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16. Abstract

Accelerated bridge construction (ABC) techniques are rapidly gaining acceptance as an alternative to conventional construction methods to reduce construction duration and minimize the impact of closures at the network level. There are different types of ABC, and each technique has its limitations and its own speed of completion. The choice of using ABC depends on a host of different factors, including the availability of capital funds for its implementation, its impact on the traveling public, and socio-economic considerations. While many states have implemented a multitude of different ABC techniques, the decision making process for choosing ABC over conventional construction, the costs of ABC, the type of ABC techniques used, and the associated timelines and incentives for faster completion are not clear.

This report aims to address this lack of clarity through a review of the available literature and interviews with a few states that have implemented ABC at different levels. It appears that the major factors impacting the timelines for ABC projects are the impacts the closures might have on the socio-economic aspects of the community. While most states acknowledge the importance of indirect costs, there is no mathematical formulation to account for these costs in the final decision making process. Most decisions are made based on qualitative input from the districts and discussions with the public. For the establishment of incentives, a procedure similar to that followed for conventional construction and that follows the Federal Highway Administration (FHWA) guidelines is suggested by most of the states.

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Development of Guidelines to Establish Effective and Efficient Timelines and Incentives for ABC

Final Report
May 2019

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EXECUTIVE SUMMARY

Accelerated bridge construction (ABC) techniques are rapidly gaining acceptance as an alternative to conventional construction methods to reduce construction duration and minimize the impact of closures at the network level. There are different types of ABC, and each technique has its limitations and its own speed of completion. The choice of using ABC depends on a host of different factors, including the availability of capital funds for its implementation, its impact on the traveling public, and socio-economic considerations. While many states have implemented a multitude of different ABC techniques, the decision making process for choosing ABC over conventional construction, the costs of ABC, the type of ABC techniques used, and the associated timelines and incentives for faster completion are not clear.

This report aims to address this lack of clarity through a review of the available literature and interviews with a few states that have implemented ABC at different levels. It appears that the major factors impacting the timelines for ABC projects are the impacts the closures might have on the socio-economic aspects of the community. While most states acknowledge the importance of indirect costs, there is no mathematical formulation to account for these costs in the final decision making process. Most decisions are made based on qualitative input from the districts and discussions with the public. For the establishment of incentives, a procedure similar to that followed for conventional construction and that follows the Federal Highway Administration (FHWA) guidelines is suggested by most of the states.

INTRODUCTION

The aging infrastructure of the transportation system and the ever-increasing demand on the system has resulted in a large demand on state departments of transportation to find approaches to rapidly replace, repair, and build new highway infrastructure. Accelerated bridge construction (ABC) techniques are quickly receiving acceptance as an alternative to conventional construction methods for their ability to reduce construction duration, improve work zone safety, improve construction quality, minimize traffic maintenance duration, and minimize project costs due to the continuing advancements in the industry that make the implementation of ABC methods feasible. With the development of state-of-the-art construction technologies, traffic disruption due to construction has been reduced to several hours compared to the months of restricted traffic movements required by conventional bridge construction techniques. The procedure has gained momentum as a means of constructing bridges on routes with heavy traffic and as a means of emergency bridge restoration.

When accounting for the costs associated with ABC construction, two aspects need to be accounted for: (1) the direct costs associated with the construction, which are estimated in tax dollars, and (2) the indirect costs associated with the disruption in the normal flow of traffic, which translates into socio-economic costs such as those stemming from driver delay, demand on detours, and opportunity losses. When deciding on using a conventional versus ABC technique, one needs to account for the total cost stemming from both direct and indirect costs.

Multiple research and implementation studies have discussed the different aspects involved in the selection of ABC over conventional construction in Utah (UDOT 2017), California (Caltrans 2015), and Washington (WSDOT 2015). These projects have shown the feasibility of using different ABC techniques for the removal and replacement of bridges in a short amount of time. Examples of smaller scale projects have also been demonstrated by the Iowa Department of Transportation (Iowa DOT 2018) and Wisconsin Department of Transportation (WisDOT 2018) that were able to achieve shorter closure times using pre-manufactured modular bridge components.

The goal of this project was to develop a series of general guidelines that could be used in states where ABC techniques have not been implemented as the basis for decision making regarding the adoption of ABC techniques and that sufficiently justify investing in the higher direct costs of ABC.

REVIEW OF ACCELERATED BRIDGE CONSTRUCTION TECHNIQUES

ABC techniques are bridge construction techniques that use innovative contracting, planning, design, environmental review processes, materials, and construction methods during projects (Culmo 2011). Reduction of road closure times, traffic disruption, and user costs, in addition to improvements in construction quality utilizing prefabricated elements, are attractive qualities of the implementation of ABC techniques. ABC techniques, initially reserved for routes with large average daily traffic (ADT) volumes and critical thoroughfares, have significantly improved and increased in popularity. For example, successful applications of ABC techniques helped nine transportation agencies to reduce bridge construction time and save over 30 million dollars (FHWA 2006). Additionally, improvements in ABC techniques for different bridge elements and systems have enhanced the durability of bridge structures (Phares and Cronin 2015, Hosteng et al. 2016). Due to the specific features pertaining to bridge site conditions, weather, and terrain at bridge locations, not all ABC techniques can be implemented on a specific site. This is an important factor that needs to be accounted for in any decision support system (DSS) developed for this purpose. The following subsections provide the unique definitions, advantages, and shortcomings of each ABC technique and common contracting methods for bridge replacement.

