GEORGIA DOT RESEARCH PROJECT 21-02

Final Report

STRATEGIC PRIORITIZATION IN BRIDGE ASSET MAINTENANCE THROUGH DATA DRIVEN LONG-TERM ASSET VALUATION WITH ADDITIONAL EMPHASIS ON PROMOTING GDOT'S PARTNERSHIPS WITH COUNTIES

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16. Abstract:

This study focuses on engaging local bridge owners through interviews and interactions, aiming to assist them in enhancing their bridge management practices, while also developing resources to support them. Key deliverables include multiple resource guides: a Non-NBI Culvert Inspection Guide, a Weather Stressors Guide, and a Supplementary Guide for Local Municipalities to GDOT's Bridge Structure Maintenance and Rehabilitation Repair Manual, each designed to improve inspection and maintenance processes, particularly for local bridge owners. The project also led to the development of the "Bridge Life Cycle" dashboard, a visualization tool that forecasts bridge performance, facilitates data sharing, and supports budgetary planning efforts. This dashboard represents the first attempt to apply data-informed methods to bridge lifecycle management for local bridge owners. The resources and strategies developed provide essential tools to improve bridge management, enhance coordination between GDOT and local bridge owners, and support more informed and efficient decision-making. Additionally, the project lays the foundation for enabling bridge owners to develop a comprehensive bridge service life cycle plan that will support locally owned bridge and culvert management in future transportation infrastructure planning.

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Contract with
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

This project focused on developing a life-cycle assessment dashboard to assist county bridge owners in prioritizing bridge element maintenance, repair, and rehabilitation (MRR). Through this research, correlations between element-inspection data, recommendations in inspection reports, MRR strategies, and long-term performance forecasting were analyzed to create a data-informed approach for bridge management. Several key deliverables were produced as a result of the project, including multiple Resource Guides: a Non-National Bridge Inventory (NBI) Culvert Inspection Guide to standardize the inspection and maintenance of culverts, a Weather Stressors Guide to assess the impact of weather conditions on bridge elements, and a Supplementary Maintenance Guide to complement GDOT's existing Bridge Structure Maintenance and Rehabilitation Repair Manual, specifically for local governments. Additionally, the project led to the creation of the Bridge Life Cycle dashboard, a tool that visualizes life-cycle data, forecasts performance, and supports the prioritization of maintenance efforts. Although this was the first attempt to create a NBI data-informed dashboard, these resources provide essential tools and strategies for improving bridge maintenance practices, facilitating better coordination between GDOT and local governments, and ensuring more efficient and informed decision-making. The project also laid the foundation for a non-NBI asset inspection process for local governments, which will support ongoing maintenance efforts and contribute to the development of a comprehensive bridge life plan, including culverts, for future bridge management.

CHAPTER 1. INTRODUCTION

OVERVIEW

The management and maintenance of bridges are critical for ensuring the safety, reliability, and longevity of transportation infrastructure. In Georgia, as in many other regions, local governments and transportation agencies face significant challenges in prioritizing bridge maintenance, repair, and rehabilitation (MRR) due to limited resources and the growing complexity of infrastructure needs. To address these challenges, this project aims to provide a comprehensive, data-driven framework that supports county bridge owners in making more informed decisions about bridge maintenance.

By leveraging data and recommendations from bridge inspections, long-term performance forecasting, and MRR strategies, this research creates a life-cycle assessment dashboard that helps counties prioritize element MRR based on predictive models. The creation of the Bridge Life Cycle Dashboard is a central outcome of this work, providing a tool for visualizing life-cycle data, forecasting future performance, and supporting proactive maintenance decision-making. Ultimately, the findings and resources produced by this project aim to improve bridge management practices for local governments, strengthen collaboration between GDOT and local governments, and ensure the long-term sustainability of Georgia's bridge infrastructure.

SCOPE AND OBJECTIVES

The scope of this project includes the development of an inspection data-driven visualization tool, resource guides, and strategies aimed at enhancing bridge maintenance practices across Georgia, with a particular focus on counties. The primary goal is to create a service life prediction tool using modern data science algorithms to assist in prioritizing element repairs, rehabilitation, and replacements based on data-informed insights. This research involves analyzing correlations between element-inspection data, inspectors' recommendations from bridge inspection reports, rehabilitation strategies, long-term performance forecasting, and exploring ways to provide resources for budgetary planning for local governments, establishing a comprehensive approach to bridge management. Additionally, the project focuses on creating a supplementary guide to GDOT’s Bridge Maintenance Unit’s existing Bridge Structure Maintenance and Rehabilitation Repair Manual, supporting coordinated maintenance efforts with county governments to enhance local bridge management effectiveness.

The project’s scope also includes the development of several key resources to improve the overall maintenance process, with a specific focus on culvert inspections and the impact of weather stressors on bridge elements. This initiative contributes to the development of a bridge life cycle plan tool that integrates data science algorithms to forecast bridge performance over time.

In summary, the research aims to achieve the following three main objectives for county bridge owners:

Objective 1: Develop resource guides, including strategic plans for bridge maintenance and management.

Objective 2: Develop a comprehensive culvert inspection guide to standardize inspection practices and enhance maintenance efforts, providing guidance for non-National Bridge Inventory (NBI) assets. The Code of Federal Regulations (CRF) Part 650.305 defines "bridge" as: "A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between under copings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it includes multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening."

Objective 3: Create a data-informed life-cycle assessment dashboard to visualize bridge performance, forecast long-term conditions, and support decision-making for maintenance prioritization.

METHODOLOGY

This section outlines the approach undertaken to achieve the objectives of the research project, which focused on improving bridge asset management practices for local governments in Georgia. A total of five deliverables were generated throughout the course of the project, each of which was led by a graduate student under the supervision of the

Principal Investigators (PIs). These deliverables are briefly described in CHAPTER 2. For further details on the contributions, please refer to the 'ACKNOWLEDGMENTS' section.

Data Collection, Engagement, and Development of Strategic Plan

The research team conducted interviews with more than 50 counties across Georgia to gather insights into the current state of bridge asset management. These interviews provided valuable information on existing practices, challenges, and needs related to bridge maintenance and inspections. Additionally, the team collaborated with counties that had more advanced or detailed non-National Bridge Inventory (NBI) asset management plans. Although the asset management practices varied across counties, this collaboration facilitated the development of a comprehensive strategic plan tailored to local needs.

Literature Review

A thorough literature review was conducted to identify best practices, tools, and methodologies for bridge asset management. The review focused on existing frameworks, inspection techniques, and cost estimation methods that could be adapted to Georgia's local government context. The findings from the literature review were integrated into the development of the inspection guide and other resources for local bridge owners.

Development of a Non-NBI Asset Inspection Guide

Based on the information gathered through county interviews and the literature review, the research team created an inspection guide designed to standardize and improve the quality of non-NBI culvert inspections across Georgia. The guide provides counties with clear recommendations and best practices for assessing the condition of culverts and determining maintenance needs. Additionally, the guide serves as a resource-sharing platform, offering counties the tools and information needed to enhance their asset management practices.

Supplementary Resources

Recognizing the need for practical, user-friendly resources, the team developed supplementary materials to enhance the understanding of the GDOT Bridge Structure Maintenance and Rehabilitation Repair Manual for local bridge owners. These resources are designed to simplify the bridge maintenance process and make the information more relevant and accessible to local governments. The supplementary guide provides concise, actionable recommendations tailored to the unique needs of smaller, locally owned bridges. In this report, "locally owned" refers to bridges that are owned and managed by local governments, such as city, county, or municipal agencies, rather than state or federal authorities. However, these bridges are inspected by the state department of transportation in accordance with federal guidelines. This project specifically focuses on county-level bridge owners.

Bridge Life Dashboard Development

Building on insights gained from interactions with counties and the resources developed throughout the project, the study team created a dashboard. This publicly accessible platform consolidates essential bridge-related information, including unit costs of typical maintenance items, inspection data, and maintenance recommendations. Designed for ease of use, the dashboard provides local bridge owners with timely, relevant data to support informed decision-making. CHAPTER 3 presents a detailed development methodology.

CHAPTER 2. RESOURCES FOR LOCAL BRIDGE OWNERS

The resources created as part of the project are made available under the Resources page of the dashboard described in CHAPTER 3. Four main resource guides have been created, and the three students' theses that led the development effort are cited. During the planning phase, these resources were designed as easy-to-read brochures rather than formal documents, while the supplementary guide adheres to the GDOT manual format.

STRATEGIC PLAN

The Strategic Plan guide (Palmgren, 2023) provides GDOT with a multi-faceted approach to address challenges in the maintenance of locally owned bridges. Based on feedback from counties and discussions with public works employees and GDOT, the research team has identified three key areas of improvement: Improving Communication, Enhancing Transparency and Access, and Promoting Learning and Engagement. The plan outlines strategies for implementing these improvements and includes assessment metrics to measure progress in each area.

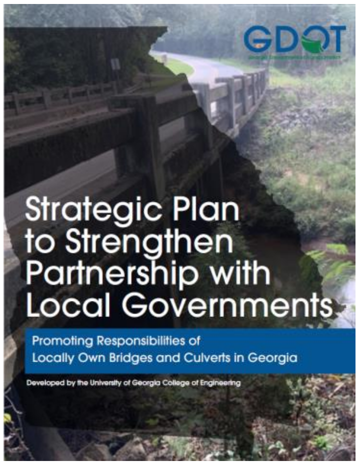


Figure 1. Illustration. Cover Page of the Strategic Plan Guide.

NON-NBI CULVERT INSPECTION GUIDE

The Georgia Non-NBI Culvert and Pipe Structure Inspection guide (Palmgren, 2023) provides local government agencies with essential information for developing a management and maintenance strategy for inspecting non-NBI culvert and pipe assets, ensuring the safety, mobility, and reliability of Georgia's transportation system. It outlines the overall strategy for managing these assets, including how to establish inventories, inspection intervals, and rating systems for prioritizing work orders. The guide also offers detailed instructions on inspecting various types of culverts and pipes, with specific guidance on how inspection methods may vary depending on the structure type.

