DEVELOPING ABC SUCCESS INDEX TO SUPPORT CONTRACTORS DURING PRE-PROJECT PLANNING

Quarterly Progress Report

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1. Project Abstract

Accelerated bridge construction (ABC) is known to reduce on-site construction time, safety hazards, and public nuisance drastically, yet contractors struggle to identify success indicators while planning for ABC projects. The goal of this research is primarily geared towards supporting ABC contractors through twofold attracting contractors to adopt ABC projects and inform project stakeholders about ABC success indicators during the pre-project planning phase. Given that some contractors are new to the ABC method providing knowledge of ABC success indicators during the pre-project planning phase will significantly impact ABC project success. This is particularly true since planning efforts conducted during the early stages of a construction project, known as pre-project planning, which encompasses all the tasks from project initiation to beginning of detailed design, have a significant effect on project success than efforts undertaken after project kickoff. Therefore, it is fundamental to reinforce the success of ABC projects during the early planning phase by pre-informing contractors about the success indicators, which can be developed into a tool elicited from analyzing successes of previous ABC projects. To achieve this goal, the first step will be to conduct a State-of-the-Art and State-of-the-Practice literature review. The data collected through a systematic literature review (SLR) will support the objective of identifying and classifying the success indicators and criteria in ABC projects as well as finding potential case studies to interview and analyze. The research plans to facilitate separate ABC industry interviews-workshops including professionals from construction, transportation, and the structural disciplines to define the required weighted success criteria. The interviews will also support evaluating those success indicators through providing success prioritization data, which will be statistically analyzed to develop a corresponding weighted score sheet, i.e., “ABC Success Index”. A machine-learning algorithm will develop a regression model to determine the correlation of ABC projects' independent variables (success indicators/project performance factors). Moreover, the ABC Contractors’ Success Index will also be evaluated and tested once completed on another set of ABC projects to validate its merits. The findings of the study foster the development of a streamlined procedure for effective adoption of ABC, which support (1) educating contractors to adopt ABC projects successfully; and (2) encouraging ABC stakeholders to understand and realize the required steps to achieve success in ABC projects during the pre-project planning phase. One example of how the index may support ABC contractors’ successes is to prioritize safety through guiding contractors to avoid the traditional requests of compressing schedules and pressuring construction since this may compromise not only safety but quality too. Furthermore, the interactive index will alert ABC contractors about expected challenges and share previous ABC successes around the nation, which would provide more confidence by showcasing quantitative comparative exemplar successes in ABC projects and thus increase bidding competition for ABC projects. It is vital to provide an ABC Success Index, which serves as a success threshold to guide ABC project stakeholders during early project planning. Consequently, the research team plans to embrace marketing strategies, including integrating the ABC Success Index into websites, educational materials, conferences, and webinars to strengthen the useability of the index amongst DOTs personnel and contractors. Finally, this index will potentially support the project’s cost, quality, and schedule, thus ultimately, endorse higher chances of planned success to ABC projects.

2. Research Plan

2.1. STATEMENT OF PROBLEM

ABC projects utilize off-site construction, alignment, material coordination, innovative design, and construction methods safely and cost-effectively to significantly reduce the onsite construction time and improve safety compared to the traditional bridge construction method. To this end, different decision-making tools have been developed to guide transportation specialists in determining the applicability of the ABC technique for a given bridge project. Two of the most common methods used for decision-making are the qualitative approach (i.e., yes/no questionnaire survey) and the quantitative approach (i.e., analytical hierarchical process), which helps to decide whether a project needs acceleration in schedules or can be constructed with conventional practices. Although these frameworks and tools provide an opportunity to make an efficient decision on construction method selection, those tools do not support in the advanced planning stage, i.e., Front End Planning through highlighting the successes and expected challenges when planning for ABC projects. As such, there is a growing concern for elevated costs incurred by the ABC method. Many contractors and manufacturers face technical problems due to a lack of appropriate knowledge and tool to assess the successes and potential challenges in integrating the ABC technique. Several different factors impact the successes of ABC projects, particularly during the planning phase, which is yet to be investigated. ABC contractors not only need a framework to support in helping make a decision to pursue an ABC project but also can strongly benefit from a tool that supports their advanced planning in ABC as well as learn and leverages from previous successes of ABC projects. The demand to successfully support contractors in pursuing ABC projects is not only inaugurated by contractors but also from other stakeholders, including AASHTO and DOTs personnel. Unfortunately, sometimes projects are asked to rush the delivery of the project to meet a new opening date, which may threaten safety and compromise quality. Therefore, leveraging our existing ABC database inventory of ABC Projects with tight construction schedules is critical to inform and guide future ABC projects about success indicators as well as safety risks, schedule overruns, quality issues, and additional costs. To this end, the index will support, educate and direct ABC contractors to realize/value the significance and consequences of such changes. This research fills in the research gaps by providing a user-friendly and flexible success indicator tool that not only encourages the adoption of ABC but, more importantly, supports contractors during the advanced planning stage of an ABC project.

2.2. RESEARCH APPROACH AND OBJECTIVES

The research team set forth the objective of producing a user-friendly tool for identifying ABC success indicators with the following characteristics and functions: (1) identify the success indicators based upon the literature and industry expertise; (2) conduct ABC industry interviews-workshops for professionals from construction, transportation, and the structural disciplines to define the required weighted success criteria, i.e., ABC Success matrix; and (3) develop regression model with a machine learning algorithm that would help to determine the correlation between different project performance factors and expected success in ABC projects as well make accurate predictions. The developed index will support ABC stakeholders, and contractors use the tool to anticipate successes and risks, thus managing safety and the quality, schedule, and cost of ABC projects. Given the need to involve and learn from different ABC expects in construction, transportation, and structural, the research team will develop a Research Advisory Panel to represent all stakeholders to support, guide research, and ensure the research is satisfactory by different experts. The study will utilize a structured approach to identify success indicators through a Systematic literature review (SLR) of relevant literature. Then, the research team will develop an interactive ABC-Success Index, which provides a qualitative score associated with the successful performance index for ABC projects. Furthermore, the developed matrix will be analyzed through statistical analysis such as correlation and regression analysis to evaluate the efficacy of the interactive matrix/tool. This approach will not only be beneficial for contractors to make an efficient decision on advanced planning in ABC projects but also provide co-benefits such as an increase in bidding competition for ABC projects since contractors will be able to identify success indicators and risks during the pre-project planning phase and thus have better confidence, risk assessment, the realization of succusses benchmarks and primary knowledge about ABC projects. Despite that a comprehensive educational strategy to support ABC contractors remains needed, the development of the proposed ABC Success Index is a necessary foundation step to educate, guide, and support contractors when pursuing ABC projects.

