

# Development of User-friendly Tools and Decision-making Algorithms for Service Life Design of ABC Bridges

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# Introduction

- Half to two-thirds of U.S. bridges will exceed their design life by 2030
- Design life: time period design assumptions remain valid, typically 50-75 years
- Service life: time period the bridge will continue to provide its intended function
- Service life design limited by available guidance
- Explicit design of bridges for service life is receiving more attention
  - AASHTO Guide Specification for Service Life Design of Highway Bridges
  - Provide practical guidance for service life design

# Introduction

- ABC has great potential for bridge replacement and service life design
- Prefabricated bridge elements are the most popular ABC techniques
- Full-depth deck panels and pretopped modular units are the most popular prefabricated elements
  - Require durable connections – closure joints
  - Strength design is relatively simple
  - Service life design is more complicated
- Need for guidance for selecting appropriate details for ABC closure joints

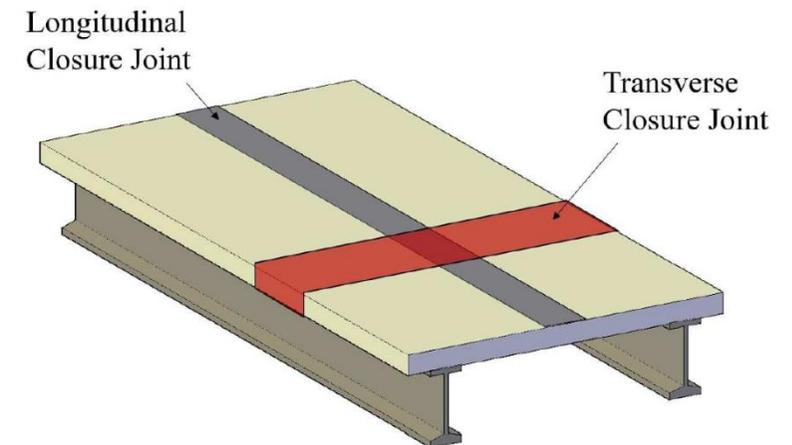


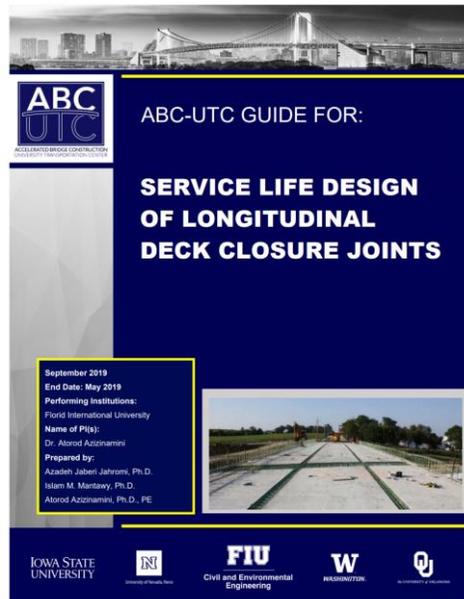
Illustration of closure joints from Jahromi et al. (2020)

# Introduction

- ABC-UTC Guide for Service Life Design of Longitudinal Deck Closure Joints published in 2019 (Jahromi et al. 2019, Jahromi et al. 2020)
- Developed a framework for service life design of closure joints used in ABC
  1. Identify project requirements relevant to service life
  2. Identify and select feasible closure joint types
  3. Identify factors influencing service life, modes of failure, and consequences
  4. Identify suitable methods for mitigating failure modes or assessing damage risk
  5. Modify closure joint with potential mitigation strategies
  6. Estimate service life
  7. Conduct life cycle cost analysis and choose joint meeting strength and service life

# Introduction

- **Mitigation strategies for closure joints**: (a) increasing deck and closure joint thickness by 0.5” using Normal Strength Concrete (NSC), Ultra High-Performance Concrete (UHPC), or overlay material, (b) stainless steel reinforcement, and (c) bottom sealer



# Introduction

- Time to reinforcement corrosion initiation used as service life metric
- Based on chloride ingress reaching the threshold value at reinforcement
- Fick's second law and assumption of one-dimensional ingress of chloride through the concrete deck

