed answers which helps guide the decision maker through the decision making process. This set of questions is divided under three major categories which are: rapid onsite construction, costs, and other factors. The costs category is then further divided into three subcategories which are traffic maintenance costs, contractor's costs, and owner's costs; while the other factors are subcategorized into: safety issues, environmental issues, site issues and standardization issues. These set of considerations provide a more detailed analysis and guidelines for the PBES decision making process; albeit still in a qualitative form which are difficult to quantify.

3.2. <u>AHP-Based Tools:</u>

Recognizing the need for a more quantitative approach that can provide the decision makers with a tool to decide on the optimum construction strategy for their bridge projects, several studies developed decision making tools using the AHP technique. AHP is a decision making tool that utilizes multilevel hierarchal structure of criteria, sub-criteria, and alternatives to find out the best alternative that suits the decision maker's goals by performing pair-wise comparisons of the alternatives based on their relative performance in each evaluation criterion using a numerical scale from 1-9 (Doolen et al. 2011a). The pair-wise comparison is done over two steps, first a pair-wise comparison between the criteria and between the sub-criteria is conducted to determine their relative importance, second each decision alternative is assessed relative to each sub-criteria to determine its final score (Doolen et al. 2011b). Furthermore, what makes AHP more suitable for the use during the ABC decision making process is that the factors that impact the decision are both qualitative and quantitative which need to be integrated (Doolen et al. 2011a). In the next sections two of the AHP decision making tools aimed at determining the suitability of ABC for individual bridge projects will be explored.

3.2.1. Oregon Department of Transportation (ODOT) AHP Tool:

ODOT, with the collaboration of seven other DOTs, developed an ABC decision making tool using AHP (Doolen et al. 2011b). In this tool, the research team identified five main decision criteria through brainstorming sessions between all the team members; these criteria are: direct cost, indirect cost, schedule constraints, site constraints, and customer service. Furthermore, a set of sub-criteria was developed for each of these five criteria as shown in figure (2); however, it is worth noting that due to the flexibility of the AHP technique, any criteria/sub-criteria can be added or dropped if deemed necessary by the decision maker (Doolen et al. 2011b).

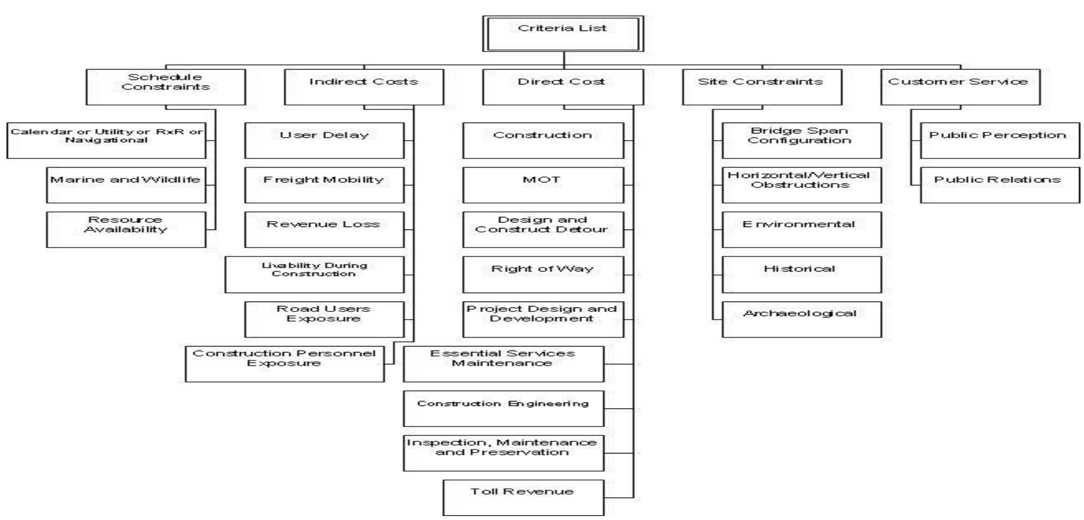


Fig. 2: ABC Decision Criteria and Sub-criteria

Having set these criteria, the study team developed a software (figure 3) by which the decision makers can perform the two-step pair-wise comparison for their projects and their construction alternatives based on their goals and priorities. The software was developed using Microsoft Visual Studio .Net adopting both modular and object oriented designs (FHWA 2012). Moreover, the software interface has four different tabs: the first for the decision hierarchy in which the user can select the criteria & sub-criteria relevant for his/her project, the second for pair-wise comparisons in which the user conduct the pair-wise comparison between each pair of sub-criteria & criteria, the third shows the results, while the fourth is for additional cost weighted analysis (FHWA 2012).

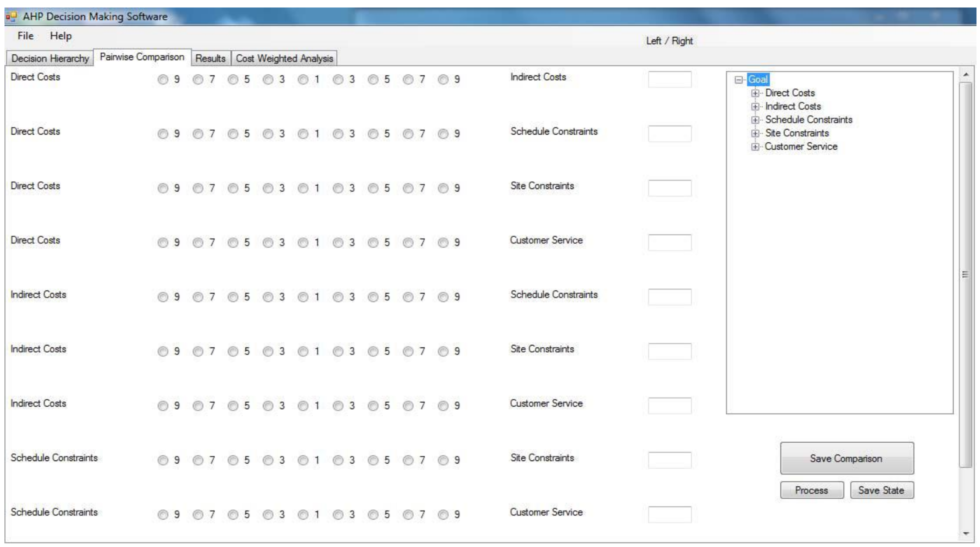


Fig. 3: ODOT AHP Software

3.2.2. MRUTC AHP Tool:

Salem & Miller (2006) developed a decision making tool for ABC using the AHP technique. In their study, the researchers identified six non-technical criteria that help in realizing the goals of most bridge projects through a survey sent to all 50 DOTs and five Canadian DOTs; these factors are: safety, impact on local economy, cost, impact on traffic flow, impact on environment, and the social impact on the communities. Furthermore, another follow-up survey related to the above criteria and their sub-criteria was sent to 25 DOTs for the purpose of weighing the relative importance of these criteria and sub-criteria. By analyzing these responses and conducting t-tests on the results with 95% confidence interval, the mean weights for each of these criteria and sub-criteria and their pair-wise comparison were determined. Finally, each construction alternative will be scored on the basis of achieving each sub-criteria and criteria and then the total weighted score for each alternative will be calculated and, consequently, the highest scoring alternative will be the most suitable alternative for the project under consideration. The major advantages of this tool are: the development of hierarchy of project priorities and analysis of the construction plan's performance using both qualitative and quantitative criteria (Salem et. Al 2013). Nevertheless, unlike the ODOT tool, the calculations for this decision making process have to be done manually by the decision makers.

3.2.3. MDOT Hybrid AHP Tool:

Aktan & Attanayake (2006) developed an ABC decision making tool for Michigan DOT (MDOT) called MiABCD. This decision making tool was aiming at avoiding the shortcomings of the ones based on AHP by creating a hybrid AHP model that used ordinal scale ratings (OSR) of the decision parameters and integrates them with site-specific data, traffic data, and life-cycle cost data. (Mohammed et al. 2014). In this tool, the decision is based on six decision-making parameters which are: 1) Site and structure considerations, (2) Cost, (3) Work zone mobility, (4) Technical feasibility and risk, (5) Environmental considerations, and (6) Seasonal constraints and project schedule. These parameters are further sub-divided into 26 sub-parameters which can be expanded to 36 sub-parameters as shown in the below table:

Table 2: MiABCD Decision Parameters and Sub-parameters

Major-Parameters	Site and Structure Considerations (S&ST)	Cost	Work Zone Mobility (WZM)	Technical Feasibility & Risk (TF&R)	Environmental Considerations (EC)	Seasonal Constraints and Project Schedule (SC&PS)
Sub-Parameters	Precast/Ready-mix supplier proximity	Initial Construction cost	Significance of maintenance of traffic on facility carried	Contractor Experience	Environmental protection (e.g., wet land)	Seasonal limitations
	Availability of staging area	Life-cycle cost	Significance of maintenance of traffic on feature intersected	Manufacturer/Precast plant experience	Aesthetic requirements	Construction duration
	Existing structure type and foundations	User cost	Length of detour	Work zone traffic risk		Stakeholder(s) limitations
Sub-Parameters	Terrain to traverse	Economic impact on surrounding businesses	Significance of level of service on detour route	Construction risks		
	Access and mobility of construction equipment	Economic impact on surrounding communities	Impact on nearby major intersection due to traffic on facility carried			
	Number of similar spans		Impact on nearby major intersection due to traffic on feature intersected			
User-Defined Sub-Parameters		Direct cost		Scour		

In an effort to best utilize the experts' experience and avoid the potential bias & subjectiveness of the pair-wise comparison used in the AHP process, the user must specify whether each parameter & sub-parameter favors conventional construction or ABC and then give a score for each alternative in each parameter/sub-parameter on a scale of 1-9 without direct comparison between alternative, where "1" represents low significance & "9" high significance. The model includes tables that define the relationships among the project data, ordinal scale ratings, and the AHP pair-wise comparison ratings which cannot be modified. Having set the process, Aktan & Attanayake (2006) developed a software by which the decision makers can perform this process. The software is developed using Microsoft Excel and Visual Basic where the former executes the procedures and the later provides the user's graphical interface (Aktan et al. 2013). The software has two types of users, advanced and basic. The advanced user is responsible for entering the project details, site-specific data, traffic data, life-cycle cost data, and then performs the preference rating; while, the basic user can only performs preference ratings. After the users complete their tasks, the system calculates the scores for both ABC and conventional construction and presents the results in four formats; which are (Aktan et al. 2013):

1) Two pie charts showing the Upper Bound and Lower Bound construction alternative preferences for ABC and conventional construction.

