DEVELOPMENT OF GUIDE FOR SELECTION OF SUBSTRUCTURE FOR ABC PROJECTS

Quarterly Progress Report

For the period ending November 30, 2018

Submitted by:
PIs - Armin Mehrabi, Hesham Ali
Graduate Students - Mohamadtaqi Baqersad, Saman Farhangdoust

Department of Civil and Environmental Engineering
Florida International University
Miami, FL

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

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ABC-UTC
Florida International University
Miami, FL

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1 Background and Introduction

While much attention has been paid to means and methods of accelerated construction of the bridge superstructure, little has been done to provide proper guidance to designers and bridge owners on the selection of type, design and construction of the substructure. The primary objective is to provide guidelines for decision making by the designers and bridge owners for the selection of substructure and foundation for new bridges and replacement of existing bridges using the ABC methods, including evaluation, retrofitting, design, and construction. The project will include a comprehensive review of the current practice and compilation of available ABC methods for substructures and superstructures. This review should result in categorization of sub- and superstructures that are best match. Efforts will be divided into two major categories: new bridge construction and existing bridge replacement. An attempt will be made to identify issues and obstacles preventing the adoption of ABC substructures for bridge projects, and exploring solutions for facilitating a wider use of ABC substructure. Development of the Guide would rely on information from various sources including open literature, survey of experts and stakeholders, input of ABC-UTC Advisory Board members, and other domain experts nationally and globally. Information obtained from these sources will be reviewed and synthesized carefully and organized systematically. Gaps in the knowledge will be evident from this synthesis. This research project is a collaborative project between Florida International University and the Oklahoma University. FIU will focus its work on substructure and lead the development of the guideline, and OU will focus its activities on foundation related subjects and provide support to FIU on other tasks.

2 Problem Statement

The aim of accelerated bridge construction (ABC) is to reduce the impact of bridge construction on the public and bridge usage by reducing the construction time, especially when replacement of an existing bridge is involved. In addition to reducing construction time significantly, ABC has been found to enhance safety and reduce congestion. Although much work has been done in the past to investigate the design, configuration, and erection methods for bridge superstructure, very limited studies have addressed substructures and foundations (in this proposal "substructure and Foundation" and "substructure" are used interchangeably). Often, it is assumed that the bridge substructure and foundation are ready to receive the superstructure. Based on field experience, site-specific testing, design and construction of foundations and substructures can be the most time-consuming part of bridge construction. An informed and educated decision on the type of foundation and substructure may define the viability and economic feasibility of the entire ABC project. In the proposed study, the research team seeks to develop a Guide that can be readily used by practitioners for the selection of substructures and foundations for different ABC projects. The Guide will include parameters in design and construction of substructure and foundation including type, geometry, location, superstructure and bridge configurations, and design methodology. Issues related to construction of new bridges and replacement of existing bridges will be addressed including evaluation and strengthening of existing substructure and foundation for potential reuse. In addition to developing the Guide, the proposed study will identify gaps in existing knowledge and practice and make recommendations for future studies to address these gaps.

3 Research Approach and Methods

The primary objective of this project is to provide guidelines for decision making by the designers and bridge owners for the selection of substructure and foundation for new bridges and replacement of existing bridges using the ABC methods, including evaluation, retrofitting, design, and construction. The decision will depend strongly on the type and configuration of the superstructure intended for the bridge. From compatibility and conformity considerations, the decision on the type and design of both substructure and superstructure needs to be done concurrently. Geometric parameters such as span length, bridge width and bridge clearance are also important parameters in the selection of substructure type. This study may also review new types of substructures and/or closure joints and connection types for better performance and service life of the bridge. As noted in the Problem Statement, the evaluation of substructure and foundation of existing bridges for their structural capacity and functional adequacy and decision on reuse or replacement will be an important part of this study.

4 Description of Research Project Tasks

An overview of the study tasks is given below. The project is a collaborative effort with active participation of Florida International University (FIU) and Oklahoma University (OU).

4.1 Task 1 – Draft Outline

A draft outline of the Guide for the selection of substructure and foundation for ABC projects was developed collaboratively by the research teams at FIU and OU.

4.2 Task 2 – Conduct Literature Search on Topics Identified in the Draft Outline

A comprehensive literature search is underway on the topics identified in the guideline. To date, different component of ABC bridge components has been identified as reported in the previous progress report. Also, a preliminary flowchart to help selecting the substructure elements for construction of new bridges using ABC technique has been developed. A summary describing the development of the flowchart is as follows.

4.2.1 Construction of New Brides

The particular concept in the use of ABC method and prefabricated elements in the construction of bridges is considering time equivalent to money. The main mission of the ABC and the use of prefabricated elements in the bridge construction is reducing the onsite construction time and erecting the bridge elements in the offsite area. This approach can reduce the project cost due to offsite manufacturing, improve safety, and quality that leads to improving the long-term performance of the bridge. The proper design and planning should be considered in the ABC to make its advantages significantly pronounced in comparison to the conventional bridge construction. While this study focuses on ABC substructure, it is also realized that design and type of substructure is highly dependent on the design and type of superstructure and foundation, as well as construction methods employed for the ABC project.