Prefabricated Bridge Elements (PBES)

Prefabricated bridge elements are a commonly used ABC method and can be incorporated into most bridge projects as a form of accelerated construction. In this approach, bridge elements are prefabricated, transported to the construction site, placed in the final location, and tied into the rest of the structure. The approach can be used to replace an entire bridge or just parts of it. The PBES can be used in combination with other ABC techniques as well. PBES allows for high performance of the structure in the long term due to the controlled conditions of fabrication and the reduction of on-site construction time. They allow for the production of multiple elements of the bridge at once and under similar construction conditions, which could be used for bundled design and replacement of bridges.

Geosynthetic Reinforced Soil – Integrated Bridge Systems (GRS-IBS)

Geosynthetic reinforced soil – integrated bridge systems (GRS-IBS) are composed of two main components: geosynthetic reinforced soil (GRS) and integrated bridge systems (IBS). GRS is an engineered fill of closely spaced alternating layers of compacted fill and geosynthetic reinforcement that eliminates the need for traditional concrete abutments. IBS is a quickly built, potentially cost-effective method of bridge support that blends the roadway into the superstructure using GRS technology. This integration system creates a transition area that allows for uniform settlement between the bridge substructure and the roadway approach, alleviating the “bump at the bridge” problem caused by uneven settlement. The result of this system is a smoother bridge approach. The technology allows for simple construction; potentially lower initial cost; a safer, more cost-effective, longer lasting structure; faster construction time, and less dependency on weather.

Slide-In Bridge Construction (SIBC)

This method requires the new bridge to be built in parallel to the proposed finished location. The structure is normally built on a temporary support frame that is equipped with rails. The bridge can be moved transversely using cables or hydraulic systems. Several different methods have traditionally been used to slide a bridge into place, such as pushing with a hydraulic ram or winches to slide the bridge on a smooth surface or rails. Some modifications to the technique include the longitudinal launch of the bridge. This method is one of the most expensive ABC techniques and has been shown to be beneficial for the replacement of bridges on arterial roads. Major aspects limiting the use of SIBC are limited right of way for staging, geometric constraints, profile changes in the vicinity of the bridge, and impact on existing utilities.

Self-Propelled Modular Transporter (SPMT)

SPMT is a combination of multi-axle platforms operated through a state-of-the-art computer-controlled system that is capable of pivoting 360 degrees as needed to lift, carry, and set very large and heavy loads of many types. This technique is usually used to move and place large prefabricated bridge elements. SPMT results in drastically shortening construction time and consequently significantly reducing traffic disruption and improving work zone safety and improving quality and constructability, enhancing quality and lowering life-cycle costs, reducing environmental impacts, and increasing contractor and owner options. The major limitations of the technique are significantly higher construction costs and limitations imposed by the length and geometry of the travel path, the availability of the bridge staging area, and specific requirements for the supporting soil.

Incremental Launching Method (ILM)

Bridges are mostly of the box girder design and work with straight or constant curve shapes, with a constant radius. Fifteen to 30 meter box girder sections of the bridge deck are fabricated at one end of the bridge in factory conditions. Each section is manufactured in approximately one week. The technique results in minimal disturbance to the bridge's surroundings, including environmentally sensitive areas and a smaller but more concentrated area required for superstructure assembly.

Innovative Contracting Methods

The traditional approach in most states is design-bid-build (DBB), which involves design and construction being completed by two different entities. Project schedules using the DBB method are lengthened because the design and construction cannot be completed concurrently. In addition to the technical methods leading to the implementation of ABC, as discussed above, the Federal Highway Administration's (FHWA) Every Day Counts (EDC) initiative includes innovative contracting and project delivery methods that are used as a method to shorten the project duration or ensure the completion of the project in the designated time.

Design-Build (DB)

This is an accelerated project delivery method in which the design and construction phases are combined into one contract, thereby eliminating the separate bid phase in the traditional design-bid-build method, which in turn allows certain aspects of design and construction to take place at the same time. The DB process requires the designer-builder to assume responsibility for both the design and construction of the project. This method increases the risk for the designer-builder and reduces the risk for the owner. Project delivery time can be reduced, since the DB process allows for the design and construction phases to overlap.

Construction Manager/General Contractor (CM/GC)

This is an accelerated project delivery method that occupies the middle ground between the traditional DBB and DB methods. In a typical CM/GC scenario, the owners of a project hire either a general contractor or design firm to serve as the construction manager, placing responsibility for design review, design modifications, system integration, and construction with that single contractor. CM/GC allows the state department of transportation (DOT) to remain active in the design process while assigning risks to the parties most able to mitigate them. As with the design-build approach, there are potential time savings because of the ability to undertake a number of activities concurrently. It should be noted that the state's legislation should allow for the CM/GC structure to be implemented by state DOT contractors.