- $C_{(x,t)} = C_0 \left( 1 - \operatorname{erf} \frac{x}{2\sqrt{D_c t}} \right)$
- $C_{(x,t)}$  is chloride concentration at depth  $x$  and time  $t$
- $C_0$  is surface chloride concentration
- $D_c$  is chloride diffusion constant
- $\operatorname{erf}$  is the error function

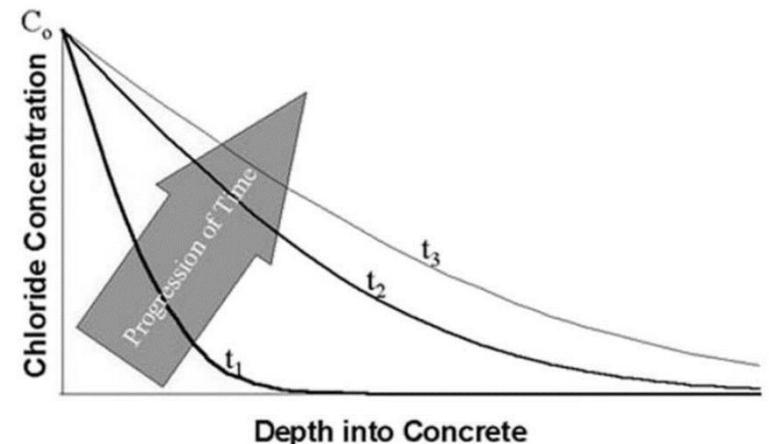


Illustration of chloride depth with time from Jahromi et al. (2020)

