

ALTERNATIVE TECHNICAL CONCEPTS FOR CONTRACT DELIVERY
METHODS IN ACCELERATED BRIDGE CONSTRUCTION

Quarterly Progress Report
For the period ending August 31, 2020

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Submitted to:
ABC-UTC
Florida International University
Miami, FL

1 Background and Introduction

Accelerated bridge construction (ABC) is known to reduce the construction time and traffic disruption drastically, yet there are several issues in its delivery methods that have yet to be fully investigated. It is vital to provide specific frameworks and guidelines for ABC projects, which disseminates knowledge to encourage ABC stakeholders to understand the various contract delivery methods that promise possible savings on a project's cost and schedule. This study aims to address one effective contract delivery methods, by highlighting and providing a metric that supports ABC stakeholders and contractors recognize the merits of using Alternative Technical Concepts (ATC) on ABC projects. ATC is an effective project delivery method that is achieved through early contractor involvement, thus encouraging early understanding of the project, reducing risks proposing materials, and modifications to contract requirements before the bidding or proposal process. That said, employing ABC projects with the ATC contract method not only will reduce traffic and travelers' disturbances, but also reduces ABC's contract duration and cost by avoiding change orders as well as eliminating uncertainties within ABC projects. To be able to achieve this goal and showcase to ABC stakeholders the advantages of ATC, the first step will be to conduct a rigorous literature review to understand the status of contract delivery methods in ABC projects and identify any potential case studies with ATC methods. Then, the decision criteria are identified based on review of these literature that are usually used in the analysis of the analytical hierarchical process (AHP). Afterward, a semi-structured survey to representative samples of ABC stakeholders will be conducted to validate and rank the hierarchical decision criteria. The obtained results from the survey are also used to develop a binary logistic regression model to determine the benefits of using ATC specifically on time/schedule in ABC projects. The findings of the study foster the development of a streamlined procedure for effective adoption of ATC, which would surely expedite ABC projects' delivery, eliminate uncertainties about the ATC as a contract delivery method for ABC projects and provide a framework to support early contractor involvement when ATC is adopted thus advance the frontier of ABC.

2 Problem Statement

There are clear benefits to early contractor involvement in Accelerated Bridge Construction (ABC) projects. Alternative Technical Concepts (ATC) is one method of early contractor involvement allowing them to propose modifications to contract requirements before the bidding or proposal process. Past studies have investigated the cost savings gained by using ATC. The proposed project would focus on the construction time savings realized when ATC is used on ABC projects. ABC is an effective methodology that eliminates the disruption of traffic and reduces safety hazards and public nuisance. To achieve this, ABC technique implements innovative technologies during the replacement of a deteriorating bridge or constructing a new one. Even though this technique has been regarded as an effective method for reducing overall construction time besides avoiding traffic disruption, there are some risks involved in accelerated constraints indicated in this method. First, there is a growing concern for elevated costs incurred by the ABC method in a project. Similarly, lack of standardization, inexperienced contractors, and manufacturers and technical

problems related to its strength and long-term performance are some of the major issues in this methodology (Ofili 2015). Past studies have investigated the gain in cost savings when using Alternative Technical Concepts (ATC). The proposed project would focus on the construction time savings realized when ATC is used on ABC projects. Therefore, this study will also be geared towards addressing these issues in the ABC method by fully embracing the benefits offered by ATC.

3 Objectives and Research Approach

The proposed research project will be geared towards determining the factors which impact the integration of ATC in ABC projects through the analytic hierarchy process (AHP). The objective of conducting this analysis is to develop a hierarchical model that can be used to develop a guideline for effective adoption of ATC thus expediting the contract delivery. These streamlined procedures for ATC would aid to successfully accelerate the design, construction process, and procurement of infrastructure assets for either rehabilitation or new projects related to ABC. The integration of ATC in ABC projects not only ensures smooth regulation of traffic and adequate safety but more importantly addresses the issues of elevated cost and delay in the project schedule. One of the main motivations of this study is to fulfill the literature gap by providing a separate ATC guide that is specific to ABC. One very effective example that supports the fact that ABC projects need their own tailored ATC guidelines is the Construction Industry Institute (CII) tools that are dedicated to each project type (infrastructure, residential, industrial, medical, etc.). CII provided each project type with an individually tailored tool to determine its particular associated risks which in turn ensure supporting each specific project type (ElZomor 2017). That said and because one of the major issues in ABC is lack of standardization that impedes the mass production of modules, this approach would foster the development of a separate tailored ATC guide, which is specific to ABC, thus would further facilitate the required standardization. Another main goal of the study is also to develop a linear regression model that evaluates the influence of ATC adoption on construction time savings, particularly for the ABC project.

3.1 Summary of Project Activities

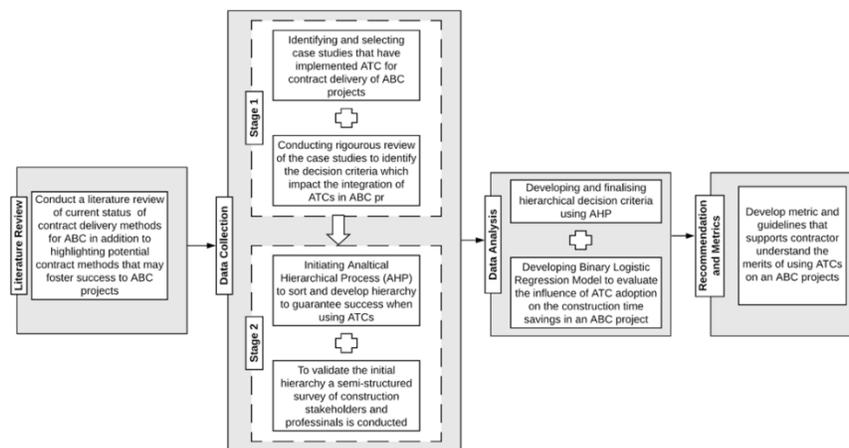


Figure 1: Overview of Project Activities and their Sequence

4 Description of Research Project Tasks

To date the Task One, literature review, has been partially completed.

Task 1 – Literature Review

Proposed task description: conducting a Literature Review.

Description of work performed up to this period is encompassed in the below set of paragraphs.

The objective of the first task is to understand the current status of contract delivery methods for Accelerated Bridge Construction (ABC) in addition to highlighting potential methods that may foster success in ABC projects. The succeeding section highlights the current state of ABC technology, project delivery methods used in ABC projects, an overview of alternative technical concepts (ATC) for contract delivery, and finally, prospective of ATC for contract delivery of ABC projects.

4.1 Current State of Accelerated Bridge Construction (ABC)

Out of 614, 387 bridges in the United States approximately 39% of the bridges are more than 50 years or older and are either structurally deficient or approaching the end of their design life (ASCE-Report-Card 2017). Although 56,007 bridges in the U.S. have been found to be structural deficient in 2016, more than 188 million trips have been made across a structurally deficient bridge every day. Figure 1. shows structurally deficient bridges across different states in the U.S. which require periodic maintenance, rehabilitation or replacement. Since the critical load carrying elements in structurally deficient bridges can be in poor condition due to deterioration or damage, it is crucial to adopt innovative solutions for effective replacement or renovation of these structures. It is imperative to reduce the number of structurally deficient and functionally obsolete bridges to ensure safety of travelling vehicles. One of the recent technologies that addresses this issue is accelerated bridge construction (ABC) which has facilitated engineers to build better and faster as well as maintain a longer bridge life. ABC is an innovative bridge construction technique consisting of effective plans, high-performance materials, safe designs, and cost-effective construction methods for reducing the overall construction time of new bridges or rehabilitation of existing bridges (Phares and Cronin 2015). Since faster delivery of projects with reduced congestion and safe execution is a top priority in the industry, many bridge construction projects are gradually adopting this technique to achieve this objective (Khaleghi et al. 2012). Ofili (2015) indicated that ABC techniques that have been used for several years in the past mainly focused on prefabricating bridge elements for constructing or renovating a bridge. It is only in recent years that the extensive use of this technique is currently being scrutinized and several discoveries are being made (Zhu and Ma 2010). Although ABC has been found to reduce the bridges' overall construction time, recent studies indicate that there are several issues associated with its delivery method (MDOT 2015). Some of these major issues include the high initial cost of ABC, lack of standardization, inexperienced contractors and manufacturers, etc., which have impeded its mass adoption (Saeedi et al. 2013). As such, there is an inevitability to identify the most effective delivery method for ABC projects that promises controllability and reduction of construction costs

and schedules. Thus, this will initiate an opportunity to replace a large number of our deteriorating bridges with minimum traffic disruption, reduction in the environmental impacts, and guaranteeing improved worker safety (Jia et al. 2018).

