GEORGIA DOT RESEARCH PROJECT NO. 18-13

FINAL REPORT

DEVELOPING A NEW CASH FLOW EXPENDITURES MODEL CONSIDERING THE FLEXIBILITIES OFFERED BY THE DESIGN–BUILD–FINANCE (DBF) AND PUBLIC–PRIVATE PARTNERSHIP (P3) PROJECT DELIVERY METHODS

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1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No**
FHWA-GA-21-1813	N/A	N/A

4. Title and Subtitle
Developing a New Cash Flow Expenditures Model Considering the Flexibilities Offered by the Design–Build–Finance (DBF) and Public–Private Partnership (P3) Project Delivery Methods

5. Report Date
December 2020

6. Performing Organization Code
N/A

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8. Performing Organ. Report No.
N/A

9. Performing Organization Name and Address
Economics of Sustainable Built Environment (ESBE) Lab
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10. Work Unit No.
N/A

11. Contract or Grant No.
RP 18-13

12. Sponsoring Agency Name and Address
Georgia Department of Transportation,
Office of Performance-based
Management and Research,
600 W. Peachtree Street NW, Atlanta, GA 30308

13. Type of Report and Period Covered:
Final; August 2018 – December 2020

14. Sponsoring Agency Code
N/A

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

State departments of transportation (state DOTs) have implemented transportation financial plans to utilize federal and state transportation funding within at least a four-year horizon and possibly longer. It is critical for state DOTs to maintain adequate cash balance that helps establish a clear transportation plan and program. Over the past decades, an array of alternative project delivery methods has been introduced to enhance the financing capabilities of the state DOT. The new delivery methods need to be properly treated in developing more realistic cash flow models for the project expenditures. The overarching objective of this research is to develop a forecasting model for expenditure cash flow for the GDOT design and construction program, taking into account flexibilities offered by the innovative project delivery methods, such as design–build (DB), design–build–finance (DBF) and public–private partnership (P3). To achieve the research objectives, current state of the practices in schedule of value and payment for design and construction activities in several state DOTs are reviewed and best practices are identified. An expenditure cash flow forecasting model is developed for transportation design–build projects via a case-based reasoning (CBR) approach. The developed model generates accurate forecasts with limited training data and high-level describable project attributes. The proposed model can handle inputs with missing data. An Excel® Visual Basic for Application (VBA) tool is developed for project managers by using the proposed CBR model. The significance of the developed cash flow model lies on its capabilities to inform the Department about its actual future financial obligations and, thereby, effectively use its limited capital to deliver more needed projects. The new cash flow model shows opportunities for deferred payments and other savings anticipated in the alternative delivery models. The proposed model was tested and confirmed by all the completed transportation design–build projects in the State of Georgia, ranging from April 2007 to January 2020.

17. Key Words
Cash Flow, Case-Based Reasoning, Design-Build, Financial Analysis

18. Distribution Statement

19.Security Classification (of this report)	**20. Security Classification (of this page)**	**21. Number of Pages**	**22. Price**
Unclassified	Unclassified	109	Free

GDOT Research Project No. 18-13

Final Report

DEVELOPING A NEW CASH FLOW EXPENDITURES MODEL CONSIDERING THE FLEXIBILITIES OFFERED BY THE DESIGN–BUILD–FINANCE (DBF) AND PUBLIC–PRIVATE PARTNERSHIP (P3) PROJECT DELIVERY METHODS

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December 2020

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EXECUTIVE SUMMARY

State departments of transportation (state DOTs) have implemented transportation financial plans, such as transportation improvement programs (TIPs) and statewide transportation improvement programs (STIPs), to utilize federal and state transportation funding within at least a four-year horizon and possibly longer. It is critical for state DOTs to maintain adequate cash balance that helps establish a clear transportation plan and program. An accurate construction expenditure forecasting model would help state DOTs by presenting a realistic view of expenditures in a given fiscal period. The significance of an accurate cash flow model lies in the capabilities to inform the Department about its actual future financial obligations and, thereby, effectively use its limited capital to deliver more needed projects. Over the past decades, an array of alternative project delivery methods has been introduced to enhance the financing capabilities of the state DOT. The new delivery methods need to be properly handled in developing more realistic cash flow models for the project expenditures. The new cash flow model would show opportunities for deferred payments and other savings anticipated in the alternative delivery models.

The overarching objective of this research is to develop a forecasting model for expenditure cash flow for the Georgia DOT (GDOT) design and construction program, taking into account flexibilities offered by the innovative project delivery methods, such as design–build (DB), design–build–finance (DBF) and public–private-partnership (P3). To achieve the research objectives, current "state of the practice" in schedule of value (SOV) and payment for design and construction activities in several state DOTs is reviewed, and best practices are identified. Finally, an expenditure cash flow forecasting model is developed for transportation design–build projects via a case-based reasoning (CBR) approach. The developed model could generate accurate forecasts with limited training data and high-level describable project attributes, and it could handle inputs with missing data. An Excel® Visual Basic for Application (VBA) Tool is developed for project managers by using the proposed CBR model.

The first half of the research was performed to review the current state of the practice in state DOTs regarding the SOVs and progress payments of DB and other innovative project delivery for highway projects. The findings of the first part of the research are summarized as the following recommendations, which should be effective for enhancing the practice of progress payment management:

- A well-established SOV helps the Department develop a project-specific basis for reviewing and approving the design–builder's work and developing a periodic pay estimate throughout the project.
- An updated SOV that accommodates any changes in the scope of work is essential to smooth execution of the progress payment and a successful DB project.

- A detailed/updated *payment breakdown* for progress payments helps the Department approve/disapprove the payment to the contractor and reduce disputes.
- Including early completion incentives in the DB request for proposals (RFP) can encourage the design–builder to not only finish the project on time but also minimize the impact on the communities in which the projects are constructed.
- A well-defined cost-loaded critical path method (CPM) schedule enables the Department to establish the expected cash flow for the life of the project.
- Establishing and providing specific bid items that are eligible for price adjustments in a contract provides the Department with a more accurate and dynamic adjustment tool for payments.

The second half of the research effort is to develop a forecasting model suitable for transportation design–build projects to be awarded. The proposed model was tested and confirmed by all the completed transportation design–build projects in the state of Georgia, ranging from April 2007 to January 2020. A straightforward user manual is also provided to give users step-by-step guidance on how to use the software, along with snapshots of data entry and results publication.

ACKNOWLEDGMENTS

The research reported herein was sponsored by the Georgia Department of Transportation through Research Project Number 18-13. The authors acknowledge and appreciate the help from Mr. Darryl VanMeter, Mr. Andrew Hoenig, and Mr. Stephen Lively. Their invaluable assistance and insight were critical to the completion of this research.
Mr. John Hancock and Ms. Lenicia Rogers-Lattimore shared their knowledge and experience on the application of cost estimation and risk management practices throughout the course of this project. The authors also thank Dr. Yashovardhan Jallan, Ms. Supriya Kamatkar, Mr. Sunil Thapa, Mr. Phani Kumar Aluri, and Ms. Gnana Deepthi Guduru, who have helped us throughout the progress of this research project.

CHAPTER 1. INTRODUCTION

Funding availability plays a major role in determining strategic priorities for the long-range statewide transportation development plan (LRSTP). State Departments of Transportation (state DOTs) have implemented transportation financial plans, such as transportation improvement programs (TIPs) and statewide transportation improvement programs (STIPs), to utilize federal and state transportation funding within at least a four-year horizon, and possibly longer. It is critical for state DOTs to maintain an adequate cash balance that helps establish a clear transportation plan and program (NASEM 2017). In recent years, a variety of issues, including changing economic conditions, delayed federal transportation reauthorization bills, and the declining value of fuel tax, have affected the ability of the states to provide an adequate budget for building new capacity and performing necessary maintenance on existing infrastructure (Rall et al. 2010). Considering significant uncertainty about project cost and construction market conditions, state DOTs have faced great challenges to manage construction expenditure cash flow of transportation projects (Camph 2008). Under these circumstances, an accurate construction expenditure forecasting model would help state DOTs by presenting a realistic view of expenditures in a given fiscal period.

