A COMPREHENSIVE DECISION SUPPORT TOOL FOR ACCELERATED BRIDGE CONSTRUCTION CONSIDERING SOCIAL EQUITY

Quarterly Progress Report
For the period ending November 30, 2022

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ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

Submitted to:
ABC-UTC
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1. Background and Introduction

The suitability of using accelerated bridge construction (ABC) techniques in bridge construction projects has potential interdependencies with several social and environmental factors related to communities affected by the bridge project in addition to economic, safety, and technical factors related to the design and construction of bridges. Decision-makers and bridge owners (e.g., Departments of Transportation- DOTs) demand assurance that the ABC techniques are thoughtfully implemented since many of the projects have limited budget, time constraints, and construction limitations. State DOTs across the country utilize different decision-making approaches, ranging from complex to simple processes, to determinate the suitability of ABC methods in bridge projects. Connecticut DOT (CTDOT) uses a middle-ground multi-criteria decision-making approach entitled "ABC Decision Matrix" based on a spreadsheet tool to aid decision makers in adopting ABC methods. The CTDOT ABC Decision Matrix is a relatively simple, yet effective, tool that considers the impacts of ABC on road users and environment and accounts for total project costs but offsets ABC costs with the costs that can be reduced or eliminated with ABC. However, there are some issues that affect the comprehensiveness, accuracy, and widespread use of the tool. The objective of this research is to extend the CTDOT ABC Decision Matrix to (1) consider the benefits of ABC on roadway safety and risk of accidents, (2) consider the impacts and contributions of ABC on social equity and environmental justice in communities especially underserved ones, (3) include quantitative measures for the evaluation of decision criteria where possible, and (4) leverage a systematic method for the determination of relative importance (weights) of criteria. A case study will be used to demonstrate the applicability of the improved tool. The improved ABC decision making tool will be more comprehensive, less subjective (more accurate), and more flexible to be used by state DOTs.

2. Problem Statement

The suitability of ABC techniques has potential interdependencies with several natural hazard, (e.g., floods), social, and environmental factors in urban areas in addition to economic, safety, and technical factors related to the design and construction of bridges (Jia et al., 2018). Decision-makers (e.g., state DOTs) need to assure that the ABC techniques are thoughtfully viewed since many of the projects include construction limitations and have only access to the limited budget and time (Chaphalkar et al., 2013). Flood related factors can contribute to bridge scour, the biggest cause of bridge failure in the United States and a major cause for increased construction and maintenance costs of bridges in the United States (FDOT, 2005; Wang et al., 2017). Construction of a bridge can potentially generate additional flood issues because of the alterations to natural streams and rivers including temporary flow diversions during construction. Reducing the construction time through ABC methods can potentially minimize the risk of flooding due to temporary flood diversions during the construction phase.

Social equity in the context of urban infrastructure can be defined as equal resources and opportunities that infrastructure systems provide for urban communities. Incorporating social equity in infrastructure planning results in the elimination or reduction of disparate access to amenities and services among different community groups, including ethnic minorities, low-income groups, people with disabilities, and the elderly among the other groups (Dhakal et al. 2021). Environmental justice is the fair treatment and involvement of all people with regard to environmental policies and requires the same degree of protection from environmental and health hazards for everyone (EPA 2022). ABC has implications in social equity and environmental justice that can be incorporated into the decision-making process for evaluating the suitability of adopting ABC methods in bridge projects.

For example, social and demographic factors such as high crime rates and high population densities can cause interruptions to the bridge construction process, increasing the construction time. Adopting ABC method can help reducing the chance of those interruptions. More importantly, ABC can help faster revitalization of these urban neighborhoods (e.g., improving economic conditions in low-income neighborhood by addressing traffic issues that used to affect the businesses and property values). Finally, the reduced construction time due to adopting ABC techniques would result in more public consent because the everyday life of residents will be less affected by construction processes. Environmental issues such as high air temperatures and low air quality are potential threats for human health and can cause health issues for the workforce and increase construction time of projects. Using ABC methods can minimize these threats to the workforce. Moreover, ABC can contribute to accelerated revitalization of these urban neighborhoods (e.g., faster achievement of good air quality by addressing traffic issues in a densely populated urban area). To address the existing inequalities built into urban communities and create better communities for all, social equity and environmental justice should be incorporated into civil infrastructure planning (APA 2022), including the decision making about suitability of ABC projects.

3. Objectives and Research Approach

The overall goal of this research is to improve the CTDOT ABC decision making tool to obtain an improved tool that is more comprehensive, less subjective, and more flexible to be used by other state DOTs. The specific objectives of this research are

(1) Considering the benefits of ABC on roadway safety and incorporating risk of accidents as new quantitative criteria in the tool

(2) Considering the contributions of ABC to social equity and environmental justice as new quantitative criteria in the tool

(3) Developing quantitative measures for the evaluation of decision criteria where possible

(4) Developing a systematic method for determining relative importance (weights) of criteria

(5) Demonstrating the application of the improved tool in a case study.

4. Description of Research Project Tasks

The planned activities in this project are toward improving the CTDOT ABC decision making tool. The improved tool extends the benefits of ABC to improving roadway safety (reducing risk of accidents) and considers social equity and environmental justice in the decision-making process. Hence, it will be more comprehensive than the CTDOT and other existing ABC decision making tools. Moreover, the improved tool quantifies some of the qualitative evaluations in the existing CTDOT tool, reducing the subjective aspects of decision process and increasing the accuracy of the results. Finally, the improved tool will develop a procedure to determine relative weights of criteria, making the tool flexible to be used by other state DOTs. Once the improved tool is developed, its application will be demonstrated in a bridge construction project.

The research tasks in this project are designed to address the overall goal and specific objectives of the project. Figure 1 shows the research tasks and their interrelationship as a flowchart. More details about each task are presented below.

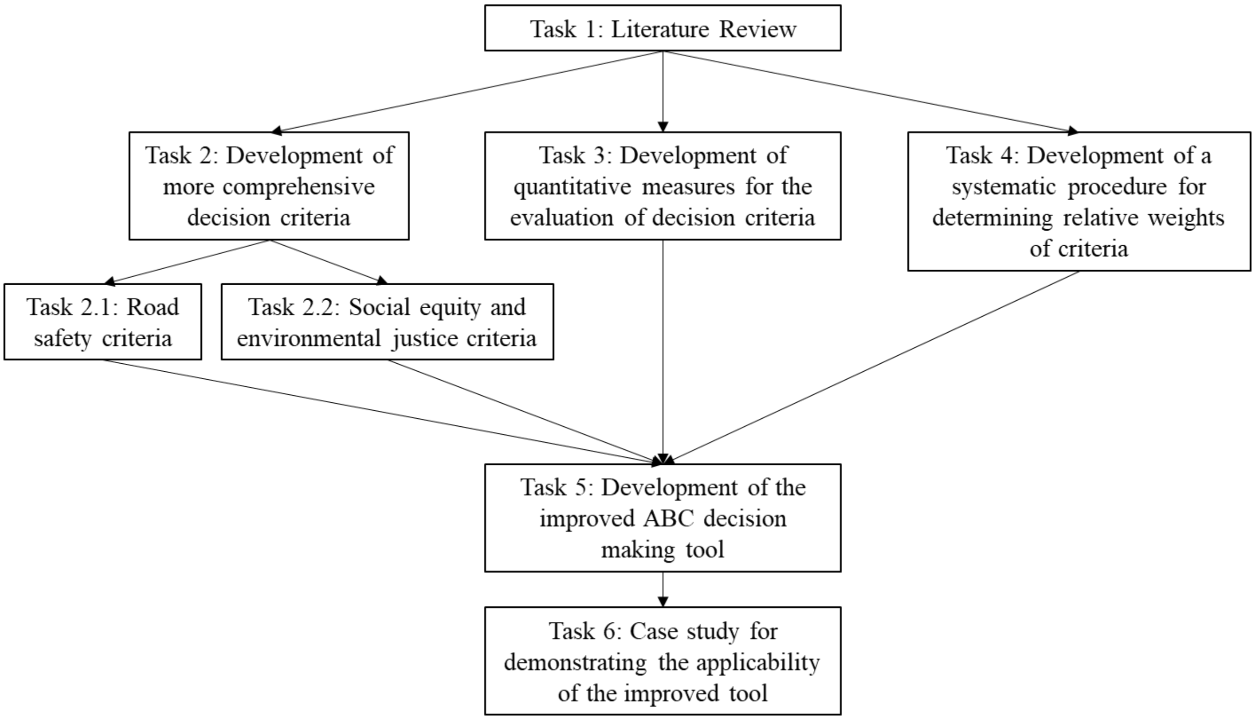

Figure 1. Flowchart of the Proposed Methodology that Shows the Research Tasks and their Interrelationships

Task 1 – Literature Review

The project includes a literature review to identify the existing state of the knowledge and practice about 1) ABC decision making tools from different DOTs and 2) incorporating social equity and environmental justice in infrastructure planning.

ABC Decision Making Tools Review

FHWA ABC Decision Making Guidance

ABC projects decision making tool is developed based on a Prefabricated Bridge Elements and System (PBES) by FHWA. In this method, a flowchart and matrix integrate a set of decision criteria to choose between conventional and ABC alternatives, Figure 2 and Table 1. After answering all the questions in the matrix, if many of the answers are yes, the project should use PBES. If not, PBES should not be applied.

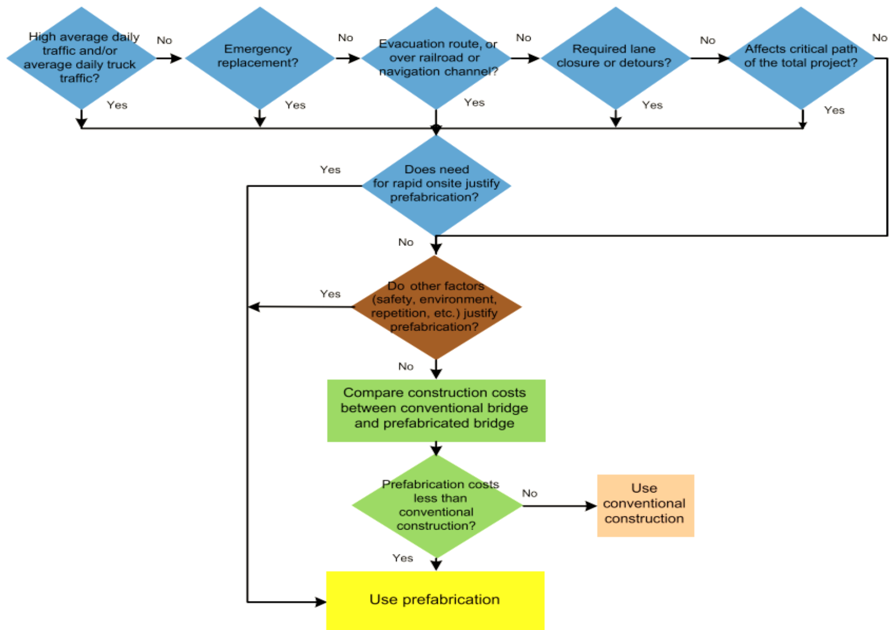

Figure 2. FHWA ABC Decision Making Flowchart (FHWA 2006)

Table 1. FHWA ABC Decision Making Matrix (FHWA 2006)

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 nesting?			
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:			

In December 2009, Oregon Department of Transportation (ODOT) working with several other states (California, Iowa, Minnesota, Montana, Texas, Utah and Washington) lunched a FHWA-sponsored AHP-based tool for identifying whether ABC should be applied to a specific project or not. This tool considered five main criteria: direct cost, indirect cost, schedule constraints, site constraints, and customer service. The Oregon State University ABC AHP decision tool was developed using Microsoft Visual Studio .NET. This method has a set of decision criteria Analytical Hierarchy Process (AHP) to plan if ABC is an economical and reasonable choice for the defined bridge or not. The AHP process involves three basic stages, a flowchart, matrix, and considerations section which may be used individually or in combination. Figure 3 shows a screen shot from the ABC-AHP user interface. The final stage considers AHP calculations, which produces an output value used for the purposes of decision-making. For the first step, preliminary inputs are shown in Table 2.