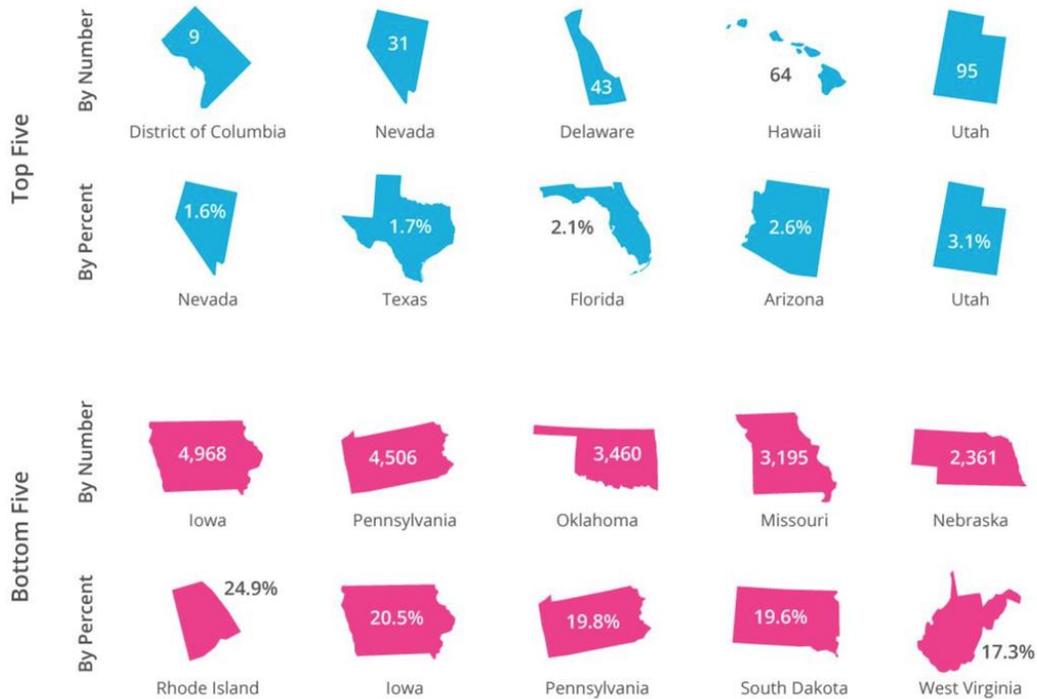


Figure 1: Structurally deficient bridges in the U.S.: Top and bottom five states by number and percent (ASCE-Report-Card 2017)

To this end, the accelerated bridge construction (ABC) technique has significant potential to thrive but it requires constant improvement in the methods and a significant reduction in construction time as well as overall cost. Specialized construction methods such as ABC often require larger and more sophisticated equipment that can execute the construction effectively. Specialized equipment such as self-propelled modular transporter (SPMT), lateral slide, prefabricated elements and systems as well as other lifting equipment like large cranes, strand jacks, and hydraulic jacks are mostly used large equipment for installation of the bridge (Hällmark et al. 2012). Although innovative equipment like SPMT has been found to reduce traffic disruption, improve work zone safety, and improve quality and constructability, the major disadvantage of SPMT is that they are extremely expensive and can only be implemented in an area with a clear delivery path from the erection site to the bridge (Jia et al. 2018). The most effective and economical way to implement the use of this equipment is to keep it in use as much as possible. Similarly, high-performance materials such as Fiber-Reinforced Plastic (FRP) and Ultra-High-Performance Concrete (UHPC) are some crucial discoveries in recent time that has brought advancement in ABC technology (Ghasemi et al. 2016). The adoption of UHPC in ABC projects has significantly improved the performance characteristics in terms of high ductility, ultra-high compressive strength, chloride impermeability, minimal creep and shrinkage after curing, among others. However, each

construction project has different environmental, geometric, and traffic conditions that influence the type of material, design, and construction to be used for the project. Similarly, the lightweight materials with high strength characteristics i.e. UHPC and FRP have practical limitations in terms of fabrication and cost. It is likely that they may become more feasible and viable with an increase in use and more extensive research in improving their widespread use (Tazarv and Saiidi 2015). Furthermore, Garber et al. (2020) have conducted experimental study on non-proprietary UHPC mix made with local materials to lower the costs as well as achieve the important mechanical properties and durability for its utilization in bridge components, connections, and repair.

The successful construction and operation of the ABC project are influenced by various factors which can be identified from several past projects. One of the most important factors that impact the construction duration of the project is the constructability of the bridge. Since construction stakeholders are relatively new to the ABC techniques especially local contractors who are more experienced in small bridges, there are challenges in designing the bridge with constructability in mind. For instance, the installation of the Black Hawk County Bridge in Iowa was challenging and complex in terms of adding reinforcing steel in the longitudinal joints (Klaiber et al. 2009). Likewise, 24th Street Bridge in Council Bluffs and Boone County Bridges had highly congested longitudinal joints and were difficult to install which increased the actual time required to complete the bridge installation process (Cheng et al. 2020). Secondly, traffic disruption is another important factor which not only impacts the construction duration but also travel distance of vehicles utilizing the bridge for reducing the time taken to reach the destination. Since ABC project reduces traffic disruption through fewer construction activities on-site, traffic will be disrupted only during installation and during that period commuters need to follow alternate routes (Hällmark et al. 2012). However, areas with a high volume of traffic where longer detour routes are not possible, bridges have to be built alongside an existing bridge. For instance, the 24th Street Bridge in Council Bluffs had no traffic disruption at any time during the construction period and maintained three lanes of traffic at all times, thereby eliminating the requirement of the use of detour (Becker et al. 2009). The third factor which influences the use of ABC technique in bridge construction projects is the total cost of all preliminary work, materials, and construction. Lessons learned from ABC projects have indicated that the projects utilizing ABC technology have mostly higher costs than the projects that depend on conventional construction methods. For example, the 24th Street Bridge in Council Bluffs was built at a cost of \$185 per square foot of bridge deck that is slightly higher than the non-ABC cost of \$155 per square foot of bridge deck (Cheng et al. 2020). This cost difference is mostly due to the use of high-cost, innovative materials and cost incurred by the maintenance of traffic in high traffic volume areas throughout the construction phase. Lastly, the durability of the bridge is one of the significant factors that can be achieved by using high-quality materials and innovative construction methods. In the last few decades, studies in ABC projects have indicated that prefabrication of bridges in a controlled setting provides higher durability properties than the traditional cast in place concrete bridge because it ensures that there are appropriate curing and formation of concrete (Ofili 2015). Thus, ABC bridges have the potential to have a significantly longer life cycle than a traditionally cast-in-place concrete bridge.

Considering all these factors, decision could be made regarding whether accelerated bridge construction technique can be adopted, and a comprehensive flowchart can be used to make such decision as shown in Figure 3.