2.2.1. SUMMARY OF PROJECT ACTIVITIES

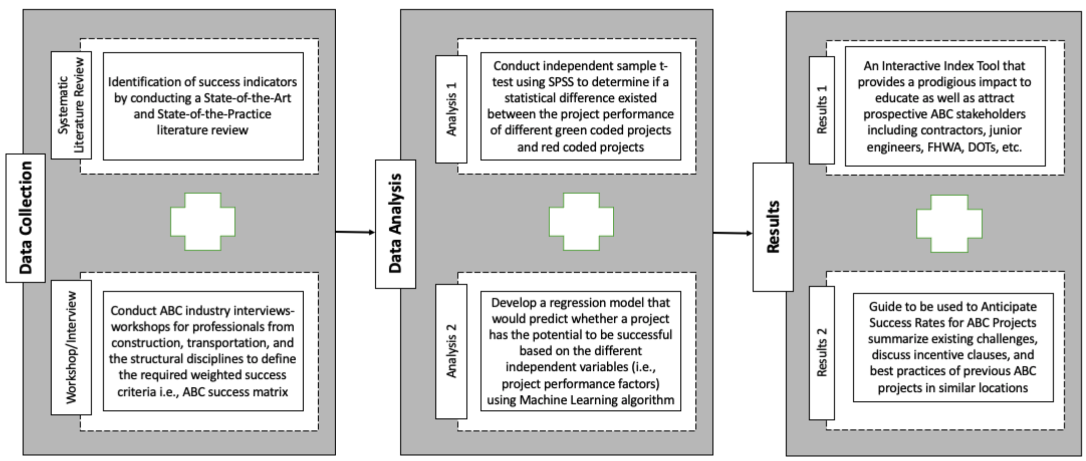

Figure 1: Overview of Project Activities and their Sequence

2.2.2. DETAILED WORK PLAN

The research objectives will be accomplished through the following work plan.

Task 1 – Literature Review

The objective of the first task is to understand the current status of infrastructure projects with a focus on accelerated bridge construction projects and the importance of Front-end Planning in infrastructure projects. The succeeding section highlights the current state of infrastructure projects, ABC technology, and Front-end planning techniques and tools.

Current Status of Infrastructure Projects

An infrastructure project is defined as a project that provides distribution, transmission, transportation, collection, or other capabilities supporting the interaction of goods, services, or people. Infrastructure projects play a critical role in the built environment. Infrastructures provide the basis for personal security and public health, influence communities' economic growth and competitiveness, provide drinking water and handle waste, and, most importantly, allow building and industrial projects to connect with all main utilities. In comparison to building projects (vertical construction), infrastructure projects are “horizontal” and act as vectors that connect residential and industrial nodes and provide services and goods within the built environment. Thus, due to such nature of infrastructure systems, these are commonly overlooked and underfunded until the service is interrupted or deteriorated. According to ISI (2018a), massive investments in infrastructure are now needed due to decades of negligence and outdated infrastructure around the world. Moreover, infrastructure projects require significant investments and result in high impacts on the built environment and the served communities. Thus, these kinds of projects pose many environmental and social repercussions over the sustainability of the built environment. Since most of the natural resources are finite and community development has consequences that affect the TBL, the construction of infrastructures should be cost-effective and sustainable (ISI 2015). The concept of sustainability originated in the late 1980s after the United Nations’ Brundtland Commission Report identified it as a “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Keeble 1988). Nowadays, sustainability concepts have become more vital among the architecture, engineering, and construction (AEC) industries.

Climate change and waste management are two environmental issues that pose a growing challenge to the construction industry and threaten the well-being of life on earth (Pradhananga and ElZomor 2020). To this end, infrastructure projects tend to reduce the ability of the natural environment (i.e., permeable soils), its habitats, and species to adapt to climate change. Despite such an impact on infrastructure projects, sustainability principles are seldom integrated during the initial phases of these projects (ASCE 2007). Additionally, these projects face unique planning challenges such as right-of-way (ROW) acquisitions or adjustments, underground works, and more interface with the public and the environment. Low awareness of a project’s societal and environmental impacts, as well as a lack of standardized procedures to quantify these impacts, are often roadblocks to achieving sustainability (Weerasinghe et al. 2007). Sustainable design aims to improve the built environment’s performance through a suite of economic, social, and environmental aspects, also known as “Triple Bottom Line (TBL)” (Elkington 1998). Some of the current sustainable management methods in construction projects are the Leadership in Energy and Environmental Design (LEED) and the Envision Rating System. While LEED mainly focuses on building (i.e., vertical) projects, Envision is a practical framework applicable to all infrastructure (horizontal) projects. Since most of the natural resources are finite and community development has consequences that affect the TBL, the construction of infrastructures should be robust and sustainable (ISI 2015). However, due to the additional challenges of infrastructure projects, i.e., more complex technologies and dynamic societal and political conditions (Wegrich et al. 2017), these projects are often left out of sustainable design and construction efforts.

The American Society of Civil Engineers (ASCE) rates the U.S. infrastructure every four years, and in 2021 ASCE reported a score of C- for infrastructures. In the report, the bridges in all 50 states were graded C, which in comparison to C+ of the ASCE 2017 report card, reflects a significant backlog of needs facing our nation’s bridges. One of the primary causes for a low score may be due to the fact that out of 617,000 bridges in the United States, approximately 42% of the bridges are more than 50 years or older and are either structurally deficient or approaching the end of their design life as shown in Figure 2 (ASCE 2021). Although 46,154 bridges in the U.S. are in poor condition in 2021, more than 178 million trips have been made across such bridges every day. Additionally, in the last two years, the annual reduction rate of structurally deficient bridges has considerably decelerated to 0.1% annually. Furthermore, several bridges’ quality has deteriorated from good to fair condition every year. ASCE (2021) report also estimated that the investment in bridge replacement and rehabilitation needs to increase from approximately $14 billion to $22.7 billion annually or by 58% to improve the current condition of bridges throughout the U.S. Although the current plan of investment from the government promises repairment of at least 10,000 critically damaged bridges and an investment of at least $20 billion (USDOT 2021), it might take until 2071 to make all of the repairs that are critically needed, with the current rate of investment. Moreover, there might be an additional deterioration over the next 50 years, making it overwhelming for the construction stakeholders to progress. Since the critical load-carrying elements in structurally deficient bridges can be in poor condition due to deterioration or damage, it is critical to adopt innovative solutions for effective replacement or renovation of these structures. Therefore, efforts are required to ensure the safety of traveling vehicles through incessant research and innovation.

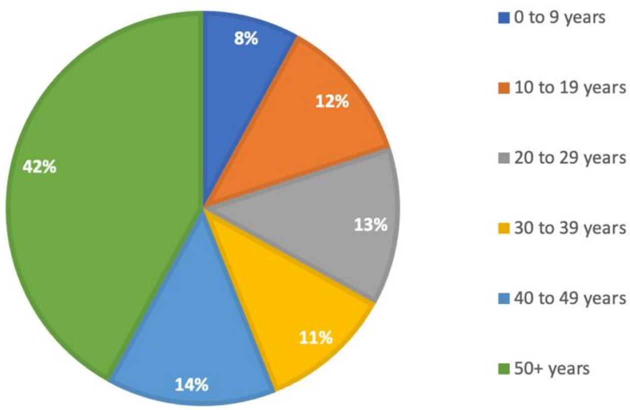

Figure 2: Age of bridges across America based on ASCE (2021) report

Current State of Accelerated Bridge Construction (ABC) Projects

Accelerated bridge construction (ABC) is one of the recent technologies that have been adopted in several bridge projects to address the issue. ABC method accelerates the construction schedule through the construction of prefabricated elements such as bridge decks, girders, pier caps, or deck panels in a controlled environment. Besides reduction in construction time, this method incorporates the use of high-performance materials, safe designs, and innovative technologies such as self-propelled modular transporter (SPMT), among others which improves the quality and constructability of the bridge (Jia et al. 2018). 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, the decision could be made regarding whether the accelerated bridge construction technique can be adopted. A comprehensive flowchart can be used to make such a decision, as shown in Figure 3.