The Federal Highway Administration (FHW) provides a flowchart that, in general and mostly qualitative terms, can help to identify whether implementing ABC method in a project is beneficial (Figure 1) [1]. The decision makers including the owners and contractors who are responsible for selecting the construction method should consider the flowchart and related factors in utilizing the prefabricated elements in the construction of a bridge.

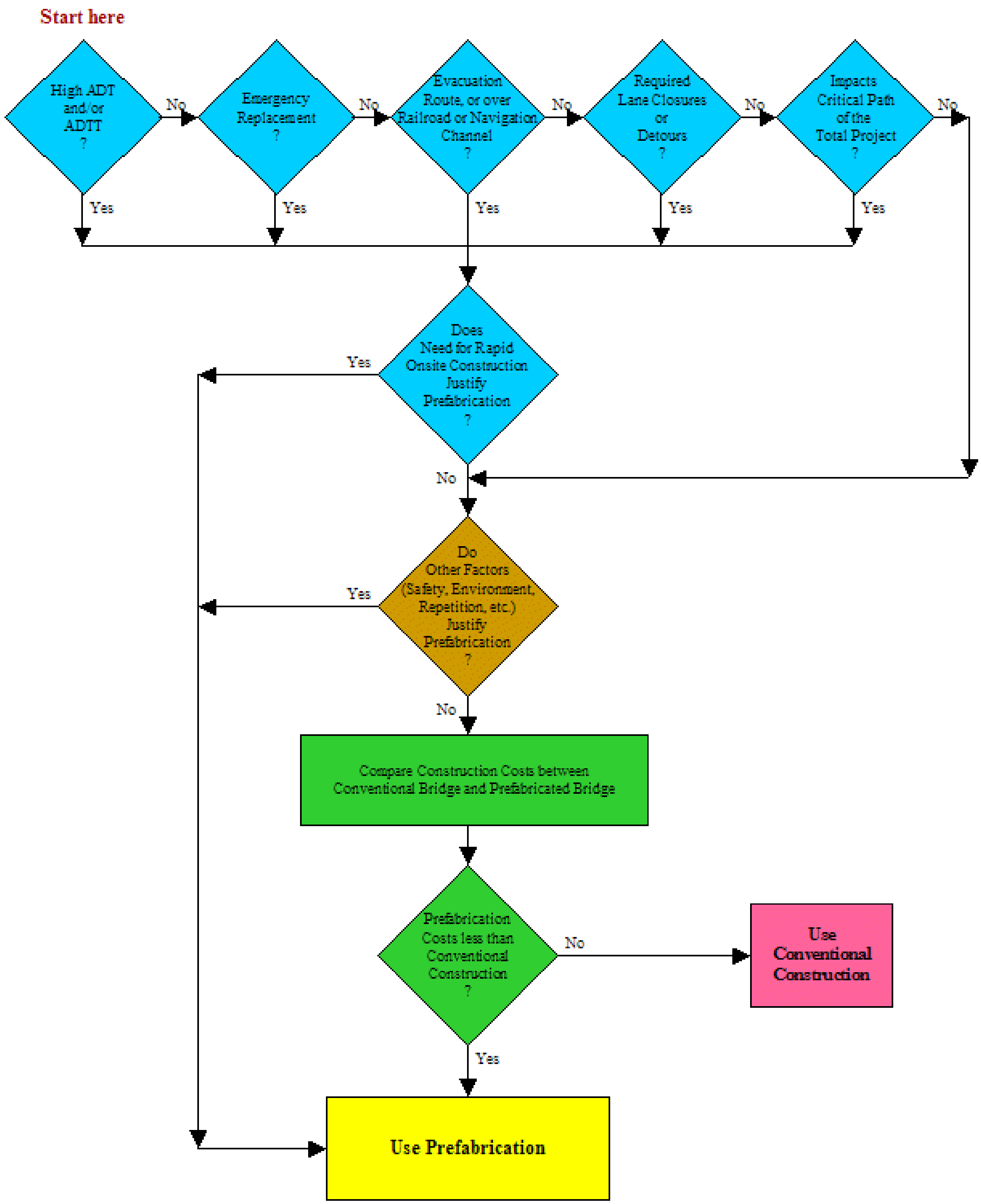


Figure 1: Decision-making flowchart to use prefabricated elements in bridge construction [1]

4.2.2 Major Parameters Affecting selection of bridge type in general

The case of new bridge construction affords the designer the freedom to select the most appropriate system for implementation. There are some major parameters that affect not only the decision making for the construction method, but also provide constraints or facilitate selection of details at system and element level. Common factors to be considered in the selection of new ABC Bridge components are summarized in Figure 2.