A+B Bidding

This is a cost-plus-time bidding procedure. The low bidder is selected based on a combination of the contract bid items (A) and the time bid for construction times the daily road user cost (RUC) (B). The number of days bid becomes the contract time. In other words, the low bidder is selected based on a combination of the traditional contract unit price items–based bid (A) and the time component proposed by the bidder to complete the project or a critical portion of the project (B). The time to complete the project (B) is assigned a monetary value and combined with the contract items–based bid (A) to select the contractor. The bidder with the lowest overall combined bid (A+B) is awarded the contract. Under the A+B method of contracting, the DOT contractually recognizes that there is a monetary value for each working day that can be eliminated from the contract. Further, a contractor who can work faster but at a higher cost may provide the best value to the public.

Incentives/Disincentives (I/D)

This is a contract provision that compensates the contractor a set amount of money for each day that the identified critical work is completed ahead of time and that assesses a deduction for each day the contractor overruns the time. I/D provisions are primarily intended for those critical projects where traffic inconvenience and delays are to be held to a minimum. The liquidated damages (LDs) are defined as follows: the daily amount set forth in the contract to be deducted from the contract price to cover additional costs incurred by a state highway agency (SHA) because of the contractor's failure to complete all the contract work within the number of calendar days or workdays specified or by the completion date specified. The determination of an appropriate I/D dollar amount is critical for maximizing the potential for project acceleration. FHWA suggests that I/D amounts should be based on SHA overhead, traffic control and detour costs, and RUCs on a project-by-project basis. The I/D amount must provide a favorable cost/benefit ratio while covering the contractor's acceleration costs (based on extended shifts with extra workers for seven days a week).

The ABC techniques and innovative contracting methods can significantly reduce project duration and provide a better construction environment for workers while resulting in more durable structures. One of the most extensive databases of completed ABC projects was reviewed to collect information on the construction costs of ABC projects as stated on the Florida International University (FIU) Accelerated Bridge Construction University Transportation Center (ABC-UTC) website (ABC-UTC 2018). Figure 1 shows the results, which indicate that 83% of ABC projects have higher costs compared to the equivalent conventional construction costs (Figure 1, left). The average additional construction costs of all projects using ABC techniques compared to the conventional costs is as high as 48.9% (Figure 1, right), which agrees with the general consensus that ABC techniques are more costly. Consequently, it is necessary to integrate project-level and network-level studies to find the suitable ABC technique for a given bridge and use the savings resulting from reduced bridge closure times and minimized impacts to the transportation system to offset the high construction costs of ABC bridges.

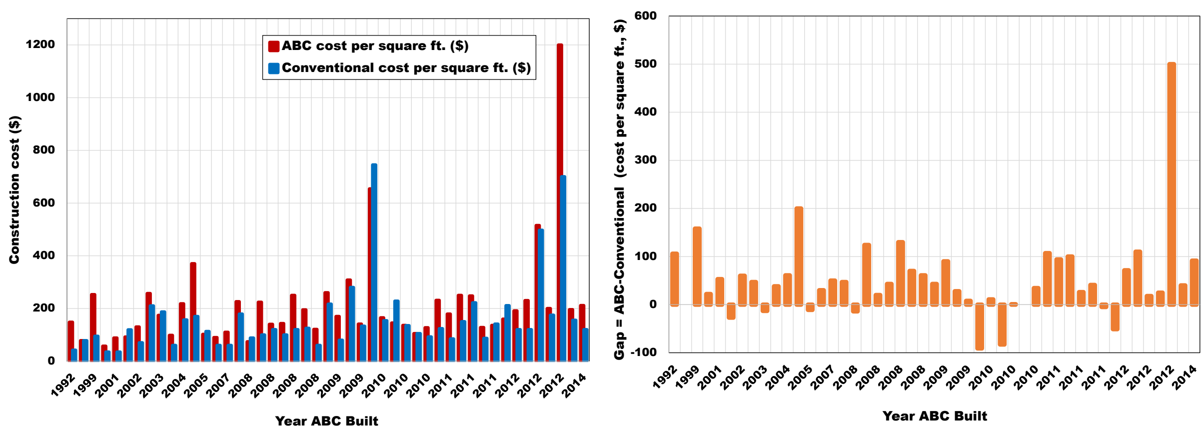


Figure 1. Comparison of ABC versus conventional construction cost estimates: (left) comparison of construction costs of conventional and ABC bridges, (right) difference between ABC and conventional construction costs

AVAILABLE DECISION MAKING TOOLS

ABC has received significant recognition and has gained in popularity in recent years as a method to construct and rehabilitate bridges (Ralls 2007). ABC uses both new technology and innovative project management techniques to mitigate the effects of bridge construction on the public, reduce construction costs, promote traffic and worker safety, and improve bridge durability due to standardized and controlled construction conditions (Saeedi et al. 2013). The perceived higher initial costs associated with ABC are often cited as a reason for state DOTs to be less inclined towards its adoption for repair and replacement projects (Barutha et al. 2017). Another major factor contributing to this hesitancy is the unavailability of decision support systems (DSS) that would help with selection of appropriate techniques. Multiple research studies in the field of infrastructure management have addressed DSS for bridges. This research has been primarily focused on either a detailed total life cycle analysis of the bridges under deterioration mechanisms or the selection of maintenance actions for individual bridges. As for the availability of DSS, there are three tools that are available. The first one, developed by FHWA, is based on a framework involving prefabricated bridge elements and systems decision making, where a flowchart and matrix incorporating a set of decision criteria are used to help decision makers choose between conventional and accelerated bridge construction alternatives (Tang 2006, Salem and Miller 2006). The second tool is a method to evaluate construction plans based on factors such as safety, accessibility, schedule performance, and budget performance, where a scoring system based on expert opinion is used to prioritize the construction plans (El-Diraby and O'Connor 2001). The third tool is based on analytic hierarchy processes (AHP) (Escobar and Moreno-Jiménez 2002, Saaty 1980), which uses pairwise comparisons to evaluate the importance of defined factors relative to other factors using either a numerical or verbal scale (Doolen et al. 2011). The analytic hierarchy process consists of three components: the overall goal of the decision, a hierarchy of criteria by which the alternatives will be evaluated, and the available alternatives.