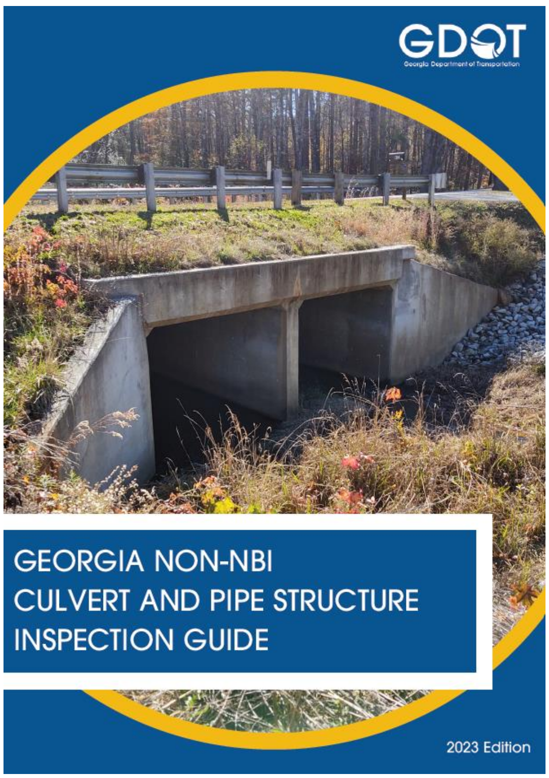


Figure 2. Illustration. Cover Page of the Non-NBI Culvert Inspection Guide.

WEATHER STRESSORS GUIDE

The “Impact of Weather Stressors on Bridge Assets” guide (Kopf, 2023) aims to inform local Georgia governments about the potential impacts of weather stressors on their bridge assets. The guide highlights the safety and financial consequences that local governments may face when bridge maintenance requests remain unaddressed. Additionally, it provides guidance to help counties prioritize maintenance and rehabilitation actions, ultimately supporting better management of bridge assets.

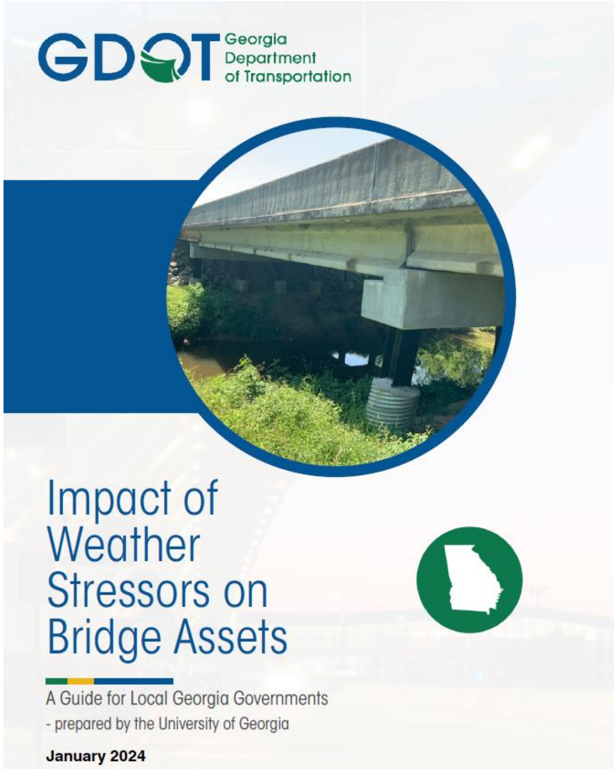


Figure 3. Illustration. Cover Page of Weather Stressors Guide.

SUPPLEMENTARY GUIDE FOR LOCAL MUNICIPALITIES

This “Supplementary Bridge Management and Preservation Guide for Local Municipalities” guide (Johnson, 2024) serves as a supplement to the Georgia Department of Transportation’s "Bridge Structure Maintenance and Rehabilitation Manual" (GDOT, 2025). It is intended to provide local governments, counties, cities, and other local municipalities the tools and information needed to better understand their structures, prioritize bridge maintenance items, and learn about funding resources.

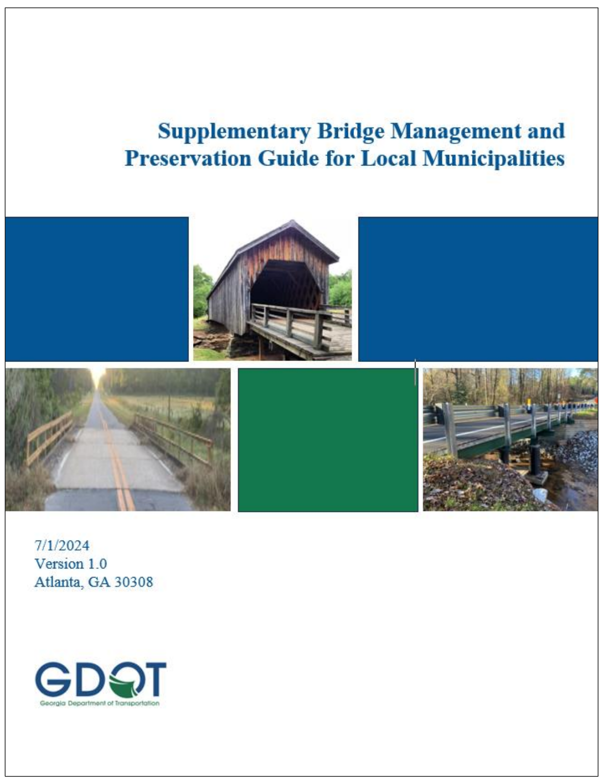


Figure 4. Illustration. Cover Page of Supplementary Guide for Local Governments.

CHAPTER 3. "BRIDGE LIFE CYCLE" DASHBOARD DEVELOPMENT

OBJECTIVES

The "Bridge Life Cycle" dashboard is designed to assist local governments in managing the lifecycle of their bridge assets more effectively. Its primary goal is to provide a data-informed approach for bridge maintenance planning and resource allocation optimization. By visualizing current bridge conditions and predicting future states, the dashboard empowers bridge owners to make more informed decisions regarding maintenance, repair, and rehabilitation (MRR) actions.

This tool integrates life-cycle analysis and cost estimation models to support the decision-making processes. The web-based platform, built using ArcGIS Online, allows users to interact with geospatial data, view bridge health maps, and analyze maintenance costs and service life extensions. ArcGIS Dashboards is a tool used for visualizing and monitoring key metrics within a webpage. Experience Builder is also an ArcGIS tool that allows users to integrate multiple Dashboard pages into a cohesive and interactive webpage.

GIS technology, which is central to the dashboard, provides a comprehensive approach to infrastructure planning, maintenance, and decision-making (Kajastie, 2024). Its integration into asset management systems improves decision-making by combining spatial visualization, analytics, and centralized data management (Adedoyin, 2012; Villarino et al., 2014). GIS also facilitates synchronized workflows that allow infrastructure managers to assess bridge health data, optimizing operational efficiency (Gough, 2024).

The "Bridge Life Cycle" dashboard aims to offer local governments a range of benefits, including prioritizing maintenance activities, corresponding Bridge Health Indices (BHI), and cost-effective strategies. This enables more efficient resource allocation and ensures that the most urgent maintenance needs are addressed first.

By simulating various maintenance scenarios, the dashboard aids in long-term bridge planning, allowing local bridge owners to evaluate the effects of proactive versus deferred repairs and avoid costly replacements. With timely data integration from sources such as the National Bridge Inventory (NBI) and inspection reports, the dashboard ensures decisions are based on the most current information available.

Finally, interactive maps and charts within the dashboard provide a spatial overview of bridge conditions and maintenance needs, helping local governments coordinate maintenance activities more effectively.

DEVELOPMENT METHODOLOGY

Figure 5 illustrates the dashboard development process, which involves several key steps: accessing source data, constructing bridge performance prediction models, determining maintenance costs, calculating the remaining service life under various scenarios, and integrating these analyses into the dashboard interface.

The Source Data

The Bridge Life Cycle dashboard is derived from PDF inspection reports and National Bridge Inventory (NBI) data files, with the PDF files individually downloaded from InspectX. InspectX is a software platform used by GDOT to streamline the inspection and management of bridge conditions.

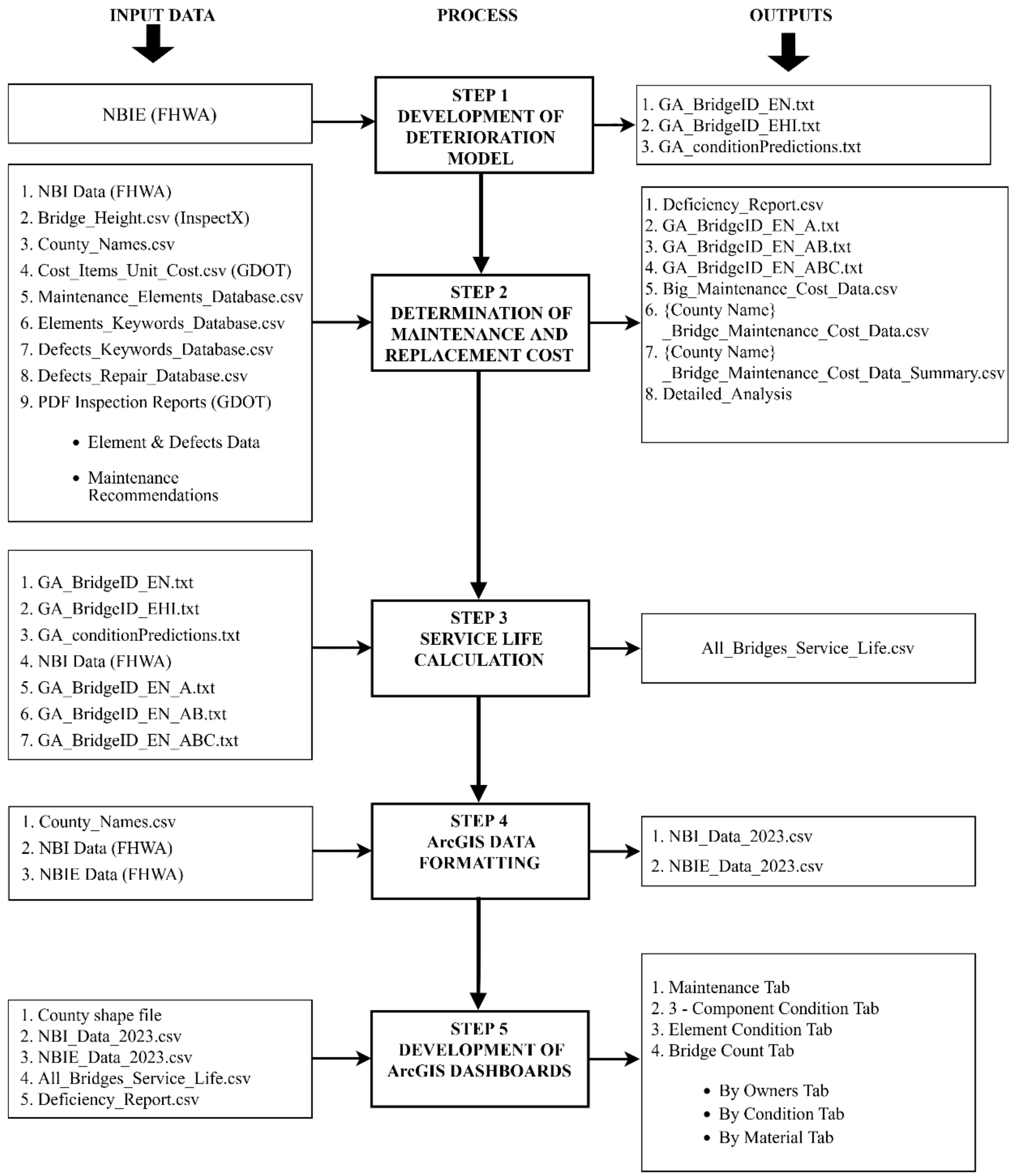


Figure 5. Process. Development of "Bridge Life Cycle" Dashboard Flowchart.