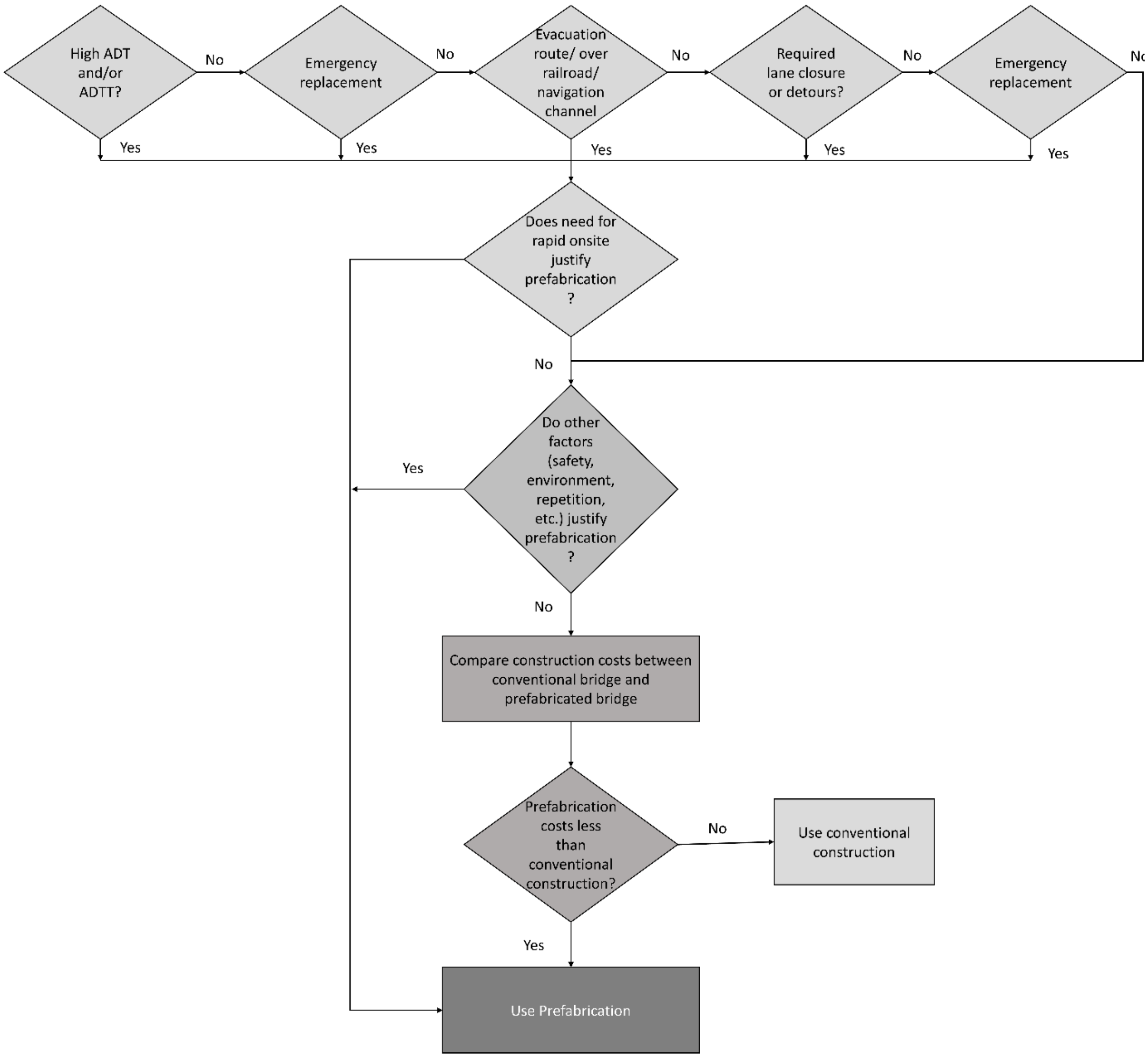

Figure 1: Flowchart for decision making on the use of the prefabricated bridge (adopted from Federal Highway Administration (FWHA) 2017)

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 Black Hawk County Bridge installation 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). Attanayake et al. (2014) also highlighted challenges in constructability faced during the integration of the ABC technique. In particular, contractors faced issues during bridge construction due to misalignment of longitudinal post-tensioning duct caused by design error during the prefabrication process. Consequently, there were delays in schedule, and the contractor adopted the conventional cast-in-place method to complete the construction process. Secondly, traffic disruption is another important factor that impacts the construction duration and the travel distance of vehicles utilizing the bridge to reduce the time taken to reach the destination. Since the ABC project reduces traffic disruption through fewer on-site construction activities, traffic will be disrupted only during installation, and during that period, commuters need to follow alternate routes (Hällmark et al. 2012). However, bridges have to be built alongside an existing bridge in areas with a high volume of traffic where longer detour routes are not possible. For instance, the 24th Street Bridge in Council Bluffs had no traffic disruption at any time during the construction period. It maintained three lanes of traffic at all times, thereby eliminating the requirement of the use of detours (Becker 2009). The third factor influencing the use of the 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 the 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 primarily due to the use of high-cost, innovative materials and the 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 (Klaiber et al. 2009). Thus, ABC bridges have the potential to have a significantly longer life cycle than a traditionally cast-in-place concrete bridge; however, lack of pre-project planning tool for ABC projects have resulted in several issues during the construction phase. Although the adoption of ABC has several benefits that foster resilient and sustainable infrastructures, there are challenges in its widespread adoption due to lack of standardization, inexperienced contractors, and lack of an advanced tool to ensure the success of ABC projects (Saeedi et al. 2013). To improve opportunities for replacing many deteriorating bridges with minimum traffic disruption, high quality, and improved worker safety in less time as possible, a flexible success indicator tool is required to support contractors during an ABC project's advanced planning stage. Such a tool can play a role in attracting contractors to adopt ABC projects and inform project stakeholders to assess success indicators during the pre-project planning phase.

To this end, many bridges constructed with the Accelerated Bridge Construction (ABC) technique have significantly reduced construction schedule, environmental impact, and traffic disruption. Yet, contractors are reluctant to use ABC techniques, especially due to perceived risks during construction (Ofili 2015). To assure proper use of this technique, different departments of transportation (DOTs) have formulated decision-making guidelines such that those projects which do not require acceleration in schedules and can be constructed with conventional practices utilize those methods instead of ABC (Freeseman et al. 2020). Based on the decision-making framework developed by Federal Highway Administration (FHWA), the owner/user may efficiently decide on the applicability of the ABC method in a bridge construction project with the help of either qualitative or quantitative decision-making tools. For instance, the Utah Department of Transportation (UDOT) has developed an ABC decision flowchart to determine if an ABC approach is required yet does not anticipate ABC project success indicators (West et al. 2012).