While many states have developed ABC design and decision making guidelines (e.g., Caltrans 2015, WSDOT 2015, Iowa DOT 2018, TxDOT 2018), the decision making process developed by UDOT seems to be the most holistic one (UDOT 2017). The UDOT ABC decision making process consists of two steps: completing the ABC rating procedure and then using the rating in the ABC decision flowchart to determine if an ABC approach is required.

DECISION MAKING PROCESSES WITHIN DOTS

The typical approach to decision making in most states is to develop a multi-level team that includes a concept team and an oversight team to make decisions on the selection of bridge candidates for ABC.

The concept team can include individuals from offices that manage bridges, design, and environmental concerns who conduct the preliminary studies. A multi-stage or single-stage process can be used to investigate the feasibility of ABC techniques for bridges and develop a scoring system using identified performance measures. Different states may decide to conduct this analysis in a coarse manner using a scoring or rating scheme or use more sophisticated techniques such as analytical hierarchy process (AHP) decision making software.

It is expected that the results will then be communicated to the oversight team that will take part in the prioritization of bridge candidates for ABC techniques. While the focus of the concept team is generally to rate the feasibility of ABC techniques for candidate bridges, the role of the oversight team is to ensure the availability of resources and funding for prioritizing the candidate bridges for ABC.

ACCELERATED BRIDGE CONSTRUCTION RATING PROCESS

In an ABC rating process, a set of measures is defined and a rating scheme is assigned to assess the applicability of ABC to a bridge project. This allows for the preliminary design team to justify the need for ABC at a specific site. Most of the available decision making guidelines use a scoring system that is then integrated with some modified version of the AHP tool. At this stage, the concept team initially assesses the applicability of ABC to the bridge construction process. The score technically acts as a filter by ranking the suitability of bridge replacement candidates for ABC based on a set of measures. Table 1 provides a list of the available measures and a list of the states that use them as a means to score the ABC technique in comparison with conventional construction methods.

Table 1. ABC technique measures by states

Measure	CA	IA	MN	OR	UT	WA	WI
Average daily traffic (ADT)	×	×	×		×	×	
Out of distance travel/detour length		×	×	×			×
Delay/detour time	×			×	×	×	
Bridge classification					×		
User costs	×	×	×		×	×	×
Economy of scale	×	×		×	×	×	×
Use of typical details					×		
Safety				×	×		
Railroad impacts	×				×	×	×
Accessibility of navigation channels							×
Weather-related impacts	×					×	×
Environmental impacts	×			×		×	×
Preference of the districts	×					×	
Traffic and maintenance	×			×		×	
Utility impacts	×					×	
Historical impact				×			
Traffic density			×				
Construction cost		×		×			×
Right of way				×			
Toll revenue				×			
Revenue loss				×			
Construction personnel safety				×			×
Physical constraints				×			
Emergency replacement							×
Impact to economy						×	×

Aside from the ABC measures that are used for scoring purposes to decide whether an ABC technique is a suitable choice for a specific bridge construction project, there are no specific guidelines on the how decisions are made regarding the assignment of duration to projects and the use of user cost contracting methods such as I/D. This project’s goal is to provide guidelines for estimating the direct and indirect costs associated with the project’s duration and how these costs could impact decisions about whether ABC techniques should be used instead of conventional construction techniques.

DETERMINATION OF APPROPRIATE ABC TECHNIQUE

The FHWA manual on ABC techniques lists six major techniques and combinations thereof that can be used. The determination regarding whether to use each technique is dependent on a host of different factors that can also be related to the ABC measures described above. Additionally, aspects such as the requirements of the site, site geometrics, and project funding play an important role in selecting the type of ABC technique used. In general, ABC techniques can be categorized as either offsite or onsite. Offsite construction techniques involve building the bridge away from the final location using normal construction and/or prefabricated elements. Once construction is complete, the bridge is moved into place. These techniques include SPMT, lateral slides, longitudinal launches, and crane-based launches. It should be noted that, in general, SPMT is more expensive than a lateral slide for a single move due to the need for special equipment for SPMT. The higher costs could be alleviated if multiple bridges at the site use this technique. Lateral slides seem to be the most cost-effective among the offsite techniques. Longitudinal slides and crane-based techniques cost somewhere between SPMT and lateral slides, though longitudinal slides require more design effort.

As part of this project, the database of ABC projects available on the FIU ABC-UTC website (ABC-UTC 2018) was reviewed. Of the 111 projects reported in the database (at the time of this study; note that more bridges may be added later), only 47 have the detailed project schedule included. The schedules of the 47 projects were reviewed, and the closure durations (impact on traffic in days) were extracted from the schedules. Figure 2 shows the average traffic impact rating (Tier 1 to 6) for each state based on reporting from the states and the estimated closure duration (for projects with reported schedules). For all of the bridge projects in the database, Figure 3 lists the relationship between the bridge's recorded ADT value and the assigned duration of the project.

