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Economical Impact of Full Closure for Accelerated Bridge Construction and Conventional Staged Construction

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Economical Impact of Full Closure for Accelerated Bridge Construction and Conventional Staged Construction

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16. Abstract

Accelerated bridge construction (ABC) methods have been increasingly used in recent years to reduce the impact of construction operations on traffic and mobility. ABC methods, however, often require a higher initial cost, more planning, and additional design coordination. Several tools have been developed to assist decision-makers in the selection of conventional staged construction or ABC methods based on bridge characteristics and requirements. Most of these existing tools, however, are qualitative and depend on the subjective opinion of decision-makers/experts. Accordingly, there is a need for additional research to develop quantitative tools for generating reliable cost estimates for conventional and accelerated bridge construction methods. This report presents the findings of a research project funded by the Illinois Department of Transportation (IDOT) to develop a decision support tool (DST) that IDOT can use to estimate and compare the cost of all bridge construction methods, including conventional staged construction and ABC methods. This project has four objectives. The first objective is to develop a qualitative DST that can be used by IDOT planners and decision-makers to identify all feasible bridge construction methods for any bridge project based on its specific characteristics, requirements, and constraints. The second objective is to create a quantitative cost-estimating DST that can be used to accurately estimate construction, road user, maintenance and rehabilitation, and life cycle costs for all feasible construction methods including conventional and ABC methods. The third objective is to develop guidance for the user interface of the developed DST to explain how it can be used to compare and rank all feasible bridge construction methods based on their individual performance in design, construction, road user, and maintenance and rehabilitation costs. The fourth objective is to evaluate the performance and accuracy of the developed quantitative DST for estimating bridge costs.

17. Key Words Accelerated Bridge Construction Methods, Prefabricated, Lateral Slide, Self-Propelled Modular Transporter, Conventional Construction Method, Construction Cost, Road User Cost, Maintenance and Rehabilitation Costs, Life Cycle Cost Analysis	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

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EXECUTIVE SUMMARY

Accelerated bridge construction (ABC) methods have been increasingly used for bridge rehabilitation and replacement projects in recent years. The main advantage of ABC methods over conventional staged construction is the reduced impact on traffic and mobility caused by on-site bridge construction, lane closures, and detours (FHWA, 2011). However, ABC methods often require a higher initial cost and the potential for more planning, design coordination, and increased construction lead time (Ozimok & Claussen, 2020). Several tools have been developed to assist decision-makers in the selection of conventional staged construction or ABC methods based on bridge characteristics and requirements. Most of the existing tools, however, focus and depend on the subjective opinions of decision-makers/experts. Despite the advantages of these tools, they do not provide a systematic or effective framework for estimating the cost of the two methods. Accordingly, a research project funded by the Illinois Department of Transportation (IDOT) was conducted to develop a decision support tool that can be used by IDOT to estimate the cost of all bridge construction methods, including conventional staged construction and ABC methods, including (a) prefabricated elements or systems, (b) lateral slide, and (c) self-propelled modular transporter. This report presents the findings of this research project. The objectives of this project were as follows:

- Develop a qualitative decision support tool (DST) that IDOT planners and decision-makers can use to identify all feasible bridge construction methods for any bridge project based on its specific characteristics, requirements, and constraints.

- Create a quantitative cost-estimating DST that can be used to accurately estimate construction, road user, maintenance, and rehabilitation costs for all feasible construction methods including conventional and ABC methods. The developed DST is designed to generate (i) a rough order of magnitude (ROM) construction cost estimate during early project phases such as Phase I engineering reports and (ii) a detailed construction cost estimate based on the specific design and dimension of all bridge elements.

- Develop guidance for the user interface of the developed DST to explain how it can be used to compare and rank all feasible bridge construction methods based on their individual performance in design, construction, road user, maintenance and rehabilitation, and life cycle costs.

- Evaluate the performance and accuracy of the developed quantitative DST for estimating bridge costs by using two sets of case studies that include a representative sample of completed and future IDOT bridge projects.

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LIST OF ACRONYMS

- AADT: Average Annual Daily Traffic
- ABC: Accelerated Bridge Construction
- BLCC: Bridge Life Cycle Cost
- DST: Decision Support Tool
- FHWA: Federal Highway Administration
- IDOT: Illinois Department of Transportation
- LCC: Life Cycle Cost
- MAPE: Mean Absolute Percentage Error
- ML: Machine Learning
- MLR: Multiple Linear Regression
- MR: Maintenance and Rehabilitation
- R Squared/R^2: Coefficient of Determination
- ROM: Rough Order of Magnitude
- RUC: Road User Cost
- SPMT: Self-Propelled Modular Transporter

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CHAPTER 1: INTRODUCTION

PROBLEM STATEMENT

Accelerated bridge construction (ABC) techniques and technologies have been increasingly used for bridge rehabilitation and replacement projects in recent years. ABC methods include (a) prefabricated elements or systems, (b) lateral slide, and (c) self-propelled modular transporter (SPMT). ABC methods use innovative planning, design, materials, and construction methods in a safe and cost-effective manner to reduce the on-site construction time that occurs when building new bridges or replacing and rehabilitating existing ones (FHWA, 2011). The main advantage of the ABC method over conventional staged construction is the reduced impact on traffic and mobility caused by on-site bridge construction, lane closures, and detours (FHWA, 2011). ABC methods, on the other hand, often require a higher initial cost and the potential for more planning, design coordination, and increased construction lead time (Ozimok & Claussen, 2020). Several tools have been developed to assist decision-makers in the selection of conventional staged construction or ABC methods based on bridge characteristics and requirements. Most of the existing tools, however, focus and depend on the subjective opinions of decision-makers/experts. Despite the advantages of these tools, they do not provide a systematic or effective framework for estimating the cost of the two methods. Accordingly, there is a pressing need for additional research to provide IDOT planners and decision-makers with a decision support tool that can be used to estimate and compare different bridge cost components of all feasible construction methods to select the most suitable construction method for any future bridge project based on its specific characteristics, requirements, and constraints.

RESEARCH OBJECTIVES AND METHODOLOGY

The main goal of this research project was to develop a decision support tool that can be used by IDOT planners and decision-makers to estimate and compare different bridge cost components to identify the most suitable construction cost for any planned bridge project based on its specific characteristics, requirements, and constraints. To accomplish this, the objectives of the proposed research were as follows:

1. Develop a qualitative decision support tool (DST) that can be used by IDOT planners and decision-makers to identify all feasible bridge construction methods for any bridge project based on its specific characteristics, requirements, and constraints.

2. Create a quantitative cost-estimating DST that can be used to accurately estimate construction, road user, maintenance, and rehabilitation costs for all feasible construction methods, including conventional and ABC methods. The developed DST is designed to generate (i) a rough order of magnitude (ROM) construction cost estimate during the early project phases such as Phase I engineering reports and (ii) a detailed construction cost estimate based on the specific design and dimension of all bridge elements.

3. Develop guidance for the user interface of the developed DST to explain how it can be used to compare and rank all feasible bridge construction methods based on their individual

performance in design, construction, road user, maintenance and rehabilitation, and life cycle costs.

4. Evaluate the performance and accuracy of the developed quantitative DST for estimating bridge costs by using two sets of case studies that include a representative sample of completed and future IDOT bridge projects.

Proposed Techniques and Methodologies

The research team accomplished the objectives of this project by adopting a rigorous research methodology. The methodology breaks down the research work into five major tasks (see Figure 1) that are described in more detail in the following chapters and appendices.

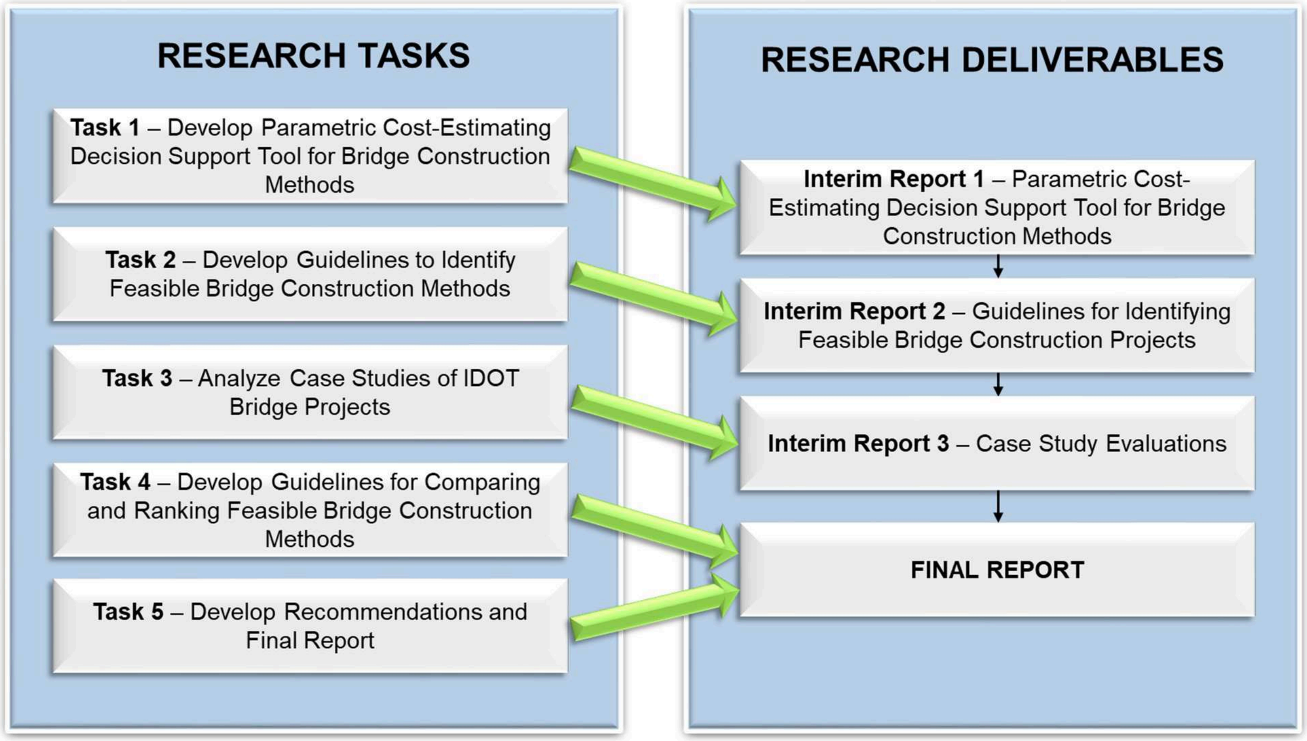


Figure 1. Diagram. Research tasks and deliverables.

CHAPTER 2: QUALITATIVE DECISION SUPPORT TOOL

This chapter presents the development of a qualitative decision support tool (DST) that IDOT can use to identify feasible construction methods for each bridge based on its characteristics, including availability of nearby prefabrication facilities, availability of travel path from prefabrication facility to the structure, availability of space for constructing a new structure adjacent to the existing bridge, presence of overhead power lines, availability and capacity of lifting cranes, and geotechnical requirements. This tool was developed to incorporate and to expand effective procedures used by IDOT and other state DOTs such as those provided by the Federal Highway Administration (FHWA) in its *Accelerated Bridge Construction* manual (FHWA, 2011).

The first step of the developed qualitative tool utilizes a matrix of questions to support IDOT decision-makers in determining if ABC methods are appropriate for the planned bridge project. This matrix includes questions that focus on three main categories: (i) site constraints such as the average daily traffic and whether the project is an emergency bridge replacement, (ii) costs such as whether the traffic control plan will change significantly through the course of the project due to development, local expansion, or other projects in the area, and (iii) other factors such as safety and environmental concerns, as shown in Figure 2. The outcome of the first step is a recommendation on whether to consider ABC methods for the planned project.

The second step is designed to support IDOT decision-makers in identifying all feasible ABC methods for planned bridge projects that were found to be appropriate for ABC methods in the first step. The second step of the developed guidelines utilizes another matrix that enables planners to select one of four possible scenarios for the construction of the planned bridge project based on its location and type of work. The four possible scenarios are (a) superstructure over roadway, (b) superstructure over railroad, (c) superstructure over waterway, and (d) substructure elements construction, as shown in Figure 2. For each scenario, the developed guidelines enable IDOT planners to answer a series of yes/no questions on the planned project site and requirements such as presence of nearby prefabricated construction facilities and/or clear travel path to accommodate the transportation of prefabricated bridge sections. Based on the provided answers to these questions, the developed guideline tool provides a list of feasible ABC methods for the planned bridge project.

The third step utilizes the output of the second step to automatically generate a comprehensive list of all feasible conventional construction and ABC methods that can be used in the quantitative analysis phase of the planned bridge project, as shown in Figure 3. The following sections provide a detailed description of the three steps of the developed qualitative guidelines.

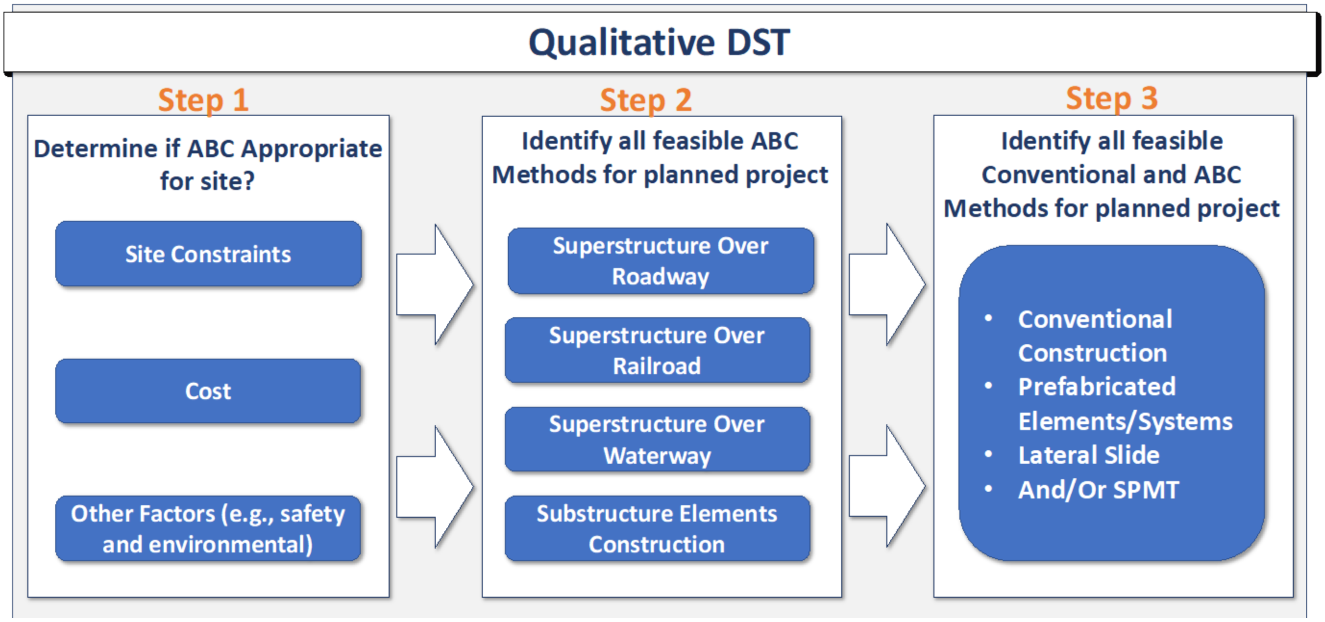
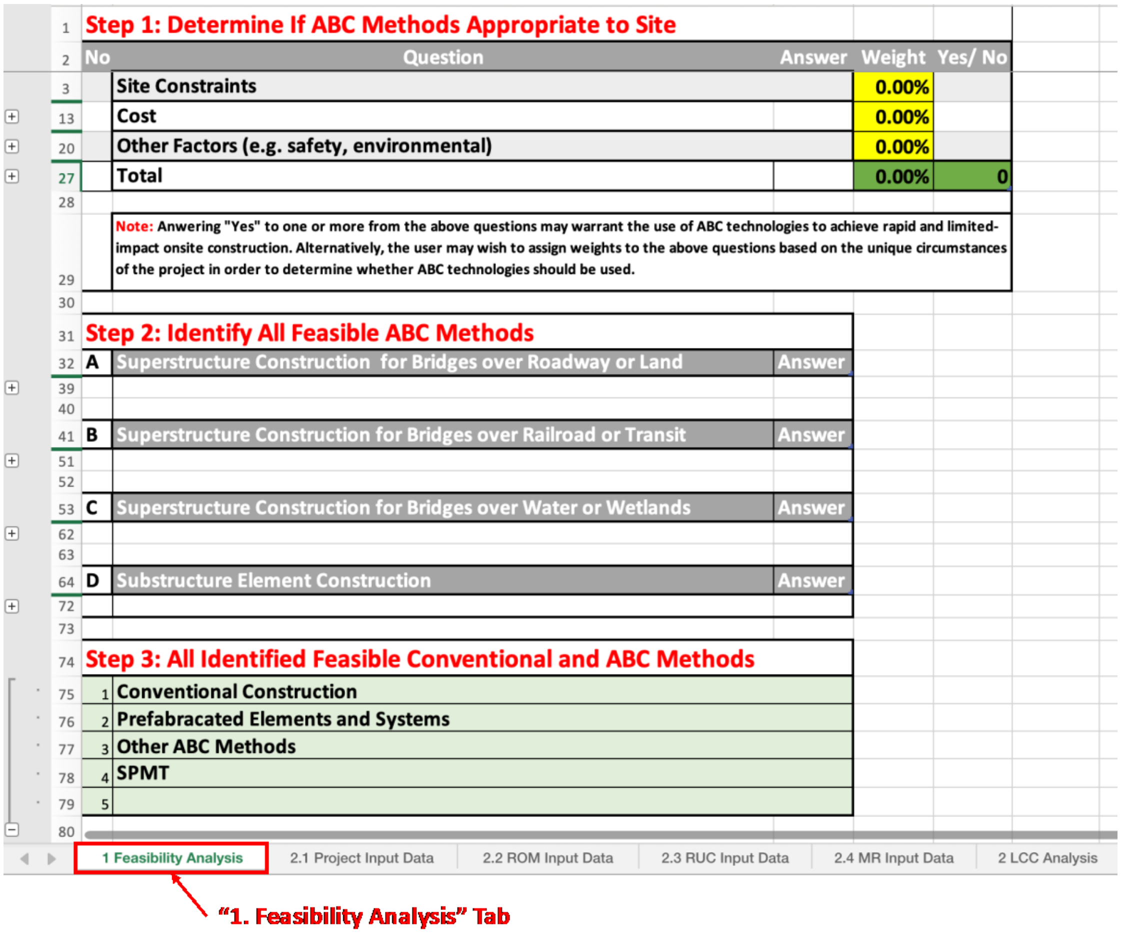


Figure 2. Diagram. Steps for the developed qualitative decision support tool.



Step 1: Determine If ABC Methods Appropriate to Site

No	Question	Answer	Weight	Yes/ No
	Site Constraints		0.00%	
	Cost		0.00%	
	Other Factors (e.g. safety, environmental)		0.00%	
	Total		0.00%	0

Note: Anwering "Yes" to one or more from the above questions may warrant the use of ABC technologies to achieve rapid and limited-impact onsite construction. Alternatively, the user may wish to assign weights to the above questions based on the unique circumstances of the project in order to determine whether ABC technologies should be used.

Step 2: Identify All Feasible ABC Methods

A	Superstructure Construction for Bridges over Roadway or Land	Answer
B	Superstructure Construction for Bridges over Railroad or Transit	Answer
C	Superstructure Construction for Bridges over Water or Wetlands	Answer
D	Substructure Element Construction	Answer

Step 3: All Identified Feasible Conventional and ABC Methods

1	Conventional Construction
2	Prefabracated Elements and Systems
3	Other ABC Methods
4	SPMT
5	

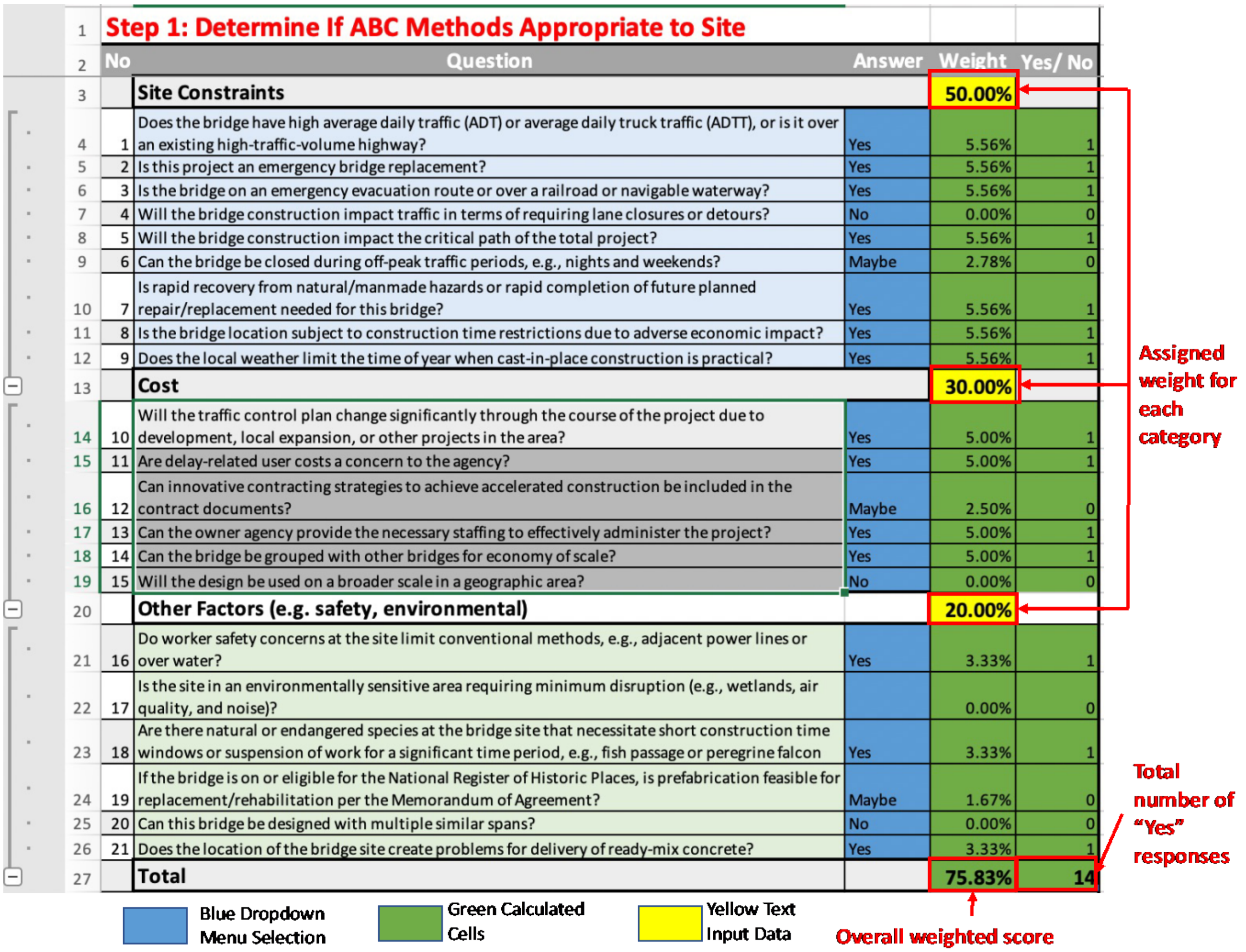
“1. Feasibility Analysis” Tab

Figure 3. Screenshot. Graphical user interface of qualitative decision support tool.

DETERMINING IF ABC METHODS ARE APPROPRIATE FOR SITE

The developed qualitative decision support tool and its guidelines were developed based on FHWA's *Accelerated Bridge Construction* manual (FHWA, 2011). Accordingly, the qualitative decision support tool utilizes a set of 21 questions to support IDOT decision-makers in determining if ABC methods are appropriate for the planned bridge project. The 21 questions are organized into three main categories: (i) site constraints, which includes nine questions such as whether the bridge construction will impact traffic in terms of requiring lane closures or detours and whether the local weather limits the time of year when cast-in-place construction is practical; (ii) costs, which includes six questions such as whether delay-related user costs are a concern to the agency; and (iii) other factors, which includes six questions such as safety and environmental concerns, as shown in Figure 4. For each of the 21 questions, the developed qualitative DST enables IDOT decision-makers to provide an answer of "Yes," "No," or "Maybe."

The DST is designed to analyze the responses to the 21 questions using two FHWA-recommended methods that are designed to sum up the total number of "Yes" responses and/or overall weighted score based on user-defined weights for each of the three categories of questions, as shown in Figure 4. Note that the developed qualitative DST equally distributes the user-defined weight of each category evenly among all listed questions. For example, if the user-defined weight for the site constraint category is 50%, then the assigned weight for each of its nine questions automatically calculated by the DST is 5.56%, as shown in Figure 4. FHWA recommends that DOT designers specify a threshold that indicates the feasibility of using ABC methods such as providing at least one or two "Yes" responses (FHWA, 2011). The DST is designed to automatically (a) calculate the total number of "Yes" responses and the overall weighted score based on the user responses to the 21 questions and (b) provide a recommendation on the feasibility of utilizing ABC methods for the planned bridge project, as shown in Figure 4. The following three sections provide a detailed description of the three categories of questions integrated in the developed DST.



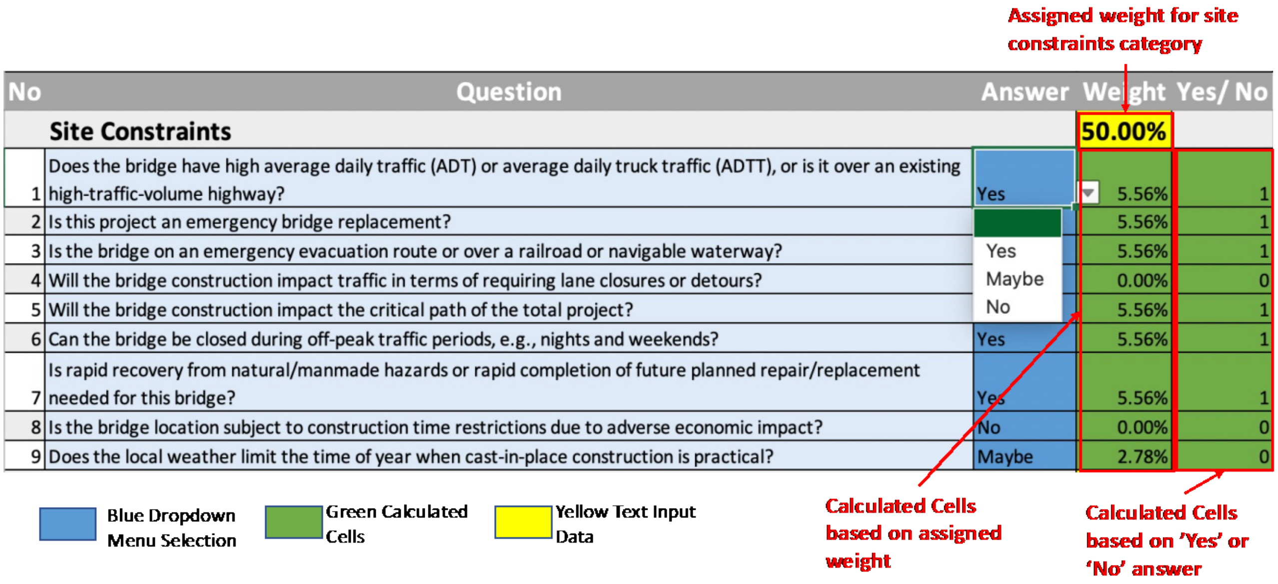
Step 1: Determine If ABC Methods Appropriate to Site

	No	Question	Answer	Weight	Yes/ No
3		**Site Constraints**		50.00%	
4	1	Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?	Yes	5.56%	1
5	2	Is this project an emergency bridge replacement?	Yes	5.56%	1
6	3	Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?	Yes	5.56%	1
7	4	Will the bridge construction impact traffic in terms of requiring lane closures or detours?	No	0.00%	0
8	5	Will the bridge construction impact the critical path of the total project?	Yes	5.56%	1
9	6	Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?	Maybe	2.78%	0
10	7	Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?	Yes	5.56%	1
11	8	Is the bridge location subject to construction time restrictions due to adverse economic impact?	Yes	5.56%	1
12	9	Does the local weather limit the time of year when cast-in-place construction is practical?	Yes	5.56%	1
13		**Cost**		30.00%	
14	10	Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?	Yes	5.00%	1
15	11	Are delay-related user costs a concern to the agency?	Yes	5.00%	1
16	12	Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?	Maybe	2.50%	0
17	13	Can the owner agency provide the necessary staffing to effectively administer the project?	Yes	5.00%	1
18	14	Can the bridge be grouped with other bridges for economy of scale?	Yes	5.00%	1
19	15	Will the design be used on a broader scale in a geographic area?	No	0.00%	0
20		**Other Factors (e.g. safety, environmental)**		20.00%	
21	16	Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?	Yes	3.33%	1
22	17	Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise)?		0.00%	0
23	18	Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon	Yes	3.33%	1
24	19	If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?	Maybe	1.67%	0
25	20	Can this bridge be designed with multiple similar spans?	No	0.00%	0
26	21	Does the location of the bridge site create problems for delivery of ready-mix concrete?	Yes	3.33%	1
27		**Total**		75.83%	14

Figure 4. Screenshot. DST method for determining if ABC method is appropriate for planned bridge.

Site Constraints

Questions in this category were collected and organized to enable IDOT planners and designers to easily decide if the use of ABC methods is appropriate for a specific planned bridge project based on its site constraints (FHWA, 2005). This category includes nine questions that require planners to answer if (1) the site has high average daily traffic, (2) the project is an emergency bridge replacement, (3) the bridge is on an emergency evacuation route or over a railroad or navigable waterway, (4) the bridge construction impacts traffic, (5) the bridge construction impacts the critical path of the total project, (6) the bridge can be closed during off-peak traffic period, (7) rapid recovery from natural/man-made hazards or rapid completion of future planned repair/replacement is needed for the bridge, (8) bridge location is subject to construction time restrictions due to adverse economic impact, and (9) local weather limits the time of year when cast-in-place construction is practical, as shown in Figure 5. Based on user-provided answers to the nine questions, the developed qualitative decision support tool is designed to automatically fill in values in the “Weight” and “Yes/No” columns, as shown in Figure 5.



No	Question	Answer	Weight	Yes/ No
	Site Constraints		50.00%	
1	Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?	Yes	5.56%	1
2	Is this project an emergency bridge replacement?		5.56%	1
3	Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?		5.56%	1
4	Will the bridge construction impact traffic in terms of requiring lane closures or detours?		0.00%	0
5	Will the bridge construction impact the critical path of the total project?		5.56%	1
6	Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?	Yes	5.56%	1
7	Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?	Yes	5.56%	1
8	Is the bridge location subject to construction time restrictions due to adverse economic impact?	No	0.00%	0
9	Does the local weather limit the time of year when cast-in-place construction is practical?	Maybe	2.78%	0

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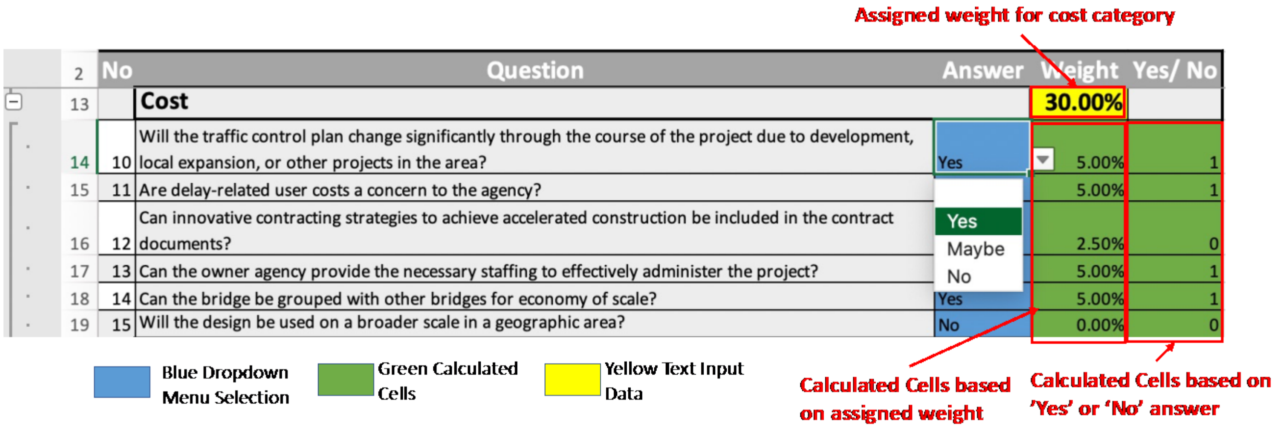
Figure 5. Screenshot. Site constraints category in the developed qualitative DST.

Cost

Questions in this category were collected and organized to enable IDOT planners and designers to easily decide if the use of ABC methods is appropriate for a specific planned bridge project based on its cost (FHWA, 2005). This category includes six questions that require planners to answer if (1) the traffic control plan will change significantly through the course of the project due to development, local expansion, or other projects in the area, (2) delay-related user costs are a concern to the agency, (3) innovative contracting strategies to achieve accelerated construction can be included in the contract documents, (4) the owner agency can provide the necessary staffing to effectively administer the project, (5) the bridge can be grouped with other bridges for economy of scale, (6) the design will be used on a broader scale in a geographic area, as shown in Figure 6. Based on user-provided answers to these six questions, the developed qualitative decision support tool is designed to automatically fill in values in the "Weight" and "Yes/No" columns, see Figure 6.



2	No	Question	Answer	Weight	Yes/ No
13		**Cost**		30.00%	
14	10	Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?	Yes	5.00%	1
15	11	Are delay-related user costs a concern to the agency?		5.00%	1
16	12	Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?		2.50%	0
17	13	Can the owner agency provide the necessary staffing to effectively administer the project?		5.00%	1
18	14	Can the bridge be grouped with other bridges for economy of scale?	Yes	5.00%	1
19	15	Will the design be used on a broader scale in a geographic area?	No	0.00%	0

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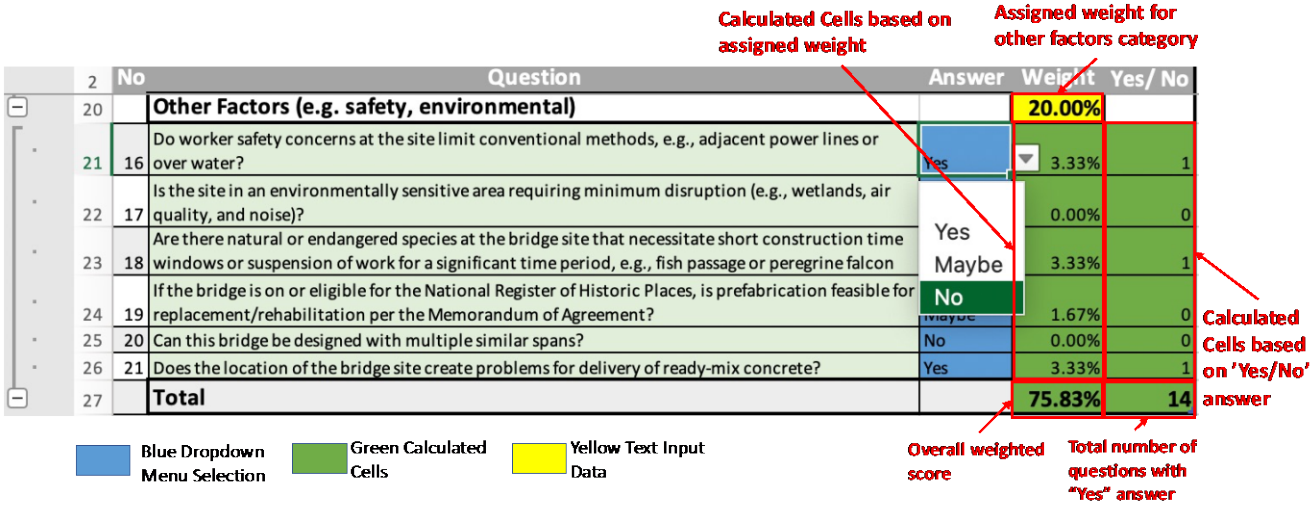
Figure 6. Screenshot. Cost category in the developed qualitative DST.

Other Factors

Questions in this category were collected and organized to enable IDOT planners and designers to easily decide if the use of ABC methods is appropriate for a specific planned bridge project based on other factors such as safety and environmental concerns (FHWA, 2005). This category includes six questions that require planners to answer if (1) worker safety concerns at the site limit conventional methods (e.g., adjacent power lines or over water), (2) the site is in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise), (3) there are natural or endangered species at the bridge site that necessitate short construction windows or suspension of work for a significant period (e.g., fish passage or peregrine falcon nesting), (4) the bridge is on or eligible for the National Register of Historic Places, where prefabrication is feasible for replacement/rehabilitation per the Memorandum of Agreement, (5) the bridge can be designed with multiple similar spans, (6) the location of the bridge site creates problems for the delivery of ready-mix concrete, as shown in Figure 7. Based on user-provided answers to the six questions, the developed qualitative decision support tool is designed to automatically fill in values in the "Weight" and "Yes/No" columns, see Figure 7.



Calculated Cells based on assigned weight

Assigned weight for other factors category

2	No	Question	Answer	Weight	Yes/ No
20		**Other Factors (e.g. safety, environmental)**		20.00%	
21	16	Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?	Yes	3.33%	1
22	17	Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise)?		0.00%	0
23	18	Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon		3.33%	1
24	19	If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?	Maybe	1.67%	0
25	20	Can this bridge be designed with multiple similar spans?	No	0.00%	0
26	21	Does the location of the bridge site create problems for delivery of ready-mix concrete?	Yes	3.33%	1
27		**Total**		75.83%	14

Calculated Cells based on 'Yes/No' answer

Overall weighted score

Total number of questions with "Yes" answer

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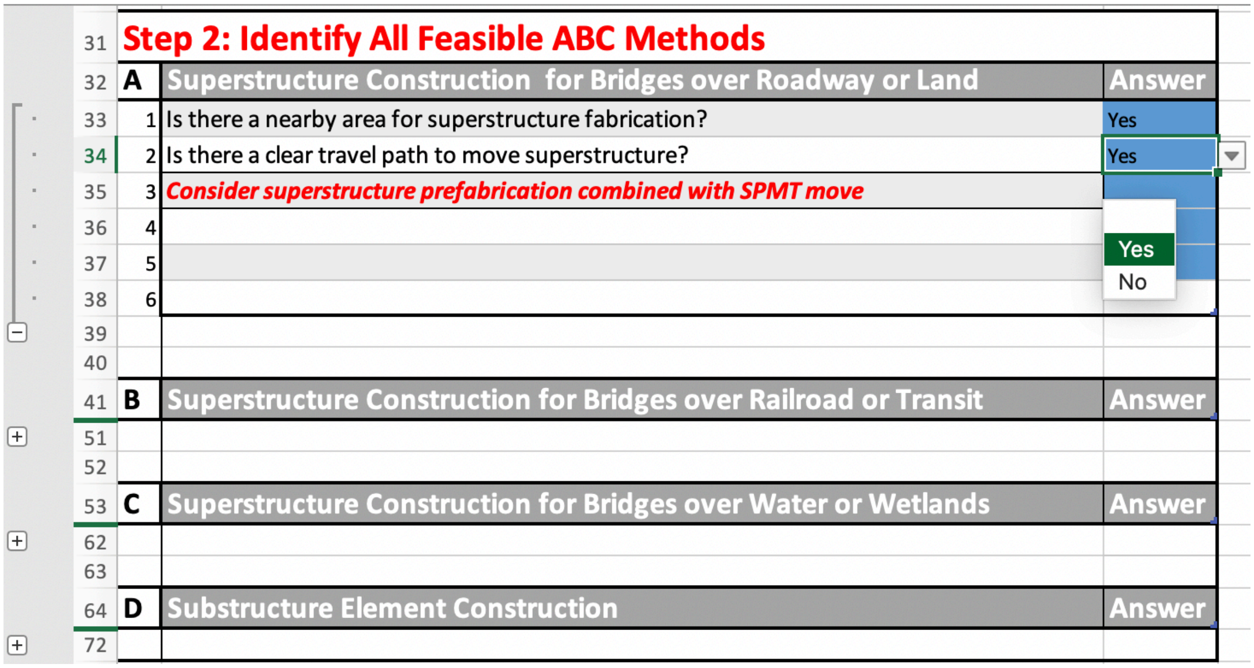
Figure 7. Screenshot. Other factors category in the developed qualitative DST.

IDENTIFYING ALL FEASIBLE ABC METHODS

The second step of the developed qualitative DST is designed to support IDOT decision-makers in identifying all feasible ABC methods for planned bridge projects that were found to be appropriate for ABC methods in the first step. The second step of the developed guidelines utilizes another matrix that enables planners to select one of four possible scenarios for the construction of the planned bridge project based on its location and type of work. The four possible scenarios are (a) superstructure over roadway, (b) superstructure over railroad, (c) superstructure over waterway, and (d) substructure elements construction, as shown in Figure 8. For each scenario, the FHWA guidelines utilize flowcharts that include a series of sequential questions to identify feasible ABC methods for a planned bridge project. The developed qualitative DST was designed to integrate a graphical user-friendly interface that transforms each of the four FHWA flowcharts into a series of nested questions that can be easily answered by IDOT planners using a drop-down list of yes/no responses, as shown in Figure 8. Based on the planners’ provided responses, the developed qualitative DST automatically identifies and recommends all feasible ABC methods for the planned bridge project, as shown in Figure 8. The following four sections provide a detailed description of the developed DST for each of the four scenarios.



31		**Step 2: Identify All Feasible ABC Methods**	
32	**A**	**Superstructure Construction for Bridges over Roadway or Land**	**Answer**
33	1	Is there a nearby area for superstructure fabrication?	Yes
34	2	Is there a clear travel path to move superstructure?	Yes
35	3	***Consider superstructure prefabrication combined with SPMT move***	
36	4		
37	5		
38	6		
39			
40			
41	**B**	**Superstructure Construction for Bridges over Railroad or Transit**	**Answer**
51			
52			
53	**C**	**Superstructure Construction for Bridges over Water or Wetlands**	**Answer**
62			
63			
64	**D**	**Substructure Element Construction**	**Answer**
72			

Figure 8. Screenshot. DST method for identifying all feasible ABC methods for bridge project.

Superstructure Construction Bridges over Roadway or Land

This section focuses on simplifying the decision flowchart provided by FHWA for a superstructure over a roadway to a set of nested questions to facilitate its use by IDOT planners, as shown in Figure 9 and Figure 10. The DST is designed to enable decision-makers to identify “Superstructure over Roadway or Land” as the appropriate scenario for a planned project and then select the “+” icon to the left of this section of the developed guidelines to expand it. Decision-makers are then presented with one question only, which they must answer to proceed. Based on their answer to that first question, a new question will be revealed in the next row. Once they answer this new question, another question will be revealed to take them further along the process. Decision-makers need to follow these questions until they receive a final recommendation. For example, the first question in the superstructure over roadway or land matrix is “Is there a nearby area for superstructure fabrication?” If decision-makers answer “Yes,” then the next question will be “Is there a clear path to move the superstructure?” However, if the answer is “No,” then the next question will be “Is there room directly adjacent (parallel) to the bridge for erection of the new superstructure?” (Figure 9). Decision-makers must follow these questions until they receive a final recommendation.

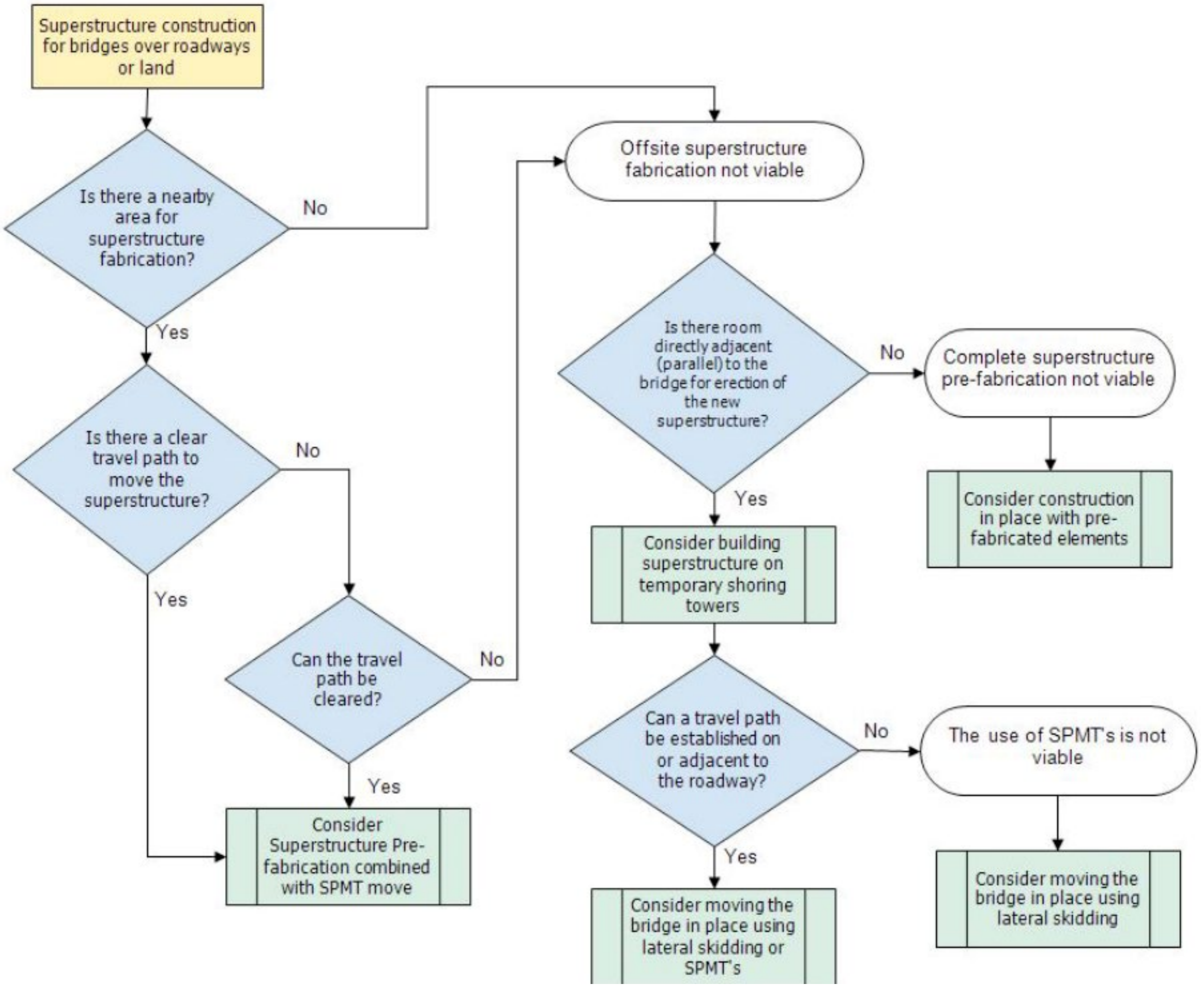
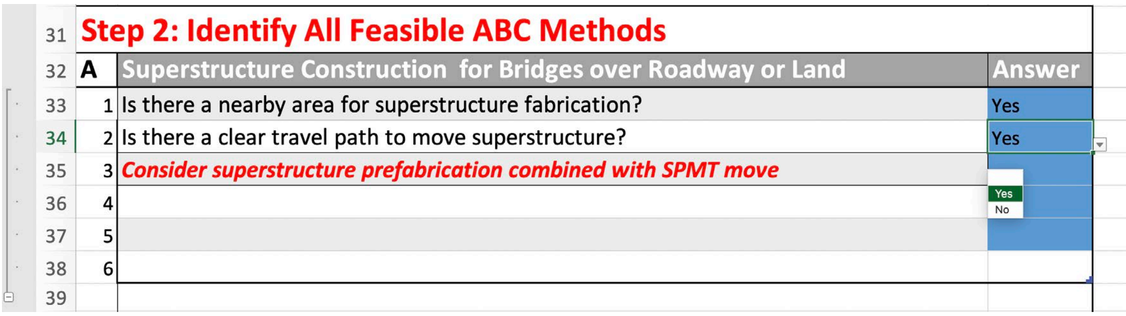


Figure 9. Flowchart. Decision flowchart for superstructure over roadway (FHWA, 2011).



