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 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 have a significant impact on 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 regression model will be developed through a machine-learning algorithm to determine the correlation of independent variables (success indicators/project performance factors) of ABC projects. 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 as well as share previous ABC successes around the nation, which in turn would provide more confidence through 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 the integration of the ABC Success Index into websites, educational materials, conferences, and webinars to strengthen the useability of the index amongst DOTs personnel as well as 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 determine 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 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, and many contractors, as well as 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 ABC existing 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 manage not only safety but also 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 with the identification of 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 an important foundation step to educate, guide, and support contractors when pursuing ABC projects.

2.2.1. Summary of Project Activities

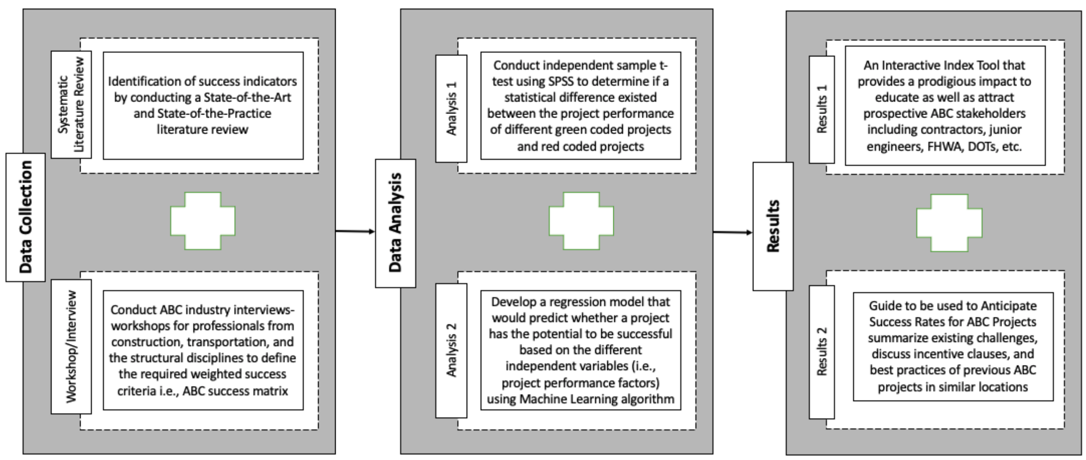

Figure 1: Overview of Project Activities and their Sequence

2.2.2. Detailed Work Plan

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

Task 1 – Literature Review

The American Society of Civil Engineers (ASCE) rates the U.S. infrastructure every 4 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 rate of reduction 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 recent 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.

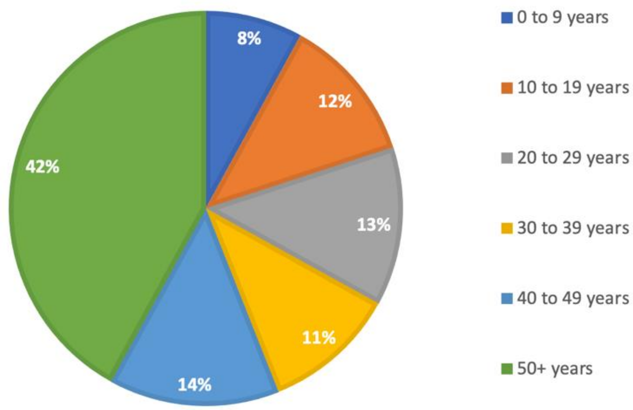

Figure 2: Age of bridges across America based on ASCE (2021) report

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, and a comprehensive flowchart can be used to make such a decision as shown in Figure 3. 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 a large number of deteriorating bridges with minimum traffic disruption, high quality, and improved worker safety in less amount time as possible, a flexible success indicator tool is required that supports contractors during the advanced planning stage of an ABC project. 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.