Over the past two decades, an array of alternative project delivery methods has been introduced, in order to facilitate access to capital markets and encourage the private sector's participation in transportation project development. Introduction of alternative project delivery methods provides significant opportunities to enhance the financing capabilities of the state DOT. The new delivery methods need to be properly handled in developing more realistic cash flow models for the project expenditures.

The cash flow model shows opportunities for deferred payments and other savings anticipated in the alternative delivery models. The significance of the new cash flow models lies in their capabilities to inform the Department about its actual future financial obligations, and, thereby, effectively use its limited capital to deliver more needed projects.

The major objective of this research is to develop a new cash flow expenditures model for the Georgia Department of Transportation (GDOT) design and construction program, taking into account flexibilities offered by innovative project delivery methods, such as design–build (DB), design–build–finance (DBF) and public–private partnership (P3). To achieve the research objectives, the following tasks have been done, and the report is structured as follows:

- **Chapter 2: Review of the state of the practice of cash flow forecasting in other state DOTs.** Through comprehensive content analysis of documents (i.e., requests for proposals [RFPs], price proposals, and design–build manuals), this chapter reviews the current practice of state DOTs in the following areas: (1) use of a schedule of values (SOV) for DB contracts, (2) updates to the schedule of values, (3) approval and disapproval of progress payments, (4) incentives for early completion for DB contracts, (5) use of cost-loaded schedules for design and construction activities, and (6) use of *price adjustment clauses* in progress payments. Recommendations are given on how to improve the progress payment of DB and other innovative project delivery for highway projects.

- **Chapter 3: Construction expenditure flows forecasting tool for transportation design–build projects.** A forecasting model is developed via a case-based reasoning (CBR) approach. By utilizing 19 project-specific attributes that are available for Georgia Department of Transportation (GDOT) projects at the time that the design–build contracts are awarded, the model generates two types of predictions: periodic construction expenditure flow and cumulative construction expenditure flow. The proposed model was tested and confirmed by all the completed transportation design–build projects in the state of Georgia, ranging from April 2007 to January 2020.
- **Chapter 4: User manual for the developed Excel Visual Basic for Application (VBA) Tool.** A straightforward and step-by-step description of how to use the software, along with snapshots of data entry and results publication, is provided.
- **Chapter 5: Conclusions.** A summary of the research findings is presented.

CHAPTER 2. SCHEDULE OF VALUES AND PAYMENT FOR DESIGN AND CONSTRUCTION ACTIVITIES

INTRODUCTION

A schedule of values is a detailed schedule providing a complete breakdown of the lump sum contract price and change orders into components that represent work or cost codes. Developing an SOV relies heavily on the selection of delivery methods (e.g., design–bid–build [DBB] and design–build) for a highway project.

Major differences between the SOV of design–bid–build and design–build projects are summarized as follows:

- SOV of DBB Projects:
  - Being used with a unit price payment method for the construction progress.
  - Including unit price items and their measured quantities.
  - Being bases payments to the contractor on detailed take-offs.
- SOV of DB Projects:
  - Being used with a lump-sum payment method for both the design and construction progress.
  - Including lump-sum items.

- Being bases payments to the contractor on the submitted monthly pay estimates.

Most DBB projects utilize a unit price payment method, where unit price items and their measured quantities are listed in the bid tab (FHWA 2018). Under a traditional unit-price contract, the owner typically selects the lowest bid for a project submitted by a contractor. The submitted bid for a project is computed by multiplying the submitted unit price by the contractor and the estimated quantity of each bid item by the owner. The owner makes payments to the contractor based on detailed take-offs of installed quantities for each unit-priced item. Thus, the owner should be able to inspect and monitor the contractor's progress and measure actual quantities installed (Scott and Mitchell 2007).

In contrast to DBB projects, DB projects commonly use a lump-sum payment method, where a value or budget for both design and construction progress split into an SOV based on each major feature of work (e.g., bridge projects, bridge painting, and guardrail) (Koch et al. 2010). Under a lump-sum contract, contractors develop quantity take-offs to estimate a lump-sum item for a project using the plans provided by the owner. An SOV for the DB project is developed by the selected contractor for design and construction activities. Based on consent on a payout schedule in the SOV or a cost-loaded critical path method schedule between the owner and contractor, the contractor is responsible to prepare and submit monthly pay estimates based on progress as a percentage of the lump-sum prices. Under a lump-sum contract, the owner focuses more on monitoring and ensuring the quality of the work, rather than measuring and documenting quantities (Scott and Mitchell 2007).

In addition to the SOV, establishing a payment mechanism for both design and construction progress is paramount to the success of DB and other innovative project delivery projects (e.g., design–build–finance, design–build–finance–operate–maintain [DBFOM], or other forms of P3s). The most common approach for calculating progress payment for DB and DBF contracts is a lump-sum payment method. In the DB/DBF contract, the design–builder is required to assign a value (budget) of every activity or progress on an SOV, a compilation of the values of the various phases of the work (DeWitt et al. 2005, Koch et al. 2010).

In a DB contract, the owner makes a payment for the completion of each major feature of work (e.g., design completion, foundation, and superstructure), which are defined by the design–builder. The owner also uses the completion of predetermined milestones for payment (e.g., fifty percent of design completion, ninety percent of design completion, and certain project completion thresholds), which is defined as a milestone payment method (Koch et al. 2010, Titus-Glover et al. 2016).

In a DBF contract, the Department defers payment either completely or partially to the design–builder over the construction period. The design–builder is responsible for the design work, construction activities, and financing for all or a portion of the project, while the Department retains responsibility for the long-term operation and maintenance of the project.

Furthermore, DBFOM contracts as a form of public–private partnership projects typically use milestone payments and availability payments (i.e., a performance-based payment) during the construction and operation periods (FHWA 2020). On the condition that the project meets defined performance specifications and specific project milestones, the owner makes a periodic payment for the concessionaire to compensate for designing, constructing, operating, and maintaining the project for a set concession period. To compensate for the costs of the design and construction activities, the owner uses revenue streams from taxes, fees, and/or tolls (FHWA 2017a). To determine the amount of the availability payment, a competitive procurement is utilized to select the bidder that submits the lowest availability payment. The availability payment approach allows the owner to attract more bidders and avoid risks of construction cost overruns and late completion, and risk related to operations, maintenance, and rehabilitation (Poole 2017).

The following sections provide a summary of state DOTs' practices of the SOV and payment approaches for DB contracts.

PRACTICES OF STATE DOTS' SCHEDULE OF VALUES FOR DB CONTRACTS

State DOTs in the United States utilize a scheme of the SOV for DB projects. The design–builder is requested to develop and submit the SOV to the Department for approval. The Department uses the submitted SOV as the basis of payment for work completed at a specified time of the project duration. The design–builder is required to update the SOV to ensure that the SOV accurately accounts for the scope and financial changes of a project.

Under DB contracts, the SOV typically contains three major elements: work items, unit price, and the total contract price. Since the design–build contract is procured with a lump-sum agreement, the items for the DB SOV are less detailed, compared to the SOV in the traditional delivery method. The classifications/categories of the work items/project components on the SOV vary from Department to Department. State DOTs' SOVs present a wide range of required levels of details of SOV. For instance, Georgia, Florida, and Delaware DOTs require two levels of details for SOV, consisting of major work categories and lump-sum work items, while Virginia and Maryland DOTs require a list of lump-sum items in their SOV. Table 1 provides a summary of state DOTs' SOV practices for DB projects. Examples of several state DOTs—Georgia, Florida, Delaware, Virginia, Tennessee, and New York—are also provided.