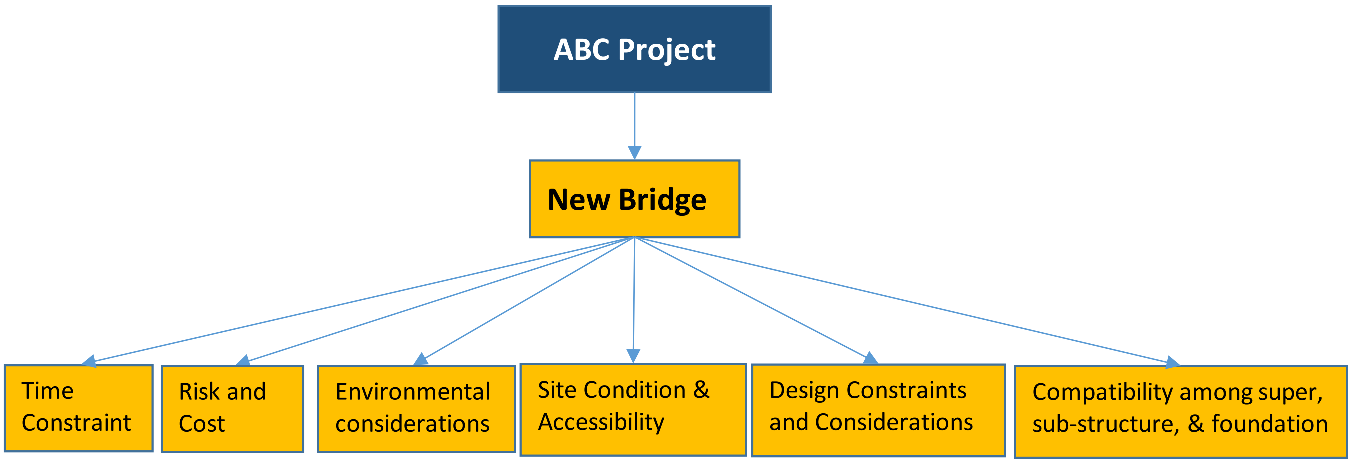


Figure 2: Parameters affecting selection of ABC components

4.3 Selection of Construction Method and Type of Superstructure

Selection of the construction method and type of superstructure certainly is affected by the parameters discussed above. FHWA Manual [1] has presented three flowcharts based on the construction of a bridge over roads (Figure 3), over railroads (Figure 4), and over wetlands (Figure 5). By use of these flowcharts, the ABC method can be identified and subsequently the corresponding superstructure systems can be selected. The type of superstructure element or systems therefore is dependent on the feasible construction method according to various constraints but mostly on accessibility as per condition of road, waterway, or railway the bridge is going to cross over. It should be noted that the use of prefabricated elements is viable for all types of ABC methods. Although these flowcharts have been developed to address type of construction methods and superstructure, they will also be applicable for the case of substructure type and associated construction methods without a need for major modification in the charts. For example, if lack of access under bridge or around it limits the type of construction to prefabricated individual elements and the use of conventional crane, the same will apply to the type and construction of the substructure.

