DEVELOPMENT OF ARCHITECTURE FOR GENERATIVE PRE-TRAINED TRANSFORMER (GPT) INSPIRED MODEL FOR BRIDGE ENGINEERING WITH APPLICATION TO SERVICE LIFE DESIGN, CALLED BRIDGEGPT

Quarterly Progress Report
For the period ending April 2025

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1. Background and Introduction

A Generative Pre-trained Transformer (GPT) system can, if coupled with data, make a paradigm shift in our approaches to bridge design and construction. The research proposed in this project focuses on the development of BridgeGPT architecture, using bridge service life design as the first application.

The SHRP2 R19A project has gathered a wealth of data on bridge service life design. However, the full potential of this data has yet to be utilized. Traditional methods of bridge design and maintenance, while reliable, can benefit greatly from the predictive power and adaptability of models like BridgeGPT. There is a crucial need to more closely relate cutting edge AI technology and bridge engineering to optimize service life design, reduce costs, and enhance infrastructure safety. This project aims to utilize the capabilities of GPT-like models, adapt them for bridge engineering, and create a tool that learns and improves over time.

2. Problem Statement

Bridge service life design today is limited by fragmented data, inconsistent assumptions, and tools that do not learn from accumulating evidence. The SHRP2 R19A program produced a rich corpus of reports, interim documents, and datasets, but most of this knowledge is locked in unstructured formats and is under-utilized in day-to-day decision making.

General-purpose GPT systems demonstrate capacity for knowledge synthesis, but they are not purpose-built for bridge engineering: they lack domain grounding, numeric/reliability reasoning, traceable citations to standards and data, and guardrails against hallucinations. Without a specialized, data-coupled architecture, there is a risk of incorrect service life predictions, overly conservative designs, and reduced trust among practitioners.

This project addresses these gaps by developing BridgeGPT: a domain-adapted architecture that integrates a curated and versioned SHRP2 R19A knowledge base with other service life data and bridge design sources. In addition, BridgeGPT employs fine-tuning of open-source foundation models to encode bridge engineering knowledge directly within the model weights using the curated corpus (R19A and related datasets).

The initial application is service life design, selected for its immediate utility and the availability of high-quality data and methods. The outcome will be a validated, explainable assistant that turns R19A and related sources into design guidance.

3. Objectives and Research Approach

The research approach for this project focuses on developing the general architecture of the BridgeGPT platform, demonstrating the feasibility and usefulness of the BridgeGPT by developing a service life module compatible with the requirements of BridgeGPT. The beta version of the developed BridgeGPT platform and service life design module will be tested by select DOTs and consultants. The service life design module will be completed after receiving their feedback. This project will also include the development of a roadmap for future activities leading to the design of other modules, as well as a business plan for ensuring sustainability of the developed system.

4. Description of Research Project Tasks

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

Task 1 - Development of System Architecture.

This task will develop the overall architecture of a main platform that can accommodate different subsystems, each devoted to certain aspects of activities that are part of design and construction of bridges. Attempts will be made to develop an initial list of activities for which development of subsystem compatible with main platform requirements is feasible. Undoubtedly this list will expand in future; nevertheless, it will help to incorporate what is needed in the main platform to accommodate the potential subsystems.

Progress: This task is 30% complete.

During this period, the Mistral 7B model was tested locally to understand its performance and compatibility with the available GPU resources before applying it to bridge-related data. As part of the data pipeline, further steps were taken to clean and organize the collected bridge manuals. It was decided to temporarily exclude figures from the extraction process to simplify the first training phase.

Task 2 - Collection of Service Life Design Data.

During the development of "Design Guide for Bridges for Service Life", many interim and phase reports were prepared that were not included in the final report of SHRP2 R19A. These interim and phase reports contain a tremendous amount of useful data and information. Having served as PI of the SHRP2 R19A project, Dr. Azizinamini has access to complete documentations and has kept a good inventory of them. All data and information developed during conduct of SHRP2 R19A project will be reviewed, and available information will be categorized.

Progress: This task is 25% complete.

A comprehensive search of documents and reports related to bridge design and service-life design has been initiated. The search prioritized freely accessible sources (without paywalls) that can be used for educational and research purposes. The collected materials include references on bridge service-life design and evaluation, general bridge design, state and international bridge manuals, technical guides, and relevant documents.

Task 3 - Development of General Strategy for using AI and ML for Service Life Design.

To demonstrate the usefulness of the overall system, service life design of bridges will be used as the testbed. Under this task the strategy for how best to utilize principles of AI and ML for service life design of bridges in conjunction with available data will be developed.

Progress: This task is 10% complete.

The task was to focus on improving the data extraction methods. It was recognized that some documents may contain scanned images instead of editable text, so OCR methods will be needed to accurately extract information from those files.

At this stage, research was also carried out to identify standard data preprocessing practices for, and we reviewed papers on GPT and BERT. However, since most studies did not clearly explain their data-cleaning approaches, PyMuPDF was used for text extraction, while OCR techniques were applied specifically for extracting formulas and equations.

Task 4 - Sharing Beta Version of Service Life Design Module with Selected Users.

This task will share the interface to use service life design module with select DOTs and consultants who are willing to test the system and provide feedback.

Progress: Not started.

Task 5 – Making Changes and finalizing the Service Life Design Module

The feedback received will be used to modify and finalize the service life design module. This step may require several iterations.

Progress: Not started.

Task 6 – Developing Roadmap for Future Work

This task will develop the roadmap for future activities, which will also include the business aspect of the initiative.

Progress: Not started.

Task 7 – Final Report

This task will summarize overall aspects of the project.

Progress: Not started.

5. Expected Results and Specific Deliverables

This research is expected to produce both technical advances and practical tools that can be piloted and used by DOTs and consultants.

The project is anticipated to generate the following key results and deliverables:

- A documented system design (Bridge GPT).
- Service Life Design Module (Beta).
- Final Service Life Design Module (v1.0)
- Evaluation and Validation Report.

- Roadmap & Business Plan.
- Final Project Report.

6. Schedule

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

Item	% Completed
Percentage of Completion of this project to Date	25