2) A chart showing the distribution of Major-Parameter Preferences from Multiple Users

3) A chart showing the distribution of Construction Alternative Preferences from Multiple Users

4) A table showing the contribution (in percentage) of each major-parameter towards the Overall Preference for ABC and CC.

3.3. <u>Current DOTs' Tools:</u>

In addition to the previously mentioned decision making tools and with the expansion in the adoption of ABC techniques, several DOTs developed their own guidelines and decision making practices either through utilizing their own experiences or modifying a previously developed tool to suit their special needs and goals. In the following sections, some of these guidelines and practices will be explored in details.

.

3.3.1. Utah DOT:

One of the first DOTs to expand on the use of ABC techniques, as a standard practice, for its bridge construction and rehabilitation projects was Utah DOT (UDOT). To assist its decision makers in assessing the suitability of ABC for their projects, UDOT developed its own approach for the decision making process (UDOT 2010). The new approach is based on assessing the project under consideration against eight main factors which are: average daily traffic, delay/detour time, bridge classification, user costs, economy of scale, use of typical details, safety, and railroad impacts. These factors are weighed against each other in a way that coincide with UDOT's current project priorities and cannot be changed for individual projects. The decision making process, itself, involves a number of steps; first, the decision maker gives the project under consideration a measured response relative to its performance to each of the above factors. Second, an ABC rating score that accounts for all the factors is calculated as the ratio of the weighted score to the maximum score. These two steps can be performed using a UDOT developed worksheet in which the decision maker enters the project's scores under each criterion and then the ABC rating is calculated automatically. Finally, based on its ABC rating score, the project is then categorized in one of three categories each lead to a different entry point in a decision flowchart (figure 4). As seen in the flowchart, if the project's ABC rating is between 0 & 20, then it is up to the regional director to decide if ABC has any indirect benefits or not that merits its use for the project. If the project's ABC rating is above 50, then ABC should be used if the site conditions support it. Finally, if the project's rating is between 20 & 50, then the decision maker has to further examine another set of questions before deciding if ABC is suitable for the project or not; these questions are: if ABC will accelerate the overall project delivery, if it will mitigate any critical environmental issue, and if it provides the lowest cost. If the answer to any of these questions is “yes”, then ABC should be used if the site conditions support it.

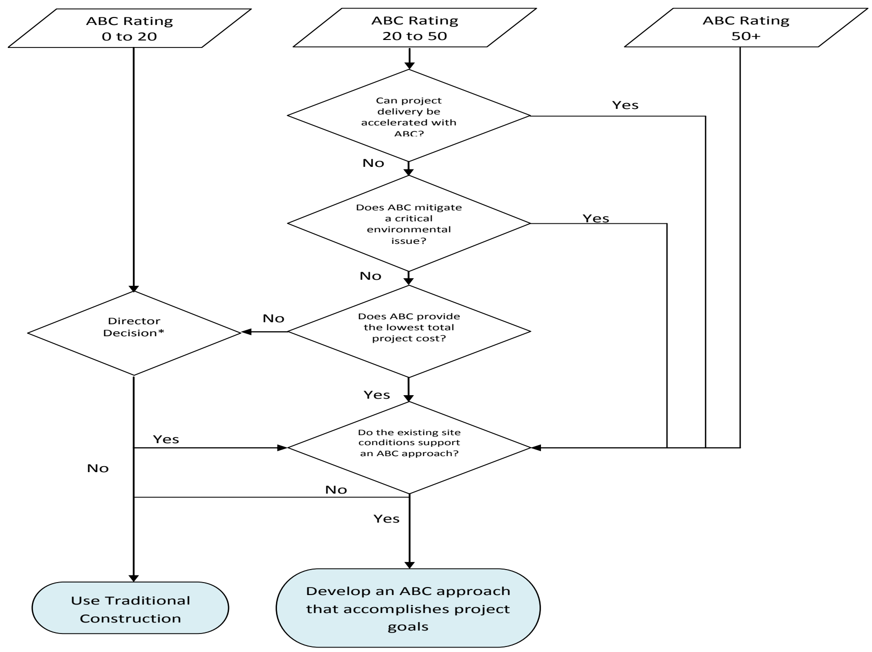


Fig. 4: UDOT ABC Decision Flowchart

3.3.2. Massachusetts DOT:

Massachusetts DOT (massDOT) did not develop an ABC decision making approach per say, instead in 2011 it selected the bridges to be included in its accelerated bridge program (ABP) in a two-step process (massDOT n.d.). First all bridges that falls into the following six categories are selected; these categories are: structurally deficient, have weight restrictions, are closed due to significant structural issues, in danger of falling into structurally deficient status, not expected to see repairs till the end of 2011, and are significant to the DCR system. After all these bridges were selected, they were then further prioritized based upon four factors which are: average daily traffic, fracture critical issues, scour issues, and the district’s priorities (massDOT n.d.).

3.3.3. Washington State DOT:

Washington State DOT (WSDOT) uses a qualitative framework similar to the matrix form developed by FHWA to assist in its ABC decision making process. WSDOT matrix consists of 21 items (see table 4) that the decision maker has to answer with “yes”, “no”, or “maybe” and if the majority of the answers are “yes”, then the project under consideration will be a good ABC candidate (WSDOT 2009).

Table 3: WSDOT ABC Decision Making Matrix

	Question	Yes	Maybe	No
1	High traffic volume			
2	Emergency replacement			
3	Worker safety conditions			
4	High daily traffic control costs			
5	Evacuation route or over railroad or navigable channel			
6	Lane closures or			
7	detours			
8	Critical path of project			
9	Close during off-peak traffic			
10	Rapid recovery/repair required			
11	Adverse economic impact			
12	Weather constraints			
13	Environmentally sensitive site			
14	Natural or endangered species			
15	Feasibility if historic bridge			
16	Multiple similar spans (segments)			
17	Problem for ready-mix concrete			
18	Delay-related user cost concern			
19	Innovative contracting strategies			
20	Group with other bridges			
21	Future Use			
	Totals			

3.3.4. Colorado DOT:

Colorado DOT (CDOT) has one of the most extensive ABC decision making process that combines both qualitative & quantitative decision making tools to reach two types of decisions; first whether to utilize ABC or not, second to determine which ABC method to be used (Far & Chomsrimake 2013). This decision making process is a multi-step process as shown in figure (5).

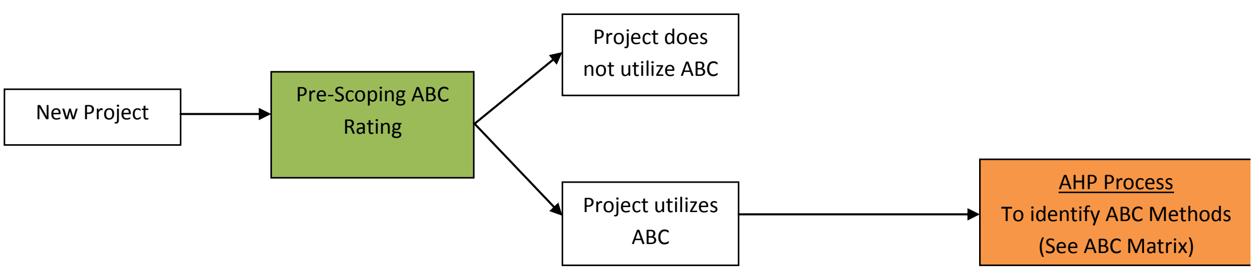


Fig. 5: CDOT ABC Decision Workflow

The first step in this process is to develop an ABC rating for the project in a similar way as utilized by UDOT based on the following eight decision factors: average daily traffic, delay/detour time, bridge classification, user costs, economy of scale, safety, railroad impacts, and site conditions. Next, based on its ABC rating score, the project is then categorized in one of three categories each lead to a different entry point in a decision flowchart similar to one of UDOT with some minor differences (figure 6). If the project's ABC rating is between 0 & 20, then it is up to the regional director to decide if ABC has any indirect benefits or not that merits its use for the project only in case it provides lower project total cost. If the project's ABC rating is above 50, then ABC should be used if it leads to a lower project cost. Finally, if the project's rating is between 20 & 50, then the decision maker has to further examine another set of questions before deciding if ABC is suitable for the project or not; these questions are: if ABC will accelerate the overall project delivery, if it will mitigate any critical environmental issue, if the bridge construction is on the critical path, and if the site conditions support its use. If the answer to any of these questions is "yes", then ABC should be used if it provides lower total project cost.