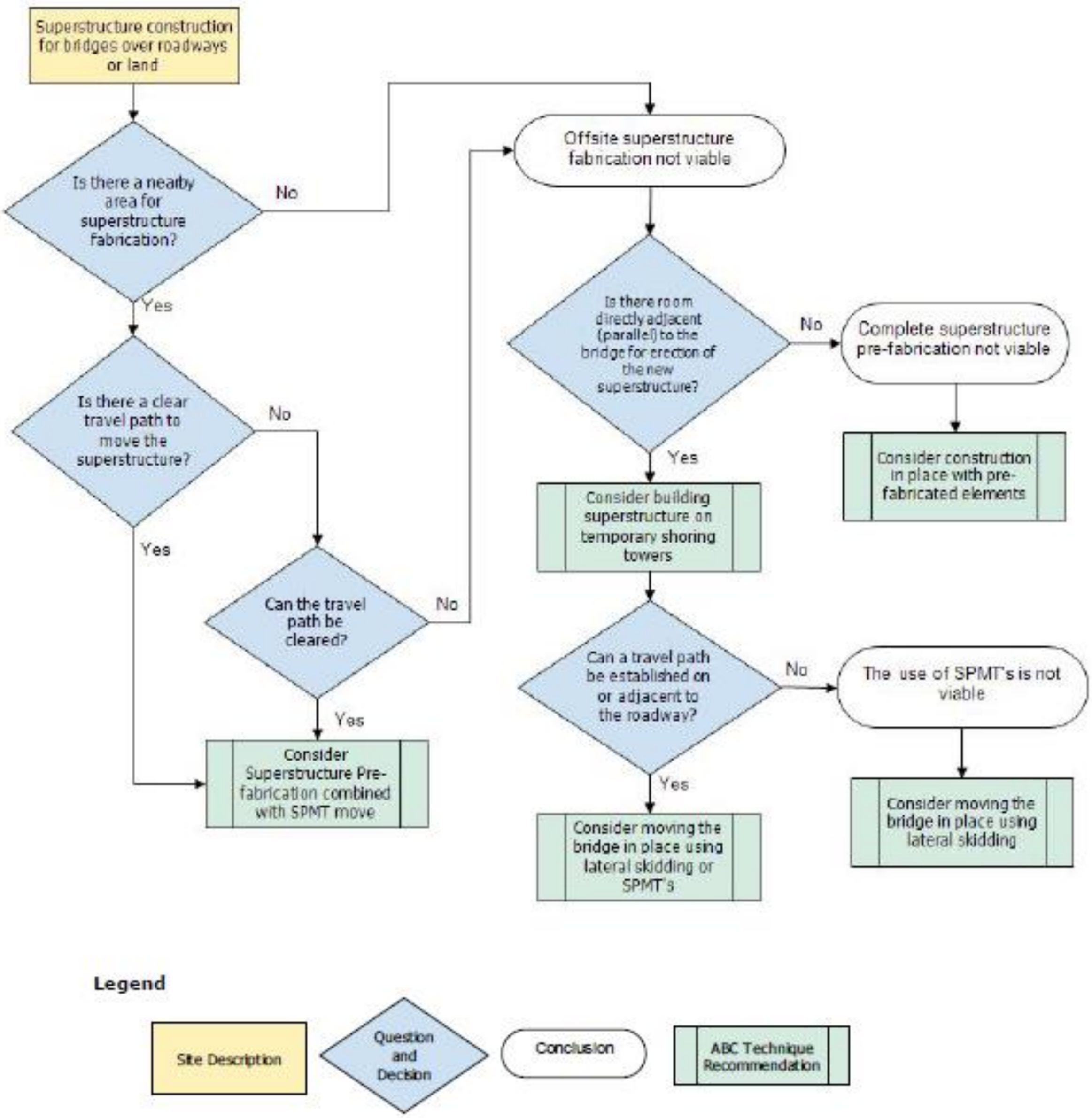


Figure 4: Decision flowchart for superstructure construction over the roadways [2]

