

**DEVELOPMENT OF USER-FRIENDLY TOOLS AND DECISION-
MAKING ALGORITHMS FOR SERVICE LIFE DESIGN OF ABC
BRIDGES**

**Quarterly Progress Report
For the period ending May 31, 2020**

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**ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER**

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

1. Background and Introduction

Accelerated bridge construction (ABC) is a paradigm shift in the project planning where the necessity to lessen mobility impacts that occur due to onsite construction activities are given to a major priority. ABC techniques use innovative design and construction methods that are advantageous in a cost-effective and safe manner. Among the ABC techniques, prefabricated bridge elements are the most prominent methods. These are structural components that are manufactured offsite and shipped to the site upon the requirement that aims the reduction in onsite construction time, traffic disruption, improvement in product quality, and durability. An ABC application called closure joint is used to connect two adjacent prefabricated deck panels by casting filler material (i.e. normal concrete, polymer concrete, and ultra-high performance concrete) in between them with the use of different reinforcement details. The connections, however, can be affected by environmental and structural degradations. Consequently, durability issues have been encountered in closure joints. There are proof tested and approved ABC design methods available in the literature. The recent publication by ABC-UTC discussed the closure joint design methods to mitigate the durability in a comprehensive manner (Jahromi et al., 2020).

This project will design and implement a prototype web-based decision support tool to facilitate the use of existing manuals and bridge specifications in practice. We first derive decision-making algorithms and criteria presented in the guideline for service life design of longitudinal deck closure joints. We then translate them into UML (Unified Modeling Language) use cases and develop a series of well-designed interactive questions and user interfaces. This will allow users to walk through the service life process with the aids of visual elements, suggestions and tips, and make final design decisions, without much knowledge of probabilistic approaches.

2. Problem Statement

Implementation of ABC technology has been gaining great momentum by Federal Highway Administration (FHWA) and several state DOTs during the last two decades (Culmo, 2011). ABC methods minimize the construction activities performed in the field, reduce the detour time and traffic disruptions, and improve the safety of workers and the public. Methods typically used for ABC include prefabricated bridge elements and systems (PBES), lateral slides, and self-propelled modular transporters (SPMT). Prefabricated elements used for ABC will be connected using longitudinal or transverse closure joints. It is noted that many prefabricated decks with longitudinal closure joints have performed well. Connections of PBES are critical as the performance of connections under loads and natural environmental conditions can affect the service life of the bridges. In addition, some issues like leakage and cracking in prefabricated deck connections have been identified with respect to operational or production defects. Different ABC design methods have been developed to connect prefabricated deck panels (e.g. Jahromi et al., 2020; Haber and Graybeal, 2018; Graybeal, 2014; Li et al., 2009). These design methods and new solutions are in progress to be incorporated in AASHTO LRFD Bridge Design Specifications for ABC but are not available yet. However, the methods have been proof tested and verified by the bridge community including bridge engineering research group in FHWA, ABC-UTC, and several state DOTs.

Recently, ABC-UTC has published a guideline for service life design of longitudinal deck closure joints (Jahromi et al., 2020) which was a customized version of a project for Bridges with Service Life Beyond 100 Years. While the published ABC-UTC Guide is comprehensive, it is not user

friendly for bridge engineers and state DOTs to be used and implemented in their design. Therefore, a reliable decision support tool is required to assist stakeholders and engineers in choosing appropriate design options and solutions. To this end, we will develop a prototype web-based tool that provides customized design by applying the decision-making algorithm focusing primarily on service life and durability of closure joints. The proposed decision support tool will be implemented based on the general steps presented in the ABC-UTC design guide. It will be visual and allow users to easily navigate through the design options, design steps, on-site requirements, geometry, material properties, and modes of failures.

3. Objectives and Research Approach

Specific objectives of the projects are as follows:

- Develop a prototype web-based tool that will contain in a data base the entire information listed in the ABC-UTC Guide for Service Life Design of Longitudinal Deck Closure Joints and host it at FIU in a dedicated server.
- Develop a series of well-designed interactive questions and user interfaces that will allow the user to walk through service life process with the aids of visual elements, suggestions and tips.
- Allow, easily, the information in the data base, such as reported closure joint service life performance and types to be updated as information becomes available
- Develop decision making tools that will assist the user to make final design decisions, without having to know fully the theory behind probabilistic approaches that will be used in the decision-making process.