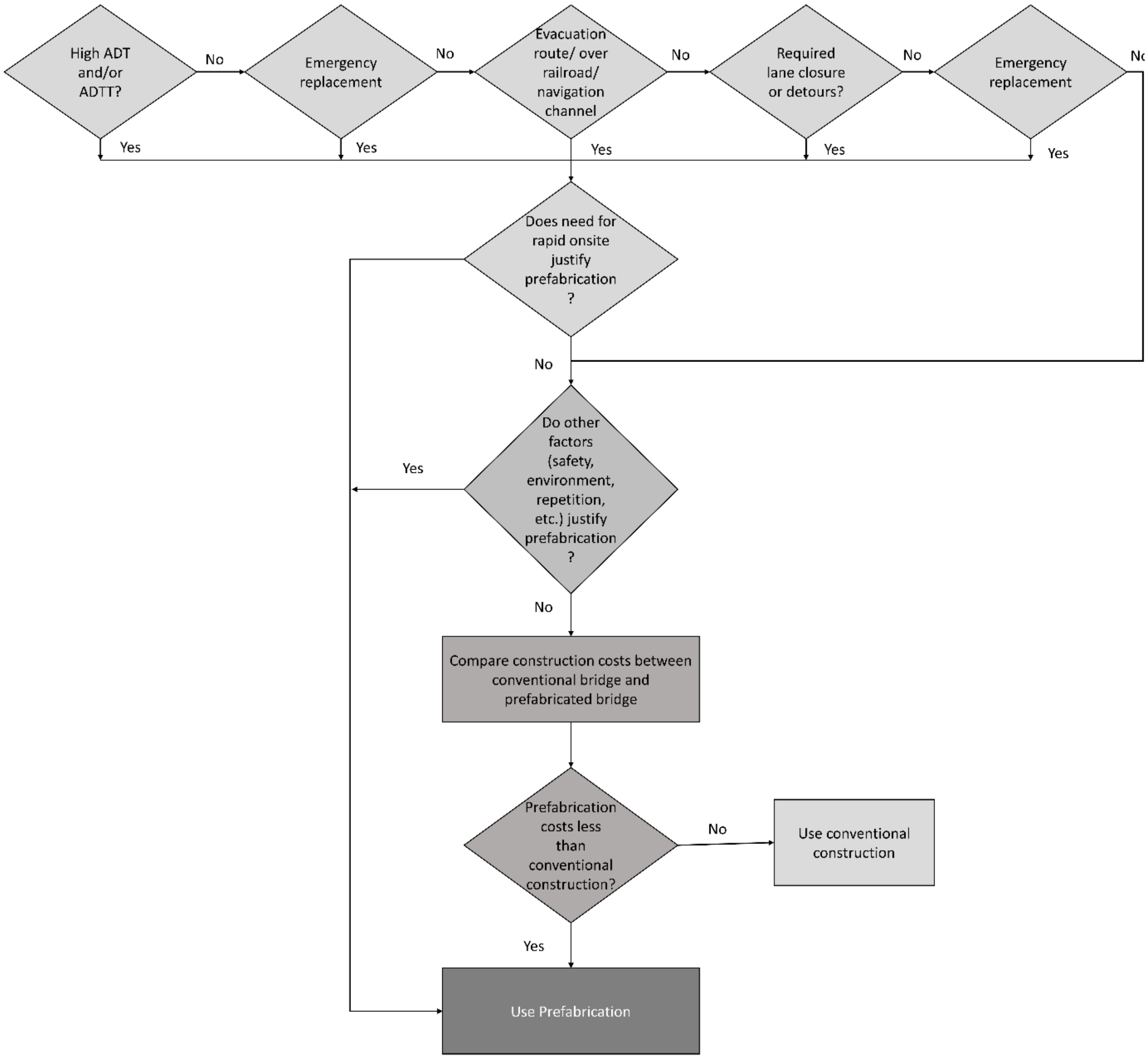

Figure 1: Flowchart for decision making on the use of the prefabricated bridge (adopted from Federal Highway Administration (FWHA) 2017)

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 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). 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 not only impacts the construction duration but also the travel distance of vehicles utilizing the bridge for reducing 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, in 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 detours (Becker et al. 2009). The third factor which influences 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 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 (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.

To this end, many bridges constructed with the Accelerated Bridge Construction (ABC) technique have significantly reduced construction schedule, environmental impact, and disruption in traffic, 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 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 (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 the success indicators for ABC projects (West et al. 2012). Similarly, a report was also prepared for the Michigan Department of Transportation (MDOT) as a decision-making process, which included alternatives to site-specific, traffic, and cost, yet not an interactive tool that supports the ABC project's anticipated success (MDOT 2015). Hence, merely deciding on the adoption of a specific method of construction may not be sufficient for thriving in an infrastructure project. Considering the growing complexity of bridge construction projects, advanced planning strategies are necessary that ensures 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 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.

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 as well as 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 as well as improving performance. Risk mitigation in infrastructure projects can be achieved through the integration of 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 been seldom explored in ABC projects and an investigation is deemed necessary for assessing 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 (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 have a direct correlation with a project's success. Hansen et al. (2018) conducted a literature review to understand the general FEP process and how it differs 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 can 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 contribute to identifying and mitigating risks stemming from issues such as environmental hazards, permits, right-of-way concerns, utility adjustments, and logistic problems. CII (2006) also highlighted that proper FEP can help achieve project objectives such as improved scheduling, cost, and operating characteristics, as well as social and environmental goals.