Table 2. ABC-AHP Decision Tool Inputs (FHWA 2012)

Category	**Subcategory**
Direct Costs	Construction
	Maintenance of Transport
	Design and Construct Detours
	Right of Way
	Project Design and Development
	Maintenance of Essential Services
	Construction Engineering
	Inspection and Maintenance and Preservation
	Toll Revenue
Indirect Costs	User Delay
	Freight Mobility
	Revenue Loss
	Livability During Construction
	Road Users Exposure
	Construction Personnel Exposure
Schedule Constraints	Calendar or Utility or RxR or Navigational
	Marine and Wildlife
	Resource Availability
Site Constraints	Bridge Span Configurations
	Horizontal/Vertical Obstructions
	Environmental
	Historical
	Archaeological Constraints
Customer Service	Public Perception
	Public Relations

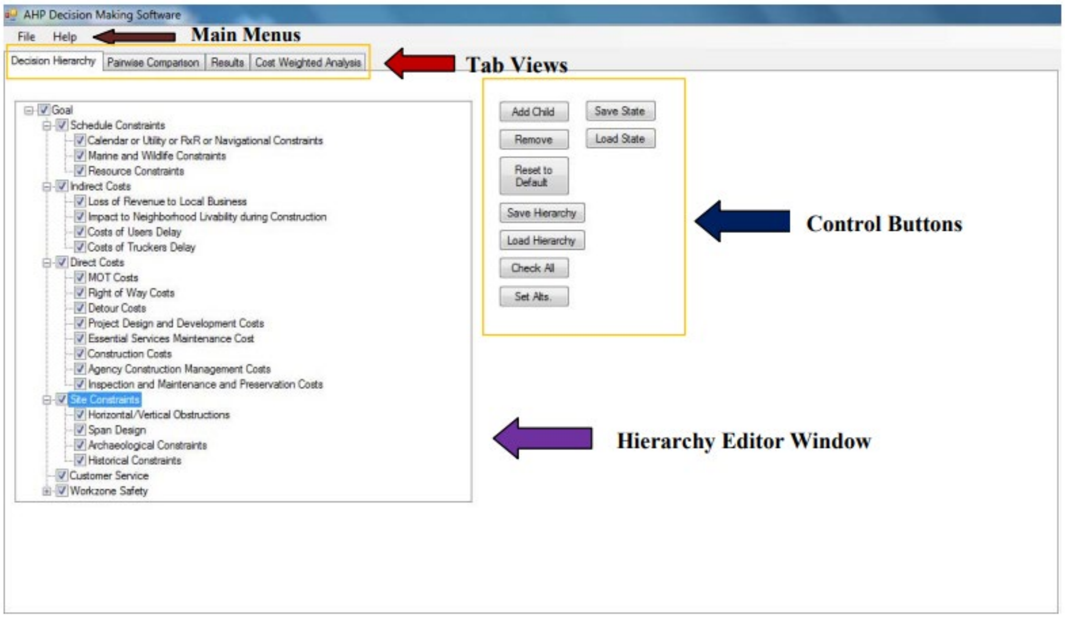

Figure 3. ABC-AHP Decision Tool (FHWA 2012)

For the second step, each criterion is ranked pairwise comparison. Figure 4 shows an example displaying the use of ABC or conventional construction.

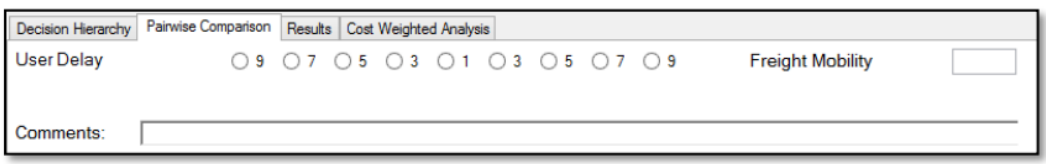

Figure 4. ABC/Conventional Construction Ranking (FHWA 2012)

After stage 2, the assessment process should move to the last step, which uses AHP theory to determine if ABC techniques should be used for the bridge construction projects or not.

California DOT ABC Decision Making Guidance

Caltrans which manages more than 50,000 miles of California's highway and freeway lanes provides ABC manual for California. The ABC Caltrans decision making guidance is consist of a questionnaire and a flowchart, Figures 5 and 6. The questionnaire is a qualitative evaluation of how ABC techniques could lessen or eliminate the effects of construction on the whole project. The questionnaire should be completed by the PE and the Technical Liaison Engineer (TLE), the district project engineer, and the project development team. To get the rating, all questions should be scored and then summed. In the next step, through the flowchart it is determined whether an ABC alternative should be developed or not.

Project Delivery: Design Impact Questionnaire

Given: Construction Impact Time (CIT), and Construction Completion Time (CCT)
Structure Type: *CIP, Precast, or other types of construction*

Questions		No 1	2	3	4	Yes 5	Priority Low 1	High 2	**Score**
General	# of Items 6								
1. Is this an emergency bridge replacement?									0
2. Is bridge on an emergency evacuation route or over railroad/waterway?									0
3. Is there a funding requirement to accelerated project delivery?									0
4. Is rapid recovery or completion of planned repair/replacement needed?									0
5. Is the bridge construction a critical path of the total project?									0
6. Are there significant economic benefits if construction is completed ahead of schedule?									0
								Individual Category Score =	0
Traffic	# of Items 5								
7. Bridge carries high ADT or ADTT?									0
8. Bridge over existing high ADT or ADTT facility?									0
9. Bridge construction significantly impact traffic? (Does it have high user-delay costs?)									0
10. Can the bridge be closed during off-peak traffic periods?									0
11. Will the traffic control plan be significantly impacted?									0
								Individual Category Score =	0
Construction	# of Items 3								
12. Do worker safety concerns at the site limit conventional methods? (e.g. adjacent power lines or over water?)									0
13. Is the bridge location subject to construction time restrictions due to adverse economic impact?									0
14. Does the site create problems for conventional construction methods? (e.g. falsework, concrete delivery, etc.?)									0
								Individual Category Score =	0
Utilities	# of Items 2								
15. Are there existing utilities/Railroad that impact the construction window?									0
16. Are there existing utilities/Railroad that impact construction operations?									0
								Individual Category Score =	0
Environmental	# of Items 4								
17. Is the site environmentally sensitive area requiring minimum disruption? (e.g. wetlands, air quality, and noise?)									0
18. Are there natural or endangered species at the bridge site? (Shorten construction window needed?)									0
19. Local weather limit the time of year for construction?									0
20. Is the bridge on or eligible for the National Register or Historic Places, or a designed landmark structure?									0
								Individual Category Score =	0
								Total Score =	**0**

ABC structure alternative is recommended for the APS if either:
i) Total score > 120
ii) Individual category score makes it eligible for ABC alternative
(PDT to decide which individual category(ies), if any, can activate the ABC recommendation)

Notes: 1) A high priority score of 2 is used for items of most importance.
2) 1.5 should be used for moderate priority

Figure 5. Caltrans ABC Decision Making Model

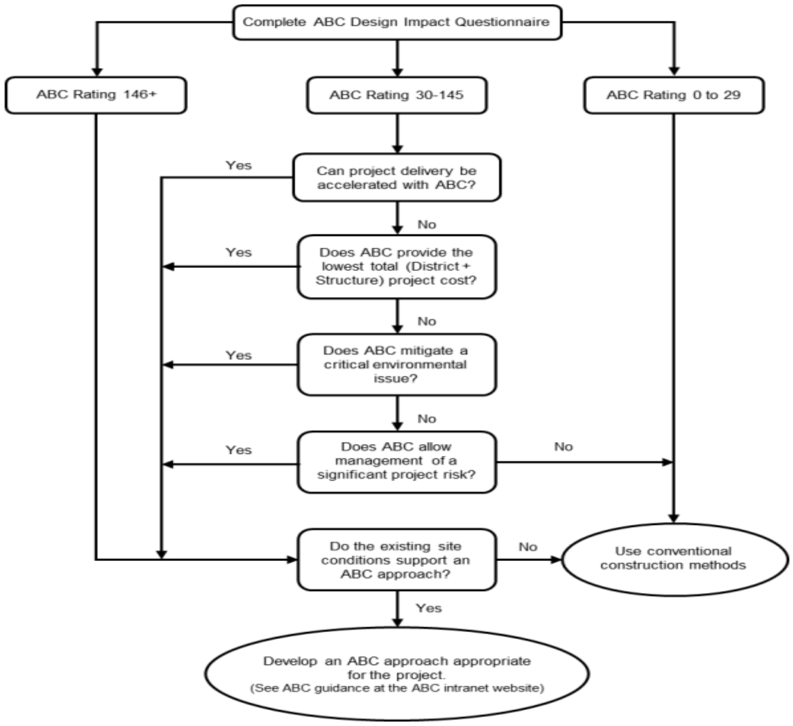

Figure 6. Caltrans ABC Decision Flowchart

Oregon DOT ABC Decision Making Guidance

A decision-making software tool for deciding whether to use ABC techniques was created based on the AHP process, which uses in early stages of the design process. The first step in is to have a series of pairwise comparisons among the criteria. After collecting the data, AHP method should be applied. Figure 7 shows the applied criteria direct cost, indirect cost, schedule constraints, site constraints, and customer service. Figure 8 introduces the mechanism of the ABC-AHP software.

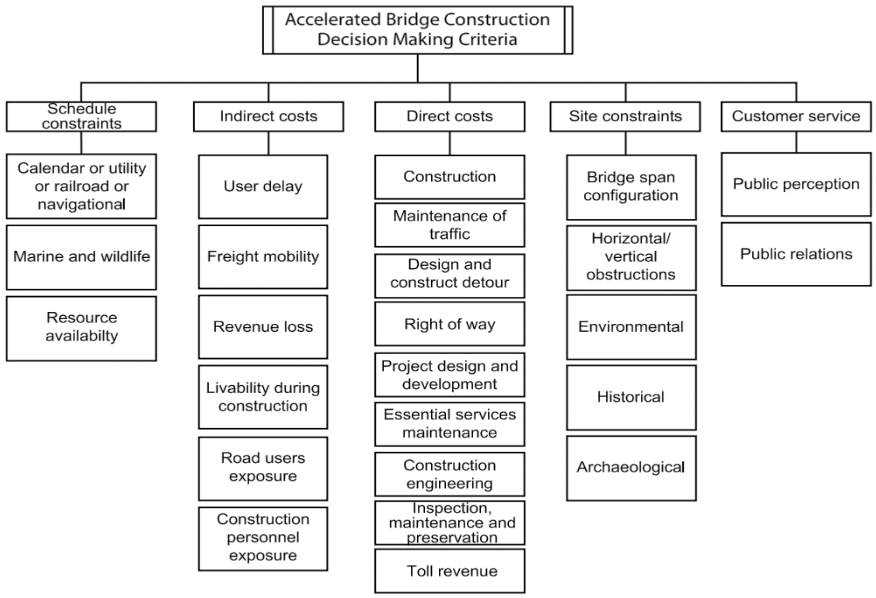

Figure 7. Hierarchy of ABC Decision Making Criteria

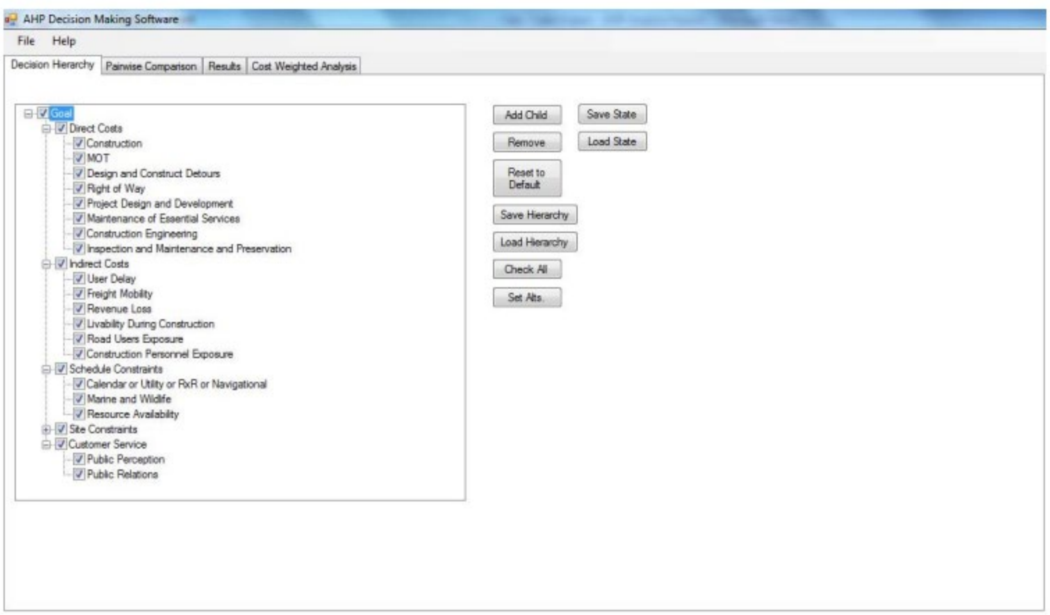

Figure 8. ABC-AHP Decision Tool, Microsoft .NET Framework

Texas DOT ABC Decision Making Guidance

Some DOTs have captured the framework of other states or FWHA and modified that to develop their specific practices and needs. TxDOT uses ABC Decision flowchart and software launched by FWHA that addresses yes/no ABC to be considered on construction approach, Figure 9.