The project team first translates the design solutions, presented in the ABC-UTC Guide, into UML use case and state charts, and designs the interactive questions based on the decision-making criteria and probabilistic approaches. We then organize preliminary meetings with the research advisory panel to solicit their feedback and update the use case diagrams for the decision support tool. Once the information flow, decision algorithms, and system functionality are approved, we use Python, an object-oriented programming language, and available open-source libraries (e.g. Pandas, Scikit, Numpy, SQLite) to implement the user interfaces and algorithms. To facilitate the decision support tool deployment on FIU server, the project team works closely with the Office of Information Technology to allocate the required space and maintenance resources.

4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1 – Architecture Design

The system architecture is the optimum way to understand the interaction among components. Our architecture comprises three components which include GUI, application server, and database server. The main components are shown in Fig. 1.

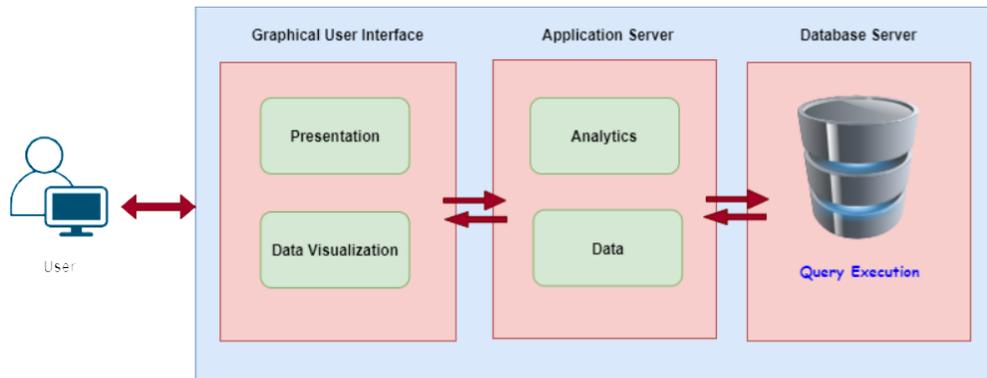


Fig. 1. System Architecture

Graphical User Interface: The user will be provided with an interface or frontend where the specific parameters need to be given by the user to assist in identifying the list of closure joints. The interface helps to establish the environment where the user can interact with the system by providing necessary inputs and getting the desired output.

Application Server: The application server is the middle tier of the system. It is a business logic application or set of applications on the local network. When an application server gets a request from the user, it then performs logical operations based on the designed algorithm.

Database Server: It is a crucial component where the query requested by the user will be processed at this stage. The database will be populated with the required information that allows the algorithm to process the data and make appropriate decisions.

The decision support tool will be deployed on the FIU server. The OU research team will initiate communication with the Office of Information Technology at FIU to identify software requirements and allocate the required space and maintenance resources.

Task 2 – Content/Information Flow Identification, Algorithms and Analytics, Dashboard Design.

We will design UML use case diagrams, based on the published ABC-UTC Guide for service life design of longitudinal deck closure joints, to define interactive questions, systems functionalities, and required underlying decision algorithms.

Research team mainly focused on content flow identification. Fig. 2 illustrates the system use case diagram. The user is a primary actor who initiates the system. In our project, the database is the secondary actor which provides the necessary details to process the request. In this diagram, tasks or use cases are represented in three different colors to differentiate among tasks. Use cases represented in blue color are nothing but inputs/specifications that the user is required to provide in order to interact with the system. Use cases represented in orange color are outputs that the user receives as the result of the requested query. Rest of the use cases represents internal working process of the query.