Performance Predictions

The development of a performance prediction model is a key component of the "Bridge Life Cycle" dashboard, providing a structured approach to predict the deterioration of bridge elements over time. This model enables bridge owners to prioritize maintenance, repair, and rehabilitation by estimating future bridge health based on historical data. Aligned with the framework outlined in GDOT's RP 17-28, the model employs an element-based approach as specified in the AASHTO Manual for Bridge Element Inspection (2013), offering a detailed quantitative assessment of individual bridge components.

The model incorporates a Markov deterioration process to simulate the transition of bridge elements between different condition states, predicting future deterioration based on past condition ratings. It processes data from the National Bridge Inventory (NBI) to calculate Element Health Indices (EHI) for each bridge element. The EHI is computed using a non-linear health index coefficient formula, where CS1%, CS2%, CS3%, and CS4% represent the percentage of the bridge element in each respective condition state:

$$\mathrm{EHI} = 1.0\ \times \mathrm{CS1\%} + 0.4\ \times \mathrm{CS2\%} + 0.1\ \times \mathrm{CS3\%} + 0\ \times \mathrm{CS4\%} \qquad \text{Eq. (1)}$$

These coefficients reflect the non-linear impact (Jiang and Rens, 2010) of each condition state on the overall element health, ensuring a more accurate real-world characterization, despite the traditional nature of the Markov approach. This method has been selected due to its established reliability and widespread acceptance in modeling performance predictions. The output of the depreciation model includes predictions of future condition ratings for each bridge element. These predictions are then used in other components of the dashboard, such as the Bridge Health Index Prediction and maintenance scenario cost estimation.

Maintenance Cost Estimates

Life-cycle cost analysis has proven to be a valuable tool for developing rational maintenance programs and ensuring the long-term sustainability of bridge infrastructure (Furuta, 2010). In this context, maintenance costs were initially estimated based on the quantities and recommendations provided in inspection reports. Determining MRR (Maintenance, Repair, and Rehabilitation) costs was identified as a critical component of the “Bridge Life Cycle” dashboard, providing bridge owners with essential tools for budgetary planning.

The primary data sources include inspection reports from GDOT, NBI and NBI Element (NBIE) data from the Federal Highway Administration (FHWA), and the Bridge MRR Items Unit Cost database provided by GDOT. These inputs offer detailed descriptions of recommended MRR items, the urgency of these maintenance and repairs, and specific observations noted during inspections. By integrating these diverse data sources, a more comprehensive understanding of bridge maintenance needs is achieved, enabling the automation of identifying elements requiring maintenance and estimating their associated MRR costs. The flowchart in Figure 6 illustrates this multi-step process, which assists in identifying elements in need of maintenance and estimating their associated MRR costs.

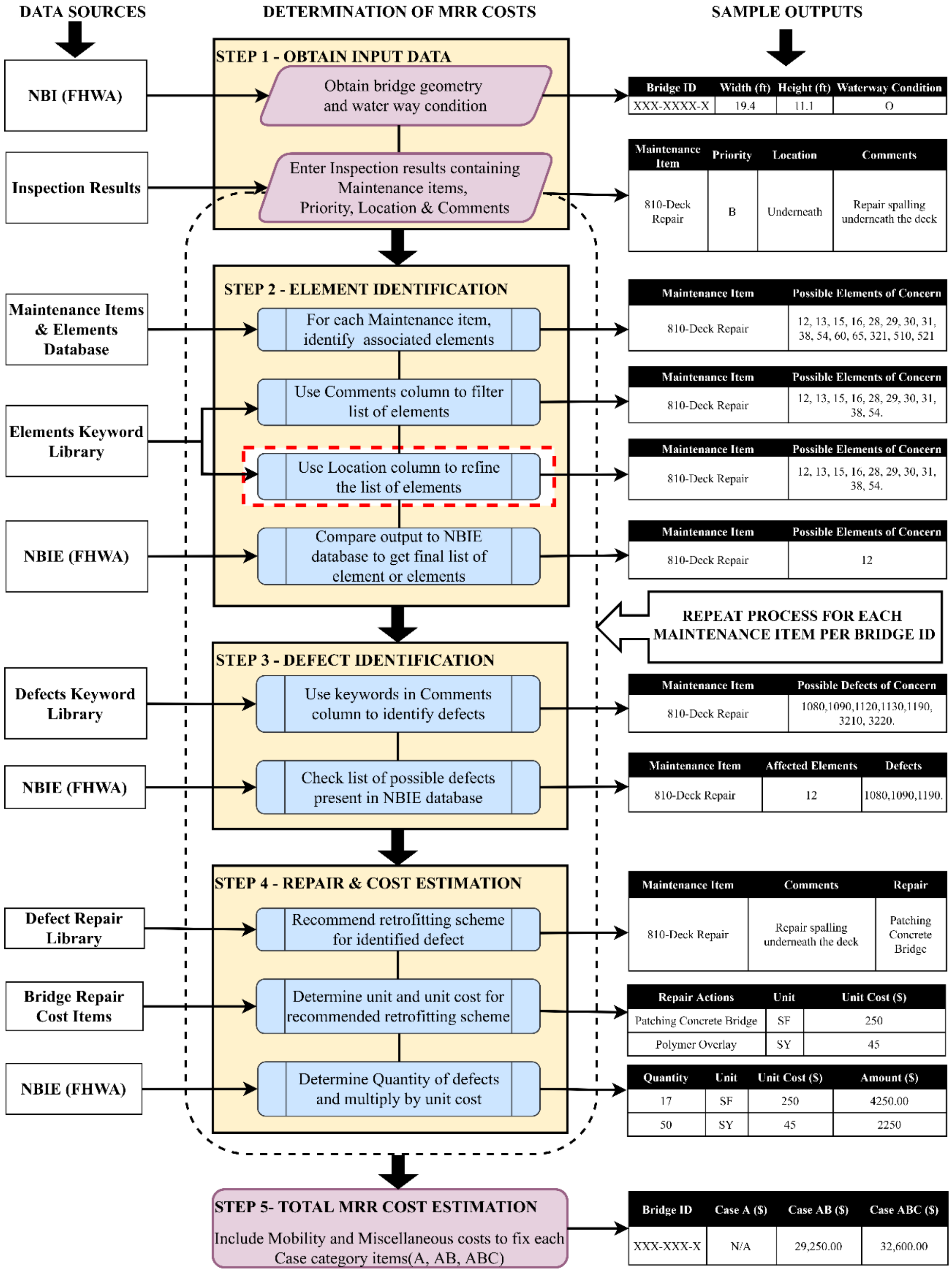


Figure 6. Process. Maintenance, Repair, and Rehabilitation Cost Estimation Process.

Obtain Input Data

The process begins with collecting relevant information from inspection reports and the NBI database, including maintenance items, priorities, locations, inspectors' comments, and bridge geometry. In addition to these primary data sources, the research team has developed custom databases to support the automation of the information identification process. The Maintenance Items - Elements database links maintenance tasks to their associated elements, providing a structured approach to understanding the scope of required work. The Element Keyword database is used to identify elements based on keywords extracted from comments in inspection reports. Similarly, the Defect - Keyword database identifies specific defects associated with each element. Finally, the Defect - Repair database includes GDOT-recommended repairs for each defect, streamlining the identification of appropriate maintenance actions.

Element Identification

Once the input data are gathered, the next step is identifying the elements associated with each maintenance recommendation provided by bridge inspectors. This process begins by using the Maintenance Items - Elements database to retrieve a list of potential elements linked to the specific maintenance item. For example, if the maintenance item is ‘Deck Repair,’ the process retrieves all deck-related elements. Next, the inspector’s comments are analyzed, and each word is cross-referenced with the Element Keyword database. This helps pinpoint the exact element in question by identifying relevant keywords. For instance, if the comment is “Repair spalling underneath the deck,” the keyword “deck” helps isolate element EN 12 (Reinforced Concrete Deck). This refined list of elements is then cross-checked against the bridge's NBIE data to ensure accurate identification and classification of the elements requiring maintenance.

Defect Identification

After identifying the relevant bridge elements, the comments section is analyzed again to identify any defects associated with the maintenance item. Keywords are extracted from the comments and cross-referenced with the Defects - Keyword database. For example, the keyword “spalling” from the comments is used to query the database, returning defects such as 1080 (Delamination/Spall/Patched Area), 1090 (Exposed Rebar), and 1190 (Abrasion/Wear).

MRR and Cost Estimation

Once the defects are identified, an appropriate maintenance, repair, and rehabilitation scheme is recommended from the Defect - Repair database. Subsequently, the unit cost for each repair item is determined using the Bridge Repair Cost Items database. The quantity of each defect is extracted from the inspection reports and multiplied by the unit cost to provide an initial estimate of repair costs for each element.

Total MRR Cost Estimation

The final step involves calculating the total MRR cost, which includes additional considerations such as mobility costs and miscellaneous expenses for repairing the identified defects. The costs are grouped into three scenarios (AB+, AB+B, AB+BC), providing a comprehensive estimate of the financial outlay required for maintenance actions. These estimates are summarized and made available as part of the dashboard’s output. The process of determining MRR cost generates several important outputs that assist bridge owners in planning and prioritizing maintenance activities. One key output is the detailed maintenance cost estimate for each individual bridge, providing a breakdown of the costs associated with addressing specific elements and defects. Additionally, the dashboard displays the replacement cost for each bridge, and this allows local governments to view the financial implications of maintenance actions for each bridge against the replacement cost, facilitating better resource allocation and long-term planning.