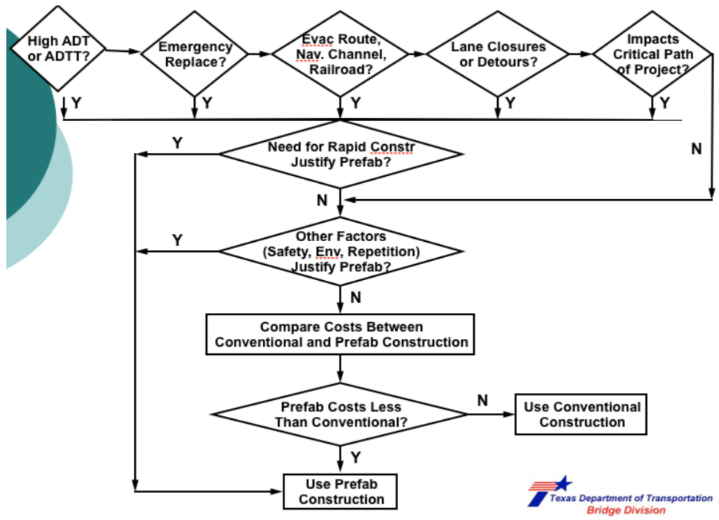

Figure 9. TxDOT ABC Decision Flowchart

Utah DOT ABC Decision Making Guidance

Utah DOT as one of the first states in the US that applied ABC techniques as an alternative to conventional bridge construction developed framework consist of several decision measures such as ADT, detour time, evacuation route, economy of scale, applicability to standards, worker safety, environmental issues, railroad impacts, and weather limitations. These criteria are entered within given ranges. For example, if the average daily traffic is 17,000, the input for ADT is considered 4 on a scale from 0 to 5. In the next step, individual inputs are weighted. The initial weighting factors, ultimate indicator, and cost considerations of the UDOT decision tool are displayed in Figure 10. This flowchart shown in Figures 11 is used to provide direction on the use of ABC for the project.

Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84114	Project:	Hypothetical Bridge Project
	By: MPC	Checked: BLB
	Date: 8/30/2010	8/30/2010
	Sheet No. 1 of 3	
ABC Rating Procedure		**June 2010**

Enter values for each aspect of the project. Attach applicable supporting data.

Aspect	Value		
Average Daily Traffic Combined on and under Enter 5 for Interstate Highways	5	0 1 2 3 4 5	No traffic impacts Less than 5000 5000 to 10000 10000 to 15000 15000 to 20000 More than 20000
Delay/Detour Time	2	0 1 2 3 4 5	No delays Less than 5 minutes 5-10 minutes 10-15 minutes 15-20 minutes More than 20 minutes
Bridge Classification	1	1 3 5	Normal Bridge Essential Bridge Critical Bridge
User Costs	4	0 1 2 3 4 5	No user costs Less than $10,000 $10,000 to $50,000 $50,000 to $75,000 $75,000 to $100,000 More than $100,000
Economy of Scale (total number of spans)	2	0 1 2 3	1 span 2 to 3 spans 4 to 5 spans More than 5 spans
Use of Typical Details	1	1 3 5	Complex geometry or unfavorable site conditions Some complexity, but favorable site conditions Simple geometry and favorable site conditions
Safety	5	1 2 3 4 5	Short duration impact with simple MOT scheme Short duration impact with multiple traffic shifts Normal duration impact with multiple traffic shifts Extended duration impact with multiple traffic shifts Extended duration impact with complex MOT scheme
Railroad Impacts	0	0 3 5	No railroad or minor railroad spur One mainline railroad track Multiple mainline railroad tracks

Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84114	Project:	Hypothetical Bridge Project
	By: MPC	Checked: BLB
	Date: 8/30/2010	8/30/2010
	Sheet No. 2 of 3	
ABC Rating Procedure		**June 2010**

Note: Do not adjust weight factors without prior consultation with UDOT Structures Division Project Manager

ABC RATING SCORE FACTORS AND WEIGHTS

	Score	Weight Factor	Adjusted Score	Maximum Score	Adjusted Score
Average Daily Traffic	5	10	50	5	50
Delay/Detour Time	2	10	20	5	50
Bridge Classification	1	5	5	5	25
User Costs	4	10	40	5	50
Economy of Scale	2	3	6	3	9
Use of Typical Details	1	3	3	5	15
Safety	5	10	50	5	50
Railroad Impacts	0	5	0	5	25
		Total Score	174	Max. Score	274

ABC Rating Score: 64

Cost Considerations:
Calculate the following costs for use in determining the lowest total project cost

TOTAL PROJECT COST EVALUATION

	Alternative #1	Alternative #2
Construction Costs	$2,500,000	$3,000,000
User Costs	$1,000,000	$250,000
Total Project Cost	**$3,500,000**	**$3,250,000**

Figure 10. UDOT ABC Decision Making Matrix

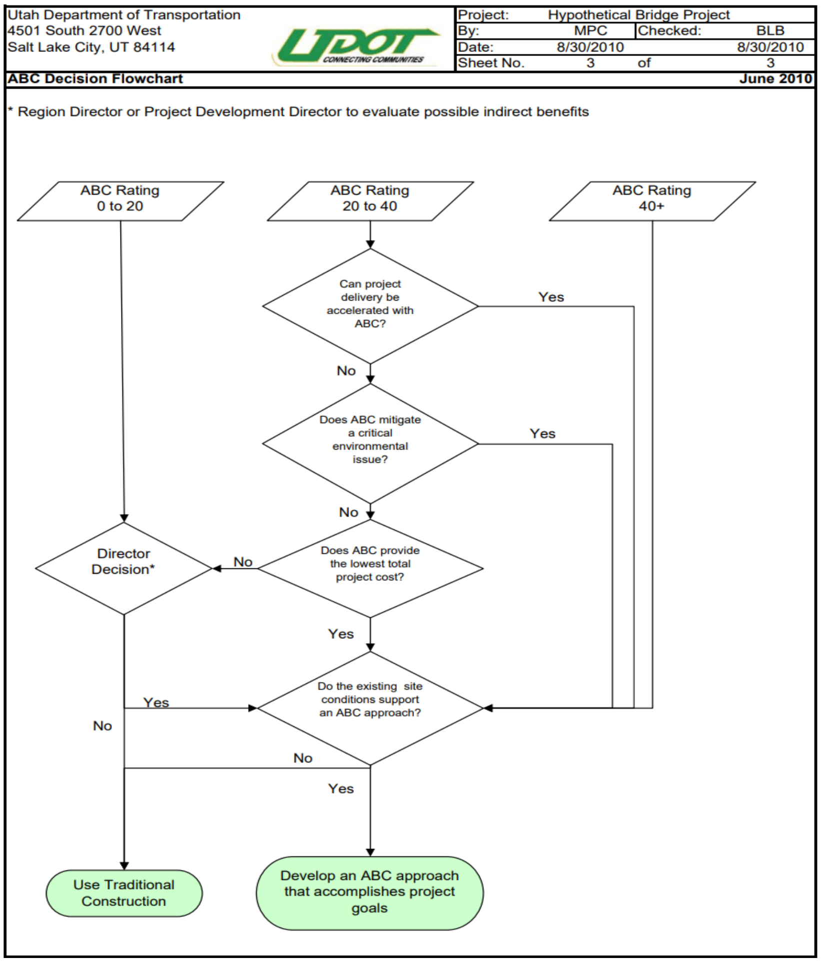

Figure 11. UDOT ABC Decision Flowchart

Washington DOT ABC Decision Making Guidance

Washington DOT uses a two-step method: 1) a multi-criteria decision matrix to calculate an ABC rating score for each project, and 2) a flowchart for further evaluation of the suitability of ABC for all projects (even for those with very low ABC rating scores). In other words, the questionnaire and flowchart determine how well suited a project may be for ABC. In addition, questionnaire and flowchart exist in both the decision matrix and the flowchart should be used together. To use the flowchart, the ABC score should be determined from the questionnaire. Ultimately, the flow chart will determine whether the ABC approach is recommended or not. Figures 12 and 13 are steps that may be used for each bridge project to determine whether it is recommended for ABC or not.

ABC DESIGN IMPACT QUESTIONNAIRE				
Project: Date: Completed by:		(R) Relevance Range 0 = NA 1 (Low) to 5 (High)	(P) Priority Rating 1 = Low 2 = Med 3 = High	(RxP) Score
Category	Decision Making Question			
Construction Time	Are there weather limitations for conventional construction?			
	Is there restricted construction time due to environmental schedules?			
	Is there restricted construction time due to economic impact?			
	Has the District expressed the desire to complete the bridge construction in one season?			
	Is the bridge construction on a critical path of the total project?			
Environmental	Does ABC avoid, minimize, or mitigate a critical environmental impact or sensitive environmental issue?			
User Costs and Delays	Does the bridge carry or is it over a route with high ADT and/or ADTT?			
	Would ABC significantly improve the traffic control/maintenance plan?			
	Are only short-term closures allowable?			
	Will conventional bridge construction cause a significant delay/detour time?			
	Will bridge construction have an adverse impact on the local economy?			
Site Conditions	Are there existing railroads that impact the construction window or construction activities?			
	Are there existing utilities that impact the construction window or construction activities?			
	Does the site create problems for conventional construction methods?			
	Is the bridge over a waterway?			
Risk Management	Does ABC improve worker safety?			
	Does ABC improve traveler safety?			
	Does ABC allow management of a particular risk? If yes, identify risk here:			
Other	Will repetition of elements allow for economy of scale?			
		ABC Rating		

Figure 12. WisDOT ABC Decision Matrix

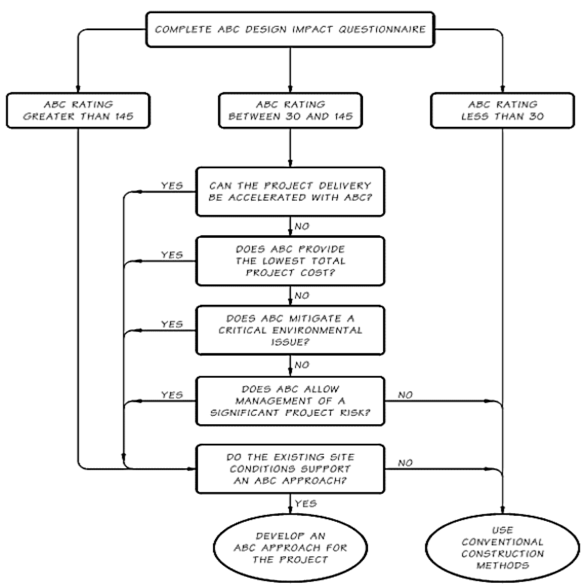

Figure 13. WisDOT ABC Decision Flowchart

Iowa DOT ABC Decision Making Guidance

Iowa DOT presented a two-stage decision-making process for ABC technique implementation for an individual project. The method then sends candidates with a high potential for achievable use of the ABC process, and through a simpler and more thorough decision-making process helps determine use of the ABC strategy. The primary stage of IowaDOT decision preparation includes processes similar to the UDOT documents which contains five principal inputs with defined weighting variables, as shown in Figure 14. The inputs work in this way, just like the inputs in the UDOT, and a given weight variable is used assigns relative importance to each input. At this point, the same mathematical operations are performed to obtain the ABC rating score.

The second stage involves the ABC-AHP Decision method previously discussed. However, IDOT completes time-consuming process of using the ABC-AHP Decision method for those candidates that have already showed high score for ABC.