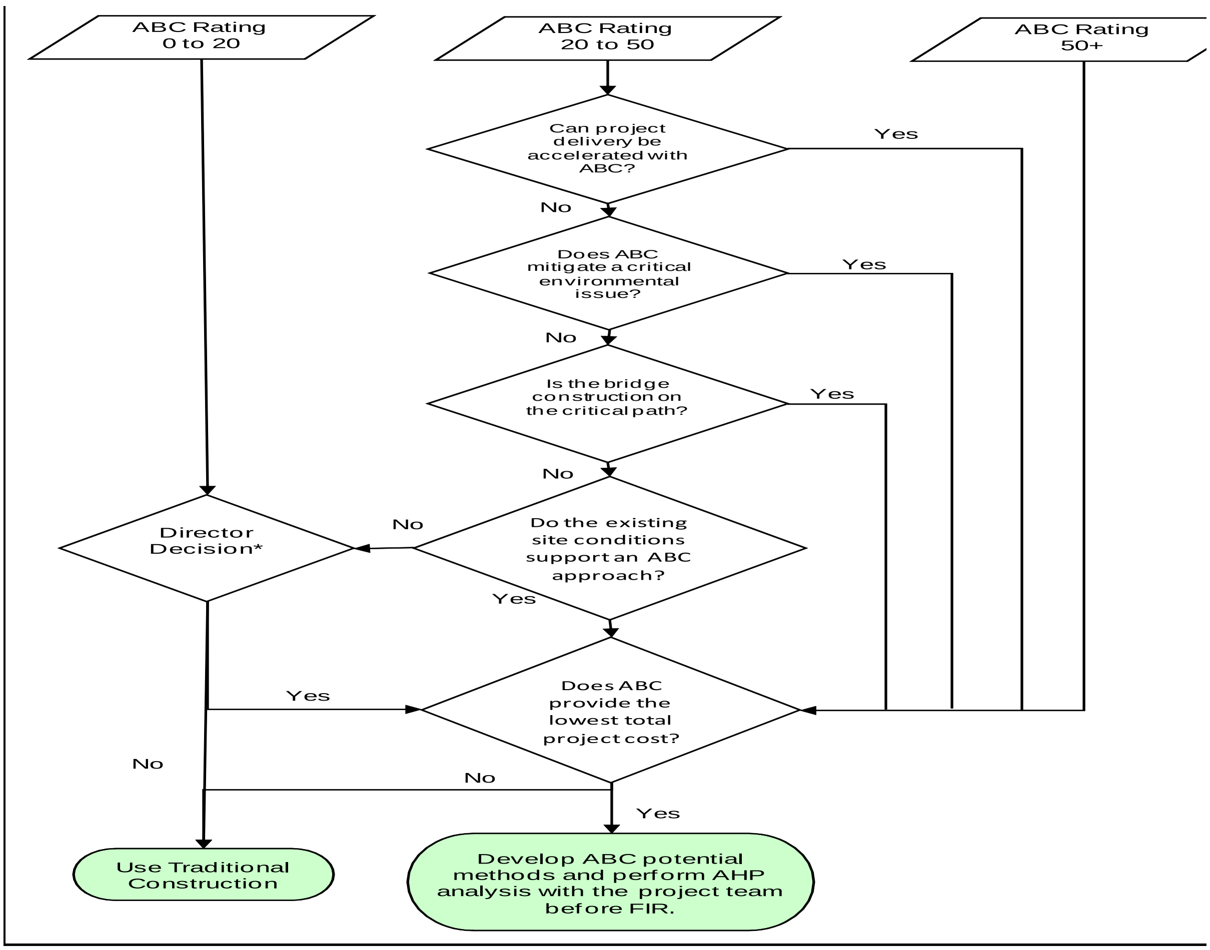
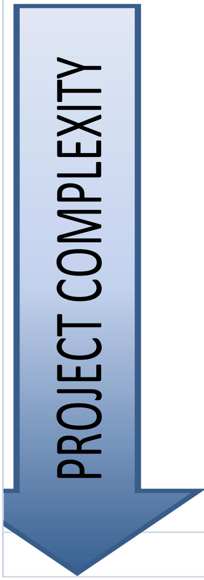


Fig. 6: CDOT ABC Decision Flowchart

Finally, if it was decided to use ABC for this particular project, two tools are used by CDOT to help the decision maker determine which ABC method to use. First, an ABC construction matrix (figure 7) provides suggestions on accelerated methods that can be applied based on the complexity of the project. Then, after narrowing down the alternatives, the decision maker uses the AHP tool developed by ODOT to select the best alternative i.e. the best ABC construction method.



Substructure	Approach, Embankment &	Superstructure	Super Structure placement
	Pre-fabricated approach slabs	Adjacent Girders[2]	
	Flowfill	Precast Deck Panels (partial depth)[2]	
Pre-fabricated Pier Caps	Expanded Polystyrene (EPS) Geofoam	Pre-fabricated pedestrian bridge[2]	
Pre-fabricated columns		Pre-fabricated box culvert[2]	
Pre-fabricated foundations		Precast Deck Panels (full depth)[2]	
Geosynthetic Reinforced Soil (GRS) Abutment[1]		Modular Girder and Deck elements[2]	
Pre-fabricated wingwalls/backwalls[2]		Post-tensioned concrete through beams[2]	Heavy Lift Cranes
Continuous Flight Auger Piles (CFA)		Pre-fabricated truss or arch span[2]	Skid or Slide In
			Longitudinal Bridge Launch
			Self Propelled Modular Transport (SPMT)

Fig. 7: ABC Construction Matrix

3.3.5. Wisconsin DOT:

Wisconsin DOT (WisDOT) uses a two-step decision making process in order to reach a decision of whether to implement ABC or not and also on deciding which ABC method to best suitable for the project; these two steps are in the form of a matrix and a flowchart (WisDOT 2014). The first task required by the decision maker is to use the decision matrix in order to obtain a weighted total score for the project which will then be used in the decision flowchart. This matrix is based on eight main decision criteria; namely: disruptions, urgency, user costs, construction time, environment, construction cost, risk management, and others (which includes: economy of scale, weather, and use of typical details). These eight criteria are then further divided into 18 sub-criteria each with a preset weight. The decision maker rates his/her project relative to each of these sub-criteria on a predefined numerical scale, and then the total weighted score is calculated.

Based on this calculated total score, the project is then categorized in one of three categories each lead to a different entry point in a decision flowchart similar to one of UDOT (figure 8). If the project's score is between 0 & 20, then ABC should only be used if this project is a program initiative & the site conditions support ABC. If the project's score is above 50, then ABC should be used if site conditions support it. Finally, if the project's score is between 21 & 49, then the decision maker has to further examine another set of questions before deciding if ABC is suitable for the project or not; these questions are: if ABC will accelerate the overall project delivery, if the benefits outweigh the additional costs, and if the site conditions support its use.

Furthermore, if it is decided that ABC will be used for that project, the flowchart helps the decision maker in choosing the best ABC method. First, the flowchart asks if the ultimate goal is to minimize the bridge out-of-service time or the total construction time. If it is the former and there is a location to build the bridge off-site and a window of time to close the bridge, then slide or SPMT should be used; if it is the latter and PBES or GRS-IBS should be used if the site conditions support either. If the above conditions are not fulfilled, then the decision maker should consider another ABC alternative.