31	**Step 2: Identify All Feasible ABC Methods**		
32	**A**	**Superstructure Construction for Bridges over Roadway or Land**	**Answer**
33	1	Is there a nearby area for superstructure fabrication?	Yes
34	2	Is there a clear travel path to move superstructure?	Yes
35	3	***Consider superstructure prefabrication combined with SPMT move***	
36	4		
37	5		
38	6		
39			

Figure 10. Screenshot. Developed qualitative DST questions for superstructure over roadway.

Superstructure Construction Bridges over Railroad

In this section, the decision flowchart provided by FHWA for a superstructure over a railroad or transit was transformed into a set of nested questions to facilitate its use by IDOT planners, as shown in Figure 11 and Figure 12. Note that longitudinal launching is extremely rare, and there is a lack of completed projects that utilize this technology. This ABC method, therefore, was excluded from the developed guidelines (FHWA, 2011).

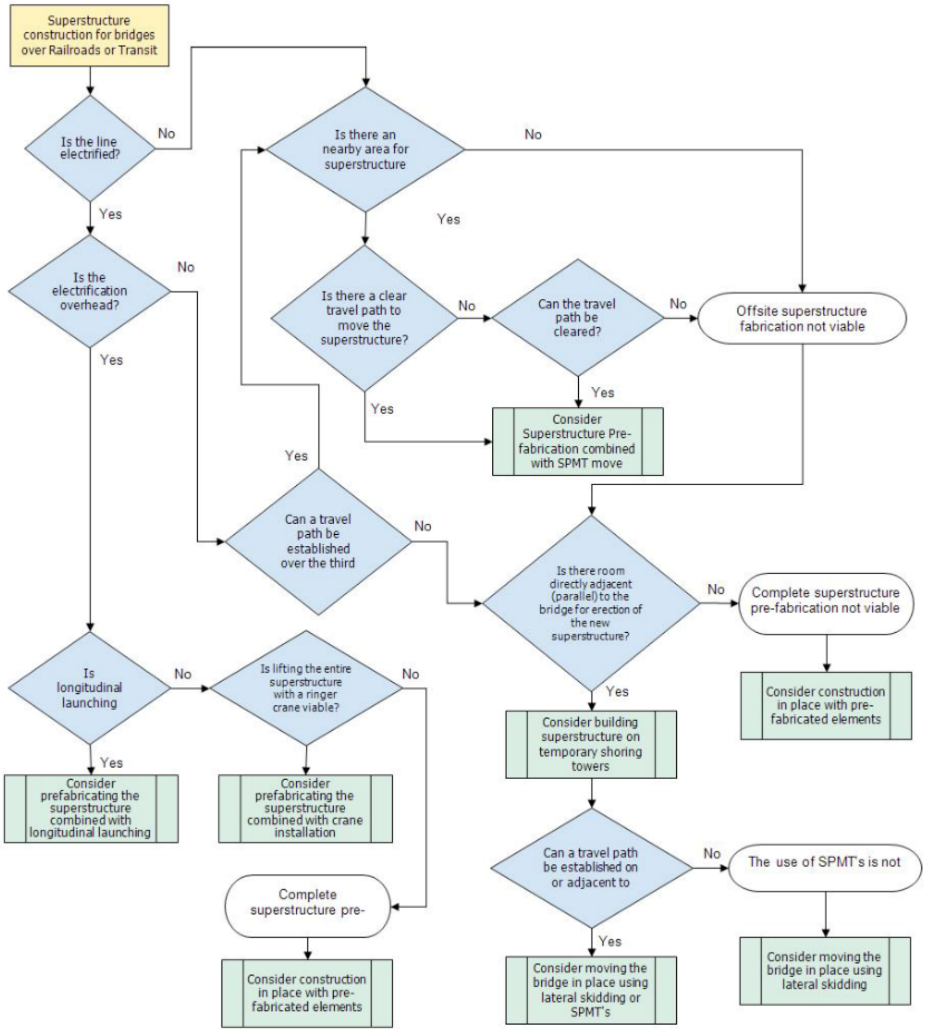
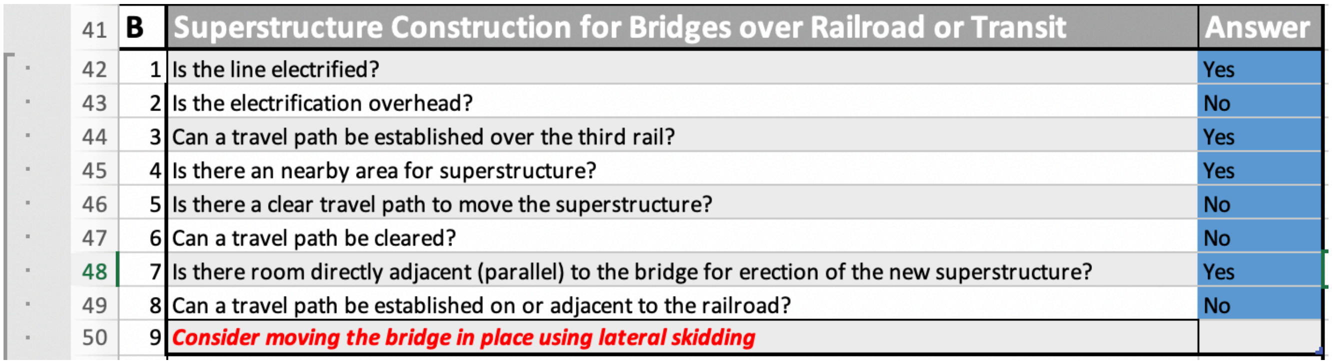


Figure 11. Flowchart. Decision flowchart for superstructure over railroad (FHWA, 2011).



41	B	Superstructure Construction for Bridges over Railroad or Transit	Answer
42	1	Is the line electrified?	Yes
43	2	Is the electrification overhead?	No
44	3	Can a travel path be established over the third rail?	Yes
45	4	Is there an nearby area for superstructure?	Yes
46	5	Is there a clear travel path to move the superstructure?	No
47	6	Can a travel path be cleared?	No
48	7	Is there room directly adjacent (parallel) to the bridge for erection of the new superstructure?	Yes
49	8	Can a travel path be established on or adjacent to the railroad?	No
50	9	***Consider moving the bridge in place using lateral skidding***	

Figure 12. Screenshot. Developed qualitative DST questions for superstructure construction over railroad.

Superstructure Construction Bridges over Waterway

In the developed DST, the decision flowchart provided by FHWA for a superstructure over a waterway or wetland was transformed to a set of nested questions to facilitate its use by IDOT planners, as shown in Figure 13 and Figure 14.

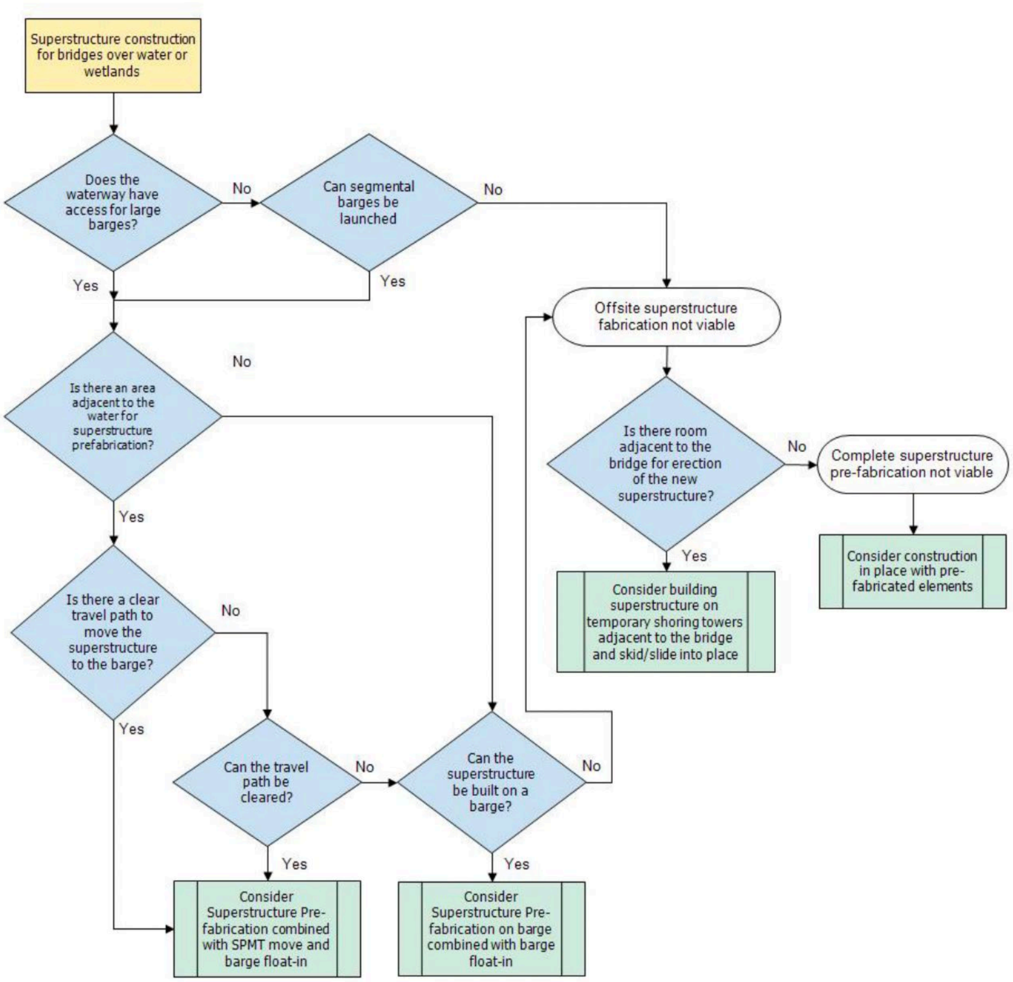
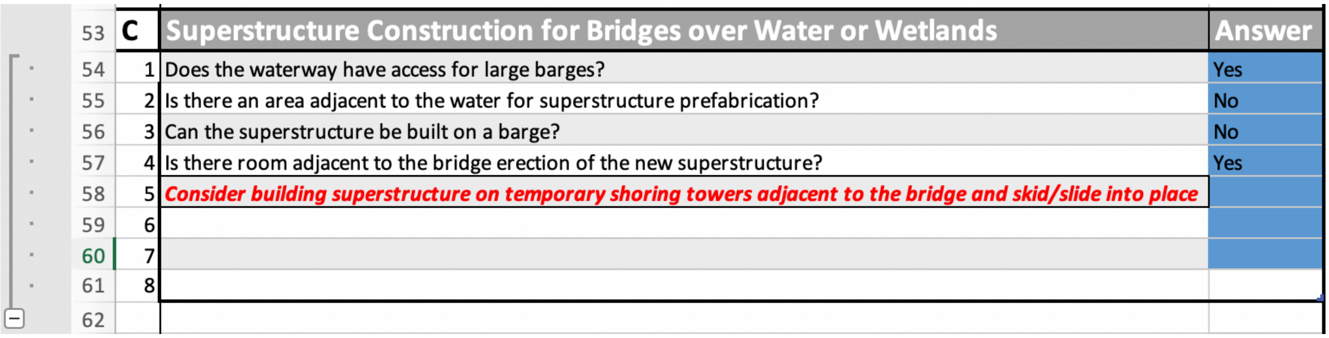


Figure 13. Flowchart. Decision flowchart for superstructure over waterway (FHWA, 2011).



53	C	Superstructure Construction for Bridges over Water or Wetlands	Answer
54	1	Does the waterway have access for large barges?	Yes
55	2	Is there an area adjacent to the water for superstructure prefabrication?	No
56	3	Can the superstructure be built on a barge?	No
57	4	Is there room adjacent to the bridge erection of the new superstructure?	Yes
58	5	***Consider building superstructure on temporary shoring towers adjacent to the bridge and skid/slide into place***	
59	6		
60	7		
61	8		
62			

Figure 14. Screenshot. Developed qualitative DST questions for superstructure construction over waterway.

Substructure Elements Construction

The decision flowchart provided by FHWA for substructure elements construction was transformed into a set of nested questions to facilitate its use by IDOT planners, as shown in Figure 15 and Figure 16.

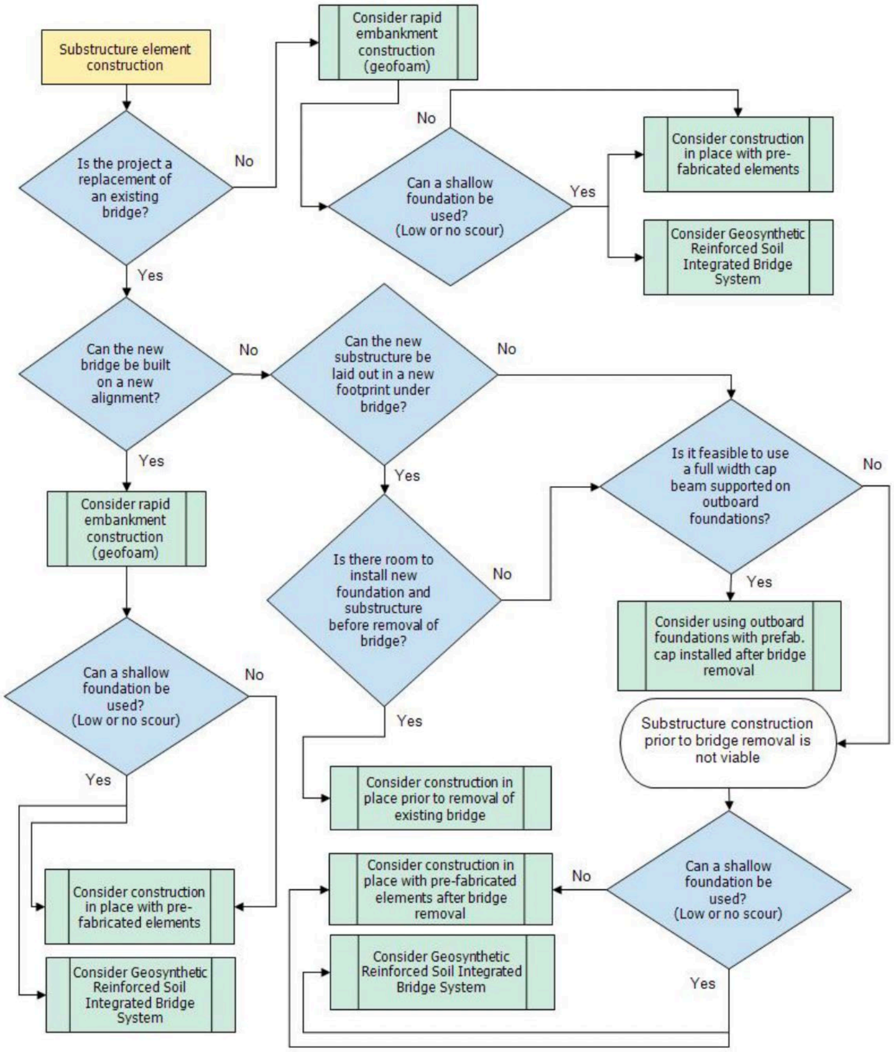
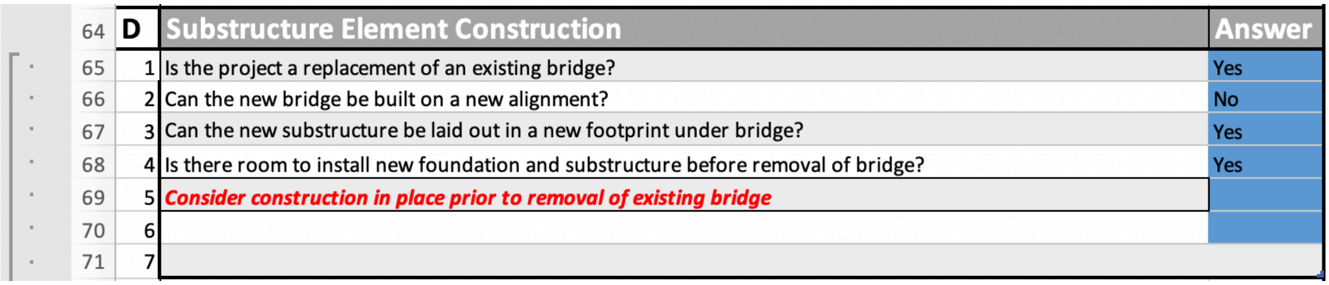


Figure 15. Flowchart. Decision flowchart for substructure elements construction (FHWA, 2011).

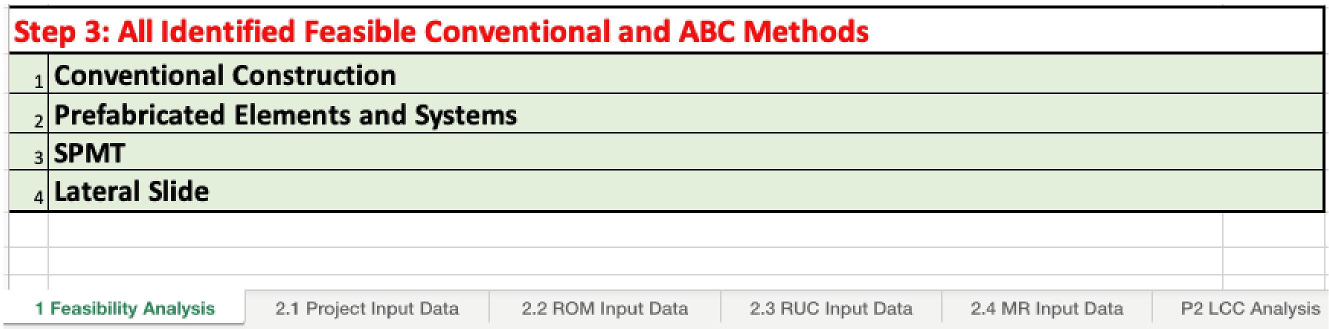


64	D	Substructure Element Construction	Answer
65	1	Is the project a replacement of an existing bridge?	Yes
66	2	Can the new bridge be built on a new alignment?	No
67	3	Can the new substructure be laid out in a new footprint under bridge?	Yes
68	4	Is there room to install new foundation and substructure before removal of bridge?	Yes
69	5	*Consider construction in place prior to removal of existing bridge*	
70	6		
71	7		

Figure 16. Screenshot. Developed qualitative DST questions for substructure elements construction.

IDENTIFYING ALL FEASIBLE CONVENTIONAL AND ABC METHODS

The third step in the developed qualitative DST utilizes the output of the second step to automatically generate a list of all feasible conventional construction and ABC methods that can be used in the quantitative analysis phase of the planned bridge project, as shown in Figure 17. This list includes a subset of the following four bridge construction methods: (a) conventional construction, (b) prefabricated elements/systems, (c) SPMT, and (d) lateral slide, as shown in Figure 17. This generated list will be used in the developed qualitative DST to estimate and compare the costs of all feasible bridge construction methods.



Step 3: All Identified Feasible Conventional and ABC Methods

1	**Conventional Construction**
2	**Prefabricated Elements and Systems**
3	**SPMT**
4	**Lateral Slide**

Figure 17. Screenshot. DST method for identifying all feasible conventional and ABC methods for a planned bridge project.

CHAPTER 3: QUANTITATIVE DECISION SUPPORT TOOL

This chapter presents the development of the quantitative decision support tool (DST) to enable IDOT designers and decision-makers to accurately estimate construction, road user, maintenance, and rehabilitation costs of all feasible bridge construction methods. The tool covers both conventional staged construction methods and ABC methods, including: (a) prefabricated elements or systems, (b) lateral slide, and (c) self-propelled modular transporter (SPMT). The DST was developed and integrated in an Excel spreadsheet because of its widespread use and practicality. The developed cost-estimating DST is designed to provide IDOT designers and decision-makers with two Excel files that can be used to generate (i) a rough order of magnitude (ROM) cost estimate during the early project planning/engineering phases and (ii) a detailed cost estimate based on the specific design and dimension of all bridge elements. The cost-estimating DST was developed in six tasks that were designed to (1) collect historical cost data of various bridge projects constructed using both conventional staged construction and ABC methods; (2) create a database of all collected bridge cost data; (3) develop a construction cost module that enables IDOT planners to develop rough order of magnitude estimates and/or definitive estimates for each bridge construction method; (4) implement a road user cost module that estimates the cost to the travelling public resulting from detours and traffic delays during bridge construction; (5) develop a life cycle cost module that includes construction, road user, maintenance, and replacement costs; and (6) compare the construction, road user, and life cycle costs for each bridge construction method, as shown in Figure 18. The research work and outcomes of the six tasks are described in the following six sections, respectively.

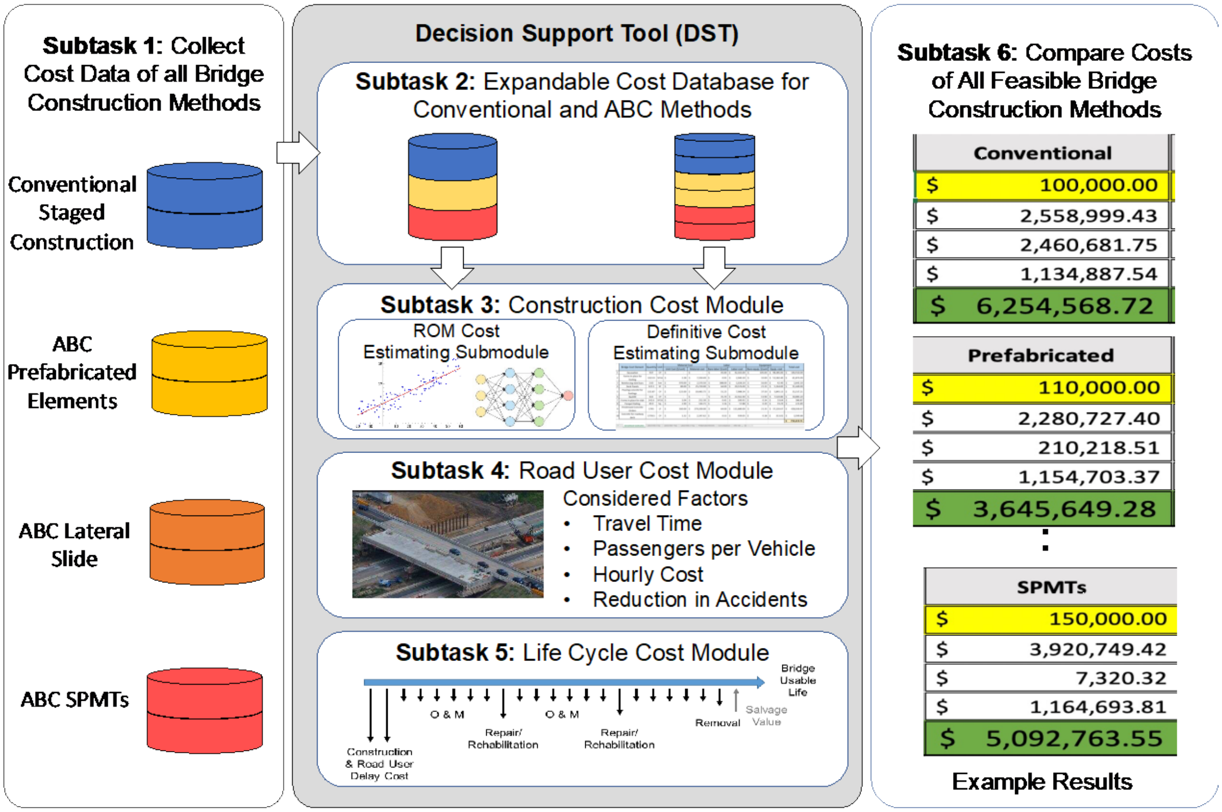


Figure 18. Diagram. Development steps of the cost-estimating decision support tool.

BRIDGE DATA COLLECTION

This section focuses on the collection and storing of all available historical cost data and characteristics of previously constructed conventional and ABC bridge projects in Illinois and other states. The bridge cost data were collected from two main sources: (a) FHWA National ABC Project Exchange (FHWA, 2013; FIU, 2022) and (b) IDOT Notices of Letting (IDOT, 2022c). The following two sections provide a detailed description of the two data sources and their data.

FHWA National ABC Project Exchange

In this section, all data required for estimating the bridge ROM cost per square foot were collected from the FHWA National ABC Project Exchange. This exchange stores historical ABC bridge data, including the construction cost for 124 bridge projects that were constructed in 41 states. The FHWA National ABC Project Exchange was used to collect ABC historical bridge data in three steps: (1) generate a list of all ABC bridge projects, (2) collect the required data for each project, and (3) organize and store the data in an Excel spreadsheet.

List of ABC Bridge Projects

The FHWA National ABC Project Exchange was thoroughly analyzed to identify a list of all ABC projects that are available in that database. This resulted in identifying a list of 124 historical bridge projects that were constructed using different ABC methods. This list of 124 bridges was organized and grouped in five categories based on ABC method: (a) prefabricated bridge elements and systems (75 projects), (b) lateral slide ABC method (17 projects), (c) SPMT ABC method (11 projects), (d) longitudinal launching ABC method (1 project), and (e) other ABC equipment such as high-capacity crane (20 projects), as shown in Figure 19. Note that the collected ABC bridge projects for "longitudinal launching ABC method" and "other ABC equipment" will not be used in developing the ROM cost estimate in the next chapter due to their limited dataset and representation of a very broad category of utilized construction equipment such as a high-capacity crane, Caterpillar 623 Scrapers, rock truck, and hydraulic cranes, respectively.

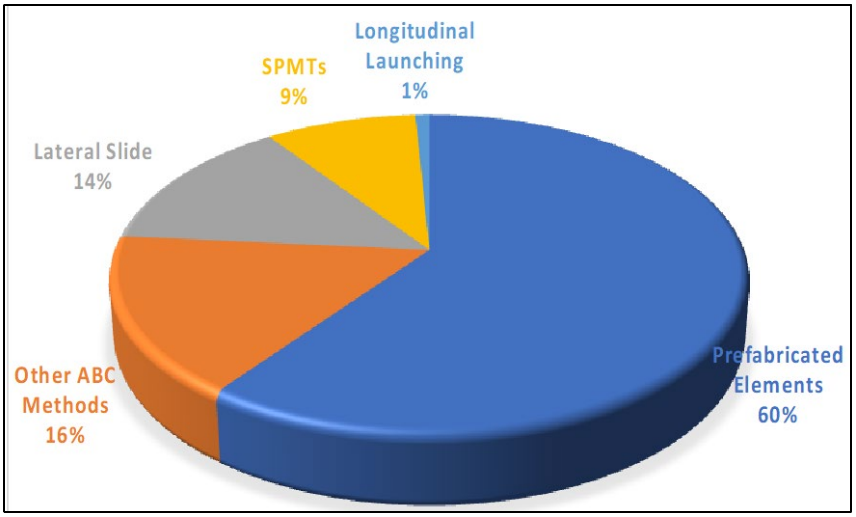
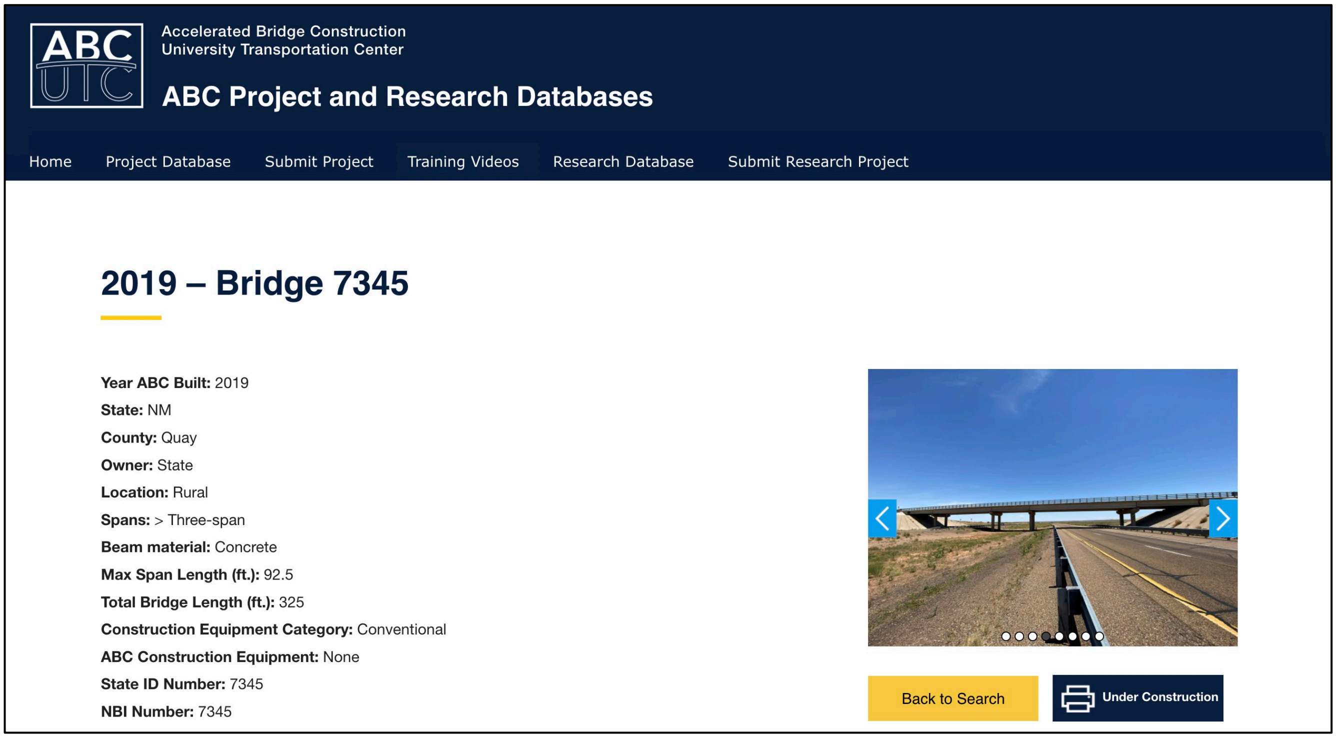


Figure 19. Chart. Bridge construction methods in the FHWA National ABC Project Exchange.

Data Collection

In this step, all data required for estimating the bridge ROM cost per square foot were collected from the FHWA National ABC Project Exchange. Based on the findings of a literature review, the data that were most widely reported to impact bridge construction costs include total project length, bridge width, bridge length, number of lanes, number of spans, maximum span length, average daily traffic (ADT), construction method/equipment, design type, location type, project type, deck material, beam material, type of service, mobility impact category, high-performance materials, structural solutions, and geotechnical solutions (Hollar et al., 2013; Jia et al., 2018).

The data for each of the identified 124 bridge projects were collected from two main sources: (a) the web page of each project and (b) the detailed cost-estimate report, if available. The collected data from the web page of each project include year ABC built, state, county, location, spans, beam material, maximum span length, number of spans, number of lanes, total bridge length, bridge width, construction equipment category, ABC construction equipment, bridge description, project location, impact category, mobility impact time, mobility impact time if conventional, ADT at time of construction, existing bridge description, project type, construction method, high-performance material, geotechnical solutions, structural solutions, and total project bid, as shown in Figure 20. The collected data from each detailed cost-estimate report include quantity, unit of measure, and unit cost for each pay-code item in the project.



2019 – Bridge 7345

Year ABC Built: 2019
State: NM
County: Quay
Owner: State
Location: Rural
Spans: > Three-span
Beam material: Concrete
Max Span Length (ft.): 92.5
Total Bridge Length (ft.): 325
Construction Equipment Category: Conventional
ABC Construction Equipment: None
State ID Number: 7345
NBI Number: 7345

Figure 20. Screenshot. Example web page of the National ABC Project Exchange Project (FIU, 2022).

Data Processing

The purpose of this step was to clean the collected data to exclude irrelevant and outdated data as well as to organize and store the collected data. First, the collected data in the previous step are cleaned to remove all bridge projects with irrelevant and outdated data. For example, the Fremont Bridge in Multnomah County, Oregon, which was built in 1973, was excluded because it utilized outdated construction techniques. Similarly, the Uxbridge–River Road Bridge over Ironstone Brook in Worcester County, Massachusetts, was excluded due to its excessive cost that resulted from its use of new technology as it was the first-ever bridge to use the folded plate system. The Willis Avenue Bridge over the Harlem River in New York City was also excluded because of its excessive cost that was caused by its unique structural design that utilized swing spans. This data-cleaning process produced a shortened list of 89 relevant ABC projects. Second, this list of 89 projects was then organized and grouped into four categories based on bridge construction method: (a) prefabricated bridge elements and systems (64 projects), (b) lateral slide ABC method (8 projects), (c) SPMT ABC method (7 projects), and (d) other ABC equipment such as high-capacity crane (10 projects), as shown in Figure 21. The organized bridge data were then stored in an Excel spreadsheet with 25 columns that represent all fields in the database, as shown in Figure 22.

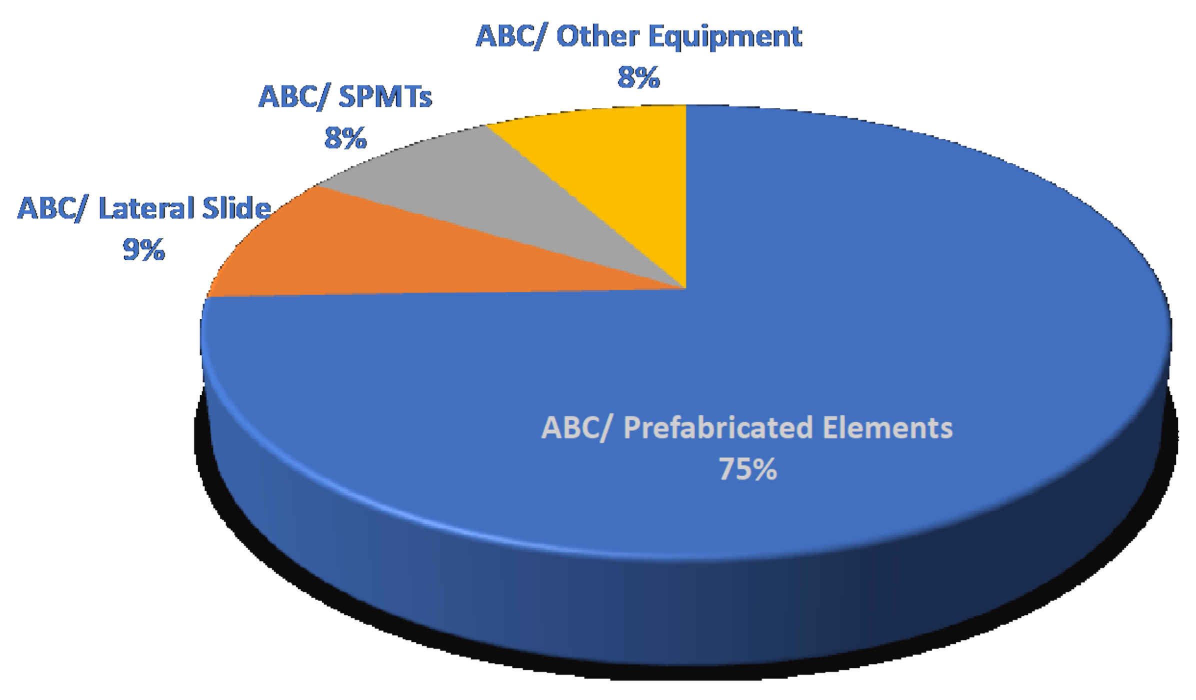
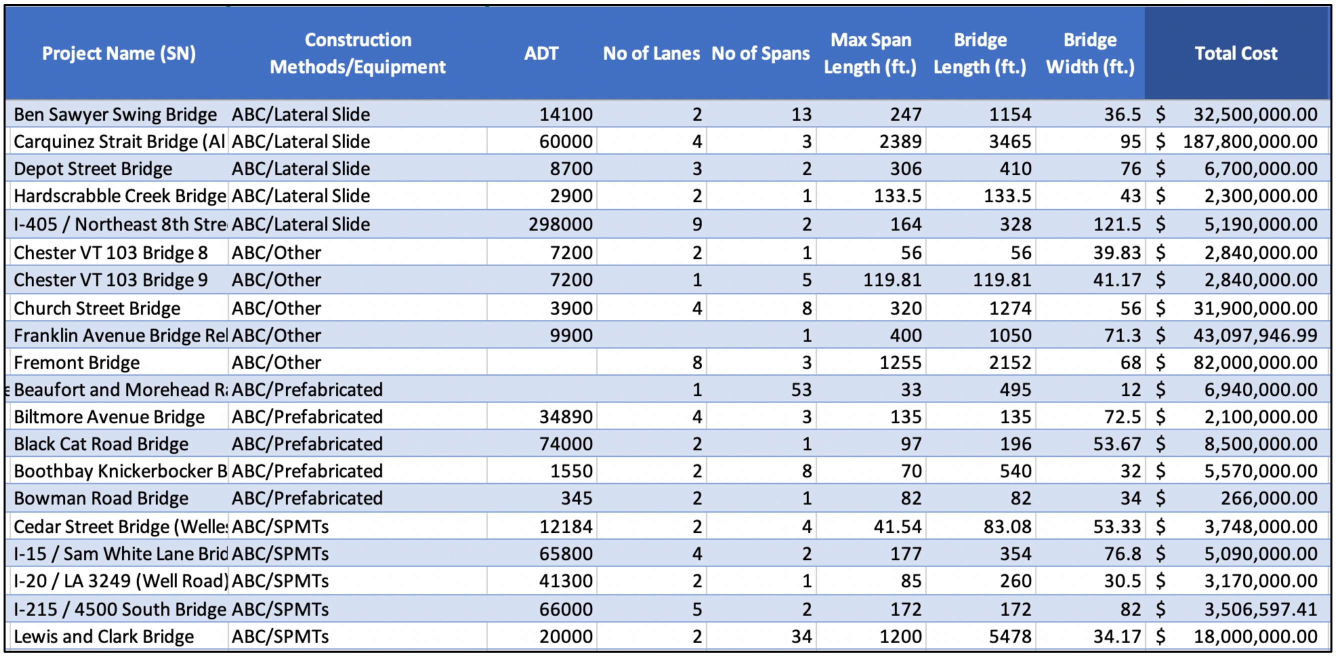


Figure 21. Chart. Organization of collected FHWA bridge data based on ABC methods.



Project Name (SN)	Construction Methods/Equipment	ADT	No of Lanes	No of Spans	Max Span Length (ft.)	Bridge Length (ft.)	Bridge Width (ft.)	Total Cost
Ben Sawyer Swing Bridge	ABC/Lateral Slide	14100	2	13	247	1154	36.5	$ 32,500,000.00
Carquinez Strait Bridge (Al	ABC/Lateral Slide	60000	4	3	2389	3465	95	$ 187,800,000.00
Depot Street Bridge	ABC/Lateral Slide	8700	3	2	306	410	76	$ 6,700,000.00
Hardscrabble Creek Bridge	ABC/Lateral Slide	2900	2	1	133.5	133.5	43	$ 2,300,000.00
I-405 / Northeast 8th Stre	ABC/Lateral Slide	298000	9	2	164	328	121.5	$ 5,190,000.00
Chester VT 103 Bridge 8	ABC/Other	7200	2	1	56	56	39.83	$ 2,840,000.00
Chester VT 103 Bridge 9	ABC/Other	7200	1	5	119.81	119.81	41.17	$ 2,840,000.00
Church Street Bridge	ABC/Other	3900	4	8	320	1274	56	$ 31,900,000.00
Franklin Avenue Bridge Rel	ABC/Other	9900		1	400	1050	71.3	$ 43,097,946.99
Fremont Bridge	ABC/Other		8	3	1255	2152	68	$ 82,000,000.00
Beaufort and Morehead R	ABC/Prefabricated		1	53	33	495	12	$ 6,940,000.00
Biltmore Avenue Bridge	ABC/Prefabricated	34890	4	3	135	135	72.5	$ 2,100,000.00
Black Cat Road Bridge	ABC/Prefabricated	74000	2	1	97	196	53.67	$ 8,500,000.00
Boothbay Knickerbocker B	ABC/Prefabricated	1550	2	8	70	540	32	$ 5,570,000.00
Bowman Road Bridge	ABC/Prefabricated	345	2	1	82	82	34	$ 266,000.00
Cedar Street Bridge (Welle	ABC/SPMTs	12184	2	4	41.54	83.08	53.33	$ 3,748,000.00
I-15 / Sam White Lane Brid	ABC/SPMTs	65800	4	2	177	354	76.8	$ 5,090,000.00
I-20 / LA 3249 (Well Road)	ABC/SPMTs	41300	2	1	85	260	30.5	$ 3,170,000.00
I-215 / 4500 South Bridge	ABC/SPMTs	66000	5	2	172	172	82	$ 3,506,597.41
Lewis and Clark Bridge	ABC/SPMTs	20000	2	34	1200	5478	34.17	$ 18,000,000.00

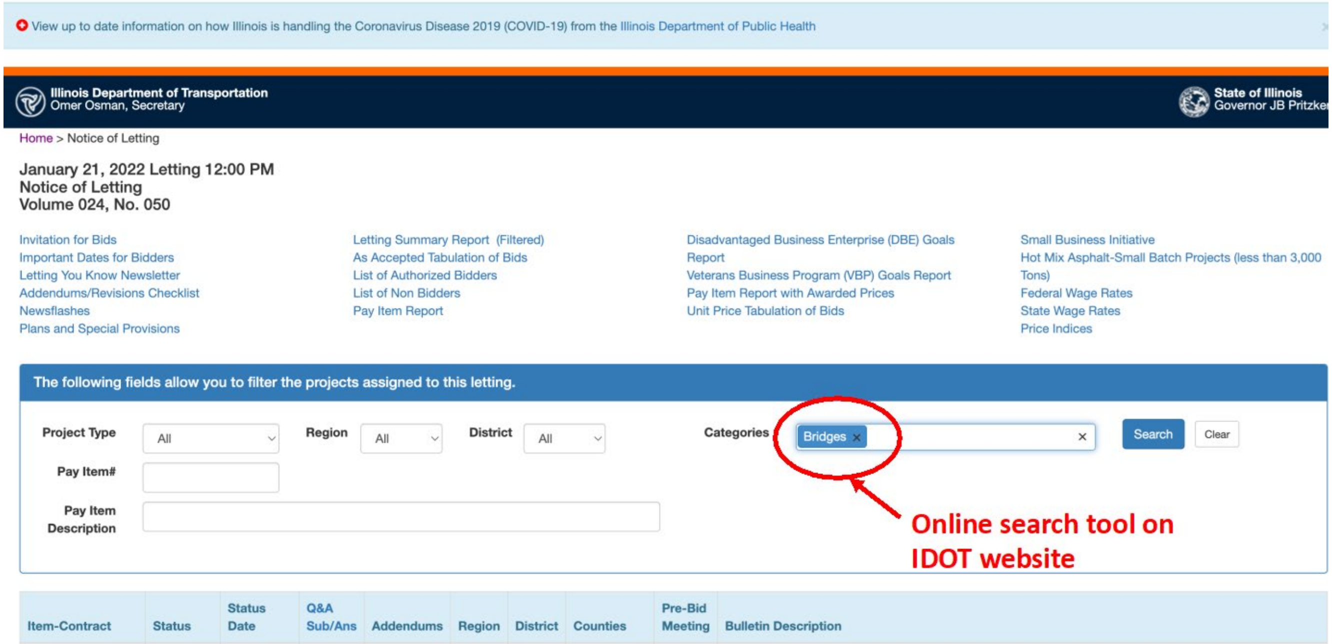
Figure 22. Screenshot. Sample stored bridge data from FHWA National ABC Project Exchange.

IDOT Bridge Data

IDOT keeps records of previous highway and bridge construction projects on IDOT’s Notice of Letting website (IDOT, 2022c) and IDOT’s Bridge Information System website (IDOT, 2022b). The two websites were used to collect historical IDOT bridge construction data in four steps: (1) generate a list of all IDOT bridge projects since 2008, (2) identify a short list of all new and replacement IDOT bridge projects since 2008, (3) collect the required data for each identified project, and (4) organize and store the data in an Excel spreadsheet.

Comprehensive List of All Bridge Projects

This step focuses on identifying a list of all IDOT bridge projects since 2008. This comprehensive list consisted of 112,122 conventional, prefabricated elements/systems, and lateral slide IDOT bridge projects that were constructed since 2008. This list was collected from the IDOT online search portal (see Figure 23) and databases provided by Technical Review Panel members.



View up to date information on how Illinois is handling the Coronavirus Disease 2019 (COVID-19) from the Illinois Department of Public Health

Illinois Department of Transportation
Omer Osman, Secretary

State of Illinois
Governor JB Pritzke

Home > Notice of Letting

January 21, 2022 Letting 12:00 PM
Notice of Letting
Volume 024, No. 050

The following fields allow you to filter the projects assigned to this letting.