Table 1. Summary of state DOTs' SOV practices for DB projects.

State DOT	Definition of SOV	Payment Method	Required Level of Detail for SOV
Georgia DOT (GDOT 2018a)	• **An itemized list** that establishes the value or cost for each major element of the design–build work. • SOV is used as the basis for progress payments.	• Payment is based on a percent complete for each activity as per the approved SOV. • Besides, Georgia DOT's Program Management Consultant Project Manager (PMC-PM) is responsible for processing payments based on the approved SOV.	• 1st Level: Design and Construction • 2nd Level: Lump-Sum Work Items
Florida DOT (FDOT 2014)	• **A sufficient breakdown of each bid item** for the costs of work and such other information that enable the Department to evaluate the progress of work and the value. • A basis for computing and/or verifying the contractor's progress payment requests.	• Based on the schedule of values, the design–builder develops the payout schedule, which is used as the basis for monthly payment for the percentage of work completed.	• 1st Level: Major Category Items • 2nd Level: Lump-Sum Work Items
Delaware DOT (DelDOT 2007)	• The submitted SOV by the design–builder is used as the basis of payment. • The SOV contains **the list of project components (work items)**, project component values, and total lump-sum proposal price for a project.	• The design–builder makes requests for periodic payment using the form of RPP (Request for Periodic Payment) for the specified project component.	• 1st Level: Project Sections • 2nd Level: Project Components
Virginia DOT (VDOT 2014)	• The **schedule of items (SOI)**, which is a corresponding term for the SOV, is used. • The design–builder develops the SOI that contains **proposed pay items**, unit of measure, price/unit, and aggregate budgeted units and costs for all activities.	• The design–builder develops the cost-loaded project schedule based on the schedule of items. • The cost-loaded project schedule is used as the basis for progress payments.	• 1st Level: Lump-Sum Work Items

Table 1 (Continued). Summary of state DOTs' SOV practices for DB projects.

State DOT	Definition of SOV	Payment Method	Required Level of Detail for SOV
Tennessee DOT (TDOT 2017)	• The SOI for a DB contract, which includes **the list of pay items**, is used. • The design–builder assigns the value of work on the SOI.	• Submission of progress schedules with the SOI is required for reimbursement monthly. • Progress schedule is sent to the designated Department contact person for verification of progress.	• 1st Level: Project Management and Engineering & Construction • 2nd Level: Lump-Sum Work Items
New York State DOT (NYSDOT 2005)	• The SOV contains **the list of work items** or project component for a DB project. • The SOV also includes the prices for the project components and the sum of the lump sum prices.	• Based on the SOV, the design–builder develops a **proposal periodic payment schedule** (PPS-P), which contains the distribution of the proposal price throughout the contract. • The PPS-P is used as the basis of periodic payment to the design–builder along with the SOV	• 1st Level: Project Components
Maryland DOT (MDOT 2018a)	• Maryland DOT provides to the design–build team the **schedule of prices (SOP)**, which contains **all work for a DB project**. • The design–build team is requested to fill the SOP and include it in the price proposal.	• For a lump-sum contract, the contractor prepares an acceptable breakdown of the lump-sum contract price that shows the amount for each principal category of the work. • The Administration pays the contractor monthly for the contract value of the work according to the procurement officer's estimate of quantity satisfactorily performed (MDOT 2018b).	• 1st Level: Items of Work

Georgia DOT

Georgia DOT requests the DB firm to submit a schedule of values, which is a tabular layout that lists all payment activities for the design and construction. For example, table 2 provides the form of the DB SOV used for GDOT's I-16 at 1-95 interchange reconstruction and I-16 widening from I-95 to I-516 project. The Georgia DOT's DB SOV is divided into two major sections: *design complete* and *construction completion*. It contains detailed information about activities, units of measure, quantities of the activities, unit prices, total prices, subtotals for the design and construction complete, and the sum of SOV (GDOT 2018a).

Table 2. Form of DB SOV of Georgia DOT's I-16 at I-95 Improvement Projects.

Activity Description	Unit	Quantity	Unit Price	Total Price
DESIGN COMPLETE	N/A	N/A	N/A	N/A
• Design Cost & Support	LS	1	$	$
• Work Zone Law Enforcement	LS	1	$	$
• Permits	LS	1	$	$
• Insurance & Bonds	LS	1	$	$
• ROW – DB Team	LS	1	$	$
• Project Management and Administration	LS	1	$	$
			Design Complete	$
CONSTRUCTION COMPLETE	N/A	N/A	N/A	N/A
• Final Acceptance	LS	1	$	$
• Developer Quality Management	LS	1	$	$
• Field Office	LS	1	$	$
• Erosion Control	LS	1	$	$
• Traffic Control	LS	1	$	$
• Earthwork & Roadway Removals	LS	1	$	$
• Drainage	LS	1	$	$
• Barrier & Guardrail	LS	1	$	$
• Base and Paving	LS	1	$	$
• Landscaping	LS	1	$	$
• ITS, Tolling & Signals	LS	1	$	$
• Structural Walls	LS	1	$	$
• Bridges	LS	1	$	$
• Pavement Markings	LS	1	$	$
• Sound Barriers	LS	1	$	$
• Mobilization	LS	1	$	$
• Maintenance During Construction	LS	1	$	$
• Utilities	LS	1	$	$
• Signs & Overhead Sign Structures	LS	1	$	$
• Lighting	LS	1	$	$
• Structural Removal/Demo	LS	1	$	$
• Hazardous Materials/Environmental Mitigation	LS	1	$	$
• Record Drawing (As-Builts)	LS	1	$	$
• Completion of Punch List	LS	1	$	$
• Final Close-Out	LS	1	$	$
• Demobilization	LS	1	$	$
TRAINING HOURS	HR	50,000	$	$
			Construction Complete	$
			Sum of Schedule of Values	$

Florida DOT

The Florida DOT requests that the developer submit an SOV that contains a sufficient breakdown of each bid item for the costs of work in the price proposal. The Florida DOT uses the SOV to evaluate the progress of the work and the value. For example, table 3 shows the form of an SOV used for the Florida DOT's DBFOM I-4 Ultimate project. The SOV for the I-4 Ultimate project contains detailed line items on 16 major sections. In addition, the Florida DOT tracks and monitors the completion of the design and construction progress (FDOT 2014). The sections and items of the SOV can vary from project to project. Compared to the Georgia DOT's SOV, the work items for a project in the Florida DOT's SOV are categorized into detailed sections of project components, such as *Engineering Services*, *Utility Relocations*, and *Mobilization*. In addition, the Florida DOT's SOV contains a column of *% of Design & Construction* to track the percent completion of the work items.