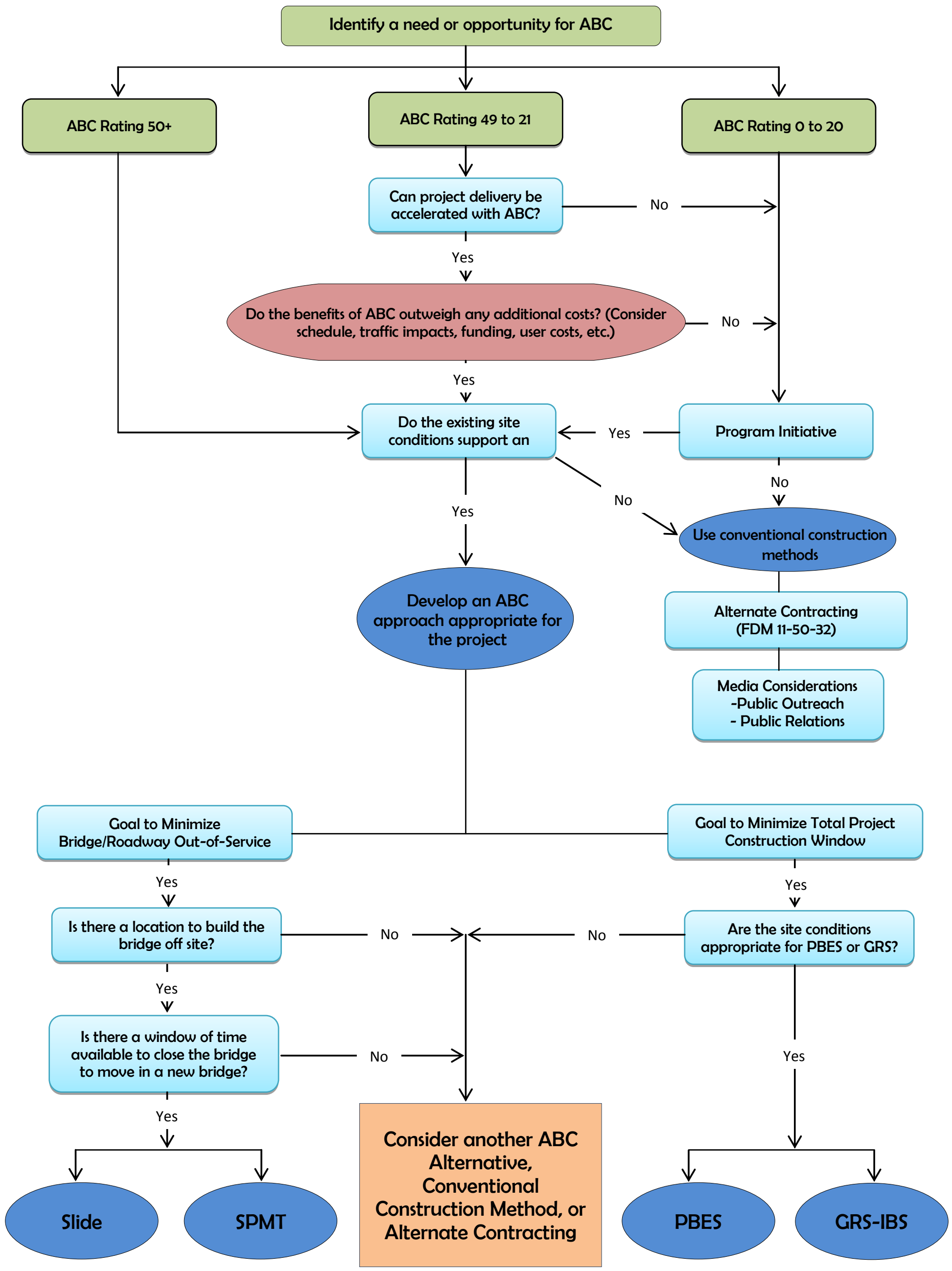


Fig. 8: WisDOT ABC Decision Flowchart

3.3.6. Iowa DOT:

Iowa DOT (IDOT) uses a two-stage decision making process in order to reach a decision of whether to implement ABC or not (IDOT 2012). As seen in figure (9), The process of ABC decision making starts with an ABC rating for the project and based on this rating, the project enters a two-stage filtering phase using a decision flowchart and ODOT AHP ABC decision making tool.

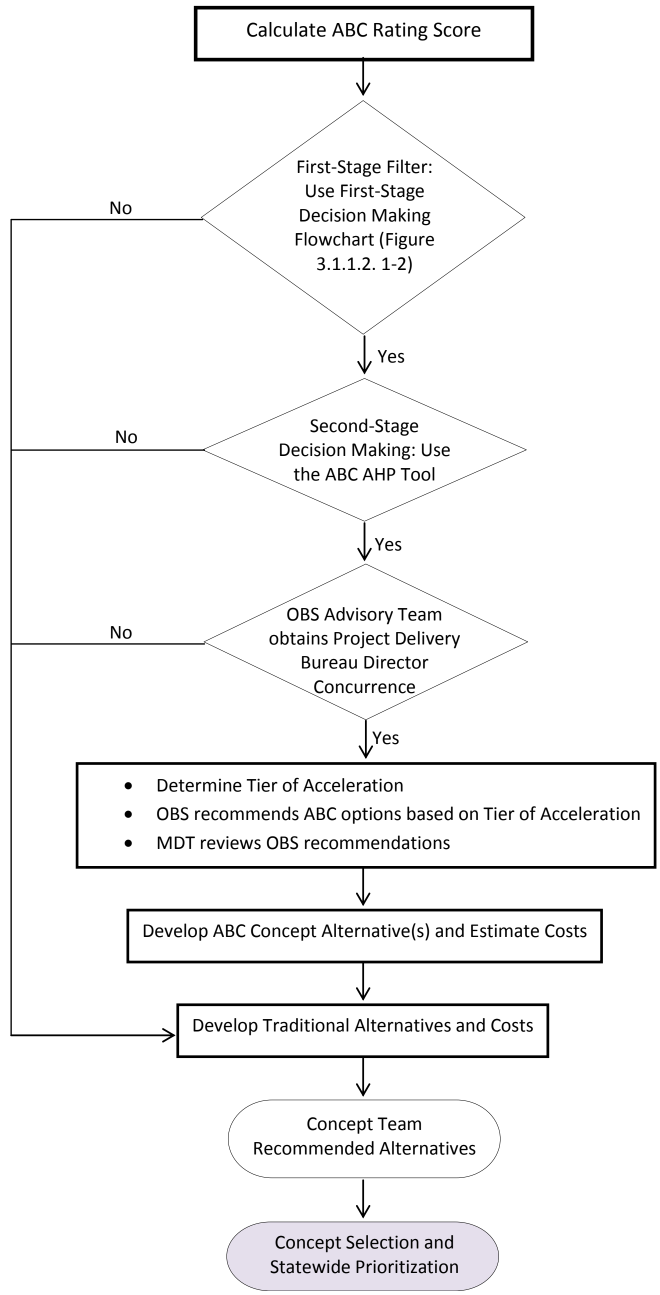


Fig. 9: IDOT ABC Decision Making Process

The first stage consists of developing an ABC rating for the project in a similar way as utilized by UDOT based on four decision criteria; namely: average annual daily traffic, out of distance travel, daily road user cost, economy of scale. Each of these criteria has a preset weight and a predefined scoring scale. Next, based on its ABC rating score, the project is then categorized in one of two categories each lead to a different entry point in a decision flowchart (figure 10). If the project's ABC rating is less than 50, then the project will only be further evaluated at the request of the district as they may be aware of some unique circumstances for that particular project. If the project's ABC rating is above 50 and the site conditions & project delivery support ABC, then the project will be further evaluated for ABC using the second decision making phase.

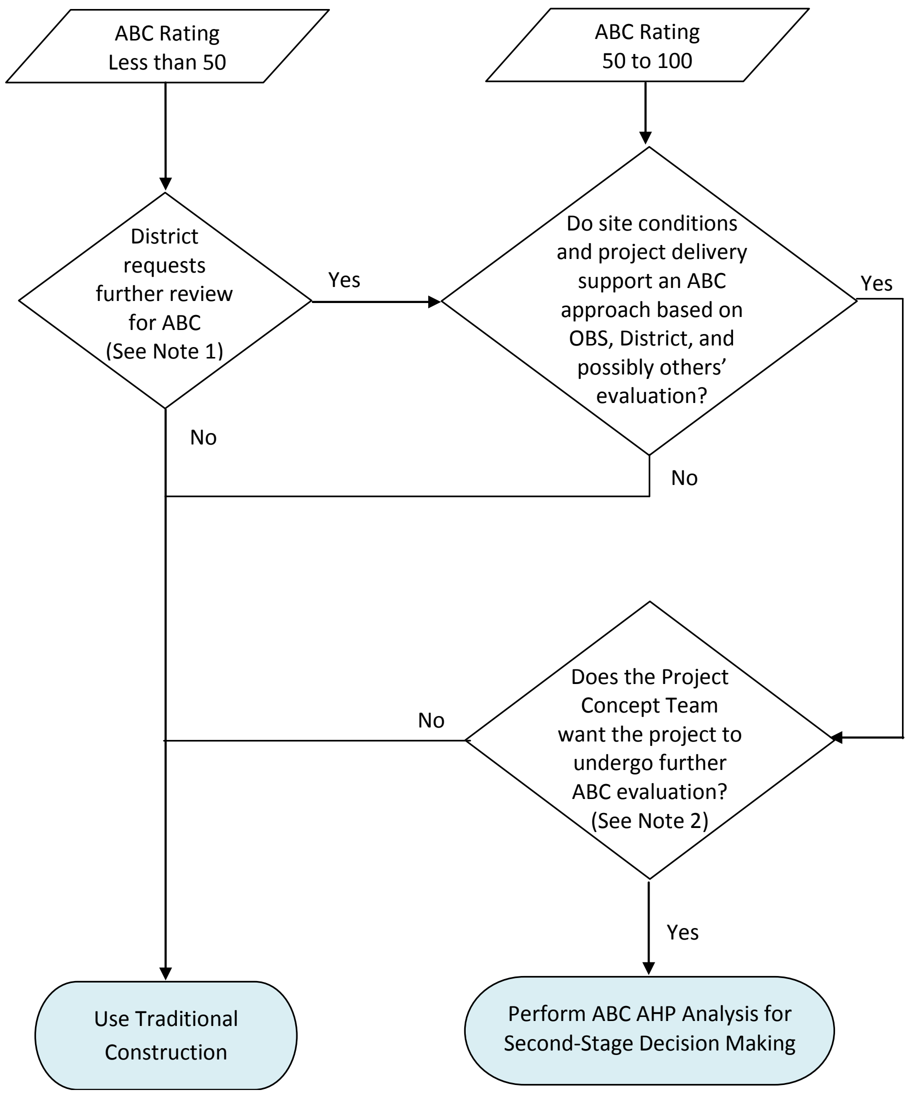


Fig. 10: IDOT ABC Decision Flowchart

The second stage of the decision making process involves further analysis of the projects that passed the first stage using ODOT AHP tool which is based on five main criteria as discussed in previous sections. In this stage several ABC alternatives as well as the traditional construction method are evaluated against each other to decide whether ABC is best suited for this project or not. Finally, after passing through the two-stage filtering process, the advisory team will have to obtain the bureau director approval, determine the required tier of acceleration based on the project's impact on traffic, recommend an ABC option, develop the concept, and estimate the project costs.

3.4. Analysis of the Different Decision-Making Tools:

By grouping the different tools into qualitative and quantitative, the following analysis can be drawn:

3.4.1. Qualitative Tools:

This type of tools is characterized by helping the decision makers in assessing their projects suitability for ABC using qualitative measure based solely on his/her experience. Most of these tools are in the form of flowchart or matrices that require the decision maker to answer some questions and based on these answers, a decision is reached. Several examples of these tools are: FHWA flowchart & matrix, the matrix based decision support tool, UDOT matrix and ranking system (hybrid), CDOT decision making system (hybrid), and WSDOT matrix. These tools have some common features and differences in terms of the factors being assessed and the final scoring of the project. Regarding the latter, both FHWA & WSDOT matrices require a simple count of the "yes", "no", or "maybe" answers and based on this count, the project's suitability is determined. On the other hand, the UDOT & CDOT ranking system allows the user to answer the questions on a scale of 1-5 and then calculate the final ranking as the ratio of the weighted score to the maximum score. Finally, the matrix based decision making system uses a different approach in selecting the project's strategy which is based on three developed matrices that shows how each bridge construction alternative satisfies certain project goals. Regarding the flowcharts, both UDOT & CDOT have entry points based on the ABC ranking then through a set of questions the decision is reached. These two tools almost share all the questions being asked with the exception that CDOT adds a criterion about whether the bridge is on the critical path of the project or not when assessing the suitability of ABC.