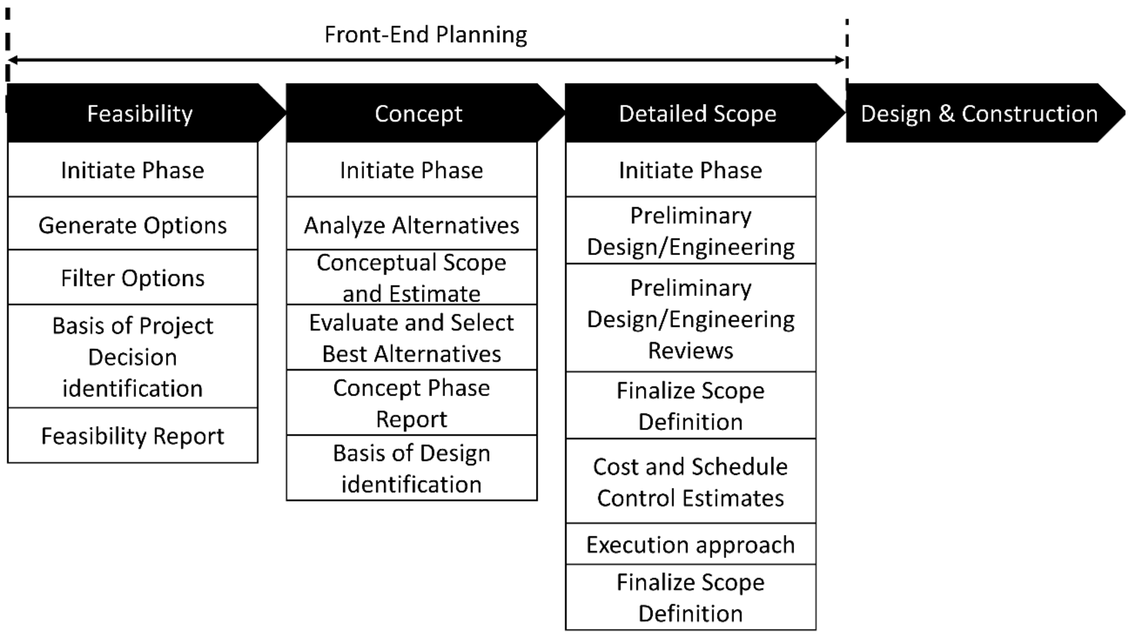

Figure 4. Front-end planning process for infrastructure project

ElZomor et al. (2018) 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 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) prepare 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 through defining keywords, searching relevant literature, and identification of research gaps which when addressed strengthens 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.

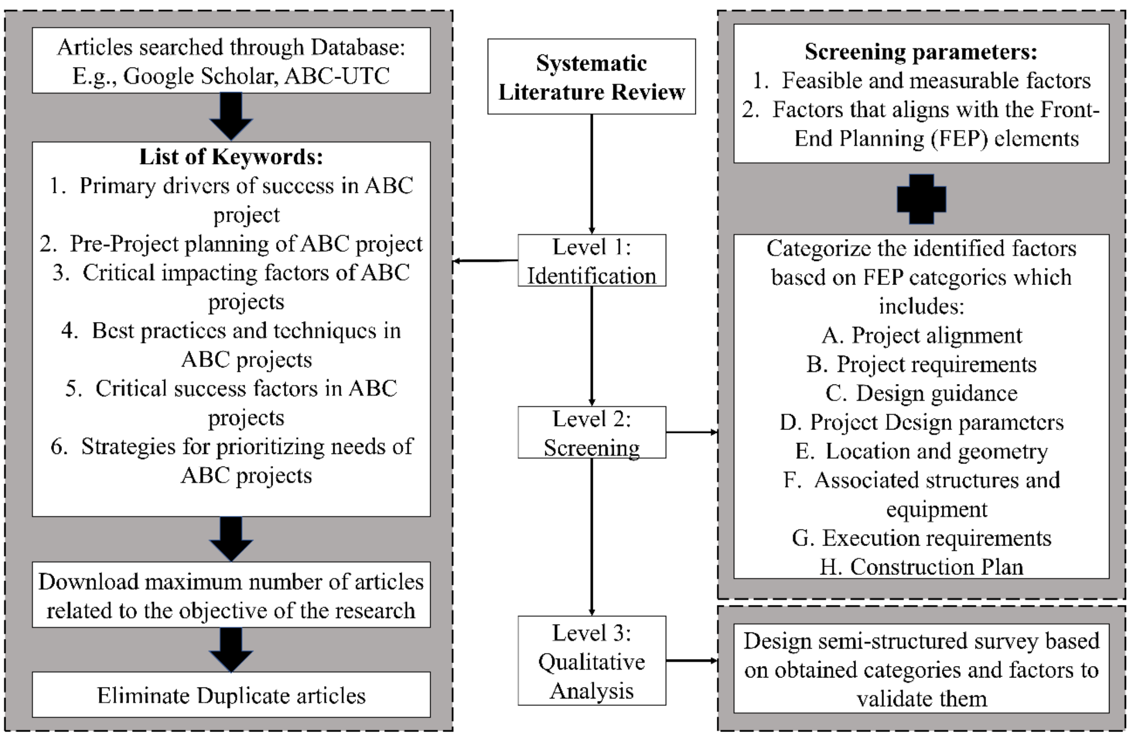

Figure 5. Systematic literature review framework for identification of critical success factors in ABC projects

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 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 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	5%

APPENDIX A

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