Concept Measure Scores

Concept Measure	Score		
Average Annual Daily Traffic Combined value of 100% on and 25% under = 18,300	4	0	No traffic impacts
		1	Less than 5000
		2	5000 to less than 10,000
		3	10,000 to less than 15,000
		4	15,000 to less than 20,000
		5	20,000 or more
Out of Distance Travel Value in miles = 9	2	0	No detour
		1	Less than 5
		2	5 to less than 10
		3	10 to less than 15
		4	15 to less than 20
		5	20 or more
User Costs Value in $ = $76,585.50	4	0	No user costs
		1	Less than $10,000
		2	$10,000 to less than $50,000
		3	$50,000 to less than $75,000
		4	$75,000 to less than $100,000
		5	$100,000 or more
Economy of Scale Value is total number of spans = 3	1	0	1 span
		1	2 or 3 spans
		2	4 or 5 spans
		3	6 spans or more

ABC Rating Score Factors and Weights

Concept Measure	Score	Weight Factor	Adjusted Score	Maximum Score	Adjusted Score
Average Annual Daily Traffic	4	10	40	5	50
Out of Distance Travel	2	10	20	5	50
User Costs	4	10	40	5	50
Economy of Scale	1	5	5	3	15
		Total Score	105	Max. Score	165
		Calculated ABC Rating Score	64		
		ABC Rating Score	**64**		

Figure 14. IDOT ABC Decision Matrix

Minnesota ABC Decision Making Guidance

The three-stage decision making guidance introduced by MnDOT. Stage 1, Figure 15, consists of a primary screening and rating based on a set of questions. Score for each of the criteria should be calculated, and then, normalized to a recommendation of Yes or No for further investigation. Bridges with a Yes should be considered for the stage 2. Through stage 2, more subjective issues are covered. Complex traffic control schemes, long detours, extended duration, or significant user impacts due to bridge construction, culverts, shoulders to maintain traffic on the existing route or the detour route are defined in the stage 2. This stage should be filled out and recorded by the District Project Manager, with assistance from the district bridge engineer, traffic engineer, resident engineer, and the bridge preliminary plans unit and regional bridge construction engineer. After a conclusion at stage 2, further consideration through stage 3, figure 16, is warranted. In this stage also alternative contracting methods which may help the ABC activities are discussed. After thoroughly reviewing the questions, the district project manager, in conjunction with other appropriate experts and the bridge office should make a final decision. Example responses may include:

"A suitable detour is available, and the traffic demands at this site do not warrant the use of ABC."
Or
"Roadway user impacts and safety make ABC a viable alternative."
Or
"Use of a lateral slide (or other ABC alternative) will be further investigated."

Stage 1 - Selection of Accelerated Bridge Construction Projects
MnDOT Decision Making Tool (DMT) v9 07/22/2013
Score computed using Bridge Management Data (5 Criteria):

Daily Vehicle Operating Costs - Dependent on Bridge Length			**30% Wt.**
"On Bridge" AADT and HCAADT Only	**Distribution**	**Score**	**Criteria**
Bridge Length Factor:	16.0%	0	No user costs
Total Length from 10'-100' = 1.0	16.7%	1	Less than $4,150
Total Length from 100'-300' = 1.2	16.9%	2	$4,150 to $9,250
Total Length from 300'-500' = 1.6	16.8%	3	$9,251 to $18,100
Total Length greater than 500' = 2.0	16.9%	4	$18,101 to $44,000
	16.7%	5	More than $44,000
User Cost Formula = (AADT x $0.31/mile + HCAADT x $0.64/mile) x Detour Length x Br Length Factor			

Average Annual Daily Traffic (AADT)			**20% Wt.**
Combined "On and Under" Bridge	**Distribution**	**Score**	**Criteria**
	16.2%	0	Less than 2,400
	16.7%	1	2,401 to 6,650
	16.9%	2	6,651 to 13,500
	16.7%	3	13,501 to 31,000
	16.7%	4	31,001 to 75,000
	16.9%	5	More than 75,000

Heavy Commercial Average Annual Daily Traffic (HCAADT)			**10% Wt.**
Combined "On and Under" Bridge	**Distribution**	**Score**	**Criteria**
	16.0%	0	Less than 165
	16.7%	1	166 to 485
	16.7%	2	486 to 1,085
	16.9%	3	1,086 to 1,950
	16.7%	4	1,951 to 3,750
	16.9%	5	More than 3,750

Detour Length			**30% Wt.**
Detour Length on Similar Functional Class Rdwy	**Distribution**	**Score**	**Criteria**
	15.9%	0	No Detour
	9.8%	1	Less than 1 mile
	24.2%	2	1-2 miles
	17.9%	3	2-7 miles
	16.2%	4	7-14 miles
	15.9%	5	More than 14 miles

Traffic Density			**10% Wt.**
AADT "On" Bridge	**Distribution**	**Score**	**Criteria**
Vehicles per Day/Ft of Bridge Roadway Width	16.0%	0	Less than 35
	16.7%	1	36-78
	16.9%	2	79-138
	16.9%	3	139-240
	16.7%	4	241-470
	16.7%	5	More than 470

****Scores normalized to 100 point maximum. Bridges with score ≥ 60 selected for Stage 2. ****

Figure 15. MnDOT Decision Making Tool, First Stage

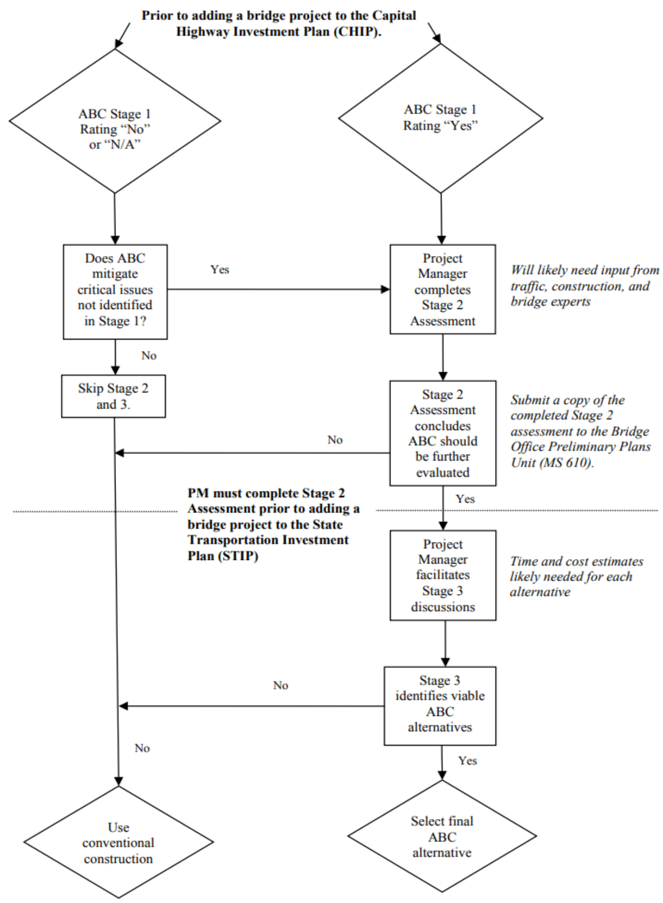

Figure 16. MnDOT Decision Making Flowchart

Colorado ABC Decision Making Guidance

This is a two-phase approach for the ABC decision-making that combines both qualitative and quantitative decision making. The ABC Decision Flowchart applies the ABC rating score and then addresses Yes/No factors that are considered before making a final decision on the construction approach, Figure 17. Factors include project schedule, environmental concerns, total project cost, site conditions, and high-level indirect costs such as political capital, safety, or impacts to stakeholders. Together, the ABC Rating Procedure and ABC Decision Flowchart are used to make a final determination of the appropriate construction methods for each project. If ABC is applicable to the project the second step in the evaluation process is applying the AHP software.

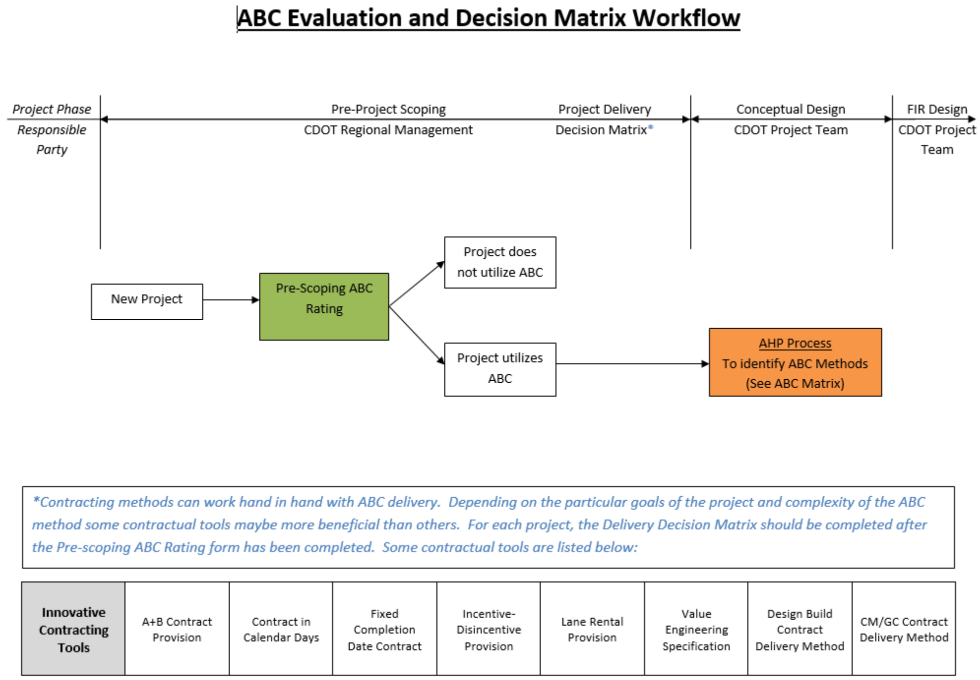

Figure 17. CDOT Decision Matrix Workflow

If the rating is between 0 and 20, the regional director should decide if ABC is needed or not. If the ABC rating is above 50, ABC should be used if it leads to a lower project cost. Finally, if it is between 20 and 50, further examine is needed by another set of questions. The ABC Matrix, Figure 18, provides suggestions for accelerated construction techniques that may be applied depending on the complexity of the project.

COLORADO Department of Transportation

Accelerated Bridge Construction Matrix

This matrix provides suggestions and previously utilized methods for accelerated bridge construction. It is not all inclusive nor intended to dictate any particular method.

PROJECT COMPLEXITY

Substructure	Approach, Embankment & Backfill	Superstructure	Superstructure 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)

[1] FHWA Every Day Counts Initiatives

[2] Prefabricated Bridge Elements and Systems (PBES)

ABC Costs *ABC method construction costs generally increase with project complexity. However, many methods of ABC may reduce the overall project cost, specifically where ABC methods can eliminate or reduce detours or traffic control.*

Figure 18. CDOT ABC Matrix

Arizona ABC Decision Making Guidance

ADOT uses a two-stage decision-making method, where a matrix questionnaire should be used as guidance in calculating the related scores. The ABC decision matrix rating score used in ADOT guideline shown in Figure 19, varies from 0 to 100 identifying the viability of an individual project in considering ABC. The higher the score, the better for ABC. Once the score is calculated, the ABC decision flowchart should be followed, Figure 20.