During the course of the project, the new B+ priority category is introduced, indicating that maintenance is required within 12 months. It falls between ‘A’ (immediate safety-critical maintenance) and ‘B’ (scheduled maintenance). This addition helps prioritize maintenance actions, ensuring timely attention to potential issues before they escalate, while the ‘C’ priority category remains for preventative maintenance.

The final step involves calculating the total MRR cost, which includes additional considerations such as mobility costs and miscellaneous expenses associated with addressing the identified defects. These costs are grouped into three scenarios (AB+, AB+B, AB+BC) to provide a comprehensive estimate of the financial outlay required for maintenance actions. These estimates are then summarized and made available as part of the dashboard’s output.

The MRR cost determination process generates several key outputs that assist bridge owners in planning and prioritizing maintenance activities. One of the critical outputs is a detailed maintenance cost estimate for each individual bridge, offering a breakdown of the costs related to addressing specific elements and defects. Additionally, the process displays the MRR cost for each bridge, allowing local governments to compare the financial implications of maintenance actions against the replacement cost. This comparison helps optimize resource allocation and supports more effective long-term planning.

Service Life Predictions

The financial implications of addressing or deferring maintenance recommendations are evaluated to enhance strategic decision-making. A key metric used in this assessment is the Bridge Health Index (BHI), which provides an overall condition score for a bridge by aggregating the health of individual bridge elements into a single value. The BHI is calculated as a weighted average of the Element Health Indices (EHI) for each component, with weight factors reflecting the importance of each element as specified in GDOT's RP 17-28. Similar to the study, element weight factors were adapted from the Florida Department of Transportation (FDOT) guidelines to better account for variations in element importance (Sobanjo and Thompson, 2016). The EHI for each element (EHI_e) is determined based on the percentage quantity of the element (pct_{ej}) in each condition state (j), as described in the previous study (Inkoom et al., 2017).

$$\mathrm{EHI_e} = \sum_{j}^{N_e} \mathrm{pct_{ej} W_{ej}} \qquad \text{Eq. (2)}$$

$$\mathrm{BHI} = \frac{\sum_e \mathrm{W_e EHI_e}}{\sum_e \mathrm{W_e}} \qquad \text{Eq. (3)}$$

The recalculation of the Bridge Health Index (BHI) enables users to simulate different maintenance scenarios based on priority categories A, B, and/or C, and assess their impact on overall bridge health. During the cost estimation process, bridge elements requiring maintenance are identified, and their Element Health Indices (EHIs) and corresponding bridge health indices are re-calculated based on the specific maintenance actions performed.

Table 1. Impact of Maintenance Actions on EHI and BHI for a Selected Bridge.

Maintenance Item	Priority	Associated Elements	Current EHI	Recalculated EHI (Case AB+B)	Recalculated EHI (Case AB+BC)
810 - Deck Repair	B	12	31	100	100
830 - Repair Main Structural Members	B	107	29	100	100
845 - Other Bridge Maintenance	B	215	68	68	68
000 - Bridge Painting	C	515	0	0	100
845 - Other Bridge Maintenance	B	N/A	N/A	N/A	N/A
Bridge Health Index (BHI)			**33.48**	**90.04**	**95.48**

Table 1 illustrates how maintenance activities, such as deck repair or repair of main structural members, directly improve the EHI for the respective elements of a selected bridge. For example, prior to maintenance, the Reinforced Concrete Deck (EN 12) and Steel Girders (EN 107) received Health Indices (HIs) of 31 and 29, respectively, reflecting their deteriorated states. Following the implementation of recommended maintenance actions, the HIs for these elements are reset to 100, reflecting their fully restored condition. Setting the element health index to 100 is a logical choice, as it effectively demonstrates the significant benefits of implementing the recommended maintenance. These recalculated element health indices (EHIs) are then incorporated into the BHI calculation, yielding an updated and more accurate overall health score for the bridge, which in turn supports informed maintenance planning and decision-making. It is important to note that setting a few EHIs to 100 does not elevate the overall bridge health condition to 100, as the BHI is a weighted average of all element health indices.

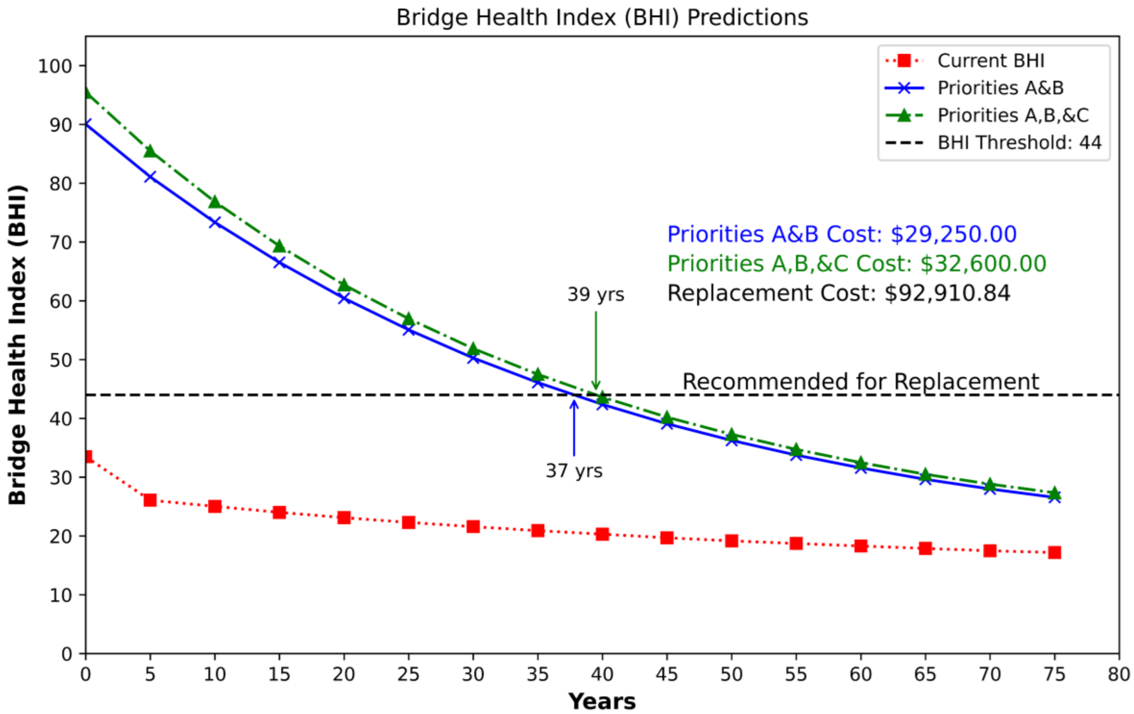


Figure 7. Illustration. Bridge Health Index (BHI) Predictions for a Sample Bridge.

Figure 7 illustrates the effect of recalculated Health Indices (HIs) over a 75-year period. The Georgia data suggest that bridges are typically replaced when the Bridge Health Index (BHI) falls below 44.0, as shown by the dashed line in the figure. Each point on the curve represents the predicted future BHI based on updated Element Health Indices (EHIs) for all elements involved in the maintenance scenario. This allows for a dynamic representation of how different maintenance strategies influence bridge health over time.

For example, under the "Priorities A, B & C" scenario, where all repairs are prioritized, the bridge's BHI improves significantly from 33.48 to 95.48, and the rate of deterioration slows. This results in an extended service life of 39 years before the bridge reaches the replacement recommendation threshold. In contrast, the "Current BHI" trajectory, where no maintenance is performed, shows a steep decline in bridge health, with the BHI dropping to a critical level much earlier. This recalculation process enables bridge owners to evaluate various maintenance options and their long-term impact on bridge health, helping them make informed decisions and optimize resource allocation for maximum benefit.

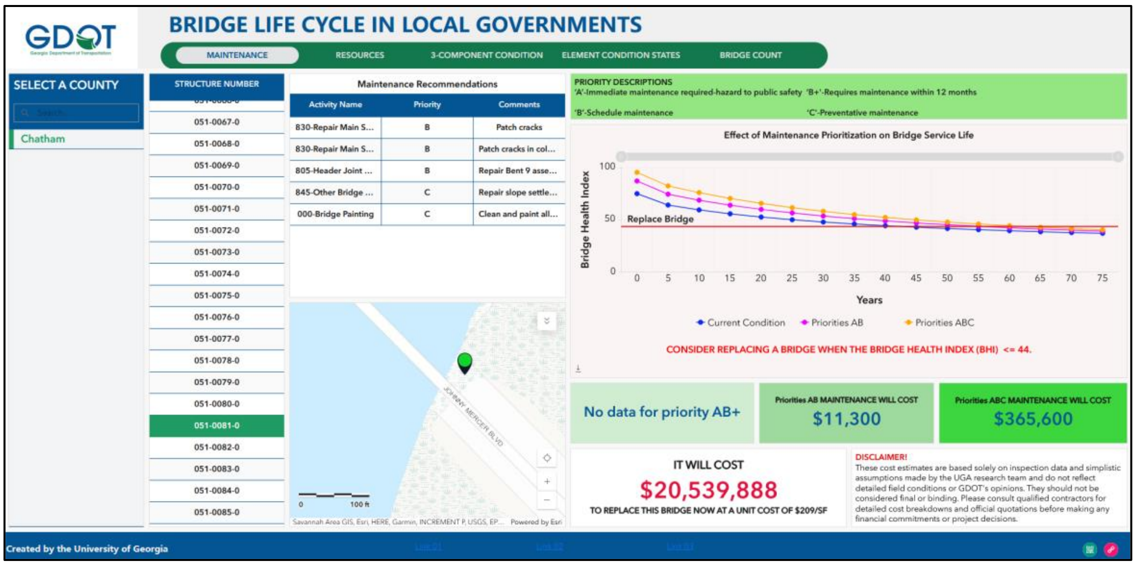


Figure 8. Illustration. Initial Design of the Dashboard Maintenance Page.

The study team aimed to provide the most accurate maintenance cost estimates based on the available inspection data, as illustrated in Figure 8. However, after multiple iterations and comparisons with cost data provided by the Office of Bridge Design and Maintenance, the team decided to present unit costs on the dashboard rather than detailed maintenance costs. This decision was carefully considered following extensive analysis, comparing the costs of numerous bridges. For more details, refer to the "Limitations in Cost Estimation" section.

CHAPTER 4. OUTCOMES OF THE DASHBOARD

KEY FEATURES OF THE DASHBOARD INTERFACE

The "Bridge Life Cycle" dashboard interface is designed to provide an easy-to-use and user-friendly platform for visualizing and managing bridge data and is accessed using the following weblink: https://arcg.is/0Pqv892

Developed on a web-based ArcGIS platform, the dashboard integrates geospatial and tabular data to offer real-time insights into bridge conditions, maintenance needs, and cost estimations. Users can interact with various pages and visualizations to explore the condition of individual bridges, forecast future bridge condition under different maintenance scenarios and access useful resources. The interface is tailored to meet the needs of local bridge owners, enabling them to make data-informed decisions for long-term bridge asset management. The dashboard comprises five main pages which can be accessed by clicking on their names, as described below.