With regards to the factors and decision criteria being assessed by these tools, there are some common ones as well as differences. Table (4) below summarizes the common and different decision criteria between used by these tools:

Table 4: Decision Criteria of Qualitative Decision Making Tools

	Factor	**FHWA Flowchart**	**FHWA Matrix**	**Matrix-based Tool**	**UDOT System**	**CDOT System**	**WSDOT Matrix**	**WisDOT System**	**IDOT System**
1	Daily Traffic Volume	√	√	√	√	√	√		√
2	Impact on Critical Path	√				√	√	√	
3	Construction Cost	√		√	√	√	√	√	√

	Factor	FHWA Flowchart	FHWA Matrix	Matrix-based Tool	UDOT System	CDOT System	WSDOT Matrix	WisDOT System	IDOT System
4	Emergency/Evacuation	√	√	√			√	√	
5	Impact on Traffic	√	√	√	√	√	√	√	
6	Economic Impact			√			√		
7	Safety	√	√	√	√	√	√		
8	Environmental Impact	√	√		√	√	√		
9	User Cost		√		√	√	√	√	√
10	Economy of Scale	√	√		√	√	√	√	√
11	Bridge Geometry				√			√	
12	Railroad Impact				√	√			
13	Project Time Acceleration			√	√	√		√	√
14	Site Conditions		√		√	√			√
15	Traffic Control Cost		√				√		
16	Weather Constraints		√				√	√	
17	Quality			√					
18	Social Impact			√					√
19	Detour Distance				√	√	√	√	√

As seen from the above table, the factors that are considered by all these tools are: daily traffic volume, impact on traffic, and safety; while, the other frequently used factors include: cost, environmental impact and economy of scale. In contrast, quality, economic and social impacts are only being considered in the matrix-based tool and the bridge geometry only in UDOT system; while, weather conditions and traffic control costs are only being regarded as a decision factor in both FHWA & WSDOT matrices and railroad impact in UDOT & CDOT systems.

3.4.2. Quantitative Tools:

This type of tools is characterized by helping the decision makers in assessing their projects' suitability using quantitative measures based on both the decision maker's experience and weighing technique that leads to a numerical value for each alternative assessed. Examples of these tools are: ODOT tool, MRUTC tool, Mi-ABCD tool, and the model for evaluating bridge construction plans (BCPs). The first three tools are based on the AHP decision making technique in which the decision criteria are given weights according to their importance and then the decision maker conduct a pair-wise comparison between each pair of alternatives with regards to each decision criteria on a scale from 1-9 to reach a weighted score for each alternative; however, in the Mi-ABCD tool, the decision maker rates each alternative relative to the decision criteria without pair-wise comparison; albeit, each criteria has to be set by the decision maker as whether it favors ABC or conventional construction. Nevertheless, the model for evaluating bridge construction plans is based on weighing the decision criteria and scoring each alternative against them without any comparison between alternatives.

With regards to the factors and decision criteria being considered by these tools, there are some common ones as well as differences. Table (5) below summarizes the common and different decision criteria between these tools:

Table 5: Decision Criteria of Quantitative Decision Making Tools

	Factor	**ODOT Tool**	**MRUTC Tool**	**Mi-ABCD Tool**	**BCP Model**
1	Direct Cost	√	√	√	√
2	Indirect Cost	√			
3	Safety		√		√
4	Impact on Local Communities		√		
5	Schedule Constraints	√		√	√
6	Site Constraints	√		√	
7	Customer Service	√			
8	Impact on Environment		√	√	
9	Work Zone Mobility			√	
10	Technical Feasibility			√	
11	Impact on Traffic Flow		√		
12	Impact on Local Economy		√		
13	Accessibility				√
14	Carrying Capacity				√

As seen from the above table, the only factor that is considered by all of these tools is the cost; while, the other frequently used factors include: schedule & site constraints and environmental impact. Furthermore, in each of these tools, the decision criteria are further subdivided into sub criteria totaling: 25, 15, 26, and 22 sub-criteria, respectively.

4. SURVEY OF CURRENT ABC DECISION-MAKING PRACTICES

To further understand the different decision parameters considered by the decision makers and the ways by which they calculate these parameters, a comprehensive survey was designed that includes questions regarding the above-mentioned objectives. The survey was designed to capture the different aspects regarding the ABC decision making process and, to this end, it was divided into five different sections with a total of 27 different questions with the focus on the cost parameters; these sections are: 1) current ABC state-of-practice; 2) ABC barriers and drivers; 3) ABC decision support tools; 4) ABC cost evaluation; and 5) other considerations (see appendix I). The survey development process passed through different phases including inputs from different team and the supervising committee members; however, it was not deployed to the industry professionals, as intended; hence no results were drawn from this particular task.

5. ABC PARAMETRIC CONSTRUCTION COST ESTIMATION

Two different tasks were performed in this project with regards to the parametric cost estimation of the ABC projects; first, a tool to predict this cost based on different bridge characteristics was developed; and, second, a comparison between the cost per square feet for both the ABC and conventional bridges was performed.

5.1. Parametric Cost Estimation Tool:

In order to develop a tool to estimate the construction cost per square feet for the ABC projects, several steps were performed to reach this objective; these steps are:

5.1.1. Data Collection:

The first task involved in developing the construction cost estimation tool was collecting historical nationwide data about the final construction costs and characteristics of previously constructed ABC projects. The primary source of collecting such data was the FHWA share point database developed as part of the National ABC Project Exchange which is an ongoing project sponsored by Florida International University – University Transportation Center (FIU-UTC). In addition, correspondence was sent to some bridge engineers nationwide requesting such type of data for their ABC projects. Through this two sources, several nationwide ABC projects, which had data about the final construction cost were collected leading to a total of 65 projects from 29 different states, constructed between 1998 and 2013. Figure (11) shows the number of projects collected from each of these 29 states and table (6) shows the list of these projects:

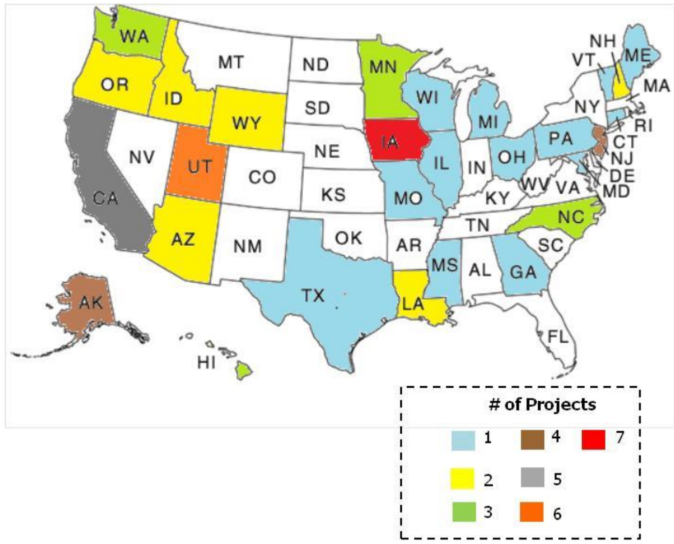


Fig. 11: Data from nationwide ABC projects

Table 6: Construction Cost Data

	State	Project Name
1	Alaska	O'Malley
2		Grayling Creek
3		Kouwegok Slough
4		Pelican Creek
5	Arizona	Mescal Road / J-Six Ranch Road
6		Oak Creek
7	California	Craig Creek
8		Hardscrabble Creek
9		North Fork of Mill Creek
10		Carquinez Strait
11		Ft. Goff Creek
12	Connecticut	Church Street
13	Georgia	Kia Blvd
14	Hawaii	South Punaluu Stream
15		North Kahana Stream
16		Keaiwa Stream
17	Idaho	Vista Interchange
18		Black Cat Road
19	Illinois	Illinois Rt. 29 over Sugar Creek
20	Iowa	US 6 over Keg Creek
21		Little Cedar Creek
22		640th Street over Branch Raccoon River
23		Jakway Park
24		24th Steet over I-29/80
25		Madison Co
26		Mackey (Marsh Rainbow Arch)
27	Louisiana	LA 3249 (Well Road) Bridge over I-20
28		I-10 over Lake Pontchartrain
29	Maine	Boothbay
30	Maryland	MD Route 24 over Deer Creek
31	Michigan	Parkview over US 131
32	Minnesota	TH 53 over Paleface River
33		TH 61 over Gilbert Creek
34		MN Bridge 27504 over SH 62
35	Mississippi	Kickapoo Road over Bogue Chitto Creek
36	Missouri	I-44 over Gasconade River
37	New Hampshire	I-93 over Loudon Road
38		Mill St. over Lamprey River
39	New Jersey	Route 202 over Passaic River
40		Gordon's Corner Road over Route 9
41		Route 70 over Manasquan River
42		Route 1 over Olden Ave & Mulberry Street
43	North Carolina	Biltmore Avenue
44		Tar River - Washington Bypass
45		NC 12 over Molasses Creek - Ocracoke Island
46	Ohio	Bowman Road
47	Oregon	OR 213 over Washington Street (Jughandle)
48		Kimberly
49	Pennsylvania	Montour Run #6
50	South Dakota	Buffalo Creek
51		41st Street
52	Texas	SH 290 at Live Oak Creek
53	Utah	Sam White over I-15
54		Layton Parkway over I-15
55		I-70 over Eagle Canyon
56		I-80 over 2300 East
57		Riverdale Road over I-84
58		I-215/4500 South Bridge
59	Vermont	Rte 4 Bridge 50 - Woodstock
60	Washington	US 12 over I-5 at Grand Mound
61		Northeast 8th Street
62		South 38th Street
63	Wisconsin	CTH B over Parsons Creek
64	Wyoming	Ham's For River
65		Inyan Kara Creek

5.1.2. Data Analysis:

Since the data collected was from different states and different locations within each state and also spans over a long period of time, the first sub-task of the data analysis was to normalize all the data for location and time in order to be able to perform an accurate analysis. To achieve the above objective, location and time indices tables from RSMeans were used. Through these tables, data from across the country were normalized to the national average and data from different years were normalized for 2014.