Table 3. Form of design and construction SOV of the Florida DOT's I-4 Ultimate project.(FDOT 2014)

Section	Item Description	% of Design & Construction	Amount* ($)
I	**Engineering Services**		
	a. Design/ Miscellaneous Services b. Quality Assurance Firm (QAF) services c. Miscellaneous**		
	Subtotal for Section I		
II	**Utility Relocations**		
	a. Utility Relocations b. Miscellaneous**		
	Subtotal for Section II		
III	**Mobilization**		
IV	**Maintenance of Traffic (Includes temporary barrier wall installation & relocation)**		
V	**Clearing & Grubbing**		
VI	**Roadway**		
	a. Flexible Pavement (Milling, Stabilization, Optional Base, Structural Course, Friction Course, Miscellaneous Asphalt, Miscellaneous) b. Rigid Pavement (Stabilization, Structural Course, Permeable Base, Cement Concrete Pavement, Edgedrain, Miscellaneous) c. Earthwork (Embankment, Excavation, Subsoil Excavation, Miscellaneous) d. Concrete (Curb & Gutter, Sidewalk, Miscellaneous) e. Barriers (Barrier Wall, Guardrail, Miscellaneous) f. Miscellaneous**		
	Subtotal for Section VI		
VII	**Drainage**		
	a. Drainage b. Miscellaneous**		
	Subtotal for Section VII		
VIII	**Walls**		
	a. Permanent MSE Wall b. Other Permanent Wall c. Noise Wall (Ground Mount) d. Noise Wall (Barrier Mount) e. Temp Sheet Pile (Includes Soil Anchors) f. Temp MSE Wall g. Miscellaneous**		
	Subtotal for Section VIII		
IX	**Bridge**		
	a. Bridge Demolition b. Substructure c. Superstructure d. Miscellaneous**		
	Subtotal for Section IX		
X	**Signing and Pavement Marking**		
XI	**Signalization**		
XII	**Lighting**		
XIII	**ITS System Including Tolls Systems**		
XIV	**SR 50 / Ivanhoe Gateway Feature (Not to exceed US $1,700,000)**		
XV	**Miscellaneous****		
XVI	**Landscaping (Minimum 1.5% of items III, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV)**		
PROJECT TOTAL (SECTIONS I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI)			

NoteS: *Proposers are required to fill in costs associated with design and construction and maintaining the Project Site during the Construction Period only. Other costs including, but not limited to, financing, operation, and maintenance shall not be included in this form. Each line item shall reflect the fully inflated cost for that item. **Proposers are required to fill in additional items that are classified as "Miscellaneous." Use the additional space provided within each section.

Virginia DOT

Virginia DOT utilizes the schedule of items (i.e., SOV) in which the design–builder defines the quantity of each pay item and its price (VDOT 2014). Virginia DOT requires the developer to submit the Price Proposal Form, which contains the Price Proposal Cost Breakdown Summary for design, construction, quality assurance, quality control services, and all other costs. Moreover, Virginia DOT asks the developer to identify quantities and costs of each proposed pay item in a schedule of items, which serves as the basis for progress payments. Table 4 shows part of an SOI for the Virginia DOT's DB I-64 project, provided by the developer. One of the main differences between the Georgia DOT's SOV and the Virginia DOT's SOI is that the work items are listed in the SOI without any categories. The Virginia DOT's SOV for the DB project contains not only lump-sum items but also unit-price items with their units. Any pay items considered for price adjustments should be identified in VDOT's schedule of items.

Table 4. A schedule of items for the Virginia DOT's DB I-64 project.

VDOT Item Code [1]	Item Description	Fuel (F) or Price (P) Adjustment	Approximate Quantity	Units[1]	Budgeted Cost ($)
	Design Service		1	LS	42,000,000.00
	QA (Construction)		1	LS	6,282,000.00
	QC (Construction)		1	LS	10,300,000.00
100	Mobilization		1	LS	20,350,000.00
101	Construction Surveying		1	LS	6,126,320.00
	Project Management		1	LS	20,000,000.00
	Wrecker Service		1	LS	1,000,000.00
	Field Office		1	LS	4,139,754.55
	Insurance		1	LS	6,605,000.00
	Bond		1	LS	2,820,000.00
100110	Clearing & Grubbing	F	64	ACRE	896,000.00
100120	Regular Excavation	F	157,102	CY	2,513,632.00
100125	Grading	F	764,086	SY	1,910,215.00
100152	Embankment	F	128,690	CY	2,187,730.00
100272	Select Backfill	F	38,599	CY	154,396.00
TOTAL					$ 409,595,765.00

Note: [1]Use five-digit work item codes and units of measure that are consistent with Virginia DOT's list of standard and non-standard item codes (i.e., 00100-Mobilization; 00120-Regular Excavation, etc.).

Delaware DOT

Delaware DOT uses the schedule of values for DB contracts as a baseline progress schedule. The design–builder is requested to complete and submit the SOV to the Department, including a lump-sum price (i.e., the project component value) for each project component on the SOV. Table 5 provides the form of the schedule of values for the Delaware DOT's Bridge 3-156 DB replacement project. The SOV consists of four sections (Project Sections A–D) with the list of project components (i.e., work items). In addition, the design–builder includes the project component values (lump-sum price) into each project component in the SOV. The cumulative total of all lump-sum prices included on the SOV is the total lump-sum contract price for the project (DelDOT 2007). Compared to the Georgia DOT's SOV, the Delaware DOT divides the SOV into several sections, which contain proposed project components. The Delaware DOT requires the contractor to provide values for all project components in an SOV. However, the Delaware DOT's SOV does not have a unit of measurement and estimated quantity for the project components.

Table 5. Form of Delaware DOT's schedule of values for replacement of Bridge 3-156. (DelDOT 2007)

PROJECT SECTION A (Project-Wide Activities)

Project Component Code	Project Component Title/Component Identification	Project Component Values
	PC1 Preliminaries and General Requirements	
	PC2 Project-Wide Engineering and Design Activities	
	PC3 Project-Wide Maintenance of Traffic	
	PC4 Project-Wide Environmental Compliance and Mitigation	
	PC5 Project-Wide Public Outreach	

PROJECT SECTION B

Project Component Code	Project Component Title/Component Identification	Project Component Values
	PC6-B Site Work	
	PC7-B Excavation and Embankment	
	PC8-B Utility Relocations	
	PC9-B Pavement Structure (20-year design) (Base and Paving)	
	PC10-B Drainage	
	PC11-B Retaining Structures	
	PC12-B Permanent Signing and Striping	

PROJECT SECTION C

Project Component Code	Project Component Title/Component Identification	Project Component Values
	PC6-C Site Work	
	PC9-C Pavement Structure (20-year design) (Base and Paving)	
	PC10-C Drainage	
	PC11-C Retaining Structures	
	PC12-C Permanent Signing and Striping	
	PC13-C Bridge	

PROJECT SECTION D

Project Component Code	Project Component Title/Component Identification	Project Component Values
	PC6-D Site Work	
	PC7-D Excavation and Embankment	
	PC8-D Utility Relocations	
	PC9-D Pavement Structure (20-year design) (Base and Paving)	
	PC10-D Drainage	
	PC11-D Retaining Structures	
	PC12-D Permanent Signing and Striping	

TOTAL

Total Lump Sum Proposal Price	

New York State DOT

New York State DOT requests the design–builder to prepare a schedule of values for a DB contract. The design–builder coordinates with the Department in preparation for the SOV. Also, the design–builder allocates a breakdown of the contract sum to the various portions of the work by taking into account labor, material, and major equipment costs. New York State DOT provides the design–builder with the form of the SOV as a guide to establish line items for it (NYSDOT 2005). Table 6 shows the form of the SOV, which consists of a list of items or components, a unit of measure, and the unit price. One of the major differences between the Georgia DOT's SOV and the New York State DOT's SOV is that the New York State DOT uses the unit price items with their units of measurement for the DB project's SOV. In the New York State DOT's SOV, the contractor is required to provide the unit prices for each work item. Moreover, the New York State DOT's SOV does not contain the design development component.