Maintenance Page

The *Maintenance* page provides a comprehensive overview of all assets within the selected county, enabling users to visualize the location of each asset on an interactive map. This page provides an intuitive overview of asset conditions and highlights specific bridges requiring attention. Additionally, the page includes a detailed list of recommended maintenance actions for each selected bridge, allowing users to easily review and prioritize necessary repairs and interventions.

As shown in Figure 9, the left-hand side of the dashboard allows users to select a county, after which a list of asset owners (e.g., State, County, City, etc.) associated with the selected county is displayed. Upon selecting a specific asset owner, the dashboard displays a list of bridges owned by the selected owner, identified by their structure numbers. Once a specific bridge identification number is selected, the dashboard populates with maintenance recommendations and associated details, such as priority levels and comments from inspection reports. In the center panel, the maintenance recommendations section provides a breakdown of each relevant maintenance activity, including the activity name, priority, and comments for the selected bridge. Each row represents a specific maintenance task, such as deck repair or bridge painting, categorized by priority: 'A' (immediate), 'B+' (within 12 months), 'B' (scheduled), and 'C' (preventative). The "Comments" column offers additional context on the required work, such as the location or specific issue to address (e.g., "patch cracks in columns").

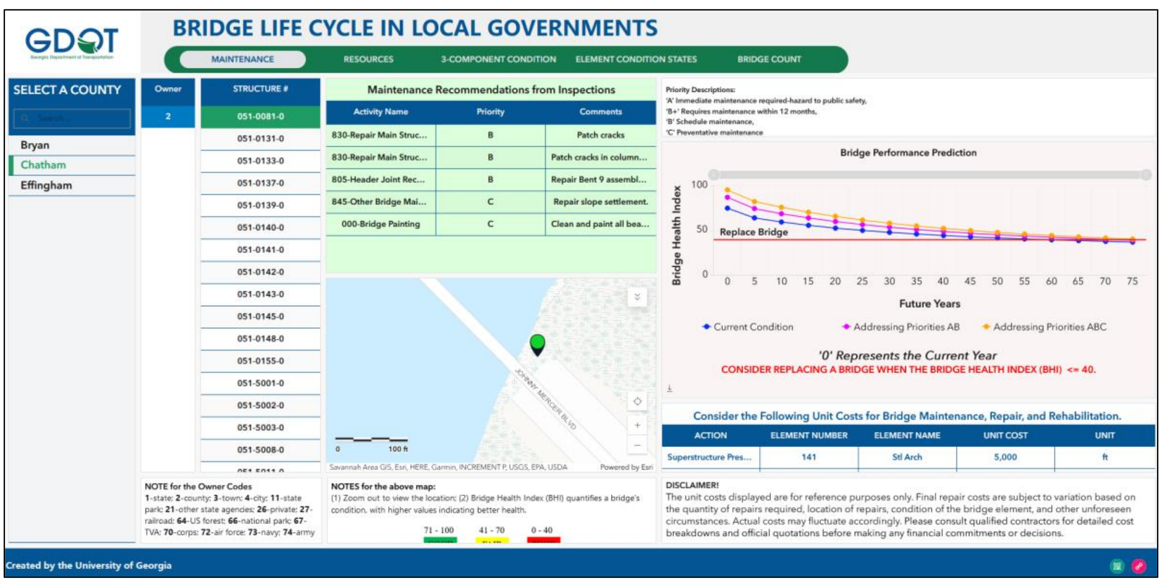


Figure 9. Illustration. Maintenance Page of the Dashboard.

Below the table, the dashboard displays the selected bridge's location on the map. To the right, a Bridge Health Index (BHI) prediction chart shows the predicted BHI over 75 years on a 100-point scale, with 100 representing excellent health. The chart allows users to compare the bridge's current deterioration trajectory with potential BHI improvements under various maintenance scenarios (e.g., AB+, AB+B, or AB+BC). This visualization helps users understand how different maintenance strategies may affect the bridge's future service life and when replacement might be recommended, as indicated by the BHI threshold line. Additionally, the unit costs of performing maintenance are displayed beneath the chart. By integrating performance data, cost considerations, and maintenance priorities, this page empowers bridge owners to make data-informed decisions about maintenance interventions.

Resources Page

The *Resources* page provides links to key reference materials, manuals, guides, strategic plans, InspectX, list of pre-qualified engineering firms and contractors, and FHWA data platforms like the Long-Term Bridge Performance Program (LTBP) InfoBridge.

Figure 10. Illustration. Resources Page of the Dashboard.

Three Component Condition Page

The *3-Component Condition* page, as illustrated in Figure 11, provides a simplified overview of the key structural condition ratings for each bridge. After selecting a county and specific bridge ID, the dashboard displays the condition ratings for the Deck, Superstructure, and Substructure components, as recorded in the NBI database. Each rating is based on a scale from 0 to 9, with higher values indicating better condition. If applicable, the Culvert Condition Rating is also shown. This page allows users to quickly assess the overall condition of a bridge's major components, offering a clear snapshot of bridges that may require attention.

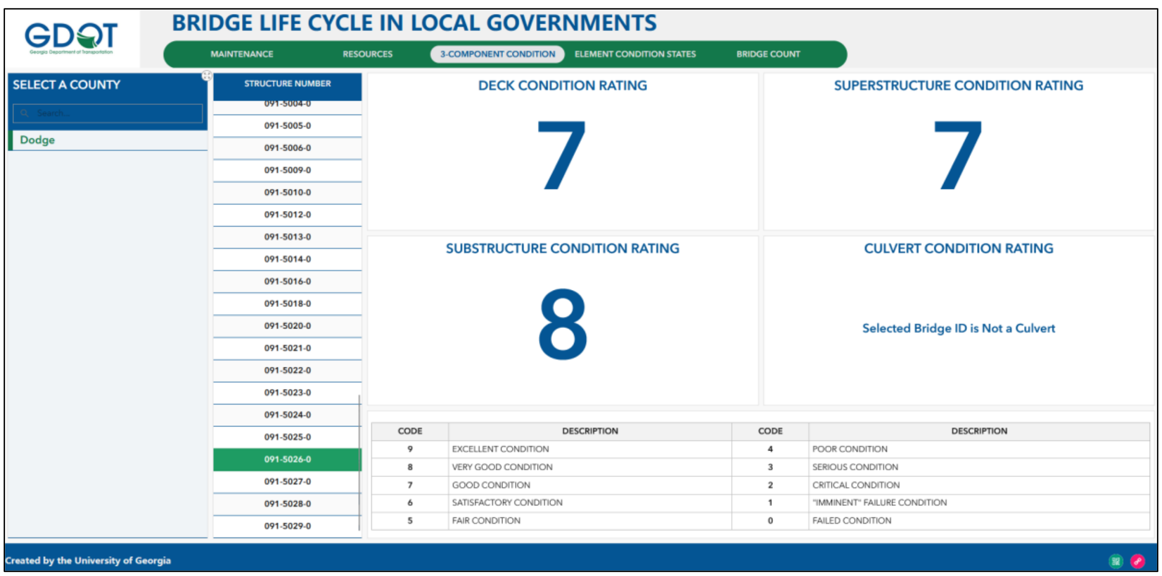


Figure 11. Illustration. 3-Component Condition Tab of the Dashboard.

Element Condition States Page

The *Element Condition States* page provides a detailed view of the condition states for each bridge element. After selecting a county and a specific bridge, users can view the elements associated with that bridge on the left, as illustrated in Figure 12. Upon selecting an element, the dashboard displays the quantity of that element in each condition state (CS), visualized through a pie chart on the right. Condition states are categorized as follows: CS1 (Good), CS2 (Fair), CS3 (Poor), and CS4 (Severe). This tab enables users to assess the extent of wear and damage across different elements, offering critical insights into which components require maintenance or rehabilitation.

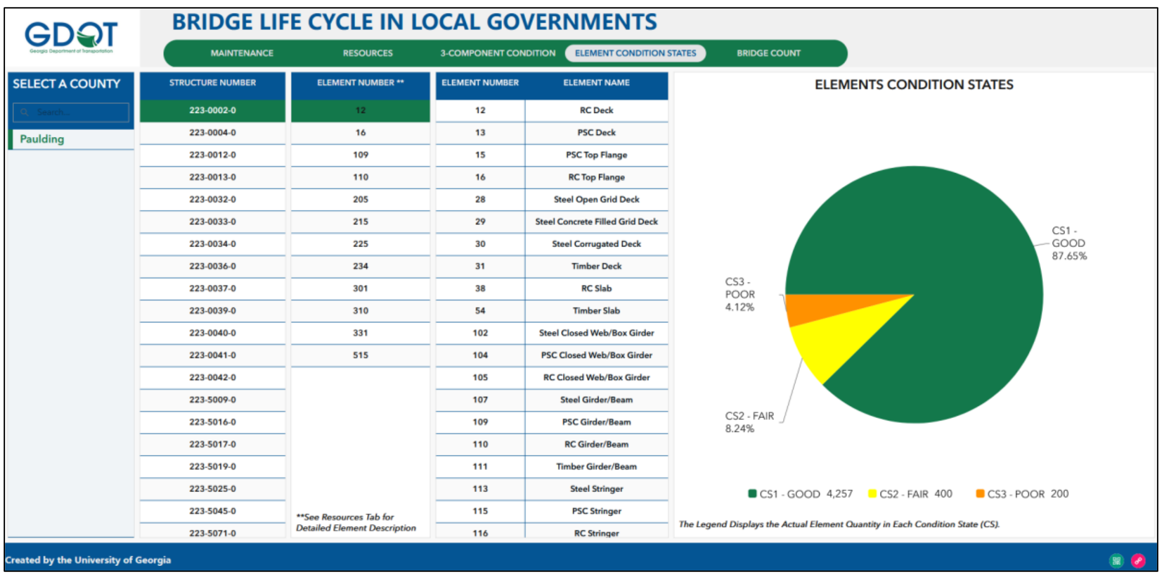


Figure 12. Illustration. Element Condition States Tab of the Dashboard.

Bridge Count Page

The *Bridge Count* page offers users an interactive summary of the bridges within a selected county, categorized by ownership, material, and condition.