ADOT ABC Decision Making Matrix

Category	Decision-Making Item	Possible Points	Points Allocated	Scoring Guidance
Railroad	Railroad/ Rail Transit under Bridge?	4		0 No track under bridge 2 Minor track under bridge 4 Major track(s) under bridge
Construction Impacts	ADT (Combined ADT on and under bridge)	10		1 ADT under 10,000 3 ADT 10,000 to 25,000 5 ADT 25,000 to 50,000 6 ADT 50,000 to 75,000 7 ADT 75,000 to 100,000 10 ADT 100,000+
	Allowable Lane Closure (Roadway on Bridge)	4		0 Long Term Lane Reduction Allowed During Construction 4 No Long Term Lane Reduction Allowed During Construction
	Allowable Lane Closure (Roadway under Bridge)	4		0 Long Term Lane Reduction Allowed During Construction 4 No Long Term Lane Reduction Allowed During Construction
	Allowable Bridge Closure (Roadway on Bridge)	6		0 Bridge Can closed - Viable Detour Available 6 Bridge Cannot be Closed
	Allowable Roadway Closure (Roadway under bridge)	4		0 Roadway under can be closed 4 Roadway under cannot be closed
	Permanent Align Shift w/ single phase an option	3		0 A permanent alignment shift is achievable to facilitate construction 3 A permanent alignment shift is achievable, but undesirable.
	Is phased construction with widening an option?	8		0 Widening will fit updated standards or future roadway improvements 6 Widening achievable, but undesireable due to unused investment 8 No alternatives available for widening
	Impact to Local Access (Local business access, Local resident access etc.)	6		0 Minor or no impact to access 3 Moderate impact to access 6 Major impact to access
Project Duration	Impacts Critical Path of the Total Project?	8		0 Minor or no impact to critical path of total project 4 Moderate impact to critical path of the total project 8 Major impact to critical path of the total project
	Restricted Construction Time (Environmental schedules, Economic Impact-e.g. local business access, special events, etc.)	10		0 No construction time restrictions 3 Minor construction time restrictions 6 Moderate construction time restrictions 10 Major construction time restrictions
	Seasonal Limitations for conventional construction?	4		0 No seasonal limitations for conventional construction 4 Seasonal limitations for conventional construction
Environment	Does ABC mitigate a critical environmental impact or sensitive environmental issue?	5		0 ABC does not mitigate an environmental issue 2 ABC mitigates a minor environmental issue 3 ABC mitigates several minor environmental issues 4 ABC mitigates a major environmental issue 5 ABC mitigates several major environmental issues
Safety	Safety (Workers Concerns)	8		0 Short duration impact 4 Normal duration impact 8 Extended duration impact
	Safety (Traveling Public Concerns)	8		0 Short duration impact 4 Normal duration impact 8 Extended duration impact
Economy of Scale	Bridge Economy of Scale (repetition of components in a bridge or bridges in a project) (Total spans=sum of all spans on all bridges on the project)	4		0 1 total span 1 2 total spans 2 3 total spans 3 4 total spans 4 5+ total spans
Risk Management	Does ABC allow management of a particular risk?	4		0-4 Use judgement to determine if risks can be managed through ABC that arent covered in other topics
	Total Possible	100		
		Sum of Points:	0	

Figure 19. ADOT ABC Decision Matrix

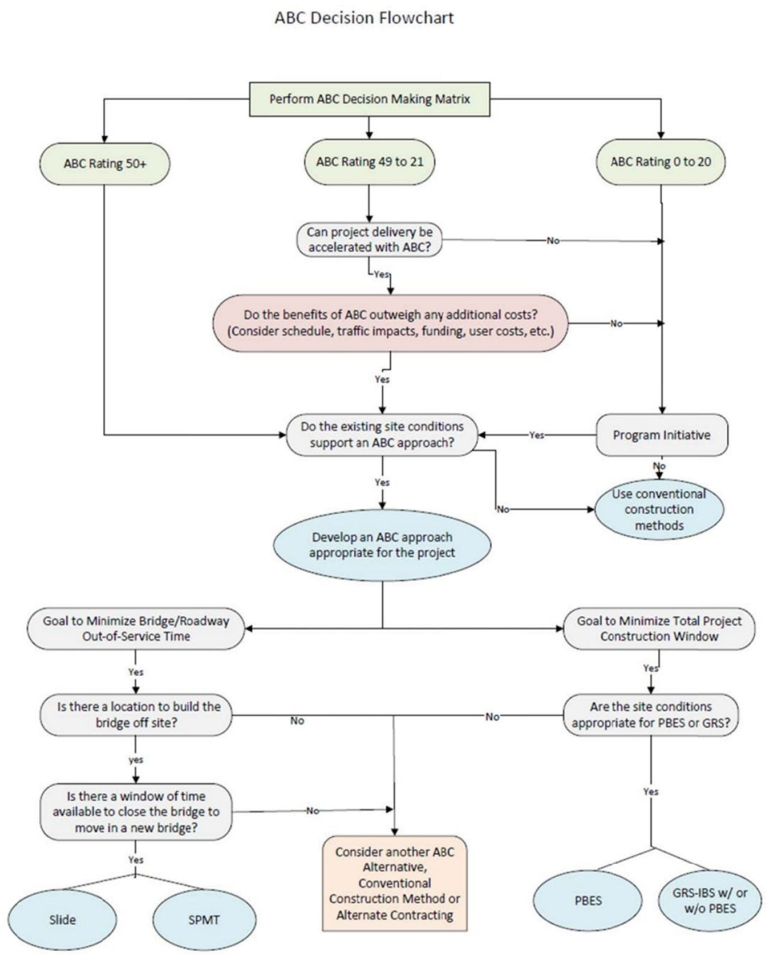

Figure 20. ADOT ABC Decision Flowchart

Wisconsin DOT ABC Decision Making Guidance

A decision process introduced by WisDOT is a two-stage process, where a decision matrix, Figure 21, should be sued to determine a total score, and then, the obtained score is used to follow the decision flowchart, Figure 22. The tool considers various types of criteria to help the right decision making. This method introduces specific ABC alternatives through the decision flowchart.

% Weight	Category	Decision-Making Item	Possible Points	Points Allocated	Scoring Guidance
17%	Disruptions (on/under Bridge)	**Railroad on Bridge?**	8		0 No railroad track on bridge 4 Minor railroad track on bridge 8 Major railroad track on bridge
		Railroad under Bridge?	3		0 No railroad track under bridge 1 Minor railroad track under bridge 3 Major railroad track(s) under Bridge
		Over Navigation Channel that needs to remain open?	6		0 No navigation channel that needs to remain open 3 Minor navigation channel that needs to remain open 6 Major navigation channel that needs to remain open
8%	Urgency	**Emergency Replacement?**	8		0 Not emergency replacement 4 Emergency replacement on minor roadway 8 Emergency replacement on major roadway
23%	User Costs and Delays	**ADT and/or ADTT** (Combined Construction Year ADT on and under bridge)	6		0 No traffic impacts 1 ADT under 10,000 2 ADT 10,000 to 25,000 3 ADT 25,000 to 50,000 4 ADT 50,000 to 75,000 5 ADT 75,000 to 100,000 6 ADT 100,000+
		Required Lane Closures/Detours? (Length of Delay to Traveling Public)	6		0 Delay 0-5 minutes 1 Delay 5-15 minutes 2 Delay 15-25 minutes 3 Delay 25-35 minutes 4 Delay 35-45 minutes 5 Delay 45-55 minutes 6 Delay 55+ minutes
		Are only Short Term Closures Allowable?	5		0 Alternatives available for staged construction 3 Alternatives available for staged construction, but undesirable 5 No alternatives available for staged construction
		Impact to Economy (Local business access, impact to manufacturing etc.)	6		0 Minor or no impact to economy 3 Moderate impact to economy 6 Major impact to economy
14%	Construction Time	**Impacts Critical Path of the Total Project?**	6		0 Minor or no impact to critical path of the total project 3 Moderate impact to critical path of the total project 6 Major impact to critical path of the total project
		Restricted Construction Time (Environmental schedules, Economic Impact – e.g. local business access, Holiday schedules, special events, etc.)	8		0 No construction time restrictions 3 Minor construction time restrictions 6 Moderate construction time restrictions 8 Major construction time restrictions
5%	Environment	**Does ABC mitigate a critical environmental impact or sensitive environmental issue?**	5		0 ABC does not mitigate an environmental issue 2 ABC mitigates a minor environmental issue 3 ABC mitigates several minor environmental issues 4 ABC mitigates a major environmental issue 5 ABC mitigates several major environmental issues
3%	Cost	**Compare *Comprehensive* Construction Costs** (Compare conventional vs. prefabrication)	3		0 ABC costs are 25%+ higher than conventional costs 1 ABC costs are 1% to 25% higher than conventional costs 2 ABC costs are equal to conventional costs 3 ABC costs are lower than conventional costs
18%	Risk Management	**Does ABC allow management of a particular risk?**	6		0 - 6 Use judgment to determine if risks can be managed through ABC that aren't covered in other topics
		Safety (Worker Concerns)	6		0 Short duration impact with TMP Type 1 3 Normal duration impact with TMP Type 2 6 Extended duration impact with TMP Type 3-4
		Safety (Traveling Public Concerns)	6		0 Short duration impact with TMP Type 1 3 Normal duration impact with TMP Type 2 6 Extended duration impact with TMP Type 3-4
12%	Other	**Economy of Scale** (repetition of components in a bridge or bridges in a project) (Total spans = sum of all spans on all bridges on the project)	5		0 1 total span 1 2 total spans 2 3 total spans 3 4 total spans 4 5 total spans 5 6+ total spans
		Weather Limitations for conventional construction?	2		0 No weather limitations for conventional construction 1 Moderate limitations for conventional construction 2 Severe limitations for conventional construction
		Use of Typical Standard Details (Complexity)	5		0 No typical standard details will be used 3 Some typical standard details will be used 5 All typical standard details will be used
			Sum of Points:	0	(100 Possible Points)

Figure 21. WisDOT ABC Decision Matrix

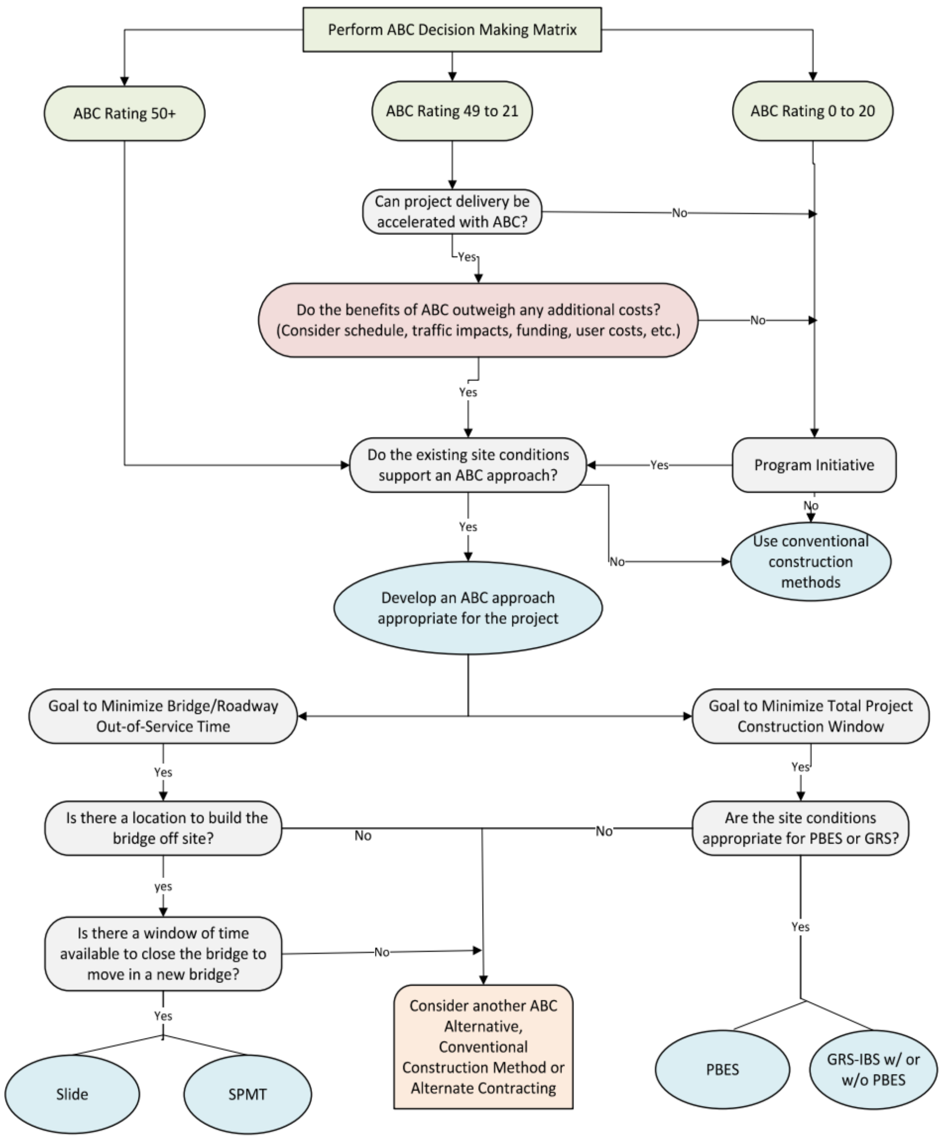

Figure 22. WisDOT ABC Decision Flowchart

South Dakota DOT ABC Decision Making Guidance

The process of ABC decision tool for SDDOT consists of three existing tools developed by other agencies: 1) the ABC-AHP (Analytical Hierarchy Process) Decision Tool published by FHWA (FHWA 2012), 2) the ABC decision-making process used by UDOT (UDOT 2010), and 3) the ABC decision-making process used by Iowa DOT (Iowa DOT 2012). For SDDOT, the decision-making tool is a two-stage process. In the second stage more detailed computation are considered. The layout and orientation of the two stages of the decision-making process are displayed in Figure 23 and 24.