Project Type: All
Region: All
District: All
Categories: Bridges ×
Pay Item#:
Pay Item Description:

Online search tool on IDOT website

Item-Contract	Status	Status Date	Q&A Sub/Ans	Addendums	Region	District	Counties	Pre-Bid Meeting	Bulletin Description

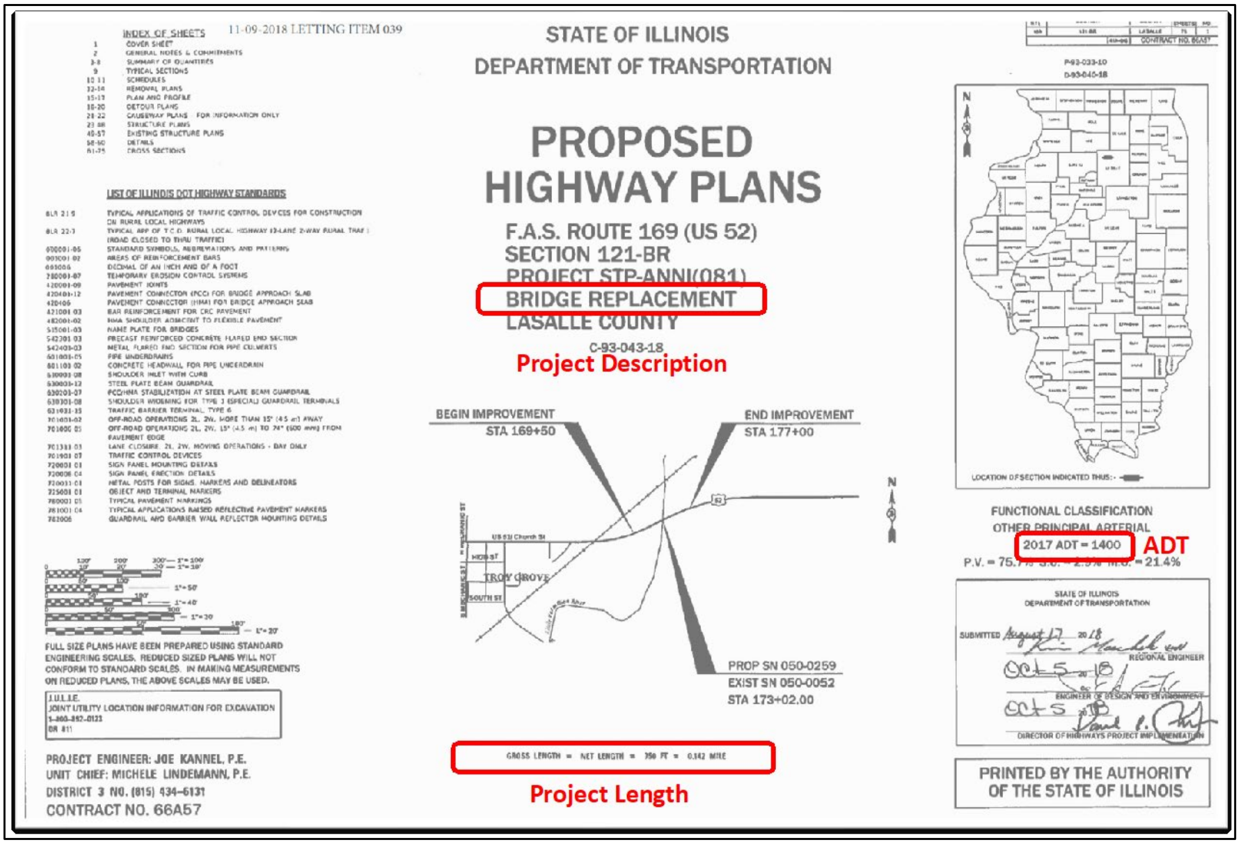
Figure 23. Screenshot. Example of IDOT notice of letting search page (IDOT, 2022c).

List of New and Replacement Bridge Projects

This step focuses on identifying a short list of all IDOT new and replacement bridge projects that were awarded since 2008. A list of 243 bridge projects was identified by filtering the list of IDOT bridge projects that was generated in the previous step to remove all non-construction projects such as painting, cleaning, and minor repairs.

Data Collection

In this step, all data required for estimating the bridge ROM cost per square foot were collected for each of the identified 243 IDOT bridge projects from four main sources: (a) the contract detail page, (b) plans and provisions documents, (c) pay-code item reports, and (d) the IDOT Bridge Information System. The collected data from each contract detail page include total project cost, project duration, and project completion date. The collected data from each “plans and provisions” document include ADT, project length, bridge length, and bridge width, as shown in Figure 24 and Figure 25. The collected data from each pay-code item report include unit of measure as well as unit cost for each pay-code item in the project. The collected data from the IDOT Bridge Information System website include number of spans, number of lanes, deck material, design type, type of service, and beam material.


INDEX OF SHEETS

11-09-2018 LETTING ITEM 039

1	COVER SHEET
2	GENERAL NOTES & COMMITMENTS
3-8	SUMMARY OF QUANTITIES
9	TYPICAL SECTIONS
10 11	SCHEDULES
12-14	REMOVAL PLANS
15-17	PLAN AND PROFILE
18-20	DETOUR PLANS
21-22	CAUSEWAY PLANS FOR INFORMATION ONLY
23 48	STRUCTURE PLANS
49-57	EXISTING STRUCTURE PLANS
58-60	DETAILS
61-75	CROSS SECTIONS

LIST OF ILLINOIS DOT HIGHWAY STANDARDS

BLR 21-9	TYPICAL APPLICATIONS OF TRAFFIC CONTROL DEVICES FOR CONSTRUCTION ON RURAL LOCAL HIGHWAYS
BLR 22-7	TYPICAL APP OF T.C.D. RURAL LOCAL HIGHWAY (2-LANE 2-WAY RURAL TRAF.) (ROAD CLOSED TO THRU TRAFFIC)
000001-06	STANDARD SYMBOLS, ABBREVIATIONS AND PATTERNS
001001-02	AREAS OF REINFORCEMENT BARS
001006	DECIMAL OF AN INCH AND OF A FOOT
280001-07	TEMPORARY EROSION CONTROL SYSTEMS
420001-09	PAVEMENT JOINTS
420401-12	PAVEMENT CONNECTOR (PCC) FOR BRIDGE APPROACH SLAB
420406	PAVEMENT CONNECTOR (HMA) FOR BRIDGE APPROACH SLAB
421001-03	BAR REINFORCEMENT FOR CRC PAVEMENT
482001-02	HMA SHOULDER ADJACENT TO FLEXIBLE PAVEMENT
515001-03	NAME PLATE FOR BRIDGES
542301-03	PRECAST REINFORCED CONCRETE FLARED END SECTION
542401-03	METAL FLARED END SECTION FOR PIPE CULVERTS
601001-05	PIPE UNDERDRAINS
601101-02	CONCRETE HEADWALL FOR PIPE UNDERDRAIN
610001-08	SHOULDER INLET WITH CURB
630001-12	STEEL PLATE BEAM GUARDRAIL
630201-07	PCC/HMA STABILIZATION AT STEEL PLATE BEAM GUARDRAIL
630301-08	SHOULDER WIDENING FOR TYPE 1 (SPECIAL) GUARDRAIL TERMINALS
631031-15	TRAFFIC BARRIER TERMINAL, TYPE 6
701001-02	OFF-ROAD OPERATIONS 2L, 2W, MORE THAN 15' (4.5 m) AWAY
701006-05	OFF-ROAD OPERATIONS 2L, 2W, 15' (4.5 m) TO 24" (600 mm) FROM PAVEMENT EDGE
701311-03	LANE CLOSURE, 2L, 2W, MOVING OPERATIONS - DAY ONLY
701901-07	TRAFFIC CONTROL DEVICES
720001-01	SIGN PANEL MOUNTING DETAILS
720006-04	SIGN PANEL ERECTION DETAILS
720011-01	METAL POSTS FOR SIGNS, MARKERS AND DELINEATORS
725001-01	OBJECT AND TERMINAL MARKERS
780001-05	TYPICAL PAVEMENT MARKINGS
781001-04	TYPICAL APPLICATIONS RAISED REFLECTIVE PAVEMENT MARKERS
782006	GUARDRAIL AND BARRIER WALL REFLECTOR MOUNTING DETAILS

FULL SIZE PLANS HAVE BEEN PREPARED USING STANDARD ENGINEERING SCALES. REDUCED SIZED PLANS WILL NOT CONFORM TO STANDARD SCALES. IN MAKING MEASUREMENTS ON REDUCED PLANS, THE ABOVE SCALES MAY BE USED.

J.U.L.I.E.
JOINT UTILITY LOCATION INFORMATION FOR EXCAVATION
1-800-892-0123
OR 811

PROJECT ENGINEER: JOE KANNEL, P.E.
UNIT CHIEF: MICHELE LINDEMANN, P.E.
DISTRICT 3 NO. (815) 434-6131
CONTRACT NO. 66A57

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

PROPOSED
HIGHWAY PLANS

F.A.S. ROUTE 169 (US 52)
SECTION 121-BR
PROJECT STP-ANNI(081)
BRIDGE REPLACEMENT
LASALLE COUNTY
C-93-043-18

BEGIN IMPROVEMENT
STA 169+50

END IMPROVEMENT
STA 177+00

PROP SN 050-0259
EXIST SN 050-0052
STA 173+02.00

GROSS LENGTH = NET LENGTH = 750 FT = 0.142 MILE

	121-BR	LASALLE	75	1
		CONTRACT NO. 66A57		

P-93-033-10
D-93-040-18

LOCATION OF SECTION INDICATED THUS:-

FUNCTIONAL CLASSIFICATION
OTHER PRINCIPAL ARTERIAL
2017 ADT = 1400
P.V. = 75.7% S.U. = 2.9% M.U. = 21.4%

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

SUBMITTED August 17 2018
REGIONAL ENGINEER
Oct 5 2018
ENGINEER OF DESIGN AND ENVIRONMENT
Oct 5 2018
DIRECTOR OF HIGHWAYS PROJECT IMPLEMENTATION

PRINTED BY THE AUTHORITY
OF THE STATE OF ILLINOIS

Figure 24. Screenshot. Example of data collected from IDOT plans and provisions documents (IDOT, 2022c).

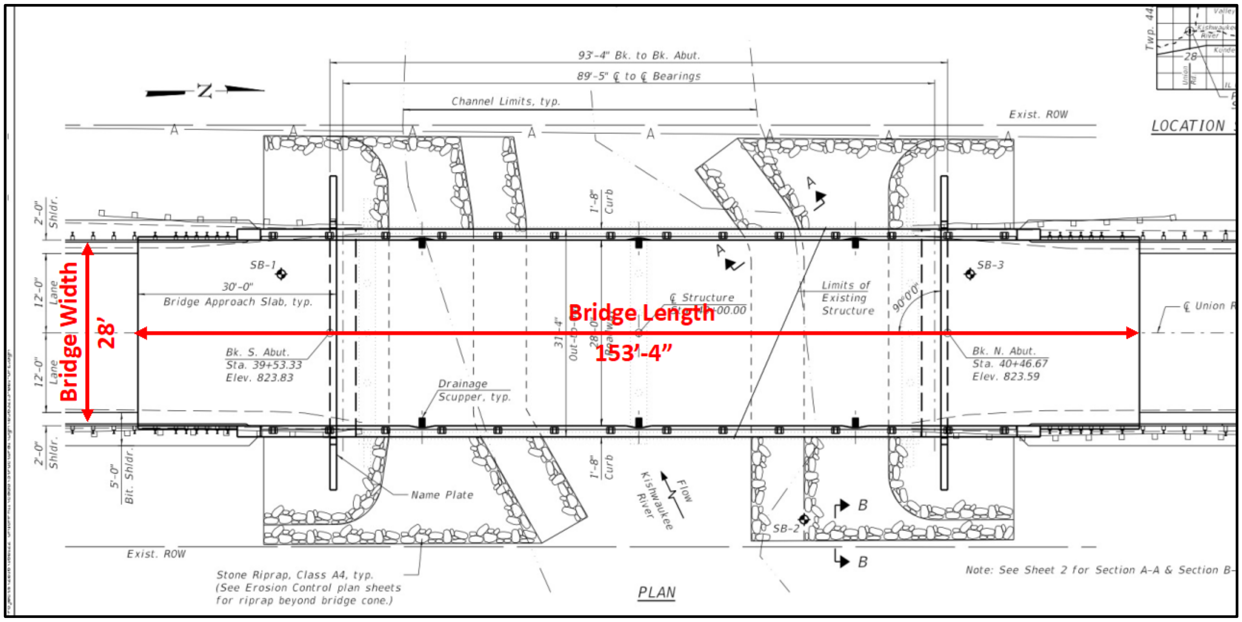
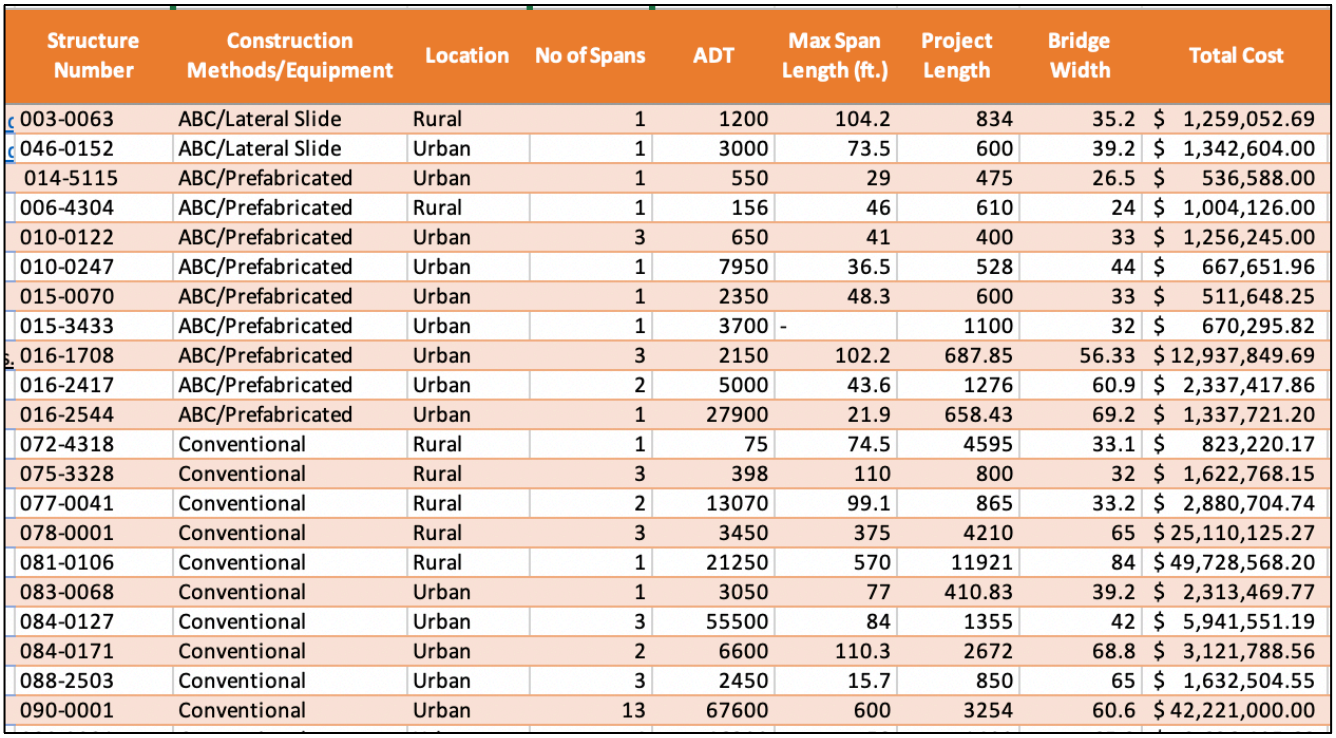


Figure 25. Screenshot. Example of bridge length and width collected from IDOT documents (IDOT, 2022c).

Data Processing

In this step, all collected data in the previous step were organized and stored in an Excel spreadsheet, as shown in Figure 26. The identified list of 243 IDOT bridge projects in the second step was organized and grouped in three categories based on bridge construction method: (a) conventional construction methods (181 projects), (b) prefabricated bridge elements and systems (60 projects), and (c) lateral slide ABC method (2 projects), as shown in Figure 27.



Structure Number	Construction Methods/Equipment	Location	No of Spans	ADT	Max Span Length (ft.)	Project Length	Bridge Width	Total Cost
003-0063	ABC/Lateral Slide	Rural	1	1200	104.2	834	35.2	$ 1,259,052.69
046-0152	ABC/Lateral Slide	Urban	1	3000	73.5	600	39.2	$ 1,342,604.00
014-5115	ABC/Prefabricated	Urban	1	550	29	475	26.5	$ 536,588.00
006-4304	ABC/Prefabricated	Rural	1	156	46	610	24	$ 1,004,126.00
010-0122	ABC/Prefabricated	Urban	3	650	41	400	33	$ 1,256,245.00
010-0247	ABC/Prefabricated	Urban	1	7950	36.5	528	44	$ 667,651.96
015-0070	ABC/Prefabricated	Urban	1	2350	48.3	600	33	$ 511,648.25
015-3433	ABC/Prefabricated	Urban	1	3700	-	1100	32	$ 670,295.82
016-1708	ABC/Prefabricated	Urban	3	2150	102.2	687.85	56.33	$ 12,937,849.69
016-2417	ABC/Prefabricated	Urban	2	5000	43.6	1276	60.9	$ 2,337,417.86
016-2544	ABC/Prefabricated	Urban	1	27900	21.9	658.43	69.2	$ 1,337,721.20
072-4318	Conventional	Rural	1	75	74.5	4595	33.1	$ 823,220.17
075-3328	Conventional	Rural	3	398	110	800	32	$ 1,622,768.15
077-0041	Conventional	Rural	2	13070	99.1	865	33.2	$ 2,880,704.74
078-0001	Conventional	Rural	3	3450	375	4210	65	$ 25,110,125.27
081-0106	Conventional	Rural	1	21250	570	11921	84	$ 49,728,568.20
083-0068	Conventional	Urban	1	3050	77	410.83	39.2	$ 2,313,469.77
084-0127	Conventional	Urban	3	55500	84	1355	42	$ 5,941,551.19
084-0171	Conventional	Urban	2	6600	110.3	2672	68.8	$ 3,121,788.56
088-2503	Conventional	Urban	3	2450	15.7	850	65	$ 1,632,504.55
090-0001	Conventional	Urban	13	67600	600	3254	60.6	$ 42,221,000.00

Figure 26. Screenshot. Sample stored data of collected IDOT bridge projects.

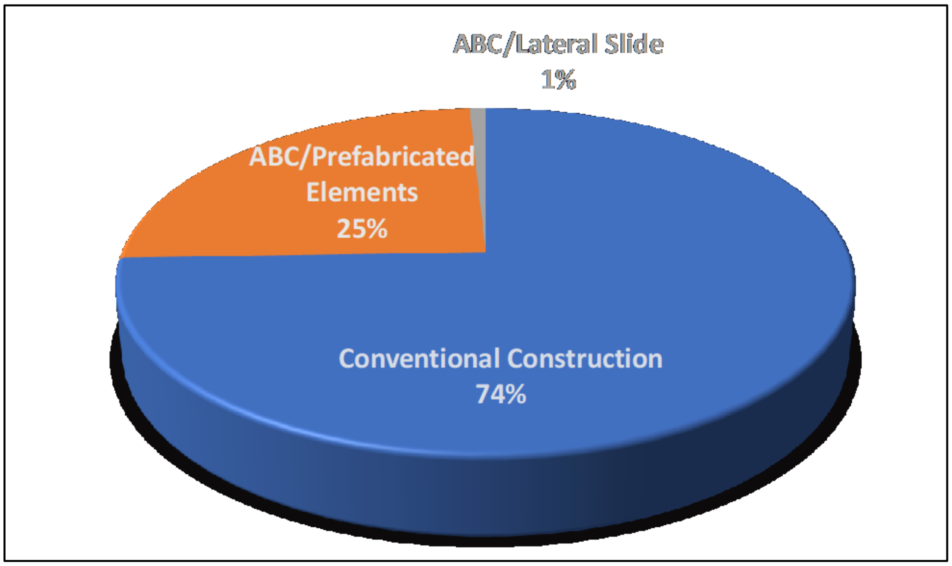


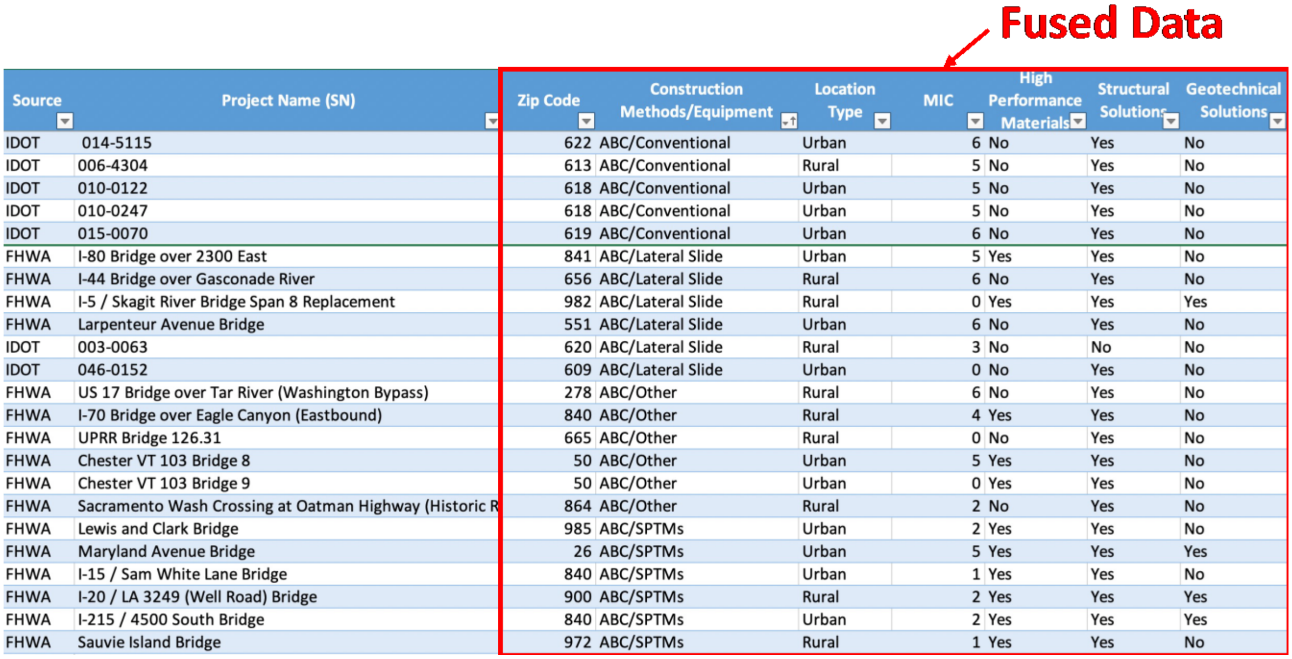
Figure 27. Chart. Organization of collected IDOT bridge projects based on construction method.

DATABASE OF CONVENTIONAL AND ABC METHODS

This step focuses on creating an expandable database that integrates all bridge data collected in the previous chapter. This database was created in three steps that are designed to (1) fuse the data collected from both the FHWA exchange and IDOT databases, (2) adjust project cost data to account for variations in bridge construction year and location, and (3) create two databases that contain all collected data for both conventional construction and ABC methods. The following three sections provide a detailed description of these steps.

Data Fusion

The data collected from both the FHWA exchange and IDOT databases was fused to enable their integration into a single database. This data fusion step was needed because the same type of data field was represented differently in the FHWA and IDOT databases. For example, the bridge location data were represented by (1) latitude and longitude in the FHWA database and (2) county in the IDOT database. To enable seamless integration of the two representations of the bridge location data fields, they were transformed to their equivalent zip codes (see Figure 28). A similar fusion method was used to unify and integrate other data fields with varying representations in the two databases such as zip code, construction method/equipment, mobility impact category (MIC), high-performance material, structural solution, and geotechnical solution, as shown in Figure 28. This resulted in a unified set of data fields that was used in creating an expandable bridge cost database. This unified set of data fields includes source, link, project name/structure number, zip code, year built, construction method/equipment, design type, location type, project type, deck material, beam material, mobility impact category, high-performance materials, structural solutions, geotechnical solutions, ADT, number of lanes, number of spans, max span length, total project length, bridge width, bridge length, and project description. A detailed description of each field is included in Appendix A.



Source	Project Name (SN)	Zip Code	Construction Methods/Equipment	Location Type	MIC	High Performance Materials	Structural Solutions	Geotechnical Solutions
IDOT	014-5115	622	ABC/Conventional	Urban	6	No	Yes	No
IDOT	006-4304	613	ABC/Conventional	Rural	5	No	Yes	No
IDOT	010-0122	618	ABC/Conventional	Urban	5	No	Yes	No
IDOT	010-0247	618	ABC/Conventional	Urban	5	No	Yes	No
IDOT	015-0070	619	ABC/Conventional	Urban	6	No	Yes	No
FHWA	I-80 Bridge over 2300 East	841	ABC/Lateral Slide	Urban	5	Yes	Yes	No
FHWA	I-44 Bridge over Gasconade River	656	ABC/Lateral Slide	Rural	6	No	Yes	No
FHWA	I-5 / Skagit River Bridge Span 8 Replacement	982	ABC/Lateral Slide	Rural	0	Yes	Yes	Yes
FHWA	Larpenteur Avenue Bridge	551	ABC/Lateral Slide	Urban	6	No	Yes	No
IDOT	003-0063	620	ABC/Lateral Slide	Rural	3	No	No	No
IDOT	046-0152	609	ABC/Lateral Slide	Urban	0	No	Yes	No
FHWA	US 17 Bridge over Tar River (Washington Bypass)	278	ABC/Other	Rural	6	No	Yes	No
FHWA	I-70 Bridge over Eagle Canyon (Eastbound)	840	ABC/Other	Rural	4	Yes	Yes	No
FHWA	UPRR Bridge 126.31	665	ABC/Other	Rural	0	No	Yes	No
FHWA	Chester VT 103 Bridge 8	50	ABC/Other	Urban	5	Yes	Yes	No
FHWA	Chester VT 103 Bridge 9	50	ABC/Other	Urban	0	Yes	Yes	No
FHWA	Sacramento Wash Crossing at Oatman Highway (Historic R	864	ABC/Other	Rural	2	No	Yes	No
FHWA	Lewis and Clark Bridge	985	ABC/SPTMs	Urban	2	Yes	Yes	No
FHWA	Maryland Avenue Bridge	26	ABC/SPTMs	Urban	5	Yes	Yes	Yes
FHWA	I-15 / Sam White Lane Bridge	840	ABC/SPTMs	Urban	1	Yes	Yes	No
FHWA	I-20 / LA 3249 (Well Road) Bridge	900	ABC/SPTMs	Rural	2	Yes	Yes	Yes
FHWA	I-215 / 4500 South Bridge	840	ABC/SPTMs	Urban	2	Yes	Yes	Yes
FHWA	Sauvie Island Bridge	972	ABC/SPTMs	Rural	1	Yes	Yes	No

Figure 28. Screenshot. Sample of fused data from both the FHWA exchange and IDOT databases.

Project Cost Adjustment

This step focuses on adjusting project cost data to adjust for variations in bridge construction year and location using the 2023 RSMeans construction cost data manual (Doheny, 2022). This adjustment is needed because the collected data represent bridge projects that were constructed many years ago (1992 to 2021) and in different states. Accordingly, all collected cost data were adjusted by time and location to adjust for any changes in material, labor, and equipment cost over time and between different states.

Project Cost Adjustment by Time

The purpose of this step was to adjust the cost of any bridge project from the year of construction to current-year cost. This adjustment is performed using the Historical Cost Index section of the 2023 RSMeans construction cost data manual, as shown in Figure 29 (Doheny, 2022). The manual includes a list of cost indices that can be used to adjust historical construction costs for all years ranging from 1970 to 2023, as shown in Figure 29. For example, the Gordon's Corner Road Bridge from the FHWA National ABC Project Exchange was built in 2010 and its historical square foot cost was reported in the database to be \$520/sf. This historical unit bridge cost can be adjusted to estimate its current year cost to be \$903/sf using the equation in Figure 30 and the RSMeans cost indices for years 2010 and 2023 that are reported to be 183.5 and 318.8, respectively (see Figure 29).

Year	Historical Cost Index Jan1,1993 = 100
2010	183.5
2011	191.2
2012	194.6
2013	201.2
2014	204.9
2015	206.2
2016	207.3
2017	213.6
2018	222.9
2019	232.2
2020	234.6
2021	257.5
2022	297.1
2023	318.8

Figure 29. Screenshot. Sample of historical cost indices in RSMeans 2023.

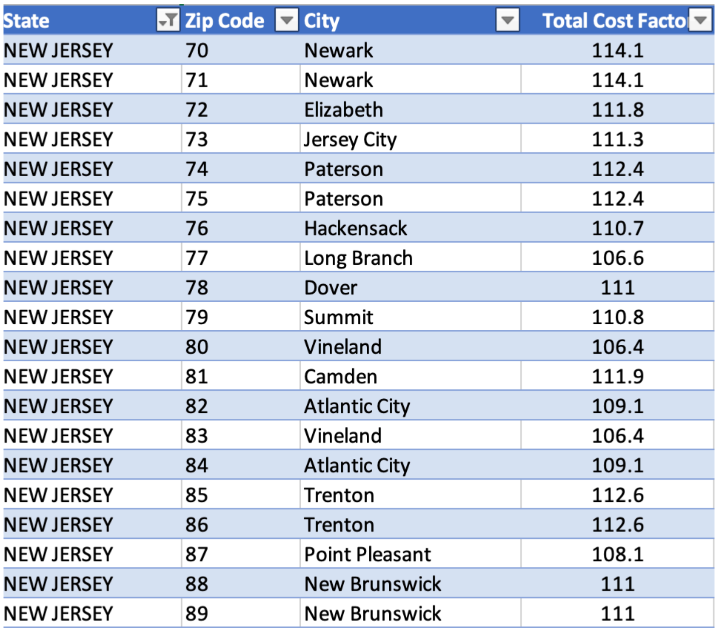
Source: Doheny (2022)

$$Current\ year\ cost\ (\$) = Bridge\ Cost\ in\ Year\ A \times \frac{Cost\ Index\ for\ Current\ Year}{Cost\ Index\ for\ Year\ A}$$

Figure 30. Equation. Equation to adjust bridge project cost by time.

Project Cost Adjustment by Location

The purpose of this step was to adjust the collected bridge costs to consider the differences between the local construction cost in the geographical location of each bridge and the national average cost. This national average cost can then be adjusted to estimate the bridge cost in any specific location in Illinois using the developed DST. The location cost adjustment methodology adopted in the DST utilizes the Location Factors section of the 2023 RSMeans construction cost data manual, as shown in Figure 31 (Doheny, 2022). The manual includes a list of location factors for all major cities in the United States. For example, the Gordon's Corner Road Bridge from the FHWA National ABC Project Exchange was built in Long Branch, New Jersey, and its square foot cost was reported in the database to be $520/sf. This local unit bridge cost in New Jersey can be adjusted to calculate its corresponding national unit cost to be $488/sf using Figure 32. This adjusted national unit cost is calculated using the RSMeans location factors for Long Branch, New Jersey, and the national average, which are 106.6 and 100.0, respectively (see Figure 31).



State	Zip Code	City	Total Cost Facto
NEW JERSEY	70	Newark	114.1
NEW JERSEY	71	Newark	114.1
NEW JERSEY	72	Elizabeth	111.8
NEW JERSEY	73	Jersey City	111.3
NEW JERSEY	74	Paterson	112.4
NEW JERSEY	75	Paterson	112.4
NEW JERSEY	76	Hackensack	110.7
NEW JERSEY	77	Long Branch	106.6
NEW JERSEY	78	Dover	111
NEW JERSEY	79	Summit	110.8
NEW JERSEY	80	Vineland	106.4
NEW JERSEY	81	Camden	111.9
NEW JERSEY	82	Atlantic City	109.1
NEW JERSEY	83	Vineland	106.4
NEW JERSEY	84	Atlantic City	109.1
NEW JERSEY	85	Trenton	112.6
NEW JERSEY	86	Trenton	112.6
NEW JERSEY	87	Point Pleasant	108.1
NEW JERSEY	88	New Brunswick	111
NEW JERSEY	89	New Brunswick	111

Figure 31. Screenshot. Sample of location factors in RSMeans 2023.

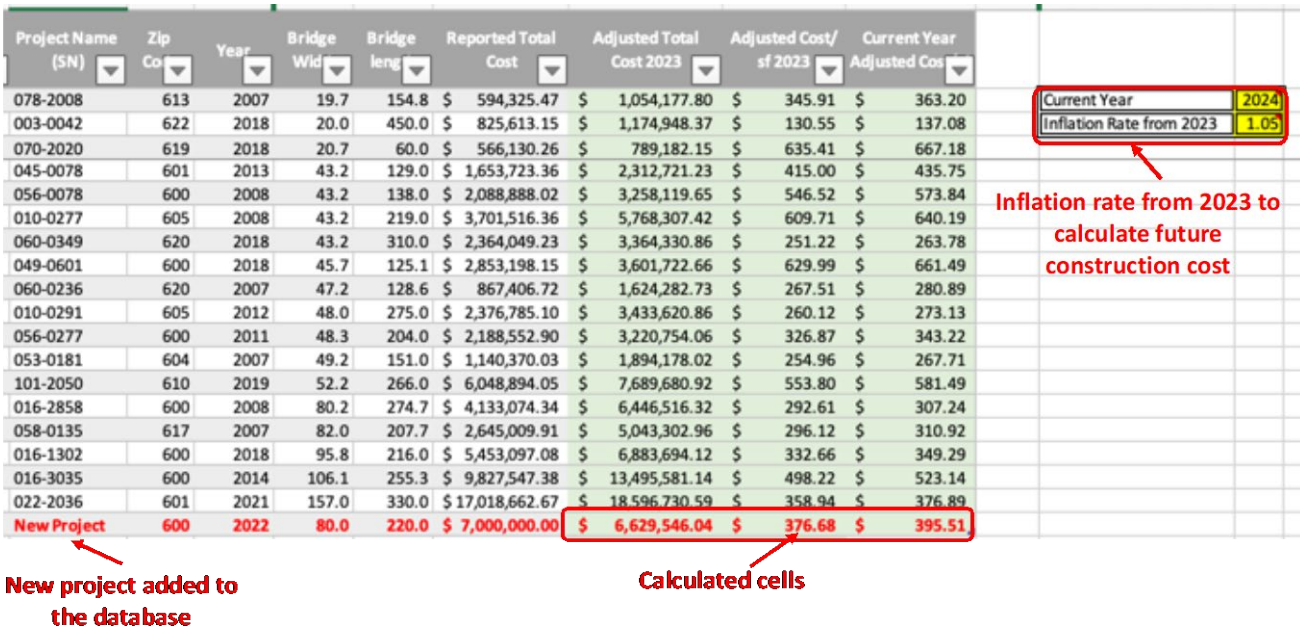
Source: Doheny (2022)

$$Cost\ in\ Location\ A = Cost\ in\ Location\ B \times \frac{Location\ Factor\ for\ Location\ A}{Location\ Factor\ for\ Location\ B}$$

Figure 32. Equation. Equation to adjust bridge project cost by location.

Bridge Cost Databases

In this step, all data collected from both the FHWA exchange and IDOT databases were organized and stored in a single Excel file that includes two spreadsheets: (1) conventional construction methods and (2) ABC construction methods. The Excel spreadsheet of conventional construction methods includes all data fields for 181 bridge projects. The Excel spreadsheet of ABC construction methods includes all data fields for 155 projects. The developed bridge database was designed to be user-friendly and to allow for easy expansion by including additional projects in the same Excel file. The database was also designed to (1) adjust all historical bridge costs to reflect the 2023 cost, as shown in the "Adjusted Total Cost 2023" column in Figure 33, and (2) to calculate the cost per square foot for each bridge project by dividing the adjusted total cost by bridge area, as shown in the "Adjusted Cost/sf 2023" column in Figure 33. Furthermore, the database was designed to provide IDOT planners and decision-makers with the flexibility to easily update the 2023 bridge costs for future years without the need to reinput any additional data. For example, this database can be easily updated to display adjusted bridge costs in 2024 by specifying the "Current Year" as 2024 and the "Inflation Rate from 2023" as 1.05, as shown in Figure 33.



Project Name (SN)	Zip Co	Year	Bridge Wid	Bridge leng	Reported Total Cost	Adjusted Total Cost 2023	Adjusted Cost/ sf 2023	Current Year Adjusted Cos
078-2008	613	2007	19.7	154.8	$ 594,325.47	$ 1,054,177.80	$ 345.91	$ 363.20
003-0042	622	2018	20.0	450.0	$ 825,613.15	$ 1,174,948.37	$ 130.55	$ 137.08
070-2020	619	2018	20.7	60.0	$ 566,130.26	$ 789,182.15	$ 635.41	$ 667.18
045-0078	601	2013	43.2	129.0	$ 1,653,723.36	$ 2,312,721.23	$ 415.00	$ 435.75
056-0078	600	2008	43.2	138.0	$ 2,088,888.02	$ 3,258,119.65	$ 546.52	$ 573.84
010-0277	605	2008	43.2	219.0	$ 3,701,516.36	$ 5,768,307.42	$ 609.71	$ 640.19
060-0349	620	2018	43.2	310.0	$ 2,364,049.23	$ 3,364,330.86	$ 251.22	$ 263.78
049-0601	600	2018	45.7	125.1	$ 2,853,198.15	$ 3,601,722.66	$ 629.99	$ 661.49
060-0236	620	2007	47.2	128.6	$ 867,406.72	$ 1,624,282.73	$ 267.51	$ 280.89
010-0291	605	2012	48.0	275.0	$ 2,376,785.10	$ 3,433,620.86	$ 260.12	$ 273.13
056-0277	600	2011	48.3	204.0	$ 2,188,552.90	$ 3,220,754.06	$ 326.87	$ 343.22
053-0181	604	2007	49.2	151.0	$ 1,140,370.03	$ 1,894,178.02	$ 254.96	$ 267.71
101-2050	610	2019	52.2	266.0	$ 6,048,894.05	$ 7,689,680.92	$ 553.80	$ 581.49
016-2858	600	2008	80.2	274.7	$ 4,133,074.34	$ 6,446,516.32	$ 292.61	$ 307.24
058-0135	617	2007	82.0	207.7	$ 2,645,009.91	$ 5,043,302.96	$ 296.12	$ 310.92
016-1302	600	2018	95.8	216.0	$ 5,453,097.08	$ 6,883,694.12	$ 332.66	$ 349.29
016-3035	600	2014	106.1	255.3	$ 9,827,547.38	$ 13,495,581.14	$ 498.22	$ 523.14
022-2036	601	2021	157.0	330.0	$ 17,018,662.67	$ 18,596,730.59	$ 358.94	$ 376.89
New Project	600	2022	80.0	220.0	$ 7,000,000.00	$ 6,629,546.04	$ 376.68	$ 395.51

Current Year	2024
Inflation Rate from 2023	1.05

Inflation rate from 2023 to calculate future construction cost

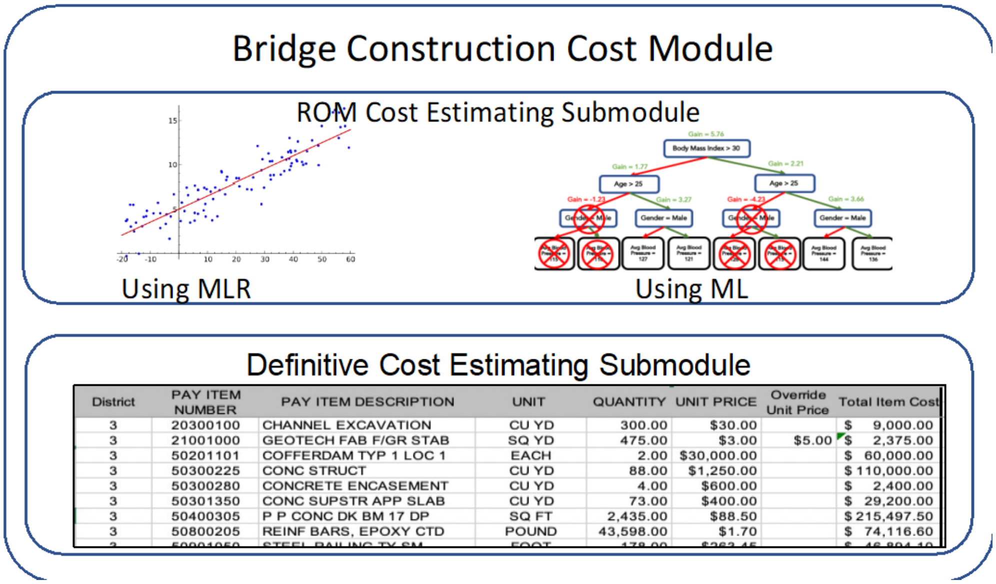
New project added to the database

Calculated cells

Figure 33. Screenshot. Sample of developed expandable bridge database.

CONSTRUCTION COST MODULES

This section focuses on creating a practical and user-friendly construction cost module for estimating the cost of all bridge construction methods, including conventional staged construction and ABC methods, including: (a) prefabricated elements or systems, (b) lateral slide, and (c) self-propelled modular transporter (SPMT). This cost-estimating module was designed to account for all on-site construction costs, off-site prefabrication costs, transportation costs of all prefabricated bridge elements, and installation costs of prefabricated bridge elements. To support IDOT bridge planners in developing and generating accurate bridge cost estimates, this module in the DST is designed to integrate two submodules: (1) a ROM cost-estimating submodule, which can be used during the early project phases such as Phase I engineering reports based on early planning parameters, and (2) a detailed cost-estimating submodule, which can be used to generate a detailed estimate after Phase II project development based on the specific design and dimension of all bridge elements, as shown in Figure 34. The following two sections provide a detailed description of these submodules.



District	PAY ITEM NUMBER	PAY ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	Override Unit Price	Total Item Cost
3	20300100	CHANNEL EXCAVATION	CU YD	300.00	$30.00		$ 9,000.00
3	21001000	GEOTECH FAB F/GR STAB	SQ YD	475.00	$3.00	$5.00	$ 2,375.00
3	50201101	COFFERDAM TYP 1 LOC 1	EACH	2.00	$30,000.00		$ 60,000.00
3	50300225	CONC STRUCT	CU YD	88.00	$1,250.00		$ 110,000.00
3	50300280	CONCRETE ENCASEMENT	CU YD	4.00	$600.00		$ 2,400.00
3	50301350	CONC SUPSTR APP SLAB	CU YD	73.00	$400.00		$ 29,200.00
3	50400305	P P CONC DK BM 17 DP	SQ FT	2,435.00	$88.50		$ 215,497.50
3	50800205	REINF BARS, EPOXY CTD	POUND	43,598.00	$1.70		$ 74,116.60

Figure 34. Diagram. Developed bridge construction cost module.

Rough Order of Magnitude Cost-Estimating Submodule

The purpose of this submodule was to support IDOT planners in generating accurate ROM bridge cost estimates during early project phases such as Phase I engineering reports. Accordingly, this submodule is designed to integrate newly developed predictive models that can be used to generate ROM cost estimates of any future bridge construction project based on its early planning parameters such as total project length, bridge length, bridge width, maximum span length, number of spans, location type, design type, geotechnical solutions, high-performance materials, and/or mobility impact category. These predictive models were developed using multiple linear regression (MLR) and machine learning (ML), which are widely used in developing predictive models (Chen & Guestrin, 2016; Hollar et al., 2013; Lowe et al., 2006). The predictive models were developed in four steps: (1) identify all predicted and predictor variables, (2) specify performance evaluation procedures for all developed predictive models, (3) develop cost-estimating predictive models using multiple linear regression and machine learning, and (4) evaluate the performance of developed MLR and ML models and select the best-performing model for each bridge construction method.

Predicted and Predictor Variables

This step focuses on identifying and processing all predicted and predictor variables that are needed in generating the ROM bridge cost estimates. First, the predicted variable in this submodule was identified as the square foot cost of bridge construction projects because it can be used to estimate the total cost of any future bridge project by multiplying it by the length and width of the bridge, as shown in Figure 35. Second, all possible predictor variables that have an impact on bridge square foot cost were identified based on a literature review that revealed that 16 predictor variables were reported to have the highest impact on bridge construction cost, as shown in Figure 35 (Hollar et al., 2013; Jia et al., 2018). The identified 16 predictor variables were then organized into two main categories based on their data type: numerical and categorical. The numerical variables include all predictor variables that can be represented by discrete numerical variables, such as number of spans and number of lanes, and continuous numerical variables, such as bridge length, bridge width, and project length. The categorical variables include all predictor variables that can be represented by categories such as new or replacement bridge project, urban or rural location, and steel or concrete deck (see Figure 35). Note that all identified categorical variables were converted into binary variables (dummy variables) to facilitate their processing by the developed regression models using the "binary coding" methodology (Hardy, 1993). For example, the location type categorical variable can only have two possible values: urban or rural. Accordingly, it can be converted to one binary variable where 0 = urban and 1 = rural. A detailed description of each predictor variable with their possible values is included in Appendix A.

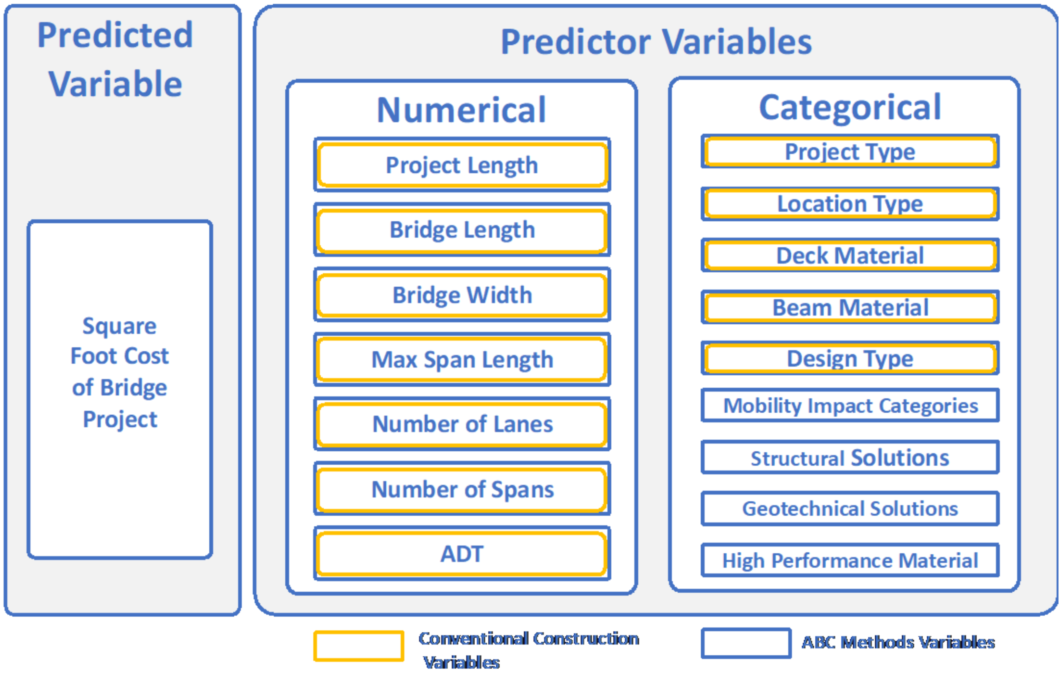


Figure 35. Diagram. Identified predicted and predictor variables in the ROM submodule.

Performance Evaluation Procedures

This step focuses on specifying the procedures and metrics that will be used to evaluate and refine the performance of all developed predictive models. To enable a reliable performance evaluation procedure, the collected historical bridge cost data were divided into two separate datasets for each developed predictive model: (1) a training dataset that includes 80% of all available data in the database that will be used in developing the model, and (2) a testing dataset that includes 20% of all available data in the database that will be used for evaluating the performance of the developed model.