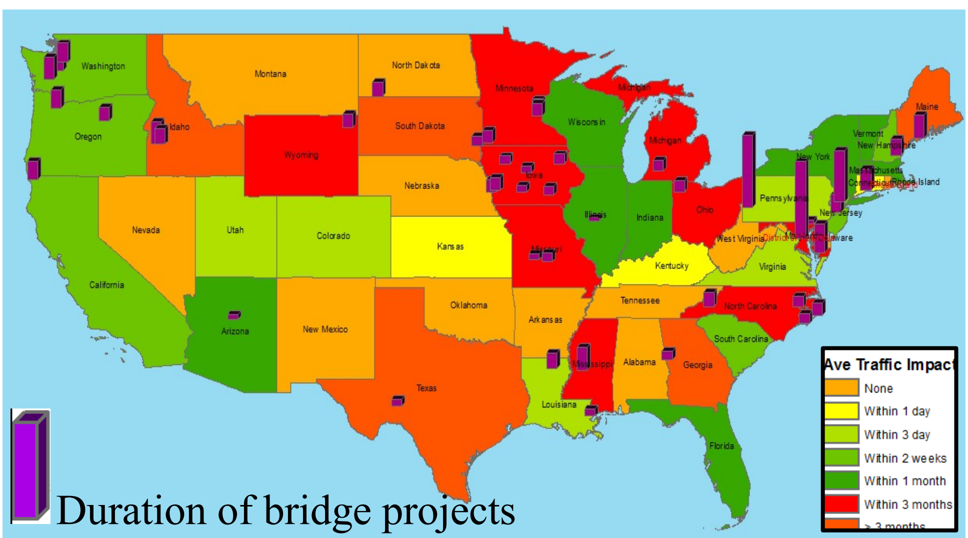


Figure 2. Average traffic impact rating tiers reported by states and closure duration on a project basis

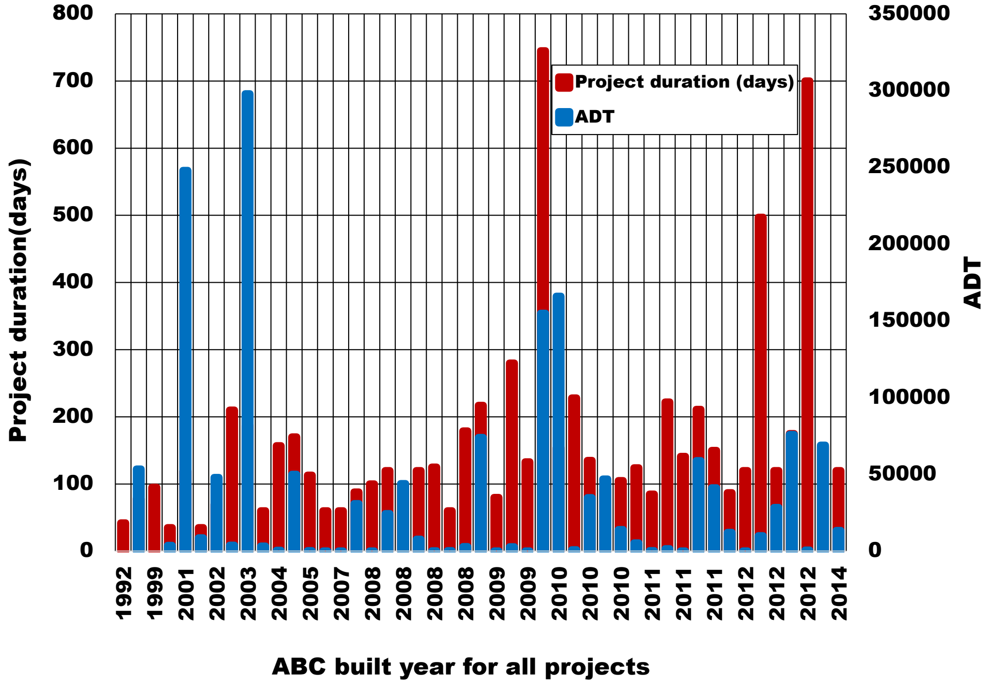


Figure 3. Comparison of ADT and project duration for all projects

As Figure 3 shows, the two projects with the highest ADT values of 298,000 and 248,000 had closure durations of 187 and 199 days, and the project with the longest duration (745 days) had an ADT of 155,000. The average ADT is 34,915, and the average closure duration is 158 days. The minimum ADT on a bridge is 10, and the minimum closure duration is 60 days. While there is a general trend for the lower ADT projects to have relatively longer durations (though still not as long as those with higher ADT values), it is hard to establish a trend between ADT and the duration of the project. One major factor contributing to this difficulty is that, most likely, bridges with higher ADT values tend to be larger in terms of square footage and therefore require more closure time for replacement (even at the fastest speeds).