Similarly, a report was also prepared for the Michigan Department of Transportation (MDOT) as a decision-making process, which included site-specific, traffic, and cost alternatives, yet not an interactive tool supporting the ABC project's anticipated success (MDOT 2015). Hence, merely deciding on the adoption of a specific construction method may not be sufficient for thriving in an infrastructure project. Considering the growing complexity of bridge construction projects, advanced planning strategies are necessary that ensure constructability, safety, and quality in bridge projects. Several studies have developed different tools to make a well-informed decision and facilitate pre-project planning. The Construction Industry Institute (CII) has developed pre-project planning tools that support project stakeholders to anticipate success rates and attract contractors in adopting ABC projects (Gibson et al. 2010); however, such tools do not align with ABC projects nor anticipated their success indicators. Each ABC project has different environmental, traffic, and geometric conditions that influence the type of design, material, and project delivery method to be used for the construction. Therefore, there is an urgent need for a unique pre-project planning tool similar to those prepared by the CII to determine particularly associated risks with ABC.

The accelerated bridge construction method may not be applicable for all types of bridge construction projects (Abu-Hawash et al. 2009). For instance, a large bridge construction project may require a huge initial investment, and acquisition of a huge amount of funding within a limited duration of a few months may not be viable. Consequently, the rapid construction of bridges may be delayed due to funding constraints (Yavuz et al. 2017). Without adequate funding, contractors may need to distribute labor based on reduced demand, construction materials arrival may be delayed, and work may have to be done in different phases over a longer time. Therefore, there cannot be a uniform construction duration for all bridge projects since different projects require a different amount of investment. According to Khan (2015), bridge projects can be categorized into four different groups based on the funding allocated by these projects: Bridge projects with funding of 5 million dollars are considered small projects, projects that do not exceed 50 million are medium-sized projects, projects not exceeding 250 million dollars are large projects and those projects exceeding 250 million dollars are considered very large projects. Thus, based on the size of the bridge project, all the construction activities such as technical, administrative, coordination, non-technical, and accounting, among others, will increase in number and intensity (Orabi et al. 2016). Considering that funding and resource allocation may take some time, rapid construction would suit for only smally project delivery. However, if accelerated construction methods are required to be integrated into large or very large projects, proper pre-project planning for design and construction should be conducted. To this end, research studies have seldom investigated the integration of front-end planning of accelerated bridge construction projects, and this study is an initiative to address the gap.

Infrastructure projects such as Accelerated Bridge Construction (ABC) are often complex, and contractors need to have substantial experience to thrive in ABC projects (Ofili 2015). Without proper knowledge of potential challenges in advanced planning, there may be schedule overruns, liquidated damages, and legal and contractual issues. These projects play a critical role in the built environment, and some of the projects face unique planning challenges such as right-of-way (ROW) acquisitions or adjustments, underground, more interface with the public and the environment. Low awareness of a project's societal and environmental impacts, as well as a lack of standardized procedures to quantify these impacts, are often roadblocks to achieving sustainability (Weerasinghe et al. 2007). Therefore, there is a growing need for a success index that can be utilized for pre-project planning of infrastructure projects like ABC to support contractors in achieving sustainability goals and improving performance. Risk mitigation in infrastructure projects can be achieved by integrating one of the most powerful tools referred to as Front-end planning (FEP) which facilitates infrastructure projects to improve early understanding of scope definition elements to accomplish improved project outcomes (Gibson et al. 2010). However, such tools have seldom been explored in ABC projects, and an investigation is necessary to assess its efficacy.

Lu et al. (2020) investigated the trends of critical factors that impact the design, construction, and maintenance of ABC bridges. The study highlighted that adoption of new construction materials or structures and new construction techniques, change in the cost of construction, advanced health monitoring technology, among others, are the impactful factors that are trending in the ABC method. In another study, Barutha et al. (2017) developed a metric based on social return on investment (SROI) that measured the value of an investment in ABC methods to reduce economic, environmental, and social impacts to the road network users. The authors highlighted that the SROI metric gives a holistic measure to prioritize socio-economic aspects in the ABC techniques. On the other hand, Prajapati and Ouk Choi (2019) developed a preliminary list of execution plan differences in ABC projects in comparison to conventional bridge projects to extend the scope of its implementation. Considering the subjective nature of the 61-execution plan identified in the study, a comprehensive investigation is necessary to validate the execution plan in the pre-project planning stages. Although identification of these factors is useful for transportation decision-makers and policymakers, there remains a literature gap on how environmental, social, economic, and technological factors can be utilized in the pre-project planning to assist contractors in ensuring the success of ABC projects.

Front-End Planning of Infrastructure Projects

Front-end planning (FEP) is a process for developing an appropriate scope definition and strategic information with which owners can uncover any project unknown and risks to maximize the chance for a successful project, as shown in Figure 4 (Bingham and Gibson 2017). Gibson et al. (2006) demonstrated that the FEP tools play a significant role in capital projects and directly correlate with a project’s success. Hansen et al. (2018) conducted a literature review to understand the general FEP process and its differences from traditional project planning. The research highlighted that there is a strong need for implementation of FEP in the infrastructure projects due to several benefits, which include: ease in financial management, reduction in contractual disputes, lower design changes, improved operational performance, increased predictability of cost and schedule, and better risk management. The CII (2006) indicated that despite the requirement for initial investment for FEP, even higher savings could be achieved on a project. Typically, FEP costs around 2.5% of total project cost but will return on average 10% cost savings, 5% fewer changes, and 7% shorter schedule delivery. According to Bingham and Gibson (2017), the FEP process in infrastructure projects can identify and mitigate risks stemming from environmental hazards, permits, right-of-way concerns, utility adjustments, and logistic problems. CII (2006) also highlighted that proper FEP could help achieve project objectives such as improved scheduling, cost, operating characteristics, and social and environmental goals.