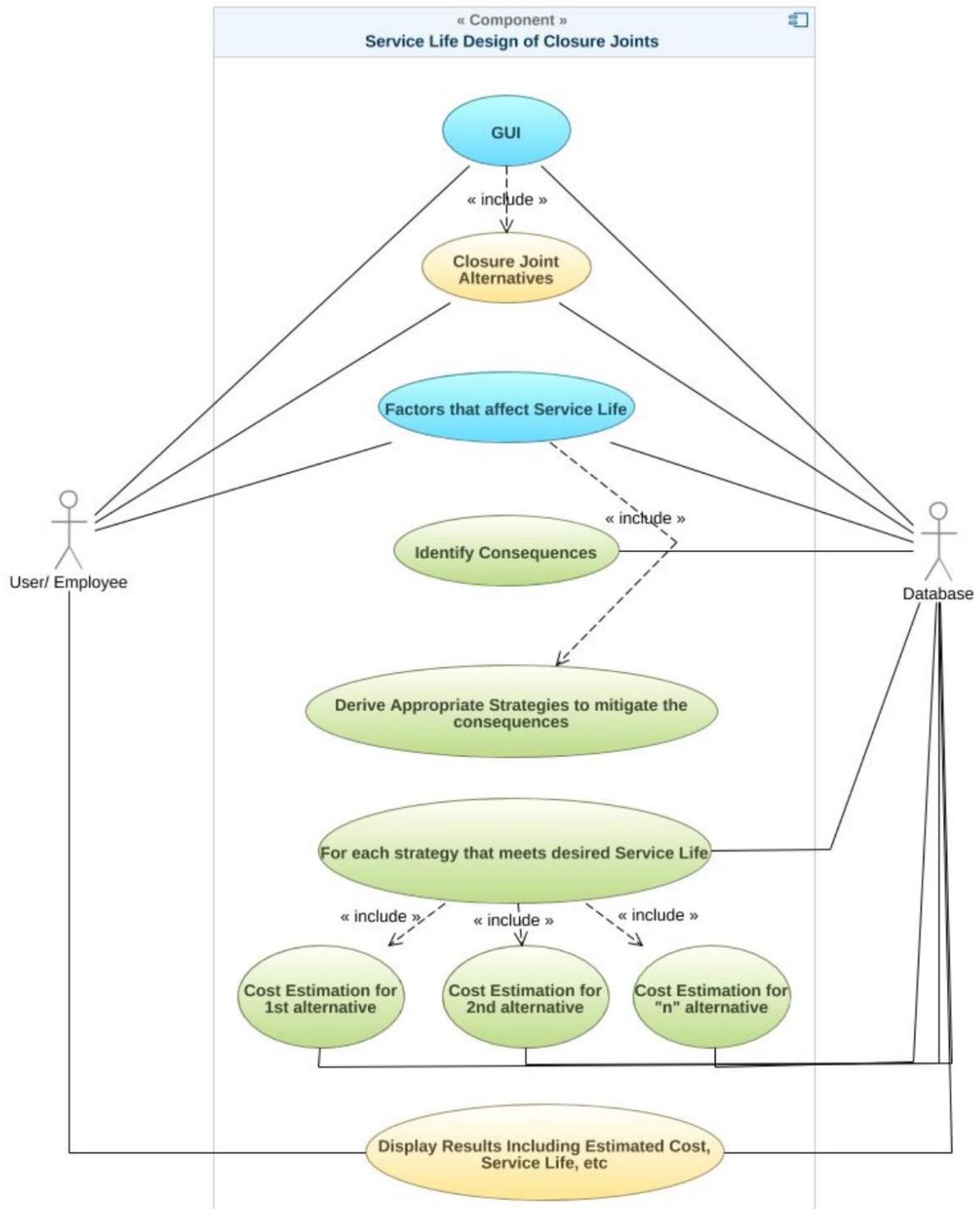


Fig. 2: UML Use case Diagram

Flow of Use cases: The interaction with the system starts once the user initiates the request through GUI by providing specifications through parameters. For each identified closure joint, with provided factors such as service loads, natural or manmade hazards that affect the service life of closure joints, the algorithm will determine appropriate mitigation strategies available in the

guideline. For each derived alternative, the service life will be calculated based on Fick’s law. For all alternatives, the estimated cost will be calculated and displayed along with the estimated service life. This allows for trade-off analysis and assists the user in making decisions.

Research advisory board: Two members representing Oklahoma DOT and a consulting company were invited and joined the advisory panel.

5. Expected Results and Specific Deliverables

The expected deliverables are: (a) a prototype web-based tool; and (b) a manual (software documentation) which will guide users to make final design decisions, listed in the ABC-UTC Guide for Service Life Design of Longitudinal Deck Closure Joints. The interactive user interfaces will provide effective visual elements and suggestions to guide users, without fully knowing the theory behind probabilistic approaches.

6. Schedule

This project started in May, and the progress of tasks is shown in the table below.

Item	% Completed
Percentage of Completion of this project to Date	10%

PROJECT TASK	2020							
	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
T1. Architecture Design	Work Performed	Work to be Performed	Work to be Performed					
T2. Content Identification, algorithms, analytics, dashboard	Work Performed	Work to be Performed						
T3. Prototype implementation				Work to be Performed				
T4. Final Report							Work to be Performed	Work to be Performed
				Work Performed	Work to be Performed			
				Work to be Performed	Work to be Performed			

7. References

M. Culmo, (2011), “Accelerated Bridge Construction: Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems: Final Manual”, Federal Highway Administration, Office of Bridge Technology (Rep. No. FHWA-HIF-12-013). United States.

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