Next a statistical analysis of the normalized data was performed to determine the distinctive characteristics of the bridges collected. As seen from figure (12), 39 of the bridges collected were constructed in rural locations and 50 of them were concrete bridges. The 65 bridges had spans ranging from a single span to seven spans with an AADT ranging from as low as few hundreds to as high as 200,000.

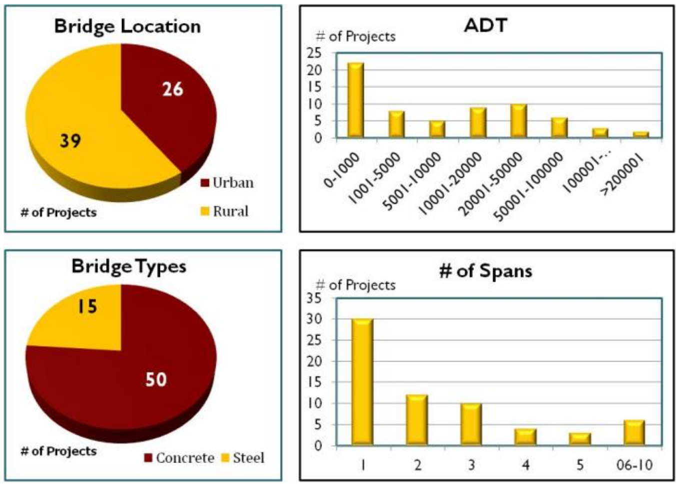


Fig. 12: Characteristics of the collected data

After conducting the above statistical analysis, a classification and regression tree (C&RT) analysis was performed to determine the impact of the above four bridge properties on the final construction cost. Through the C&RT analysis and as shown in table (7), it was evident that all of the above four properties had a significant impact on the final total construction cost of the ABC bridges with the AADT being the factor with the highest impact followed by the span of the bridge.

Table 7: C&RT Results

Independent Variable	Importance
ADT	9637.374
Span	9558.077
Type	5722.184
Location	3401.562

5.1.3. Regression Model:

After determining the important parameters that impact the cost/sq.ft. for ABC bridges, an estimation tool was developed that has the capability of estimating the range of the final ABC projects' construction cost based on the above parameters. The tool is based on a linear regression model that predicts the final cost range based on the input parameters of AADT, span, type, and location. However, due to the different nature of the input parameters, each of them was treated differently in a way that best reflects their impacts when being input in the model. Due to the wide range of AADT values in the collected data, and to improve the accuracy of the model, AADT values were divided into eight different intervals with each given a categorical value as shown in table (8). At the same time, since the type of the bridge is a qualitative value and has two input options, a value of "0" was given for concrete bridges and a value of "1" was given for steel bridges; similarly a value of "0" is give for rural locations and a value of "1" for urban ones. Finally, since the span has quantitative value, the number of spans is inputted directly into the model.

Table 8: AADT Input Intervals

Interval	Categorical
0 to 1000	0
1001 to 5000	1
5001 to 10000	2
10001 to 20000	3
20001 to 50000	4
50001 to 100000	5
100001 to	6
More than	7

On the other hand, when treating the cost output and due to the high number of different values in the collected data, the final cost output was treated as a range rather than a specific value. These ranges together with their categorical values are shown in table (9):

Table 9: Final Cost Ranges

Interval	Categorical
0-100	1
101-200	2
201-300	3
301-400	4
401-500	5
501-600	6
601-700	7
701-800	8
801-900	9
901-1000	10

Based on the above, a regression model with an R^2 of 0.36 that best relates the input parameters to the output is expressed using the following equation:

$$Cost = 2.662 + 1.289 \times Type - 0.174 \times Span - 0.344 \times Location + 0.238 \times AADT \quad (1)$$

Where the cost is expressed as a value ranging from 1-10

Finally, this model was implemented in an excel spreadsheet to provide a tool to bridge decision makers that enables them to estimate the range of the final construction cost for their ABC projects. Through this tool the user inputs the values for the four parameters as described above through a drop down menu and the tools automatically calculates the cost range for the bridge and display it in terms of $\$/ft^2$.

5.2. ABC vs. Conventional Bridges:

In order to perform a comparison between the construction cost per square feet for ABC vs. conventional bridges, the following steps were performed.

5.2.1. Data Collection:

Data for comparable projects were collected from three different sources: 42 projects from the FHWA database, 10 projects from ODOT engineers; and one project from MassDOT engineers; hence, a total of 53 bridge cases were analyzed.

5.2.2. Data Analysis:

The collected data were grouped according to some common characteristics and the costs of ABC vs. the conventional bridges were compared and yielded the following results, with regards to the direct cost, as shown in table (10):

Table 10: Comparison between ABC and Conventional Direct Cost per Square Feet

	Number of Projects	ABC vs. Conventional (%)			Cases ABC cost < Conventional	t-test Results (ABC > Conv.)
		Average	Min	Max		
All Data	53	20%	17%	-16%	11	Significant
ODOT Data	10	12%	108%	-16%	3	Not Significant
Database Data	42	32%	17%	17%	7	Significant
Concrete Bridges	40	23%	17%	4%	8	Significant
Steel Bridges	13	12%	108%	-16%	3	N/A
Urban Bridges	20	28%	17%	17%	3	N/A
Rural Bridges	33	17%	151%	-16%	8	Not Significant
Beams	9	3%	41%	-25%	2	N/A

	Number of Projects	ABC vs. Conventional (%)			Cases ABC cost < Conventional	t-test Results (ABC > Conv.)
		Average	Min	Max		
Decks	14	25%	17%	4%	3	N/A
Superstructure	6	45%	205%	34%	1	N/A

Regarding the indirect construction cost, the data from ODOT was the only source for this analysis and from this data four main types of indirect costs were analyzed; namely: preliminary engineering, construction engineering, ROW, and inspection. The results of the analysis of the difference between the indirect costs for both ABC and conventional bridges are shown in table (11):

Table 11: Comparison between ABC and Conventional Indirect Cost

	Number of Projects	ABC vs. Conventional (%)			Cases ABC cost < Conventional	t-test Results (ABC > Conv.)
		Average	Min	Max		
PE	10	0.4%	0.4%	1.4%	5	Not Significant
ROW	10	1%	N/A	5%	3	N/A
CE	10	-1.5%	-3.2%	-1.5%	7	Not Significant
Inspection	10	1%	N/A	5%	4	N/A

6. ABC DETAILED CONSTRUCTION COST ESTIMATION

Two different tasks were performed in this project with regards to the detailed cost estimation of the ABC projects; first, a preliminary attempt to estimate this cost based for different ABC methods was conducted; and, second, a comparison between the costs of different construction activities both the ABC and conventional bridges was performed.

6.1.<u>Detailed Cost Estimation Tool:</u>

The first step in an attempt to develop a detailed construction cost estimation tool was to try and capture the different activities accompanied with each ABC construction method; these methods were: modular construction, SPMT, and lateral sliding. To achieve this objective, detailed schedules from a total of 16 different ABC projects were collected from 11 different states using FHWA database. In addition, data from a CMGC project in Tennessee was collected, this project consists of four different bridges.

From these schedules, a preliminary list of the common activities for each ABC method was developed (see appendix II) with the intention to share this list with bridge engineers from different DOTs to get their feedback before attempting to develop a final list with the average cost associated with each activity. Furthermore, detailed cost data of the different activities of the above-mentioned projects were collected from the projects' bid tabs and mapped with the activities in the generalized activities' lists. Moreover, in order for the cost mapping data to be comparable, the costs of each project were normalized by the project size in order to negate the impact of the project size on the activities cost and be able to compare cost/sq.ft for all the projects.

6.2.<u>ABC vs. Conventional:</u>

Data about six FDOT hypothetical ABC projects (SPMT) and their comparable conventional projects were collected. Using the collected FDOT ABC & conventional projects cost data, statistical analyses using the paired sample t-test were performed to identify the cost items that contributed to the difference between ABC & conventional bridges. This analysis was performed on both the different types of cost categories; for example, direct & indirect costs, different types of bridge structures; for instance, superstructure & substructure, and different type of work; for example, concrete and steel. The results of all these analyses are shown in table 12.