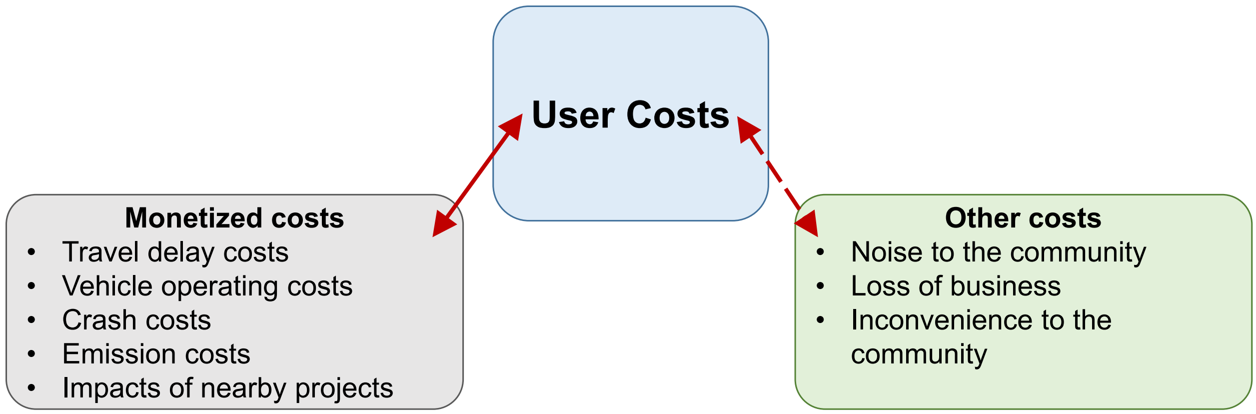
USER COSTS

User cost is defined as the additional costs borne by motorists and the community at large as a result of construction activities (Lee and McCullouch 2009). The user cost can include components such as user delay cost, vehicle operating cost, crash costs, and emission costs, which are generally easy to estimate. There are other components, such as noise levels and the impacts of construction on business, the local environment, and the community, that are often harder to estimate.

The process of selecting infrastructure improvement projects, whether building new roads, maintaining bridges, etc., is becoming increasingly difficult due to the growing need to be absolutely diligent with spending while keeping the growing number of drivers safe and satisfied with road conditions. Each improvement option must be weighed, and its overall benefit to the affected community in terms of the timing of its implementation or its existence as a whole may become the deciding factor. The benefit is determined through calculating user costs incurred during the construction process and comparing that to the user cost after the proposed improvement strategy. Transportation planners rely on analytic tools to evaluate the relative merits of each candidate project and that ultimately provide a means for allocating resources to that set of projects that will maximize the total benefits (AASHTO 2003).

RUC directly affects those traveling through project sites and indirectly affects the surrounding areas through, for example, impacts to the environment, the local economy, and urban growth. Just as in the bulk of the literature reviewed for this research, the focus of this discussion will be on the direct costs, as they are more easily quantifiable for a project. The overall benefit of a project or the particular sequencing for that project is determined by a multitude of travel costs. The American Association of State Highway and Transportation Officials (AASHTO) *User Benefit Analysis for Highways* manual breaks costs into three distinct categories: travel time costs, operating costs, and accident costs. Taken together, the total of these costs is essentially the price that travelers must pay to travel (AASHTO 2003). Review of some of the most prominent documents in RUC estimation shows that most transportation agencies use some combination of these costs when developing a methodology for determining road user costs.

The main priority of the AASHTO manual (2003) is to justify a project by its RUC, as this justification allows for a clear analysis of the project's benefits as well as a method for the direct comparison of different improvement projects. Total user cost is equal to the sum of the vehicle running costs (VOC), the value of travel time (VOT), and the accident costs (AC). After reviewing the relevant literature, it was concluded that most DOTs' RUC methodologies, with only a few exceptions, consist of a combination of these three. Some literature references outside or "off-site" impacts in addition to the monetized impacts that can be quantified, but as shown by a recent survey that asked respondents to rank the order of importance of the user cost components, vehicle emissions were deemed practically insignificant. Figure 4 summarizes the components of RUC.



Adapted from Mallela and Sadasivan 2011

Figure 4. Breakdown of the user cost estimation

INCENTIVES/DISINCENTIVES

Incentives have been used for years on construction projects. These incentives have different means of motivation, including economic means, business relations, the legal system, and psychological stimulus. Incentives and disincentives in construction contracts have become commonplace among transportation agencies, which use all of these motivational tactics. The methods and reasons for incentives vary greatly and may include specifications and bonuses for increased workmanship on pavement, bonuses for early project completion or meeting milestones, liquidated damages for missed milestones, and procurement "points" for reduced disruptions to the traveling public.

Hughes et al. (2007) note that incentives have been used in construction for many years. They cite work from 1953 regarding labor expenditures for companies using incentives and those not. The authors further cite work form 1967 discussing productivity in the home building industry that included modifications to contracts to "encourage more efficient working methods." The discussion further demonstrates that there are different ways to motivate contractors. These may be through economic means, business relations, the legal system, and psychological motivation.

Use of economic motivation is likely one of the most prominent incentives. However, it should not be the only means of motivation, especially when looking at different types of roadways and locations. A study of Missouri incentives and disincentives related to road user costs found that road user costs were most effective for urban projects, full-closure projects, and emergency projects. Projects that were rural, non-emergency projects saw savings related to road user costs, but the incentives/disincentives were not on the same level as the other types of projects (Sun et al. 2012).