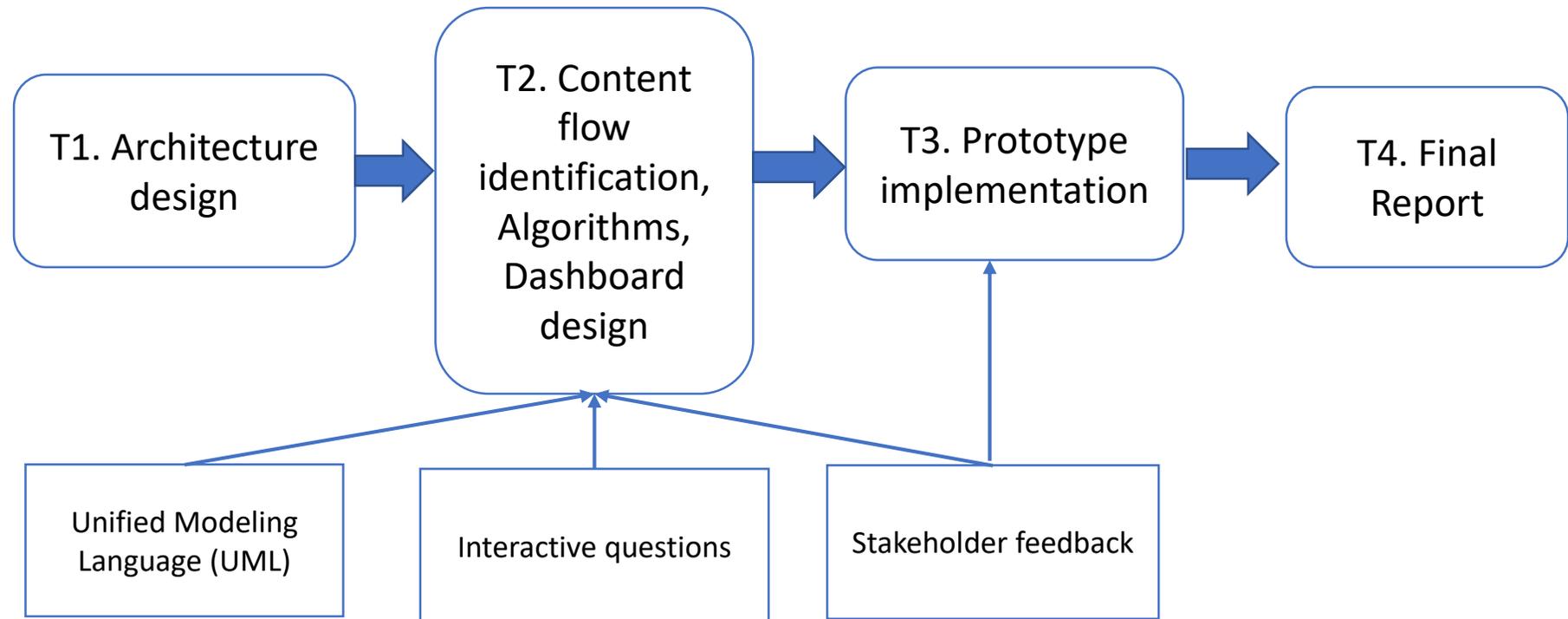
# Introduction

- How can we make it user friendly for bridge engineers and state DOTs?

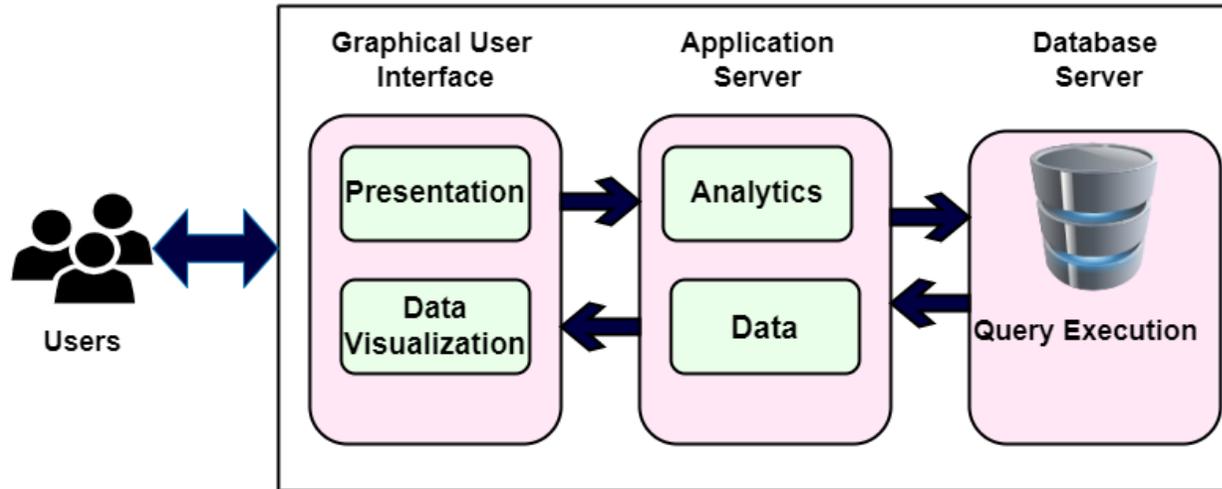
# Research Objectives

- Design and implement a web-based decision support tool
  - based on the general steps presented in the ABC-UTC design guide
  - visual and allow users to easily navigate through the design options, design steps, on-site requirements, etc.
  - calculate the estimated service life of the bridge deck and initial costs
  - utilize a multi-criteria decision making algorithm to help users choose the best option (mitigation strategy)