Project No.	PCN 02AB		
Inputs			
Average Daily Truck Traffic	51		
Mileage Rate	37.5		
Average Annual Daily Traffic (AADT)	1	0	No traffic impacts
Combined value of 100% on and 25% under		1	Less than 5000
structure:		2	5000 to less than 10000
746		3	10000 to less than 15000
		4	15000 to less than 20000
		5	20000 or more
Out of Distance Travel (OODT)	1	0	No detour
Detour distance in miles*:		1	Less than 5
0.25		2	5 to less than 10
*Note: OODT should not be 0 if DRUC formula		3	10 to less than 15
is to be used, as DRUC will then be $0.		4	15 to less than 20
		5	20 or more
Daily Road User Costs (DRUC)	1	0	No user costs
(AADT+2*ADTT)(OODT)(Mileage Rate)=		1	Less than $100
$79.50		2	$100 to less than $500
*Note: If OODT is 0, SDSU DRUC Tool can be used		3	$500 to less than $750
to estimate DRUC for Stage 1.		4	$750 to less than $1000
		5	$1000 or more
Economy of Scale (EOS)	2	0	1 span
Total number of repeatable of spans:		1	2 or 3 spans
4		2	4 or 5 spans
		3	6 spans or more

ABC Rating Score Factors and Weights

	Score	Factor	Adjusted Score	Max. Score	Adjusted Score
AADT	1	10	10	5	50
OODT	1	10	10	5	50
DRUC	1	10	10	5	50
EOS	2	10	20	3	30
		Total Score:	50	Max. Score:	180
		ABC Rating Score:		28	

Project No.			
Inputs			
Direct Costs	3	0	$100000 or more additional cost
Input approximate costs for superstructure,		1	$75000 to less than $100000 additional cost
substructure, and/or placement:		2	$50000 to less than $75000 additional cost
$32,000		3	$25000 to less than $50000 additional cost
		4	$0 to less than $25000 additional cost
		5	Lesser cost than conventional
Indirect Costs	2	0	No user costs
Transfer info from Daily Road User Cost tool:		1	Less than $100
$120		2	$100 to less than $500
.		3	$500 to less than $750
		4	$750 to less than $1000
		5	$1000 or more
Non-ABC Conventional Costs	3	0	$0 to less than $50/SF of bridge
Transfer info from SDDOT cost data per sq. ft.		1	$50 to less than $75/SF of bridge
of bridge:		2	$75 to less than $100/SF of bridge
$112		3	$100 to less than $125/SF of bridge
		4	$125 to less than $150/SF of bridge
		5	$150 or more/SF of bridge
Schedule Constraints	1	0	No schedule constraints
i.e. emergency repairs, seasonal deadlines, etc.		1	Slight schedule constraints
		2	Moderate schedule constraints
		3	Substantial schedule constraints
Site Constraints	1	0	No site constraints
i.e. critical path, geographic constraints, etc.		1	Slight site constraints
		2	Moderate site constraints
		3	Substantial site constraints

ABC Rating Score Factors and Weights

	Score	Weight Factor	Adjusted Score	Max. Score	Adjusted Score
DC	3	10	30	5	50
IC	2	10	20	5	50
NCC	3	10	30	5	50
SchC	1	10	10	3	30
SC	1	10	10	3	30
		Total Score:	100	Max. Score:	210
		ABC Rating Score:		48	

Figure 23. SDDOT ABC Decision Matrix

After criteria have been selected and are entered into the evaluation tool, and then, the assigned score for each input is multiplied by each predetermined weighting factor to obtain the project adjusted score. The maximum adjusted scores are summed as are the project adjusted scores; and the total project adjusted score divided by the maximum adjusted score is the output indicator for the project being analyzed by the evaluation tool.

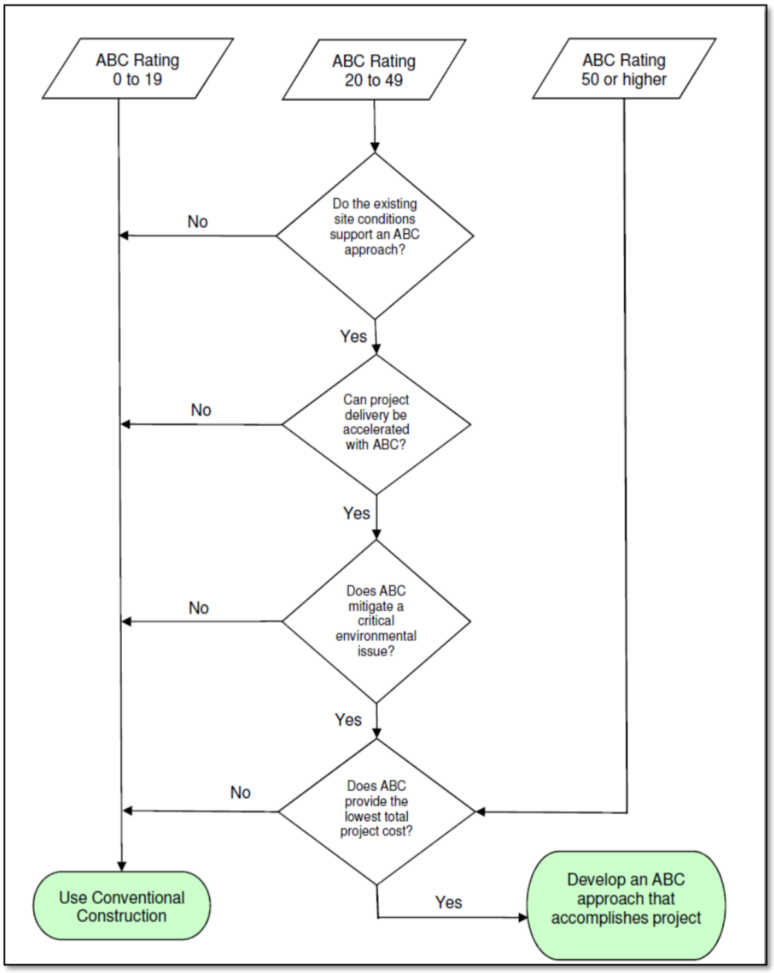

Figure 2.12 Stage Two Decision-Making Flowchart

Figure 24. SDDOT ABC Decision Flowchart

Connecticut DOT ABC Decision Making Guidance

Connecticut DOT (CTDOT) used a middle ground approach to develop a spreadsheet-based tool entitled "ABC Decision Matrix", Figure 25, that uses the SAW method to calculate ABC rating scores for different projects. Adopting some aspects of the Utah method and building on the methods used by other states, the ABC Decision Matrix is a relatively simple and well-received tool based on the impacts of ABC on road users and environment that accounts for total project costs but offsets ABC costs with the costs that can be reduced or eliminated with ABC.

The CTDOT ABC Decision Matrix is a spreadsheet tool that evaluates the suitability of adopting ABC techniques by calculating an ABC rating score between 0 to 100 for each bridge construction project. The tool uses the SAW method for calculating the ABC rating scores by considering ten criteria (i.e., average daily traffic, user impact reduction, bridge location, use of typical details, work zone geometry, site conditions, railroad impacts, cost analysis, environmental/water handling, and waterway limitations). Evaluation of each criterion is used based on a score of 0 to 5. If the calculated final ABC rating score is greater than 60, use of ABC techniques will be recommended. When the final ABC score is smaller than 50, conventional construction methods will be preferred. If the final score is found to be between 50-60, further evaluation will be recommended for considering ABC.

The CTDOT method uses a multi-criterion, yet simple-enough, process that makes it appropriate and applicable to different bridge construction projects.

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	Date:				
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CTDOT ABC Decision Making Process Oct-17

Site Information

Project Description:

Prop. ABC Method:

Conventional Construction Method:

Roadway on Bridge

Average Daily Traffic			vehicles per day
Conventional Construction			
	Delay Time (Per Delay Time Sheets)		minutes
	Construction Impact Duration		Days
	Aggregate Impact Time	0	Person Days
ABC			
	Delay Time (Per Delay Time Sheets)		minutes
	Construction Impact Duration		Days
	Aggregate Impact Time	0	Person Days

Roadway Below Bridge

Average Daily Traffic			vehicles per day
Conventional Construction			
	Delay Time (Per Delay Time Sheets)		minutes
	Construction Impact Duration		Days
	Aggregate Impact Time	0	Person Days
ABC			
	Delay Time (Per Delay Time Sheets)		minutes
	Construction Impact Duration		Days
	Aggregate Impact Time	0	Person Days

Percent Reduction in Aggregate Impact Time

Conventional Construction			
	Total Aggregate Impact Time	0	Person Days
ABC			
	Total Aggregate Impact Time	0	Person Days

User Impact Reduction	#DIV/0!

Note: Negative value indicated that ABC has more impact

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CTDOT ABC Decision Making Process Oct-17

Preliminary Cost Evaluation

Estimated conventional construction project cost =			
	Required Bridge		
	Overbuild	$0	
	Total conventional bridge cost	$0	
Estimated CE&I Costs per month			
	Field office monthly cost		
	CE&I staff monthly cost (field plus main office)		
	Total CE&I Monthly Cost =	$0	

Notes: Small field office = $xxx per month
Medium office = $xxx per month
Large office = $xxx per month
Staff = $20,000 per person per month

Net time savings for ABC =			months
Estimated Percent Premium for ABC =			
MPT savings with ABC			
Things that you can eliminate from conventional construction by using ABC			
	Overbuild for staging	$0	
	Temporary bridge	$0	
	Temporary signal	$0	
	Other	$0	
	Total MPT Savings with ABC	$0	

Cost analysis

Premium for ABC =	$0
CEI Cost Savings =	$0
MPT savings with ABC =	$0
Net cost change for ABC =	$0
ABC is less expensive than conventional	
Net percentage of conventional cost =	#DIV/0!

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CTDOT ABC Decision Making Process Oct-17

ABC Rating procedure

Enter values for each aspect of the project. Attach back-up data if applicable

Average Daily Traffic	0	No traffic impacts
Combined traffic on and under	1	Less than 10000
	2	10000 to 40000
	3	40000 to 70000
	4	70000 to 100000
	5	More than 100000
User Impact Reduction #DIV/0!	0	Zero
Calculated by spreadsheet	1	1% to 20%
	2	21% to 40%
	3	41% to 60%
	4	61% to 80%
	5	81% to 100%
Bridge Location	0	Rural Bridge away from town center
Stakeholder Impact	1	Rural bridge near town center
	2	Suburban bridge away from town center
	3	Suburban bridge near major traffic generators
	4	Urban Bridge near major traffic generators
	5	Urban Bridge near emergency services
Use of Typical Details	1	Complex and unfavorable geometry
	2	Curved and skewed bridges
	3	Curved bridges
	4	Skewed Bridges
	5	Simple geometry well suited for typical details
Work Zone Geometry	1	Short duration project with good geometry & flow
Detour quality and/or	2	Short duration project with moderate geometry & flow
MPT Quality	3	Average project duration with average geometry & flow
	4	Long duration project with moderate geometry & flow
	5	Long duration project with complex geometry & flow
Site Conditions	0	significant limitations on work
Utilities/ROW/Env. Compliance	1	moderate construction limitations for portions of the work
	2	
	3	minor construction limitations
	4	
	5	No Restrictions
Railroad Impacts	0	No Railroad (entry of 0 = not considered in score)
	1	Freight Siding (Less than 1 train per week)
	2	Light Freight (1 Train per week to 1 Train per day)
	3	Heavy Freight (More than 1 Train per day)
	4	Commuter rail
	5	Electrified Commuter Rail

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CTDOT ABC Decision Making Process Oct-17

Cost Analysis	0	>30%
Factor = #DIV/0!	1	20% < Factor < 30%
Net percentage of conventional cos	2	10% < Factor < 20%
Negative value means that ABC ha	3	5% < Factor < 10%
less net cost when compared to	4	0% < Factor < 5%
conventional construction	5	Factor <0%
Envir. /Water Handling	0	No Restrictions (entry of 0 = not considered in score)
	1	minor construction limitations
	2	
	3	moderate construction limitations for portions of the work
	4	
	5	significant limitations on work
Waterway Limitations	0	No impact (entry of 0 = not considered in score)
	1	Minor impacts
	2	
	3	Seasonal recreational impacts
	4	Significant recreational impacts
	5	Significant commercial impacts

ABC Rating

	Score	Weight Factor	Adjusted Score	Maximum Score	Adjusted Score
Average Daily Traffic	0	10	0	5	50
User Impact Reduction	#DIV/0!	30	#DIV/0!	5	150
Bridge Location	0	5	0	5	25
Use of Typical Details	0	5	0	5	25
Work Zone Geometry	0	8	0	5	40
Site Conditions	0	5	0	5	25
Railroad Impacts	0	5	0	0	0
Cost Analysis	0	30	0	5	150
Envir. /Water Handling	0	5	0	0	0
Waterway Limitations	0	5	0	0	0
		Total Score	#DIV/0!	Max. Score	465

ABC Rating	**#DIV/0!**

ABC Rating Scale	
60-100	Use ABC
50-60	Consider ABC
0-50	Do not use ABC

Note: Weight factors determined by CTDOT. Do not adjust factors without prior consultation.