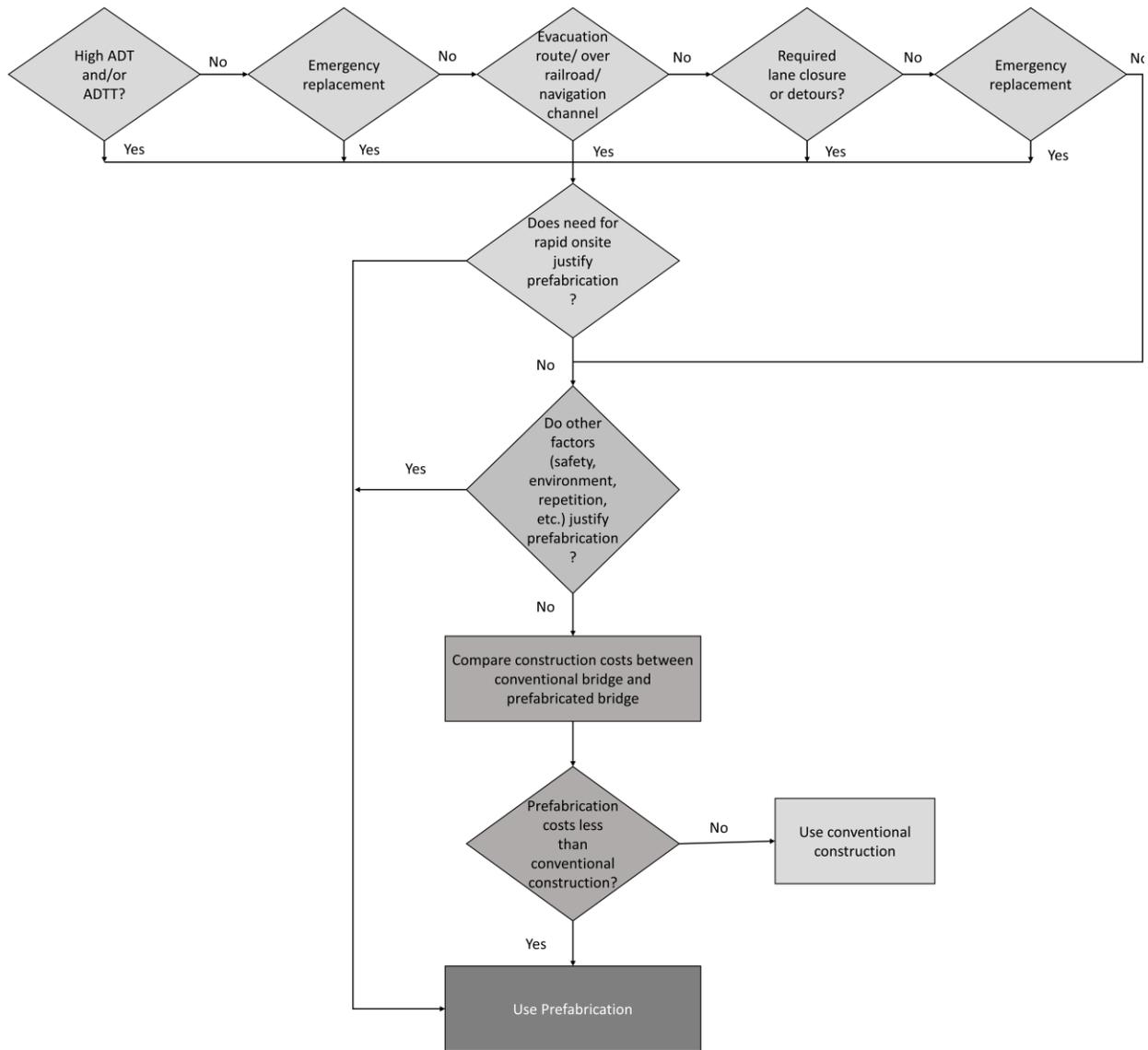


Figure 2: Flowchart for decision making on the use of the prefabricated bridge (Federal Highway Administration (FHWA) 2017)

Although Accelerated Bridge Construction (ABC) provides benefits such as a reduction in the construction schedule, environmental impact, and disruption in traffic, it may not be the most appropriate technique for all projects. To assure proper use of this technique different department of transportation (DOTs) have formulated decision-making guideline such that those projects which do not require acceleration in schedules and can be constructed with conventional practices utilize those methods instead of ABC (Freeseaman et al. 2020). There are two methods for decision making on the choice of bridge construction technique which include a qualitative approach and a

quantitative approach. A qualitative approach involves the use of yes/no questions generally with the use of flowcharts to assist in the decision-making process. On the other hand, a quantitative approach involves use of decision making technique such as Analytical hierarchical process (AHP) that has been used by several DOTs in recent times to determine whether the ABC technique is advantageous for a specific project (Saeedi et al. 2013). AHP technique uses a pair-wise comparison of different criteria and sub-criteria to determine the best alternative solution for the project. The criteria and sub-criteria used for evaluation of the best alternative solution varied from one state to another (Salem et al. 2018). Table 1 summarizes the different criteria utilized for decision making of ABC adoption in various states.

Table 1: AHP Criteria and sub-criteria list for adoption of ABC in different states (Freese et al. 2020)

State	Criteria	Number of Sub-Criteria
Oregon	(1) Direct cost; (2) Indirect Costs; (3) Site Constraints; (4) Schedule Constraints; (5) Customer Service	25
Michigan	(1) Site and structure; (2) Cost; (3) Work zone mobility; (4) Technical feasibility and risk; (5) Environmental consideration; (6) Seasonal constraints; (7) Project schedule	26 to 36
Wisconsin	(1) Disruptions; (2) Urgency; (3) User cost and delays; (4) Construction times; (5) Environment; (6) Cost; (7) Risk management; (8) Other factors (e.g., economy of scale, weather limitations and complexity)	N/A
Arizona	(1) Categories of railroad; (2) Construction impacts; (3) Project duration; (4) Environment; Safety; (5) Economy of scale; (6) Risk management	N/A

4.2 Overview of the Opportunities and Challenges in Project Delivery Methods

There are several project delivery methods that can be used for the contract delivery of ABC projects as shown in Figure 4. Project delivery methods are the methods facilitating the delivery of goods and services through effective organization and financing of designs, construction, operations, and maintenance activities. The determination of a suitable project delivery method for construction projects is a complex decision and may largely depend on project aim, budget, project schedule, associated risks, the expertise of stakeholders, and opportunities (Ptschelinzew et al. 2013). Efficient contracting methods are critical for creating an environment where a project can be successfully delivered. Traditionally, the cost was generally considered as a significant criterion for determining the winning bid, and most of the highways were built with Design-Bid-Build (DBB) contract delivery method. Hence, in the last few decades, Federal Highway Administration (FHWA) has started to use alternative contracting methods that encourage the deployment of innovative design solutions and minimization of unforeseen delays and cost overruns such that it accelerates the project delivery (Salem et al. 2018). Alternative contracting methods for highway construction such as Design-Build (DB) and Construction Manager-General Contractor (CM-GC)

have become popular in recent times due to factors such as social and economic impact, life-cycle costs, public perception, quality, safety, and delivery time. Thus, the federal highway started to use the DB project delivery method in the 1990s while the use of CMGC began after 2005 (Federal Highway Administration (FHWA) 2017). A comprehensive understanding of opportunities and challenges implied by each of the project delivery methods provides better apprehension of their abilities and these are explained in detail in the following section.