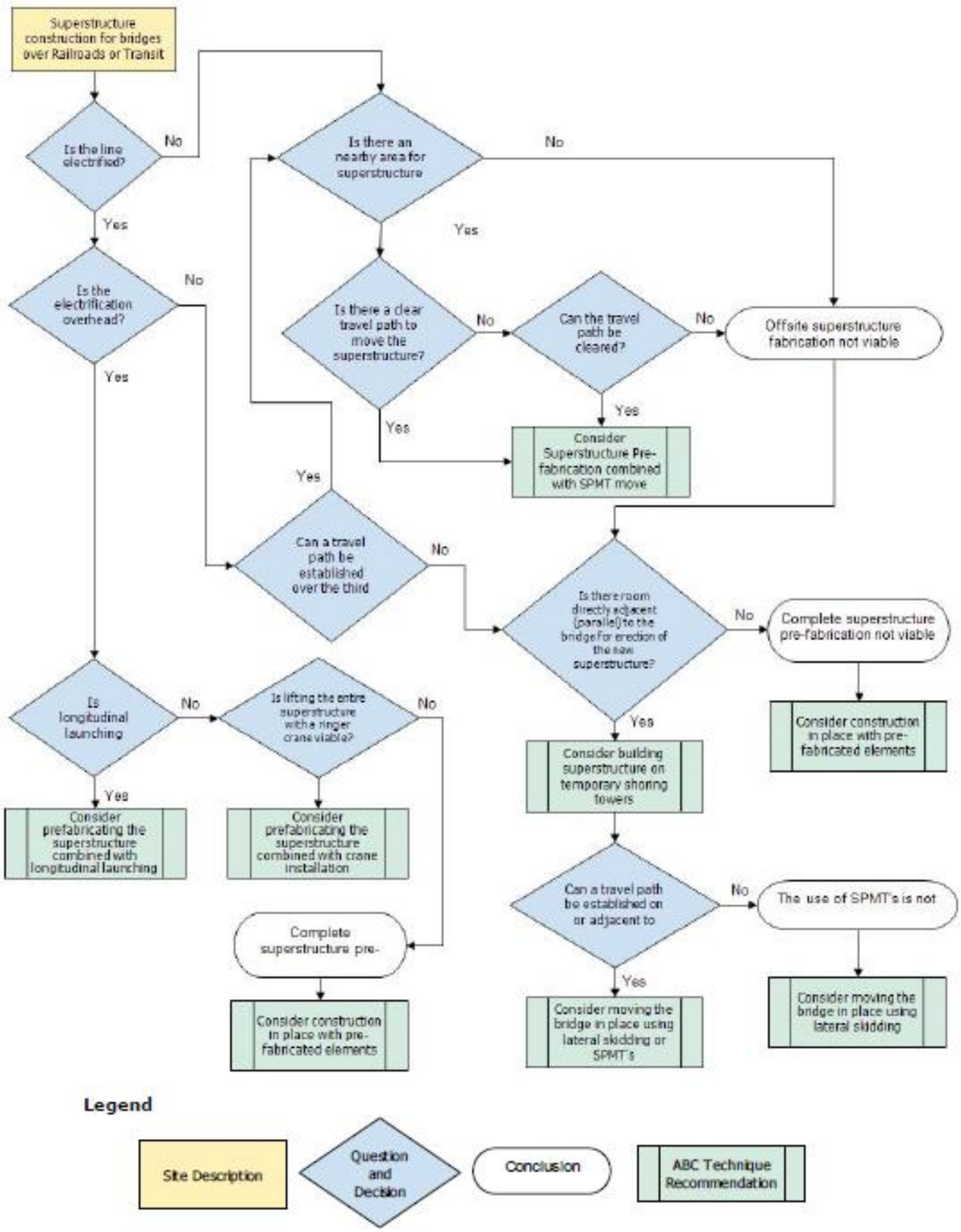


Figure 4: Decision flowchart for superstructure construction over the railroads [2]

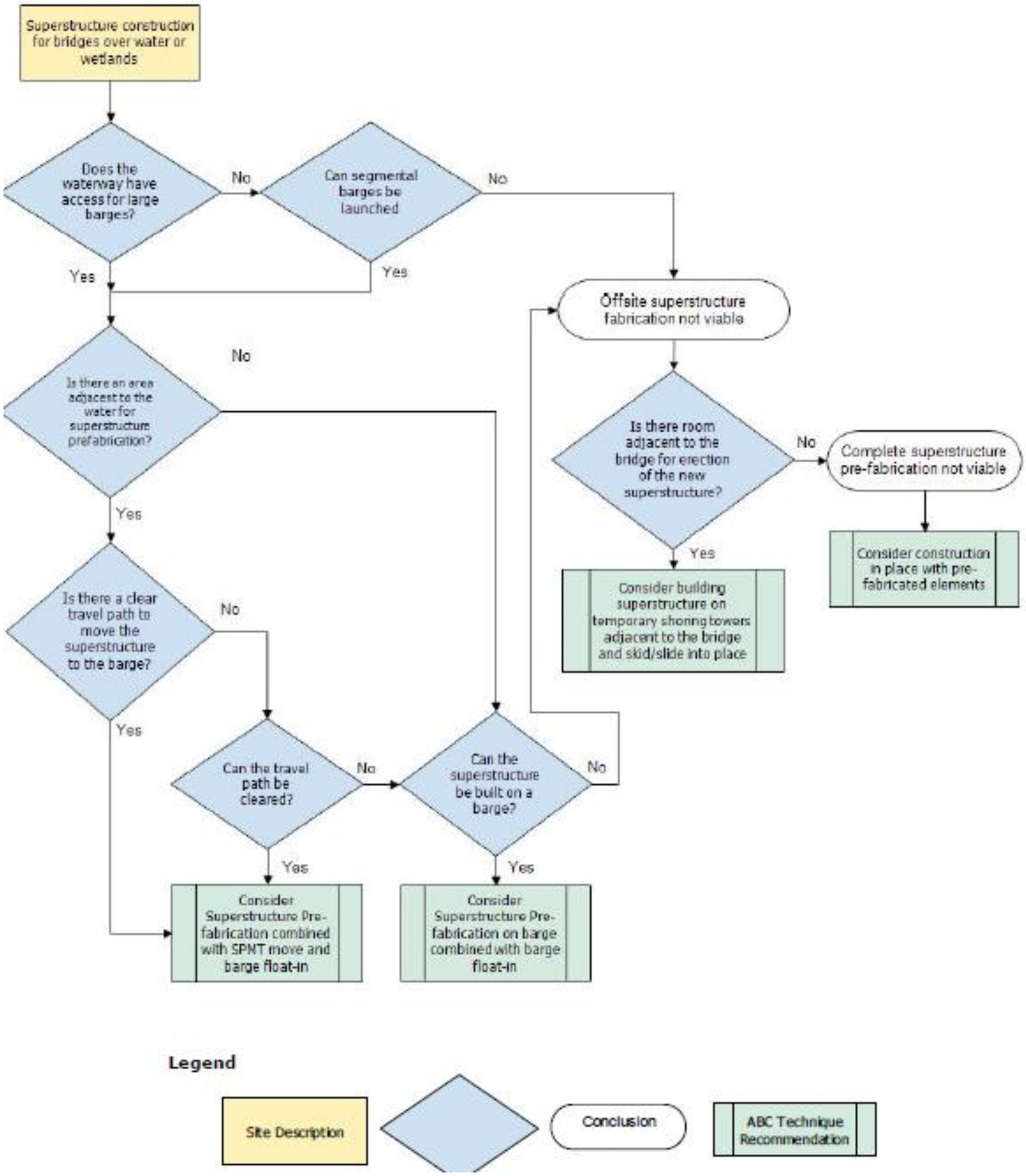


Figure 5: Decision flowchart for superstructure construction over the water [2]

4.4 Selection of Substructure Elements and Systems

The type of substructure elements and systems depends on; a) parameters affecting selection of ABC methods and elements in general as described in Figure 2, b) compatibility of substructure with superstructure and foundation, and c) parameters specific to the substructure (Figure 6).