Table 12: ABC vs. Conventional Bridges Statistical Analysis

Item			Conclusion
Total Cost			**Significant Difference (ABC Lower)**
	Indirect Cost		**Significant Difference (ABC Lower)**
	Direct Cost		No Significant Difference
		Detour	No Significant Difference
		General Conditions	**Significant Difference (ABC Lower)**
		End Bents	No Significant Difference
		Piers	No Significant Difference
		Superstructure	No Significant Difference
		Concrete	No Significant Difference
		Steel	No Significant Difference
		Expansion Joints	No Significant Difference
		Pads	No Significant Difference
		Pre-stressed Beams	No Significant Difference

In addition, the averages of the difference between the costs of ABC and conventional construction were calculated as shown in table (13):

Table 13: ABC vs. Conventional Bridges Averages Analysis

Item	ABC vs. Conventional
Total General Conditions	-45.57%
Total Permanent Wall	-0.29%

Item	ABC vs. Conventional
Total Substructure End Bents	-7.60%
Total Substructure Piers	-7.55%
Total Superstructure	3.31%
TOTAL DIRECT COST	-2.45%
TOTAL INDIRECT COST	-58.53%
TOTAL PROJECT COST	**-24.72%**

From the above two analyses, it is proved that the ABC bridges had lower total cost than the conventional bridges which was mainly a result of lower indirect cost and general conditions. Another type of analysis was performed on the collected data in which the difference in cost was analyzed for each individual project separately. From this analysis, the main reasons behind the cost differences for each individual project were identified and summarized as shown in table (14):

Table 14: ABC vs. Conventional Bridges Statistical Analysis

Project	Major Cost Difference	Reason
Interstate over Local Road	Detour	The use of ABC eliminated the need to construct a detour which led to cost savings
Interstate over Railroad	Shorter Duration	ABC reduced the overall construction duration of the bridge
Multiple Bridges	Mobilization	Economy of scale and distributing the mobilization cost over six bridges
Local Bridge	Shorter Duration	ABC reduced the overall construction duration of the bridge
Bridge over Waterway	Shorter Duration	ABC reduced the overall construction duration of the bridge
Viaduct	Piers	Cost of piers is less because of labor cost as more labor is required with conventional to dismantle complex falsework

7. CONCLUSION

Several decision making tools are used by DOTs' engineers in order to decide whether to construct their projects using ABC or not. Although, these decision making tools differe in terms of type, they have some common features especially when dealing with the decision parameters used. One of the most decision parameters considered by the majority of tools is the construction cost associated with ABC. However, none of the available tools provide a way to estimate this cost as they depend on the engineer's input. Therefore, the need to provide decision makers with tools to estimate the construction cost associated with ABC is a vital task to improve the decision making process. In this research projects, two attempts were made with regards to this objective.

First a parametric cost estimation tool was developed to estimate a range to the construction cost per feet associated with different bridges' types and locations. Through this tool, the decision maker can input some bridge characteristics; namely: location, type, number of spans; and AADT, and the tool will estimate a range of the predictable cost per square feet for that particular bridge. Moreover, an analysis of the difference between the cost per square feet for ABC vs. conventional bridges was performed. From this analysis it was deduced that there is a significant difference between the cost associated with ABC and conventional construction, with ABC being higher.

Second, an attempt to develop a tool to provide a detailed cost estimation for ABC projects was performed. This attempt was conducted for the three most-widely used ABC methods; namely: modular, SPMT, and lateral sliding. Nevertheless, this was a preliminary attempt and further refinements for the tool are needed. Lastly, a comparison between the construction cost of different activities between ABC and conventional bridges was performed. From this comparison, it is proved that the ABC bridges had lower total cost than the conventional bridges which was mainly a result of lower indirect cost and general conditions.

Finally, future research tasks for this project are recommended as follows:

1. Develop construction & indirect cost activities checklists associated with conventional construction and develop a comparison chart between the total cost of each of the ABC construction methods & the conventional bridge construction method and relate the differences to the different project characteristics.
2. Collect more comparable data and perform further statistical analysis to identify the cost items that contribute to the difference between ABC and conventional construction.
3. Collect more data about the activities involved in both types of bridge construction to construct a broader list of activities and categories.

References

Department of Transportation (2013). *2013 Status of the nation's highways and bridges: Conditions and performance*. U.S. Department of Transportation, Washington, D.C. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/pdfs.htm. (June 27, 2014).

Doolen, T., Saeedi, A., & Emami, S. (2011). *Accelerated bridge construction (ABC) decision making and economic modeling tool*. Federal Highway Administration, Washington, D.C. Retrieved from http://ntl.bts.gov/lib/43000/43500/43521/ABC (June 30, 2014).

Federal Highway Administration (FHWA) (2005). *Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making.* Washington, D.C. Retrieved from http://www.fhwa.dot.gov/bridge/prefab/if06030.pdf (June 29, 2014).

Federal Highway Administration (FHWA) (October 2012). Accelerated bridge construction: changing how America builds infrastructure. *Structure Magazine*. Retrieved from http://www.structuremag.org/Archives/2012-10/C-ConstrIssues-FHWA-Oct12.pdf (June 27, 2014).

Salem, S., & Miller, R. (2006). *Accelerated construction decision-making process for bridges*. U.S.

Department of Transportation, Washington, D.C. Retrieved from http://www.wistrans.org/mrutc/files/FR_05-04_Revised1.pdf (June 30, 2014).

Transportation Research Board (TRB) (2013). *Innovative bridge design for rapid renewals: ABC toolkit.* Washington, D.C. Retrieved from http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R04-RR-2.pdf. (June 27, 2014).

Appendix I: Survey

Survey of the States of Knowledge and Practice of Accelerated Bridge Construction in State Transportation Agencies

Florida International University

This survey is administered as part of a research project conducted by a team from the Accelerated Bridge Construction University Transportation Center (ABC-UTC) AT Florida International University. The objective of this project is to develop a framework for evaluating and utilizing public costs as an integral part of the decision-making processes associated with accelerated bridge construction. The framework will include several tools for estimating and analyzing public costs.

In this survey, the objective is to identify the important aspects related to the decision making processes related to the use of Accelerated Bridge Construction (ABC) versus conventional bridge construction methods in State Transportation Agencies. The survey is composed of six main sections covering questions on: general information; current state-of-practice; barriers and drivers to ABC implementation; experience with ABC decision support tools; cost evaluation for bridge construction; and other considerations. By participating in this survey, you will be contributing to the improvement of this process, which will in return improve bridge design, construction, and management.

For questions and comments, please contact the principal investigators of this study: Dr. Mohammed Hadi (hadim@fiu.edu); Dr. Albert Gan (gana@fiu.edu), Dr. Wallied Orabi (worabi@fiu.edu), and Dr. Ali Mostafavi (almostaf@fiu.edu).

A. *General Information:*

Name: ______________________________ Title: ______________________________
Agency: ______________________________ Department: ______________________________
Email: ______________________________ Phone: ______________________________
May we contact you with follow-up questions? ☐ Yes ☐ No

B. *Current ABC State-of-Practice:*

1. What is your agency's past experience with ABC?

☐ No experience ☐ Have a policy but do not implement it
☐ In the process of developing a policy ☐ Have a policy and implementing it
☐ Other (please specify) ____________________

2. For how long have your agency been using ABC for bridge projects?
   - ☐ Less than 2 years
   - ☐ 2-5 years
   - ☐ 5-10 years
   - ☐ More than 10 years

3. Approximately how many bridge projects have been completed using ABC in your agency in the past 5 years?
   - ☐ 1 - 5
   - ☐ 6 - 10
   - ☐ 11-15
   - ☐ 16 - 20
   - ☐ More than 20

4. Which of the following ABC methods does your agency use?
   [1- Never Used 2- Used Once 3- Used but Not Our Major Approach
   4- Used in the Majority of our Projects]

a.	Prefabricated Bridge Elements and Systems (PBES)	1 2 3 4
b.	Geosynthetic Reinforced Soil – Integrated Bridge System (GRS-IBS)	1 2 3 4
c.	Self Propelled Modular Transporters (SPMT)	1 2 3 4
d.	Lateral Sliding	1 2 3 4
e.	Other (please specify)___________________________	1 2 3 4

5. Please provide the reasons behind using certain ABC methods?
   ____
   ____

6. At which stage(s) of the business process is your agency's ABC decision making policy been applied? (pop-up window with the definition of each stage)
   ☐ Long Range Planning ☐ Programming ☐ Corridor Planning and Preliminary Design & Engineering (PD&E) ☐ Congestion Management Process ☐ Operations Planning
   ☐ Design ☐ Implementation ☐ Other (please specify)______________

7. In your agency's current practice, what are the ABC-related decisions made during the following business processes? (please select all that apply)
   (pop-up window with the explanation of each decision)

Decision / Business Processes	Initial List of Candidate ABC Projects	Initial Project Prioritization	ABC Utilization	Selection of ABC Method	Selection of Contracting Method	ABC Staging
Long Range Planning						
Programming						
Corridor Planning and Preliminary Design & Engineering						
Congestion Management Process						
Operations Planning						
Design						
Implementation						
Other (please specify)______________						

7a. If a policy is available, in your opinion, what ABC decisions should be made during the following business processes? (please select all that apply)
(pop-up window with the explanation of each decision)

Decision / Business Processes	Initial List of Candidate ABC Projects	Initial Project Prioritization	ABC Utilization	Selection of ABC Method	Selection of Contracting Method	ABC Staging
Long Range Planning						
Programming						
Corridor Planning and Preliminary Design & Engineering						
Congestion Management Process						
Operations Planning						
Design						
Implementation						
Other (please specify)						

C. *Barriers & Drivers:*

8. What are the barriers to a wider implementation of ABC in your agency?
   - ☐ Lack of support for innovation
   - ☐ High initial construction costs
   - ☐ Lack of qualified contractors & suppliers
   - ☐ The benefits do not offset the costs incurred
   - ☐ Limited in-house expertise
   - ☐ Other (please specify) ____________________

9. What are the drivers for wider implementation of ABC in your agency?
   - ☐ Savings in user costs
   - ☐ Accelerate project completion
   - ☐ Public convienience
   - ☐ Safety
   - ☐ Other (please specify) ____________________

10. What are the pursued organizational benefits of a wider implementation of ABC?

    ☐ Better use of the agency's personal resource (e.g. inspection staff) ☐ Time saving