Figure 25. CTDOT ABC Decision Tool

ABC Decision Making Tools Conclusion

The ultimate outcome from ABC rating tools is to generate a comparative rating for the ABC activities decision-making. Many different methodologies for ABC projects decision-making have been used by state DOTs. Towards this, the FHWA had a qualitative decision-making tool as PBES where answering to questions about specific project characteristics was the base line of decision-making process. Although, this framework was a good starting point for the ABC decision-making, it did not help with the economic impact of selecting ABC over traditional methods. Later on, another approach presented for ABC evaluation over traditional methods. This method incorporated some major factors extracted through observation. Then using simple additive weighted method, it was weighted by experts. Example of such method are the ones used by WisDOT, MnDOT and ADOT. The third method is based on AHP introduced in December 2009. Oregon Department of Transportation (ODOT) working with several other states (California, Iowa, Minnesota, Montana, Texas, Utah and Washington) lunched a FHWA-sponsored AHP-based tool for identifying whether ABC should be applied to a specific project or not. From the brainstorming work of ABC decision-making tools, it is determined that:

1) Factors that used in decision-making were a combination of quantitative and qualitative data.
2) The weight of factors in some methods is unchangeable. At the same time, for many cases, the indirect cost has an interactive relationship with other factors.
3) They lack the consideration of factor dependence or risk overlapping scoring.

4) The hierarchies of the ABC-AHP can only be in the range of 1 to 9 and in some parts no real data can be inputted in this tool. This makes the tool inflexible.
5) The grading of some models relies on decision makers to provide interpretation. Because the comparisons are performed by personal or subjective judgments, some degree of inconsistency may occur.
6) The individual factors were pre-weighted within the tool and cannot be revised.

Road Safety Review

According to the Fatality Analysis Reporting System (FARS), more than 500 fatalities in motor vehicle traffic crashes were occurred in work zones in 2010. FHWA defined Safety as a significant reduction in traffic fatalities and serious injuries on all public roads (FHWA, 2012). Based on a review of literature, this criterion is often indirectly calculated, with functional deficiencies typically linked to traffic safety (clear deck width, vertical and horizontal clearance). In the NCDOT P5.0, the safety is identified by crash information for a given highway segment. Crash density (20%), crash severity (20%), critical crash rate (20%) and safety benefits (40%) are used in prioritization of roadway projects. In addition, the crash frequency and severity index are used in prioritization of highway intersection projects (NCDOT, 2018). Many studies indicated that the zone crash rates are likely to be increased up to 70 percent when there is a work zone in place. On the other hand, worker safety concerns at the site which limits conventional methods, e.g., working adjacent to power lines. In general, construction safety increases with reduced exposure time during the construction. Construction site safety will be increased due to the introduction of ABC methods (limit traffic interference to a period of two weeks or less). In addition, minimizing the need for future maintenance will reduce traffic flow, congestion and crashes.

Safety also contributes to driver behavior at highway construction or maintenance zones. Statistics shows that many crashes at work zone areas occurred in lane closure areas where there were mixed drivers, workers and barriers. In Michigan, more than 40% of work zone crashes occurred in lane closure areas (Michigan State Police, 1999). several studies introduced Geometric rating (roadway width or horizontal clearance), Vertical clearances, Functional obsolescence, Inventory or operating rating, Crash density, Crash severity, and Critical crash rate typically utilized measures for safety (NCHRP Report 530 (Patidar et al., 2007), Indiana DOT (Sinha et al., 2009), North Carolina DOT (NCDOT, 2018))

Social Equity and Environmental Justice Review

ABC activities are generally safer than conventional construction in terms of environmental issues because much of the construction can be done offsite. Quality can be mitigated because the construction is often completed in a more controlled situation. In this regard, ABC decision making needs new criteria to be added to the tool to incorporate the benefits of ABC in improving social equity and environmental justice in community groups affected by the bridge project. Examples of social and environmental data that can potentially be used for this purpose are as follows:
Social data: Income, Population density, Elderly population density, Land use, and Crime rate.
Environmental data: Air temperature, air quality, normalized difference vegetation index (NDVI), and tree canopy.
Environmentally vulnerable areas, like urban areas where air and water quality and noise pollution are challenges, put limit on the amount of construction work that can be done on site, or the time work in a season. Offsite prefabrication and rapid onsite installation can be done with limited impact to the site. Many researchers combined rainfall intensity with population density for risk analysis.

Some other studies added more social indicators to their methodology, however, there is still limited number of studies that explored the integration of temperature, NDVI, traffic load, road accessibility with flood risk factors namely rainfall intensity. Table 3 summarizes the common and different decision criteria between used by state DOTs tools. Tables 4 and 5 represent some of the recent MCDA flood-based studies considered flooding risk integrated with social equity and environmental justice. ABC provides the contractor more flexibility when environmental restrictions is an issue. In terms of social factors, social and cultural heterogeneity changes in different urban communities and then, many various methodologies can be applied to assess social vulnerability at each scale and system.

Table 3. Decision criteria of qualitative decision-making tools

State DOT	**Air Quality**	**Noise pollution**	**Endangered species**	**Historical places**	**Natural recourse e.g., wetlands**	**Weather e.g., humidity**
California	*	*	*	*	*	
FHWA	*	*	*	*	*	
Washington			*	*		*
Oregon	*	*	*	*	*	*
Connecticut				*	Occasionally[1]	Occasionally[2]

Table 4. MCDA flood-based studies considered flooding risk integrated with social equity and environmental justice

Reference	**Indicator**				
	DEM	**Slope**	**Road network**	**Bridge network**	**Land cover**
Turner et al., 2003		*			
Chen et al., 2021	*	*			
Mondoro et al., 2018	*			*	

Table 5. MCDA studies considered social equity

Reference	**Land use**	**Population density**	**Gender**	**People age**	**Employment rate**	**Income rate**	**Building type**	**Building density**
Turner et al., 2003	*	*						
Zou et al., 2013	*	*						
Chen et al., 2021	*	*						
Fernandez et al., 2016		*	*	*	*	*	*	*
Messener & Meyer, 2005		*	*	*				

[1] Generally in-water work is required
[2] If construction seasons control construction method

Task 2 – Decision Criteria

The existing CTDOT tool includes multiple decision criteria such as traffic condition, user impact reduction (time), site conditions, and cost. However, the decision criteria can be expanded to incorporate the contribution (i.e., benefits) of ABC to important problems such as roadway safety, social equity, and environmental justice. This agrees with the FHWA's definition of ABC's intrinsic benefits that include improvements in safety, social, and environmental impacts (FHWA, 2021).

Task 2.1 – Road Safety Criterion

To incorporate the benefits of ABC in improving the work-zone safety for the traveling public, the tool should consider the reduction in risk of crashes in the corridor that the bridge will be constructed (or replaced). This will be addressed by adding a criterion based on crash cost analysis to calculate the contribution of safety to the benefit-cost ratio of ABC as compared to conventional methods. The proposed safety criterion will quantitatively evaluate the benefits of ABC methods in improving the work zone safety compared to the safety conditions when using conventional bridge construction methods. Benefits from ABC on roadway safety can be evaluated based on the past observations of crash density and severity (e.g., crash data from the National Highway Traffic Safety Administration- NHTSA) and future crash predictions (e.g., using statistical or machine learning methods). These methods have been investigated in a recent ABC-UTC project entitled "Work Zone Safety Analysis, Investigating Benefits from Accelerated Bridge Construction (ABC) on Roadway Safety [ABC-UTC-2016-C3-FIU03]" and a PhD dissertation by Mokhtarimousavi (2020) at FIU. The road safety criteria in this project will be based on the findings of Mokhtarimousavi (2020) and the mentioned ABC-UTC project. In addition, a limited survey will be conducted from some state DOTs to identify the existing crash data types at different state DOTs. The survey results will inform the type of crash data that will be used in the improved tool, increasing the widespread use of the improved ABC tool by different state DOTs.

Task 2.2 – Social Equity and Environmental Justice Criteria

New criteria will be added to the tool to incorporate the benefits of ABC in improving social equity and environmental justice in community groups affected by the bridge project. Efforts will be made to develop social and environmental criteria that are based on available spatial data (GIS data layers) from national datasets, as much as possible, to increase the applicability of the tool to different geographic regions. Examples of social and environmental data that can potentially be used for this purpose are as follows:

Social data: Income, Population density, Elderly population density, Land use, and Crime rate.

Environmental data: Air temperature, air quality, normalized difference vegetation index (NDVI), and tree canopy.

PI Ebrahimian has the experience of developing a multi-criteria decision support framework for prioritizing the existing bridges for accelerated bridge rehabilitations based on socio-environmental criteria integrated with technical (structural and traffic) criteria through a recent ABC-UTC project entitled "Integrated Flood and Socio-Environmental Risk Analysis for Prioritizing ABC Activities (ABC-UTC-2016-C4-FIU05)". The findings of the mentioned project will be leveraged for developing criteria for the quantitative evaluation of potential ABC contributions to improving social equity and environmental justice.

Task 3 – Quantitative Measures for the Evaluation of Criteria

Quantitative evaluation of criteria reduces the subjectivity in the decision-making process and creates more accurate results. While using quantitative evaluations is not possible for every decision criterion, efforts should be made to minimize the number of qualitative evaluations in the decision-making process. To address this concern, two types of activities will be performed in this task:

1) While the CTDOT ABC tool uses quantitative analyses for some criteria such as “Average Daily Traffic” and “Cost”, and “User Impact Reduction”, qualitative measures (scores of 0 to 5) are still used by the tool to calculate the final ABC rating scores. Quantitative measures will be developed for the evaluation of these criteria in the improved ABC tool.

2) Qualitative evaluation of criteria in the CTDOT tool includes subjective aspects that affects the accuracy of the results. For example, the evaluation of “Bridge location” criterion is performed by categorizing the bridge locations in six groups with assigned scores as follows: Score 0: Rural bridge away from town center, score 1: Rural bridge near town center, score 2: Suburban bridge away from town center, score 3: Suburban bridge near major traffic generators, Score 4: Urban bridge near major traffic generators, and Score 5: Urban bridge near emergency services. Here, it is not clear what “near” and “away” mean. Defining a numerical range of distances instead of using “near” and “away” can reduce the subjectivity in evaluations and facilitate the decision-making process. Also, “Urban”, “Suburban”, and “Rural” land uses may not be adequate for evaluating the benefits of ABC regarding the bridge location. Considering different land uses in each area (e.g., land use classes such as high-density residential, commercial, or green spaces for urban areas and those such as residential and agricultural for rural areas) can improve the evaluations. Other example would be for the quantification of the “Environmental/ Water Handling Impacts” criterion. The CTDOT tool uses a subjective method based on evaluating “construction limitations” related to environmental and water handling issues for determining this criterion. Quantification of this criterion can be done by developing quantitative measures based on items such as Length/size of diversion pipes/channels, Number/size/type of required cofferdams, and Flood potential in the area based on factors such as precipitation, soil type, imperviousness, groundwater level, and proximity to coastlines. Similarly, quantitative evaluation of “construction limitations” regarding the “Site Conditions” criterion (e.g., utilities and ROW) could be performed by developing quantitative measures based on the number of buildings or area of properties that cannot be acquired (for ROW) and type/size of utilities and their distance to the bridge location (for utilities).