Table 6. Form of New York State DOT's SOV for a DB project. (NYSDOT 2005)

Section No.	Description of Item of Component[1]	Unit of Measure	Unit Price[2]
[Instructions: Develop a project-specific list to fit each project. The list on this template is for illustrative purposes only.]			
	Clearing and Grubbing	Hectare	
	Unclassified Excavation	Cu M	
	Borrow	Cu M	
	Sub-excavation	Cu M	
	Unsuitable Material Excavation	Cu M	
	Structure Excavation	Cu M	
	Structure Backfill	Cu M	
	Bituminous-Treated base	Cu M	
	Base Course	Sq M/cm of Depth	
	Open-Graded Friction Course	Sq M	
	Minor Paving	Sq M	
	Plant-Mix Bituminous Pavement (Superpave)	Sq M/cm of Depth	
	Mechanically-Stabilized Earth Retaining Structures	Sq M (Face Area)	
	Portland Cement Concrete, Class AA	Cu M	
	Portland Cement Concrete, Class A	Cu M	
	Concrete Structures, Structural Concrete, Class A	Cu M	
	Super Structure Concrete	Cu M	
	Reinforced Concrete for Minor Structures	Cu M	
	Flowable Fill	Cu M	
	Pipe Culverts		

Notes: (1) Proposal shall provide additional descriptions as necessary to fully describe the Work covered by the unit prices shown; (2) Unit prices shall cover all construction costs to provide the item or component listed installed and in place per Contract Documents Part 2.

UPDATES TO THE SCHEDULE OF VALUES

Updating and revising the SOV as the project progresses is critical to the success of DB projects. The SOV should be continuously updated to account for complete activities, changes to the work sequence, changes to the scope of work, and other events that affect project completion (i.e., change order and adjustment of the contract price). The SOV is typically updated by the contractor by accumulating schedule change information for a payment period and is then submitted to the owner (Koch et al. 2010). The updating process for the project schedule can be completed by the agreement between the Department and the contractor.

In addition, approved change orders should be incorporated into the SOV to accurately reflect the financial changes during the construction. Change orders can be added to the SOV by increasing or decreasing the scope of an existing activity or creating new individual activities for change orders (Koch et al. 2010). Maintaining the most current SOV is critical, as it provides essential information for planning for efficient contract execution, monitoring the project for payments, and providing communication between the owner and the contractor (Molenaar et al. 2005). Several state DOTs—Tennessee, South Carolina, and New York—clearly stipulate updating and revising the SOV in a request for proposals for DB projects, which are provided in table 7. Compared to other state DOTs, such as Tennessee, South Carolina, and New York, the Georgia DOT explicitly states all the premises required for updating the SOV for DB projects.

Table 7. Provisions for updating/revising SOV for a DB project.

State DOTs	Description
Georgia DOT (GDOT 2018a)	The DB team updates and revises the SOV during the progress of the work when a *revised baseline schedule* is submitted, when the State Road and Tollway Authority (SRTA) requests, or when the contract sum is required to be adjusted to reflect according to the supplemental agreement(s).
Tennessee DOT (TDOT 2017)	The design–builder should update, adjust, and document the contract amount according to the change order. The contract amount should be reflected immediately in the critical path method (CPM) schedule.
South Carolina DOT (SCDOT 2018)	The contractor updates the schedule of values and the CPM schedule to reflect the adjustment in the contract price. The contractors submit the updated schedule of values to the Department for approval.
New York State DOT (NYSDOT 2016)	The design–builder updates and resubmits the schedule of values when change orders affect the list of the project components.

APPROVAL AND DISAPPROVAL OF PROGRESS PAYMENTS

As a tool for tracking monetary change and quantitative change, a schedule of values in DB contracts plays a critical role during design and construction activities in ensuring that the owner and developer have the same understanding of the financial implications to their standard business practice for aligning goals and quality requirements and avoiding disputes (Koch et al. 2010). A progress payment is made based on the SOV and work performed through the payment period for DB projects. The developer typically requests the progress payment monthly. Based on the completed-to-date quantities of work, the Department pays the developer an undisputed percentage for the work performed during the period covered by the application for payments. Table 8 provides the summary of state DOTs' provision for approval and disapproval of progress payments for DB contracts.

Table 8. Summary of state DOTs' provision for approval and disapproval of progress payments.

State DOT	Description
Georgia DOT (GDOT 2018a)	The design–build team submits a **draft payment** request to Georgia DOT, which contains the amount to be payable for each line SOV line item and amounts due under Supplemental Agreements. Next, the design–build team holds the **Payment Request Review Meeting** with Georgia DOT to finalize the draft payment request. The design–build team submits the **final payment request** based on the approved draft payment request to the State Road and Tollway Authority for review and processing for the progress payment. With the Georgia DOT's approval of the Payment Request, the SRTA makes payment on approved amounts to the design–build team.
Florida DOT (FDOT 2020a)	Approval of progress payment for the work completed by the design–build firm is made by the Department's project manager/engineer through reviewing the quality and quantity of the work and comparing the reported percent complete against actual work accomplished.
Maryland DOT (MDOT 2018a)	The design–build team submits an **itemized Progress Payment Breakdown** and supporting documentation (i.e., a written Application for Progress Payment), as a basis for payment, to the Administration. For a DB project, the design–build team submits the monthly estimate based on a percentage applied to each lump-sum item. Based on **the approval of the Administration**, progress payment can be made to the design–build team on a monthly basis. The Administration can request to submit additional detail/updates of the Payment Breakdown from the design–build team in order to process progress payments.

Georgia DOT

Georgia DOT requires the DB team to submit a draft payment request to Georgia DOT, who acts as a payment review and approval agent for SRTA. In the draft payment request, the DB team provides information about the amount asserted to be payable for each SOV line item and amount due under supplemental agreements. Figure 1 shows the form for payment requests for the DB contract. Georgia DOT uses the baseline schedule and monthly progress schedule to form the basis of payment for the project. The design–build team is required to submit the progress schedule that describes the sequence and duration of the activities comprising the plans to accomplish the work within the contract time. Also, the DB team should submit an updated project SOV when the progress schedule is submitted for the payment for the project. Once the Georgia DOT approves the draft payment request, the DB team submits the final payment request to the SRTA. After the SRTA's final review and approval, the DB team receives progress payments (GDOT 2018a).

Form of Payment Request

Project: ______________________________
SRTA Contract No.: P.I. No. ____________
Payment Request Period: ________, 20__ through __________, 20__

Payment Requests for this Payment Request Period:

Payment Request No	**Payment Request Amount**	**Deposit to Designated Account**
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
	$	
Total	$	

Designated Account 1: [TO BE PROVIDED TO SRTA BY DB TEAM]
Designated Account 2: [TO BE PROVIDED TO SRTA BY DB TEAM]

Total Payment Request Amounts for this Payment Request Period must equal the amount reflected on Line 2(c) below.

Figure 1. Image. Georgia DOT's Form of Payment Request.

The Georgia DOT will not make payment to the design–build team if there is an acceptance of any defective work or improper materials. In addition, the Georgia DOT withholds payments if the DB team does not comply with the following conditions (GDOT 2018a):

a. Released for Construction Documents are on Site for the Work being performed;

b. Released for Construction Documents have been checked and reviewed, and design documentation has been maintained, in accordance with the Contract Documents; and

c. Nonconforming Work Items are corrected and/or resolved to the satisfaction of GDOT.

Moreover, Georgia DOT includes the Office of Innovative Delivery program management consultant construction manager (OID PMC-CM) in delivering the DB contract. The OID PMC-CM's responsibility includes processing payments based on the approved SOV with the detailed breakdown of lump-sum items, providing comments on any critical path method schedule submittals, and monitoring the status of the project based on the approved SOV (GDOT 2018b). In addition to the schedule of value, the PMC-CM uses the American Association of State Highway and Transportation Officials' (AASHTO) AASHTOWare Project SiteManager™ construction management software to prepare the necessary paperwork and approve the pay estimate (GDOT 2017). The process of project documentation, reporting, and tracking is critical for the Georgia DOT to validate that the work on each paid activity has occurred.