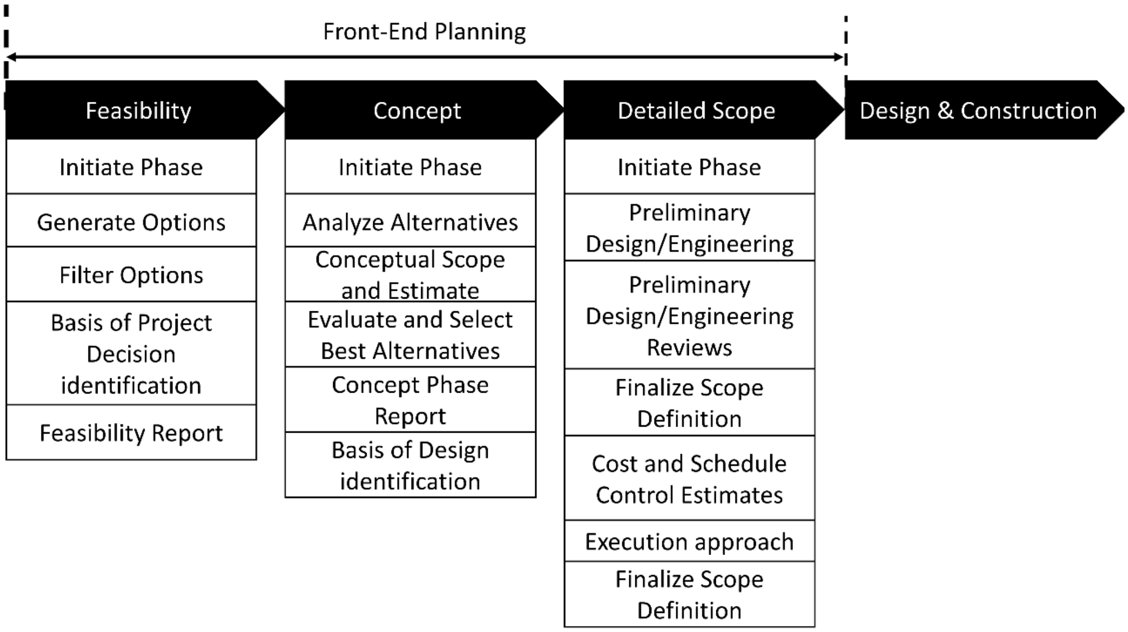

Figure 4. Front-end planning process for infrastructure project

Poor scope definition in an infrastructure project has severe consequences on the projects' schedule, cost, and operational performance. As shown in Figure 5, decisions made during earlier phases of a projects' lifecycle have a significant influence on a project's outcome than those made during the later stages. According to Gibson et al. (2010), one of the critical tasks in FEP is the development of proper strategic information for creating a stronger link between the project goals and scope throughout the entire infrastructure projects' life cycle. However, many owners, agencies, and contractors often neglect the criticality of FEP due to which infrastructure projects are plagued by poor project performance that leads to a deficient design basis (Bingham and Gibson 2017). As an effort to overcome such challenges, the Project Definition Rating Index (PDRI) tools have been developed. PDRI is a weighted matrix with scope definition elements that allows stakeholders to assess, quantify, and rate the level of scope definition and readiness for project execution before detailed design and construction (CII 1997, 2001, 2006). The Construction Industry Institute (CII), together with Bingham and Gibson Jr. (2010), Elzomor and Parrish (2017), Collins et al. (2017), among others, created the different PDRI tools: PDRI-General Buildings Projects, PDRI-Infrastructure Projects, PDRI-Small Infrastructure Projects, and PDRI-Small Industrial Projects, respectively.

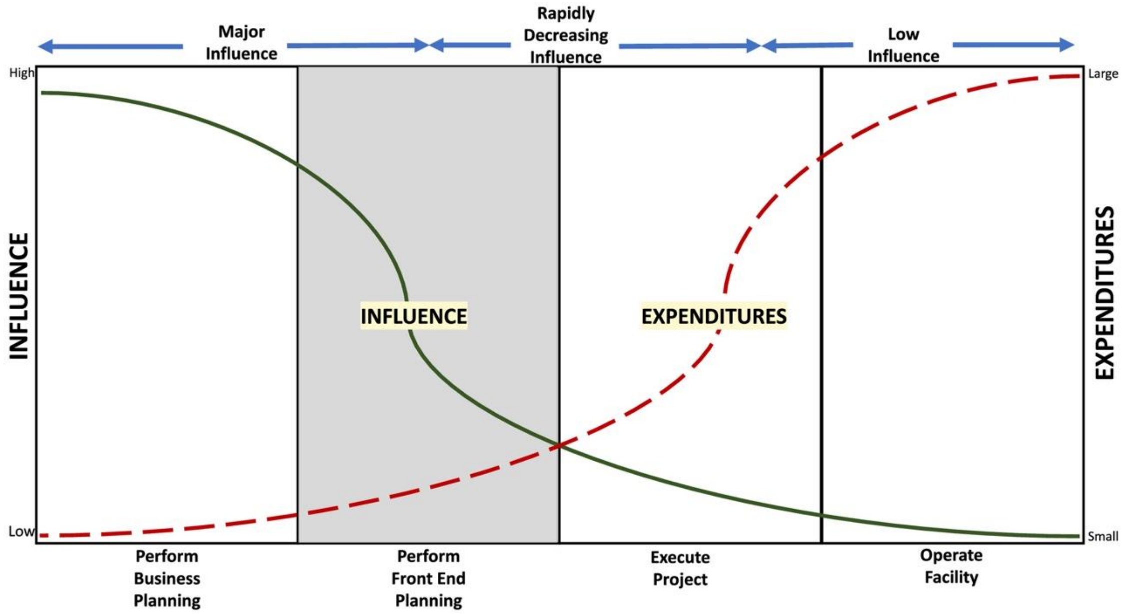

Figure 5. Project lifecycle with influence and expenditure curves (Gibson et al. 1995)

PDRI tools include a structured list of scope definition elements categorized in three separate sections: Section I. Basis of Project Decision, Section II. Basis of Design and Section III. Execution Approach. Then, these sections are broken down into subcategories with their respective elements. PDRI – Small Infrastructure consists of 40 scope definition elements grouped into eight categories, while PDRI – Infrastructure (Large infrastructures) entails 68 elements grouped into 16 categories. Both tools have a maximum score of 1000 points, where a lower score indicates a project with a greater level of scope definition, and a higher score indicates a lesser amount of scope definition (Elzomor et al. 2017). In other words, projects with lower PDRI scores usually maintain more robust cost and schedule performance than those with higher PDRI scores. Although all PDRI tools are divided into the same three categories, each tool has its unique complexities to score each of the respective categories. The first category, Basis of Project Decision, consists of information necessary for understanding the project objectives, which indicates whether the project team is strongly aligned to fulfill the project's business objectives and drivers. Similarly, the second category, Basis of Design, highlights processes and technical information elements that should be evaluated to fully understand the engineering/design requirements necessary for the project. Lastly, the third category, Execution Approach, consists of elements that should be evaluated to understand the owner's strategy fully and the required approach for executing the project construction and closeout (Elzomor et al. 2017). Elzomor et al. (2018) carried out a comparative study between PDRI for small infrastructure and PDRI for large infrastructure in terms of their structure, content, weight, and target score of the elements. The authors determined that the most important section for PDRI-Small Infrastructure was Section II: Basis of Design, with 470 points, while for PDRI-Infrastructure, the highest weighted section was Section I: Basis of Project Decision, with 437 points. This is related to the fact that large infrastructure projects frequently need a more robust decision-making effort to define the project scope, while small infrastructure projects may be less complex and already have the location and scope defined prior to the FEP phase.

Cho and Gibson Jr. (2001), summarized FEP in five major processes: (1) initiation, (2) scope planning, (3) scope definition, (4) scope verification, and (5) scope change control. Gibson and

Gebken (2003) recommended the implementation of PDRI in all five steps of FEP. During the initiation, the PDRI tool serves as guidance in defining the project strategy and objectives. In scope planning and scope definition phases, the PDRI helps in defining a scope management plan and assigning roles to each stakeholder. For the scope verification process, the PDRI specifies the quality and level of completeness of the project and aids in the decision-making process of moving forward to the construction phase. Finally, in the scope change control, the PDRI shows which elements have been poorly defined and need attention, which allows the project team to act and improve those deficiencies. PDRI is an important tool for its efficient use during FEP in terms of evaluating how likely a project is to achieve a specific set of objectives, including social and environmental considerations (Kang et al. 2013). Kivilä et al. (2017) stated the significance of integrating sustainability criteria during the entire project management process, particularly in large infrastructure projects that have long-lasting effects on society.

ElZomor et al. (2018) highlighted that tools such as Project Definition Rating Index (PDRI) had 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 have not been integrated nor aligned within ABC project planning, due to which it is critical to developing an ABC Success Index to integrate the FEP process and support project teams to assess the gaps in a scope definition. The main motivation of this study is to fulfill the literature gap by pre-informing project stakeholders of their success indicators through effective pre-project planning. Therefore, our proposed tool will couple the Framework for Decision-Making that was developed by FHWA with weighted criteria to show success indicators once the project is pursuing an ABC method.