Bridge Count by Owners

When the “By Owners” tab is clicked, the dashboard presents a breakdown of the number of bridges in a selected county based on ownership type. Users can view the bridge counts categorized by various ownership groups, including state highway agencies, county highway agencies, city or municipal highway agencies, and other specific asset owners. The interface, as shown in Figure 13, includes a map displaying the location of the bridges, along with a bar chart showing the number of bridges in each ownership category. This feature enables bridge owners to understand how many bridges they are responsible for, which is essential for planning inspection and maintenance efforts.

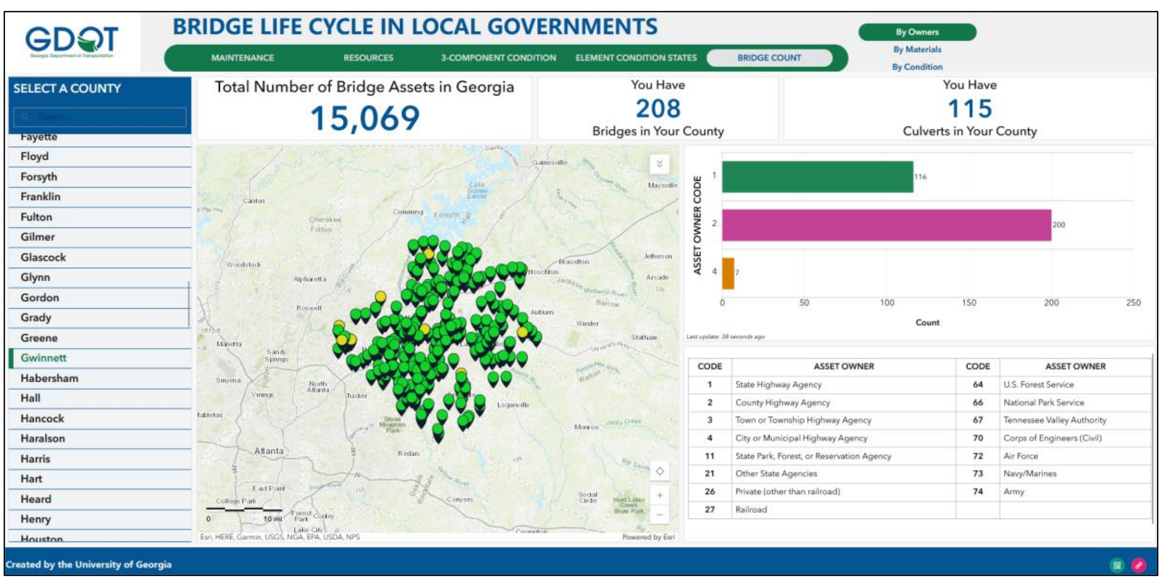


Figure 13. Illustration. Bridge Count “by Owners” Tab of the Dashboard.

Bridge Count by Materials

When the "By Materials" tab is clicked, as illustrated in Figure 14, the dashboard presents a breakdown of bridges in the selected county based on the type of girder material. Users can view the distribution of bridges by materials such as concrete, steel, timber, prestressed concrete, and others. A bar chart displays the number of bridges for each material type, while a map shows their geographical locations within the county. This sub-tab is useful for assessing the predominant materials used, helping with material-specific maintenance planning and resource allocation.

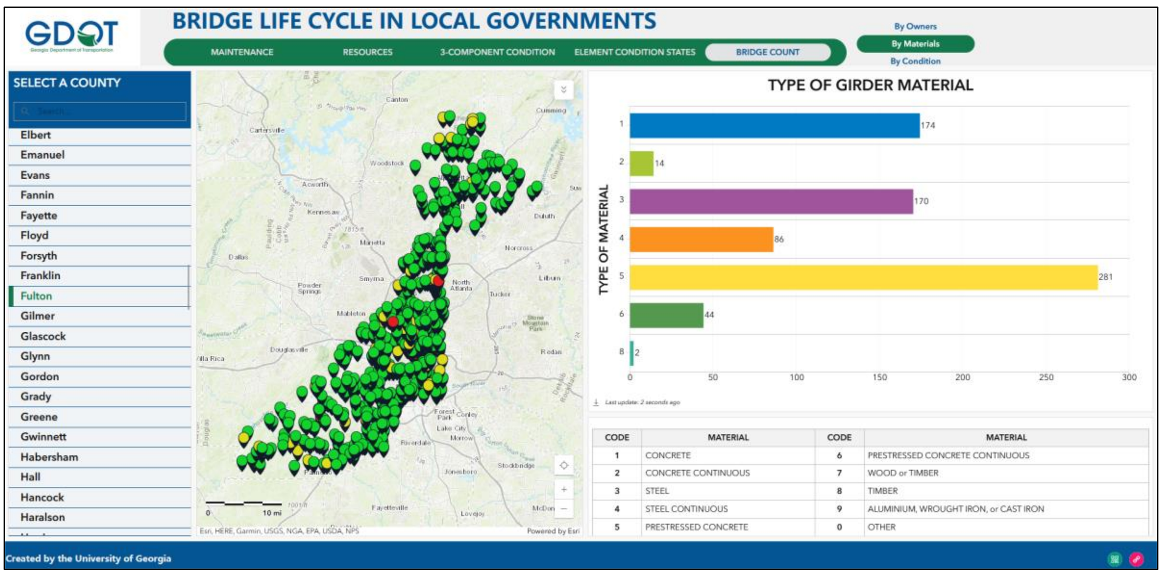


Figure 14. Illustration. Bridge Count “by Materials” Tab of the Dashboard.

Bridge Count by Condition

When the "By Condition" tab is clicked, as illustrated in Figure 15, the dashboard provides a summary of bridges in the selected county based on their condition ratings. The bridges are categorized into three condition groups according to the NBI condition rating: Good (9-7), Fair (6-5), and Poor (4-0). Each component of the bridge—deck, superstructure, substructure, and culverts—is displayed with its respective condition distribution in bar charts. This visualization offers users a county-wide assessment of the overall health of bridges, helping to identify components that may require additional or immediate maintenance or replacement.

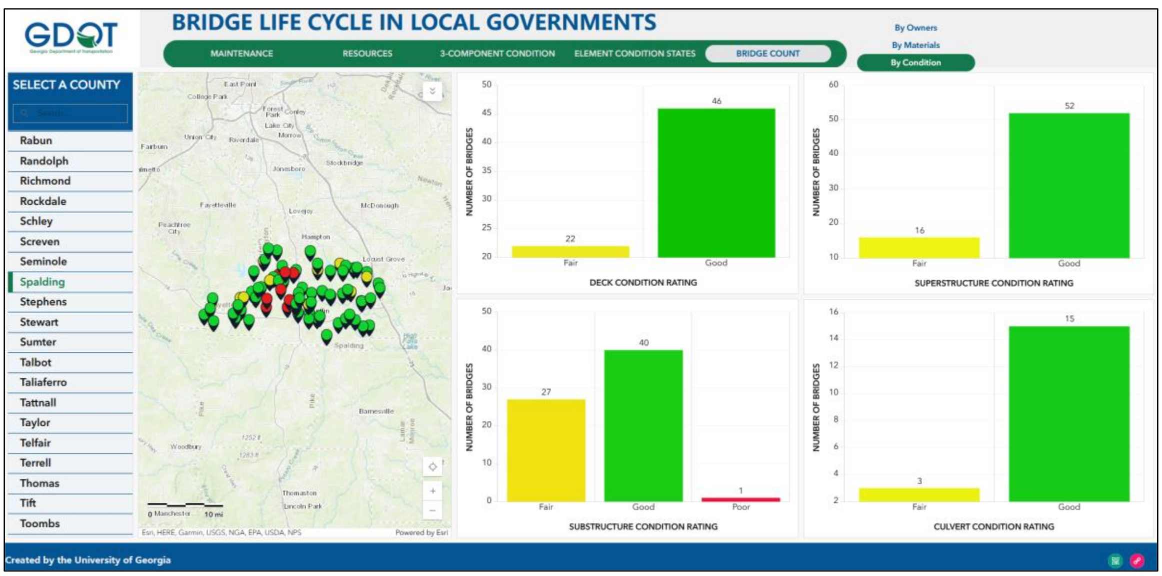


Figure 15. Illustration. Bridge Count "by Condition" of the Dashboard.

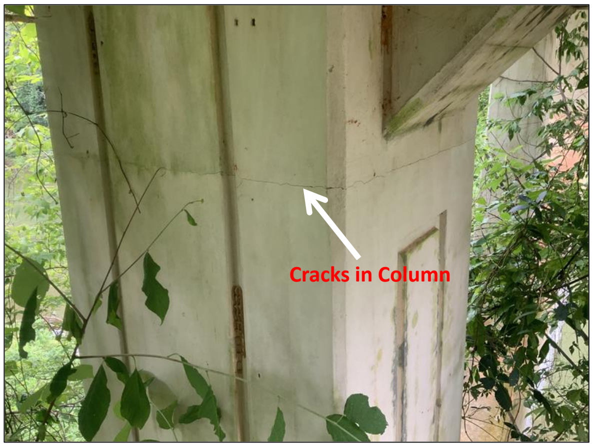
LIMITATIONS IN COST ESTIMATION

The initial cost estimates are derived solely from inspection data and do not account for detailed field conditions. In practice, local bridge owners should consult qualified contractors to obtain comprehensive cost breakdowns and official quotations. This process is essential for making informed financial commitments and developing accurate budgetary plans. Consequently, the approach emphasizes providing unit costs that contractors or consultants may use as a reference, rather than relying solely on cost estimates driven by visual inspections.

Specific Challenges in Estimating Maintenance Costs

During the development and implementation of the cost estimation feature for the “Bridge Life Cycle” Dashboard, several challenges emerged, impacting data accuracy, model outputs, and overall functionality. One primary challenge was the variability in defect information recorded by inspectors, particularly in quantifying defect quantities for certain elements. The recorded data often lacked the detail required for precise, data-driven cost estimation, limiting the overall effectiveness of the approach. This limitation stems from the nature of visual inspections.

For example, as illustrated in Figure 16, the right panel shows an inspection report where cracking in concrete columns was recorded in units of "each" (EA), while repair recommendations for vertical elements were expressed in linear feet (LF). This mismatch in measurement units created difficulties in quantifying defects for cost estimation. The left panel of the figure depicts an actual instance of cracking in a vertical concrete column, emphasizing the complexity of translating inspection data into actionable repair estimates.