Florida DOT

The Florida DOT determines the monthly progress and certifies the value of work performed by the design–build firm on the project during each month based on the design–build firm's approved pay schedule (i.e., schedule of values). The design–build firm submits the monthly estimates to the Department engineer for approval for progress payments for the work. Once the Engineer approves the monthly estimate, the design–build firm receives payments. If the design–build firm fails to submit an acceptable schedule or monthly updates within the time frame, the Engineer withholds monthly payments for the work. The Florida DOT withholds payment when the design–build firm does not meet the performance criteria (i.e., defective work or failure to comply with contract-agreed conditions). For instance, if the Department discovers any defective work or material or has reasonable doubt about any part of the complete work, the Department withholds payment until the design–build firm has resolved the defective work and any causes of doubt. Also, the Department holds progress payment if the design–build firm fails to comply with the following conditions within 60 days after beginning work (FDOT 2009):

a. *Comply with and submit required paperwork relating to prevailing wage rate provisions, Equal Employment Opportunity, On-The-Job-Training, and Affirmative Action;*
b. *Comply with the requirement to report all necessary information, including actual payments to DBEs [Disadvantaged Business Enterprises], all other subcontractors and major suppliers, through the Internet-based Equal Opportunity Reporting System;*

c. *Comply with or make a good faith effort to ensure equal employment opportunity for minorities and females hiring goals; and*
d. *Comply with or make a good faith effort to meet On-The-Job-Training goals.*

One of the major differences of the approval process for progress payments between the Georgia DOT and the Florida DOT is that the Florida DOT approves the progress payment within the Department with a project manager/engineer's review and approval, while the Georgia DOT needs final approval for progress payment from SRTA for P3 contracts and uses the OID PMC-CM for processing the progress payments.

Maryland DOT

Maryland DOT requests that the design–build team submit an itemized *cost breakdown* to establish pay items, which is used as the basis of the approval for progress payment. A cost breakdown is a realistic and documentable presentation of the costs for the major elements of work, comprising the lump-sum price for the work (e.g., Clearing & Grubbing, Mobilization, Design Engineering, As-Built Drawings, and Pavement Markings). To make effective the progress payment, the design–build team should provide a more detailed *progress payment breakdown* to the Department. The unbalanced cost breakdown submitted by the design–build team will not be approved until the breakdown is acceptable (MDOT 2009).

To generate the payment to the contractor, Maryland DOT utilizes the Maryland Construction Management System (MCMS) software to monitor the project CPM and cash flow schedules, and review and process progress and final payments (MDOT 2016). The design–build team submits the monthly estimates, a percentage of each lump-sum item, to the Maryland DOT. The Maryland DOT verifies the accuracy of the percentage for each work item and coordinates with the area engineer for acceptance of the estimate. The approved monthly estimates are entered in the MCMS system and finalized for processing the payment to the contractor (MDOT 2013).

The design–build team should submit a written Application for Progress Payment to the Administration to receive payment for the work monthly. The Maryland DOT will withhold the applicable payment in whole or in part if the Application for Progress Payment is inconsistent with the payment breakdown, the projected schedule of payments, or the actual progress of work (MDOT 2016). Compared to the Georgia DOT's approval and disapproval process for progress payments, the Maryland DOT's approval for progress payment in P3 projects is made within the Department.

INCENTIVES FOR EARLY COMPLETION

An incentive for early completion is a contract provision with which the developer receives a certain amount of money for each day when identified critical work is complete ahead of schedule. Early completion is defined as completing all the specified work in the plans and specifications and as meeting the Department's satisfaction for the final acceptance before the original completion date. The incentive for early completion is commonly used for critical projects where traffic inconvenience and delays need to be minimized. The incentive amount/bonuses for early completion are highly dependent on delivery methods (e.g., DB, DBFM, and DBFOM) and performance items (e.g., traffic control and maintenance costs, detour costs, and road user cost) (FHWA 2017b). Table 9 provides examples of state DOTs' early completion incentives for DB contracts. State DOTs, including Virginia, California, and Florida, use early completion incentives to expedite the completion of a project.

Table 9. Examples of state DOTs' early completion incentives for DB contracts.

State DOT	Description
Virginia DOT (VDOT 2019a)	**"No Excuse Incentive" –** Virginia DOT pays **a financial incentive** to the Contractor for **meeting the requirements of Early Completion before the fixed Completion Date**. The Contractor should complete all the work as detailed in the Plans and Specifications to the Department's satisfaction for the final acceptance. The Engineer will hold responsibility in determining the early completion.
California Department of Transportation (Caltrans) (Caltrans 2008)	"**No Excuse Incentive**" – Caltrans uses an Incentive Provision to motivate the contractors to complete the project within the established completion date. If the contractor **completes the work on or before the completion date**, the contractor receives the incentive.
Florida DOT (FDOT 2020b)	**"No Excuse Bonus" –** Florida DOT uses the No Excuse Bonus concept to **shorten the construction time** by providing the contractor with a substantial bonus to complete required work within a specified time frame. The intention of the No Excuse Bonus is to encourage the contractor to **keep the project on schedule and reward a contractor for early completion**.

COST-LOADED SCHEDULES FOR DESIGN AND CONSTRUCTION ACTIVITIES

Under lump-sum contracts for design and construction activities, the payment schedule of values should be developed for securing the Department from overpayments, compensating the design–builders fairly for completed work, and defining the project's cash flow through earned value analysis (Molenaar et al. 2005). To establish a payment schedule for a DB project, the design–builder is required to submit a cost-loaded schedule, along with the SOV in the price proposal, for the owner's approval, which is also called *cost-loaded critical path method schedules*, that show the expected cash flow for the life of the project. In cost-loaded schedules, the design–builder determines and assigns appropriate cost values to individual schedule activities or groups of activities in each payment period.

The cost values for individual schedule activities in each pay period are the accumulated costs, including all the direct costs associated with each work item and indirect costs and profit margins. Once the cost-loaded schedules are approved by the owner, they become the baseline schedule to calculate earned value along with periodic progress payments (Koch et al. 2010). In other words, the cost-loaded schedules play an important role in earned value analysis, which enables the owner and the design–builder to measure a project's progress at each payment period and revise schedule milestones of the design development and construction. Thus, if there are any changes to the scope of an existing activity or the project's critical path, the cost-loaded schedules should be updated by the design–builder to provide the most current schedule for the project, used as a reliable basis for decisions related to progress payments. Several state DOTs, including Georgia, Tennessee, South Carolina, and Virginia, have provisions of a cost-loaded schedule for their DB projects, which are provided in table 10. For example, one of the distinct differences between state DOTs is that Virginia DOT requires the DB contractor to submit a cost-loaded schedule for complex, high-risk, and costly megaprojects, while a cost-loaded schedule is optional for other projects (i.e., maintenance, simple construction, and slightly complex projects).

Table 10. Provisions for cost-loaded schedule for state DOTs' DB projects.

State DOT	Description
Georgia DOT (GDOT 2018a)	Georgia DOT requests the DB team to submit the **cost-loaded schedule** that includes any milestone deadlines and schedule activity start and finish dates (or any durations) with assigned dollar amounts for all scheduled activities. The DB team revises and updates the cost-loaded schedule to ensure the proposed expenditure remains under the Annual Cumulative Payment Caps.
Tennessee DOT (TDOT 2017)	The design–builder is required to prepare and submit a project CPM schedule, including time and cost-loaded, to the Department for review and acceptance. The **cost-loaded CPM** should be updated by the design–builder from time to time following contract requirements and depicting the following components: (a) pay items and subordinated activities and their respective prices; (b) duration, sequences, and interrelationships that represent design–builder's work plans; (c) design–builder's work structure for designing, constructing, and completing the project; and (d) the contract amount, distributed over the term of the contract.
South Carolina DOT (SCDOT 2018)	South Carolina DOT uses the **cost-loaded CPM schedule** for progress payments requested by and made to the contractor. The cost-loaded CPM schedule should be updated by the contractor to reflect the adjustment in the contract price.
Virginia DOT (VDOT 2012)	Virginia DOT uses a **cost-loaded schedule** for **Category IV and V projects**, representing complex, high-risk, and medium- to large-size projects and very complex and very costly mega-projects, respectively. The cost-loaded schedule is used to generate the time-distributed cost data on which the progress earning schedule is based. Thus, the cost-loaded schedule allows the Department to track the costs and assess the progress of the activity and the amount of time needed to complete the work. The cost-loaded schedule is prepared and revised by the contractor to reflect the current status of the work and any changes in the contractor's current work plan.