The performance and accuracy of each developed predictive model will be evaluated and refined using two widely used statistical measures/metrics: (a) coefficient of determination (R-Squared or R^2)

(Hagquist & Stenbeck, 1998) and (b) mean absolute percentage error (MAPE) (Lowe et al., 2006; Tayman & Swanson, 1999).

Coefficient of Determination

The coefficient of determination (R^2) measures the percentage of the total variance between actual costs and predicted costs that is explained by changes in predictor variables. It is calculated using the equation in Figure 36 (Hagquist & Stenbeck, 1998). A model with a higher R^2 value typically performs better in predicting bridge construction costs than models with lower R^2 values.

$$R^2 = \frac{\Sigma\left(\hat{Y} - \overline{Y}\right)^2}{\Sigma\left(Y - \overline{Y}\right)^2}$$

Figure 36. Equation. Calculate R^2 for regression models.

Where R^2 is the coefficient of determination, $\hat{Y}$ is the predicted cost, Y is the actual cost, and $\overline{Y}$ is the mean of actual costs.

Mean Absolute Percentage Error

Mean Absolute Percentage Error (MAPE) is a measure of model prediction quality. MAPE will evaluate the accuracy of each developed predictive model by comparing its predicted bridge cost per square foot to the actual cost for all bridges in the testing dataset. This enables an objective evaluation of the performance of the developed predictive models by testing their performance using a testing dataset that was never used or seen by the developed model. MAPE can be calculated using the equation in Figure 37.

$$MAPE_g = Average\left(\frac{|\hat{Y} - Y|}{|Y|}\right) \times 100$$

Figure 37. Screenshot. Equation. Calculate MAPE for regression models.

Where g is the predictive model, $\hat{Y}$ is the predicted cost, and Y is the actual cost. A model with a lower MAPE value typically performs better in predicting bridge construction cost than models with higher MAPE values.

Development of Cost-Estimating Models

This step focuses on developing cost-estimating models using multiple linear regression (MLR) and machine learning (ML) models for each bridge construction method: (1) conventional construction, (2) prefabricated elements or systems, (3) lateral slide, and (4) SPMT. The following sections provide a concise description of the development for the four predictive models.

Cost-Estimating Models Using Multiple Linear Regression

This section presents the development of cost-estimating models using MLR models for each bridge construction method: (1) conventional construction, (2) prefabricated elements or systems, (3) lateral slide, and (4) SPMT.

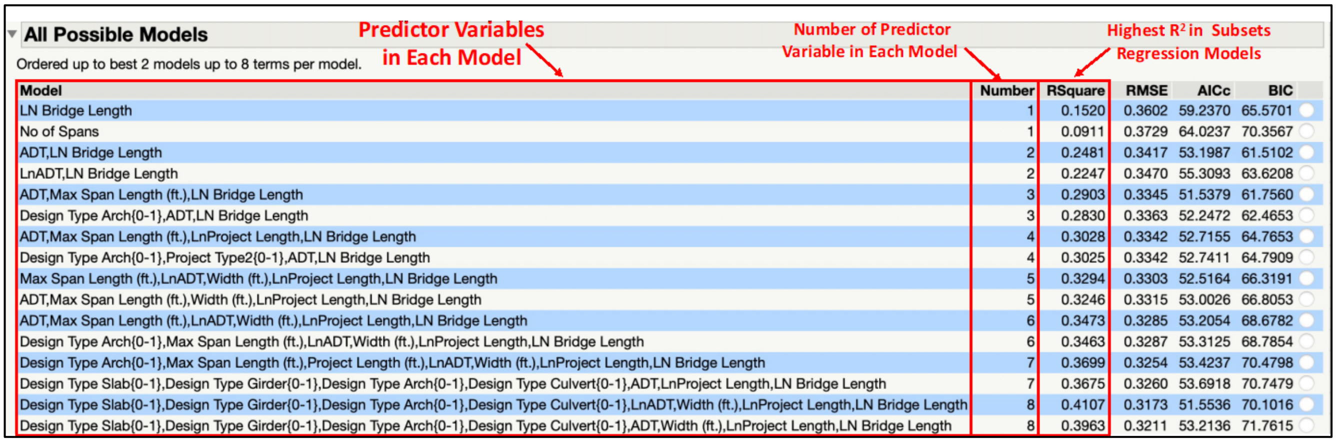
Conventional Bridge Construction Method Models

This step focuses on developing MLR cost-estimating models for the conventional construction method. The MLR models were developed using the identified predictor variables in Figure 35. Note that this list of 16 predictor variables includes four variables that are not applicable to conventional construction methods such as structural solutions, geotechnical solutions, high-performance material, and mobility impact category, as shown in Figure 35. Accordingly, 12 predictor variables were used in the development of the MLR model for the conventional construction method. This list of 12 predictor variables consists of (1) 7 numerical variables (bridge length, bridge width, project length, ADT, number of lanes, number of spans, maximum span length) and (2) 5 categorical variables (design type, location type, project type, deck material, and beam material), as shown in Figure 35. To improve the capability of the developed MLR models, log-transformed versions of the six identified numerical variables were also examined. The predicted variable was also log-transformed to improve the capability of modelling nonlinearity between the predicted and predictor variables.

To improve the prediction accuracy of the developed MLR cost-estimating model for the conventional bridge construction method, 56 MLR models were developed and compared to identify and select the best-performing MLR model. Each MLR model was developed using JMP Pro 16, which is a robust statistical software package that can be used to efficiently generate and evaluate the performance of a large number of MLR models (SAS Institute, 2021). The 56 MLR models were developed using (1) the stepwise regression method (Agostinelli, 2002) and (2) the best subsets regression method (Hocking & Leslie, 1967).

First, the stepwise regression method was used to develop two MLR models for the conventional bridge construction method to model the impact of the predictor variables on the predicted variable in terms of (a) cost per square foot and (b) log-transformed cost per square foot. These two models were developed in seven sequential steps that were designed to (1) evaluate the significance of each predictor variable based on its P-value (threshold of 0.15), (2) discard predictor variables that have a P-value greater than 0.15, (3) create an initial model with only one predictor variable that has the smallest P-value, (4) create a set of expanded models with an additional predictor variable that includes all predictor variables from the previous step and one of the remaining predictor variables from the previous step, (5) choose the model from the set created in step 4 with the lowest P-value for the second predictor variable, (6) check the P-value of the first predictor variable in the selected model and remove it if its P-value is greater than 0.15, and (7) repeat steps (4–6) until adding additional predictor variables does not yield a P-value less than 0.15 (Hollar et al., 2013). These seven steps were used to develop two MLR models for the conventional bridge construction method that are capable of predicting (i) cost per square foot and (ii) log-transformed cost per square foot. The first of the two developed models identified four predictor variables that can be used to estimate the cost per square foot for the conventional bridge construction method.

Second, the best subsets regression method was used to develop several MLR models for the conventional bridge construction method in three steps that were designed to (1) develop all possible regression models (32,768 models) that can be derived from all possible combinations of the 15 predictor variables, (2) group and organize all developed models into 15 groups based on their number of predictor variables to include models with one-, two-, and three-predictor variables, etc., (3) select the top two performing models in each group with the highest R^2 producing a total of 54 models, as shown in the sample results in Figure 38. These three steps were used to develop 54 MLR models for the conventional bridge construction method that include (a) 27 models that can be used to estimate bridge cost per square foot and (b) 27 models that can be used to estimate log-transformed cost per square foot.



All Possible Models

Ordered up to best 2 models up to 8 terms per model.

Model	Number	RSquare	RMSE	AICc	BIC	
LN Bridge Length	1	0.1520	0.3602	59.2370	65.5701	○
No of Spans	1	0.0911	0.3729	64.0237	70.3567	○
ADT,LN Bridge Length	2	0.2481	0.3417	53.1987	61.5102	○
LnADT,LN Bridge Length	2	0.2247	0.3470	55.3093	63.6208	○
ADT,Max Span Length (ft.),LN Bridge Length	3	0.2903	0.3345	51.5379	61.7560	○
Design Type Arch{0-1},ADT,LN Bridge Length	3	0.2830	0.3363	52.2472	62.4653	○
ADT,Max Span Length (ft.),LnProject Length,LN Bridge Length	4	0.3028	0.3342	52.7155	64.7653	○
Design Type Arch{0-1},Project Type2{0-1},ADT,LN Bridge Length	4	0.3025	0.3342	52.7411	64.7909	○
Max Span Length (ft.),LnADT,Width (ft.),LnProject Length,LN Bridge Length	5	0.3294	0.3303	52.5164	66.3191	○
ADT,Max Span Length (ft.),Width (ft.),LnProject Length,LN Bridge Length	5	0.3246	0.3315	53.0026	66.8053	○
ADT,Max Span Length (ft.),LnADT,Width (ft.),LnProject Length,LN Bridge Length	6	0.3473	0.3285	53.2054	68.6782	○
Design Type Arch{0-1},Max Span Length (ft.),LnADT,Width (ft.),LnProject Length,LN Bridge Length	6	0.3463	0.3287	53.3125	68.7854	○
Design Type Arch{0-1},Max Span Length (ft.),Project Length (ft.),LnADT,Width (ft.),LnProject Length,LN Bridge Length	7	0.3699	0.3254	53.4237	70.4798	○
Design Type Slab{0-1},Design Type Girder{0-1},Design Type Arch{0-1},Design Type Culvert{0-1},ADT,LnProject Length,LN Bridge Length	7	0.3675	0.3260	53.6918	70.7479	○
Design Type Slab{0-1},Design Type Girder{0-1},Design Type Arch{0-1},Design Type Culvert{0-1},LnADT,Width (ft.),LnProject Length,LN Bridge Length	8	0.4107	0.3173	51.5536	70.1016	○
Design Type Slab{0-1},Design Type Girder{0-1},Design Type Arch{0-1},Design Type Culvert{0-1},ADT,Width (ft.),LnProject Length,LN Bridge Length	8	0.3963	0.3211	53.2136	71.7615	○

Figure 38. Screenshot. Sample of top two performing models with predictor variables ranging from 1 to 8.

Prefabricated Bridge Elements/Systems Method Models

This section focuses on developing MLR cost-estimating models for projects utilizing prefabricated elements or systems. The MLR models were developed using all 16 predictor variables in Figure 35. The list of predictor variables consists of (1) seven numerical variables (project length, bridge length, bridge width, max span length, ADT, number of lanes, number of spans) and (2) 5 categorical variables (project type, location type, beam material, design type, mobility impact category). To improve the capability of the developed MLR models to consider nonlinearity, the identified list of predictor variables was expanded to include additional nonlinear variables that represent log-transformed versions of the numerical variables. The predicted variable was also log-transformed to improve the capability of modelling nonlinearity between the predicted and predictor variables. Note that the bridge construction project data utilized in the development of this MLR cost-estimating model included only the 60 prefabricated bridge construction projects reported by IDOT between 2008 and 2023 and excluded the FHWA prefabricated bridge construction data because of their significantly higher unit costs compared to those in IDOT projects.

To improve the prediction accuracy of the developed MLR cost-estimating model for projects utilizing prefabricated bridge elements or systems, 52 MLR models were developed using JMP Pro 16 and a similar procedure to the one described for the conventional bridge construction method. These 52

MLR models include (a) one model using the stepwise regression method to estimate bridge cost per square foot, (b) one model using the stepwise regression method to estimate log-transformed cost per square foot, (c) 25 models using the best subsets regression method to estimate bridge cost per square foot, and (d) 25 models using the best subsets regression method to estimate log-transformed cost per square foot.

Lateral Slide Equipment Construction Method Model

The bridge construction data that were utilized in the development of this MLR cost-estimating model included seven lateral slide bridge construction projects. This limited dataset of seven bridge projects enabled the development of only 28 MLR models using JMP Pro 16. The 28 MLR models include (a) one model using the stepwise regression method to estimate bridge cost per square foot, (b) one model using the stepwise regression method to estimate log-transformed cost per square foot, (c) 13 models using the best subsets regression method to estimate bridge cost per square foot, and (d) 13 models using the best subsets regression method to estimate log-transformed cost per square foot. Note that all developed lateral slide predictive models should be used with caution because the reliability of their estimates cannot be guaranteed due to the limited dataset that was used in their development.

SPMT Construction Method Models

The bridge construction data that were utilized in the development of this MLR cost-estimating model included five SPMT bridge construction projects after excluding two bridge projects. The two excluded projects had significant additional construction costs that are not representative of SPMT projects such as additional swing truss costs, excessive number of spans (34), and additional river transportation costs using barges. This limited dataset enabled the development of only 14 MLR models using JMP Pro 16. The 14 MLR models include (a) one model using the stepwise regression method to estimate bridge cost per square foot, (b) one model using the stepwise regression method to estimate log-transformed cost per square foot, (c) six models using the best subsets regression method to estimate bridge cost per square foot, and (d) six models using the best subsets regression method to estimate log-transformed cost per square foot. Note that all developed SPMT predictive models should be used with caution because the reliability of their estimates cannot be guaranteed due to the limited dataset that was used in their development.

Cost-Estimating Models Using Machine Learning

This section provides a concise description of the development of machine learning (ML) cost-estimating models for conventional and prefabricated construction methods. Note that ML models could not be developed for the remaining bridge construction methods—lateral slide and SPMT—due to their limited availability of historical data.

Conventional Bridge Construction Method Models

More than 2,000,000 ML models were developed for estimating the construction cost for the conventional bridge construction method using different combinations of all identified predictor variables listed in Figure 35. The Scikit-learn (sklearn) Python library was utilized to generate the models due to its widespread use and robustness for developing ML models using Python (Baranwal et al., 2019). The library includes different ML models for regression that can be easily integrated into the developed DST to predict bridge construction costs. The sklearn.LinearRegression model in this library was utilized to develop all possible linear regression models that provide a comprehensive list of all possible combinations of the identified predictor variables. To improve prediction accuracy, the available dataset of 181 projects for the conventional bridge construction method was randomly split into 10,000 unique training and testing datasets to identify the best and most representative dataset split. This analysis resulted in more than 2,000,000 ML models that were developed for predicting the construction cost for bridge projects utilizing the conventional construction method.

Prefabricated Bridge Elements/Systems Method Models

More than 2,000,000 ML models were developed for estimating the construction cost of the prefabricated elements/systems bridge construction method using different combinations of all identified predictor variables using the Scikit-learn (sklearn) Python library. To improve prediction accuracy, the available dataset of 60 projects for the prefabricated elements/systems bridge construction method was randomly split into 10,000 unique training and testing datasets to identify the best and most representative dataset split. This analysis resulted in more than 2,000,000 ML models that were developed for predicting the construction cost for bridge projects utilizing the prefabricated elements/systems bridge construction method.

Evaluation of Cost-Estimating Models

For each bridge construction method, this step focuses on evaluating the performance and accuracy of the MLR and ML models in order to select the top-performing model. The following sections provide a description of the evaluation and selection of the top-performing predictive model for (1) conventional construction, (2) prefabricated elements or systems, (3) lateral slide, and (4) SPMT.

Selected Model for Conventional Construction Method

To identify the top-performing model for the conventional bridge construction method, the performance and accuracy of the developed 56 MLR and 2,000,000+ ML models were evaluated using R-Squared and MAPE metrics. As stated earlier, MAPE was calculated for each developed model using its testing dataset that includes bridge projects that were never seen by the model during the training phase. A sample of the calculated R-Squared and MAPE values for the developed predictive models for the conventional construction method is shown in Table 1. The calculated R-Squared and MAPE values were then normalized and combined to calculate an overall performance score for each developed model based on a specified relative importance weight of 75% for MAPE and 25% for R-Squared, as shown in Table 1. The selected top-performing model based on this overall combined score was a ML model that achieved an R-Squared of 44.90% and a MAPE score of 14.32%. The model included 19 statistically significant predictor variables, as shown in the equation in Figure 39. This selected model was then integrated in the developed DST to enable IDOT planners and decision-makers to generate an accurate and reliable construction cost estimate for the conventional construction method during early phases such as Phase I engineering reports based on early planning parameters. To ensure the reliability of the generated cost estimates by this model, its application should be limited to future bridge projects with dimensions and other predictor variables that are within the boundaries of those used in training the developed predictive model (see Appendix D).

Table 1. Sample of Calculated R-Squared and MAPE Values for the Developed Predictive Models for the Conventional Construction Method

MAPE	R-Squared	Model Type	Normalized MAPE	Normalized R-Squared	Overall Score	Rank	# of Variables
14.32%	44.90%	ML	0.94	0.44	0.81	1*	19
13.62%	39.85%	ML	1.00	0.20	0.80	2	12
13.66%	39.99%	ML	1.00	0.21	0.80	3	16
13.71%	40.08%	ML	0.99	0.21	0.80	4	16
14.73%	47.01%	ML	0.90	0.54	0.81	5	20
…	…	…	…	…	…	…	…
20.34%	45.29%	MLR	0.38	0.45	0.40	79	7
20.56%	46.24%	MLR	0.36	0.50	0.39	80	9
20.57%	46.12%	MLR	0.36	0.49	0.39	81	8
19.90%	40.79%	MLR	0.42	0.24	0.38	82	5
22.28%	56.91%	MLR	0.20	1.00	0.40	83	20
….	….	….	…	…	….	….	….

*Selected model for projects utilizing the conventional construction method

$$\begin{aligned} Bridge\ Cost\ per\ sf &= 771.97 + 27.51\ \ln(X_1) - 103.29\ \ln(X_2) + 0.03\,X_3 - 18.07\,X_4 + 2.13E^{-14}\,X_5 \\ &- 7.65X_6 - 114.33\,X_7 + 8.98X_8 + 18.07X_9 + 397.87X_{10} - 123.90X_{11} + 0.88X_{12} \\ &- 151.99X_{13} + 17.38\ln(X_{14}) + 22.64X_{15} - 22.64X_{16} - 8.97X_{17} + 2.77X_{18} \\ &- 34.40\ln(X_{19}) \end{aligned}$$

Figure 39. Equation. Selected cost-estimate model for projects utilizing the conventional construction method.

Where X_1 represents the log transform of the number of spans, X_2 is the log transform of bridge length, X_3 is project length in feet, X_4 is if project type is new (if yes = 1, no = 0), X_5 is if the design type is arch (if yes = 1, no = 0), X_6 is if design type is culvert (if yes = 1, no = 0), X_7 is if design type is girder (if yes = 1, no = 0), X_8 is if beam material is concrete (if yes = 1, no = 0), X_9 is if project type is replace (if yes = 1, no = 0), X_{10} is if design type is truss (if yes = 1, no = 0), X_{11} is if design type is slab (if yes = 1, no = 0), X_{12} represents maximum span length in feet, X_{13} is if design type is beam (if yes = 1, no = 0), X_{14} is the log transform of ADT, $X1_5$ is if deck material is concrete (if yes = 1, no = 0), X_{16} is if deck material is steel (if yes = 1, no = 0), X_{17} is if beam material is steel (if yes = 1, no = 0), X_{18} is if location type is urban (if yes = 1, no = 0), and X_{19} is the log transform of bridge width.

Selected Model for Prefabricated Construction Method

To identify the top-performing model for the prefabricated bridge elements/systems construction method, the performance and accuracy of the developed 52 MLR and 2,000,000+ ML models were evaluated using the metrics of R-Squared and MAPE. A sample of the calculated R-Squared and MAPE values for the developed predictive models for the prefabricated bridge elements/systems method is included in Appendix C. The calculated R-Squared and MAPE values were then normalized and combined to calculate an overall performance score for each developed model based on a specified relative importance weight of 75% for MAPE and 25% for R-Squared. The selected top-performing model based on this overall score was a ML model that achieved an R-Squared of 34.62% and a MAPE score of 13.20%. The model included 13 statistically significant predictor variables, as shown in the equation in Figure 40. This selected model was then integrated in the developed DST to enable IDOT planners and decision-makers to generate an accurate and reliable construction cost estimate for the prefabricated bridge elements/systems construction method during early phases such as Phase I engineering reports based on early planning parameters. To ensure the reliability of the generated cost estimates by this model, its application should be limited to future bridge projects with dimensions and other predictor variables that are within the boundaries of those used in training the developed predictive model (see Appendix D).

$$
\begin{aligned}
&\mathit{Bridge\ Cost\ per\ sf} \\
&\quad = 3.32 + 68.36\ \ln(X_1) - 69.08\,X_2 + 0.46\,X_3 - 11.64\,X_4 - 112.11\ \ln(X_5) \\
&\quad + 25.13\ln(X_6) - 2.39\,X_7 + 51.43X_8 - 5.73X_9 - 2.70X_{10} + 7.11E^{-14}X_{11} \\
&\quad + 54.20X_{12} + 59.74X_{13}
\end{aligned}
$$

Figure 40. Equation. Selected cost-estimate model for projects utilizing the prefabricated construction method.

Where X_1 represents the log transform of project length in feet, X_2 is if design type is beam (if yes = 1, no = 0), X_3 is maximum span length in feet, X_4 is if beam material is concrete (if yes = 1, no = 0), X_5 is the log transform of bridge length in feet, X_6 is the log transform of ADT, X_7 is the number of lanes, X_8 is if design type is slab (if yes = 1, no = 0), X_9 is the number of spans, X_{10} is bridge width, X_{11} is if project type is replace (if yes = 1, no = 0), X_{12} is if design type is culvert (if yes = 1, no = 0), X_{13} represents mobility impact category.

Selected Model for Lateral Slide Construction Method

Twenty-eight MLR models were evaluated using R-Squared and MAPE metrics to identify the top-performing model for the lateral slide bridge construction method. A sample of the calculated R-Squared and MAPE values for the developed predictive models for the lateral slide bridge construction method is included in Appendix C. The selected top-performing model with the highest overall score in Appendix C achieved an R-Squared of 91.66% and a MAPE score of 18.52%. The model included five statistically significant predictor variables, as shown in the equation in Figure 41. This selected model was then integrated in the developed DST to enable IDOT planners and decision-makers to generate a construction cost estimate for the lateral slide construction method during early phases such as Phase I engineering reports based on early planning parameters. Note that this developed lateral slide predictive model should be used with caution because the reliability of its estimates cannot be guaranteed due to the limited dataset that was used in its development.

To ensure the reliability of the generated cost estimates by this model, its application should be limited to future bridge projects with dimensions and other predictor variables that are within the boundaries of those used in training the developed predictive model (see Appendix D).

$$\begin{aligned} &Bridge\ Cost\ per\ sf \\ &\quad = 906.68 - 65.62\,X_1 + 359.29\,X_2 - 56.92\,X_3 - 105.31\,\ln(X_4) + 15.04\,\ln(X_5) \end{aligned}$$

Figure 41. Equation. Selected cost-estimate model for projects utilizing the lateral slide construction method.

Where X_1 represents if the beam material is steel (if yes = 1, no = 0), X_2 is if MIC is 5 (if yes = 1, no = 0), X_3 is if MIC is 6 (if yes = 1, no = 0), X_4 is the log transform of bridge length in feet, and X_5 is the log transform of number of spans.

Selected Model for SPMT Construction Method

To identify the top-performing model for the SPMT bridge construction method, the performance and accuracy of the developed 14 MLR models were evaluated. A sample of the calculated and normalized R-Squared and MAPE values for the developed predictive models for the SPMT bridge construction method is included in Appendix C. The selected top-performing model with the highest overall score in Appendix C achieved an R-Squared of 73.95% and a MAPE score of 7.57%. The model included only one predictor variable (number of spans), as shown in the equation in Figure 42. This selected model was then integrated in the developed DST to enable IDOT planners and decision-makers to generate a construction cost estimate for the SPMT construction method during early phases such as Phase I engineering reports based on early planning parameters. Note that this developed SPMT predictive model should be used with caution because the reliability of its estimates cannot be guaranteed due to the limited dataset that was used in its development.

To ensure the reliability of the generated cost estimates by this model, its application should be limited to future bridge projects with dimensions and other predictor variables that are within the boundaries of those used in training the developed predictive model (see Appendix D).

$$Bridge\ Cost\ per\ sf = 219.21 + 60.07\,X_1$$

Figure 42. Equation. Selected cost-estimate model for projects utilizing the SPMT construction method.

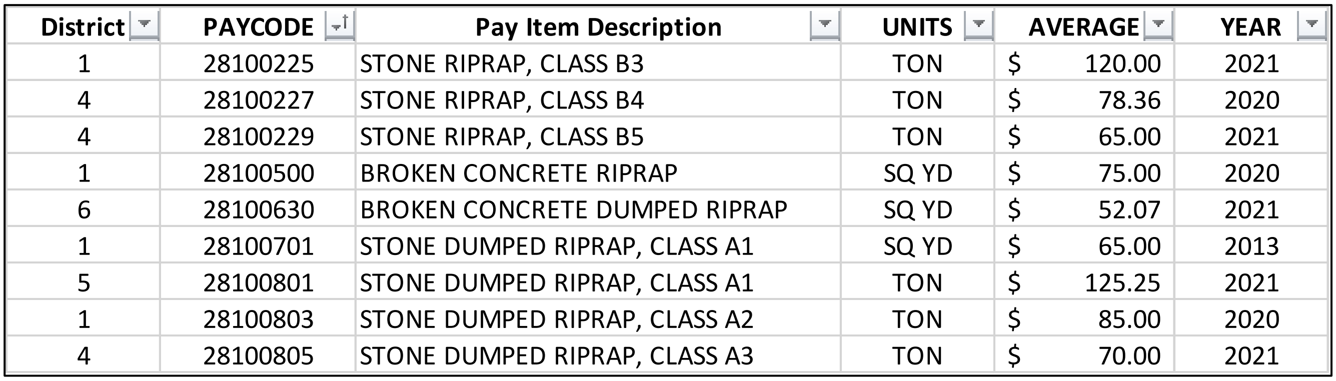
Where X_1 represents number of spans.

Detailed Cost-Estimating Submodule

This section presents the development of a practical and user-friendly submodule for estimating the detailed cost of all bridge construction methods. This submodule can be used to estimate the cost of both conventional staged bridge construction methods and ABC methods, including: (a) prefabricated elements or systems, (b) lateral slide, and (c) SPMT. The submodule was designed to support IDOT bridge and roadway planners in generating a detailed cost estimate after Phase II project development based on the specific design and dimension of all bridge elements. It was developed using Excel to provide a user-friendly interface, minimize the required input by IDOT planners, automate the extraction of relevant cost rate data from the database, and automate the computations of total cost of each pay-code item and total bridge project cost. The spreadsheet in this submodule was developed in three steps: (1) compile a comprehensive list of all pay-code items that are typically included in all bridge construction methods, (2) create an expandable database that contains a list of current-year unit cost for each of the identified pay-code items for each of IDOT's nine districts, and (3) develop a user-friendly graphical user interface to facilitate its use by IDOT planners to generate a detailed cost estimate for all types of bridge construction methods in any IDOT district.

Comprehensive List of All Bridge Pay-Code Items

This step focuses on creating a comprehensive list of all available bridge pay-code items that can be used in any of the aforementioned bridge construction methods. This list was collected from two main sources: IDOT historical average bid prices for all pay-code items and FHWA exchange available bid item reports. The data collected from the IDOT database included 15,967 unique pay-code items that were reported in all districts in the last 11 years (2011–2021) for all bridge and roadway construction projects that utilized conventional construction methods, prefabricated elements, or lateral slide, as shown in Figure 43. The 15,967 unique pay-code items were extracted from the IDOT average bid prices for all pay-code items in an Excel file that was provided by the Technical Review Panel. The data collected from the FHWA database included 7 additional unique ABC method pay-code items that were not included in the IDOT database such as pay-code items for ABC SPMT. The combined comprehensive list from both databases included a total of 15,974 unique bridge construction pay-code items that are typically included in all bridge construction methods.

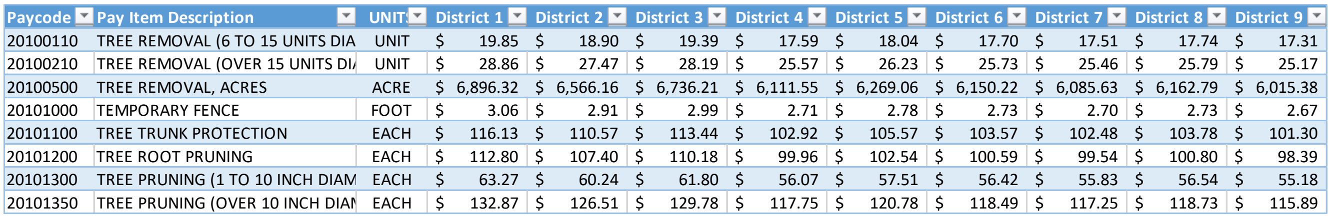


District	PAYCODE	Pay Item Description	UNITS	AVERAGE	YEAR
1	28100225	STONE RIPRAP, CLASS B3	TON	$ 120.00	2021
4	28100227	STONE RIPRAP, CLASS B4	TON	$ 78.36	2020
4	28100229	STONE RIPRAP, CLASS B5	TON	$ 65.00	2021
1	28100500	BROKEN CONCRETE RIPRAP	SQ YD	$ 75.00	2020
6	28100630	BROKEN CONCRETE DUMPED RIPRAP	SQ YD	$ 52.07	2021
1	28100701	STONE DUMPED RIPRAP, CLASS A1	SQ YD	$ 65.00	2013
5	28100801	STONE DUMPED RIPRAP, CLASS A1	TON	$ 125.25	2021
1	28100803	STONE DUMPED RIPRAP, CLASS A2	TON	$ 85.00	2020
4	28100805	STONE DUMPED RIPRAP, CLASS A3	TON	$ 70.00	2021

Figure 43. Screenshot. Sample of extracted unique IDOT pay-code items.

Database of Current-Year Pay-Code Items for All IDOT Districts

This step focuses on creating an expandable database of current-year unit cost for each of the identified pay-code items for IDOT's nine districts. This was achieved in four steps: (1) extract all related data for each of the identified 15,974 unique pay-code items in the previous step (district, pay code, pay-code item description, units of measure, and average unit cost), as shown in Figure 43, (2) adjust the average unit cost of each of the identified 15,974 pay-code items to update historical costs to current-year cost of 2023, (3) adjust the current-year average unit cost of each identified pay-code item to calculate the specific unit costs in each of the nine IDOT districts using the 2023 RSMeans construction cost data manual, (4) create and store an expandable database of 2023 unit costs for each of the identified 15,974 pay-code items in each IDOT district, as shown in Figure 44.



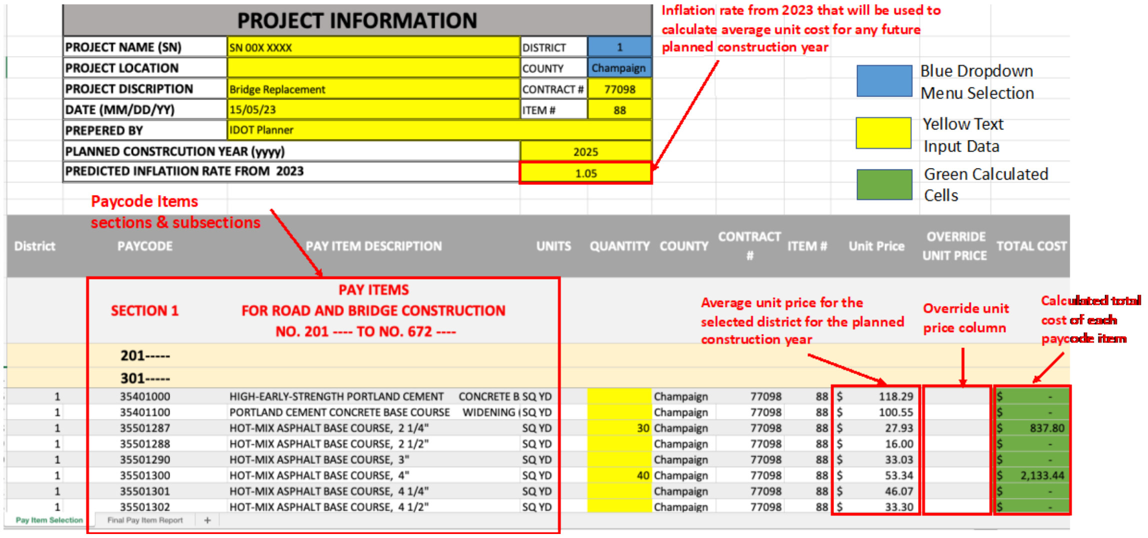
Paycode	Pay Item Description	UNIT	District 1	District 2	District 3	District 4	District 5	District 6	District 7	District 8	District 9
20100110	TREE REMOVAL (6 TO 15 UNITS DIA	UNIT	$ 19.85	$ 18.90	$ 19.39	$ 17.59	$ 18.04	$ 17.70	$ 17.51	$ 17.74	$ 17.31
20100210	TREE REMOVAL (OVER 15 UNITS DI	UNIT	$ 28.86	$ 27.47	$ 28.19	$ 25.57	$ 26.23	$ 25.73	$ 25.46	$ 25.79	$ 25.17
20100500	TREE REMOVAL, ACRES	ACRE	$ 6,896.32	$ 6,566.16	$ 6,736.21	$ 6,111.55	$ 6,269.06	$ 6,150.22	$ 6,085.63	$ 6,162.79	$ 6,015.38
20101000	TEMPORARY FENCE	FOOT	$ 3.06	$ 2.91	$ 2.99	$ 2.71	$ 2.78	$ 2.73	$ 2.70	$ 2.73	$ 2.67
20101100	TREE TRUNK PROTECTION	EACH	$ 116.13	$ 110.57	$ 113.44	$ 102.92	$ 105.57	$ 103.57	$ 102.48	$ 103.78	$ 101.30
20101200	TREE ROOT PRUNING	EACH	$ 112.80	$ 107.40	$ 110.18	$ 99.96	$ 102.54	$ 100.59	$ 99.54	$ 100.80	$ 98.39
20101300	TREE PRUNING (1 TO 10 INCH DIAM	EACH	$ 63.27	$ 60.24	$ 61.80	$ 56.07	$ 57.51	$ 56.42	$ 55.83	$ 56.54	$ 55.18
20101350	TREE PRUNING (OVER 10 INCH DIA	EACH	$ 132.87	$ 126.51	$ 129.78	$ 117.75	$ 120.78	$ 118.49	$ 117.25	$ 118.73	$ 115.89

Figure 44. Screenshot. Sample database of current-year average unit cost for all IDOT districts.

Submodule Graphical User Interface

This step focuses on creating a user-friendly graphical user interface to facilitate the use of the developed submodule for detailed cost estimating by IDOT planners. The submodule was designed to (a) enable IDOT planners to identify the IDOT district where the proposed bridge project is located from a drop-down menu, (b) automatically extract all pay-code item unit cost data from the developed database in the previous step, (c) display a comprehensive list of all identified bridge pay-code items that are organized by sections and subsections similar to those used by IDOT to facilitate the selection of all relevant pay-code items needed for the planned project, (d) automatically adjust average unit cost rates of all pay-code items to represent estimated costs during the planned year of construction based on the planner-specified "predicted inflation rate from 2023," (e) provide IDOT planners with flexibility to override the unit price of any pay-code item to account for any project-specific conditions, and (e) automatically calculate the total cost of each bridge pay-code item and for the planned project (see Figure 45).

Furthermore, the submodule graphical user interface was also designed to automatically create a detailed cost-estimate report of all bridge pay-code items in a separate Excel spreadsheet that includes district, pay-code item number, pay-code item description, unit, quantity, county, contract, item, unit cost, override unit cost, total item cost, and total project cost, as shown in Figure 46.



PROJECT INFORMATION			
PROJECT NAME (SN)	SN 00X XXXX	DISTRICT	1
PROJECT LOCATION		COUNTY	Champaign
PROJECT DISCRIPTION	Bridge Replacement	CONTRACT #	77098
DATE (MM/DD/YY)	15/05/23	ITEM #	88
PREPERED BY	IDOT Planner		
PLANNED CONSTRCUTION YEAR (yyyy)		2025	
PREDICTED INFLATIION RATE FROM 2023		1.05	

Inflation rate from 2023 that will be used to calculate average unit cost for any future planned construction year

🟦 Blue Dropdown Menu Selection

🟨 Yellow Text Input Data

🟩 Green Calculated Cells

Paycode Items sections & subsections

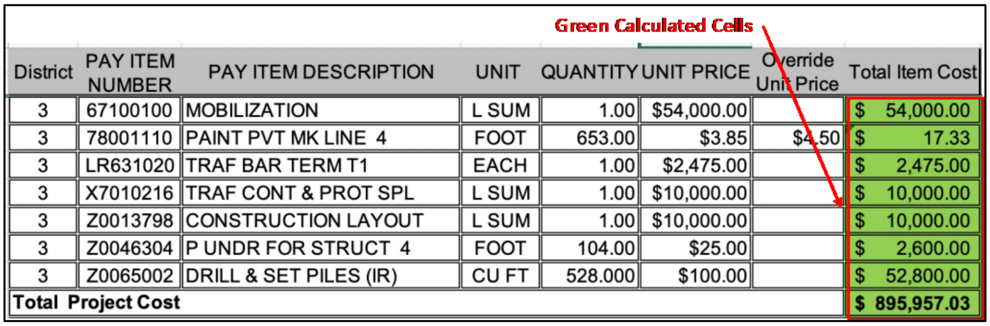
Average unit price for the selected district for the planned construction year

Override unit price column

Calculated total cost of each paycode item

District	PAYCODE	PAY ITEM DESCRIPTION	UNITS	QUANTITY	COUNTY	CONTRACT #	ITEM #	Unit Price	OVERRIDE UNIT PRICE	TOTAL COST
	SECTION 1	PAY ITEMS FOR ROAD AND BRIDGE CONSTRUCTION NO. 201 ---- TO NO. 672 ----								
	201-----									
	301-----									
1	35401000	HIGH-EARLY-STRENGTH PORTLAND CEMENT CONCRETE B	SQ YD		Champaign	77098	88	$ 118.29		$ -
1	35401100	PORTLAND CEMENT CONCRETE BASE COURSE WIDENING (	SQ YD		Champaign	77098	88	$ 100.55		$ -
1	35501287	HOT-MIX ASPHALT BASE COURSE, 2 1/4"	SQ YD	30	Champaign	77098	88	$ 27.93		$ 837.80
1	35501288	HOT-MIX ASPHALT BASE COURSE, 2 1/2"	SQ YD		Champaign	77098	88	$ 16.00		$ -
1	35501290	HOT-MIX ASPHALT BASE COURSE, 3"	SQ YD		Champaign	77098	88	$ 33.03		$ -
1	35501300	HOT-MIX ASPHALT BASE COURSE, 4"	SQ YD	40	Champaign	77098	88	$ 53.34		$ 2,133.44
1	35501301	HOT-MIX ASPHALT BASE COURSE, 4 1/4"	SQ YD		Champaign	77098	88	$ 46.07		$ -
1	35501302	HOT-MIX ASPHALT BASE COURSE, 4 1/2"	SQ YD		Champaign	77098	88	$ 33.30		$ -

Figure 45. Screenshot. Graphical user interface of the detailed cost-estimating submodule.



Green Calculated Cells

District	PAY ITEM NUMBER	PAY ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	Override Unit Price	Total Item Cost
3	67100100	MOBILIZATION	L SUM	1.00	$54,000.00		$ 54,000.00
3	78001110	PAINT PVT MK LINE 4	FOOT	653.00	$3.85	$4.50	$ 17.33
3	LR631020	TRAF BAR TERM T1	EACH	1.00	$2,475.00		$ 2,475.00
3	X7010216	TRAF CONT & PROT SPL	L SUM	1.00	$10,000.00		$ 10,000.00
3	Z0013798	CONSTRUCTION LAYOUT	L SUM	1.00	$10,000.00		$ 10,000.00
3	Z0046304	P UNDR FOR STRUCT 4	FOOT	104.00	$25.00		$ 2,600.00
3	Z0065002	DRILL & SET PILES (IR)	CU FT	528.000	$100.00		$ 52,800.00
Total Project Cost							**$ 895,957.03**

Figure 46. Screenshot. Example detailed cost-estimate report.

ROAD USER COST MODULE

This section presents the development and graphical user interface of a module for calculating the estimated road user cost and work zone crash cost based on the selected bridge construction method and duration of its planned road closures. First, the estimated road user cost in this module was calculated using the IDOT procedure described in Section 66-2.05(c) of IDOT (2022a). Second, the estimated work zone crash cost was calculated using safety performance factors (Schattler et al., 2020).

Road User Cost Calculation

This section focuses on calculating the estimated road user cost using the IDOT procedure described in Section 66-2.05(c) of IDOT (2022a). This IDOT procedure calculates road user cost based on (a) change in travel time, which is determined by comparing the travel time of all vehicles affected by the road closure, as shown in IDOT (2022a), (b) number of passengers per vehicle, which is assumed to be 1.25, and (c) hourly cost per passenger, which is assumed to be $10.00/hour (IDOT, 2022a), as shown in the equation in Figure 50. First, travel time in the normal condition is calculated by multiplying project length by average daily traffic and dividing it by average speed limit in the normal condition, as shown in the equation in Figure 47. Second, travel time under condition is calculated by multiplying project length with detour by average daily traffic and dividing it by work zone average speed limit, as shown in the equation in Figure 48. Third, daily travel delay time is calculated as the difference between travel time in the normal condition and travel time under construction condition, as shown in the equation in Figure 49. Fourth, daily road user cost is calculated by multiplying daily travel delay time by number of passengers per vehicle, which is assumed to be 1.25, and hourly cost per passenger, which is assumed to be $10.00/hour (IDOT, 2022a), as shown in the equation in Figure 50.

$$TT(normal\ condition) = L * \frac{ADT}{NWZSL}$$

Figure 47. Equation. Travel time in normal condition calculation.

$$TT(under\ construction) = L\ (w\ detour) * \frac{ADT}{WZSL}$$

Figure 48. Equation. Travel time under construction calculation.

$$Daily\ Travel\ Delay\ Time = TT\ (Under\ Construction) - TT\ (normal\ condition)$$

Figure 49. Equation. Daily travel delay time calculation.

$$Daily\ RUC = Daily\ Travel\ Delay\ Time * 1.25 * 10$$

Figure 50. Equation. Daily road used cost calculation.

Where *TT (under construction)* is the travel time during construction in hour, *L (w detour)* is work zone length with detour in miles, *ADT* is average daily traffic, *WZSL* is work zone average speed limit, *TT (normal condition)* is the travel time in normal condition in hours, *L* is project length in normal condition in miles, and *NWZSL* is average speed limit in normal condition.

Work Zone Crash Cost Calculation

This section presents the calculation methodology of work zone crash cost that was performed in three steps that were designed to calculate: (1) predicted number of work zone crashes utilizing safety performance factor, (2) percentage of each work zone crash type, and (3) total work zone crash cost. First, the equation shown in Figure 51 was used to calculate the predicted number of work zone crashes (Schattler et al., 2020). Second, the percentage of each work zone crash type is calculated based on the latest Illinois crash data that is required as input in the DST. This required Illinois crash input data can be easily extracted from the IDOT annual “Illinois Crash Facts & Statistics” that includes (a) number of crashes, fatal crashes, and injury crashes; (b) percentage of work zone crashes, fatal work zone crashes, injury work zone crashes, and type-A injury crashes; and (c) cost of each fatality crash, A-injury crash, B-injury crash, C-injury crash, and PDO crash, as shown in Figure

53. This user-specified input data is then used to calculate the expected percentage of each type of crash in the work zone, as shown in Figure 52. Third, the total work zone crash cost is estimated using the equation shown in Figure 52 based on the previously calculated predicted number of work zone crashes and percentage of each crash type as well as the unit cost of each crash type that are provided as input by DST users, as shown in Figure 51.

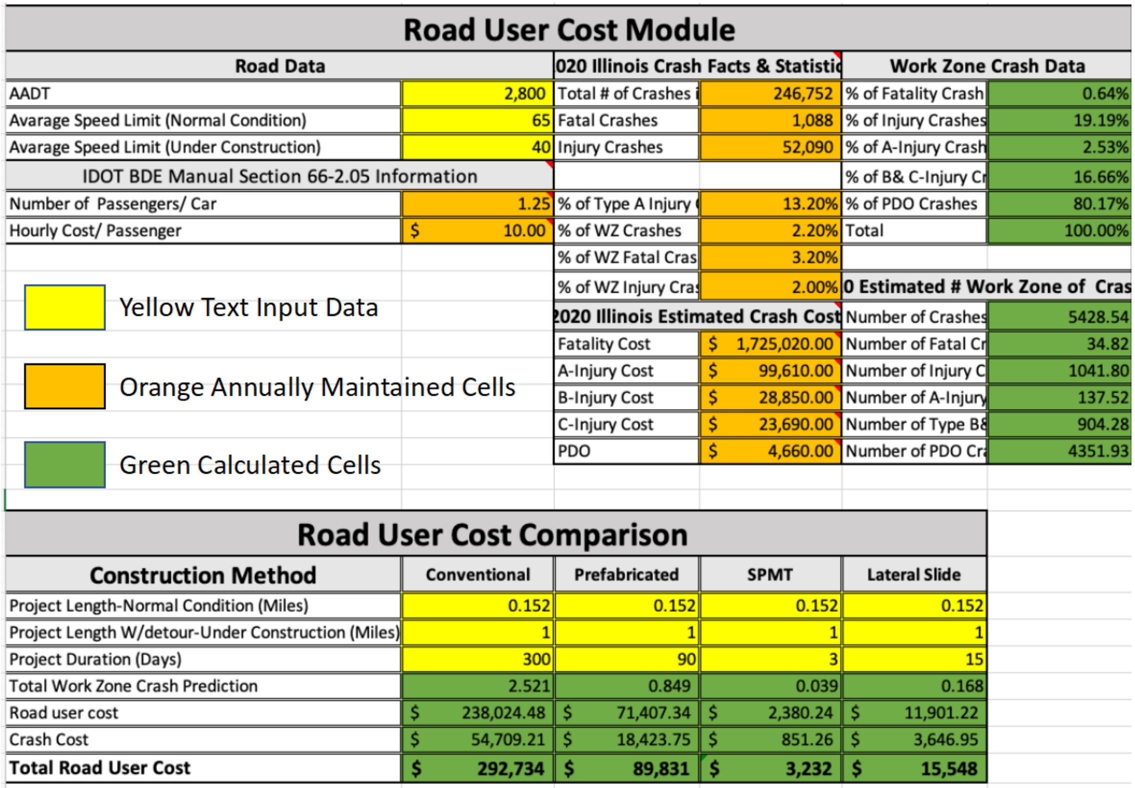
$$Predicted\ NWZC = e^{-7.049} * D^{0.904} * L^{0.317} * ADT^{0.486} * \ e^{-0.0004(NWZSL*WZSL)}$$

Figure 51. Equation. Predicted number of work zone crashes calculation.

$$WZ\ Crash\ Cost = \sum_{t=1}^{T} NWZC * \%\ of\ WZC_t * Unit\ Cost\ of\ C_t$$

Figure 52. Equation. Work zone crashes cost calculation.

Where *t* is type of work zone crash, *T* is total number of work zone crash types, *NWZC* is total number of work zone crashes, WZC_t is number of work zone crashes per type *t*, *Unit Cost of* C_t is the cost per crash of type *t*, *Predicted NWZC* is predicted number of work zone crashes, *D* is work zone duration in days, *L* is the work zone length with detour in miles, *NWZSL* is speed limit in normal condition, and *WZSL* is speed limit under construction.