Elements & Defects

ELEMENTS	DESCRIPTION	UNITS	TOTAL	CS1	CS2	CS3	CS4
16	Reinforced Concrete Top Flange	SF	1861	1111	728	22	0
1080	Delamination/Spall/Patched Area	SF	15	0	10	5	0
1090	Exposed Rebar	SF	5	0	3	2	0
1120	Efflorescence/Rust Staining	SF	15	0	15	0	0
1130	Cracking (RC and Other)	SF	715	0	700	15	0
510	Wearing Surfaces	SF	1764	0	0	1764	0
3210	Delam/Spall/Patched Area/Pothole	SF	400	0	0	400	0
3220	Crack (Wearing Surface)	SF	812	0	0	812	0
3230	Effectiveness (Wearing Surface)	SF	552	0	0	552	0
110	Reinforced Concrete Open Girder/Beam	LF	261	66	175	20	0
1130	Cracking (RC and Other)	[illegible]	195	0	175	20	0
144	Reinforced Concrete Arch	[illegible]	230	170	50	10	0
1130	Cracking (RC and Other)	[illegible]	60	0	50	10	0
205	Reinforced Concrete Column	EA	4	1	1	2	0
1130	Cracking (RC and Other)	EA	3	0	1	2	0
215	Reinforced Concrete Abutment	LF	46	19	25	2	0
1130	Cracking (RC and Other)	LF	27	0	25	2	0
234	Reinforced Concrete Pier Cap	LF	46	33	13	0	0
1130	Cracking (RC and Other)	LF	13	0	13	0	0
301	Pourable Joint Seal	LF	72	72	0	0	0

Figure 16. Illustration. Example of Vertical Concrete Element Defect Entry.

Another critical issue occurs when inspection reports omit specific quantities for certain repair activities. For example, as shown on the left panel of Figure 17, the inspector noted the need to relevel the approach roadway due to settlement. However, the corresponding 'Element & Defects' table on the right panel does not include the length (x) or area of the roadway requiring repair. As a result of this visual inspection, cost estimation must rely on assumptions about the dimensions or extent of the affected area, increasing the risk of inaccurate projections.

Elements & Defects

ELEMENTS	DESCRIPTION	UNITS	TOTAL	CS1	CS2	CS3	CS4
12	Reinforced Concrete Deck	SF	2461	858	1080	523	0
1080	Delamination/Spall/Patched Area	SF	38	0	30	8	0
1090	Exposed Rebar	SF	15	0	0	15	0
1120	Efflorescence/Rust Staining	SF	100	0	50	50	0
1130	Cracking (RC and Other)	SF	1450	0	1000	450	0
510	Wearing Surfaces	SF	2330	0	0	2330	0
3220	Crack (Wearing Surface)	SF	1000	0	0	1000	0
3230	Effectiveness (Wearing Surface)	SF	1330	0	0	1330	0

Figure 17. Illustration. Example of Missing Quantitative Data in Inspection Reports.

Even when quantities are recorded in inspection reports, there are opportunities to improve the accuracy of material estimates for certain repairs. For instance, as shown in Figure 18, the inspector recommended repairing scour under abutments and recorded a defect (Scour) quantity of 75 LF. To ensure sufficient stabilization, assessing the actual volume of flowable fill required—especially if conditions beneath the abutment are more extensive than anticipated—can enhance cost estimation accuracy. In such cases, accurately measuring the extent of the void allows estimations to align more closely with the actual quantity needed for repair, enhancing the reliability of cost estimates.

Elements & Defects

ELEMENTS	DESCRIPTION	UNITS	TOTAL	CS1	CS2	CS3	CS4
16	Reinforced Concrete Top Flange	SF	3867	3862	3	2	0
1080	Delamination/Spall/Patched Area	SF	3	0	3	0	0
1090	Exposed Rebar	SF	2	0	0	2	0
510	Wearing Surfaces	SF	2847	2763	84	0	0
3220	Crack (Wearing Surface)	SF	84	0	84	0	0
110	Reinforced Concrete Open Girder/Beam	LF	510	510	0	0	0
215	Reinforced Concrete Abutment	LF	76	0	76	0	0
1090	Exposed Rebar	LF	1	0	1	0	0
6000	Scour	LF	75	0	75	0	0
227	Reinforced Concrete Pile	EA	10	0	10	0	0
1080	Delamination/Spall/Patched Area	EA	1	0	1	0	0

Figure 18. Illustration. Example of Incomplete Quantification of Defects.

Building on the importance of accurate material estimation, opportunities exist to enhance how defects are represented in inspection reports. For example, in Figure 19, voids in an approach roadway are described in the inspector's comments but are not quantitatively detailed in the 'Elements & Defects' table. Including specific measurements, such as the amount of flowable fill needed, can improve the precision of repair estimates, especially as material requirements often evolve during the repair process. Strengthening inspection practices by integrating quantitative data with qualitative descriptions can significantly enhance the accuracy of data-driven cost estimation.

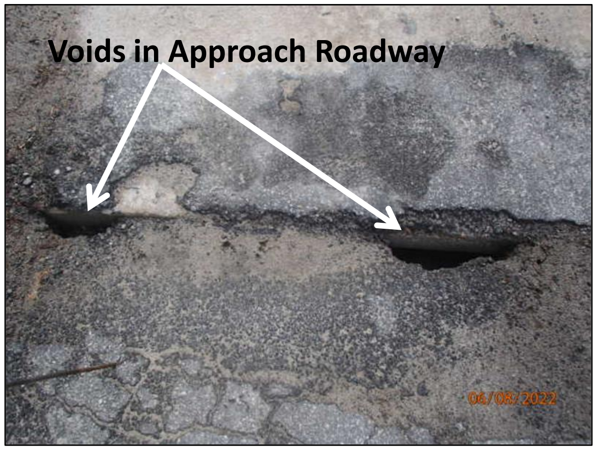
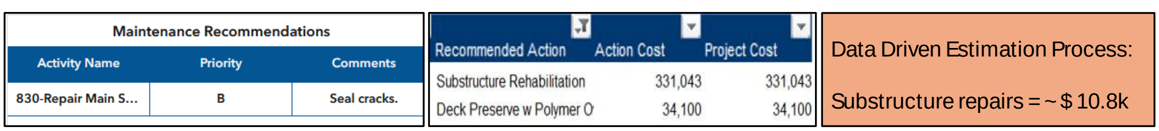


Figure 19. Illustration. Example of Uncaptured Defects in Inspection Reports.

Another significant challenge was the notable discrepancies between cost estimates generated by the dashboard and those from GDOT's BrM system. These differences primarily stemmed from inconsistencies between actual site conditions and the information documented in inspection reports. For instance, as shown in Figure 20, the inspection data-driven cost estimate for substructure repairs was approximately $10,800, which is about 31 times lower than GDOT’s project cost estimate.



(a) (b) (c)

Figure 20. Illustration. Example of Discrepancies in Cost Estimates.
(a) Maintenance Recommendations by Inspectors, (b) GDOT BrM Cost Estimate, and (c) Inspection Data-Driven Cost Estimate.

Figure 20(a) shows maintenance recommendations made by inspectors, identifying only substructure elements, such as PSC piles and RC pier caps, for repair, specifically recommending crack sealing. In contrast, the GDOT BrM system's cost estimate in Figure 20(b) included $331,043 for substructure rehabilitation and $34,100 for deck preservation, even though no deck repairs were indicated in the inspection report. Figure 20(c) displays the inspection data-driven estimate, which only accounted for substructure repairs, resulting in a significantly lower total.

These discrepancies highlight the challenge of aligning inspection data-informed cost estimates with actual project costs. Unaccounted or misinterpreted repairs resulted in substantial variations in budget projections. Addressing these challenges will require improvements in inspection data collection processes and refinement of cost estimation models, possibly by training these models using actual bridge project cost data. Such enhancements could help reduce discrepancies and improve the reliability of data-driven maintenance cost projections.

Decision to Provide Unit Costs

The Maintenance page of the dashboard was updated to present the unit costs for various bridge repair and rehabilitation items. As shown in Figure 21, instead of relying on the inspection data-driven cost estimation approach, which led to discrepancies between estimates and actual project costs, the dashboard now focuses on providing the unit costs associated with each maintenance activity.

Each unit cost, as shown in Figure 22, is linked to specific repair actions—such as deck preservation, substructure rehabilitation, or crack sealing—allowing bridge owners and local governments to access reliable, itemized repair costs. This data may be updated annually to reflect current market prices and ensure estimates align closely with actual expenses. Users can refer to these unit costs when planning budget allocations and determining feasible maintenance interventions based on available funding.

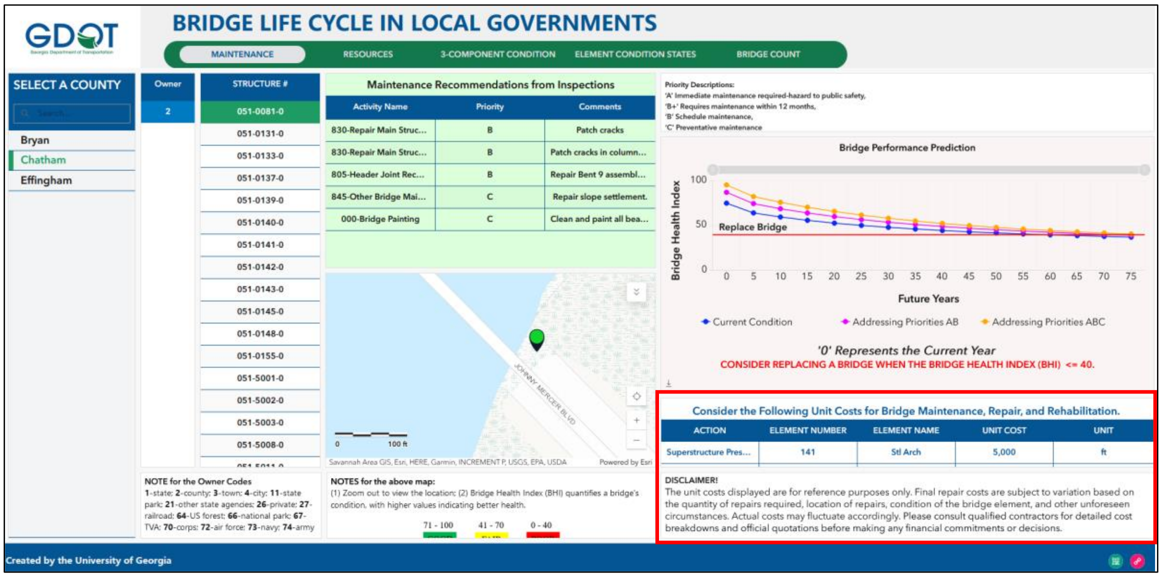


Figure 21. Illustration. Unit Costs Shown on the Dashboard.