PRICE ADJUSTMENT CLAUSES IN PROGRESS PAYMENTS

The volatility of construction materials such as asphalt, fuel, cement, and steel can result in difficulty for contractors to prepare accurate bids. A price adjustment clause (PAC) is a risk-sharing strategy that partially protects the contractor against unforeseen price increases in material or fuel that may occur between contract award and implementation of the work. With the PAC, the Department agrees to share the risk for escalating prices and pays the developer for any increases exceeding an agreed threshold (Newcomb et al.

2012). With the PAC provision, payments are typically adjusted based on unit price and an adjustment factor for material price changes. However, since the DB contract uses the lump-sum payment method, the Department should develop special provisions for DB contracts that provide base quantities and prices for all contract work to calculate price adjustments (FHWA 2017c). Some state DOTs (e.g., North Carolina and Virginia) include provisions for PACs for certain materials (e.g., asphalt, fuel, and cement) for their DB contracts. Table 11 provides examples of state DOTs' price adjustment provisions included in the DB contracts.

Table 11. Summary of state DOTs' price adjustment provisions in DB contracts.

State DOT	Description	Types of Price Adjustment
Georgia DOT (GDOT 2011)	Georgia DOT includes a special provision for Price Adjustments in the DB contract to share the **risk of fluctuations in material prices**.	• Fuel • Asphalt Cement
Maryland DOT (MDOT 2018a)	Maryland DOT includes the provision of Price Adjustments in the DB contract to provide **additional compensation to the design–build team** or **credit to the administration for the fluctuation in the cost of construction materials**.	• Diesel Fuel • Asphalt Binder
North Carolina DOT (NCDOT 2018a)	North Carolina DOT uses Price Adjustments Provisions to share **the risk of the unusual price fluctuation** and minimize **the cost effects of the price uncertainty** for construction materials used in the construction.	• Diesel Fuel • Asphalt Binder • Asphalt Concrete Plant Mix
Virginia DOT (VDOT 2019a)	Virginia DOT uses Price Adjustment Provisions to adjust monthly progress payments to take into account **cost changes in construction materials** used on specific items of work.	• Fuel • Steel • Asphalt Binder

Georgia DOT

The Georgia DOT utilizes price adjustments for DB projects to deal with uncertainty in the future price of construction materials. For instance, the Georgia DOT included special provisions of price adjustment in the interchange construction project for connector ramps on I-85/SR 403/SR 400. In the special provision, the Georgia DOT provided the list of eligible bid items for fuel and asphalt cement price adjustments. Table 12 shows eligible bid items for price adjustments (GDOT 2011).

Table 12. Eligible bid items for Georgia DOT's price adjustments.

PAC	Fuel Price Adjustments	Asphalt Price Adjustments
Eligible Items (Units)	• Excavation (Cubic Yard) • Graded Aggregate Base (Ton) • Hot Mix Asphalt (Ton) • Portland Cement Concrete Pavement (Square Yard)	• Hot Mix Asphaltic Concrete o Asphalt Cement used for Bituminous Tack cost (Ton) o Asphalt Cement used for Bituminous Surface Treatment

The Georgia DOT uses a *fuel price index*, computed on a monthly basis for both gasoline and diesel fuel, and an *asphalt cement price index*, posted on the Georgia DOT web page (i.e., http://www.dot.ga.gov/PS/Materials/AsphaltFuelIndex). The Georgia DOT states that price adjustments will be applicable on projects with greater than or equal to 366 Calendar Days (i.e., contract duration) from the Contract Letting Date to the specified completion date (GDOT 2011).

Maryland DOT

The Maryland DOT uses price adjustment for DB projects to provide additional compensation to the contractor or credit to the Administration for the fluctuation in the cost of materials. The price adjustment provisions for diesel fuel and asphalt binder were included in the Maryland DOT's DB project, vehicle safety conditions, and traffic operation improvement along US 113. Table 13 presents the Maryland DOT eligible bid items for price adjustments (MDOT 2018a).

Table 13. Eligible bid items for Maryland DOT's price adjustments.

PAC	Diesel Fuel	Asphalt Binder
Eligible Items (Units)	• Excavation (Cubic Yard) • Structure Concrete (Cubic Yard) • Aggregate Base (Ton) • Hot Mix Asphalt (Ton) • Rigid Concrete Pavement (Square Yard)	• Asphalt Binder

The Maryland DOT uses the prevailing base index price for Performance Grade (PG) 64-22 (PG64s-22) asphalt binder and the On-Highway Diesel Fuel Price for the Central Atlantic Region published by the U.S. Department of Energy, Energy Information Administration (https://www.eia.gov/dnav/pet/pet_pri_gnd_a_epm0_pte_dpgal_w.htm). In addition, the price adjustment can be made when there is more than a 5 percent increase or decrease between the index price for the month of placement and the prevailing base index price (MDOT 2018a). One of the distinct differences between the Georgia DOT's PAC and the Maryland DOT's PAC is the base index price for the fuel price. Maryland DOT uses the Diesel Fuel Price for the Central Atlantic Region, while Georgia DOT uses the Georgia average prices for the fuel price adjustment.

North Carolina DOT

The North Carolina DOT's DB contracts include provisions of price adjustments for fuel and asphalt binder. The North Carolina DOT provides the list of eligible items in the Department Standard Specification. Table 14 presents the eligible items for fuel and asphalt binder price adjustment (NCDOT 2018b). Also, the price adjustment provisions were included in the North Carolina DOT's bridge replacement project in Cumberland County (NCDOT 2018a).

Table 14. Eligible items for North Carolina DOT's price adjustments.

PAC	Fuel Price Adjustment	Asphalt Binder Price Adjustment
Eligible Items (Units)	• Unclassified Excavation (Cubic Yard) • Borrow Excavation (Cubic Yard) • Class IV Subgrade Stabilization (Ton) • Aggregate Base Course (Ton) • Sub-Ballast • Asphalt Concrete Base Course, Type ____ (Ton) • Asphalt Concrete Intermediate Course, Type ____ (Ton) • Asphalt Concrete Surface Course, Type ____ (Ton) • Open-Graded Asphalt Friction Course (Ton) • Permeable Asphalt Drainage Course, Type ____ (Ton) • Sand Asphalt Surface Course, Type ____ (Ton) • Aggregate for Cement Treated Base Course (Ton) • Portland Cement for Cement Treated Base Course (Ton) • __" Portland Cement Concrete Pavement (Square Yard) • Concrete Shoulders Adjacent to __" Pavement (Square Yard)	• Asphalt Binder for Plant Mix

The North Carolina DOT uses the monthly selling price of asphalt binder and the base index price for Diesel #2 Fuel in adjusting the payment. For instance, the price for asphalt binder is adjusted by adding the difference (+ or −) of the base price index for asphalt binder for plant mix subtracted from the monthly selling price multiplied by the total theoretical quantity of asphalt binder (NCDOT 2018b). Compared to the eligible items of the Georgia DOT's fuel price adjustment, the North Carolina DOT has more eligible items for the fuel price adjustment, such as stabilization, open-graded asphalt friction course, and sand asphalt surface course.