Road User Cost Module

Road Data		020 Illinois Crash Facts & Statistic		Work Zone Crash Data	
AADT	2,800	Total # of Crashes i	246,752	% of Fatality Crash	0.64%
Avarage Speed Limit (Normal Condition)	65	Fatal Crashes	1,088	% of Injury Crashes	19.19%
Avarage Speed Limit (Under Construction)	40	Injury Crashes	52,090	% of A-Injury Crash	2.53%
IDOT BDE Manual Section 66-2.05 Information				% of B& C-Injury Cr	16.66%
Number of Passengers/ Car	1.25	% of Type A Injury (	13.20%	% of PDO Crashes	80.17%
Hourly Cost/ Passenger	$ 10.00	% of WZ Crashes	2.20%	Total	100.00%
		% of WZ Fatal Cras	3.20%		
🟨 Yellow Text Input Data		% of WZ Injury Cra	2.00%	0 Estimated # Work Zone of Cras	
		2020 Illinois Estimated Crash Cost		Number of Crashes	5428.54
🟧 Orange Annually Maintained Cells		Fatality Cost	$ 1,725,020.00	Number of Fatal Cr	34.82
		A-Injury Cost	$ 99,610.00	Number of Injury C	1041.80
		B-Injury Cost	$ 28,850.00	Number of A-Injury	137.52
🟩 Green Calculated Cells		C-Injury Cost	$ 23,690.00	Number of Type B&	904.28
		PDO	$ 4,660.00	Number of PDO Cr	4351.93

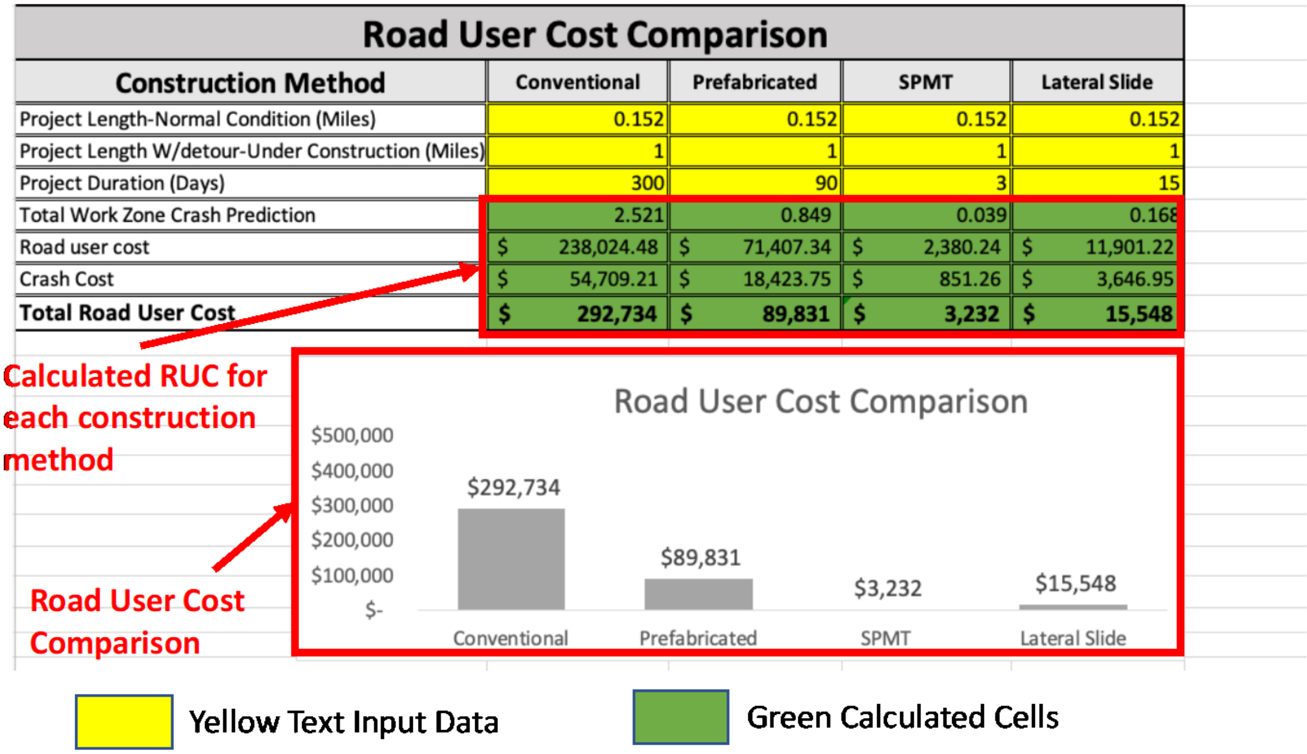
Road User Cost Comparison

Construction Method	Conventional	Prefabricated	SPMT	Lateral Slide
Project Length-Normal Condition (Miles)	0.152	0.152	0.152	0.152
Project Length W/detour-Under Construction (Miles)	1	1	1	1
Project Duration (Days)	300	90	3	15
Total Work Zone Crash Prediction	2.521	0.849	0.039	0.168
Road user cost	$ 238,024.48	$ 71,407.34	$ 2,380.24	$ 11,901.22
Crash Cost	$ 54,709.21	$ 18,423.75	$ 851.26	$ 3,646.95
Total Road User Cost	**$ 292,734**	**$ 89,831**	**$ 3,232**	**$ 15,548**

Figure 53. Screenshot. DST graphical user interface for user inputs for RUC module.

Module Graphical User Interface

This section describes the developed friendly graphical user interface (GUI) for road user cost analysis to facilitate its use by IDOT planners to (1) input all required road user cost and work zone crash cost data such as average daily traffic, average speed limit, number of passengers per car, hourly cost of each passenger, as shown in Figure 54; (2) review the DST calculation details of the road user cost and work zone crash cost; and (3) compare the calculated road user cost and work zone crash cost for both conventional bridge and accelerated bridge construction methods in both tabular and graphical formats, as shown in Figure 54.



Road User Cost Comparison

Construction Method	Conventional	Prefabricated	SPMT	Lateral Slide
Project Length-Normal Condition (Miles)	0.152	0.152	0.152	0.152
Project Length W/detour-Under Construction (Miles)	1	1	1	1
Project Duration (Days)	300	90	3	15
Total Work Zone Crash Prediction	2.521	0.849	0.039	0.168
Road user cost	$ 238,024.48	$ 71,407.34	$ 2,380.24	$ 11,901.22
Crash Cost	$ 54,709.21	$ 18,423.75	$ 851.26	$ 3,646.95
Total Road User Cost	**$ 292,734**	**$ 89,831**	**$ 3,232**	**$ 15,548**

Calculated RUC for each construction method

Road User Cost Comparison

🟨 Yellow Text Input Data

🟩 Green Calculated Cells

Figure 54. Screenshot. Graphical user interface of road user cost comparison.

LIFE CYCLE COST MODULE

This section focuses on developing a module for calculating the life cycle cost (LCC) of planned bridge projects based on each bridge construction method. The module was designed to include design, construction, road user, maintenance, and rehabilitation costs. The LCC calculations were performed using the FHWA analysis procedure for BLCC analysis that is based on (a) discount rate, (b) normal inspection and maintenance costs, (c) structural life, and (d) planning horizon (Hawk, 2003). The module used a structural life of 75 years for new bridges and the planning horizon of 20-year projection, as stated in Section 31-4.02(b) of IDOT (2022a). The equation shown in Figure 55 was used to calculate the bridge life cycle cost (BLCC) by summing up design, construction, maintenance, rehabilitation, and road user costs.

$$BLCC = DC + CC + MC + RC + RUC$$

Figure 55. Equation. Bridge life cycle cost calculation.

Where *BLCC* is the bridge life cycle cost in US dollars, *DC* is the design cost in US dollars, *CC* is the construction cost in US dollars, *MC* is the maintenance cost in US dollars, *RC* is the rehabilitation cost in US dollars, and *RUC* is the road user cost in US dollars.

Maintenance/Rehabilitation Calculation

The present cost of all planned annual bridge maintenance costs (*MC*) over its planning horizon was calculated using the annual maintenance costs (*AMC*), discount rate (*I*), and the difference between planning horizon projection in years and design and construction duration (*Y*), as shown in the equation shown in Figure 56. Similarly, the present cost of planned bridge rehabilitation costs (*RC*) was calculated by summing up the rehabilitation cost for each activity (RC_a) divided by *(1 + discount rate (I))* to the power of year of rehabilitation (*n*), as shown in the equation shown in Figure 57.

$$MC = \frac{AMC \times ((1 + I)^Y - 1)}{I \times (1 + I)^Y}$$

Figure 56. Equation. Maintenance cost calculation.

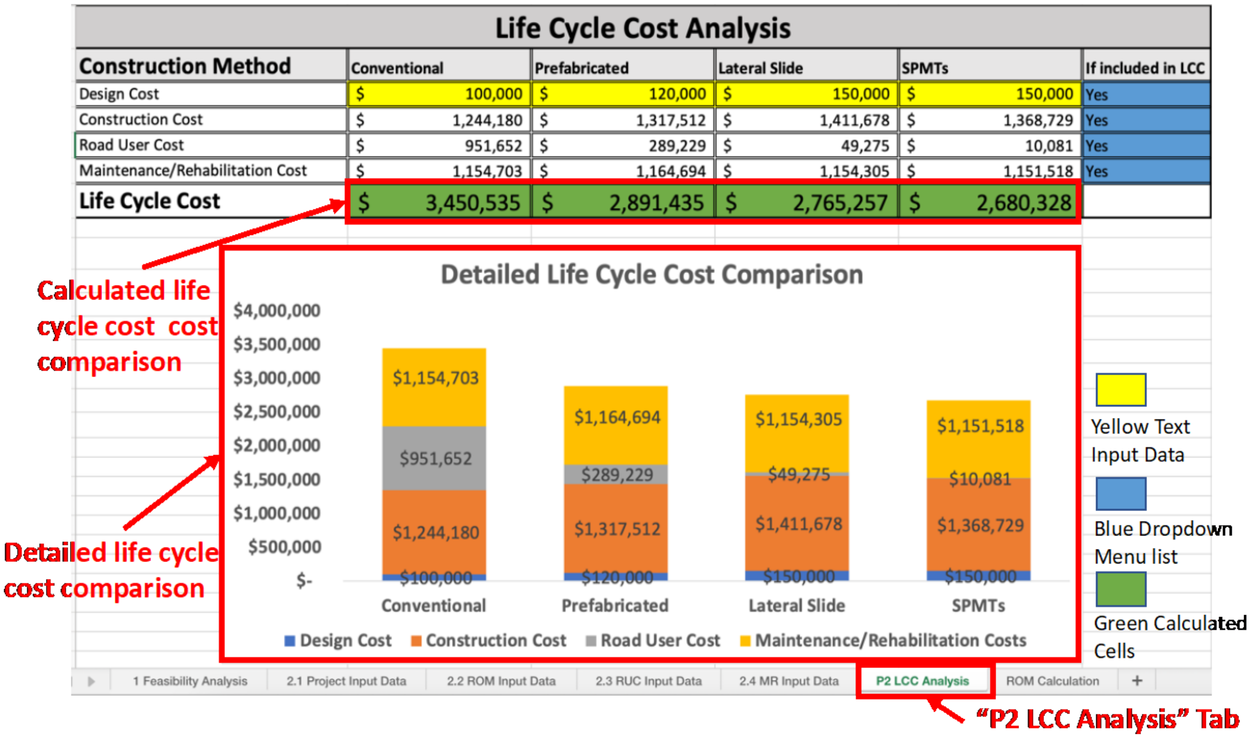
$$RC = \sum_{n=1}^{N} \sum_{a=1}^{A} \frac{RC_a}{(1 + I)^n}$$

Figure 57. Equation. Rehabilitation cost calculation.

Where *MC* is present cost of all maintenance costs, *AMC* is annual maintenance cost, *I* is discount rate, and *Y* is planning horizon projection in years minus design and construction duration. *RC* is present cost of all planned bridge rehabilitation cost over its planning horizon, *n* is the year of rehabilitation activity, *N* is planning horizon projection in years, *a* is bridge rehabilitation activity, *A* is the total number of bridge rehabilitation activities, RC_a is cost of bridge rehabilitation activity *a*, and *I* is discount rate.

Module Graphical User Interface

This section describes the developed friendly GUI for life cycle cost to facilitate its use by IDOT planners to (1) input all required LCC data such as discount rate, design duration, construction duration, annual maintenance cost for each construction method; (2) review the DST calculation details of the LCC analysis; and (3) compare the calculated life cycle cost for all bridge construction methods including conventional bridge and accelerated bridge construction methods in both tabular and graphical formats, as shown in Figure 58.



Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 1,244,180	$ 1,317,512	$ 1,411,678	$ 1,368,729	Yes
Road User Cost	$ 951,652	$ 289,229	$ 49,275	$ 10,081	Yes
Maintenance/Rehabilitation Cost	$ 1,154,703	$ 1,164,694	$ 1,154,305	$ 1,151,518	Yes
Life Cycle Cost	$ 3,450,535	$ 2,891,435	$ 2,765,257	$ 2,680,328	

Calculated life cycle cost cost comparison

Detailed life cycle cost comparison

🟨 Yellow Text Input Data

🟦 Blue Dropdown Menu list

🟩 Green Calculated Cells

"P2 LCC Analysis" Tab

Figure 58. Screenshot. Graphical user interface of life cycle cost comparison.

CHAPTER 4: GUIDANCE FOR USER INTERFACE OF DEVELOPED DST

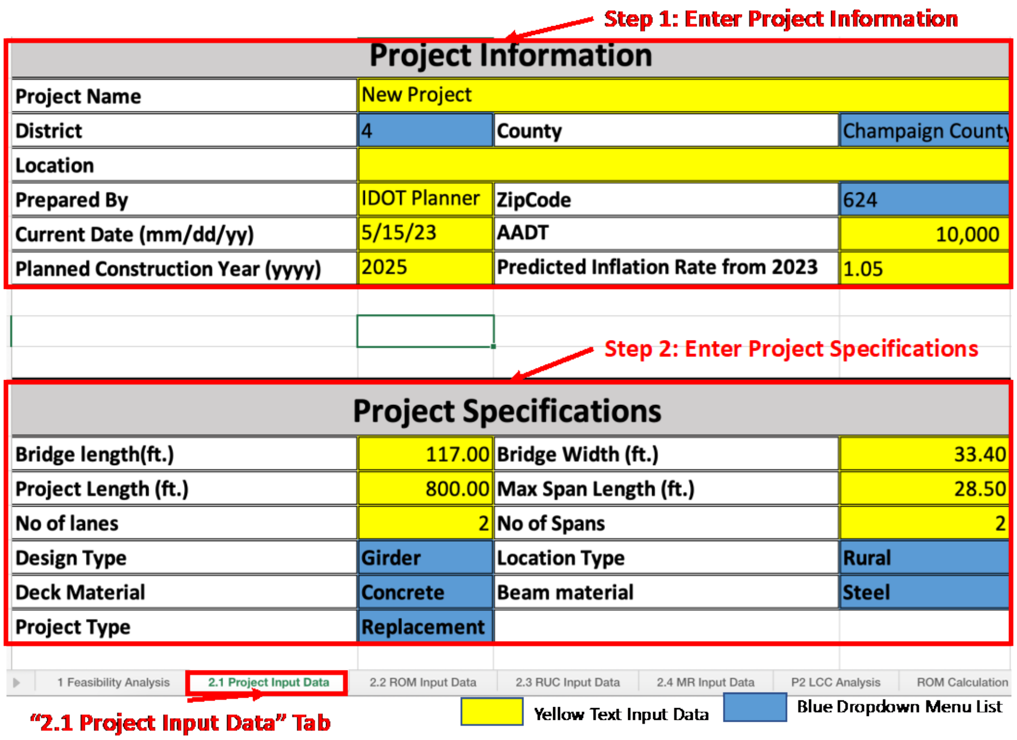
This chapter focuses on developing guidance for the user interface of the developed DST and how it can be used by IDOT planners and decision-makers to compare and rank all feasible bridge construction methods based on their individual performance in design costs, construction costs, road user costs, and maintenance and rehabilitation costs. Two case studies were selected to illustrate the use of the developed quantitative DST and demonstrate its capabilities in developing and comparing cost estimates for different bridge construction methods. The first and second case studies illustrate how the DST can be used to develop a (1) rough order of magnitude (ROM) cost estimate in the early Phase I engineering reports for different bridge construction methods and (2) detailed cost estimate after Phase II project development, respectively.

ROM COST-ESTIMATING CASE STUDY

An example case study was analyzed to illustrate the use of the developed DST and demonstrate its capabilities in generating a ROM cost estimate for an example bridge construction project. The bridge example project was assumed to be planned for construction in IDOT District 4 and was expected to have a design type of “girder,” location type of “rural,” ADT of 10,000 vehicles/day, bridge length of 117 feet, bridge width of 33.4 feet, project length 800 feet, max span length of 28.5 feet, number of lanes of 2, and number of spans of 2.

First, general project information was entered into the DST in the spreadsheet tab named “2.1 Project Input Data.” This general project information includes 10 fields: project name, district, county, location, prepared by, zip code, current date, AADT, planned construction year, and predicted inflation rate from 2023. Three of the ten fields can be selected in drop-down lists, while the other five can be typed directly into their respective cells, as shown in Figure 59. The developed DST is designed to provide IDOT planners and decision-makers with the capability to predict the construction cost of any future bridge project by specifying the inflation rate from 2023 to planned construction year, as shown in Figure 59.

Second, construction-related project data were entered into the DST in the same spreadsheet. Construction-related bridge data include bridge length, bridge width, project length, maximum span length, number of lanes, number of spans, design type, deck material, beam material, location type, and project type, as shown in Figure 59. Once construction-related data were entered, the DST automatically calculates ROM construction costs for the example project for each bridge construction method and displays the results in the spreadsheet tab named “2.2 ROM Input Data,” as shown in Figure 60. In addition, the DST creates a graphical chart that provides visual comparison for the predicted bridge construction costs for conventional construction, prefabricated, lateral slide, and SPMT, as shown in Figure 60.


Step 1: Enter Project Information

Project Information			
Project Name	New Project		
District	4	County	Champaign County
Location			
Prepared By	IDOT Planner	ZipCode	624
Current Date (mm/dd/yy)	5/15/23	AADT	10,000
Planned Construction Year (yyyy)	2025	Predicted Inflation Rate from 2023	1.05

Step 2: Enter Project Specifications

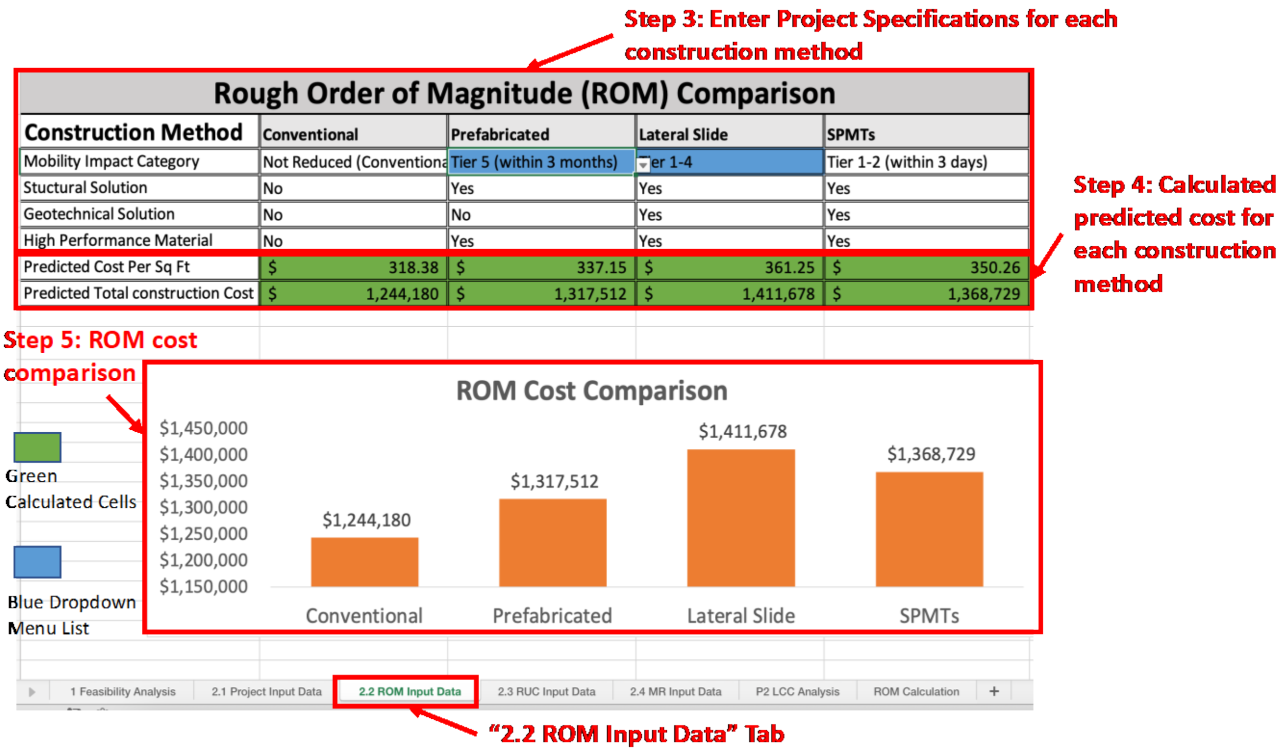
Project Specifications			
Bridge length(ft.)	117.00	Bridge Width (ft.)	33.40
Project Length (ft.)	800.00	Max Span Length (ft.)	28.50
No of lanes	2	No of Spans	2
Design Type	Girder	Location Type	Rural
Deck Material	Concrete	Beam material	Steel
Project Type	Replacement		

"2.1 Project Input Data" Tab

🟨 Yellow Text Input Data

🟦 Blue Dropdown Menu List

Figure 59. Screenshot. Project information input data.


Step 3: Enter Project Specifications for each construction method

Rough Order of Magnitude (ROM) Comparison				
Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventiona	Tier 5 (within 3 months)	er 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 318.38	$ 337.15	$ 361.25	$ 350.26
Predicted Total construction Cost	$ 1,244,180	$ 1,317,512	$ 1,411,678	$ 1,368,729

Step 4: Calculated predicted cost for each construction method

Step 5: ROM cost comparison

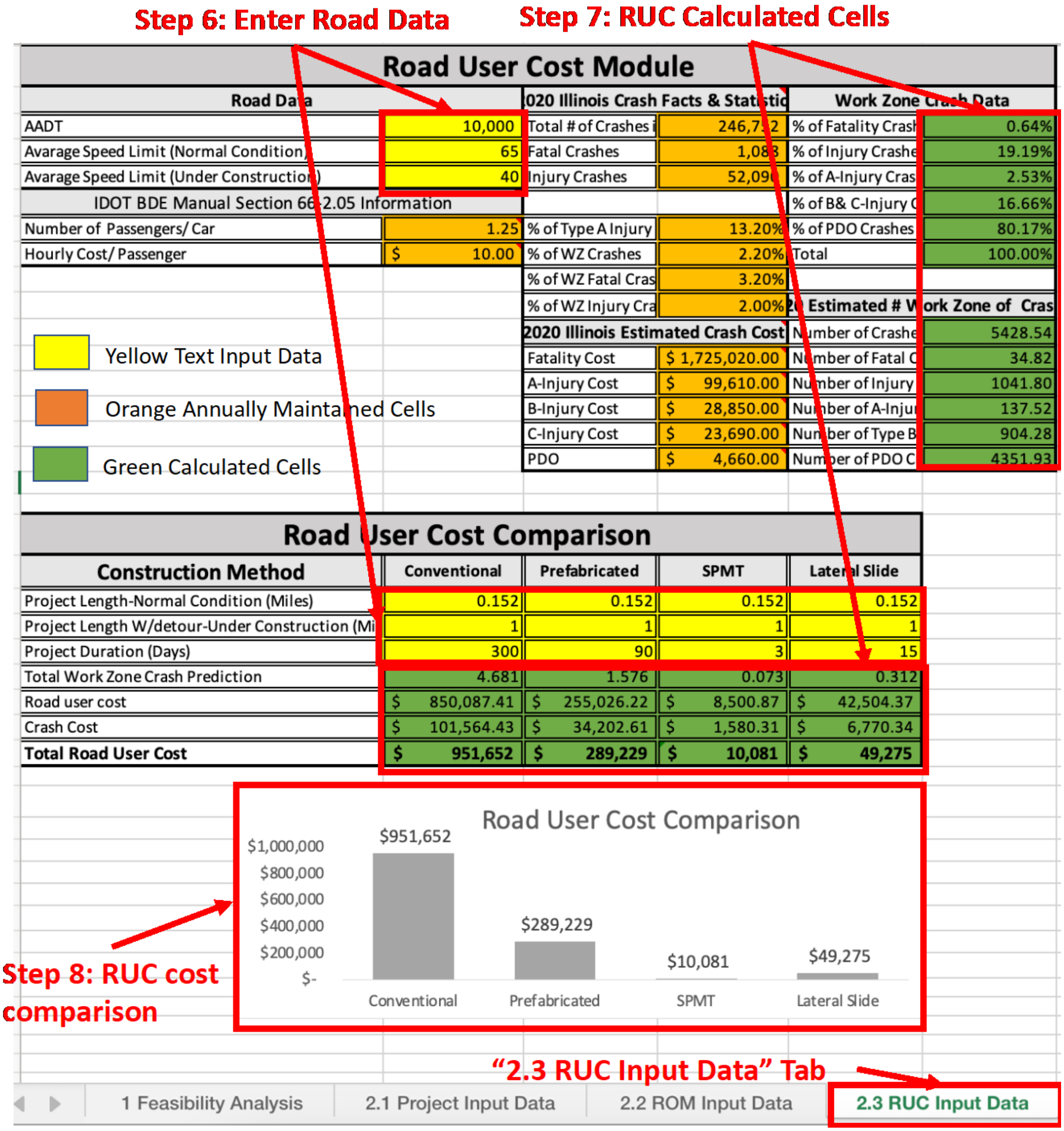
🟩 Green Calculated Cells

🟦 Blue Dropdown Menu List

"2.2 ROM Input Data" Tab

Figure 60. Screenshot. Rough order of magnitude construction cost calculations for all construction methods.

Third, road-related data were entered into the DST in the spreadsheet tab named “2.3 RUC Input Data.” Road-related data include project length in normal conditions in miles, project length in miles with detour under construction, and project duration in days. The DST is designed to provide users with the flexibility to specify different road user parameters based on the type of bridge construction method, as shown in Figure 61. Upon the input of road-related data, the DST is designed to automatically calculate and compare predicted number of work zone crashes, road user cost, crash cost, and total road user cost for all bridge construction methods, as shown in Figure 61.



Step 6: Enter Road Data

Step 7: RUC Calculated Cells

Road User Cost Module

Road Data	
AADT	10,000
Avarage Speed Limit (Normal Condition)	65
Avarage Speed Limit (Under Construction)	40
IDOT BDE Manual Section 66-2.05 Information	
Number of Passengers/ Car	1.25
Hourly Cost/ Passenger	$ 10.00

020 Illinois Crash Facts & Statistic	
Total # of Crashes i	246,7[illegible]2
Fatal Crashes	1,08[illegible]
Injury Crashes	52,09[illegible]
% of Type A Injury	13.20%
% of WZ Crashes	2.20%
% of WZ Fatal Cras	3.20%
% of WZ Injury Cra	2.00%

2020 Illinois Estimated Crash Cost	
Fatality Cost	$ 1,725,020.00
A-Injury Cost	$ 99,610.00
B-Injury Cost	$ 28,850.00
C-Injury Cost	$ 23,690.00
PDO	$ 4,660.00

Work Zone Crash Data	
% of Fatality Crash	0.64%
% of Injury Crashe	19.19%
% of A-Injury Cras	2.53%
% of B& C-Injury C	16.66%
% of PDO Crashes	80.17%
Total	100.00%

Estimated # Work Zone of Cras	
Number of Crashe	5428.54
Number of Fatal C	34.82
Number of Injury	1041.80
Number of A-Inju	137.52
Number of Type B	904.28
Number of PDO C	4351.93

🟨 Yellow Text Input Data

🟧 Orange Annually Maintained Cells

🟩 Green Calculated Cells

Road User Cost Comparison

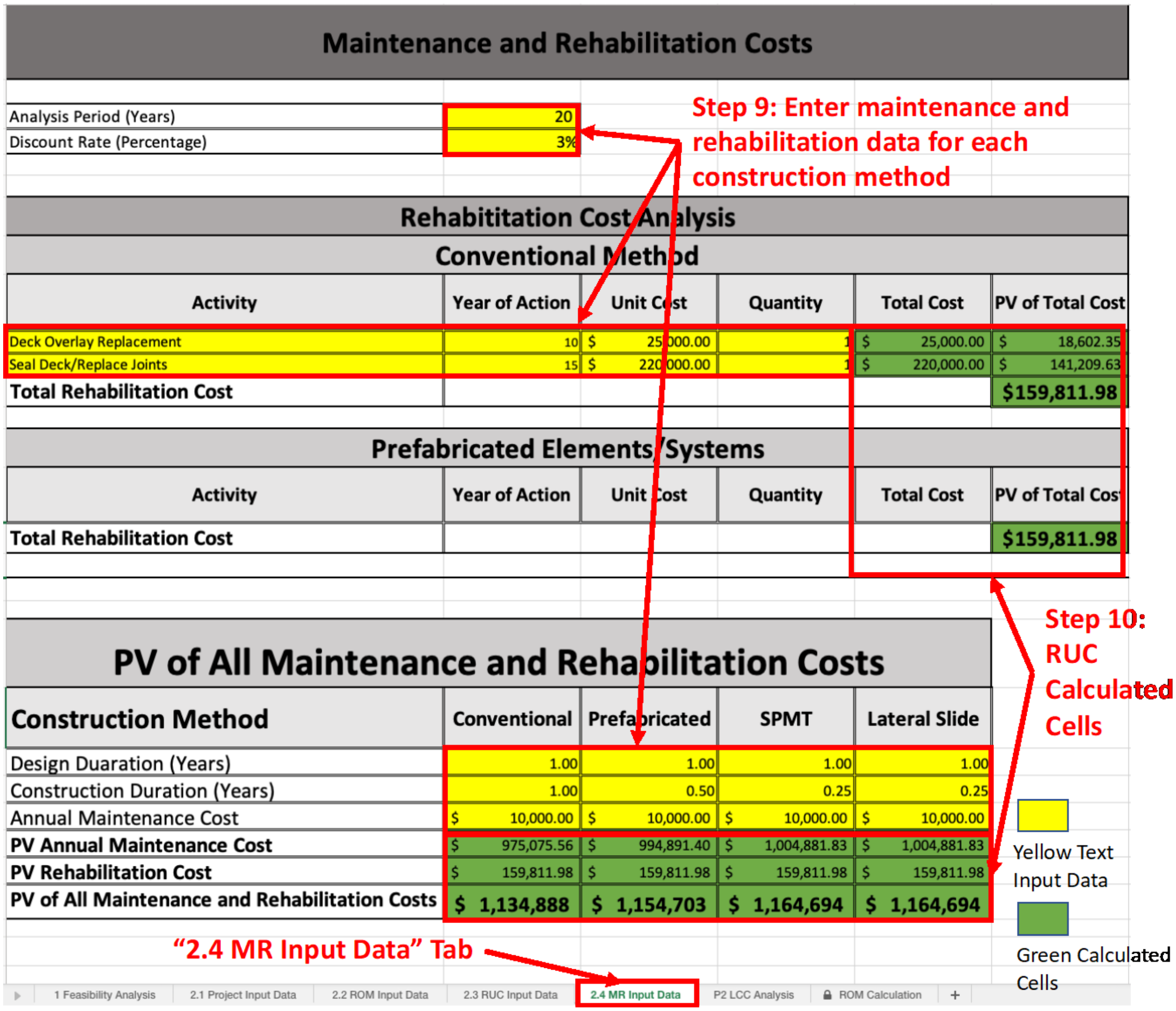
Construction Method	Conventional	Prefabricated	SPMT	Lateral Slide
Project Length-Normal Condition (Miles)	0.152	0.152	0.152	0.152
Project Length W/detour-Under Construction (Mi	1	1	1	1
Project Duration (Days)	300	90	3	15
Total Work Zone Crash Prediction	4.681	1.576	0.073	0.312
Road user cost	$ 850,087.41	$ 255,026.22	$ 8,500.87	$ 42,504.37
Crash Cost	$ 101,564.43	$ 34,202.61	$ 1,580.31	$ 6,770.34
Total Road User Cost	**$ 951,652**	**$ 289,229**	**$ 10,081**	**$ 49,275**

Step 8: RUC cost comparison

“2.3 RUC Input Data” Tab

Figure 61. Screenshot. Road user cost input, calculation, and comparison.

Fourth, bridge maintenance/rehabilitation (MR) cost data were entered into the DST in the spreadsheet tab named “2.4 MR Input Data.” Bridge MR cost data include design duration in years, construction duration in years, annual maintenance cost in dollars, analysis period in years, discount rate, activity name, year of action, unit cost, and quantity. The DST is designed to provide users with the flexibility to specify different MR costs based on the type of bridge construction method, as shown in Figure 62. The DST is designed to use this MR input cost data to automatically calculate and compare the present value (PV) of annual maintenance cost, PV of rehabilitation cost, and PV of all MR costs for all bridge construction methods, as shown in Figure 63.



Maintenance and Rehabilitation Costs

Analysis Period (Years)	20
Discount Rate (Percentage)	3%

Step 9: Enter maintenance and rehabilitation data for each construction method

Rehabititation Cost Analysis

Conventional Method

Activity	Year of Action	Unit Cost	Quantity	Total Cost	PV of Total Cost
Deck Overlay Replacement	10	$ 25,000.00	1	$ 25,000.00	$ 18,602.35
Seal Deck/Replace Joints	15	$ 220,000.00	1	$ 220,000.00	$ 141,209.63
Total Rehabilitation Cost					**$159,811.98**

Prefabricated Elements/Systems

Activity	Year of Action	Unit Cost	Quantity	Total Cost	PV of Total Cost
Total Rehabilitation Cost					**$159,811.98**

Step 10: RUC Calculated Cells

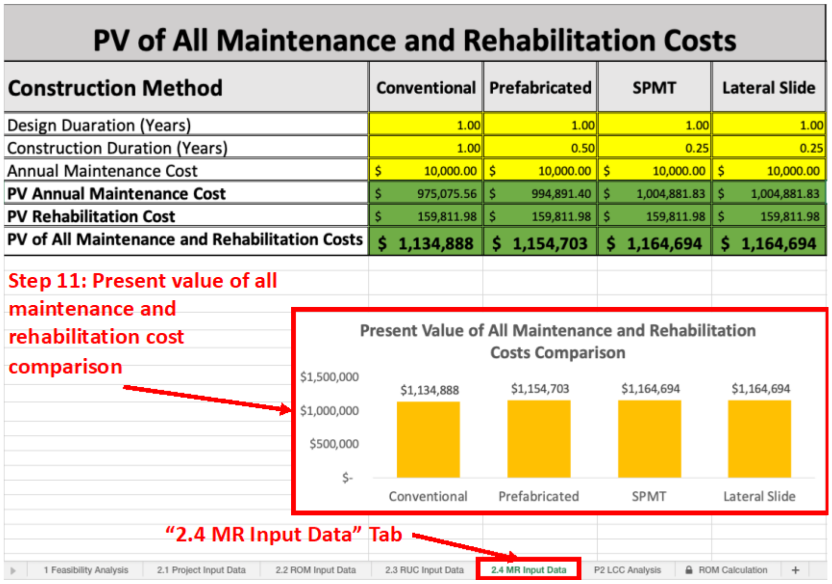
PV of All Maintenance and Rehabilitation Costs

Construction Method	Conventional	Prefabricated	SPMT	Lateral Slide
Design Duaration (Years)	1.00	1.00	1.00	1.00
Construction Duration (Years)	1.00	0.50	0.25	0.25
Annual Maintenance Cost	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
PV Annual Maintenance Cost	$ 975,075.56	$ 994,891.40	$ 1,004,881.83	$ 1,004,881.83
PV Rehabilitation Cost	$ 159,811.98	$ 159,811.98	$ 159,811.98	$ 159,811.98
PV of All Maintenance and Rehabilitation Costs	**$ 1,134,888**	**$ 1,154,703**	**$ 1,164,694**	**$ 1,164,694**

🟨	Yellow Text Input Data
🟩	Green Calculated Cells

“2.4 MR Input Data” Tab

Figure 62. Screenshot. Maintenance and rehabilitation cost input data and calculation.



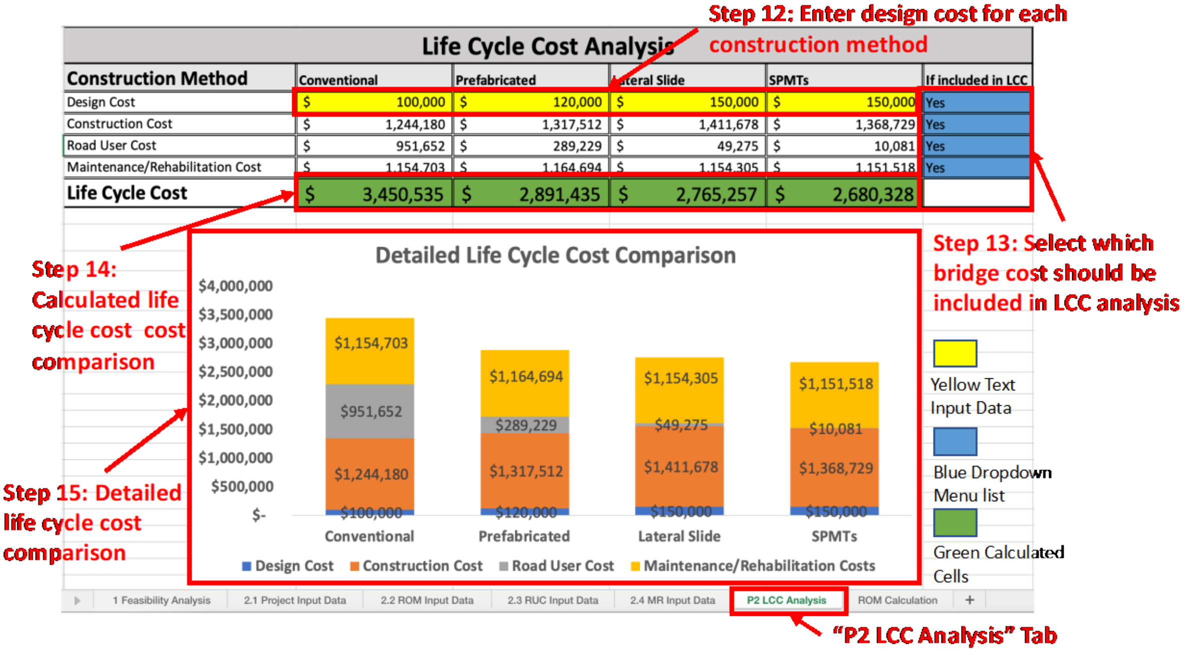
PV of All Maintenance and Rehabilitation Costs				
Construction Method	**Conventional**	**Prefabricated**	**SPMT**	**Lateral Slide**
Design Duaration (Years)	1.00	1.00	1.00	1.00
Construction Duration (Years)	1.00	0.50	0.25	0.25
Annual Maintenance Cost	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
PV Annual Maintenance Cost	$ 975,075.56	$ 994,891.40	$ 1,004,881.83	$ 1,004,881.83
PV Rehabilitation Cost	$ 159,811.98	$ 159,811.98	$ 159,811.98	$ 159,811.98
PV of All Maintenance and Rehabilitation Costs	**$ 1,134,888**	**$ 1,154,703**	**$ 1,164,694**	**$ 1,164,694**

Step 11: Present value of all maintenance and rehabilitation cost comparison

“2.4 MR Input Data” Tab

Figure 63. Screenshot. Comparison of maintenance and rehabilitation costs for all construction methods.

Fifth, design costs were entered in the spreadsheet tab named “P2 LCC Analysis.” The DST is designed to provide users with the flexibility to specify different design costs based on the type of bridge construction method, as shown in Figure 64. Sixth, the developed DST provides IDOT planners and decision-makers with the flexibility to select bridge cost components that should be included in the LCC analysis from the following list: (1) design cost, (2) construction cost, (3) road user cost, and (4) MR cost, as shown in Figure 64.



Life Cycle Cost Analysis					
Construction Method	**Conventional**	**Prefabricated**	**Lateral Slide**	**SPMTs**	**If included in LCC**
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 1,244,180	$ 1,317,512	$ 1,411,678	$ 1,368,729	Yes
Road User Cost	$ 951,652	$ 289,229	$ 49,275	$ 10,081	Yes
Maintenance/Rehabilitation Cost	$ 1,154,703	$ 1,164,694	$ 1,154,305	$ 1,151,518	Yes
Life Cycle Cost	**$ 3,450,535**	**$ 2,891,435**	**$ 2,765,257**	**$ 2,680,328**	

Step 12: Enter design cost for each construction method

Step 13: Select which bridge cost should be included in LCC analysis

Step 14: Calculated life cycle cost cost comparison

Step 15: Detailed life cycle cost comparison

🟨 Yellow Text Input Data

🟦 Blue Dropdown Menu list

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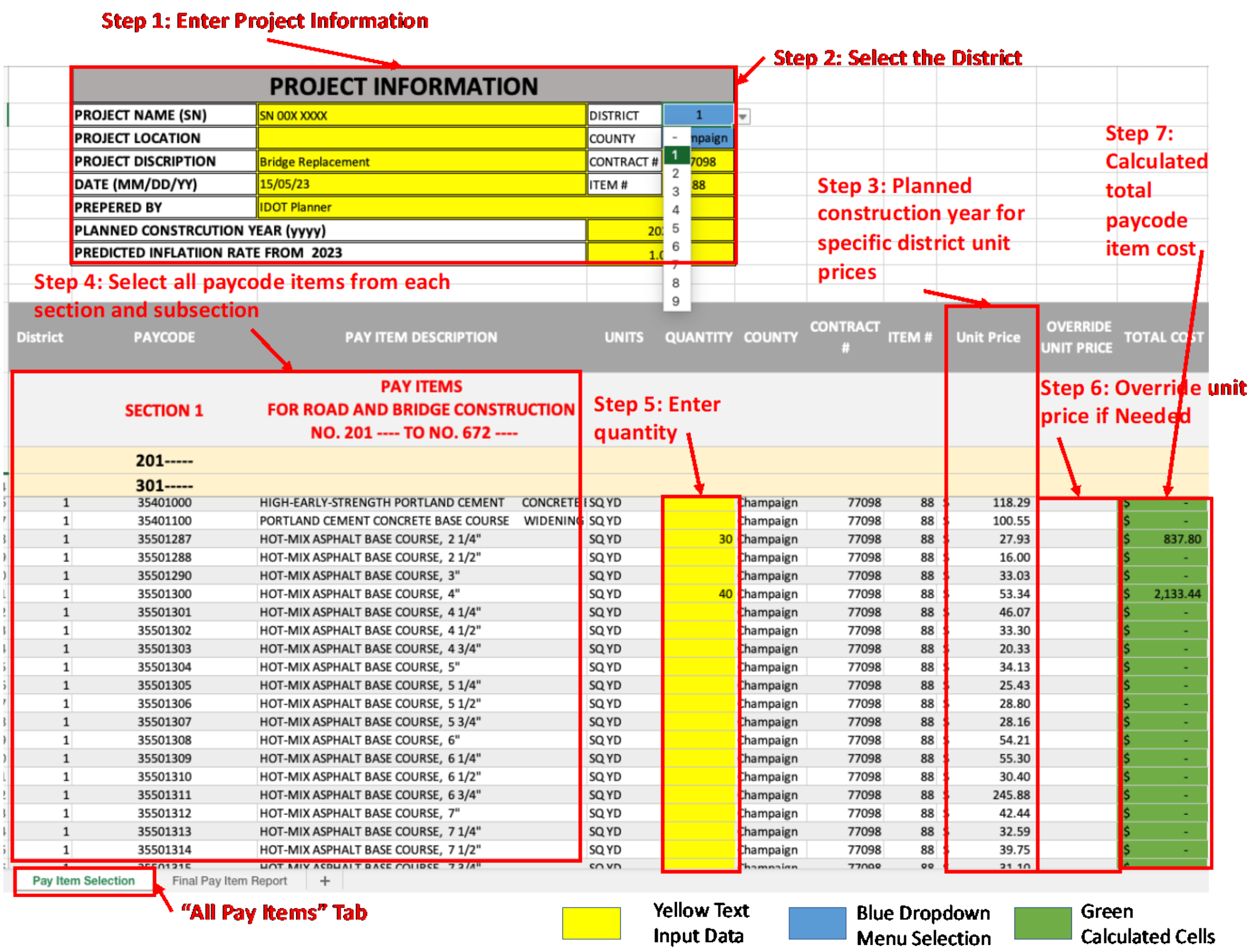
“P2 LCC Analysis” Tab

Figure 64. Screenshot. Life cycle cost calculation and comparison for all construction methods.

DETAILED COST-ESTIMATING CASE STUDY

Another case study was analyzed to illustrate the use of the developed detailed cost-estimate submodule and demonstrate its capabilities in generating a detailed cost estimate for an example bridge construction project. The example bridge project was assumed to be planned for construction in Champaign County in District 4 in 2025.

First, general project information was entered into the detailed cost-estimate submodule in the spreadsheet tab named “All Paycode Items.” This general project information includes 11 fields: project name, district, county, location, project description, contract number, report date, item number, prepared by, planned construction year, and inflation rate from 2023. Two of the 11 fields can be selected using drop-down lists, while the remaining nine can be typed directly into their respective cells. Upon completion of this input data, the submodule is designed to automatically extract all 2023 district-specific average unit prices for the identified 15,974 pay-code items from the database and multiply it by the inflation rate from 2023 to calculate the estimated average unit cost during the planned year of construction, as shown in Figure 65. Second, the DST user needs to select all pay-code items that are planned in the example bridge project from each section and subsection that were used to organize the comprehensive list of 15,974 pay-code items, as shown in Figure 65. For each selected pay-code item, the DST user needs to enter only its quantity of work in units of measure. The submodule is designed to provide IDOT planners with the flexibility to override the unit price of pay-code items by entering an adjusted unit price in the “Override Unit Price” column, as shown in Figure 65. Upon the completion of this input, the detailed cost-estimating submodule automatically calculates the total cost of each selected pay-code item and generates a detailed pay-code item report in a spreadsheet tab named “Final Paycode Item Report.” This report includes only relevant pay-code items and their complete cost-estimating details that includes district number, pay code, pay-code item description, unit of measure, quantity, county, contract number, item number, unit price, override unit price, total cost, and comments, as shown in Figure 66.