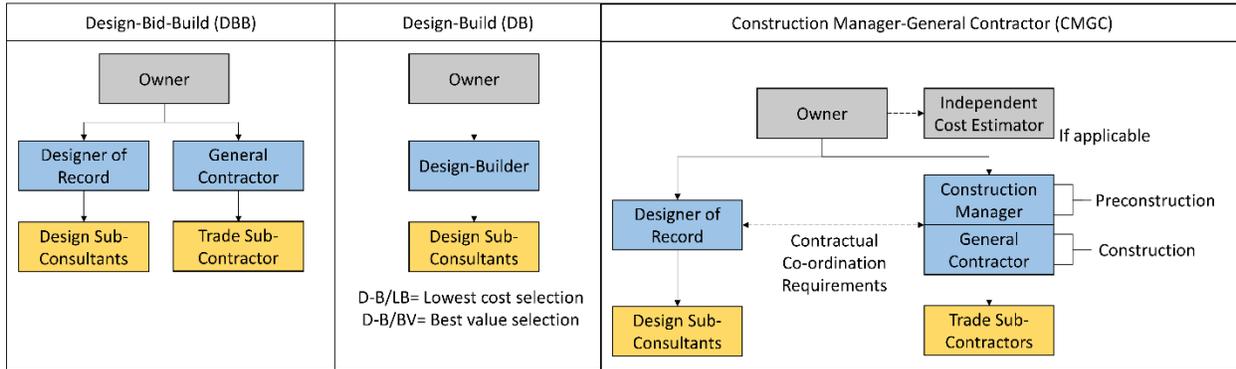


Figure 3: Project Delivery Methods Contract Structures

4.2.1 Design-Bid-Build (DBB)

Design-Bid-Build is a conventional project delivery method in which the design and construction process occurs sequentially. This linear approach of contracting involves the solicitation of the construction contract by the owner for building the project post-design completion where the lowest bidder wins the contract. Due to such price competition, the final cost of the contract may potentially become significantly higher than the bid amount. In this approach, the agency separately develops contracts of design and construction services, and the bid includes complete plans and specifications (Stutz 2000). The DBB project delivery method can be either lump-sum items or a unit-priced contract and the DOT, contractors, and consultants have a lot of experience with the traditional project delivery method (Gransberg 2013). There are some opportunities in this method in terms of reduction in potential corruption and collusion, short procurement time, predictable and manageable schedule, and increased certainty about cost estimates, among others. Despite such opportunities, some challenges also exist such as competitive innovation opportunities, level of constructability, and optimization of costs (Ptschelinzew et al. 2013). Furthermore, other disadvantages of this approach are that it may necessitate a high level of DOT staffing of technical resources as well as design, and project schedules may be unrealistic due to lack of input from the industry.

To this end, there are no legal barriers in procurement and licensing of DBB contracts due to which these are applicable to a wide range of projects. In this method, the owner needs to completely define the scope and maintain a high level of control and risk. Due to the requirement of up-front costs, the owners have sufficient time to provide input on the design since direct communication between the owner and contractor is possible (Stutz 2000). However, there is no collaboration between the designer/architect and general contractor during the design phase which makes the

process slower and consequently increases the project's timeline. In this method, most of the design risks and third-party risks should be resolved before the procurement process such as to avoid costly contractor contingency pricing, potential claims, and change orders (Ptschelinzew et al. 2013).

4.2.2 Design-Build (DB)

Design-Build is a contract delivery method where the design and construction of a project are under a single contract. A design-build contract may be a joint venture between a contractor and designer, a designer with a construction subcontractor, a single firm that performs both design and construction functions, or a contractor with a design subcontractor. In this method, the agency contracts with one entity, generally a lump sum contract with allowances or unit cost items to address the risk (Mattox 2019). Design-build is a two-phase selection process which involves qualifications in the first phase and the second phase is associated with the price plus technical components. Moreover, the design-builder is responsible for different risks specified in the contract including design errors and incomplete design. One of the key opportunities in DB contract delivery is that the contract allows innovation in resource loading and scheduling by the DB team. Furthermore, designers and contractors can collaborate to optimize means and methods as well as improve innovation (Mattox 2019). Adoption of this method also requires less DOT staff, accelerates schedule through parallel DB process, allows alternative risk allocation to the designer-builder, and avoids low bid risks in procurement (Gransberg et al. 2014a). However, DOT has less control over design, and the request for proposal development and procurement can be extensive. Other challenges implied by this method include higher procurement costs and stipends for proposers, development of request for proposal (RFP) requires a considerable amount of time, and smaller construction firms are less likely to get opportunities.

Douglas et al. (2017) highlighted that DB provides a lot of opportunities for DOT in the assessment of several solutions to the same design problem. It also provides an opportunity to properly allocate risks to the party best able to manage those risks. However, the allocated risks should be well defined such that it minimizes contractor contingency pricing of risk. Additionally, instead of using traditional construction drawings, specific requirements of design-build projects are laid for each of the potential contractors on which to base the bid of the project (Gad et al. 2020). The requirements include certain criteria that the contractor must use to design the project. In terms of delivery schedule, the procurement of the DB contract method is very lengthy due to the time required for the development of an adequate RFP, evaluation of proposals, and provide for a fair and transparent selection process.

4.2.3 Construction Manager General Contractor (CMGC)

This project delivery method involves procurement of professional services based on qualifications or best value from a construction manager during the design phase such that cost and schedule savings, innovations, and constructability issues can be offered (West et al. 2012). This method consists of three phases which include the concept phase, design phase, and construction phase.

The contractor and agency make the negotiation of construction contract price after completing the design or individual design packages, and the construction manager acts as a general contractor to complete construction (Gransberg 2014). Through the use of unit price or lump-sum contract, the contract guarantees maximum price administered on a cost-reimbursable basis. In this type of contract delivery method, the three-party process can slow the progression of design due to which strong DOT management may be required to control schedule. Additionally, the overall process depends on the designer-construction manager relationship (Gransberg et al. 2014a). Despite these obstacles, there are several advantages of utilizing this method such as procurement of long-lead items, shorter procurement schedule, innovative opportunities to allocate risks to various parties, and schedule for phasing, traffic control and constructability may be reduced through the input of contractor.

In CMGC projects, owners are able to reduce risks of cost overruns and project delays as well as transfer specific risk to the contractor. In this project delivery method, the contract is awarded during the design phase and the potential design flaws that affect construction can be reduced as the contractor has the opportunity to comment on the design being produced. Additionally, risks can also be mitigated if the contractor performs specified preconstruction work. Then, after the design is prepared, the stakeholders finalize the schedule and construction work price that involves either a fixed or a guaranteed maximum price. This type of project delivery method also allows the agency, contractor, and designer to comprehensively identify and minimize project risks and allocate risk to appropriate parties. As such, it provides an opportunity to reduce contractor contingency pricing of risk, but it can lose the element of competition in pricing.

4.3 Alternative Technical Concept and Project Delivery Methods

Alternative Technical Concept (ATC) is a proposal made during the bidding or procurement process to gain competitive benefits in terms of modifying the project's scope of work. ATC is one of the methods of early contractor involvement allowing them to propose modifications to contract requirements before the bidding or proposal process (Mattox 2019). The use of this technique helps to: (1) deliver the project on budget; (2) reduce the impact on the public by the efficient flow of regional and local traffic safely; (3) incorporate an innovative design that fosters faster construction; (4) quality control and inspection; (5) demonstrate quality construction; and (6) encourage green techniques. Likewise, since ATC fosters alteration in baseline design and provides potential design solutions to complex design problems, its usage has been successfully integrated into different types of project delivery methods (Gransberg 2014). This approach also encourages best-value solutions through an equal or better product during procurement and allows owners to receive the complete savings value rather than half of the share. The popularity of ATC in recent times has increased the number of submittals from many contractors, thereby increasing the competition and resulting in a significant number of bids. Gransberg et al. (2014b) indicated that the use of the alternative technical concept is not limited to any type of project delivery method and can be implemented regardless of technical or procurement issues of all kinds of transportation projects. Additionally, some of the states allow the alternative systems to be implemented in other projects in the future such that the benefits of ATC for contract delivery and a widely applicable

innovative design can be exploited. However, the processes involved in implementing ATCs significantly varies with each project delivery method. Moreover, the processes also vary from one state to another, and Table 2. provides general processes involved in the use of ATC for project delivery.