Task 2 – Data Collection

Data collection in this study will be geared towards developing an interactive index/matrix that would provide an easy-to-use success framework for contractors to identify strengths, challenges, and opportunities to guide ABC project performances. To achieve this, the study will adopt a structured approach which includes: (1) conduct a systematic literature review (SLR) of successful ABC projects in a web-based repository developed by Federal Highway Administration (FHWA) and Accelerated Bridge Construction – University Transportation Center (ABC-UTC) website; and (2) conduct semi-structured survey with the implementation of purposive and snowball sampling techniques. The SLR method involves a structured review of literature by defining keywords, searching relevant literature, and identifying research gaps that strengthen the field of interest (Kamble et al. 2018). SLR in this study will be conducted in three levels. The first level deals with the identification of critical success factors through the investigation of articles in a different database such as google scholar and ABC-UTC. To identify the maximum number of relevant articles, different keywords, as shown in Figure 5, are utilized, and any duplicate articles will be eliminated before the second level. In level 2, screening parameters such as feasible and measurable factors and factors that align with the front-end planning (FEP) elements will be used to narrow down the factors. Then, each identified factor will be compared with the elements in each category of FEP and distributed in the relevant categories. Finally, in level 3, the obtained critical success factors and corresponding categories will be used to design a semi-structured survey such that it can be validated through experts in the construction industry.

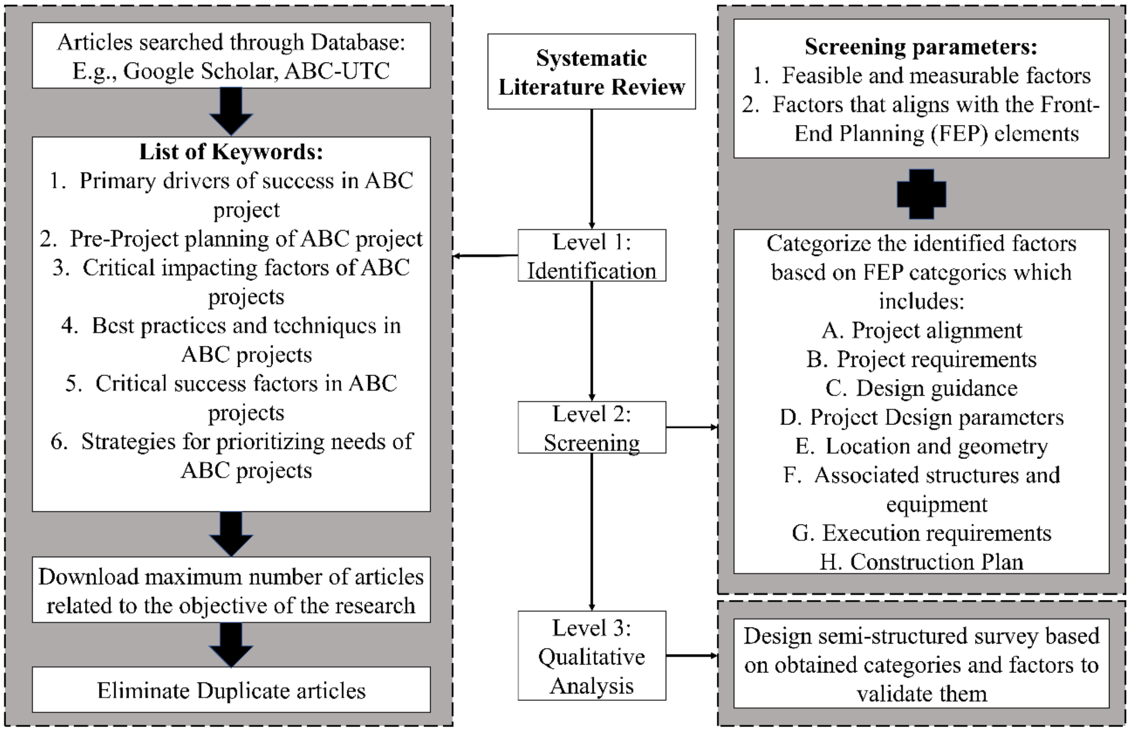

Figure 5. Systematic literature review framework for identification of critical success factors in ABC projects

Several studies have been conducted to investigate the impact of different factors on accelerated bridge construction. However, these factors are mostly focused on social, economic, environmental, and technological factors without a clear distinction of success indicators that influence better ABC project performance. Considering this gap in the literature, this study identified 14 critical success factors that need to be assessed during the pre-project planning stages of the ABC project as well as those factors that impacts the project performance. To identify these factors, the authors initially downloaded 84 research articles, of which only 58 research articles aligned with the objective of the research. Among the relevant research articles, most of them have been published in Federal Highway Administration, Accelerated Bridge Construction – University Transportation Center (ABC – UTC), Journal of the Transportation Research Board, PCI Journal, and Journal of Construction Engineering and Management, among others. These research articles were then manually reviewed to identify the critical success factors based on their impact on pre-project planning and the overall success of the ABC project. Finally, as shown in Table 1, only those related to the objective were listed with their relevant references.

Table 1: Critical success factors identified from SLR

S.N.	Critical Success Factors	References
1.	Location setting (i.e., Urban or rural, weather conditions)	(Gransberg 2013); (D'Andrea et al. 2016); (Galvis and Correal 2017);

2.	Project Delivery Method (i.e., CMGC, DBB, DB)	(El-sayegh 2008); (Ptschelinzew et al. 2013); (Culmo et al. 2013); (Jones 2014); (Freeseman et al. 2020);
3.	Project Type (Deck Retrofitting, new bridge, replacement bridge, span replacement)	(Khaleghi et al. 2012); (Khan 2015); (Muhaimin et al. 2021);
4.	Prefabrication methods	(Hällmark et al. 2012); (Aktan and Attanayake 2013); (Culmo et al. 2013); (Head et al. 2015);
5.	Timely coordination between stakeholders and highway agencies	(Becker 2009); (Gransberg 2013); (Ardani et al. 2013);
6.	Early contractor involvement	(Rex D et al. 2009); (Tobias et al. 2014); (Bhajandas and Rao 2015); (Alashari 2016); (Dean et al. 2019)
7.	Availability of Skilled Labor	(Abu-Hawash et al. 2009); (Khaleghi et al. 2012); (Aktan and Attanayake 2013); (Jia et al. 2018)
8.	Life cycle cost analysis	(Krumwiede 1998); (Abu-Hawash et al. 2009); (Akinola 2015); (Orabi et al. 2016); (Jia et al. 2018); (Chang 2021)
9.	Safety during and after construction	(Sutaria 2012); (Khaleghi et al. 2012); (Mallela et al. 2014); (Volk 2020); (Freeseman et al. 2020)
10.	Monitoring and maintenance	(Littleton and Mallela 2013); (DeJong 2019); (Farhangdoust and Mehrabi 2020);
11.	Research and development on the innovative construction method	(Ormijana and Rubio 2013); (Tazarv and Saiidi 2015); (Reid et al. 2018); (Carfagno and Dickerson 2018); (Garber et al. 2020)
12.	Training workshops on constructability	(Roddenberry and Servos 2012); (Aktan et al. 2014); (Yen et al. 2015); (Phares and Cronin 2015); (Mendez 2011)
13.	Public Private partnership	(Ormijana and Rubio 2013); (Demeke Cherkos and Jha 2020)
14.	Legislation and policies	(Lotfy 2015); (Gad et al. 2015); (Muhaimin et al. 2021);

Location Setting: To this end, location setting such as weather conditions, soil conditions, and urban or rural conditions, among others, have a significant impact on the successful construction as well as maintenance of ABC bridges. For instance, scour and erosion has been one of the most common reasons for the trend of bridge failures in the past (Gransberg 2013). Similarly, during the construction phase, there is a higher probability that a traffic detour or temporary bridges may be required, which would impose additional direct or indirect costs. In many cases, such costs can also exceed the actual costs of the primary structure itself (Galvis and Correal 2017). For example, in an urban setting where there is heavy traffic volume, full-lane closures can have a critical impact on industrial and commercial activities in such locations (D’Andrea et al. 2016). Furthermore, in case of partial lane closures, there may be safety concerns if construction activities are conducted adjacent to traffic. Although bridge components in accelerated bridge construction are produced offsite and fully assembled on-site, it is critical to consider location setting as a critical success factor that needs to be considered during pre-project planning stages of design and construction.