Step 1: Enter Project Information

Step 2: Select the District

Step 3: Planned construction year for specific district unit prices

Step 4: Select all paycode items from each section and subsection

Step 5: Enter quantity

Step 6: Override unit price if Needed

Step 7: Calculated total paycode item cost

“All Pay Items” Tab

PROJECT INFORMATION

PROJECT NAME (SN)	SN 00X XXXX	DISTRICT	1
PROJECT LOCATION		COUNTY	Champaign
PROJECT DISCRIPTION	Bridge Replacement	CONTRACT #	77098
DATE (MM/DD/YY)	15/05/23	ITEM #	88
PREPERED BY	IDOT Planner		
PLANNED CONSTRCUTION YEAR (yyyy)			20
PREDICTED INFLATIION RATE FROM 2023			1.

SECTION 1

PAY ITEMS FOR ROAD AND BRIDGE CONSTRUCTION NO. 201 ---- TO NO. 672 ----

District	PAYCODE	PAY ITEM DESCRIPTION	UNITS	QUANTITY	COUNTY	CONTRACT #	ITEM #	Unit Price	OVERRIDE UNIT PRICE	TOTAL COST
	201-----									
	301-----									
1	35401000	HIGH-EARLY-STRENGTH PORTLAND CEMENT CONCRETE	SQ YD		Champaign	77098	88	118.29		$ -
1	35401100	PORTLAND CEMENT CONCRETE BASE COURSE WIDENING	SQ YD		Champaign	77098	88	100.55		$ -
1	35501287	HOT-MIX ASPHALT BASE COURSE, 2 1/4"	SQ YD	30	Champaign	77098	88	27.93		$ 837.80
1	35501288	HOT-MIX ASPHALT BASE COURSE, 2 1/2"	SQ YD		Champaign	77098	88	16.00		$ -
1	35501290	HOT-MIX ASPHALT BASE COURSE, 3"	SQ YD		Champaign	77098	88	33.03		$ -
1	35501300	HOT-MIX ASPHALT BASE COURSE, 4"	SQ YD	40	Champaign	77098	88	53.34		$ 2,133.44
1	35501301	HOT-MIX ASPHALT BASE COURSE, 4 1/4"	SQ YD		Champaign	77098	88	46.07		$ -
1	35501302	HOT-MIX ASPHALT BASE COURSE, 4 1/2"	SQ YD		Champaign	77098	88	33.30		$ -
1	35501303	HOT-MIX ASPHALT BASE COURSE, 4 3/4"	SQ YD		Champaign	77098	88	20.33		$ -
1	35501304	HOT-MIX ASPHALT BASE COURSE, 5"	SQ YD		Champaign	77098	88	34.13		$ -
1	35501305	HOT-MIX ASPHALT BASE COURSE, 5 1/4"	SQ YD		Champaign	77098	88	25.43		$ -
1	35501306	HOT-MIX ASPHALT BASE COURSE, 5 1/2"	SQ YD		Champaign	77098	88	28.80		$ -
1	35501307	HOT-MIX ASPHALT BASE COURSE, 5 3/4"	SQ YD		Champaign	77098	88	28.16		$ -
1	35501308	HOT-MIX ASPHALT BASE COURSE, 6"	SQ YD		Champaign	77098	88	54.21		$ -
1	35501309	HOT-MIX ASPHALT BASE COURSE, 6 1/4"	SQ YD		Champaign	77098	88	55.30		$ -
1	35501310	HOT-MIX ASPHALT BASE COURSE, 6 1/2"	SQ YD		Champaign	77098	88	30.40		$ -
1	35501311	HOT-MIX ASPHALT BASE COURSE, 6 3/4"	SQ YD		Champaign	77098	88	245.88		$ -
1	35501312	HOT-MIX ASPHALT BASE COURSE, 7"	SQ YD		Champaign	77098	88	42.44		$ -
1	35501313	HOT-MIX ASPHALT BASE COURSE, 7 1/4"	SQ YD		Champaign	77098	88	32.59		$ -
1	35501314	HOT-MIX ASPHALT BASE COURSE, 7 1/2"	SQ YD		Champaign	77098	88	39.75		$ -
1	35501315	HOT-MIX ASPHALT BASE COURSE, 7 3/4"	SQ YD		Champaign	77098	88	31.10		$

🟨 Yellow Text Input Data

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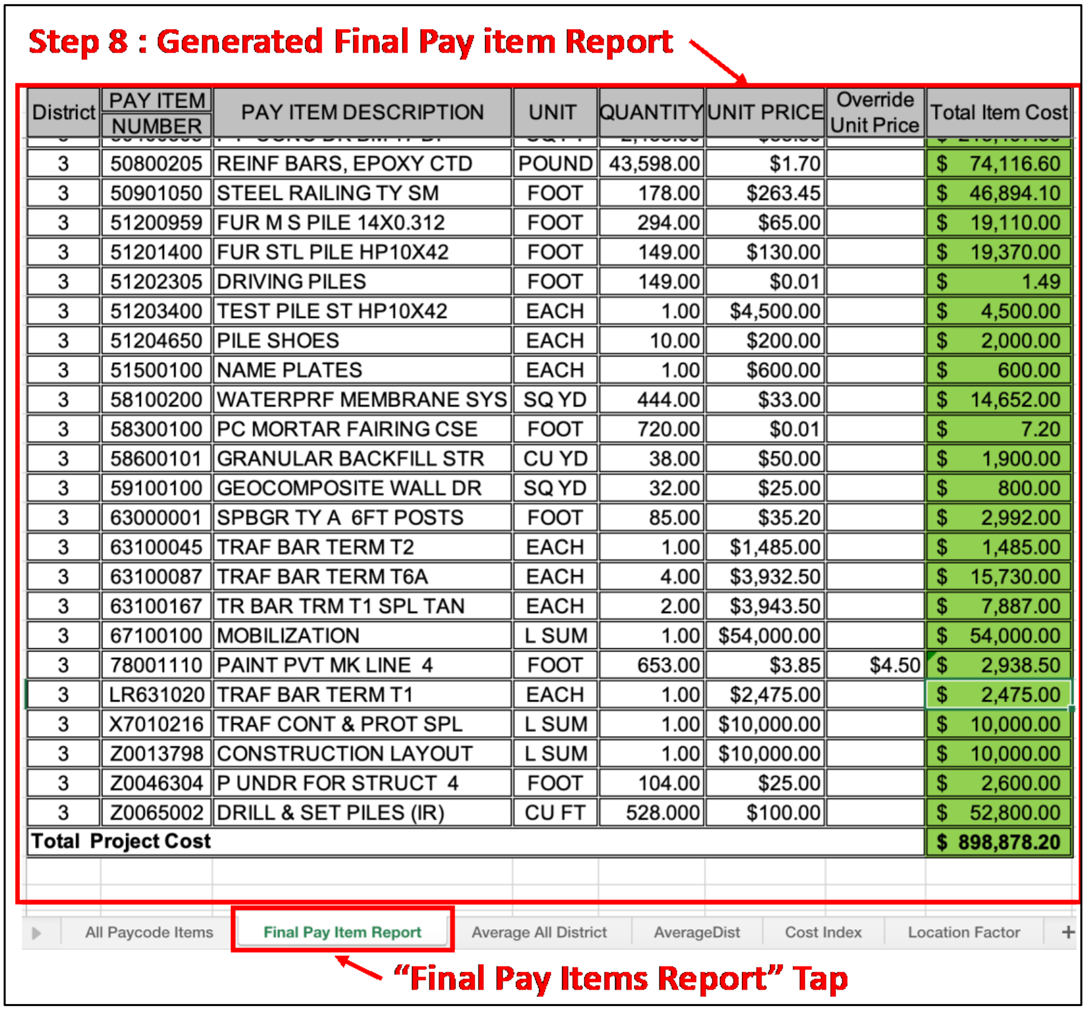
🟩 Green Calculated Cells

Figure 65. Screenshot. Detailed cost-estimate submodule graphical user interface.



Step 8 : Generated Final Pay item Report

District	PAY ITEM NUMBER	PAY ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	Override Unit Price	Total Item Cost
3	50800205	REINF BARS, EPOXY CTD	POUND	43,598.00	$1.70		$ 74,116.60
3	50901050	STEEL RAILING TY SM	FOOT	178.00	$263.45		$ 46,894.10
3	51200959	FUR M S PILE 14X0.312	FOOT	294.00	$65.00		$ 19,110.00
3	51201400	FUR STL PILE HP10X42	FOOT	149.00	$130.00		$ 19,370.00
3	51202305	DRIVING PILES	FOOT	149.00	$0.01		$ 1.49
3	51203400	TEST PILE ST HP10X42	EACH	1.00	$4,500.00		$ 4,500.00
3	51204650	PILE SHOES	EACH	10.00	$200.00		$ 2,000.00
3	51500100	NAME PLATES	EACH	1.00	$600.00		$ 600.00
3	58100200	WATERPRF MEMBRANE SYS	SQ YD	444.00	$33.00		$ 14,652.00
3	58300100	PC MORTAR FAIRING CSE	FOOT	720.00	$0.01		$ 7.20
3	58600101	GRANULAR BACKFILL STR	CU YD	38.00	$50.00		$ 1,900.00
3	59100100	GEOCOMPOSITE WALL DR	SQ YD	32.00	$25.00		$ 800.00
3	63000001	SPBGR TY A 6FT POSTS	FOOT	85.00	$35.20		$ 2,992.00
3	63100045	TRAF BAR TERM T2	EACH	1.00	$1,485.00		$ 1,485.00
3	63100087	TRAF BAR TERM T6A	EACH	4.00	$3,932.50		$ 15,730.00
3	63100167	TR BAR TRM T1 SPL TAN	EACH	2.00	$3,943.50		$ 7,887.00
3	67100100	MOBILIZATION	L SUM	1.00	$54,000.00		$ 54,000.00
3	78001110	PAINT PVT MK LINE 4	FOOT	653.00	$3.85	$4.50	$ 2,938.50
3	LR631020	TRAF BAR TERM T1	EACH	1.00	$2,475.00		$ 2,475.00
3	X7010216	TRAF CONT & PROT SPL	L SUM	1.00	$10,000.00		$ 10,000.00
3	Z0013798	CONSTRUCTION LAYOUT	L SUM	1.00	$10,000.00		$ 10,000.00
3	Z0046304	P UNDR FOR STRUCT 4	FOOT	104.00	$25.00		$ 2,600.00
3	Z0065002	DRILL & SET PILES (IR)	CU FT	528.000	$100.00		$ 52,800.00
Total Project Cost							**$ 898,878.20**

"Final Pay Items Report" Tap

Figure 66. Screenshot. Sample of detailed cost-estimate submodule pay-code item report.

CHAPTER 5: CASE STUDIES OF IDOT BRIDGE PROJECTS

This chapter focuses on evaluating the performance and accuracy of the developed quantitative decision support tool (DST) for estimating bridge costs during the early project phases such as Phase I engineering reports. The DST was used to estimate and compare bridge costs for conventional, prefabricated, lateral slide, and SPMT construction methods.

The DST performance evaluation was conducted using two sets of case studies that include five completed/ongoing projects and five future projects, as shown in Figure 67. The first set of five completed/ongoing IDOT bridge projects were analyzed to calculate the accuracy of the developed quantitative DST by comparing its estimated cost to the reported IDOT construction cost of each bridge project, as shown in Figure 68. Note that the third bridge project in this set was excluded because it represented the total cost of ten bridges (see Figure 68), and, therefore, it cannot be analyzed by the developed DST that was designed to estimate the cost of a single bridge project. Accordingly, this first completed/ongoing set includes four projects, as shown in Table 2. The second set of five future bridge projects were analyzed to estimate and compare the construction cost, road user cost, maintenance and rehabilitation costs, and total life cycle cost of each feasible bridge construction method to identify the most cost-effective method for each bridge project, as shown in Table 3.

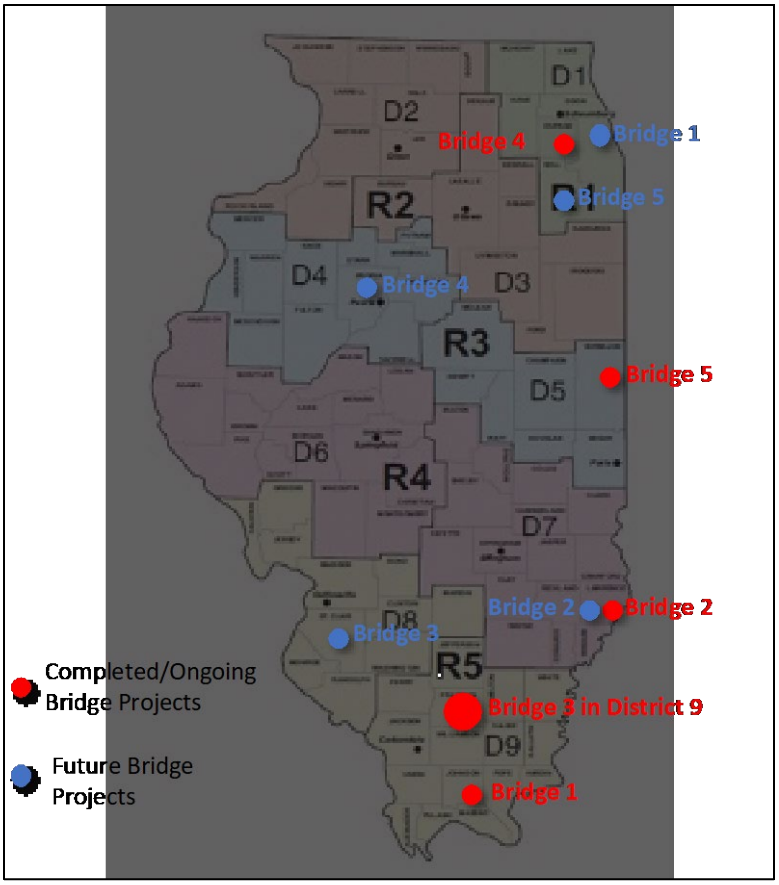


Figure 67. Map. Sets of case studies by IDOT region and district location map.

Table 2. Completed/Ongoing Set of Bridge Case Studies

Case Study	Project Name	Structure Number	District	County
1	Bridge Replacement IL 1 over Big Slough, Lawrence	SN 051-0008	7	Lawrence
2	Bridge Replacement I-55 over Lemont Road	SN 022-0001	1	DuPage
3	Nine Miles Lane Addition of I-57 From Mile Post 66 to Marcum Branch (includes 10 different bridges)	**Excluded**	9	Franklin
4	IL 146 over Little Cache Creek in Vienna	SN 044-0053		Johnson
5	Bridge Replacement under Tilton Rd. Tilton.	SN 092-0087	5	Vermillion

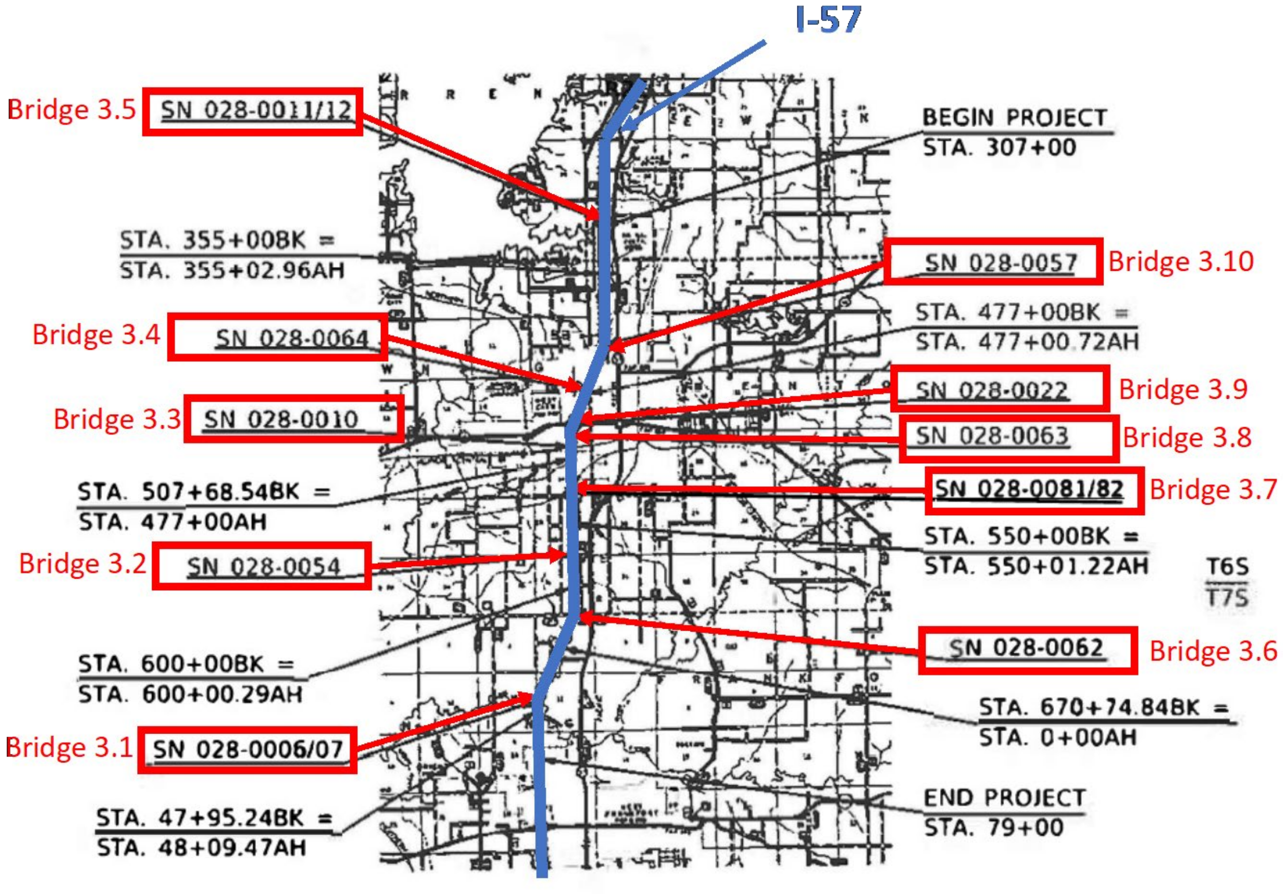


Figure 68. Map. Location of bridges on I-57 for bridge project 3.

Table 3. Future Set of Bridge Case Studies

Case Study	Project Name	Structure Number	District	County
1	Oakton ST over I-94 Edens	SN 016-0827	1	Cook
2	T5N R12W SEC 25	SN 051-0001	7	Lawrence
3	Ancient Burial Ghost	SN 082-0166	8	Clair
4	Airport RD-FAU 6578 over I-474	SN 072-0126	4	Peoria
5	IL 53 over Hickory Creek	SN 099-0083	1	Will

COMPLETED/ONGOING IDOT BRIDGE PROJECTS

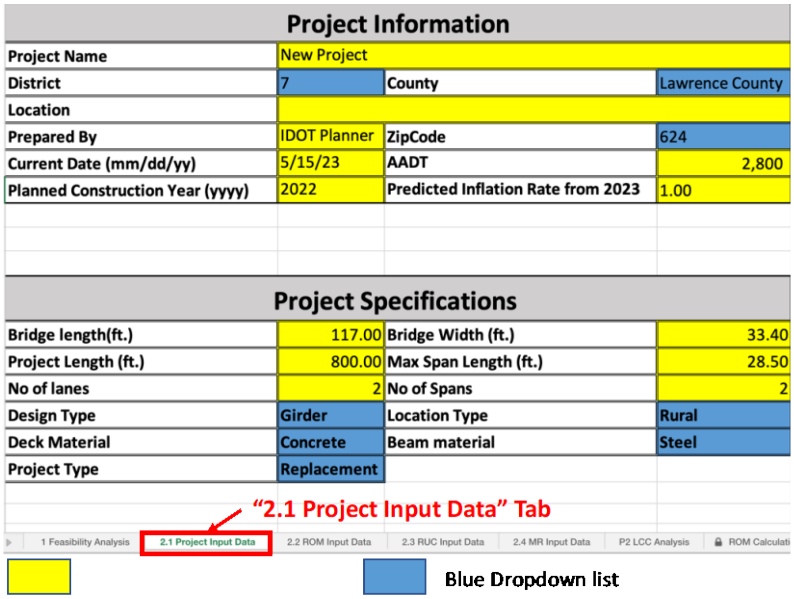
This section focuses on analyzing a representative sample of four recently completed/ongoing IDOT bridge construction projects to evaluate the performance and accuracy of the developed cost-estimating DST. The four bridges were analyzed by the developed DST to estimate their construction cost, road user cost, annual maintenance and rehabilitation costs, and total life cycle cost. The estimated construction costs of the four analyzed bridges were then compared to their reported IDOT construction costs to analyze the accuracy of the developed DST.

Estimating Bridge Costs Using Developed DST

The developed quantitative DST was used to estimate construction cost, road user cost, maintenance and rehabilitation cost, and total life cycle cost for each of the analyzed four case studies. The following sections provide a detailed description of analyzing the four recently completed/ongoing case studies by the developed DST to estimate their costs.

Bridge 1: Bridge Replacement IL 1 over Big Slough, Lawrence

The scope of this bridge project was to replace an existing bridge (SN 051-0008) carrying IL 1 over Big Slough, 5 miles south of Lawrenceville, with a triple barrel box. The project was completed in June 2022 using the conventional construction method. This bridge project was in District 7 and had a bridge length of 117 feet, bridge width of 33.4 feet, project length of 800 feet, max span length of 28.5 feet, 2 lanes, 2 spans, girder design, rural location, ADT of 2,800 vehicles/day, steel beam, and concrete deck. This project information and specifications input data were entered into the DST, as shown in Figure 69. For each analyzed construction method, the DST was used to automatically estimate and compare construction cost, road user cost, maintenance and rehabilitation cost, and total life cycle cost.



Project Information

Project Name	New Project		
District	7	County	Lawrence County
Location			
Prepared By	IDOT Planner	ZipCode	624
Current Date (mm/dd/yy)	5/15/23	AADT	2,800
Planned Construction Year (yyyy)	2022	Predicted Inflation Rate from 2023	1.00

Project Specifications

Bridge length(ft.)	117.00	Bridge Width (ft.)	33.40
Project Length (ft.)	800.00	Max Span Length (ft.)	28.50
No of lanes	2	No of Spans	2
Design Type	Girder	Location Type	Rural
Deck Material	Concrete	Beam material	Steel
Project Type	Replacement		

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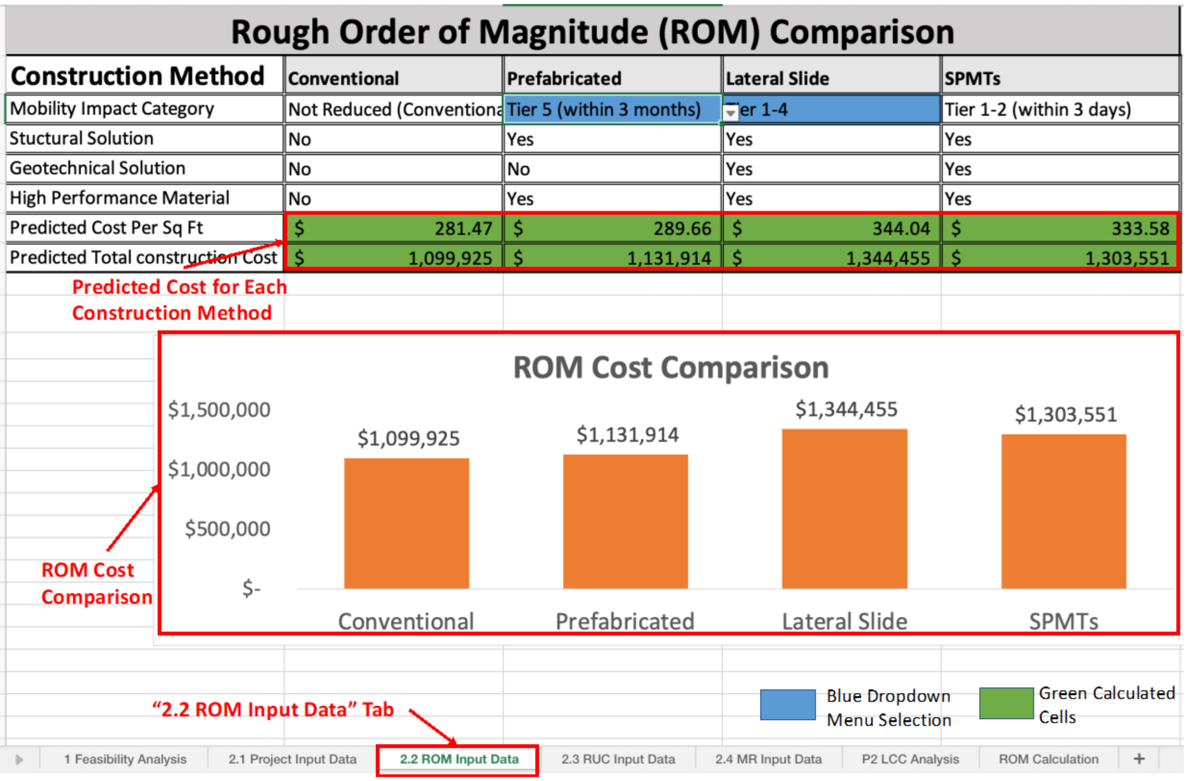
Figure 69. Screenshot. Project information input data for completed bridge 1.

The DST was used to estimate and compare bridge construction costs for conventional construction, prefabricated elements/systems, lateral slide, and SPMT, as shown in Figure 70. The estimated construction unit cost is $281.47/sf for conventional construction, $289.66/sf for prefabricated elements/systems, $344.04/sf for lateral slide, and $333.58/sf for SPMT, as shown in Figure 70.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventiona	Tier 5 (within 3 months)	▾er 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 281.47	$ 289.66	$ 344.04	$ 333.58
Predicted Total construction Cost	$ 1,099,925	$ 1,131,914	$ 1,344,455	$ 1,303,551

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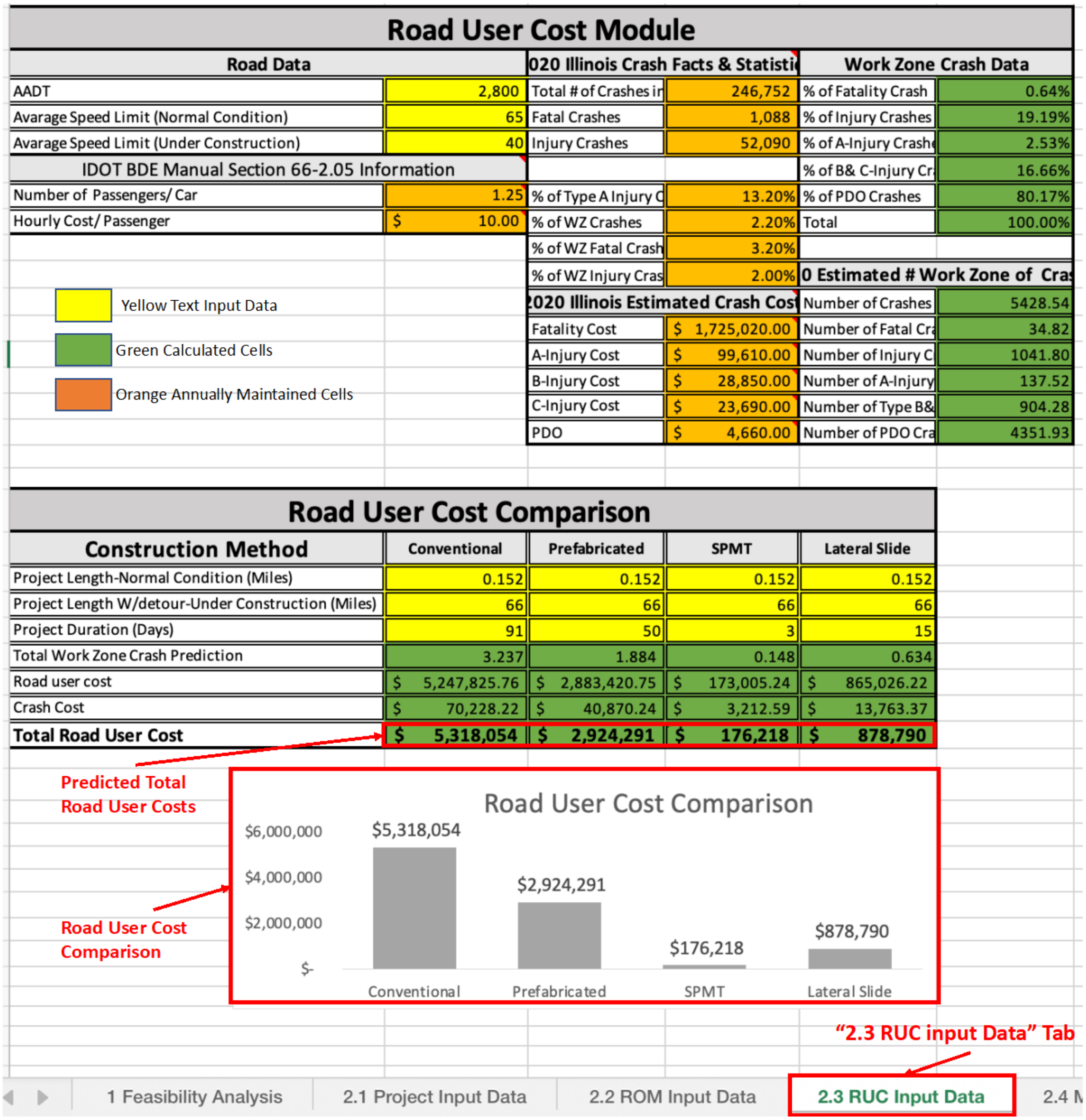
Figure 70. Screenshot. ROM comparison for bridge construction methods for completed bridge 1.

Similarly, the DST was used to estimate and compare road user costs for each construction method. For this bridge project, the road user cost input data include the speed limit during normal conditions and while under construction, which were specified to be 65 mph and 40 mph, respectively. The project length with detour was specified to be 66 miles, and the total duration of the project of 91 days using the conventional construction method, as shown in Figure 71. Based on this input data, the DST was used to automatically calculate and compare the predicted number of work zone crashes, road user cost, crash cost, and total road user cost (RUC) for all bridge construction methods, as shown in Figure 71. The calculated total RUC is $5,318,054 for conventional construction, $2,924,291 for prefabricated elements/systems, $176,218 for SPMT, and $878,790 for lateral slide.



Road User Cost Module

Road Data		020 Illinois Crash Facts & Statisti		Work Zone Crash Data	
AADT	2,800	Total # of Crashes ir	246,752	% of Fatality Crash	0.64%
Avarage Speed Limit (Normal Condition)	65	Fatal Crashes	1,088	% of Injury Crashes	19.19%
Avarage Speed Limit (Under Construction)	40	Injury Crashes	52,090	% of A-Injury Crashe	2.53%
IDOT BDE Manual Section 66-2.05 Information				% of B& C-Injury Cr	16.66%
Number of Passengers/ Car	1.25	% of Type A Injury C	13.20%	% of PDO Crashes	80.17%
Hourly Cost/ Passenger	$ 10.00	% of WZ Crashes	2.20%	Total	100.00%
		% of WZ Fatal Crash	3.20%		
		% of WZ Injury Cras	2.00%	0 Estimated # Work Zone of Cra	
		020 Illinois Estimated Crash Cost		Number of Crashes	5428.54
		Fatality Cost	$ 1,725,020.00	Number of Fatal Cr	34.82
		A-Injury Cost	$ 99,610.00	Number of Injury C	1041.80
		B-Injury Cost	$ 28,850.00	Number of A-Injury	137.52
		C-Injury Cost	$ 23,690.00	Number of Type B&	904.28
		PDO	$ 4,660.00	Number of PDO Cra	4351.93

🟨 Yellow Text Input Data

🟩 Green Calculated Cells

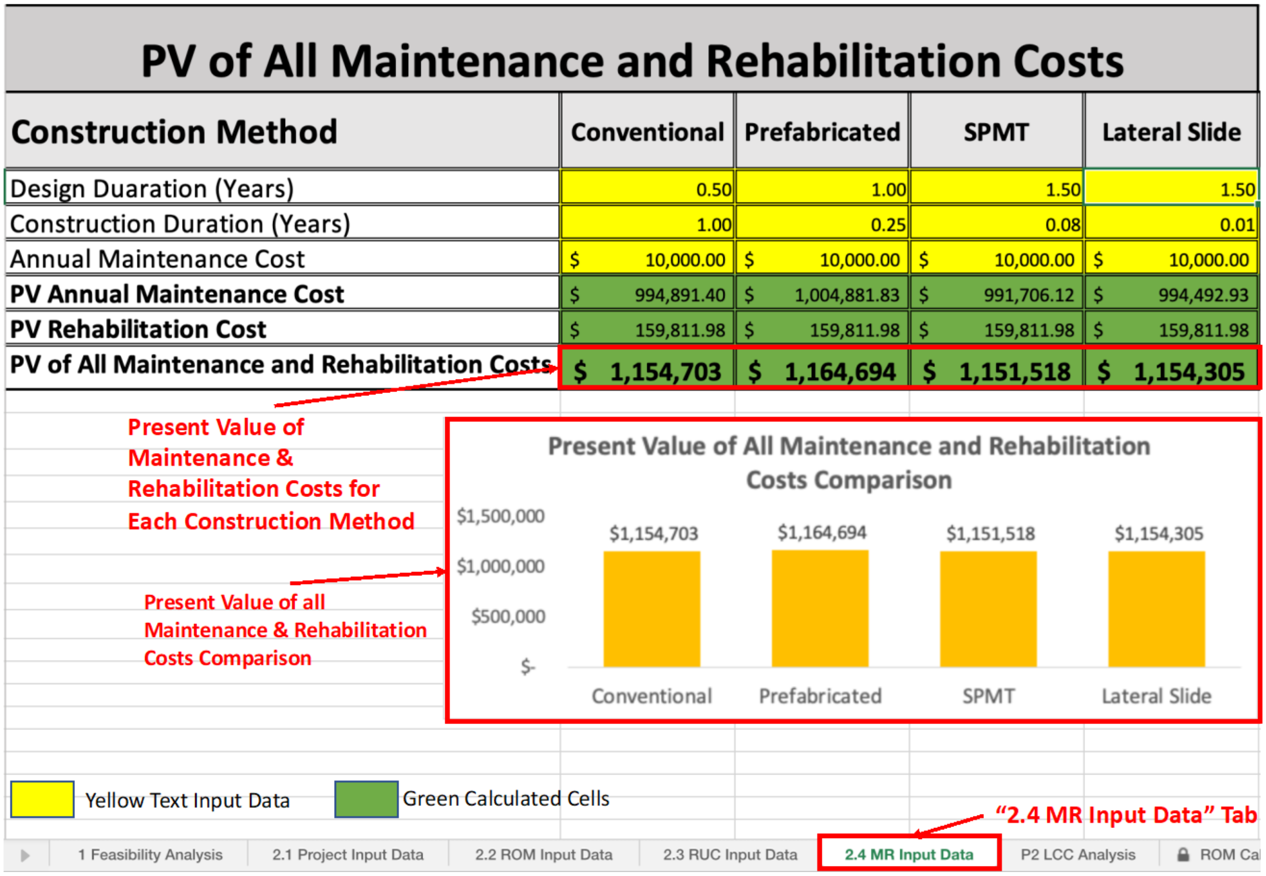
🟧 Orange Annually Maintained Cells

Road User Cost Comparison

Construction Method	Conventional	Prefabricated	SPMT	Lateral Slide
Project Length-Normal Condition (Miles)	0.152	0.152	0.152	0.152
Project Length W/detour-Under Construction (Miles)	66	66	66	66
Project Duration (Days)	91	50	3	15
Total Work Zone Crash Prediction	3.237	1.884	0.148	0.634
Road user cost	$ 5,247,825.76	$ 2,883,420.75	$ 173,005.24	$ 865,026.22
Crash Cost	$ 70,228.22	$ 40,870.24	$ 3,212.59	$ 13,763.37
Total Road User Cost	**$ 5,318,054**	**$ 2,924,291**	**$ 176,218**	**$ 878,790**

Figure 71. Screenshot. RUC comparison for bridge construction methods for completed bridge 1.

The developed DST was then used to estimate and compare the present value (PV) of annual maintenance and rehabilitation costs for each construction method. The calculated PV of all maintenance and rehabilitation costs is $1,154,703 for conventional construction, $1,164,694 for prefabricated elements/systems, $1,151,518 for lateral slide, and $1,154,305 for SPMT, as shown in Figure 72.



PV of All Maintenance and Rehabilitation Costs

Construction Method	**Conventional**	**Prefabricated**	**SPMT**	**Lateral Slide**
Design Duaration (Years)	0.50	1.00	1.50	1.50
Construction Duration (Years)	1.00	0.25	0.08	0.01
Annual Maintenance Cost	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
PV Annual Maintenance Cost	$ 994,891.40	$ 1,004,881.83	$ 991,706.12	$ 994,492.93
PV Rehabilitation Cost	$ 159,811.98	$ 159,811.98	$ 159,811.98	$ 159,811.98
PV of All Maintenance and Rehabilitation Costs	**$ 1,154,703**	**$ 1,164,694**	**$ 1,151,518**	**$ 1,154,305**

Present Value of Maintenance & Rehabilitation Costs for Each Construction Method

Present Value of all Maintenance & Rehabilitation Costs Comparison

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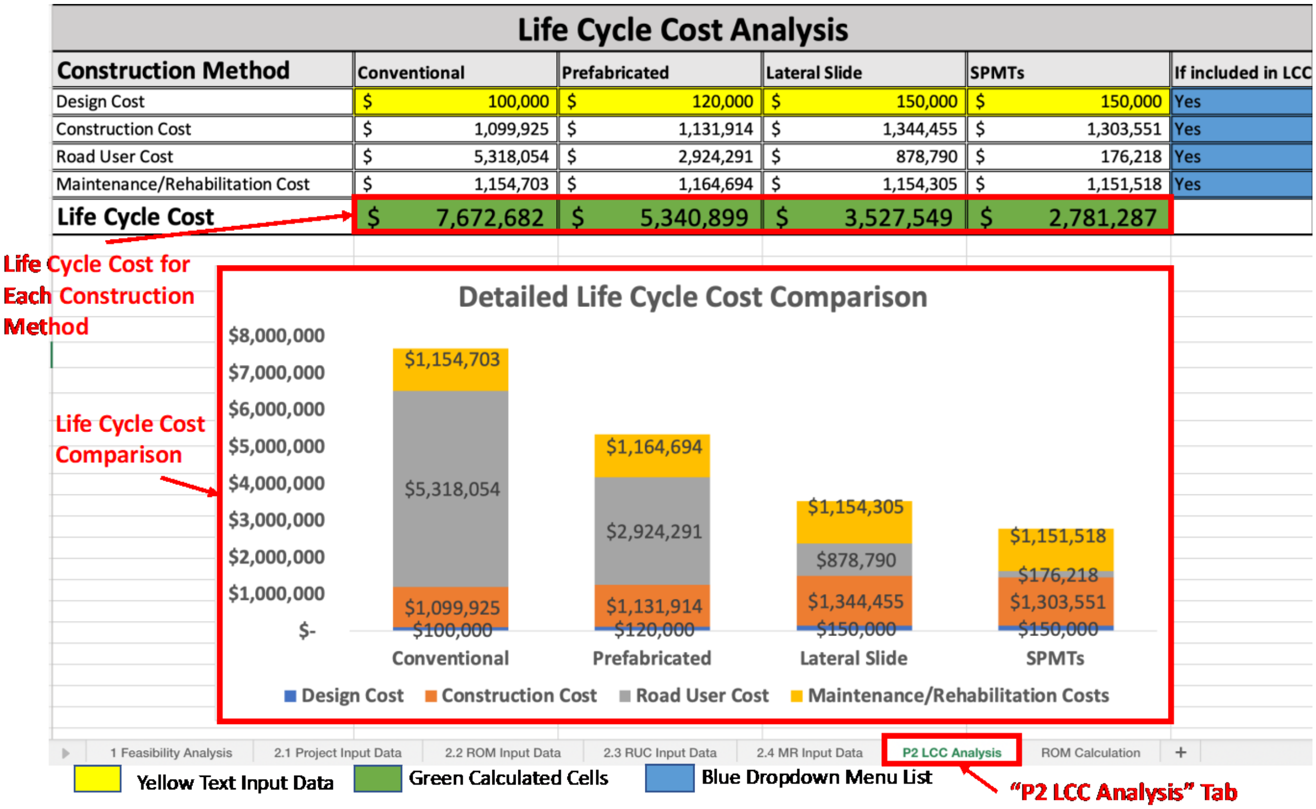
“2.4 MR Input Data” Tab

Figure 72. Screenshot. Maintenance and rehabilitation cost comparison for completed bridge 1.

The developed DST was also used to automatically calculate the life cycle cost of each construction method, as shown in Figure 73. The DST estimated life cycle cost for this project was $7,672,682 for conventional construction, $5,340,899 for prefabricated elements/systems, $3,527,549 for lateral slide, and $2,781,287 for SPMT, as shown in Figure 73.



Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 1,099,925	$ 1,131,914	$ 1,344,455	$ 1,303,551	Yes
Road User Cost	$ 5,318,054	$ 2,924,291	$ 878,790	$ 176,218	Yes
Maintenance/Rehabilitation Cost	$ 1,154,703	$ 1,164,694	$ 1,154,305	$ 1,151,518	Yes
Life Cycle Cost	$ 7,672,682	$ 5,340,899	$ 3,527,549	$ 2,781,287	

Life Cycle Cost for Each Construction Method

Life Cycle Cost Comparison

Yellow Text Input Data

Green Calculated Cells

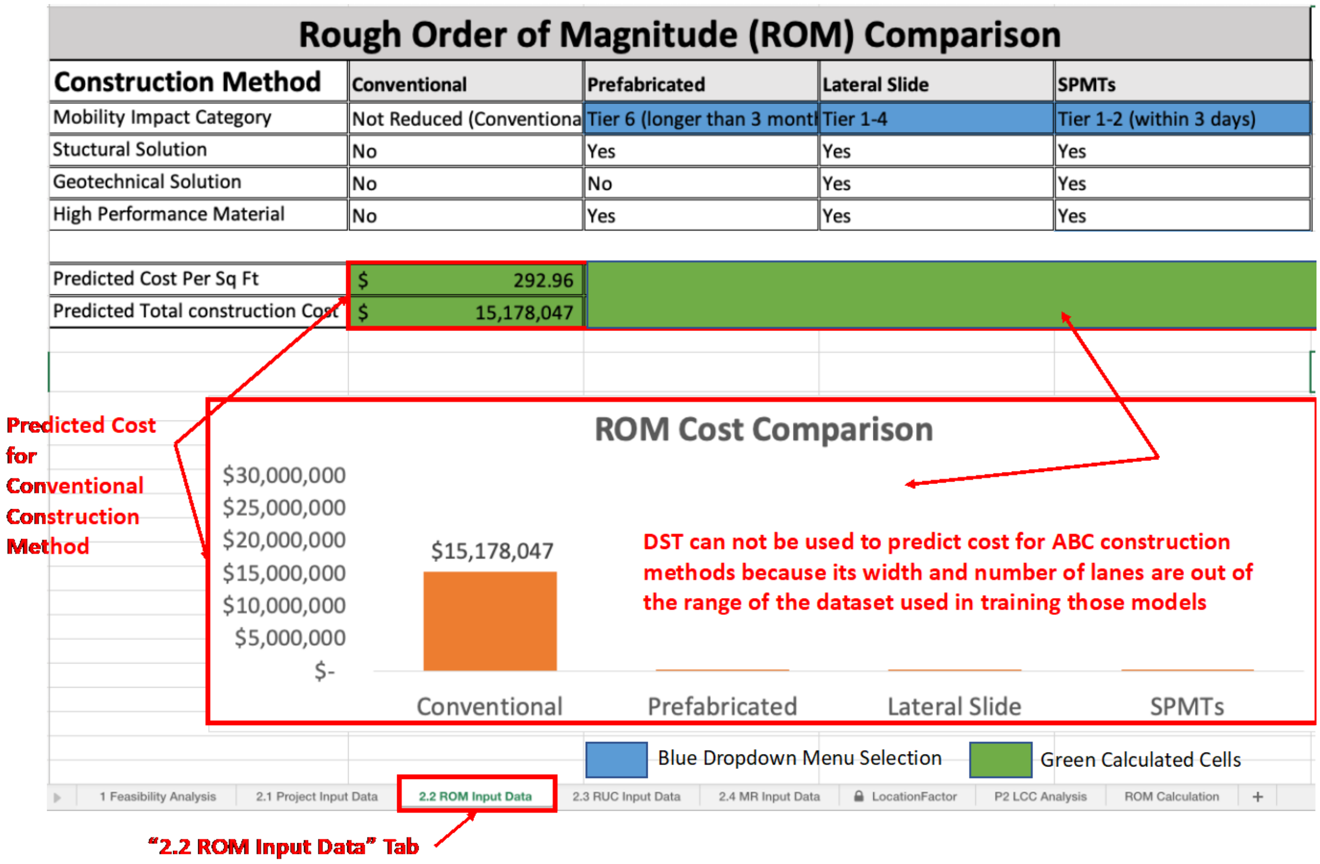
Blue Dropdown Menu List

"P2 LCC Analysis" Tab

Figure 73. Screenshot. LCC comparison for all construction methods for completed bridge 1.

Bridge 2: Bridge Replacement I-55 over Lemont Road

The scope of this bridge project was to remove an existing bridge (SN 022-0001) along I-55 over Lemont Road and replace it with a new bridge, reconstruct and resurface the roadway, and improve safety, drainage, lighting, signing, pavement marking, and landscaping in the City of Darien. The project is planned to be completed in October 2023 using the conventional construction method. This bridge project was in District 1 and had a bridge length of 330 feet, bridge width of 157 feet, project length 990.33 feet, max span length of 76.5 feet, 8 lanes, 4 spans, girder design, urban location, ADT of 122,000 vehicles/day, steel beam, and concrete deck. The estimated construction cost using the conventional construction method by the developed DST for this bridge project was $292.96, as shown in Figure 74. Note that a cost estimate for this case study using ABC construction methods could not be generated by the developed DST because its bridge width and number of lanes were beyond the range of the datasets used in training the developed predictive models for all ABC methods including prefabricated elements/systems, lateral slide, and SPMT construction methods (see Appendix D).