Table 2: Overview of ATC processes in project delivery methods (Arthur et al. 2016)

S.N.	Design-Build	Construction Manager-General Contractor	Design-Bid-Build
1.	Design-builders conduct solicitation of design and construction proposals after RFP is issued on partially completed designs by DOT	Construction managers conduct solicitation for preconstruction and construction services after RFP is issued on partially completed designs	DOT requests bids on the completed baseline design
2.	Design-builders may submit their proposals along with the implementation of ATC	Construction managers may submit their proposals along with the implementation of ATC	Contractors may submit their bids with ATCs
3.	DOT implements a confidential process to review ATCs with design-builders	DOT implements a confidential process to review ATCs with construction managers.	DOT implements a confidential process to review ATCs with contractors.
4.	Design-builders can implement ATCs in their proposal after receiving approval from the DOT	The procurement process involves the use of ATCs as a part of scoring criteria	DOT or contractors may further develop the design with the provision of unit-lump-sum costs after the approval of ATCs
5.	Based on selection criteria in RFP, DOT selects winning design-builder	Based on selection criteria in RFP, DOT selects winning construction manager	Lowest bidder wins the contract
6.	Design-builder can implement their design either based on ATCs or baseline design. If a stipend is paid to unsuccessful bidders and suitable contract language was used in RFP, the ATCs from those unsuccessful bidders can be integrated into the design	After the contract is awarded, DOT conducts a complete evaluation of ATC. During the preconstruction phase, DOT or engineer may integrate ATCs with winning CMGC. If suitable contract language was used in RFP, the ATCs from those unsuccessful bidders can be integrated into the design	Construction proceeds with design with the lowest bid and there is no requirement of any additional designs.
7.	Design-builder is responsible for the design liability for ATC	DOT or DOT hired engineer is responsible for the design liability for ATC	DOT, DOT hired an engineer, or the contractor may be responsible for the design liability based on who developed the design.

4.3.1 Alternative Technical Concept for Design-Bid-Build

Adoption of ATC in DBB provides a solution that is equal to or better than the owners' base design requirements in the invitation for bid (IFB or DBB) or request for proposal (RFP for DB) document (Mattox 2019). It has the potential to increase constructability and schedule reduction as well as intangible benefits such as enhanced safety during construction, decreased environmental impact, and reduced life-cycle costs for a project's useful life. Since the completion of cost and schedule impact analysis and subsequent evaluation and approval can be done without the pressure of a letting or proposal due date, ATC is the factor of selection in the award of preconstruction contract (Ormijana and Rubio 2013). In DBB, the contractor's bids are submitted after approval of ATC as shown in Figure 5, and it imposes a field-testing condition before the award creates an unacceptable delay in the procurement schedule. Therefore, ATCs are not constrained by an agency's project delivery selection, and agencies can implement ATCs without being constrained by technical or procurement issues on various transportation projects (Gransberg and Tapia 2016). Such nature of ATC potentially makes it the most appropriate delivery method to reduce the delivery period.

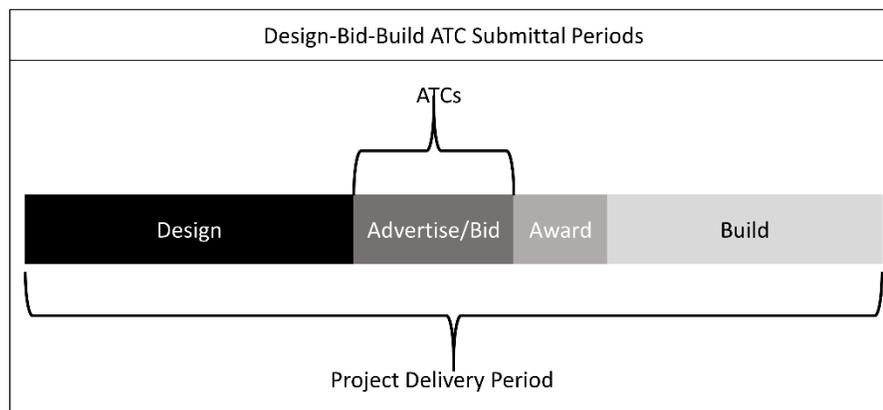


Figure 5: ATC submittal period in Design-Bid-Build method

There are different legal and contractual issues surrounding the use of ATCs on DBB projects. Confidentiality, protest rights, and criteria for consideration and acceptance are some of the legal issues related to ATC identified through procurement documents for a given project (Gransberg and Tapia 2016). It is significant to provide detailed information about the conduction of one-on-one meetings in the procurement documents to ensure confidentiality. Competitors are allowed to have confidential one-on-one meetings for determining potential ATCs and receive an indication response of department for a given ATC (Gad et al. 2015a). Figure 6. shows that ATCs may also be approved before the confidential One-on-One meeting. Hence, competing contractors are able to build a competitive edge with their ATCs by guaranteeing the confidentiality of proposed ATCs under any project delivery method (Boylston 2014). Gad et al. (2020) indicated that proprietary meetings are an effective way to maintain confidentiality and the creation of formal agreement among all participants. Additionally, the authors also recommend increasing awareness of confidentiality principles among owners and the proposer. It is also important to publish a detailed

ATC evaluation system in the projects' solicitation document to allow the competing contractors to comprehensively understand the process involved in ATC (Arthur et al. 2016). To address other legal issues, the separation of the ATC evaluation team from the proposal team is another effective practice for avoiding the appearance of impropriety (Gad et al. 2015b). Similarly, legal issues in ATC are specific to each local jurisdiction, and legal counsel knowledgeable about the jurisdiction will be the best source for advice on how to proceed with ATCs (Gransberg et al. 2014a).

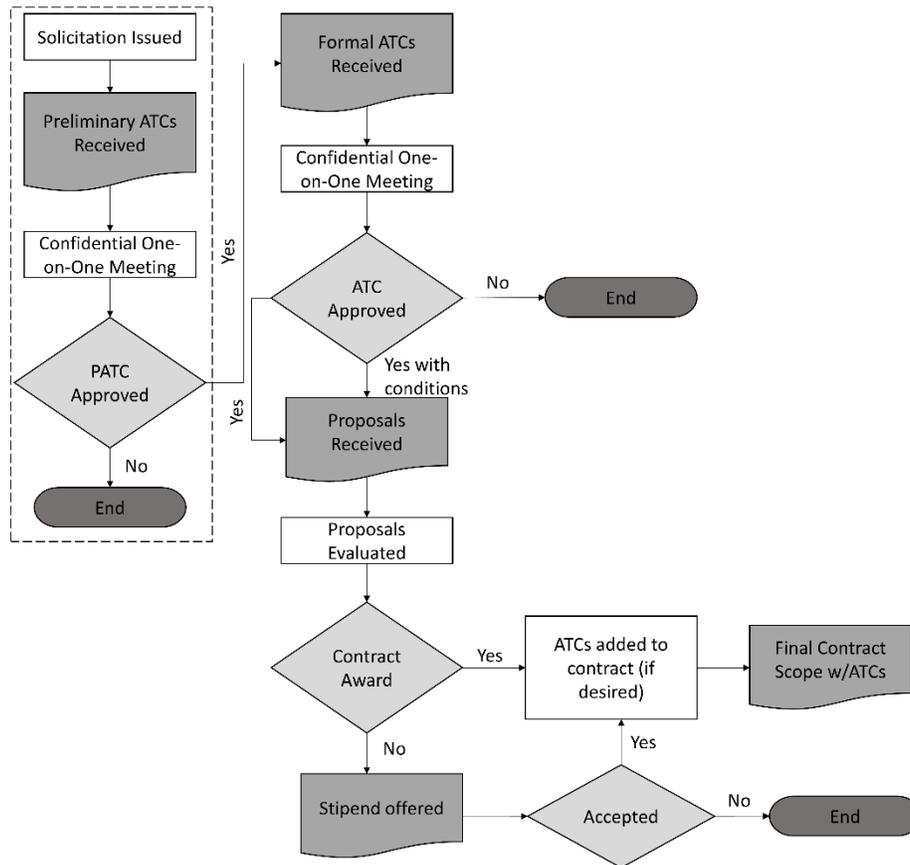


Figure 6: Generic ATC evaluation and review process (Gransberg 2014)