Project Delivery Methods: 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). 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. 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 the last few decades, Federal Highway Administration (FHWA) has started to use alternative contracting methods such as Design-Build, and Construction Manager-General Contractor that reduces risks and minimizes unforeseen delays (Jones 2014). Design-Build is a contract delivery method where the design and construction of a project are under a single contract. 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). On the other hand, the construction Manager-General Contractor 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. Therefore, it can be observed that the adoption of any specific project delivery methods has a significant impact on the success of the ABC projects (Freeseman et al. 2020).

Project Type: ABC method is applicable to several different types of bridges of structural variations such as pedestrian bridges, over streams bridges, over wide river bridges, concrete arch bridges, cable-stayed bridges, and steel arch bridges, among others (Khaleghi et al. 2012). Conventional bridges require more time to construct, due to which different parts of the bridges have started to integrate prefabricated components. Overall, different approaches are adopted for the planning of new bridges in comparison to the replacement of bridges or the widening of bridges. During the construction of new bridges in a new location, there are seldom any traffic problems for maintenance and protection of traffic (MPT). On the other hand, the replacement of bridges in an existing location is required to have a detour that increases the travel distance and time taken to reach the destination (Khan 2015). To overcome this issue, bridge engineers practice replacing the bridge in stages or constructing the new bridge adjacent to the existing one such that there is no disruption in traffic. Additionally, some bridges also require widening, which is one of the most difficult construction. It requires additional foundations, substructure, and new wing walls, due to which maintenance and protection of traffic in such construction takes significant time. Also, there are possibilities of construction hazards due to which labor needs to be protected from accidents, and nightshift should be made safer and more flexible (Muhaimin et al. 2021). Therefore, during the pre-planning stages, it is important to select the appropriate project type with minimum impact to the public, environment, and performance of the structure.

Prefabrication methods: Prefabricated materials and systems are generally utilized to minimize the on-site construction schedule of ABC bridges. The prefabricated construction materials and methods are widely different from conventional methods and require innovative concepts to make the system efficient and sustainable. A prefabricated bridge superstructure consists of prefabricated girders and precast deck panels with or without a cast-in-place concrete deck, modular systems such as segmental box girders, single-tee, double-tee, among others, and any other configuration where a continuous bridge superstructure is formed one the elements are placed and connected through the cast joints (Hällmark et al. 2012). In terms of deck-plan shapes, the use of skewed, normal, or curved decks can make a significant difference in the overall construction schedule. Similarly, cross-sectional types, span types, and selection of modern materials have equal impact on the cost, duration, performance, and quality of ABC bridges (Culmo et al. 2013). Therefore, proper investigation of necessary prefabricated elements of a bridge plays a critical role in the success of ABC bridge construction since it eliminates possible liquidated damages, delays in schedule, and waste of materials.

Timely coordination between stakeholders and highway agencies: Faster design approvals and coordination with the utility companies is highly influenced by effective coordination between the stakeholders. For instance, ABC projects in which contractors play a due role in coordination, planning, and progress management can achieve reasonable rapid progress in the project (Becker 2009). Similarly, during construction, coordination with the utility agencies is required to relocate gas, water, and other pipes supported by cross beams under the bridge. Also, an electrical engineer will need to ensure coordination with the utility agency for long-term deck and overhead lighting (Ardani et al. 2013). To ensure that there are no delays in schedule, it is critical to timely coordinate between stakeholders and utility agencies.

Early Contractor Involvement: In project delivery methods such as Design-Bid-Build (DBB), structural design is developed by a consultant which may not always align with the construction conditions and load combinations on-site (Rex D et al. 2009). Since there is seldom any communication or involvement of contractors during the design process, the quality of drawings prepared by the consultant may not always be complete to the minutest details (Tobias et al. 2014). Team effort in such construction is usually nonexistent as the contractor must follow the contractual obligations, which may restrict improvements during construction (Bhajandas and Rao 2015). Therefore, it is critical to determine a feasible solution that balances the resources with the detailed design through an agreement between contractor and consultant upfront. Consequently, this will lead to minimum cost and be implemented in the shortest construction schedule without any delays.

Availability of Skilled Labor: The availability of skilled labor is critical for ABC projects to integrate innovative technologies and techniques in the project (Khaleghi et al. 2012). For instance, Self-Propelled Modular Transporters (SPMTs) are motorized vehicles that can significantly improve workplace safety and reduce traffic disruption (Alashari 2016). However, one of the most essential requirements to use this innovative method is the availability of skilled workers who can operate them safely and effectively. Hence, it can be inferred that the success of the ABC project is highly influenced by the availability of skilled labor who are able to execute innovative equipment and methods efficiently. Moreover, during the pre-project planning stages, construction stakeholders should encourage the involvement of a skilled workforce in the ABC project to foster innovation in the construction phase.

Life cycle cost analysis: The life cycle cost analysis is the process of assessing the total economic worth of a usable project through analysis of initial costs and discounted future costs including reconstruction, rehabilitation, maintenance, resurfacing and reconstruction costs over the life of the project (Valigura et al. 2021). In case of ABC project, life cycle costs are relatively lower in long term and the returns are greater due to avoidance of discomfort and indirect costs to the public during the construction (Khan 2015). Moreover, different strategies can be adopted to minimize life-cycle costs in ABC projects, which includes: (1) to improve the durability of deck concrete, corrosion inhibitor concrete or HPC should be used; (2) to improve deck joints performance, integral abutments should be used; and (3) to improve bearings performance, elastomeric pads and isolation bearings should be used (Orabi et al. 2016). Since the increase in quality leads to an increase in service life and reduction in life cycle cost of the ABC project, it is one of the important critical success factors that should be considered during pre-project planning of ABC projects.

Safety during and after construction: An ABC project site is vulnerable to different kinds of accidents, including crane collapses, injuries from equipment, or traveling vehicles. To this end, the number of highway and bridge renovation projects is constantly increasing due to the growing number of deteriorating infrastructures (Volk 2020). As such, work zones generate traffic congestion, which can increase the risk of crash occurrence. For instance, according to Federal Highway Administration (FHWA 2020), there were 2000 fatal vehicle crashes in the construction work zones where 44% of bridge construction work injuries involve a vehicle traveling through a construction work zone. Most importantly, two-thirds of these injuries are fatal injuries indicating that there are significant challenges in safety even during construction. Since work zone crashes and injuries impose millions of dollars of cost on the project, it is critical to consider safety measures during and after construction through innovative designs and preventive measures (Mokhtarimousavi et al. 2020). Some of the common challenges to addressing safety issues include increasing fatalities, limited funds, sizable highway systems, long project development cycles, and limited safety toolbox (Khaleghi et al. 2012). To address these challenges, DOTs and ABC construction stakeholders should adopt the data-driven safety part of the strategic vision, quantitative safety analysis, and analyze the effectiveness of safety improvements (Freeseman et al. 2020). Therefore, the pre-project planning phase of ABC projects needs to ensure safety as a part of the project scope such that it is easier to achieve a successful project.