Rough Order of Magnitude (ROM) Comparison				
Construction Method	**Conventional**	**Prefabricated**	**Lateral Slide**	**SPMTs**
Mobility Impact Category	Not Reduced (Conventiona	Tier 6 (longer than 3 montl	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes

Predicted Cost Per Sq Ft	$ 292.96	
Predicted Total construction Cost	$ 15,178,047	

Predicted Cost for Conventional Construction Method

DST can not be used to predict cost for ABC construction methods because its width and number of lanes are out of the range of the dataset used in training those models

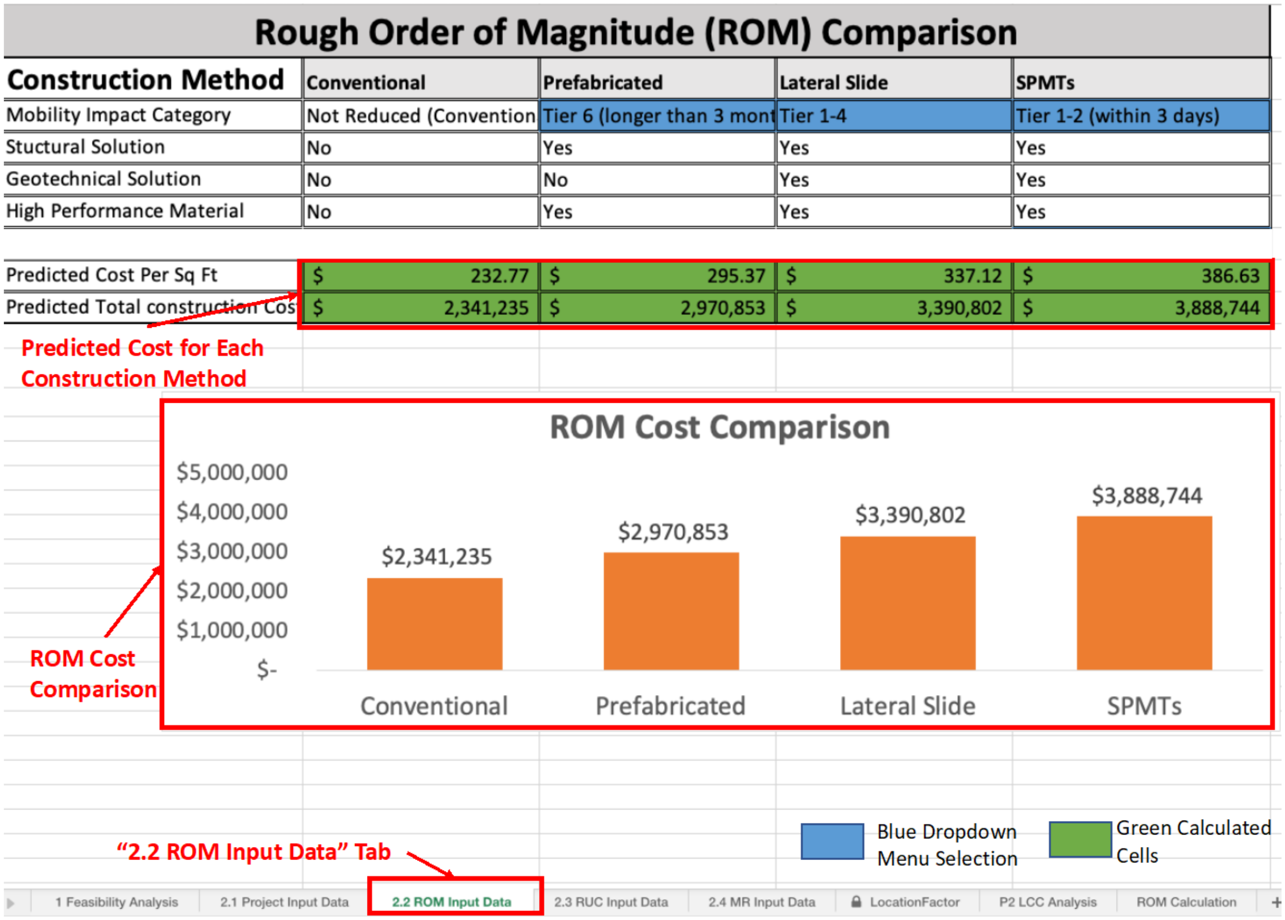
🟦 Blue Dropdown Menu Selection 🟩 Green Calculated Cells

"2.2 ROM Input Data" Tab

Figure 74. Screenshot. Predicted construction cost for conventional method for completed bridge 2.

Bridge 3: IL 146 over Little Cache Creek in Vienna, Johnson

The scope of this bridge project was to replace an existing three-span deck beam bridge (SN 044-0053) with a new three-span bridge carrying IL 146 over Little Cache Creek in Vienna, Illinois. The project was completed in July 2022 using the prefabricated elements/systems construction method. This bridge project was in District 9 and had a bridge length of 235 feet, bridge width of 42.8 feet, project length of 420.1 feet, max span length of 39.5 feet, 2 lanes, 3 spans, slab design, urban location, ADT of 6,900 vehicles/day, concrete beam, and concrete deck. The project information and specifications input data were entered into the DST. The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 75. The estimated construction unit cost is $232.77/sf for conventional construction, $295.37/sf for prefabricated elements/systems, $337.12/sf for lateral slide, and $386.63/sf for SPMT, as shown in Figure 75.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Convention	Tier 6 (longer than 3 mont	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 232.77	$ 295.37	$ 337.12	$ 386.63
Predicted Total construction Cos	$ 2,341,235	$ 2,970,853	$ 3,390,802	$ 3,888,744

Predicted Cost for Each Construction Method

ROM Cost Comparison

“2.2 ROM Input Data” Tab

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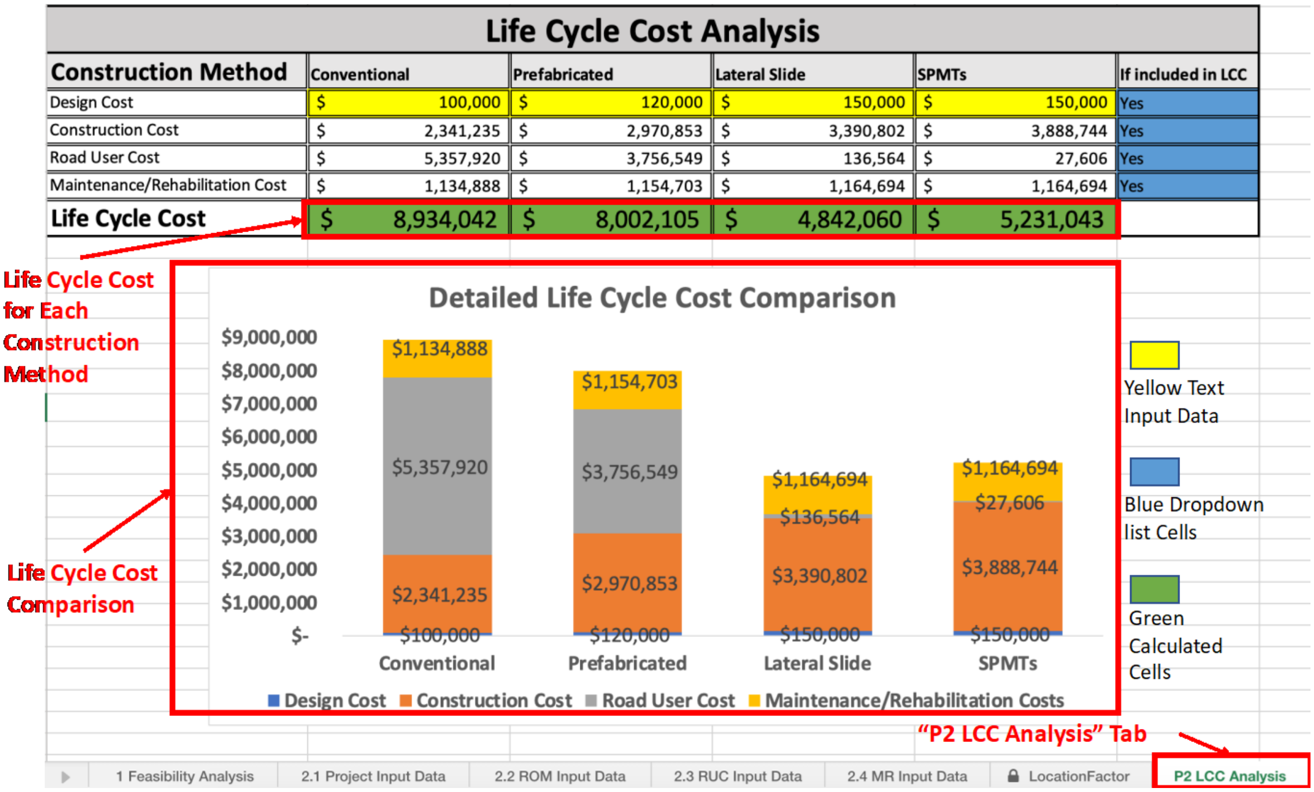
🟩 Green Calculated Cells

Figure 75. Screenshot. ROM comparison for bridge construction methods for completed bridge 3.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 76. For this project, the road user cost input data include the speed limit during normal conditions and while under construction, which were specified to be 55 mph and 40 mph, respectively. The project length with detour was specified to be 4 miles, and the total duration of the project of 420 days using the prefabricated elements/systems construction method. The DST estimated life cycle cost for this project was $8,934,042 for conventional construction, $8,002,105 for prefabricated elements/systems, $4,842,060 for lateral slide, and $5,231,043 for SPMT, as shown in Figure 76.



Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 2,341,235	$ 2,970,853	$ 3,390,802	$ 3,888,744	Yes
Road User Cost	$ 5,357,920	$ 3,756,549	$ 136,564	$ 27,606	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	**$ 8,934,042**	**$ 8,002,105**	**$ 4,842,060**	**$ 5,231,043**	

Life Cycle Cost for Each Construction Method

Life Cycle Cost Comparison

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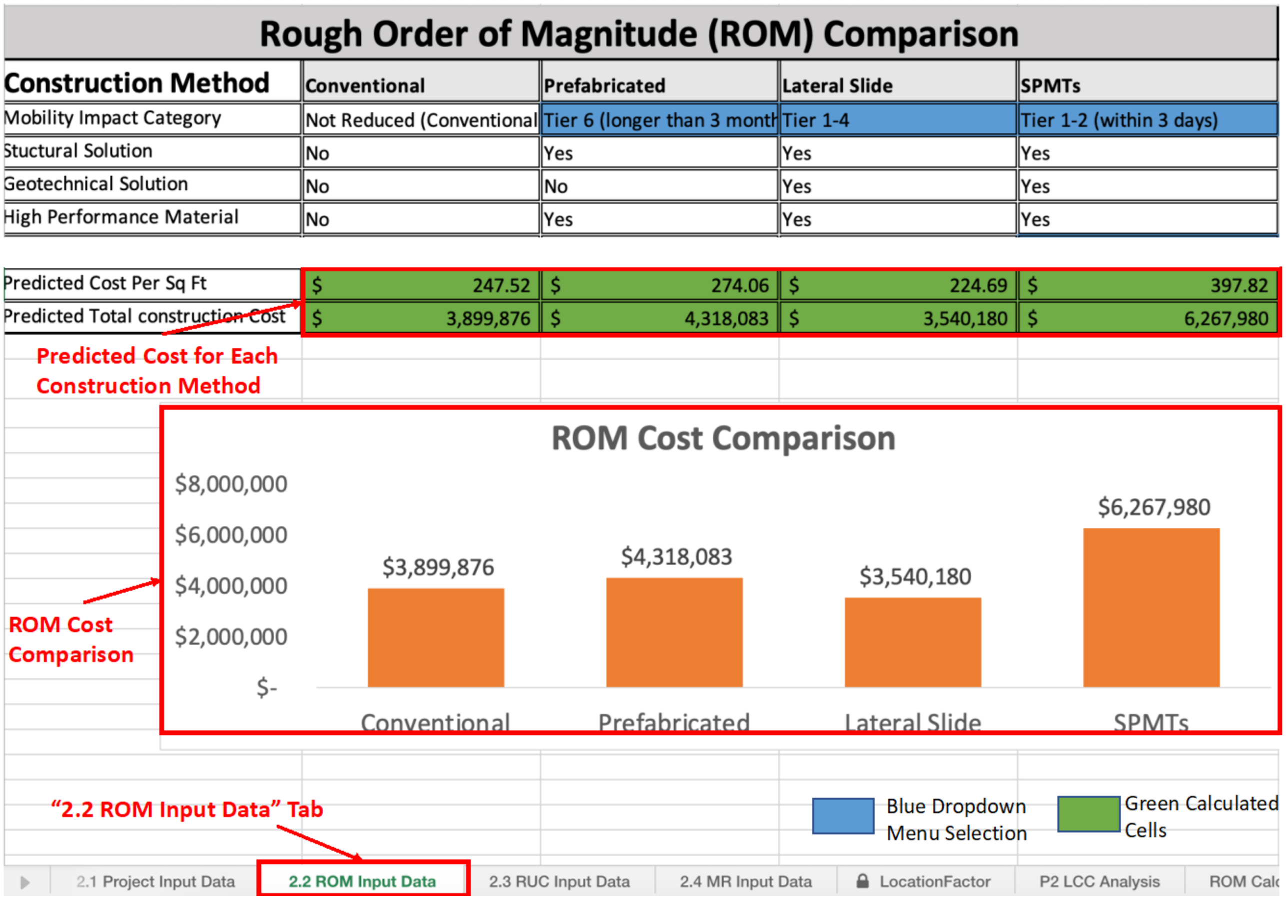
Green Calculated Cells

"P2 LCC Analysis" Tab

Figure 76. Screenshot. LCC comparison for all construction methods for completed bridge 3.

Bridge 4: Bridge Replacement under Tilton Road, Tilton

The scope of this bridge project was to replace an existing bridge (SN 092-0087) with a new bridge under Tilton Road in Tilton, Illinois. The project was completed in November 2021 using the prefabricated elements/systems construction method. This bridge project was in District 5 and had a bridge length of 404 feet, bridge width of 39 feet, project length 850 feet, max span length of 76.4 feet, 2 lanes, 3 spans, girder design, urban location, ADT of 24,400 vehicles/day, steel beam, and concrete deck. The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 77. The estimated construction unit cost is $247.52/sf for conventional construction, $274.06/sf for prefabricated elements/systems, $224.69/sf for lateral slide, and $397.82/sf for SPMT, as shown in Figure 77.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventional	Tier 6 (longer than 3 mont	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 247.52	$ 274.06	$ 224.69	$ 397.82
Predicted Total construction Cost	$ 3,899,876	$ 4,318,083	$ 3,540,180	$ 6,267,980

Predicted Cost for Each Construction Method

ROM Cost Comparison

“2.2 ROM Input Data” Tab

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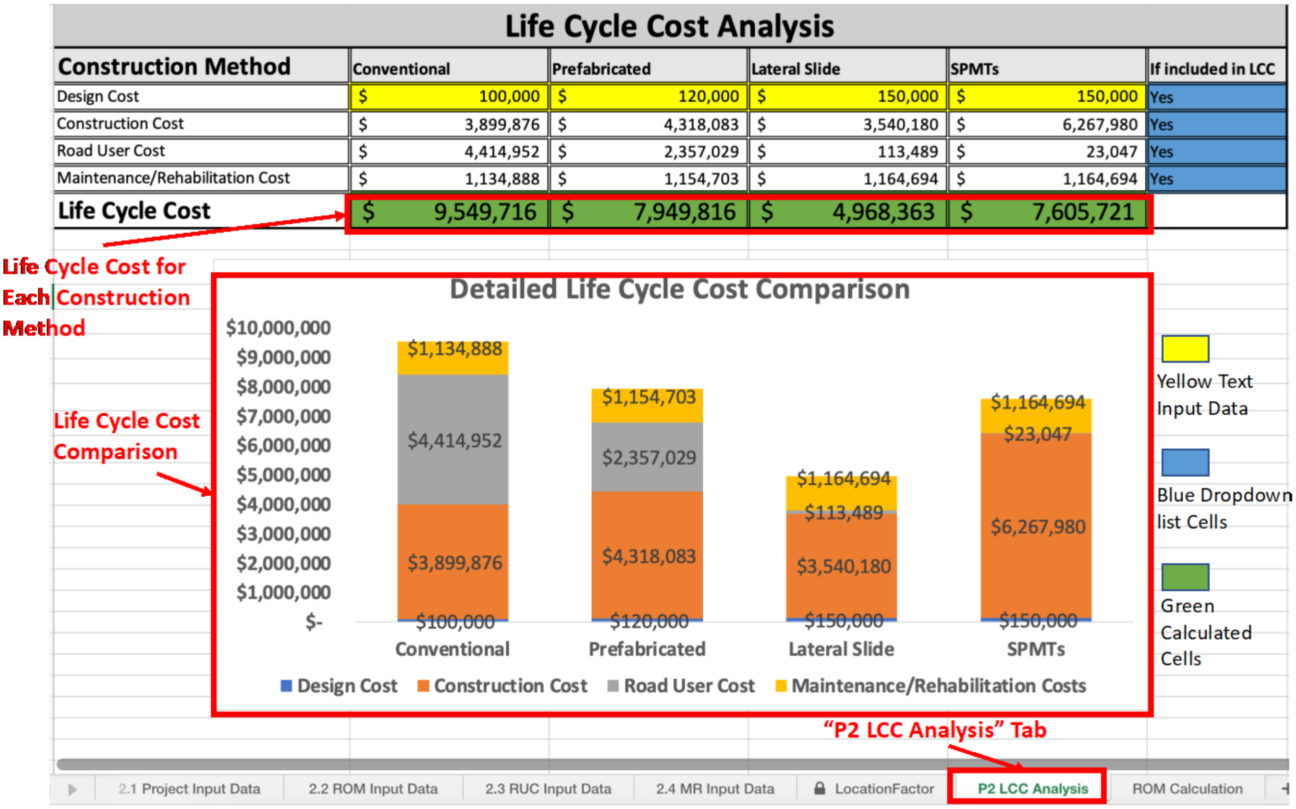
Figure 77. Screenshot. ROM comparison for bridge construction methods for completed bridge 4.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 78. For this project, the road user cost input data include the speed limit during normal conditions and while under construction, which were specified to be 55 mph and 40 mph, respectively. The project length with detour was specified to be 1 mile, and the total duration of the project was 319 days using the prefabricated elements/systems construction method. The DST estimated life cycle cost for this project was $9,549,716 for conventional construction, $7,949,816 for prefabricated elements/systems, $4,968,363 for lateral slide, and $7,605,721 for SPMT, as shown in Figure 78.



Life Cycle Cost Analysis					
Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 3,899,876	$ 4,318,083	$ 3,540,180	$ 6,267,980	Yes
Road User Cost	$ 4,414,952	$ 2,357,029	$ 113,489	$ 23,047	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	$ 9,549,716	$ 7,949,816	$ 4,968,363	$ 7,605,721	

Life Cycle Cost for Each Construction Method

Life Cycle Cost Comparison

“P2 LCC Analysis” Tab

Figure 78. Screenshot. LCC comparison for all construction methods for completed bridge 4.

Calculating the Accuracy of the Developed DST

This section focuses on calculating the accuracy of the developed DST by comparing its estimated construction cost to the IDOT-reported construction cost for each of the four completed/ongoing IDOT bridge projects. The four bridge projects can be grouped into two main categories based on their construction methods: (a) conventional construction method (two bridge projects) and (b) prefabricated elements/systems construction method (two bridge projects).

Accuracy of Conventional Construction Method Cost Estimates

The accuracy of the developed DST in estimating the cost of conventional construction bridge projects was analyzed using two bridge projects, as shown in Table 4. For example, the accuracy of the developed DST in estimating the construction cost of the first bridge project was 92.75% based on its estimated unit cost of $281.47/sf and IDOT-reported cost of $303.46/sf, as shown in Table 4. Similarly, the accuracy of the developed DST in estimating the construction cost of the second bridge project was 87.32% based on its estimated unit cost of $292.47/sf and IDOT-reported cost of $355.51/sf. The average accuracy of the developed DST for all bridge projects that utilized the conventional construction method was 90.04%, as shown in Table 4.

Table 4. Accuracy of DST Cost Estimates for Conventional Bridge Construction Method

Case Study	Structure Number	Reported Cost in $/sf	Predicted Cost in $/sf	Accuracy
1	SN 051-0008	$303.46	$281.47	92.75%
2	SN 022-0001	$355.51	$292.96	87.32%
Average Accuracy				**90.04%**

Accuracy of Prefabricated Construction Method Cost Estimates

The accuracy of the developed DST in estimating the cost of prefabricated construction bridge projects was analyzed using two bridge projects, as shown in Table 5. For example, the accuracy of the developed DST in estimating the construction cost of the first bridge project is 99.88% based on its estimated unit cost of $295.37/sf and IDOT-reported unit cost of $295.72/sf, as shown in Table 5. Similarly, the accuracy for the second bridge project was 82.27% based on its estimated unit cost of $274.06/sf and IDOT-reported unit cost of $333.14/sf. The average accuracy of the developed DST for the two analyzed prefabricated bridge projects was 91.07%, as shown in Table 5.

Table 5. Accuracy of DST Cost Estimates for Prefabricated Bridge Construction Method

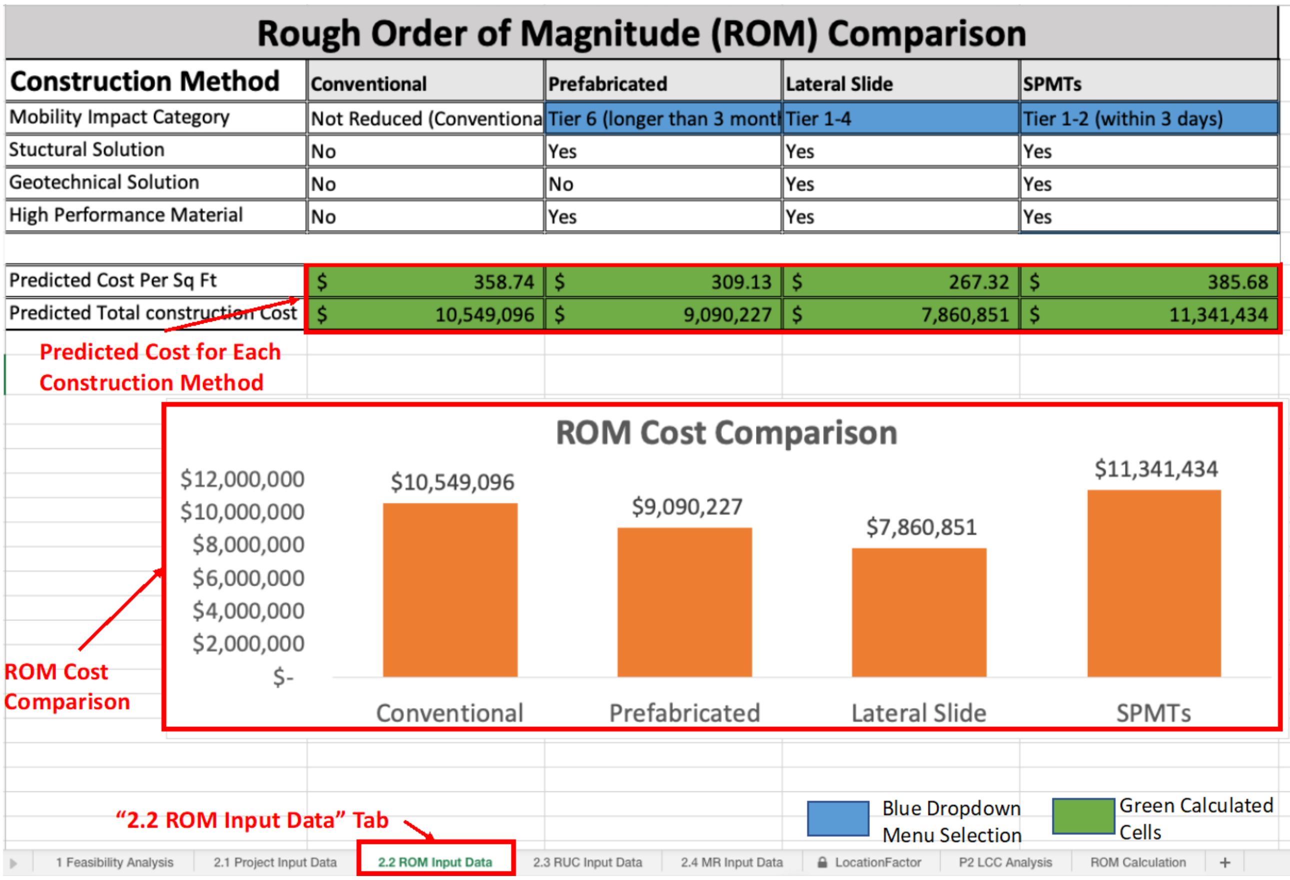
Case Study	Structure Number	Reported Cost in $/sf	Predicted Cost in $/sf	Accuracy
3	SN 044-0053	$ 295.72	$ 295.37	99.88%
4	SN 092-0087	$ 333.14	$ 274.06	82.27%
Average Accuracy				**91.07%**

FUTURE IDOT BRIDGE PROJECTS

This section focuses on analyzing a representative sample of five future IDOT bridge construction projects using the developed DST to estimate and compare the construction cost, road user cost, annual maintenance and rehabilitation costs, and total life cycle cost of each feasible bridge construction method including conventional, prefabricated, lateral slide, and SPMT. This enables IDOT planners to analyze the cost of all feasible construction methods for each bridge project in order to identify the most cost-effective method. The first future case study is included in the following section while the remaining four future case studies are included in Appendix E.

Bridge 1: Bridge Replacement Oakton Street over I-94

The scope of this project is to replace an existing bridge (SN 016-0827) with a new bridge. This bridge project is in District 1 and has a bridge length of 348 feet, bridge width of 84.5 feet, project length of 1621.68 feet, max span length of 114.4 feet, 5 lanes, 2 spans, girder design, urban location, ADT of 133,800 vehicles/day, steel beam, and concrete deck. The project is planned to be built in 2024 with a predicted inflation rate of 2.3% from 2023. The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 79. The estimated construction unit cost is $358,74/sf for conventional construction, $309,13/sf for prefabricated elements/systems, $267.32/sf for lateral slide, and $385.68/sf for SPMT, as shown in Figure 79.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventiona	Tier 6 (longer than 3 montl	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 358.74	$ 309.13	$ 267.32	$ 385.68
Predicted Total construction Cost	$ 10,549,096	$ 9,090,227	$ 7,860,851	$ 11,341,434

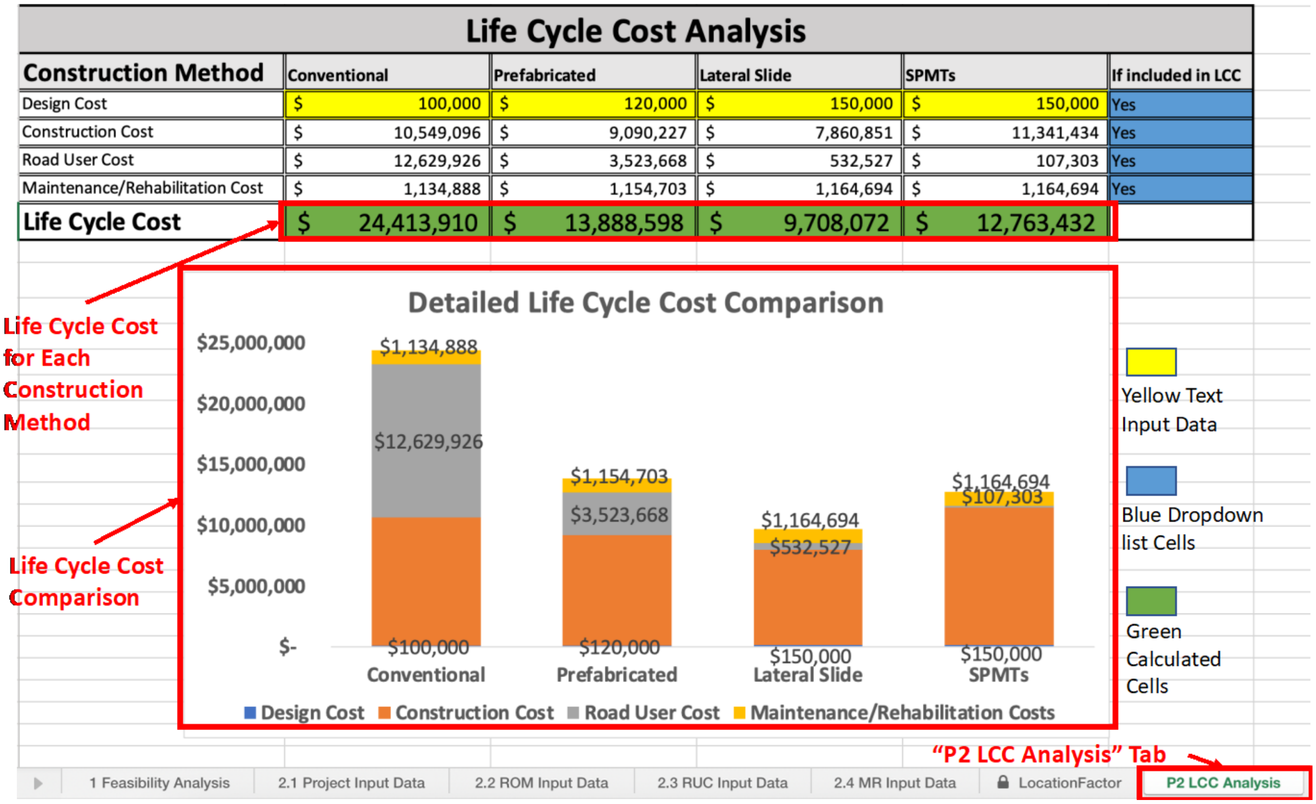
Predicted Cost for Each Construction Method

ROM Cost Comparison

“2.2 ROM Input Data” Tab

Figure 79. Screenshot. ROM comparison for bridge construction methods for future project 1.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 80. For this project, the road user cost input data include the average speed limit during normal conditions of 55 mph, the average speed limit under construction of 40 mph, the project length with a detour of 1 mile, and the total duration of the project was assumed to be 360 days using conventional construction, 100 days for the prefabricated elements/systems construction, 15 days for the lateral slide construction method, and 1 day for SPMT. The DST estimated life cycle cost for this project was $24,413,910 for conventional construction, $13,888,598 for prefabricated elements/systems, $9,708,072 for lateral slide, and $12,763,432 for SPMT, as shown in Figure 80.



Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 10,549,096	$ 9,090,227	$ 7,860,851	$ 11,341,434	Yes
Road User Cost	$ 12,629,926	$ 3,523,668	$ 532,527	$ 107,303	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	$ 24,413,910	$ 13,888,598	$ 9,708,072	$ 12,763,432	

Life Cycle Cost for Each Construction Method

Life Cycle Cost Comparison

🟨 Yellow Text Input Data

🟦 Blue Dropdown list Cells

🟩 Green Calculated Cells

"P2 LCC Analysis" Tab

Figure 80. Screenshot. LCC comparison for all construction methods for future project 1.

CHAPTER 6: FUTURE RESEARCH

During this study, the research team identified two promising research areas that need further in-depth analysis and investigation. To further improve the performance of the developed decision support tool (DST), future research can focus on (1) expanding the size of the collected dataset of bridge projects that were used in developing ROM cost-estimating models for all considered conventional and accelerated bridge construction methods and (2) developing and evaluating the performance of additional machine learning models for predicting the construction cost of bridge projects to improve the accuracy and reliability of the developed DST.

FUTURE RESEARCH 1: EXPANDING DATASET OF BRIDGE PROJECTS

Problem Statement

The performance and accuracy of the developed cost-estimating modules are significantly impacted by the size of the dataset used in their training and testing. The size of the dataset that was used in developing predictive models for each construction method was limited to the historical bridge construction projects data available on the IDOT Notice of Lettings website and the FHWA National ABC Project Exchange database. For example, the available datasets for the lateral slide and SPMT bridge construction methods included data for only seven and five completed bridge projects, respectively. These small datasets for lateral slide and SPMT construction methods limit the use of their developed predictive models because the reliability of their estimates cannot be guaranteed. Accordingly, there is a pressing need to expand the size of these small datasets to include additional bridge projects in order to develop more accurate and reliable cost-estimating models that can be used by IDOT planners and decision-makers to predict the construction cost of conventional and accelerated bridge construction methods.

Objective and Scope of Proposed Research

The objectives of this proposed research are to (1) collect and analyze additional historical cost data of various bridge projects especially lateral slide and SPMT from all available state and federal DOT sources, (2) collect data on recently completed accelerated bridge construction methods that were previously grouped under the category of “Other ABC methods” due to the limited number of completed projects in existing database, (3) expand the developed database for all conventional and accelerated bridge construction methods, (4) develop and evaluate the performance of additional predictive models for all considered bridge construction methods, and (5) update the developed DST to integrate the newly developed construction cost-estimating models.

Expected Outcome

The deliverables of this proposed research would enable IDOT to (1) improve the accuracy of their cost estimates for conventional and prefabricated bridge construction methods and (2) generate reliable cost estimates for lateral slide and SPMT bridge construction methods.

FUTURE RESEARCH 2: DEVELOPING ADDITIONAL MACHINE LEARNING MODELS

Problem Statement

According to the results in this study, the accuracy of the developed cost-estimating models using ML is higher than that of MLR models for both conventional construction and prefabricated bridge elements/systems construction methods. Accordingly, there is a need to develop and evaluate the performance of additional machine learning models using promising ML techniques such as XGBoost for predicting the construction cost of bridge projects to improve the accuracy and reliability of the developed DST.

Objective and Scope of Proposed Research

The objectives of this proposed research are to (1) collect and analyze additional historical cost data of various bridge projects to create an expanded dataset that can be used in developing ML models, (2) expand the developed database for all conventional and accelerated bridge construction methods, (3) develop and evaluate the performance of additional ML predictive models for all considered bridge construction methods, and (4) update the developed DST to integrate the newly developed construction cost-estimating models.

Expected Outcome

The deliverables of this proposed research would enable IDOT to improve the accuracy of the developed cost-estimating models for all bridge construction methods that can be used during the early project phases such as Phase I engineering reports based on early planning parameters.

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APPENDIX A: DESCRIPTION OF DATA FIELDS IN THE CREATED BRIDGE COST DATABASE

Table 6. Data Fields in the Bridge Cost Database

Data Field	**Description**
Source	This field includes information about the source of the bridge project. For example, IDOT records or FHWA National ABC Project Exchange.
Link	This field includes a hyperlink to the source of the project data.
Project Name/ Structure Number	This field includes information about project name. For example, project name for FHWA National ABC Project Exchange projects and structure number for all IDOT projects.
Zip Code	This field includes the first 3-digits of the zip code for each project using its location to be used in adjusting its cost by location factor. For example, Champaign, IL zip code is 618.
Year Bridge Built	This field includes year of construction built to be used in adjusting its cost by time factor.
Construction Methods/Equipment	This field includes information about the construction methods and/or equipment used in the construction of the bridge project. It can only include one of the following five values: conventional, prefabricated elements/systems, lateral slide, or SPMT.
Design Type	This field includes information about the structural system of the bridge project. It can only include one of the six following values: beam, slab, girder, arch, truss, culvert.
Location Type	This field includes information about location type based on its zip code. It can only include one of two possible values: rural or urban
Project Type	This field includes information about the scope of the construction project. It can only include one of two possible values: new or replace.
Deck Material	This field includes information about the construction material of the bridge deck. It can include one of these three values: concrete, steel, or other material.
Beam Material	This field includes information about the construction material of the bridge beams. It can include one of these two values: concrete, or steel.
Mobility Impact Category	This field includes information about the duration of road closure for the bridge project. It can include one of these seven possible values: Tier 1 (within 1 day), Tier 2 (within 3 days), Tier 3 (within 2 weeks), Tier 4 (within 1 month), Tier 5 (within 3 months), Tier 6 (longer than 3 months), and Not Reduced (Conventional)

Data Field	**Description**
High Performance Materials	This field indicates the use of high-performance material in the bridge project. It can only have Yes or No values.
Structural Solutions	This field indicates the use of structural solution such as prefabricated elements in the bridge project. It can only have Yes or No values.
Geotechnical Solutions	This field indicates the use of geotechnical solutions in the bridge foundation and walls. It can only have Yes or No values.
Average Daily Traffic (ADT)	This field includes information about the ADT of the bridge.
Number of Lanes	This field includes number of lanes of the bridge.
Number of Spans	This field includes number of spans of the bridge.
Max Span Length	This field includes max span length of the bridge in feet.
Total Project Length	This field includes the total projects length in feet for only IDOT records projects.
Bridge Width	This field includes bridge width in feet.
Bridge Length	This field includes bridge length in feet.
Total Cost	This field includes the reported total cost of the project in US dollars.
Adjusted Total Project Cost 2023	This field includes the adjusted total cost of the project in US dollars for 2023.
Adjusted Cost/sq Ft 2023	This field includes the adjusted cost per square foot of the project in US dollars for 2023.
Current Year Adjusted Cost/sf	This field includes the adjusted cost per square foot of the project in US dollars for any future year.

APPENDIX B: SAMPLE TRAINING AND TESTING DATASETS FOR DEVELOPED CONVENTIONAL CONSTRUCTION MODELS

Table 7. Sample Training Dataset for Conventional Construction MLR Model

Project Name (SN)	Zip Code	Year Built	Design Type	…	ADT	No of Lanes	No of Spans	Project Length	Bridge Width	Bridge length	Adjusted Total Cost 2023	Adjusted Cost/sf
038-0219	609	2015	Girder	…	3300	2	4	2246.7	43.2	406.0	$ 5,728,314.5	$ 326.6
053-0185	604	2010	Slab	…	2400	2	3	650.0	39.6	143.2	$ 1,222,921.5	$ 215.7
078-2008	613	2007	Culvert	…	5595	2	2	656.2	19.7	154.8	$ 876,601.1	$ 287.6
088-0032	614	2018	Girder	…	2000	2	1	730.0	39.2	178.6	$ 2,450,312.5	$ 350.0
057-0242	617	2007	Girder	…	2400	2	1	800.0	35.2	140.0	$ 1,052,793.3	$ 213.6
057-0243	617	2015	Girder	…	800	2	1	194.0	35.2	194.0	$ 1,796,255.9	$ 263.0
010-0292	605	2015	Beam	…	2350	2	1	569.7	32.0	129.3	$ 758,412.7	$ 183.3
059-0504	620	2007	Girder	…	3150	2	1	1100.0	39.2	149.0	$ 1,638,931.8	$ 280.6
058-0135	617	2007	Slab	…	17115	2	3	600.0	82.0	207.7	$ 4,197,964.8	$ 246.5
018-0011	624	2015	Girder	…	2850	2	3	940.0	36.0	200.6	$ 1,719,673.6	$ 238.1
093-0026	624	2014	Slab	…	4850	2	3	550.0	42.6	142.3	$ 1,775,897.7	$ 293.0
096-0070	624	2015	Girder	…	1199	2	1	1050.0	35.2	135.0	$ 1,648,437.7	$ 346.9
018-0064	624	2010	Girder	…	2170	2	3	970.0	39.2	247.0	$ 3,357,758.4	$ 346.8
070-2020	619	2018	Culvert	…	1850	2	2	60.0	20.7	60.0	$ 667,090.4	$ 537.1
082-0387	622	2007	Girder	…	2800	2	3	900.0	39.2	333.0	$ 3,305,056.5	$ 253.2
060-0236	620	2007	Slab	…	4200	2	3	68.6	47.2	128.6	$ 1,338,175.4	$ 220.4
060-0340	620	2007	Girder	…	3500	2	5	1467.6	39.1	448.0	$ 3,555,328.8	$ 203.0
028-0084	628	2010	Girder	…	4190	2	1	546.7	39.3	133.0	$ 1,068,552.0	$ 204.4
041-0110	628	2018	Girder	…	3550	2	2	850.0	39.1	204.0	$ 1,912,611.8	$ 239.8
035-0017	629	2015	Girder	…	1328	2	3	456.8	35.1	191.5	$ 1,933,893.6	$ 287.7
097-0079	628	2014	Slab	…	4890	2	3	353.8	43.1	125.5	$ 1,753,190.4	$ 324.1
010-0285	605	2010	Girder	…	650	2	2	420.0	31.2	280.0	$ 3,191,092.1	$ 365.3
020-0061	617	2010	Girder	…	1800	2	1	500.0	35.2	113.0	$ 1,031,646.6	$ 259.4
010-0276	608	2007	Slab	…	3100	2	3	809.0	39.2	142.0	$ 1,142,207.3	$ 205.2
016-2858	600	2008	Girder	…	12920	4	3	555.0	80.2	274.7	$ 5,394,613.9	$ 244.9

Project Name (SN)	Zip Code	Year Built	Design Type	…	ADT	No of Lanes	No of Spans	Project Length	Bridge Width	Bridge length	Adjusted Total Cost 2023	Adjusted Cost/sf
056-0277	600	2011	Girder	…	2400	2	3	1555.0	48.3	204.0	$ 2,695,211.4	$ 273.5
016-3035	600	2014	Girder	…	54000	5	3	1468.0	106.1	255.3	$ 11,293,456.1	$ 416.9
016-1302	600	2018	Girder	…	25400	4	3	884.0	95.8	216.0	$ 5,760,455.7	$ 278.4
045-0078	601	2013	Girder	…	5600	2	1	1650.0	43.2	129.0	$ 1,935,345.8	$ 347.3
049-0601	600	2018	Girder	…	9900	2	1	1359.0	45.8	215.0	$ 3,014,015.9	$ 306.1
049-0601	600	2018	Girder	…	9900	2	1	1359.0	45.7	125.1	$ 3,014,015.9	$ 527.2
049-6559	600	2018	Girder	…	300	2	3	853.6	36.0	241.5	$ 2,804,773.1	$ 322.6
016-6055	606	2019	Beam	…	3300	2	1	232.8	45.0	132.8	$ 589,005.9	$ 98.5
056-6014	600	2018	Beam	…	7300	2	2	139.0	60.0	121.0	$ 2,622,736.4	$ 361.3
099-3072	604	2020	Slab	…	700	2	1	108.0	33.2	105.3	$ 1,318,583.1	$ 377.2
056-3118	600	2019	Slab	…	550	2	3	425.0	38.0	105.9	$ 727,582.9	$ 180.8
045-9127	620	2019	Beam	…	2000	2	3	247.0	36.0	113.5	$ 1,009,127.1	$ 247.0
099-9101	604	2019	Beam	…	2150	2	3	545.0	30.0	104.0	$ 926,486.4	$ 297.0
016-6665	600	2021	Beam	…	2800	2	1	601.0	44.4	169.4	$ 3,174,509.4	$ 422.1
099-6480	604	2021	Arch	…	725	2	1	300.0	42.0	105.6	$ 2,053,565.6	$ 463.0
016-7612	601	2021	Beam	…	1750	2	1	84.0	44.0	86.0	$ 527,115.3	$ 139.3
022-7470	606	2021	Culvert	…	400	3	2	868.8	37.0	105.0	$ 1,065,144.7	$ 274.2
056-0078	600	2008	Girder	…	9960	2	1	1005.0	43.2	138.0	$ 2,726,479.9	$ 457.3
099-0286	604	2019	Girder	…	55500	2	5	1374.6	42.9	660.9	$ 7,710,892.4	$ 272.0
006-0181	612	2011	Girder	…	1600	2	2	982.0	35.2	205.0	$ 1,753,767.8	$ 243.0
006-0188	612	2018	Slab	…	1550	2	3	830.0	35.2	130.0	$ 1,314,722.8	$ 287.3
019-0049	601	2016	Girder	…	3550	2	1	600.0	43.2	140.3	$ 1,443,086.4	$ 238.1
046-0152	609	2017	Girder	…	3000	2	1	600.0	39.2	142.0	$ 1,551,238.5	$ 278.7
027-0104	609	2018	Girder	…	3450	2	3	700.0	36.0	253.0	$ 1,673,097.1	$ 183.7
046-0063	609	2021	Girder	…	19158	4	3	2515.0	60.0	300.0	$ 5,728,287.6	$ 318.2
036-0052	614	2008	Girder	…	6300	2	1	795.0	43.2	175.0	$ 2,538,361.9	$ 335.8
…..	…..	…..	…..	…	…..	…..	…..	…..	…..	…..	…..	…..