4.3.2 Alternative Technical Concept for Design-Build

A project delivered through the Design-Build method of procurement is generally designed and parallelly constructed with concurrent efforts of the designer and the contractor. With the progress in the project, the designer and the contractor both coordinate to combine their respective expertise to complete the project as efficiently and cost-effectively as possible. This approach also offers the greatest flexibility for both the owner and contractor which can be realized when integrating alternative technical concepts within the procurement process. When ATC is integrated into Design-Build, contractors are able to implement innovative solutions while remaining responsive to the Request for proposals (RFP) and eligible to pursue the project (Mattox 2019). However, the proposed modifications to the requirements should produce results equal to or better than that specified in the requirements of the RFP. Furthermore, the process by which the contractor may

propose an ATC is detailed in the RFP and the overall ATC submittal period is as shown in Figure 7. The process of proposal evaluation and approval by the DOT is conducted through a confidential and one-on-one meeting with each contractor. Overall, a successful contractor is thus, able to integrate innovative ideas and designs in the project outside of the original project scope (Gransberg et al. 2014a). For instance, the South Carolina Department of Transportation (SCDOT) has completed three projects by integrating ATC in Design-build projects and the other two projects are actively being procured through the same process (Mattox 2019). The evaluation of this integration indicated that the adoption of ATC has had a positive influence on design-build project bottom lines and schedules ultimately, benefitting the taxpayers of South Carolina. However, Boylston (2014) indicated that more research needs to be done to evaluate the effect of innovative ideas emerging from the integration of ATCs on transportation such that the most valuable ones can be incorporated into future design-build projects.

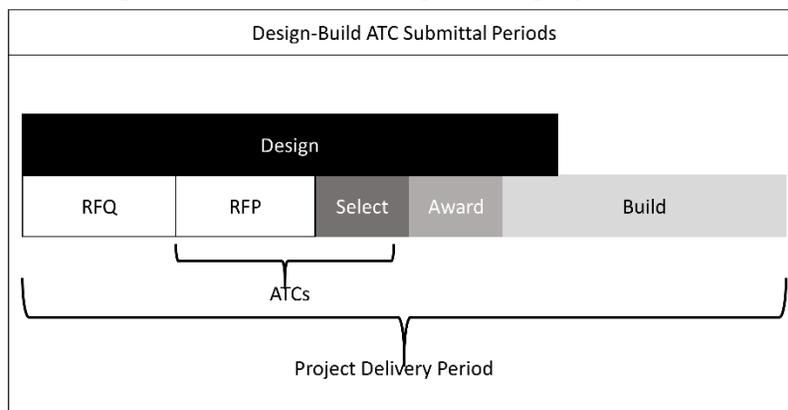


Figure 4: ATC submittal period in the Design-Build method

4.3.3 Alternative Technical Concept for Construction Manager General Contractor

Among various project delivery methods that has integrated ATC, CMGC has been found to be one of the most appropriate for the inclusion of innovative approaches to project execution in RFP (Gransberg 2013). CMGC project delivery process also simplifies the ATC evaluation process because construction pricing is not locked down. Thus, ATCs can be incorporated on CMGC directly into the final design without loss of resources exhausted on the baseline design (Ptschelinzew et al. 2013). Figure 8 shows the ATC submittal period of CMGC indicating that it offers an opportunity for management of ATC design/performance risk by requiring full-scale testing of the ATC on the project itself before approval (Gransberg and Shane 2015). Similarly, ATCs have the potential to accrue tangible benefits in terms of cost savings and reduction in life-cycle costs for a project’s useful life. To ensure the minimum cost savings constraint entailed in the solicitation document, cost data are necessary to prove that the ATC will accrue actual cost savings (Gransberg 2014). Overall, the increase in the use of CMGC is mostly due to the benefits to: (1) gain constructability input from the construction contractor for reduction of construction costs and time; (2) reduce time schedule and budget uncertainty; and (3) reduce risk and encourage innovation. For example, during the construction of a new bridge in Multnomah County, Oregon

the DOT switched the delivery method from traditional DBB to CMGC because the overall budget became tighter with the advanced designs. On the other hand, Gad et al. (2020) indicated that there may also be issues if cost data is not considered and the approval of ATC is based only on the technical evaluation. Also, there will be no expectation of specific cost savings as ATC will be considered as the contractor's bid price. Moreover, the inclusion of cost data may also influence decision of evaluators if the cost of ATC is transparent to the evaluators (Gad et al. 2015a).

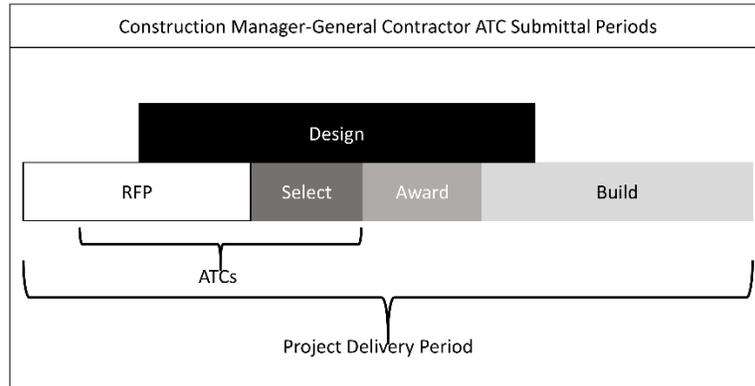


Figure 5: ATC submittal period in Construction Manager-General Contractor method

Through the use of CM/GC ATCs during bridge replacements, road stabilization, maintenance crew training, parking lot design, and construction, there were total savings of more than \$1.15 million and reduction of construction duration to less than 10 months (Gransberg and Shane 2015). Utah DOT is one of the most experienced state transportation agencies in CMGC with completion of approximately 20 CMGC projects under Utah DOT professionals. Some of their projects indicated that the contractor is extensively involved in the preparatory work to understand the project, bid properly, as well as implement innovation to save time and money. The Sellwood Bridge replacement project in Oregon also utilized ATC in CMGC contracting method and the project benefited through the assistance of contractors for dealing with constructability issues, providing real-time market pricing capabilities, and insight on more efficient design and schedule. Overall, Gransberg (2013) highlighted that there are several projects in Florida, Maine, Minnesota, Missouri, New York, and Utah that utilized design-bid-build (DBB), construction manager-general contractor (CMGC), indefinite-delivery and indefinite quantity (IDIQ) and design-build (DB) contracts to expedite the procurement process and restore the infrastructure systems. Rouhana and Hamzeh (2016) indicated that quality assurance and acceleration of project delivery are most effectively achieved in a design-build setting where the management of the design, as well as construction, is mostly controlled by the contractor. The CMGC model also integrates construction contractors into the design phase by using the contract of preconstruction services, but a DBB contract doesn't integrate such provisions (West et al. 2012). In fact, DBB often constraints innovation, leads to high cost, time growth, and seldom provides the best value to the owner (Stutz 2000). In recent years, there is a growing interest in incorporating Alternative Technical Concepts (ATC) on these contract delivery methods such that early contractor involvement for achieving integrated project delivery on conventional low bid projects is possible

(Gransberg 2014). Regardless of the aforementioned advantages of ATC, such a contract delivery method is not frequently used in ABC projects as there aren't yet guidelines which provide a streamlined procedure to embrace ATC in ABC projects.