    ☐ Better portfolio planning ☐ Cost savings

    ☐ Other (please specify) ____________________

11. Does the implementation of ABC affect your agency's process of prioritizing projects?

    ☐ Yes ☐ No

    Please explain____

12. What are the criteria used by your agency when prioritizing a project from a set of projects?

    (please rank from 1 to 7 with 1 being the most important)

    ☐ Construction cost ☐Time ☐ Bridge importance ☐ AADT ☐ User costs

    ☐ In-house staff resources ☐Other (please specify)__________

D. *Decision Support Tools:*

14. Which of the following decision making tools do you use for ABC decision making? <u>(mark all that apply)</u>

    (Each tool will be displayed as a link that takes the user to a webpage with a brief description about the tool)

    [1- Never Used 2- Used Once 3- Used but Not Our Major Approach 4- Used in the Majority of our Projects]

    a. FHWA Flowchart 1 2 3 4
    b. ABC AHP Decision Making Tool 1 2 3 4
    c. Spreadsheet (please specify)_________________ 1 2 3 4
    d. FHWA Matrix 2 2 3 4

e. Other (please specify)___________________________ 2 2 3 4

15. On what basis does your agency determine the importance of different decision making factors in evaluating ABC for projects? (e.g. cost, detour time, AADT, economy of scale, safety…etc)

____

16. Which of the following factors affect your agency's decision in using the tool(s) listed in question 14?

(please rank from 1 to 6 with 1 being the most important)

☐ User friendliness ☐Reliability of results ☐Familiarity with the procedure

☐ Ability to consider project specific attributes

☐ Ability to be used in different decision-making steps throughout different business processes

☐Other(please specify) _________________

17. Please indicate the reason(s), if any, for not adopting any of the following decision support tools? (mark all that apply)

	Not User Friendly	Subjective	Not Inclusive	Inaccurate Results	Other (Please Specify)
FHWA Flow Chart					
FHWA Matrix					
ODOT AHP					
Spreadsheet					

E. Cost Evaluation:

18. What are the types of costs considered by your agency when comparing ABC versus conventional bridge construction methods?

☐ Construction costs ☐ Right-of-Way costs ☐ Design & pre-engineering costs

☐ User costs ☐ Other (please specify)___________________________

18a. If you choose construction costs, what are the major components in your agency's consideration?

☐ Construction ☐ Detour ☐Inspection ☐ Maintenance of traffic

☐ Other (please specify)____

18b. If you choose user costs, what are the major components in your agency's consideration?

☐Safety ☐ Mobility ☐ Reliability ☐Fuel consumption ☐ Environmental impacts

☐ Other (please specify)____

19. How does your agency compare the relative importance of agency costs to user costs?

☐ Agency costs are as important as user costs
☐ Agency costs are more important than user costs by 20% or less
☐ Agency costs are more important than user costs by 20% – 40%
☐ Agency costs are more important than user costs by more than 40%
☐ Other (please specify)____

20. Does your agency have a cost database for ABC projects? ☐Yes ☐No

21. Does your agency collect real-world data to quantify user costs? ☐Yes ☐No

    21a. If yes, what are the data resources and which method is used in data collection?
    ____

22. What is the tool/method used in cost evaluation?
    Construction Cost____
    User Cost____

23. Does your agency use weights for determining the importance of each component of costs? ☐Yes ☐ No

    23a. If yes, what method is used to assign the weights?
    ____

24. Based on your agency's past experience, rank the following ABC methods based on their potential to improve the total cost of the project (agency & user costs)? (please rank from 1 to 5 with 1 being the most important)
    - ☐ Prefabricated Bridge Elements and Systems (PBES)
    - ☐ Geosynthetic Reinforced Soil – Integrated Bridge System (GRS-IBS)
    - ☐ Self Propelled Modular Transporters (SPMT)
    - ☐ Lateral Sliding
    - ☐ Other (please specify)____________________________

F. Other Considerations:

25. In addition to the factors that are currently considered by the majority of State Transportation Agencies for ABC decision-making, there are other factors that can be considered. In your opinion, what is the level of importance for the following factors when considering ABC for a project?
    [1- Not Important 2- Somehow Important 3- Important 4- Very Important 5- Extremely Important]

a.	Economic Impact	1	2	3	4	5
b.	Bridge Geometry	1	2	3	4	5
c.	Railroad Impact	1	2	3	4	5
d.	Maintenance of Traffic Cost	1	2	3	4	5

e. Quality of Construction 1 2 3 4 5
f. Availability of Suppliers 1 2 3 4 5
g. Contractor Experience 1 2 3 4 5
h. Manufacturer Experience 1 2 3 4 5

26. Did your agency use any of the following innovative contracting methods in the accelerated bridge construction project(s)?
[1- Never Used 2- Used Once 3- Used but Not Our Major Approach
4- Used in the Majority of our Projects]
    a. A + B 1 2 3 4
    b. Incentive/Disincentive 1 2 3 4
    c. A + B + Incentive/Disincentive 1 2 3 4
    d. Lane Rental 3 2 3 4
    e. Design Build 4
    f. Other (please specify)___________________________ 3 2 3 4

27. How do you rate your experience with the following contracting methods in terms of achieving your intended goals in accelerating bridge projects?
[1- Not Successful 2- Somehow Successful 3- Successful 4- Very Successful
5- Extremely Successful]
    a. A + B 1 2 3 4 5
    b. Incentive/Disincentive 1 2 3 4 5
    c. A + B + Incentive/Disincentive 1 2 3 4 5
    d. Lane Rental 1 2 3 4 5
    e. Design Build 1 2 3 4 5
    f. Other (please specify)_________________ 1 2 3 4 5

---

28. Please add any additional comments regarding the questions asked in this survey?

Thank you for your participation

Appendix II: ABC Methods' Activities Lists

Modular Construction Activities Checklist

Construction Activities	
Level 1	**Level 2**
Site Preparation	
	Erosion Control
	Demolition Debris Protection
	Mobilization
	Install Temporary Fences
	Set-up Crane
	Install Traffic Control Signs
Demolition	
	Clear & Grub
	Demolition
	Disassembly of Beams
	Excavation
	Install Temporary Sheeting
	Install Cofferdam
	Mill Existing Asphalt
	Remove existing Element
	Remove Cofferdam
Construction	
	Backfill
	Compact Backfill
	Install Precast Abutment
	Post-tension
	Place Geotextile & Riprap
	Curing
	Install Panels
	Install Diaphragms
	Install Folded Plates
	Set Rebar
	F/R/P & Grout
	Install MSE Retaining Walls
	Backfill
	Move Bridge
	Remove Rollers & Channel
	Set Grout Bearing Pads for Bridge
	Lower Bridge onto Bents
	Install Precast Approach Slab
	F/R/P Closure Pours
	F/R/P End Posts
	Construct Sidewalks
Paving	

Construction Activities	
Level 1	**Level 2**
	Sub-base
	Apply Membrane Waterproof
	Install Railings
	Cure Membrane Waterproofing
	Base Paving
	Top Paving
	Stripping & Signage
Demobilization	
	Restore landscape
	Demobilize

<u>**SPMT Construction Activities Checklist**</u>

Construction Activities	
Level 1	**Level 2**
Site Preparation	
	Erosion Control
	Demolition Debris Protection
	Mobilize SPMT Equipment
	Install Temporary Fences
	Install Temp Concrete Barriers
	Prepare Area for Bridge Frame
	Construct Shoring for Bridge Frame
	Install Traffic Control Signs
	Bridge Deck Waterproofing
	Utility Relocation
Construction Preparation	
	Widen Routes
	Prepare Pre-Fab Area
	Shoring Towers Foundation
	Fabricate & Deliver Structural Elements
	Erect Shoring Towers
	Erect Structural Beam on Shoring Towers
	Form Bridge Deck
	Construct Parapets on Deck
	Fabricate Structural Element
	Pour & Cure Bridge Deck
	Install Traffic Signals
	Install Protective Screen
Demolition	
	Clear & Grub
	Demolition
	Remove Guardrail
	Excavation
	Form Wingwall Barrier
	Pour & Cure Wingwall Barrier
	Remove Existing Spans
	Sawcut Abutments
	Install Embankment
	Install Guardrail
Construction	
	Backfill
	Place Embankment
	Place Gravel & Fine-Grade
	Install Precast Abutment
	Install Precast Approach Slabs
	Install New Spans

Construction Activities	
Level 1	**Level 2**
	Move Equipment into position
	Fabricate & Deliver Retaining Walls
	Move Binder Course
	Set Superstructure in Place
	Membrane new Deck
Paving	
	Sub-base
	Base Paving
	Top Paving
	Install Guardrail
	Stripping & Signage
Demobilization	
	Remove Signage
	Restore landscape
	Demobilize

Lateral Sliding Construction Activities Checklist

Construction Activities	
Level 1	**Level 2**
Site Preparation	
	Install Traffic Control Signs
	Move Crane
	Mobilization
	Install Temporary Fences
	Stage Equipment & Material
Construction Preparation	
	P/C Support Beam Relief
	Remove P/C Slabs
	Sheet Pile Relief
	Remove Sheet Pile
	Install Drainage Pipe
	Install Bearing Pads
	Lay Sand Bedding for Precast End panels
	Set Precast End Panels
	Core Drill & Install Dowels End Panels
	Grout Precast End Panels
	Grout Cure
	Install Permanent Asphalt on End Panels
Demolition	
	Remove P/C Slab & Support Beans
	Mill Existing Asphalt
	Remove Asphalt at End Panels
Construction	
	Backfill
	Install Drainage Pipe
	Move Bridge
	Set Grout Bearing Pads for Bridge
	Lower Bridge onto Bents
Paving	
	Sub-base
	Base Paving
	Top Paving
	Stripping & Signage
Demobilization	
	Remove Signage
	Restore landscape
	Demobilize