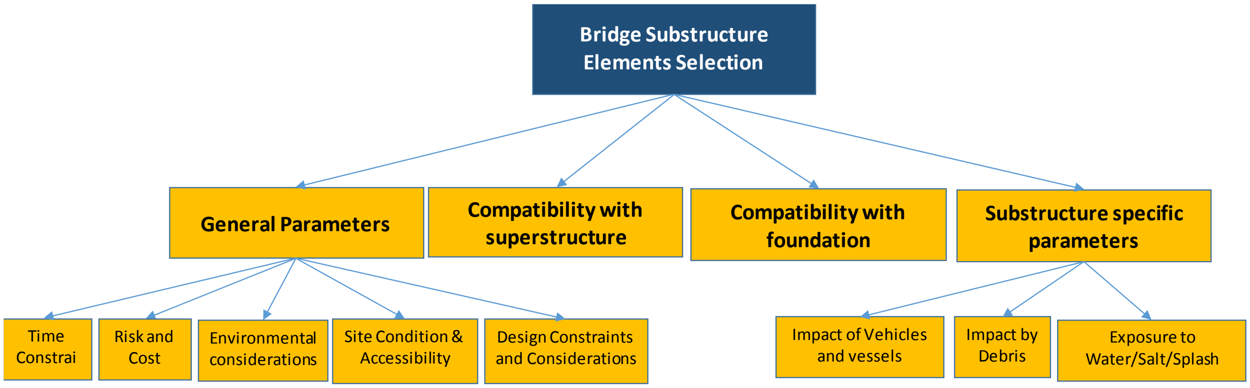


Figure 6: Bridge substructure element selection parameters

4.4.1 Parameters affecting the selection of bridge elements and construction methods in general

As discussed in the previous section related to selection of construction methods and superstructure element and system type, a set of general parameters discussed on Figure 2 influence the selection process with accessibility and availability of space having the major impact. Apparently, these parameters will affect in the same way the selection of substructure as well. For example, if there is no accessibility to transport large systems to the site, individual elements installed by conventional crane have to be used also for the substructure, the same way as for the superstructure. Therefore, for the substructure, the type of elements and methods selected for superstructure should be followed in general. Accordingly, there is no need to repeat the selection process for substructure as far as general parameters are concerned. In the same manner, this also applies to the construction method to be used for substructure, and the size of elements or subsystems. Beyond these preliminary decisions that will follow those of the superstructure, following describes the specifics on substructure in accordance with compatibility with superstructure and foundation, as well as parameters specific to substructure.

4.4.2 Compatibility of Substructure with Superstructure and Bridge Configuration

In addition to geometric compatibility, the bridge elements and units are expected to be compatible in design and construction with each other. For instance, the performance anticipated for connection between super- and substructure may favor or limit the use of one or another type of substructure. For fully-integral, semi-integral, or siding connection with the superstructure, the abutment or pier cap shall accommodate the transfer of moment and shear as per design and therefore these conditions will become defining parameters for the type of the pier or abutment.

4.4.3 Compatibility of Substructure with Foundation

Substructure is a component of the bridge that connects superstructure and substructure together and transfer loads from superstructure to foundation. Therefore, the compatibility of substructure with superstructure as well as foundation in design and construction is necessary for integrity and unity of bridge. For instance, the seismic condition of soil may constrain the use of some types of connections between foundation and substructure, causing limitation in selection of substructure element, design, and construction type.

4.4.4 Parameters Specific to Substructure

There are some factors that may only affect the selection of substructure. One of them is exposure of substructure to water, salt, or splash. In this case, special considerations should be considered to select the materials and elements of the bridge substructure that provide for more durability in the related harsh and corrosive environment. Additionally, in some cases the bridge substructure may be impacted by vehicles for the case of bridge over roadway, or in the case of bridge across waterways by debris and vessels. This may result in the use of protective elements around the piers or the use of pier wall in the substructure.

4.5 Selection of Substructure based on Compatibility with Superstructure and Substructure-specific Parameters

In this section, a flowchart for selection of substructure for ABC projects is developed based on considering interrelations between superstructure and substructure as well as contribution of other parameters that are specific to the substructure. As described earlier, the selection of substructure element/system type and associated construction method will follow the same process as was described above for the superstructure based on general parameters including the site accessibility and space availability. Therefore, an earlier process should have already defined the type of substructure system and construction method that in most cases will follow that of superstructure for new bridges. To consider the effect of parameters beyond the general parameters, a preliminary flowchart for selection of the substructure types and components accounting for compatibility with superstructure and substructure-specific parameters has been developed and is shown in Figure 7. The substructure elements included in this selection are comprised of pier system, abutment system, and modular culverts.