Potential costs associated with increased delays and safety risks to drivers in work zones are utilized to determine road user costs. Higher road user costs for a work zone may trigger the use of incentives or disincentives. A study of Missouri incentive/disincentive projects from 2008 to 2010 found that every dollar in paid incentives resulted in approximately $5.30 in road user costs saved. The data also showed that incentives/disincentives on projects reduced both mobility and safety road user costs (Sun et al. 2012). Ofili (2015) reports that Utah experiences a 5:1 to 6:1 ratio of user costs saved to construction costs incurred on ABC projects. The study notes that these ratios may not have been experienced on the early ABC projects, but, "with repetition, costs have decreased."

In a recently completed synthesis of practices for establishing contract completion dates for highway projects, Taylor et al. (2017) report that out of 23 responding states, 17 believe that the use of incentives and disincentives influenced the on-time completion of contracts. The remaining five states were unsure if there was an influence. A study from Michigan agreed with this finding, indicating that incentive clauses accelerated project schedules (El-Gafy and Abdelhamid 2015).

Fick et al. (2010) interviewed 32 states and found a perceived increase in cost of 10% or less for projects with incentives/disincentives associated with project schedule. They further report that, "on average, interviewees felt that the impact of [incentive/disincentive] provisions on costs was neutral." Further research revealed that "a competitive market environment is especially important for the effective use of [incentive/disincentive] provisions." El-Gafy and Abdelhamid (2015) found that incentive clauses do increase project costs, but the additional costs are less than the avoided user delay costs. Smith (1987) found that when incentives are included in contracts, the contractor often receives the maximum allowable amount, ranging from $2,500 to $10,000 per day. Taylor et al. (2017) also found that incentives are more often paid than disincentives are collected.

Determining an appropriate incentive for early completion or disincentive for late completion can be problematic. In 2000, the Texas Transportation Institute and Texas Department of Transportation (TxDOT) developed a set of tables to support development of road user costs. The tables simplify the process and make it easier for smaller districts to make informed choices (Daniels 2000). Ibrahim and Orabi (2016) propose a model to "quantify the impact of different levels of [incentive/disincentive] values on the trade-off between time and cost of pavement rehabilitation projects" and determine the costs of these projects. The authors propose that there is a normal point where construction costs are at a minimum and an increase or decrease in the project's duration will increase the project costs. Further, the authors propose that there may be multiple levels of incentives/disincentives based on the decrease in the project's duration. Finally, they claim that the model is capable of determining how likely it is that each level of duration reduction is achieved. Other researchers have proposed other methods for determining incentives/disincentives. Researchers from Texas A&M University propose a seven-stage framework to support this decision (Choi et al. 2013).

Incentives/disincentives may be used on ABC projects to encourage shorter closure times. These incentives/disincentives may also be used to influence closure timing. Reasons for closure timing may be to account for traffic patterns. An example of a contract that attempts to encourage a certain closure timing may be seen from the Indiana Department of Transportation (INDOT) (INDOT 2017). In this contract, liquidated damages were assigned for work completed after a specific date. Liquidated damages were also assigned for work before a specified start date or if work was started after a specific date (Table 2).

Table 2. ABC liquidated damages rates

Description	Liquidated Damages ($)	Rate
Completion date	2,500	Per day
Earliest date to begin work	2,500	Per day
Latest date to begin work	2,500	Per day
Road closure	2,500	Per day
Interstate lane closure Saturday-Thursday	2,000	Per hour
Interstate lane closure Friday	2,500	Per hour
State road closure	4,000	Per day

Source: INDOT 2017

Additionally, the contract provides for different rates, or disincentives, for lane closures on specific days of work. On this project, lane closures on Fridays cost more than lane closures on other days of the week. This project was awarded through an A+B model. The contractors were allowed to propose the number of days the roadway would be closed for bridge installation. To encourage the least disruption to the traveling public, Fridays (which were the highest traffic count days) were estimated at a different rate than other days of the week. The proposers for the project proposed 13 closure days, starting with closure on Saturday morning and opening 13 days later (on a Thursday) so that there was only one Friday where the roadway was closed, thus minimizing the penalties, which in turn minimizes the traffic disruption.

INTERVIEW RESULTS

California Department of Transportation (Caltrans)

The California Department of Transportation (Caltrans) has started the process of putting together a series of guidelines for decision making regarding the selection of projects for ABC techniques. From an engineering perspective, this DOT is working to establish a focused engineering group that exclusively deals with the design and contracting of ABC projects. On each potential project, the districts communicate their intentions for the project, such as the duration of closure and the timeline of the project, with the main design office and are provided with the options for construction and contracting. It appears that currently the final decision on whether ABC is selected for a specific project relies heavily on the district. The factors going into this decision include available funds, the impact of construction-related closure on the users' costs and opportunity losses, and seasonal considerations. To ensure that the contractors are aware of the special circumstances associated with ABC projects, such as the possible need for special equipment and the faster pace of the project, Caltrans holds informational sessions with the contractors before any bidding takes place, sometimes even having that as a requirement for a contractor to be able to submit a bid.

Discussions with a private firm involved in the design and delivery of ABC projects highlighted the positive aspects of the CM/GC method in the states where it is allowed. This is a method that allows for the contractor to provide input in early stages of ABC projects, which, in the long run, results in more cost-effective, long-lasting bridges with early completions.