4.4 Prospective of ATCs for Contract Delivery in Accelerated Bridge Construction

As many states are adopting ABC to upgrade the functionally obsolete or structurally deficient bridges across the United States, an innovative contract delivery method is necessary to improve the ABC decision-making process and expedite project delivery. For effective decision making in ABC, tools have also been developed which have helped to plan alternatives in the early stages by preventing costly investments (Saeedi et al. 2013). ElZomor et al. (2018) also highlighted that tools such as Project Definition Rating Index (PDRI) have been found to be effective for assisting in front end planning efforts for small as well as large infrastructure projects thereby, facilitating the assessment of risks and defining of infrastructure projects. However, these tools do not facilitate effective contract delivery, but rather focus on planning, alignment, and in the design stages. Therefore, there is an opportunity to exploit the benefits of ATC in ABC projects to expedite project delivery through the most economical design, which is achieved through early contractor involvement. Besides, the ATC technique not only maximizes opportunities for contractor innovations (i.e. means and methods) but also enhances constructability (Gransberg 2014). This creates possibilities for cost reduction and effective design solutions. Another advantage is that it helps to gain control over as well as accelerate the procurement of design and construction assets and the project delivery time (Mattox 2019). Gransberg et al. (2014) developed NCHRP Synthesis 455 (Alternative Technical Concepts for Contract Delivery Methods) which was completed in 2014. This synthesis project included a detailed literature review, a DOT survey, and a case study of nine projects from different states. The project was focused on contractual variances and its challenges as well as determining the cost and schedule savings when including ATC.

There are several contract delivery methods that may be adopted in ABC projects, yet for example, Build operate and transfer (BOT) postures uncertainties and risks associated with such delivery methods due to the existence of several complexities in projects (Ebrahimnejad et al. 2010). Despite lowering the role of government in the BOT project and increasing private investments, BOT poses threat to project delivery in terms of legal, technical, construction, social, and economic risks among others (Kumaraswamy and Morris 2002). Mesa et al. (2016) highlighted that integrated project delivery (IPD) is an emerging delivery system with minimum risks and is known to improve supply chain integration in complex building projects. Although the project delivery method like IPD had a positive impact on mega projects, construction stakeholders seldom comprehended the effectiveness of such a method in projects (Matthews and Howell 2005). The major feature that facilitates IPDs' effective project delivery is the early collaboration of key project stakeholders which eventually helps meet owners' performance expectations (Hanna 2016). Gransberg et al. (2014) indicated that ATC is one of the integrated project delivery methods which bolsters competitiveness during the bidding process and ultimately helps meet or even exceed the performance expectations of owners. Despite that contractors usually aspire to reduce

bid costs in infrastructure projects without consideration of contract methods, impacts on travelers, and disturbance of traffic (Saedi et al. 2013). This study challenges this concept by emphasizing the cost and schedule saving associated with ATC for ABC projects as well as highlighting and providing a metric to support contractor realize the merits of using ATC on ABC projects. Thus, there is an emerging need for a contractual framework for ABC projects that not only ensure last longing bridges but also deliver ABC projects quicker, safer, cheaper, and more innovatively.

To this end, the early contractor’s involvement not only encourages effective project delivery of ABC projects but also guarantees the success of such complex projects, which in turn prerequisites a special contract method that supports early contractors’ involvement. Focusing on ABC projects, their contractual and design agreements usually include preconstruction activities such as prefabrication of elements that require effective and well-planned procurement strategies. Therefore, to ensure the delivery and manufacturing of such long lead items for ABC projects, it is imperative to hold early meetings between the construction stakeholders (i.e., owners, contractors, engineers, consultants, suppliers, etc.); as well as ensuring early clearance and permitting associated with environmental cases for ABC projects (Khaleghi et al. 2012). The use of ATCs can reduce risk when implementing innovative design solutions to complex design issues due to which it shows great potential to be implemented in ABC projects as a project delivery method. California DOT reported overall savings of \$164 million in eight projects utilizing Design-Build ATCs with 50 to 1 return on investment (Clark and Angeles 2018). Additionally, Figure 9. shows the examples of ATC being implemented for contract delivery in accelerated bridge construction such as Larpenteur Avenue bridge construction in Minnesota, Courtland Street Bridge in Georgia, and MemFix4 project in Tennessee which are compared in terms of their advantages, opportunities and obstacles.

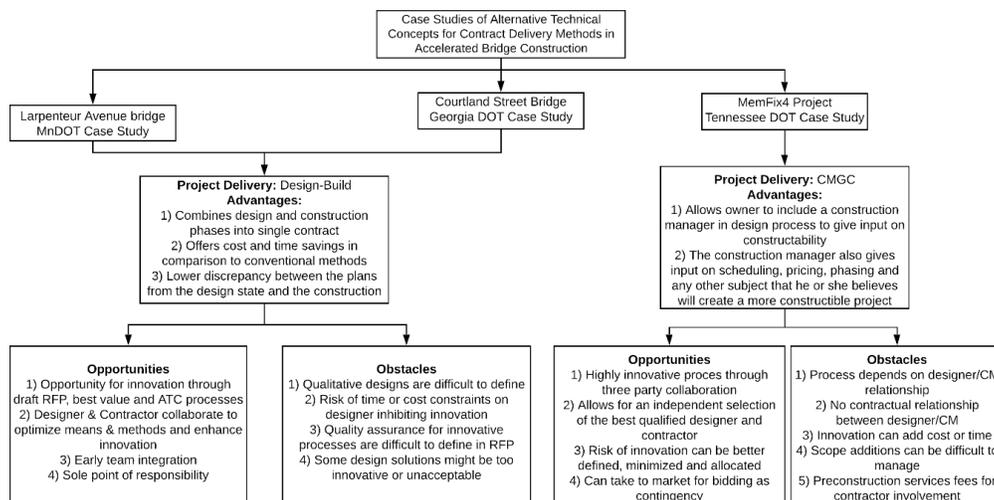


Figure 6: Comparison of different case studies utilizing DB and CMGC project delivery methods

Carfagno et al. (2018) implemented the design-build (DB) project delivery method in accelerated bridge construction projects under the Washington Department of Transportation (WSDOT) reducing the construction time to 17 days as well as minimizing the traffic impact and overall cost of the project. The design-builder team eliminated the temporary detour bridge originally proposed in favor of a full road closure with the approval of ATC. Early contractor involvement in this project provided better quality control and although there were minor delays, the project objective of demolishing the existing bridge and construction new ABC bridge was completed within 17 days by working two shifts per day. Therefore, valuable lessons can be learned from case studies that integrated ATC in project delivery method and the factors listed in Figure 10 should be considered for successful adoption of ATC. Through consideration of these success factors innovative designs and more sustainable solutions in ATC would reduce the overall carbon footprint and deforestation, thereby reducing the environmental implication throughout the construction period. Secondly, there would be reduction in construction duration which will eliminate the inconvenience to the traveling commercial vehicles, public and local businesses. Additionally, the approach would also reduce the safety concerns through the management of live traffic adjacent to the project. Hence, with the use of ATC for contract delivery the overall satisfaction level as well as costs linked to the communication and management of public relations before and during construction could also significantly improve. With the growing concern for more flexibility to adopt innovative solutions and reduce the risk of costly change orders in ABC projects, integration of ATC in contract delivery of ABC projects is critical for maintaining, replacing and rehabilitating the structurally deficient and functionally obsolete bridges across the U.S. However, there are only a few case studies integrating ATC for contract delivery in accelerated bridge construction projects which has not yet been thoroughly investigated. Therefore, this study will scrutinize these projects as well as develop guidelines for expanding the scope of the ATC approach in ABC projects.