# Work Plan



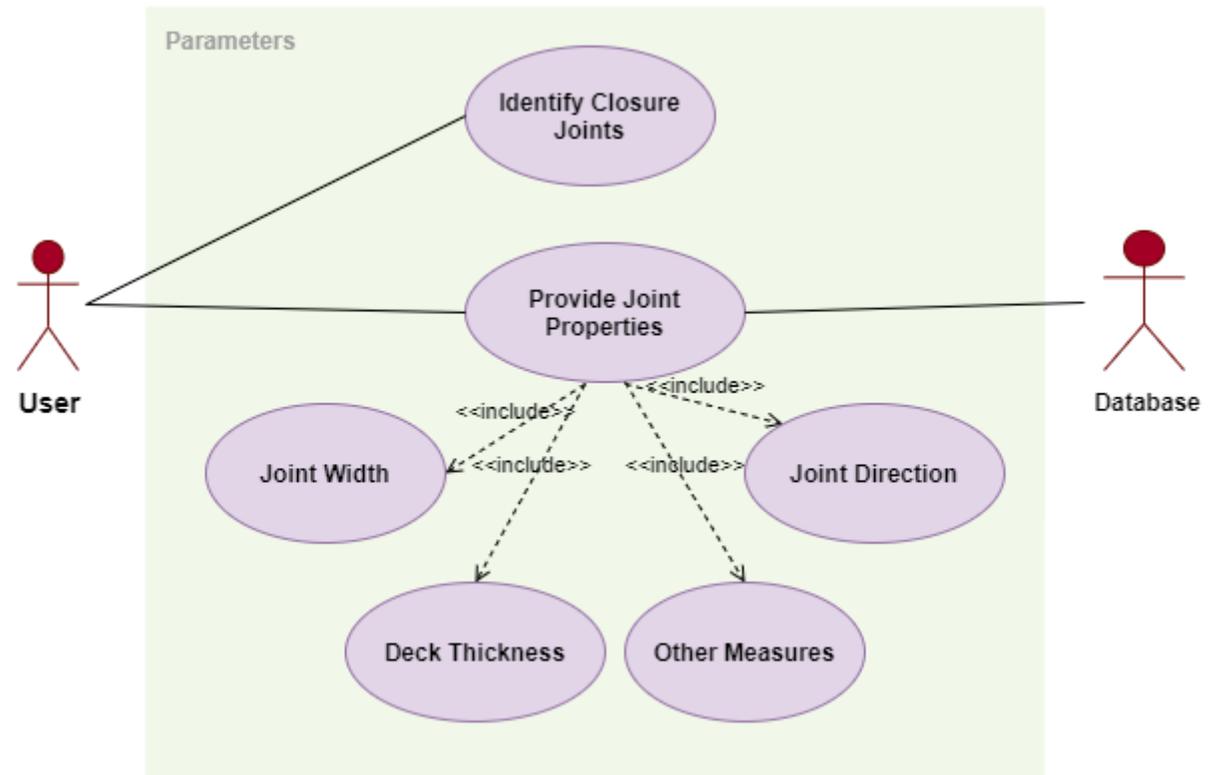
# Task 1: Architecture design



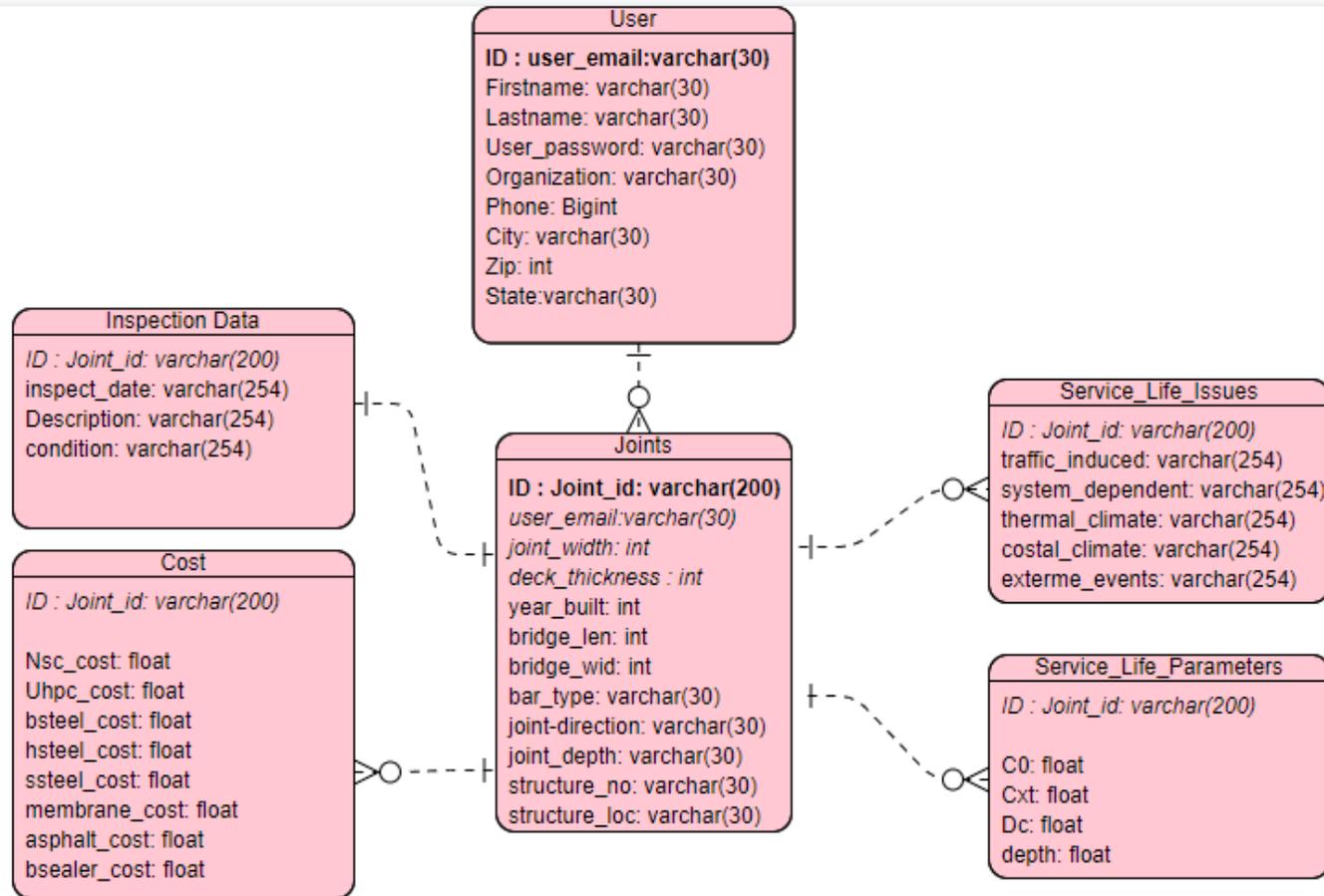
- Web-based Platform
  - Python-based open-source web framework
  - Model-View-Controller architectural plan
  - SQLite/MySQL for database
  - Computational intelligence

## T2. Content flow identification

- Designed use case diagrams and database
- Understanding the relationship between input parameters and mitigation strategies



# T2. Content flow identification



✓ Designed a relational database supporting spatiotemporal data

✓ Relations

Aggregation

Composition

Generalization

## T2. Algorithms

- Service life calculation
  - Fick's second law,
  - Time to start the corrosion, assuming one-dimensional ingress of chloride through the concrete deck
- Initial costs calculation
  - Combination of bridge length, bridge width, number of joints in the bridge, and costs of materials used
  - Limited data only good for comparison of options

## T2. Algorithms

- Multi-criteria Decision Making
  - TOPSIS (Technique for Order of Preference by Similarity) algorithm, utilizing users' preferences as weights to perform trade-off analysis between costs and service life
  - Ranking mitigation strategies based on the user's preference, and displaying the first- and second-best options
  - Similar to, but does not exactly align with AASHTO Guide Specification ranking system

# T3. Implementation

- **Live Demonstration**

# Conclusions

- Web-based decision support tool was developed based on the ABC-UTC Guide for Service Life Design of Longitudinal Deck Closure Joints
  - Visual and allows users to easily navigate through the design options, design steps, on-site requirements, etc.
  - Calculates the estimated service life of the bridge deck and initial costs
  - Utilizes a multi-criteria decision making algorithm to help users choose the best closure joint option (mitigation strategy)
- Could be expanded to other bridge elements such as expansion joints

# Thank You!



# References

- Jahromi, A. J, Mantawy, I. M., and Azizinamini, A. (2019) “ABC-UTC Guide for Service Life Design of Longitudinal Deck Closure Joints”, Accelerated Bridge Construction University Transportation Center, Florida International University, Miami, FL.
- Jahromi, A. J, Valikhani, A., Mantawy, I. M., and Azizinamini, A. (2020) “Service Live Design of Deck Closure Joints in ABC Bridges: Guidelines and Practical Implementation,” *Frontiers in Built Environment*, Vol. 5, Article 152, <https://doi.org/10.3389/fbuil.2019.00152>