Task 4 – Relative Weights of Criteria

The CTDOT tool uses a predetermined set of weight factors to consider the relative importance of different criteria for decision makers, limiting the applicability of the tool to CTDOT projects. Even within CTDOT, the predetermined weights may not be appropriate for all projects, depending on the specific problems at different locations. Also, the preferences of CTDOT decision makers may change over time, requiring a flexible method for adjusting the wights of criteria in the ABC decision making tool. Developing a systematic, yet adequately simple, procedure for determining relative weights of criteria can result in extending the applicability of the tool to other states. To address this need, two different systematic procedures for determining the relative weights of criteria based on 1) hierarchical SAW method, and 2) Analytic Hierarchy Method (AHP) will be developed. The latter will be more rigorous compared to the first method but provides more accurate results. PI Ebrahimian has the experience of performing both methods in other infrastructure problems (e.g., Ebrahimian et al. 2015, Ebrahimian and Rahimi 2022). It should be noted that the improved tool will still consider the option of using predetermined sets of weight factors.

Task 5 – Improved ABC Decision Making Tool

The CTDOT spreadsheet tool will be improved by incorporating the output of Tasks 2 (2.1 and 2.2.), 3, and 4 to the tool.

Task 6 – Case Study

The improved ABC decision making tool will be applied to a case study to demonstrate the applicability of the improved tool. Examples about the application of existing CTDOT ABC tool in two projects in Towns of Waterford and Killingly, Connecticut (resulting in "go-for" and "no-go for" ABC, respectively) were presented by Fields and Culmo (2021) through an ABC-UTC webinar. One of these projects, in consultation with advisory panel members, will be selected as the case study in this project. In addition to demonstrating the applicability of the improved tool, using this case study will provide the opportunity of comparing the results from the original and improved ABC tools.

5. Expected Results

The main output of this research would be an improved spreadsheet-based multi-criteria decision support tool to determine the suitability of bridge projects for adopting ABC techniques. In addition to technical criteria, the tool will consider the benefits of ABC in improving roadway safety as well as social equity and environmental justice in adjacent areas of bridge locations. The proposed tool would be more comprehensive and less subjective than the existing ABC decision making tools and flexible to be used by other state DOTs. Another output is a case study where the application of the developed tool will be demonstrated in a bridge construction project. Details of the development of the improved tool and the case study will be presented in a technical report.

The proposed research will provide an improved tool that will be applicable in determining the suitability of adopting ABC techniques in bridge construction projects, including the replacement of bridge deck, superstructure, and the entire bridge. The construction method will consequently contribute to bridge specifications. The proposed tool will be flexible with determining the weights of different criteria, allowing the widespread use of the tool by different state DOTs.

6. Schedule

Progress of tasks in this project is shown in the table below.

Table 6. Activities and timelines over the project's period

Item	% Completed
Percentage of Completion of this project to Date	40%

Activity	Description	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
Task 1	Literature review												
Task 2.1	Road safety criterion												
Task 2.2	Social equity and environmental justice criteria												
Task 3	Quantitative measures for the evaluation of criteria												
Task 4	Relative weights of criteria												
Task 5	Improved ABC decision making tool												
Task 6	Case study												
Task 7	Reporting												
			Work Performed										
			Work To Be Performed										

7. References

A. Ebrahimian, A. Ardeshir, I. Z. Rad, and S. H. Ghodsypour (2015), "Urban Stormwater Construction Method Selection Using a Hybrid Multi-Criteria Approach", Automation in Construction, 58, 118-128.

A. Ebrahimian, and A. Rahimi (2022), "Identification and Prioritization of Green Stormwater Infrastructure Research Needs in Miami, Florida", Technical Report, Florida Sea Grant.

ABC-Advisory Council, (2008), "Caltrans ABC Strategic Plan: Development of Practice and Policy for Future bridge Projects".

ADOT. n.d. ABC Decision Flowchart. Arizona DOT.

Alipour, A., Gransberg, D. D., & Zhang, N. (2018). An Integrated Project to Enterprise-Level Decision-Making Framework for Prioritization of Accelerated Bridge Construction (No. ABC-UTC-2013-C2-ISU02-Final). Accelerated Bridge Construction University Transportation Center (ABC-UTC).

American Society of Civil Engineers (2016). Failure to act: Closing the infrastructure investment gap for America's economic future. ASCE.

APA (2022). Social equity. American Planning Association, https://www.planning.org/knowledgebase/equity (accessed 4/7/2022).

Caltrans. Life-Cycle Costs Analysis Procedures Manual. California Department of Transportation.

Cavalline, T.L., Whelan, M.J., Tempest, B.Q., Goyal, R., and Ramsey, J. D. (2015). Determination of Bridge Deterioration Models and Bridge User Costs for the NCDOT Bridge Management System. Report FHWA/NC/2014-07. North Carolina Department of Transportation. Raleigh, North Carolina.

Chaphalkar, N. B., & Shirke, P. P. (2013). Application of multi-criteria decision making techniques for bridge construction. Int. J. Innov. Res. Sci. Eng. Technol, 2(8), 3617-3626.

Chen, X., Zhang, H., Chen, W., & Huang, G. (2021). Urbanization and climate change impacts on future flood risk in the Pearl River Delta under shared socioeconomic pathways. Science of the Total Environment, 762, 143144.

Colorado Department of Transportation (2017). Transportation Planning in Colorado. CDOT Planning Manual. DenverColorado.

Dhakal, S., Zhang, L., & Lv, X. (2021). Understanding Infrastructure Resilience, Social Equity, and Their Interrelationships: Exploratory Study Using Social Media Data in Hurricane Michael. Natural Hazards Review, 22(4), 04021045.

Doolen, T. (2011). Accelerated Bridge Construction (ABC) Decision Making and Economical Tool, TPF-5 (221).

EPA (2022). Environmental Justice. United States Environmental Protection Agency, https://www.epa.gov/environmentaljustice (acceded on 4/7/2022).

FDOT (2005). Bridge Scour Manual. State of Florida Department of Transportation, Office of Design, Drainage Section. Tallahassee, Florida.

Federal Highway Administration (FHWA). (2004). Reliability: Linking Solutions to Problems. FHWA, Washington, DC http://www. ops. fhwa. dot. gov/aboutus/opstory. Federal Highway Administration (FHWA). (2004). Work Zone safety and Mobility Rules. Federal Register, Vol. 69, No. 174.

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 (Accessed June 29, 2014).

Federal Highway Administration (FHWA). (2011). Work Zone Road User Costs Concepts and Application. FHWA Report, No. FHWA-HOP-12-005, Washington, D.C. Federal Highway Administration (FHWA). (2010). Our Nation's Highways 2010, Publication No. FHWA-PL-10-023, Office of Highway Policy Information,

Federal Highway Administration (FHWA). (2012). Accelerated bridge construction: changing how America builds infrastructure. Structure Magazine.

Federal Highway Administration (FHWA). (2012). Guidance for the Use of Dynamic Lane Merging Strategies.

Federal Highway Administration (FHWA). (2013). Work Zone Safety Data Collection and Analysis Guide. Report for FHWA. American Traffic Safety Services Association, Fredericksburg, Virginia.

Federal Highway Administration Washington D.C., 2010.

Federal Highway Administration. (1995). Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges. U.S. Department of Transportation Federal Highway Administration. Office of Engineering Bridge Division.

Fernandez, P., Mourato, S., & Moreira, M. (2016). Social vulnerability assessment of flood risk using GIS-based multicriteria decision analysis. A case study of Vila Nova de Gaia (Portugal). Geomatics, Natural Hazards and Risk, 7(4), 1367-1389.

FHWA. 2005. Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making. Federal Highway Administration, Washington, DC.

Fields, T. & Culmo, M. (2021) Development and Implementation of the Connecticut DOT ABC Program, Webinar, Accelerated Bridge Construction-University Transportation Center, September 7, 2021. https://abc-utc.fiu.edu/mc-events/development-and-implementation-of-the-connecticut-dot-abc-program/?mc_id=665 (acceded on 4/7/2022).

Florida Department of Transportation. (2012). Prioritizing Florida's Highway Investments 2012-2013. Florida Department of Transportation, Tallahassee, Florida.

FWWA (2021). Accelerated Bridge Construction. Federal Highway Administration, U.S. Department of Transportation, https://www.fhwa.dot.gov/bridge/abc (acceded on 4/7/2022).

Iowa DOT. 2018. LRFD Bridge Design Manual. Iowa Department of Transportation Office of Bridges and Structures, Ames, IA.

Jia, J., Ibrahim, M., Hadi, M., Orabi, W., & Xiao, Y. (2018). Multi-criteria evaluation framework in selection of Accelerated Bridge Construction (ABC) method. Sustainability, 10(11), 4059.

Messner, F. and Meyer, V. (2005) Flood damage, vulnerability and risk perception – Challenges for flood damage research. Report No. 13/2005, UFZ Discussion Paper. Morrow, B. H. (1999) Identifying and mapping community vulnerability, Disasters, Vol. 23, No. 1, 1–18.

Michigan Department of Transportation (2016). 2016 System Performance Measures Report. Michigan Department of Transportation. Lansing, Michigan.

Minnesota DOT Accelerated Bridge Construction Implementation. (2017)

Mohammed, A. W. (2016). *Agent-based modeling of ABC methods for decision-making in highway bridge projects including uncertainty and several stakeholders*. Western Michigan University.

Mokhtarimousavi, S. (2020). Work Zone Safety Analysis, Investigating Benefits from Accelerated Bridge Construction (ABC) on Roadway Safety, PhD dissertation in Civil Engineering, Florida International University.

Mondoro, A., Frangopol, D. M., & Liu, L. (2018). Bridge adaptation and management under climate change uncertainties: A review. Natural Hazards Review, 19(1), 04017023.

New York State DOT (2014). New York State DOT Transportation Asset Management Plan.

North Carolina Department of Transportation. (2013). Strategic Transportation Investments.

North Carolina Department of Transportation. (2016). Maintenance operations and performance analysis report (MOPAR). Technical report. December 2016.

North Carolina Department of Transportation. (2018). Prioritization 5.0. Master Presentation. North Carolina Department of Transportation. Raleigh, NC.

North Carolina Department of Transportation. (2019). Prioritization Resources.

Ohio Department of Transportation. (2003). Local Major Bridge Program Standard Procedure. Title 23, U.S.C., CFR-650. Standard Procedure No. 310-004(SP). Ohio Department of Transportation. Columbus, Ohio.

Oregon Department of Transportation. (2015.) 2015 Bridge Condition Report. Bridge Section. Oregon Department of Transportation. Salem, Oregon.

Oregon State University. 2012. Overview of ABC Alternative Selection Decision Tool and Validation – Oregon-Led Pool Funded Study. FHWA Office of Operations Peer Exchange Workshop: Innovative Contracting and Accelerated Construction Techniques for Work Zone Safety and Mobility, June 5–6, Denver, CO.

Saeedi, A., Emami, S., Doolen, T. L., & Tang, B. (2013). A decision tool for accelerated bridge construction. PCI journal, 58(2).

Sinha, K. C., Labi, S., McCullouch, B. G., Bhargava, A., and Bai, Q. (2009). Updating and enhancing the Indiana Bridge Management System (BMS). Report No. FHWA/IN/JTRP- 2008/30. Indiana Department of Transportation. Indianapolis, Indiana.

Sinha, K., Patidar, V., Li, Z., Labi, S., and Thompson, P. (2009). Establishing the Weights of Performance Criteria: Case Studies in Transportation Facility Management. Journal of Transportation Engineering, 619-631. 10.1061/(ASCE)TE.1943-5436.0000039.

South Carolina Department of Transportation. (2013). Act 114 Prioritization Requirements. Office of Secretary of Transportation.

South Dakota Department of Transportation (2016). Bridge Improvement Grant (BIG) Procedure. Office of Local Government Assistance.

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., ... & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. Proceedings of the national academy of sciences, 100(14), 8074-8079.

Utah Department of Transportation (2014) Bridge Management Manual. Chapter 2, Planning and Programming. Salt Lake City, Utah.

Vermont Agency of Transportation. (2015). Background Information Emphasis Areas and Project Prioritization. State of Vermont. Agency of Transportation. Montpelier, Vermont.

Wang, C., Yu, X., & Liang, F. (2017). A review of bridge scour: mechanism, estimation, monitoring, and countermeasures. Natural Hazards, 87(3), 1881-1906.

WisDOT. 2018. WisDOT Bridge Manual. Wisconsin DOT, Madison, WI.

Zou, Q., Zhou, J., Zhou, C., Song, L., & Guo, J. (2013). Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP. Stochastic Environmental Research and Risk Assessment, 27(2), 525-546.