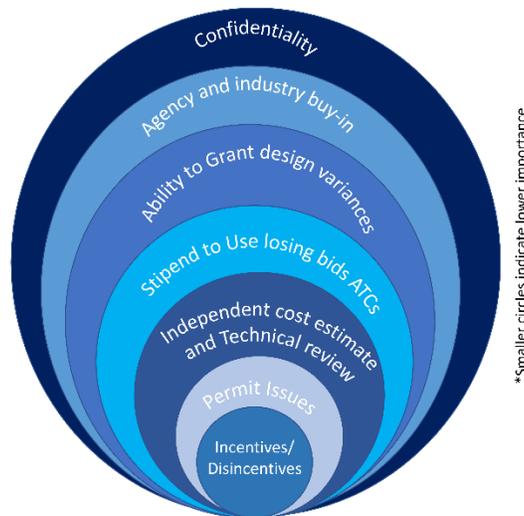


Figure 7: Alternative technical concept success factors

Task 2 – Data Collection

Proposed task description:

Analytical hierarchical process (AHP) is a decision-making tool that supports transportation specialists, researchers and decision makers to assess the alternatives with more confidence and for avoiding investment in alternatives that are most expensive. The first and most challenging process in AHP is essentially the identification of decision criteria. These criteria within the created hierarchy are homogenous at each level and indicate a similar level of specificity. The decision hierarchy of criteria was developed, in part, based on a review of relevant literature and case studies as shown in Table 3. The hierarchy includes seven criteria that will be used to evaluate three alternatives (i.e., ATC for DBB, ATC for DB and ATC for CMGC) and the analysis will facilitate to rank the most effective alternative based on survey questionnaire. The research team also identified and invited two research advisory panel (RAP) experts to validate these criteria and support the research.

Table 3: Criteria for integrating ATCs for contract delivery in ABC projects

S.N.	Criteria	Definition	References
1.	Legal and contractual issues	This criterion captures diverse issues associated with ATC implementation that create challenges for the procuring agencies and those entities responding to the procurement. E.g., Confidentiality, protest rights, and criteria for consideration and acceptance.	(Gad et al. 2015a, 2020)
2.	Direct and Indirect costs	This criterion captures direct costs including estimated construction cost, maintenance cost ,design and construction of detours, right of way, project design and development, maintenance of essential services, and toll revenue as well as indirect costs including user delay, freight mobility, revenue loss, livability during construction, road user exposure and construction personal exposure.	(Gransberg 2014; Gransberg and Shane 2015; Saeedi et al. 2013)
3.	Environmental impacts	This criterion captures the constraints placed on the project in terms of reducing impact on environment (both social and natural, including commitments).	(Boylston 2014; Freeseaman et al. 2020)
4.	Risk assessment and Innovative approaches to project execution	This criterion captures innovative opportunities to allocate risks to different parties (e.g., schedule, phasing, and means and methods), and resolve complex design issues through innovative designs.	(Carfagno and Dickerson 2018; Ormijana and Rubio 2013)
5.	Project Schedule / Duration	This criterion evaluates the total project delivery as measured from the time of the value analysis study to completion of construction.	(Freeseaman et al. 2020; Mattox 2019)
6.	Construction impact	This criterion captures the temporary impact to the public during construction related to traffic disruption, detours, and delays; impacts to business and residents in	(Clark and Angeles 2018; Mattox 2019;

		association with noise, visual, dust, access, vibration, and traffic.	Saeedi et al. 2013)
7.	Customer service (Public perception and relation)	This criterion captures the publics' perception on construction progress, their overall satisfaction level as well as costs linked to the communication and management of public relation before and during construction.	(Freeseaman et al. 2020; Gad et al. 2015b; Saeedi et al. 2013)

The authors prepared a survey questionnaire to: (1) weight the factors/criteria in a hierarchy, which provides an overall view of the relationship among the factors; and (2) evaluate and rank the alternatives i.e., ATC for contract delivery of ABC projects. The survey questionnaire is designed for collecting pairwise comparison of data using Saaty's fundamental scale as shown in Table 4. The questionnaire will include all the pairwise comparisons within criteria and alternatives. The survey will be conducted for couple of months to certify the collection of a representative sample size. Only those stakeholders who are involved in the Accelerated Bridge Construction-University Transportation Center (ABC-UTC) research project will be selected for survey as the diverse set of expertise in this research group would help to advance the frontier of ABC. The survey results would eventually assist in preparing an agreed upon guide specific for ABC stakeholders, which pledges to expedite contract delivery in ABC projects.

Table 4: Saaty's fundamental scale of absolute numbers (Saaty 2004)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Description of work performed up to this period – In-Progress.

Task 3 – Data Analysis

Proposed task description:

The objective of the third task is to conduct an analytical hierarchy process, which is a multicriteria decision-making method combining a hierarchy of decision criteria and consisting of both tangible and intangible factors for obtaining the priorities related to alternatives. In this analysis, first a decision hierarchy is developed in which the focus group/interview divides a complex decision problem into a number of hierarchical levels. Secondly, priority analysis is conducted in which a series of pairwise comparisons are made among the identified factors within each level. Lastly, consistency check is done in which the experience and knowledge of the interviewed key stakeholders are utilized to make a pairwise comparison with respect to overall decision goal. Here, a pairwise comparison refers to the comparison between pairs of homogenous elements. The results of AHP would be used to prepare a guide for practitioners to utilize ATC which eventually expedites contract delivery in ABC projects.

Furthermore, box plots will be created using R-studio to provide the descriptive statistics results of the survey. Once the data is analyzed, a binary logistic regression model will then be developed. The model helps predict the probability that an observation falls into one of two categories of a dichotomous dependent variable. Furthermore, the significance test, which validates the binary logistic regression analysis, uses the t-score to describe how the mean of the data sample with a certain number of observations is expected to behave. Whereas the P-value indicates the confidence level, in terms of correlation, of each variable with the dependent variable. For this analysis, a 90% confidence interval will be assumed.

Description of work performed up to this period – In-Progress.

Task 4 – Recommendations and Metrics

Proposed task description:

This task compiles and comprehends the data analyses by providing a robust approach using the analytic hierarchy process and binary logistic regression analysis. This approach will facilitate the construction stakeholders to determine the applicability of ATC in ABC projects by taking into account a wide range of criteria. In this research, criteria hierarchy associated with ABC will be developed through focus group/interviews. Then, the identified criteria consist of a subset of decision criteria that are relevant to the research objective of ABC projects. Due to the involvement of different construction, transportation, and structural experts with various backgrounds in this study, the decision criteria will be defined in such a way that the comparison of conventional contract delivery methods with ATC can be satisfied by many different experts. The process is highly influenced by the input data obtained from the focus group discussions, yet the validation (distribution of surveys) will be introduced to guarantee the normality of results. The analytic hierarchy process is efficient when used for problems with relatively small number of alternatives.

Description of work performed up to this period – In-Progress.

Task 5 – Final Report

Proposed task description:

A final report will be developed to summarize the research conducted by FIU and recommendations developed from the research; this deliverable also includes a Guide, 5- min video presentation and sharing of Project Data.

Description of work performed up to this period – In-Progress.

5 Expected Results and Specific Deliverables

One of the primary outputs for the project will be the “Guide to Use of Alternative Technical Concepts (ATC) for Contract Delivery Methods in Accelerated Bridge Construction (ABC)”. This guide will summarize existing challenges, discuss incentive/disincentive Clauses on ABC, and showcase best practices of ABC projects that included ATC in the bid procedure and project delivery. Anticipated output would be a metric to successful ABC projects for owners to consider.

5.1 Applicability of Results to Practice

Adding a more rigorous metric that can forecast ABC projects for owners precisely when ATC are enforced, will position this research project to complement previous endeavors where the cost and contractual methods were analyzed for ABC projects. To this end, ATC in ABC projects can be universally utilized.

6 Schedule

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

Task #	Research Task	2020								2021							
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Literature Review	Work Performed	Work Performed	Work Performed	Work Performed												
2	Data Collection				Work Performed	Work to be Performed											
3	Data Analysis							Work to be Performed									
4	Recommendations and Metrics											Work to be Performed					
5	Final Report “Guide to Use of ATC in ABC”													Work to be Performed			

■ Work Performed
■ Work to be Performed

Item	% Completed
Percentage of Completion of this project to Date	15%

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