Consider the Following Unit Costs for Bridge Maintenance, Repair, and Rehabilitation.				
ACTION	ELEMENT NUMBER	ELEMENT NAME	UNIT COST	UNIT
Deck Preserve w Polymer Overlay	12	Re Concrete Deck	5	sq.ft
Deck Rehab w LMC Overlay Only	12	Re Concrete Deck	56	sq.ft
Deck Replacement	12	Re Concrete Deck	70	sq.ft
Deck Spall Repair	12	Re Concrete Deck	28	sq.ft
Deck Preserve w Polymer Overlay	13	Pre Concrete Deck	5	sq.ft
Deck Rehab w LMC Overlay Only	13	Pre Concrete Deck	56	sq.ft
Deck Rehabilitation	13	Pre Concrete Deck	56	sq.ft
Deck Spall Repair	13	Pre Concrete Deck	28	sq.ft
Deck Preserve w Polymer Overlay	14	Exodermic Deck Panel	5	sqft
Deck Rehab w LMC Overlay Only	14	Exodermic Deck Panel	56	sqft
Deck Rehabilitation	14	Exodermic Deck Panel	56	sqft
Deck Spall Repair	14	Exodermic Deck Panel	28	sqft
Deck Preserve w Polymer Overlay	16	Re Conc Top Flange	5	sq.ft

Figure 22. Illustration. Unit Costs Provided on the Dashboard.

This approach simplifies the decision-making process by providing a straightforward cost reference that eliminates the uncertainty associated with prior data-driven cost estimates. Additionally, a disclaimer is included in this section to remind users that these unit costs are for reference purposes only, as final repair costs can vary based on the specifics of each bridge, the scope of repairs required, and other factors.

FUTURE ENHANCEMENTS

There are several areas where the “Bridge Life Cycle” dashboard can be enhanced to provide even greater value to local governments and bridge owners. These improvements could address some of the current challenges and leverage more sophisticated methodologies.

1. Establishing standardized guidelines for data entry, particularly for defect quantification, to improve consistency across inspection reports. For instance, developing a unified approach (such as using linear feet for all length-based defects such as cracking, and square feet for area-based defect such as spalling/delamination) would reduce the uncertainty and enhance the accuracy of cost estimates.

2. Use of machine learning models that can learn from past projects, considering actual site conditions, defect types, and bridge maintenance costs to predict more accurate project costs. By analyzing historical data, these models could provide cost estimates that are less sensitive to the variations seen between inspection data-driven and DOT BrM system estimates.

3. Enabling the dashboard to store and track repair logs for each bridge, documenting completed repairs, costs, and the impact on BHI over time. This would provide users with a comprehensive view of each bridge's maintenance history and facilitate lifecycle management for more accurate long-term budgeting.

4. Future versions of the dashboard could integrate advanced machine learning techniques, including Recurrent Neural Networks (RNNs) like Long Short-Term

Memory (LSTM) and Gated Recurrent Units (GRUs). Unlike the Markov model, which focuses on deterioration, these models can capture both deterioration and improvements from rehabilitation and repairs, enabling more dynamic and robust predictions of bridge conditions over time.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This study marks a significant milestone in developing a partnership with local bridge owners. Based on feedback from over 50 counties interviewed, the research team has developed a strategic plan to address key areas for improvement. The Office of Bridge Design and Maintenance (OBDM) has made notable efforts to incorporate recommendations from this study, focusing on improving communication, enhancing transparency and access, and promoting learning and engagement.

Improving Communication

GDOT has actively reached out to local bridge owners and collaborated with the research team to create a supplementary bridge guide for local municipalities.

Enhancing Transparency

The "Bridge Life Cycle in Local Governments" dashboard increases transparency by providing information on condition ratings, service life predictions, and resources for local bridge owners.

Promoting Learning and Engagement

OBDM has supported the RP23-19 project titled "Develop an Off-System Bridge Managers Training Program to Increase Collaboration and Access to GDOT’s Resources Including Local Bridge Programs and Promote Best Practices." This project is a key implementation of the study, aimed at fostering learning and engagement among local bridge owners.

RECOMMENDATIONS

This study details three key areas for improvement in the management of local bridge assets.

Continuous Effort and Customer Service

It is crucial for GDOT to maintain ongoing engagement with local bridge owners to ensure consistent communication and collaboration. By providing continuous support and improving customer service, GDOT can foster stronger relationships and better address the evolving needs of local governments in bridge management. Regular follow-ups, feedback loops, and dedicated points of contact — measures already implemented — will further strengthen partnerships and ensure that local bridge owners feel supported throughout the maintenance and rehabilitation process.

Modern Technologies

The adoption and integration of modern technologies, such as the "Bridge Life Cycle" dashboard and other geospatial tools, should be maintained to enhance asset management efficiency. Leveraging technology and Artificial Intelligence (AI) is expected to provide local governments with real-time insights, improve decision-making, reduce workload, and streamline maintenance processes. Future efforts should focus on further developing and expanding the use of digital tools, ensuring that all local bridge owners have access to the latest technological resources for managing bridge health and service life.

Assistance in Budgetary Planning

The local bridge owners often face challenges in budgeting for bridge maintenance and rehabilitation. GDOT should continue to assist in budgetary planning by offering tools, resources, and guidance on cost estimation, funding strategies, and long-term financial planning. By helping local bridge owners align their maintenance priorities with available resources, GDOT can support more effective and sustainable asset management practices, ultimately ensuring the safety and reliability of Georgia's bridge infrastructure.

DISCUSSION

Local governments may delay or avoid fixing bridges for several reasons, often stemming from a combination of financial, informational, and psychological factors as described below:

1. Budget Constraints: Many local governments operate under tight budgets, requiring them to prioritize spending on more immediate needs, such as schools, public safety, and healthcare. As a result, bridge maintenance, particularly for aging infrastructure, is often deferred, especially when there are no immediate consequences to postponing Maintenance, Repair, and Rehabilitation (MRR).
2. Insufficient Information: Local governments may have an incomplete understanding of the actual condition of their bridges or the long-term consequences of neglecting maintenance. Without clear inspection data or predictive tools, they may fail to recognize the urgency for MRR.
3. Perceived Discounting of Future Costs: A common behavioral economics concept is temporal discounting, where individuals (or municipalities) prioritize short-term costs over long-term benefits. In this case, fixing bridges today may seem costly or disruptive, so governments may delay MRR to avoid immediate expenses, even if the long-term consequences (such as higher MRR costs or catastrophic failure) are more severe.

4. Short-Term Focus: Some governments may operate with short-term budget cycles, leading to myopic behavior. Decision-makers may focus on issues that require immediate attention (e.g., roads, schools, or public services) and fail to address infrastructure maintenance, which can appear less urgent despite its long-term importance.
5. Free Rider Problem: In some cases, local governments may assume that state or federal funds will cover the costs of major bridge MRR, thus leading to the free rider problem. They may neglect taking action themselves, hoping that another level of government will step in to address the issue (e.g., replace a bridge).
6. Lack of Political Will: Politicians may be unwilling to address infrastructure issues because the benefits of fixing bridges often are not immediately visible to voters. The MRR cost of bridges may be politically unattractive, especially when other needs may appear more urgent.
7. Status Quo Bias: Local governments may exhibit status quo bias, a tendency to prefer the current state of affairs rather than making changes. Even if bridges are deteriorating, the perceived effort, disruption, or costs associated with MRR may discourage decision-makers from acting.

Despite the challenges outlined above, GDOT has shown dedication in working with local bridge owners, even in the face of significant leadership turnover within local governments. This ongoing collaboration brings GDOT one step closer to more effectively supporting local bridge owners, addressing their needs, and strengthening the management and maintenance of critical transportation infrastructure across the state.

LESSONS TO SHARE WITH BRIDGE OWNERS

1. Reliable Cost Estimation Requires In-depth Inspection and Uniform Measurement Units: Discrepancies between how the deficiency units are reported to FHWA in the inspection report vs the unit used for repair cost estimate (e.g., "each" instead of LF or SF for vertical concrete elements), incomplete quantities (e.g., missing details), and qualitative defect descriptions (e.g., erosion or undermining) may hinder the accuracy of Maintenance, Repair, and Rehabilitation (MRR) cost estimates. Therefore, In-depth inspections and uniform measurement unit of deficiencies are essential for effective budgetary planning.
2. Field Conditions May Differ from GDOT Recommendations: GDOT's maintenance recommendations, based on routine visual inspections, may not fully capture the extend of all field deficiencies, making it challenging to provide appropriate repair recommendations (e.g., deficiency such as cracks on the concrete members may require varying repair methods based on it severity rather than simply sealing with epoxy). This gap between documented and actual conditions will affect cost estimation accuracy.
3. Sharing Unit Cost Data is a Starting Point: Providing itemized maintenance cost data to local bridge owners is the first step toward supporting budgetary planning. However, local governments may require guidance and bridge specialists to efficiently utilizing this information. Encouraging them to consult contractors or consultants can help refine cost estimates, although securing the budget for this remains a challenge and may be burdensome.

4. Budgetary Planning: Over the service life of a bridge, a cost range of $60 to $65 per square foot of bridge surface area, depending on specific needs, can serve as a starting point for budgeting, rather than leaving planning unaddressed, and help adjust for current and evolving requirements to support bridge maintenance. It is noted that the 30% guideline is commonly used as a reasonable baseline for estimating maintenance costs as a percentage of the replacement cost, which is approximately $213 per square foot as of 2023 (FHWA, 2023). The annualized value for a present value of $65 over the next 50 years at an interest rate of 2% and 5% is approximately $2.00 and $3.50 per square foot, respectively.
5. Reevaluating Maintenance Priorities: Actions such as painting steel members, typically categorized as priority C, may need higher prioritization due to their significant impact on reducing bridge deterioration rates. Proper cleaning and painting protect steel from corrosion, significantly extending the lifespan of bridge components and reducing long-term maintenance costs. However, painting without following the proper procedures is ineffective and may fail to achieve the desired protective results.
6. Focus on High Return on Investment (ROI) Maintenance Items: Maintenance such as concrete patching and steel painting often yield the best return on investment. Prioritizing these actions in budgetary planning can improve overall bridge condition and longevity.
7. Addressing Regional Weather Challenges: Unique weather stressors (e.g., freeze-thaw cycles in the north and heat or marine exposure in the south) require tailored maintenance strategies to mitigate such effects.

8. Preventive Maintenance Reduces Long-Term Costs: Routine activities, such as cleaning joints, painting steel components, and addressing minor defects promptly, can extend bridge life and reduce overall maintenance expenses.

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