4.6 Suitability of Substructure Types with Respect to Foundation

Work on this section will be performed in the next period.

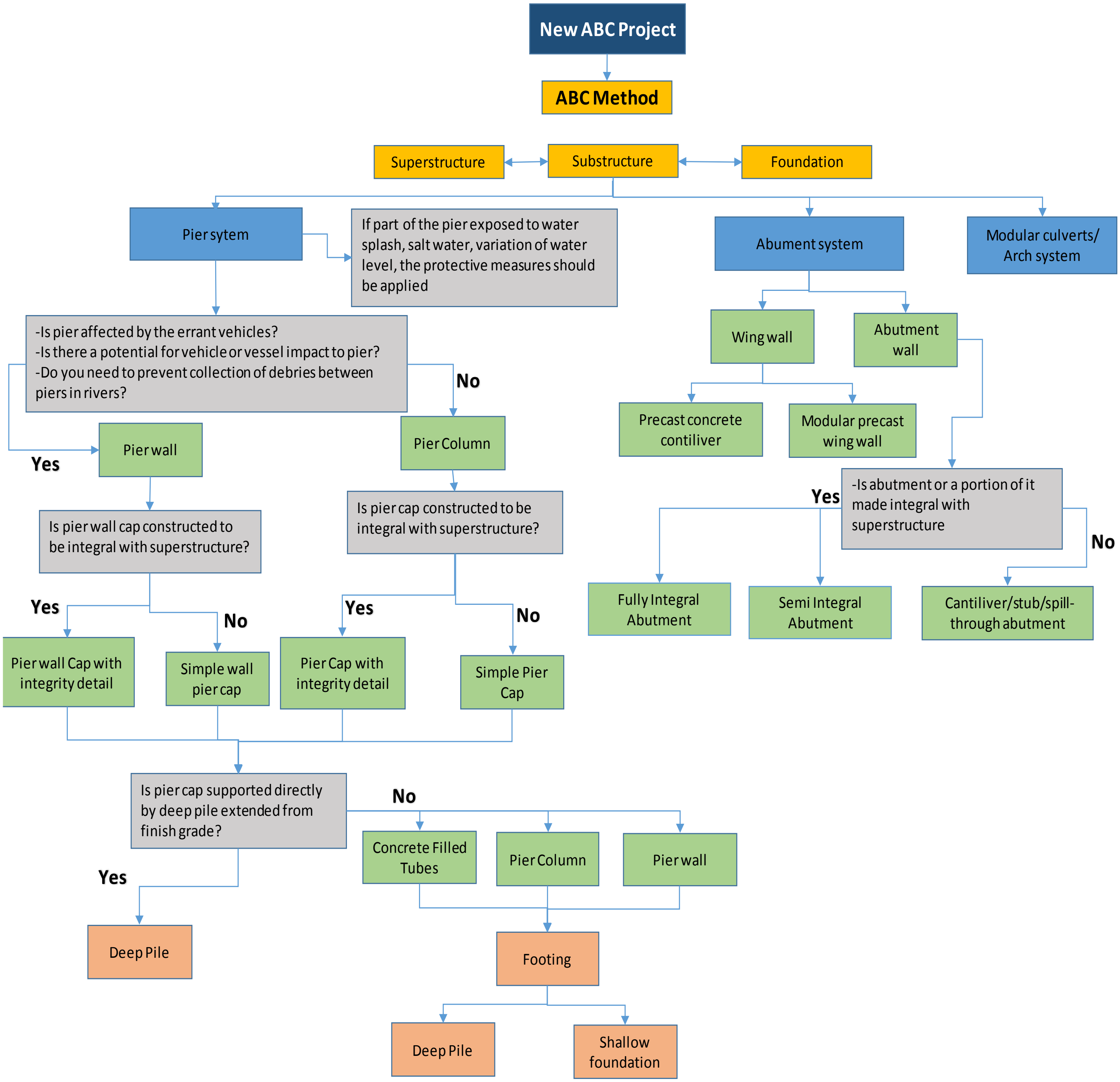


Figure 7: Preliminary flowchart for selection of substructures

4.7 Suitability of Substructure with Respect to Foundation Type

This will be covered by OU.

5 Task 3 – Identify Stakeholders and Conduct Survey

The FIU and OU research team members will work collaboratively and with the ABC-UTC committees to identify stakeholders for this study. The stakeholders would include, but not limited to, state DOTs (bridge divisions, construction divisions, and maintenance divisions), bridge designers, contractors, academic institutions, and TRB committees. A survey has been prepared to be sent to stakeholders in the next period to identify existing practices, selection processes, parameters affecting selection, and issues and challenges that are not available in the open literature (Task 2). Online instrument named Cualtrics has been used in preparing the survey. Statistical analyzes of results (for multiple choice questions) can be automatically conducted by this instrument. This task is ongoing collaboratively by FIU and OU.