Table 8. Sample Testing Dataset for Conventional Construction MLR Model

Project Name (SN)	Zip Code	Year	Design Type	…	ADT	No of Lanes	Project Length	Bridge Width	Bridge length	Adjusted Total Cost 2023	Adjusted Cost/sf
051-2010	624	2022	Girder	…	2800	2	800.0	33.4	117.0	$ 1,206,369.3	$ 308.7
022-2036	601	2021	Girder	…	122000	8	990.3	157.0	330.0	$ 15,562,231.7	$ 300.4
053-0181	604	2007	Slab	…	1950	2	380.0	49.2	151.0	$ 1,531,342.3	$ 206.1
055-0079	614	2010	Girder	…	800	2	3179.5	35.2	154.7	$ 2,955,215.7	$ 542.7
066-0021	612	2018	Girder	…	2100	2	2856.2	35.2	669.7	$ 6,735,236.5	$ 285.7
036-6073	614	2015	Girder	…	3850	2	1650.0	36.0	260.0	$ 2,503,693.2	$ 267.5
092-0203	609	2008	Girder	…	1050	2	220.0	35.2	220.0	$ 3,888,629.8	$ 502.1
057-0255	617	2015	Girder	…	1350	2	200.0	35.2	138.0	$ 1,147,305.5	$ 236.2
010-0275	605	2007	Girder	…	2300	2	540.0	35.2	195.0	$ 1,438,832.4	$ 209.6
016-2417	604	2019	Beam	…	5000	3	1270.0	62.0	148.5	$ 2,289,886.9	$ 248.7
056-3029	600	2018	Beam	…	1993	2	1300.0	43.4	516.0	$ 4,002,933.6	$ 178.7
056-3213	600	2019	Girder	…	500	2	1291.0	34.0	151.3	$ 1,695,105.6	$ 329.5
045-3161	601	2019	Slab	…	8200	2	753.0	40.0	171.5	$ 2,148,584.0	$ 313.2
016-2544	605	2019	Slab	…	27900	4	658.4	69.2	81.8	$ 1,349,236.1	$ 238.4
101-2050	610	2019	Culvert	…	7800	4	10261.2	52.2	266.0	$ 6,246,356.3	$ 449.9
006-0182	612	2011	Slab	…	1320	2	977.5	35.2	165.0	$ 1,246,291.5	$ 214.6
038-0220	609	2011	Slab	…	1130	2	615.0	35.2	136.0	$ 1,251,339.9	$ 261.4
046-0035	609	2019	Girder	…	13200	2	820.0	90.4	177.0	$ 3,941,168.5	$ 246.3
029-0076	614	2017	Beam	…	600	2	3377.0	28.0	111.2	$ 775,659.7	$ 249.1
102-0069	615	2011	Girder	…	1650	2	800.0	35.2	179.0	$ 1,465,012.5	$ 232.5
054-0514	617	2010	Girder	…	1450	2	1027.0	39.2	230.0	$ 2,619,624.3	$ 290.6
051-0064	624	2017	Girder	…	3700	2	1910.0	43.0	579.0	$ 8,853,926.3	$ 355.6
018-0057	624	2020	Slab	…	2200	2	108.9	36.0	108.9	$ 1,511,592.9	$ 385.5
070-0003	619	2018	Girder	…	5800	2	782.0	40.0	283.0	$ 2,217,007.0	$ 195.8
025-0080	624	2019	Girder	…	2800	2	1222.0	43.2	498.6	$ 3,681,956.6	$ 170.9

Project Name (SN)	Zip Code	Year	Design Type	…	ADT	No of Lanes	Project Length	Bridge Width	Bridge length	Adjusted Total Cost 2023	Adjusted Cost/sf
060-0349	620	2018	Girder	…	10000	2	1505.0	24.0	310.0	$ 2,771,724.8	$ 372.5
044-0004	629	2019	Beam	…	2100	2	303.0	36.0	164.4	$ 2,034,803.6	$ 343.8
044-0053	629	2021	Beam	…	6900	2	420.1	42.9	175.0	$ 2,401,451.5	$ 319.9
047-6401	605	2018	Beam	…	600	2	1118.7	32.0	128.0	$ 1,221,925.3	$ 298.3
019-4016	605	2020	Slab	…	150	2	600.0	27.0	317.3	$ 1,973,032.3	$ 230.3
021-4003	620	2021	Slab	…	200	2	635.0	30.0	208.0	$ 1,381,746.7	$ 221.4
010-0122	618	2021	Beam	…	650	2	400.0	32.2	183.9	$ 1,281,372.8	$ 216.4
059-3017	626	2018	Beam	…	125	2	800.0	30.0	267.0	$ 1,093,637.4	$ 136.5
075-3328	623	2019	Girder	…	398	2	800.0	32.0	280.0	$ 1,880,900.1	$ 209.9
026-3472	624	2019	Beam	…	150	2	850.0	22.0	181.9	$ 731,323.3	$ 182.7
060-3078	620	2021	Girder	…	850	1	630.7	36.5	129.5	$ 1,336,057.5	$ 282.7

APPENDIX C: SAMPLE PERFORMANCE EVALUATION OF DEVELOPED MODELS

Table 9. Sample Performance Evaluation of Developed Models for Conventional Construction

MAPE	R Squared	Model Type	Normalized MAPE	Normalized R Squared	Overall Score	Rank	# of Variables	Variables
14.32%	44.90%	ML	0.94	0.44	0.81	1*	19	Ln (No of Spans), Ln (Bridge length), Project Length, Project Type New, Design Type Arch, Design Type Culvert, Design Type Girder, Beam Material Concrete, Project Type Replace, Design Type Truss, Design Type Slab, Max Span Length, Design Type Beam, Ln (ADT), Deck Material Concrete, Deck Material Steel, Beam Material Steel, Location Type Urban, Ln (Bridge Width)
13.62%	39.85%	ML	1.00	0.20	0.80	2	12	Ln (No of Lanes), Project Type Replace, Location Type Urban, Max Span Length, Ln (Bridge length), Design Type Beam, Design Type Truss, Design Type Arch, Ln (No of Spans), Deck Material Concrete, Project Length, Design Type Girder
13.66%	39.99%	ML	1.00	0.21	0.80	3	16	Deck Material Concrete, Location Type Urban, Ln (Bridge length), Deck Material Steel, Design Type Girder, Location Type Rural, Design Type Beam, Design Type Truss, No of Lanes, Project Type New, Project Length, Ln (Bridge Width), Design Type Arch, Project Type Replace, Max Span Length, Ln (No of Spans)
13.71%	40.08%	ML	0.99	0.21	0.80	4	16	Deck Material Concrete, Location Type Urban, Ln (Bridge length), Deck Material Steel, Design Type Girder, Location Type Rural, Design Type Beam, Design Type Truss, Ln (No of Lanes), Project Type New, Project Length, Ln (Bridge Width), Design Type Arch, Project Type Replace, Max Span Length, Ln (No of Spans)
14.73%	47.01%	ML	0.90	0.54	0.80	5	20	Ln (No of Spans), Ln (No of Lanes), Design Type Truss, Design Type Beam, Beam Material Steel, Ln (ADT), Design Type Culvert, Project Type Replace, Project Type New, Location Type Urban, Design Type Arch, Ln (Bridge Width), Design Type Slab, Project Length, Max Span Length, Location Type Rural, Ln (Bridge length), Design Type Girder, Beam Material Concrete, Deck Material Concrete
…	…	…	…	…	…	…	…	…
20.34%	45.29%	MLR	0.38	0.45	0.40	79	7	Design Type Truss, Design Type Culvert, Project Type Replace, ADT, No of Lanes, Project Length, Ln (Bridge Length)
20.56%	46.24%	MLR	0.36	0.50	0.39	80	9	Design Type Truss, Design Type Culvert, Project Type Replace, ADT, No of Lanes, Project Length, Ln (No of Spans), Ln (Max Span Length), Ln (Bridge Length)
20.57%	46.12%	MLR	0.36	0.49	0.39	81	8	Design Type Truss, Design Type Culvert, Project Type Replace, ADT, No of Lanes, Project Length, Ln (Max Span Length), Ln (Bridge Length)
….	….	….	…	…	….	….	….	….

*Selected Model for projects Utilizing conventional construction method

Table 10. Sample Performance Evaluation of Developed Models for Prefabricated Construction Method

MAPE	R Squared	Model Type	Normalized MAPE	Normalized R Squared	Overall Score	Rank	# of Variables	Variables
13.20%	34.62%	ML	0.96	0.34	0.81	1*	13	Ln (Project Length), Design Type Beam, Max Span Length, Beam Material (Concrete), Ln (Bridge length), Ln (ADT), No of Lanes, Design Type Slab, No of Spans, Bridge Width, Project Type (Replace), Design Type (Culvert), MIC, Design Type (Girder)
12.39%	28.71%	ML	1.00	0.20	0.80	2	13	No of Spans, ADT, Beam Material (Steel), Bridge Width, MIC, Design Type (Beam), Design Type Girder, Location Type (Urban), Beam Material (Concrete), Ln (No of Lanes), Ln (Project Length), Location Type (Rural), Ln (Bridge length)
12.62%	29.44%	ML	0.99	0.22	0.80	3	15	Location Type (Rural), Ln (Project Length), No of Spans, Design Type Slab, Design Type (Culvert), Beam Material (Concrete), Design Type (Beam), ADT, Beam Material (Steel), Ln (Bridge length, Design Type (Girder), Location Type (Urban), MIC, Ln (Max Span Length), Project Type (Replace)
13.31%	31.54%	ML	0.96	0.27	0.79	4	14	Design Type (Girder), ADT, Ln (Bridge Width), MIC, Beam Material (Steel), Location Type (Urban), No of Lanes, Design Type (Beam), Max Span Length, Ln (Bridge length), Ln (Project Length), Project Type (Replace), No of Spans, Location Type (Rural)
…	…	…	…	…	…	…	…	…
25.38%	46.80%	MLR Stepwise	0.44	0.64	0.49	92	10	Design Type (Slab), Design Type (Culvert), Beam Material (Steel), ADT, Bridge length, MIC, Ln (No of Spans), Ln (Max Span Length), Ln (Project Length), Ln (Bridge Width)
25.65%	45.69%	MLR	0.42	0.61	0.47	93	10	Design Type (Slab), Design Type (Girder), Design Type (Culvert), ADT, Bridge length, No of Spans, MIC, Ln (Max Span length), Ln (Project Length), Ln (Bridge Width)
29.69%	60.72%	ML	0.25	0.98	0.43	94	13	Ln (Project Length), No of Lanes, Project Type (Replace), Design Type (Beam), ADT, Design Type (Girder), Max Span Length, Ln (Bridge length), MIC, Ln (Bridge Width), Beam Material (Steel), Beam Material (Concrete), Location Type (Rural)
29.73%	60.78%	ML	0.25	0.98	0.43	95	15	Ln (No of Lanes), Design Type (Girder), Design Type (Beam), Beam Material (Steel), Location Type (Urban), Ln (Bridge length), No of Spans, Location Type (Rural), Ln (Bridge Width), Max Span Length, Project Type (Replace), Ln (Project Length), MIC, Beam Material (Concrete), ADT
…	…	…	…	…	…	…	…	…

*Selected Model for projects Utilizing Prefabricated Construction Method

Table 11. Sample Performance Evaluation of Developed Models for Lateral Slide Construction Method

MAPE	R Squared	Model Type	Normalized MAPE	Normalized R Squared	Overall Score	Rank	# of Variables	Variables
18.52%	91.66%	MLR	1.00	0.96	0.99	1*	5	MIC 5, MIC 6, Ln length, Ln no of spans, beam material
22.89%	91.46%	MLR	0.94	0.95	0.95	2	5	Using Barge, Beam Material, MIC5, HPM, Ln (Bridge length)
22.84%	91.14%	MLR	0.94	0.95	0.95	3	3	MIC5, Ln (Bridge Length), Design Type (Girder)
24.92%	82.28%	MLR	0.92	0.85	0.90	4	2	MIC5, Ln (Bridge Length)
27.95%	89.67%	MLR	0.88	0.93	0.89	5	4	MIC5, Ln (Bridge Length), Design Type (Truss), MIC6
27.95%	89.67%	MLR	0.88	0.93	0.89	6	4	Using Barge, MIC5, MIC6, Ln (Bridge length)
29.29%	89.66%	MLR	0.86	0.93	0.88	7	5	Using Barge, MIC5, MIC6, Ln (Bridge length), Ln (ADT)
30.74%	89.58%	MLR	0.84	0.93	0.87	8	4	MIC5, MIC6, Ln (Bridge length), Geotechnical Solution
31.72%	89.67%	MLR	0.83	0.93	0.86	9	4	MIC5, Ln (Bridge Length), Geotechnical Solution(yes), MIC6
31.79%	89.26%	MLR	0.83	0.93	0.86	10	2	Design Type (Truss), MIC5
28.38%	77.17%	MLR	0.87	0.80	0.86	11	2	MIC5, Ln (Bridge length)
34.29%	88.97%	MLR	0.80	0.93	0.83	12	3	MIC5, Ln (Bridge length), Geotechnical Solution
34.95%	90.02%	MLR	0.79	0.94	0.83	13	3	MIC5, Ln (Bridge Length), Beam material(steel)
30.89%	75.62%	MLR	0.84	0.78	0.83	14	1	Bridge width
36.71%	93.07%	MLR	0.77	0.97	0.82	15	6	Using Barge, MIC3, Design Type (Girder), HPM, Bridge width, Ln (ADT)
35.84%	88.40%	MLR	0.78	0.92	0.81	16	2	Design Type (Truss), MIC5
38.16%	90.63%	MLR	0.75	0.94	0.80	17	5	Using Barge, Design Type (Girder), MIC5, HPM, Ln (Bridge Length)
39.54%	88.97%	MLR	0.73	0.93	0.78	18	3	MIC5, Ln (Bridge length), Using Barge
39.98%	89.56%	MLR	0.73	0.93	0.78	19	4	MIC5, MIC6, Ln (Bridge length), Using Barge
42.86%	95.70%	MLR	0.69	1.00	0.77	20	7	Location Type, Ln (ADT), HPM, MIC3, MIC2, MIC5
22.19%	22.11%	MLR	0.95	0.20	0.76	21	1	MIC5
….	….	….	….	….	….	….	….	….

*Selected Model for projects Utilizing Lateral Slide Construction Method

Table 12. Performance Evaluation of Developed Models for SPMT Construction Method

MAPE	R Squared	Model Type	Normalized MAPE	Normalized R Squared	Overall Score	Rank	# of Variables	Variables
7.57%	73.95%	MLR	1.00	0.23	0.81	1*	1	No of spans
18.76%	89.00%	MLR	0.84	0.68	0.80	2	3	Design type (girder), MIC (tier 5), max span length
21.55%	90.00%	MLR	0.81	0.71	0.78	3	3	MIC (tier 2), barge, ln max span length
15.18%	74.94%	MLR	0.89	0.26	0.74	4	1	Ln no of spans
14.08%	73.29%	MLR	0.91	0.21	0.74	5	1	Max span length
22.72%	72.85%	MLR	0.79	0.20	0.64	6	1	Ln max span length
42.16%	99.97%	MLR	0.52	1.00	0.64	7	2	Beam material, ln no of spans
42.16%	99.36%	MLR	0.52	0.98	0.63	8	2	Beam material, ln no of spans
49.33%	99.94%	MLR	0.42	1.00	0.56	9	2	MIC (tier 2), bridge length
50.74%	99.37%	MLR	0.40	0.98	0.54	10	2	Bridge length, MIC (tier 2)
55.10%	100.00%	MLR	0.34	1.00	0.50	11	3	Beam material, barge, ln max span length
65.04%	99.88%	MLR	0.20	1.00	0.40	12	2	Design type (girder), bridge width

*Selected Model for projects Utilizing SPMT Construction Method

APPENDIX D: LIMITATION OF DEVELOPED COST-ESTIMATING MODELS

Table 13. Limitation of Developed Cost-Estimating Models

Variable	Developed Model for Conventional	Developed Model for Prefabricated	Developed Model for Lateral Slide*	Developed Model for SPMT**
Project length	Less than 10,260 feet	Less than 4,210 feet	N/A	N/A
Bridge length	Less than 1,240 feet	Less than 3,085 feet	Less than 670 feet	Less than 1,117 feet
Bridge width	Less than 160 feet	Less than 90 feet	Less than 125 feet	Less than 77 feet
Number of spans	less than 7 spans	less than 7 spans	less than 5 spans	less than 5 spans
Number of lanes	less than 8 lanes	Less than 5 lanes	Less than 5 lanes	Less than 5 lanes
Max Span Length	Less than 214 feet	Less than 375 feet	Less than 165 feet	Less than 365 feet
ADT	less than 122,000 vehicles/day	less than 285,600 vehicles/day	Less than 298,000 vehicles/day	Less than 66,000 vehicles/day
MIC	N/A	Only MIC = 5 or 6	MIC 0 - MIC 6	Only MIC = 1, 2, or 5
Design Type	Slab, beam, culvert, girder, arch, or truss	Only slab, beam, culvert, or girder	Only slab or girder	Only beam, or girder
Deck Material	Concrete or steel	Only Concrete	Only Concrete	Only Concrete
Beam Material	Concrete or steel	Concrete or steel	Concrete or steel	Concrete or steel
Project Type	New or replace	Only replace	Only replace	Only replace
Location Type	Urban or rural	Urban or rural	Urban or rural	Urban or rural
High performance Material	N/A	No	Yes or no	No
Geotechnical Solution	N/A	No	No	Yes or no
Structural Solution	N/A	Yes	Yes or no	Yes

* Should be used with caution due to the limited data (only 7 bridge projects available)

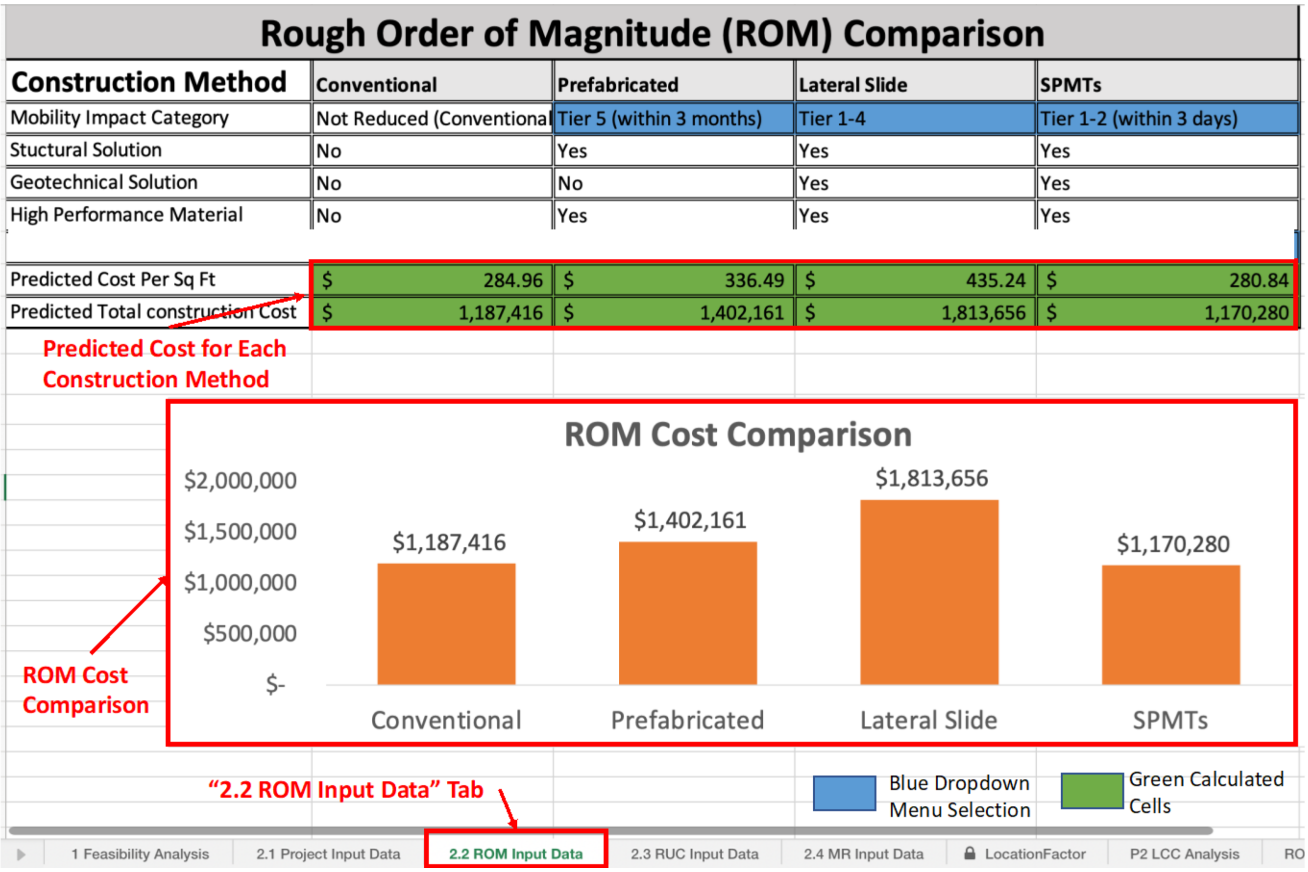
** Should be used with caution due to the limited data (only 5 bridge projects available)

APPENDIX E: FUTURE IDOT BRIDGE PROJECTS

This section focuses on analyzing a representative sample of four additional future IDOT bridge construction projects using the developed DST to estimate and compare the construction cost, road user cost, annual maintenance and rehabilitation costs, and total life cycle cost of each feasible bridge construction method including conventional, prefabricated, lateral slide, and SPMT. This enables IDOT planners to analyze the cost of all feasible construction methods for each bridge project in order to identify the most cost-effective method.

BRIDGE REPLACEMENT IL 1 OVER STREAM

The scope of this project is to replace an existing bridge (SN 051-0001) with a new bridge. This bridge project is located in District 7 and has bridge length of 90 feet, bridge width of 46.3 feet, project length of 140 feet, max span length of 29 feet, 2 lanes, 1 span, slab design, rural location, ADT of 3,800 vehicles/day, concrete beam, and concrete deck. The project is planned to be built in 2024 with a predicted inflation rate of 2.3% from 2023.The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 81. The estimated construction unit cost is $284.96/sf for conventional construction, $336.49 /sf for prefabricated elements/systems, $435.24/sf for lateral slide, and $280.84/sf for SPMT, as shown in Figure 81.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventional	Tier 5 (within 3 months)	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 284.96	$ 336.49	$ 435.24	$ 280.84
Predicted Total construction Cost	$ 1,187,416	$ 1,402,161	$ 1,813,656	$ 1,170,280

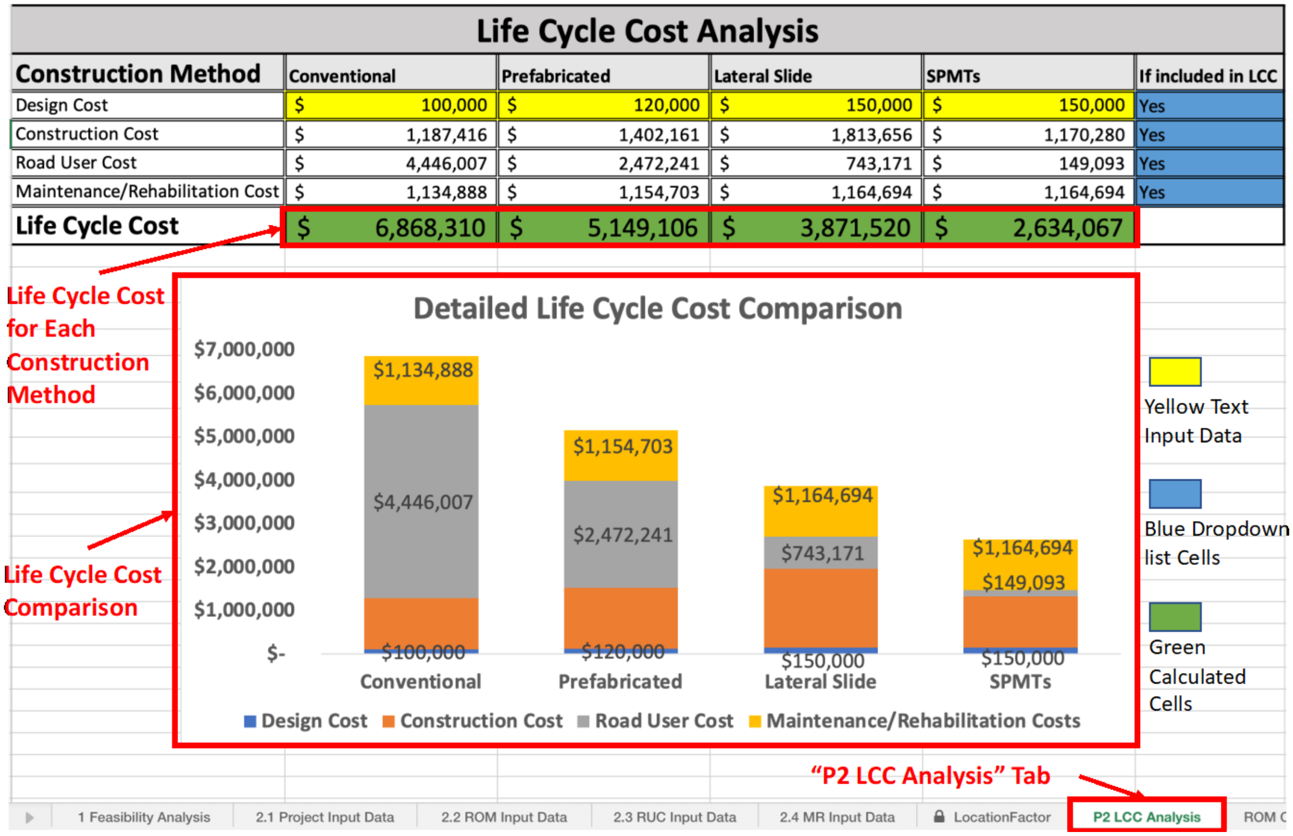
Predicted Cost for Each Construction Method

ROM Cost Comparison

“2.2 ROM Input Data” Tab

Figure 81. Screenshot. ROM comparison for bridge construction methods for future project 2.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 82. For this project, the road user cost input data includes the speed limit during normal condition and under construction that were specified to be 55 mph and 40 mph, respectively. The project length with detour was specified to be 41 miles, and the total duration of the project is assumed to be 90 days for conventional construction, 50 days for the prefabricated elements/systems construction, 15 days for the lateral slide construction method, and 3 days for SPMT. The DST estimated life cycle cost for this project was $6,868,310 for conventional construction, $5,149,106 for prefabricated elements/systems, $3,871,520 for lateral slide, and $2,634,067 for SPMT, as shown in Figure 82.



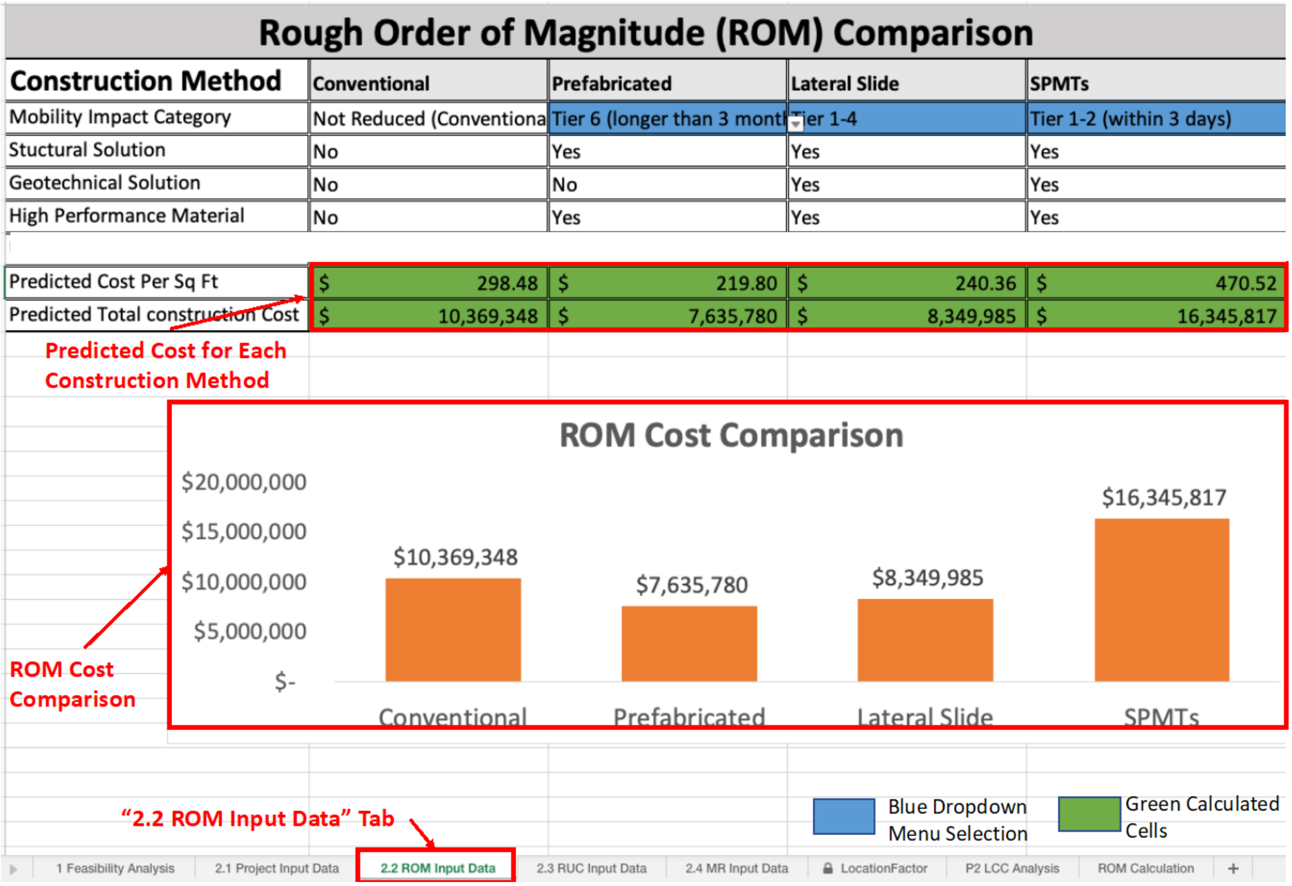
Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 1,187,416	$ 1,402,161	$ 1,813,656	$ 1,170,280	Yes
Road User Cost	$ 4,446,007	$ 2,472,241	$ 743,171	$ 149,093	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	$ 6,868,310	$ 5,149,106	$ 3,871,520	$ 2,634,067	

Figure 82. Screenshot. LCC comparison for all construction methods for future project 2.

BRIDGE REPLACEMENT IL 111 OVER I-64

The scope of this project is to replace an existing bridge (SN 082-0166) with a new bridge. This bridge project is located in District 8 and has bridge length of 326 feet, bridge width of 90 feet, project length of 1519 feet, max span length of 85.3 feet, 4 lanes, 4 spans, girder design, urban location, ADT of 72,100 vehicles/day, steel beam, and concrete deck. The project is planned to be built in 2024 with a predicted inflation rate of 2.3% from 2023.The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 83. The estimated construction unit cost is $298.48/sf for conventional construction, $219,80/sf for prefabricated elements/systems, $240.36/sf for lateral slide, and $470.52/sf for SPMT, as shown in Figure 83.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventiona	Tier 6 (longer than 3 montl	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 298.48	$ 219.80	$ 240.36	$ 470.52
Predicted Total construction Cost	$ 10,369,348	$ 7,635,780	$ 8,349,985	$ 16,345,817

Predicted Cost for Each Construction Method

ROM Cost Comparison

"2.2 ROM Input Data" Tab

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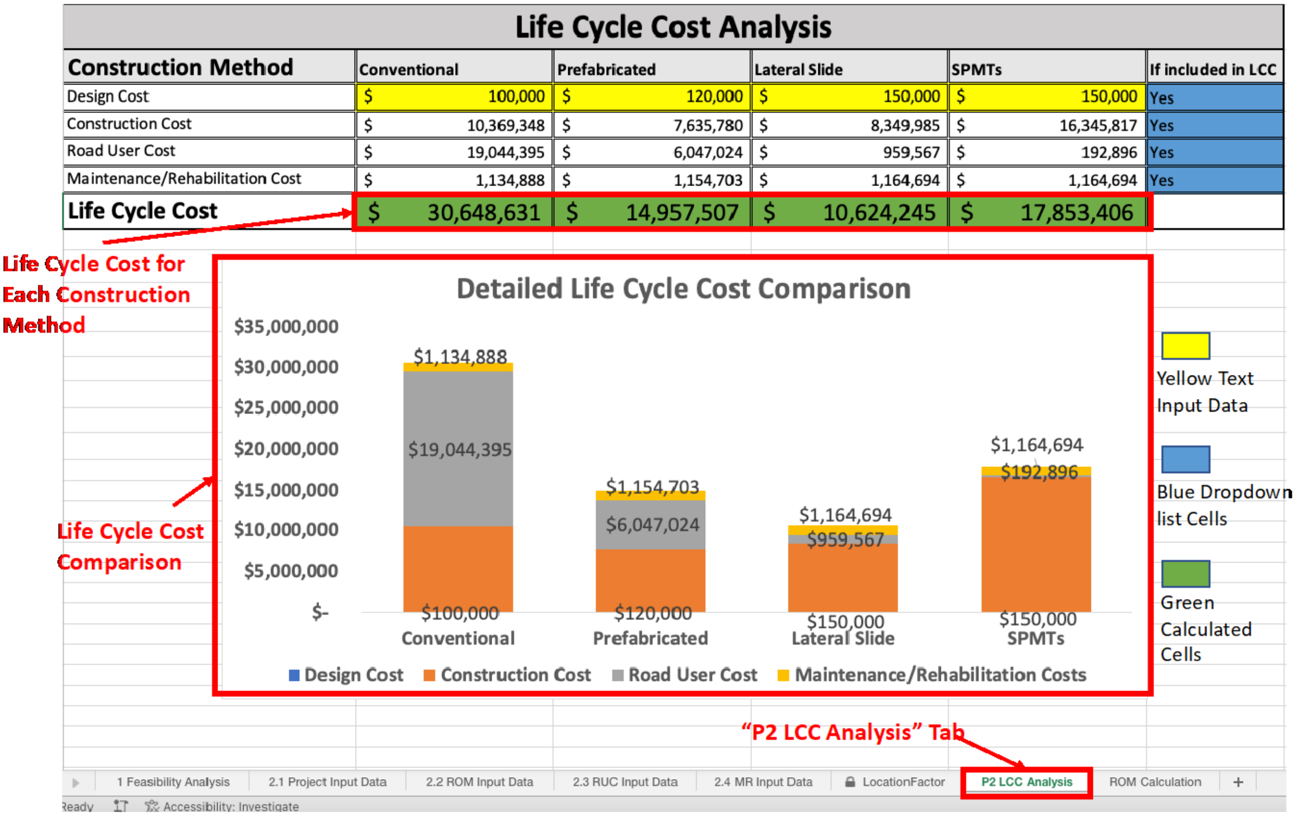
Figure 83. Screenshot. ROM comparison for bridge construction methods for future project 3.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 84. For this project, the road user cost input data includes the speed limit during normal condition and under construction that were specified to be 55 mph and 40 mph, respectively. The project length with detour was specified to be 3 miles, and the total duration of the project is assumed to be 300 days using conventional construction, 95 days for the prefabricated elements/systems construction, 15 days for the lateral slide construction method, and 3 days for SPMT. The DST estimated life cycle cost for this project was $30,648,631 for conventional construction, $14,957,507 for prefabricated elements/systems, $10,624,245 for lateral slide, and $17,853,406 for SPMT, as shown in Figure 84.

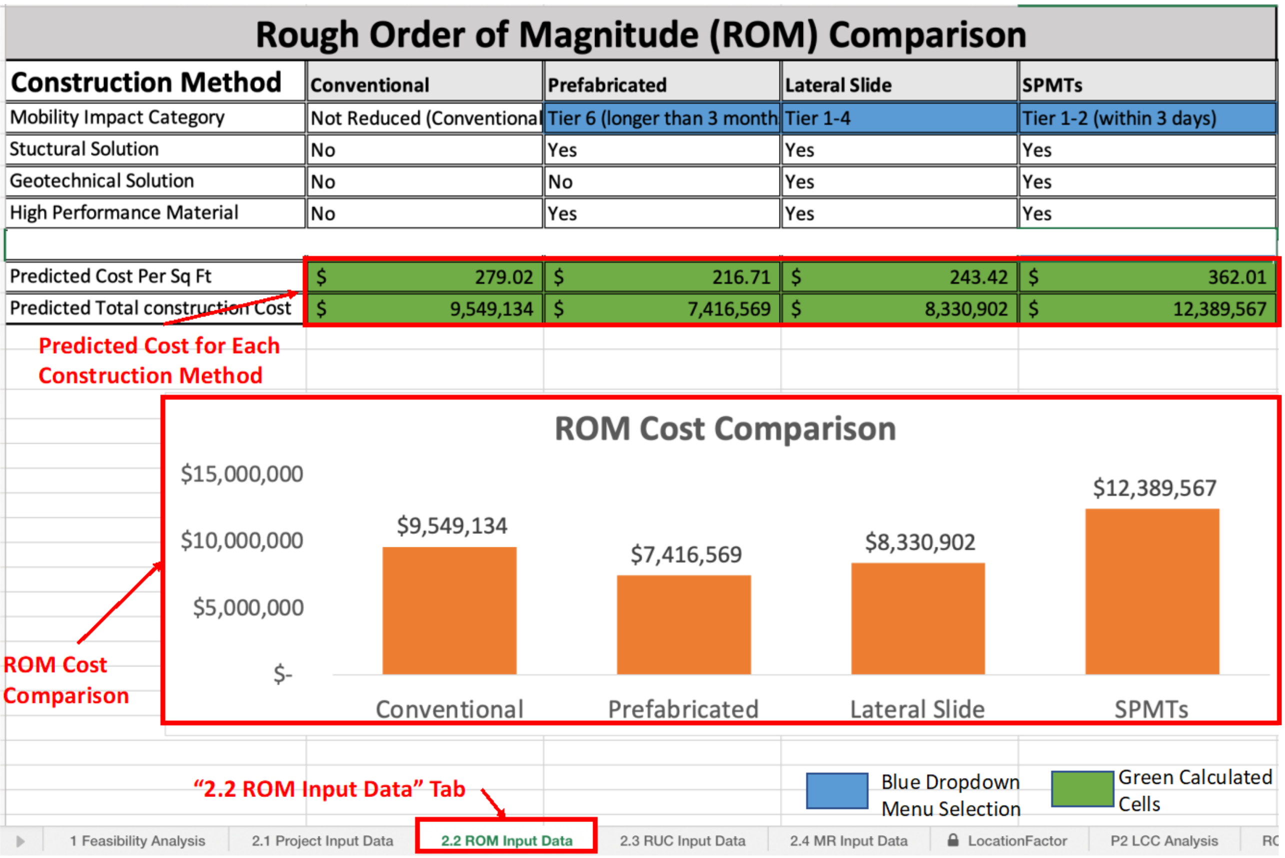


Life Cycle Cost Analysis					
Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 10,369,348	$ 7,635,780	$ 8,349,985	$ 16,345,817	Yes
Road User Cost	$ 19,044,395	$ 6,047,024	$ 959,567	$ 192,896	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	$ 30,648,631	$ 14,957,507	$ 10,624,245	$ 17,853,406	

Figure 84. Screenshot. LCC comparison for all construction methods for future project 3.

BRIDGE REPLACEMENT AIRPORT RD OVER I-474

The scope of this project is to replace an existing bridge (SN 072-0254) with a new bridge. This bridge project is located in District 4 and has bridge length of 372 feet, bridge width of 92 feet, project length of 1733.52 feet, max span length of 93 feet, 4 lanes, 2 spans, girder design, rural location, ADT of 29,200 vehicles/day, steel beam, and concrete deck. The project is planned to be built in 2025 with a predicted inflation rate of 5% from 2023.The DST was used to estimate and compare bridge construction costs for all feasible construction methods, as shown in Figure 85. The DST estimated construction unit cost is $279.02 /sf for conventional construction, $216.71 /sf for prefabricated elements/systems, $243.42 /sf for lateral slide, and $362.01 /sf for SPMT, as shown in Figure 85.



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventional	Tier 6 (longer than 3 month	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 279.02	$ 216.71	$ 243.42	$ 362.01
Predicted Total construction Cost	$ 9,549,134	$ 7,416,569	$ 8,330,902	$ 12,389,567

Predicted Cost for Each Construction Method

ROM Cost Comparison

"2.2 ROM Input Data" Tab

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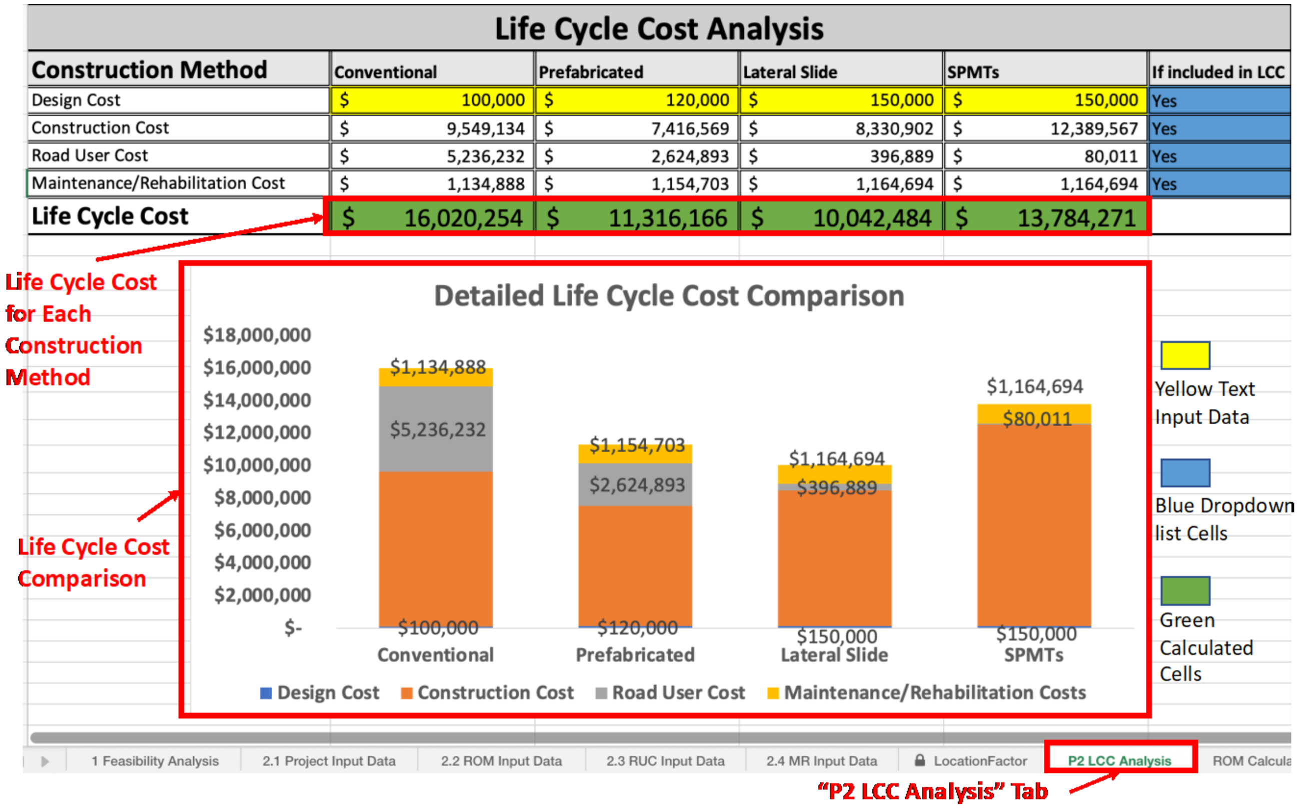
Figure 85. Screenshot. ROM comparison for bridge construction methods for future project 4.

Similarly, the DST was then used to estimate and compare the road user cost, maintenance and rehabilitation costs, and total life cycle cost, as shown in Figure 86. For this project, the road user cost input data includes the speed limit during normal condition and under construction that were specified to be 55 mph and 40 mph, respectively. The project length with detour was specified to be 3 miles, and the total duration of the project is assumed to be 200 days using conventional construction, 100 days for the prefabricated elements/systems construction, 15 days for the lateral slide construction method, and 3 days for SPMT. The estimated life cycle cost for this project was $16,020,254 for conventional construction, $11,316,166 for prefabricated elements/systems, $10,042,484 for lateral slide, and $13,784,271 for SPMT, as shown in Figure 86.



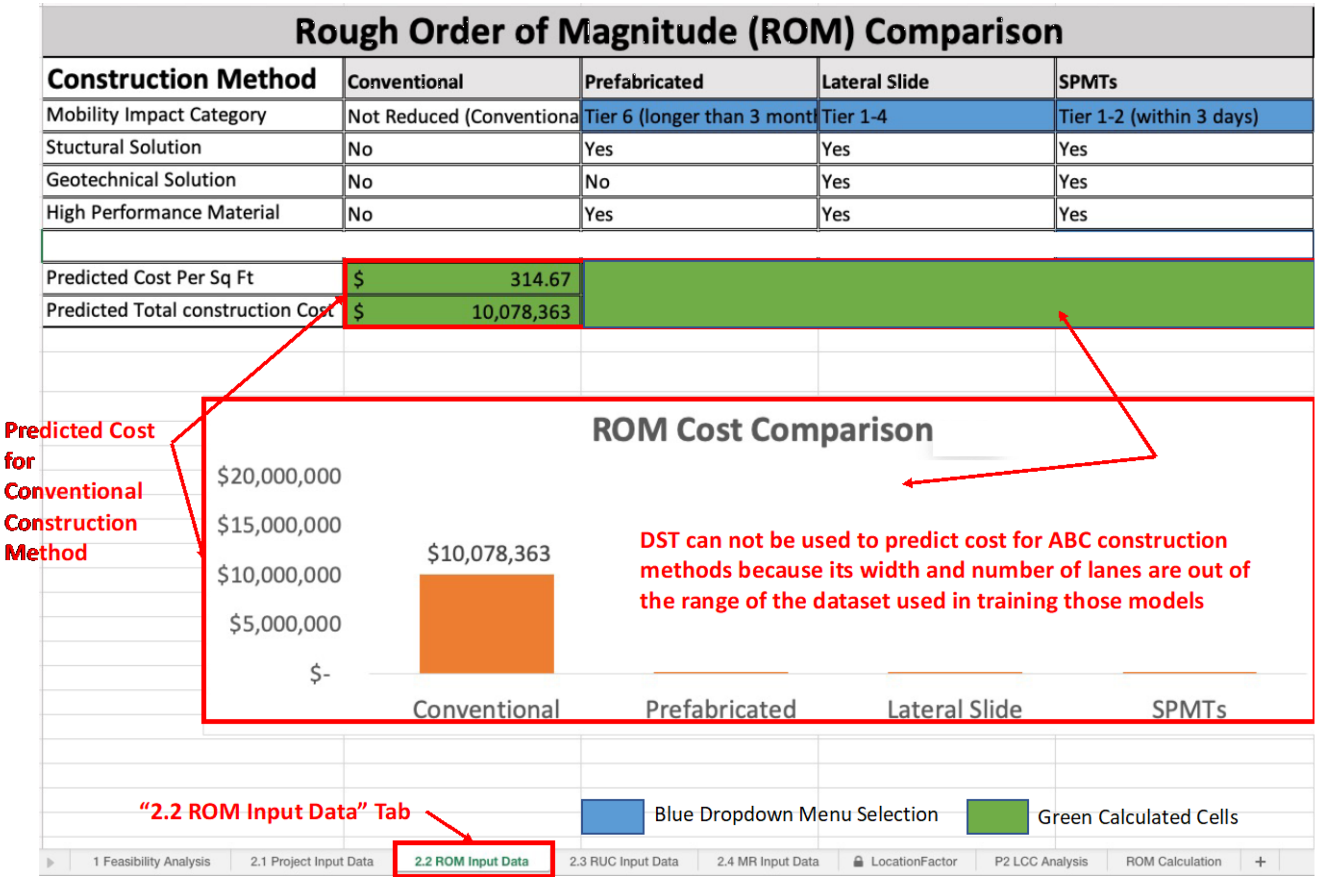
Life Cycle Cost Analysis

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs	If included in LCC
Design Cost	$ 100,000	$ 120,000	$ 150,000	$ 150,000	Yes
Construction Cost	$ 9,549,134	$ 7,416,569	$ 8,330,902	$ 12,389,567	Yes
Road User Cost	$ 5,236,232	$ 2,624,893	$ 396,889	$ 80,011	Yes
Maintenance/Rehabilitation Cost	$ 1,134,888	$ 1,154,703	$ 1,164,694	$ 1,164,694	Yes
Life Cycle Cost	$ 16,020,254	$ 11,316,166	$ 10,042,484	$ 13,784,271	

Figure 86. Screenshot. LCC comparison for all construction methods for future project 4.

BRIDGE REPLACEMENT IL 53 OVER HICKORY CREEK

The scope of this project is to replace an existing bridge (SN 099-0083) with a new bridge. This bridge project is located in District 1 and has bridge length of 314 feet, bridge width of 102 feet, project length of 1463.24 feet, max span length of 73 feet, 6 lanes, 3 spans, girder design, urban location, ADT of 24,800 vehicles/day, steel beam, and concrete deck. The estimated construction cost using conventional construction method by the developed DST for this bridge project was $314.67, as shown in Figure 87. It should be noted that a cost estimate for this case study using ABC construction methods could not be generated by the developed DST because its bridge width and number of lanes are beyond the range of the datasets used in training the developed predictive models for all ABC methods including prefabricated elements/systems, lateral slide, and SPMT construction methods (see Appendix D).



Rough Order of Magnitude (ROM) Comparison

Construction Method	Conventional	Prefabricated	Lateral Slide	SPMTs
Mobility Impact Category	Not Reduced (Conventiona	Tier 6 (longer than 3 montl	Tier 1-4	Tier 1-2 (within 3 days)
Stuctural Solution	No	Yes	Yes	Yes
Geotechnical Solution	No	No	Yes	Yes
High Performance Material	No	Yes	Yes	Yes
Predicted Cost Per Sq Ft	$ 314.67			
Predicted Total construction Cost	$ 10,078,363			

Predicted Cost for Conventional Construction Method

DST can not be used to predict cost for ABC construction methods because its width and number of lanes are out of the range of the dataset used in training those models

"2.2 ROM Input Data" Tab

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Figure 87. Screenshot. Predicted construction cost for conventional method for future project 5.

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