Monitoring and maintenance: With the recent advancement in measuring instrumentations technology, structural health monitoring is becoming a widely accepted solution for ensuring the long-term safety of the structure and reduce life-cycle costs of the project (Littleton and Mallela 2013). In particular, structural health monitoring technology helps to: (1) identify structural deficiencies; (2) measure rotations, strains, and displacements using the sensors which provide information about peak stress distributions through computer software; (3) assess the performance of high-performance concrete, hybrid materials, materials made from thermoplastic or thermosetting resins, high-performance steel, among others; and (4) assess the feasibility of repair, replacement or retrofit of bridges (Khan 2015). Such specialized technology will continue to grow and has significant potential for asset management, condition monitoring and may eventually replace the visual inspection techniques and life-cycle costs inspections. Most importantly, it would ensure better project performance and maintenance of the bridge.

Research and development on innovative construction methods: Federal Highway Administration (FHWA), along with Department of Transportation (DOT) officials, developed a list of initiatives to encourage innovative construction methods for the past several years (Reid et al. 2018). One of those initiatives included alternative technical concepts to allow states to present innovative ideas that save cost and time of construction. 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). Geospatial data collaboration is another innovative initiative that allows data sharing between ABC project stakeholders to explore a cloud-based geographic information system platform. Similarly, 3D modeling and construction equipment that utilizes global positioning system (GPS) receivers can increase productivity by 50% by identifying accurate grades in the first trial (Khan 2015). Similarly, many research initiatives from ABC-UTC have also led to the research and development of innovative construction methods. For instance, Garber et al. (2020) have conducted an 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. Therefore, encouraging research for innovative solutions during pre-project planning of ABC projects is critical for the overall success of the construction project.

Training and workshops: Training and workshops are critical for the construction and maintenance of ABC projects. For instance, a lack of maintenance of construction equipment and operating training can lead to frequent breakdowns or accidents (Aktan et al. 2014). Several precautionary measures need to be taken to avoid any hazards. Training in ABC beyond the college level education is one of the most effective ways to achieve those objectives (Yen et al. 2015). Specialized training in the form of webinars and workshops offered by DBIA, FHWA, AASHTO, state agencies, and universities like FIU is effective in informing new ABC stakeholders in understanding the methods and processes involved in ABC projects. Overall, it can be concluded that the pre-project planning stages should ensure proper training of all the ABC stakeholders through workshops and webinars for the project's overall success.

Public-Private Partnership: A Public-Private Partnership is a private business or government service which is operated and funded through the partnership of one or more private party and the government (Khan 2015). It involves a contract between a private party and a public sector authority where the private party provides a public service and assumes substantial operational, financial, and technical risks during the project (Ormijana and Rubio 2013). To this end, Public-Private Partnership or P3s are being implemented across the United States to help meet the growing needs in transportation and fund infrastructure projects without increasing government spending (Demeke Cherkos and Jha 2020). This method often results in significantly affordable and efficient project delivery of ABC projects. During the construction of ABC bridges, there may be many complex problems and risks that can be addressed through Public-Private Partnerships by harnessing creativity and exchanging responsibilities, ownership, and costs. Therefore, integration of such a method may help ensure the success of the ABC project.

Legislation and policies: Many state DOTs have their own legislation and policies regarding ABC construction projects. For instance, some states have legislation that mandates the minimization of any traffic disruption during the construction or replacement of bridges (Lotfy 2015). Similarly, if an ABC project integrates alternative technical concepts to exploit its benefits, different legislation and policies should be followed. 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 to determine potential ATCs and receive an indication response from the department for a given ATC (Gad et al. 2015). Due to such legislation or policies, a contractor is able to integrate innovative ideas and designs in the project outside of the original project scope.

Furthermore, the research plans to leverage existing ABC project databases to identify success weightings based on meeting project goals and avoiding risks. On the other hand, purposive sampling refers to a judgmental sampling method in which individuals are selected to be part of the sample based on the researcher's judgment as to which individuals would be the most useful or representative of the entire population. Therefore, interviewing ABC project stakeholders and contractors to collect information related to specific success criteria is required when meeting tight time constraints similar to those posed by ABC projects. Similarly, the snowball sampling technique will be implemented to increase the reach of the project by requesting the targeted individuals to suggest other individuals with similar expertise (Babbie 2014). An Institutional Review Board (IRB) approval will be pursued, and any personal or proprietary information collected from individuals that provided data to support the research effort will be kept confidential. In particular, responses will be coded during the analysis to ensure projects and individuals are anonymous.

Task 3 – Data Analysis

The study will focus on the assessment of completed ABC project data in order to test the hypothesis that scores are derived by assessing successful ABC projects and correlate the levels of project performance. The interactive index/tool will utilize a systematic color-coded score to highlight the success of the ABC projects. Different project performance factors identified in the SLR will be used to evaluate and analyze the matrix. For instance, the green color will indicate that the project has sufficient scope definition, reduction in cost and schedule, improve safety and innovation, among others which fostered improved project performance. On the other hand, a red color will indicate the project has an incomplete scope definition, high cost, and schedule overrun, among others, during front-end planning that leads to poor project performance. To assess the efficacy of the interactive/matrix tool, statistical analysis will be conducted through comparison of scores with cost, schedule, financial performance, change, customer satisfaction, among others, on a sample of recently completed ABC projects. Statistical Package for Social Science (SPSS) software will be used to conduct an independent sample t-test to determine if a statistical difference existed between the project performance of different, green-coded projects and red-coded projects. Additionally, the machine learning algorithm will be used to develop a regression model that would predict whether a project has the potential to be successful based on the different independent variables (i.e., project performance factors). Finally, after making predictions, an accuracy score, matrix, and classification report are computed. Scores will be used to combine both the precision and recall then, using these metrics, the effectiveness of the regression model will be assessed.

Task 4 – Recommendations and Metrics

This task compiles and comprehends the data analyses by providing a robust approach using an interactive tool to develop the ABC Success Index. This approach will serve ABC stakeholders to determine the success indicators of projects by taking into account a wide range of criteria and interacting with an easy-to-use index.

Task 5 – Final Report

A final report will be developed to summarize the research conducted by FIU and recommendations developed from the research.

Task 6 – Guide to ABC Contractor's Success Index

An ABC Success Index to Support ABC Contractors During Advanced Planning will be developed incorporating the research findings from this project.

3. Schedule of Activities (*GANT CHART*)

The proposed schedule for the planned tasks is summarized in Figure 2.

Research Task	**2021**			**2022**		
	Q2	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*
1. Literature Review						
2. Data Collection						
3. Data Analysis						
4. Recommendations and Metrics						
5. Final Report						
6. Guide						

Figure 2: Project Timeline

Item	**% Completed**
Percentage of Completion of this project to Date	20%

APPENDIX A

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