6 Task 4 – Analysis of Literature Search and Survey Results

Information from the literature search (Task 2) and the survey (Task 3) will be analyzed carefully to document existing practices, best practices, issues, and other important factors such as cost, service life, construction/retrofitting time, and durability. Outcomes of this task will be instrumental to the development of the Guide. FIU will focus on substructure and OU on foundation.

7 Task 5 – Identification of Issues and Potential Solutions

Findings of Tasks 3, 4 and 5 will be used to identify the issues related to design and implementation of ABC substructures and foundations and the knowledge gaps. They will also help identify issues hindering the design and use of ABC substructures. To the extent permitted by the scope of this project and the limited budget, solutions to these issues will be explored by the FIU and OU research teams. FIU will focus on substructure issues and OU on foundation issues.

8 Task 6 – Develop Draft Guide

Based on the outcomes of Tasks 1 through 5, a draft Guide will be compiled and submitted for review by the Advisory Panel. The draft will be revised based on the review comments. FIU will lead this task with the support from OU.

9 Task 7 – Final Report

A comprehensive final report will be prepared and submitted. In addition to discussing the Guide, the process used in the development of the Guide will be included. FIU will lead this task

10 Expected Results and Specific Deliverables

10.1 ABC-UTC Guide for Selection of Substructure and Foundation for ABC Projects

The main deliverable for this project is a Guide for selection of substructure and foundation for ABC projects.

10.2 A five-minute Video Summarizing the Project

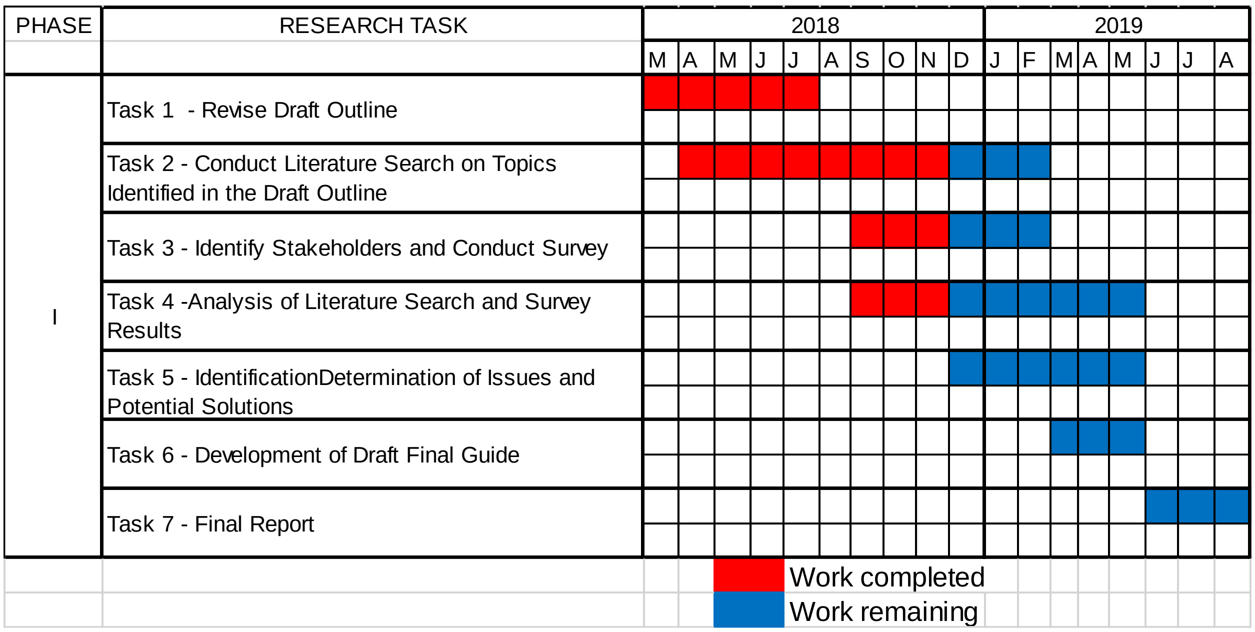
A short video will be prepared describing the guide developed in this project.

This research work and the Guide to be developed are directly applicable to the selection, design, and construction of ABC projects, including new bridges and replacement of existing bridges.

Designers, bridge owners, and other stakeholders should be able to use this Guide to determine the substructure that best serves their purposes.

11 Schedule

The bar-chart below shows the schedule and work progress.



12 References

1. Tang, B., *Framework for prefabricated bridge elements and systems (PBES) decision-making*. 2006.
2. Culmo, M.P., *Accelerated bridge construction-experience in design, fabrication and erection of prefabricated bridge elements and systems*. 2011.