Minnesota Department of Transportation (MnDOT)

The Minnesota Department of Transportation (MnDOT) has used ABC on a number of projects using a number of different delivery methods and technologies. MnDOT has a defined process for selecting and implementing ABC projects. This is a three-stage process. The first stage is to be completed during the scoping phase of the project. This stage is an initial screening and includes estimations of user costs, average daily traffic, detour length, amount of commercial traffic, and traffic density. This evaluation is completed on all bridges and included in the MnDOT Project Scoping Worksheets. The rating during this stage can indicate that ABC may be appropriate and should be considered. Even if the first stage does not indicate a "Yes" rating, ABC may still be considered, and a second stage of evaluation may be completed if the use of ABC mitigates a critical issue identified during the scoping process. The second stage is to be completed prior to the project entering the State Transportation Investment Plan (STIP). If at the end of the second stage ABC is still a consideration, the third stage includes a discussion about project-specific details, consideration of alternative delivery and contracting methods, and identification of the final construction method and contract administration. These stages are all completed through a committee or multiple parties to provide a variety of perspectives, including those of the bridge engineers, traffic engineers, estimators, and construction engineers in the central office and the district office, at different phases of the project (MnDOT 2017).

According to MnDOT, the decision to use ABC techniques is based on the process described. Reasons for using ABC may include a short construction time, which may force the use of ABC; a limited construction season; or high traffic volumes. While these conditions may cause the DOT to dictate that ABC be used, a contractor may also decide to use ABC. In at least one instance, the contractor proposing on a best-value project using alternative delivery decided to propose the use of ABC as a way to score additional points in the best-value selection process. The specific ABC technology to use can be dictated by the characteristics of different technologies, project-specific characteristics, or environmental issues.

If the closure or construction duration is determined by the DOT, the DOT personnel will look at what has been seen on other projects, both ABC and conventional construction, looking at what other states have experienced, and offer judgement. This is a group discussion, and the DOT feels that if an inappropriately short duration is mandated the contractors may comment during the bidding period. On one best-value project, the contractor selected the duration. This was based on the contractor's experience. In this case, the duration proposed by the contractor was 10 days longer than the actual project duration. The actual duration was approximately only 60% of what was expected using conventional construction.

Incentives are used on some projects, including ABC projects. The incentive is typically associated with the portion of work that is considered important by the DOT. Disincentives are also used. On at least one project the disincentive was approximately $10,000 per day for failure to complete the project on time.

Indiana Department of Transportation (INDOT)

There is not a one-to-one correlation between the incentive/disincentive and user costs. To determine user costs, an economic analysis is completed on each project. This analysis includes delays, detour length, and traffic volume. The user costs are usually developed as a range. INDOT has completed two ABC projects. There is no formal process for selecting a project for ABC. ABC was selected for the second of the two projects based on the characteristics of the project site. This was determined during a site visit by the DOT and the design consultant. Plans were developed for two different ABC technologies. The project was let with both plan sets, and the DOT left it to the contractor to determine which design would be used.

The duration of the second INDOT project was determined through talking with the construction engineers about the conventional portions of work as well as the critical path of the ABC portions of the project. The design consultant determined that 9 days was the lowest feasible closure time but limited the closure to 13 days to allow for differences. The closure was completed in 9 days. The slide-in of the bridge, when considering the entire project, is not through to be a significant issue in the critical path as long as it is done. The slide-in portion of the project was observed to generally take less than 12 hours. While the bridge is on the critical path, the critical path does not dictate the entire closure duration as long as tasks are completed as scheduled; rather, the approach work is what takes the longest amount of time.

Incentives/disincentives were used on the second INDOT project based on the number of closure days that the contractors proposed. User costs were developed by the design consultant that included detour costs and delay durations. This calculation resulted in a large value that was scaled back to what the DOT felt comfortable with to be incentives/disincentives. These incentives/disincentives were different for the various directions of the roadway and for different days of the week.

CONCLUSIONS

The purpose of this research was to collect information and provide guidelines as to how ABC project timelines and incentives are established. Discussions with multiple state DOT representatives, a review of existing literature, and a detailed review of the ABC projects in the FIU ABC-UTC database showed the following results:

- In terms of decision making tools, states with experience implementing ABC projects can be categorized into three major groups: (1) those that had adopted the AHP tool (such as UDOT and the Iowa DOT) and followed a similar scoring scheme to make decisions on using ABC, (2) those that had adopted either a scoring system that was rather qualitative (such as WisDOT and Caltrans), and (3) those that used the help of a scoping group familiar with the time and cost requirements of ABC to make a decision.

- Understanding the importance of ABC, a few states have adopted focus groups or central engineering offices dedicated to ABC. These groups normally acted as a consulting office to districts and other branches of the state DOTs to make decisions regarding the establishment of the timelines and costs associated with ABC.

- Incentives/disincentives have been a component of construction project contracting methods for a long time. The use of I/D for ABC projects seems to have resulted in different outcomes, according to the interviews conducted with the DOTs. This is mostly attributed to the previous experiences that state DOTs have had with establishing I/D for conventional construction projects.

- It appears that other innovative contracting methods such as CM/GC are gaining momentum within some states. Most states and consultants involved with this type of contracting believed that the involvement of the owner, designer, and contractor from the beginning of the project allows for the development of more effective construction solutions.

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