Virginia DOT

The Virginia DOT uses price adjustment clauses for DB projects. For instance, in the I-81 bridge replacement project, the Virginia DOT included the provision of price adjustment clauses for asphalt, fuel, and steel. The Virginia DOT included the list of eligible bid items of asphalt and steel for a price adjustment to the bid proposal and contract of the I-81 bridge replacement project. Figure 2 and figure 3 provide screenshots of the list of eligible bid items for asphalt and steel price adjustments for the bridge replacement project. The Virginia DOT uses the monthly statewide average price of asphalt materials obtained from suppliers, the diesel fuel prices published by the U.S. Department of Energy, and the producer price index published by the Bureau of Labor statistics for asphalt, fuel, and steel price adjustments, respectively. When there is a greater than 10 percent change between the current index (i.e., the unit price of all asphalt placed) and the base index (i.e., the monthly statewide average price) during the middle of the month, the price adjustment is triggered. The design–builder, then, submits a letter to the Department for the price adjustment. There are three major components used in the adjustment calculations, including base index, current index, and quantity of the construction material put in place during the month. The calculations for a price adjustment should be separated from the monthly progress payment for work packages and will not be included in the total cost of work for the determination of progress or for extension of contract time (VDOT 2016). One of the major differences between the Georgia DOT's PAC and the North Carolina DOT's PAC is that the Virginia DOT includes steel in the price adjustments for the DB contract. In addition, the Virginia DOT provides a more detailed list of eligible items for price adjustments in both the contract and the Department specifications.

ORDER NO.: A48
CONTRACT ID. NO.: C000093087B60

VIRGINIA DEPARTMENT OF TRANSPORTATION
MASTER LISTING OF
ASPHALT MATERIAL ITEMS ELIGIBLE FOR PRICE ADJUSTMENT

ITEM	DESCRIPTION	UNITS	SPECIFICATION
10062	Asphalt-Stab. Open-Graded Material	Ton	313
10416	Liquid Asphalt	Gal	311 312
10417	Tack Coat	Gal	310
10420	Blotted Seal Coat Ty. B	SY	ATTD
10422	Blotted Seal Coat Ty. C	SY	ATTD
10423	Blotted Seal Coat Ty. C-1	SY	ATTD
10424	Blotted Seal Coat Ty. D	SY	ATTD
10598	NS Asphalt Concrete	Ton	315
10603	Asphalt Concrete Ty. SM-19.0A	Ton	315
10604	Asphalt Concrete Ty. SM-19.0D	Ton	315
10605	Asphalt Concrete Ty. SM-19.0E (76-22 or 64E)	Ton	315
10606	Asphalt Concrete Ty. SM-9.5	Ton	315
10607	Asphalt Concrete Ty. SM-12.5A	Ton	315
10608	Asphalt Concrete Ty. SM-12.5D	Ton	315
10609	Asphalt Concrete Ty. SM-12.5E (64E-22)	Ton	315
10610	Asphalt Concrete Ty. IM-19.0A	Ton	315
10611	Asphalt Concrete Ty. IM-19.0D	Ton	315
10612	Asphalt Conc. Base Cr. Ty. BM-25.0	Ton	315
10613	Asphalt Concrete Ty. BM-37.5	Ton	315
10614	Asphalt Concrete Ty. IM-19.0E (76-22 or 64E)	Ton	315
10635	Asphalt Concrete Ty. SM-9.5A	Ton	315
10636	Asphalt Concrete Ty. SM-9.5D	Ton	315
10637	Asphalt Concrete Ty. SM-9.5E (64E-22)	Ton	315
10639	Asphalt Concrete Ty. SM-19.0	Ton	315

Figure 2. Screenshot. Asphalt material items eligible for price adjustment in the Virginia DOT DB contract.

ORDER NO.: A48
CONTRACT ID. NO.: C000093087B60

MASTER LISTING

STANDARD BID ITEMS ELIGIBLE FOR STEEL PRICE ADJUSTMENT

Sept. 24, 2008	rev # 1added 4 corrosion resistant re-bar items.	
Dec. 4, 2008	rev # 2 deleted item 68138 straighten structural steel	
January 14, 2009	rev # 3 identified BLS WPU used in $ adjustment	**BLS Series I. D.**
March 18, 2009	added items 61813,68109 & 68110	

ITEM NUMBER	ITEM DESCRIPTION	UNITS	Number WPU used in $ adjust.
00519	SHEET PILE, STEEL	SF	avg. 1017 & 101
00540	REINF. STEEL	LB	101704
00541	CORROSION RESISTANT REINF.STEEL CL. I	LB	101704
00542	EPOXY COATED REINF. STEEL	LB	101704
00560	STRUCTURAL STEEL JB-1	LB	avg. 1017 & 101
11030	REINF. STEEL BRIDGE APPR. SLAB	LB	101704
11181	PATCH.HYDR.CEM.CONC. PAVE.	SY	101704
13290	GUARDRAIL GR-8 (NCHRP 350 TL-3)	LF	avg. 1017 & 101
13292	GUARDRAIL GR-8A (NCHRP 350 TL-3)	LF	avg. 1017 & 101
13294	GUARDRAIL GR-8B (NCHRP 350 TL-3)	LF	avg. 1017 & 101
13310	GUARDRAIL TERMINAL GR-6 (NCHRP 350)	LF	avg. 1017 & 101
13312	GUARDRAIL TERMINAL GR-7 (NCHRP 350)	EA	avg. 1017 & 101
13315	GUARDRAIL TERMINAL GR-11	EA	avg. 1017 & 101
13320	GUARDRAIL GR-2	LF	avg. 1017 & 101
13323	GUARDRAIL GR-2A	LF	avg. 1017 & 101
13331	RAD. GUARDRAIL GR-2	LF	avg. 1017 & 101
13333	RAD. GUARDRAIL GR-2A	LF	avg. 1017 & 101
13335	GUARDRAIL GR-3	LF	avg. 1017 & 101

Figure 3. Screenshot. Standard bid items eligible for steel price adjustment in the Virginia DOT DB contract.

SUMMARY

Establishing a payment mechanism (e.g., SOV, cost-loaded schedule, and incentives) for both design and construction progress is a critical task for delivering DB and other innovative project delivery (e.g., design–build–finance, design–build–finance–operate–maintain, and public–private partnership) projects. Thus, the primary objective of this chapter is to review the current state of the practice in state DOTs regarding the schedule of values and progress payments of DB and other innovative project delivery for highway projects.

Through a comprehensive content analysis of documents (i.e., RFPs, price proposals, and design–build manuals) from other state DOTs, this research reviewed the current practice of state DOTs in the following areas: (1) use of a schedule of value for DB contracts, (2) updates to the schedule of values, (3) approval and disapproval of progress payments, (4) incentives for early completion for DB contracts, (5) use of cost-loaded schedules for design and construction activities, and (6) use of price adjustment clauses in progress payments.

The recommendations from this chapter are summarized as follows:

- A well-established SOV helps the Department develop a project-specific basis for reviewing and approving the design–builder’s work and developing a periodic pay estimate throughout the project.

- An updated SOV that accommodates any changes in the scope of work is essential to smooth execution of the progress payment and a successful DB project.
- A detailed/updated payment breakdown for progress payments helps the Department approve/disapprove the payment to the contractor and reduce disputes.
- Inclusion of early completion incentives in the DB RFP can encourage the design–builder to not only finish the project on time but also minimize the impact on the communities in which the projects are constructed.
- A well-defined cost-loaded critical path method schedule enables the Department to establish the expected cash flow for the life of the project.
- Establishing and providing specific bid items that are eligible for price adjustments in a contract provides the Department with a more accurate and dynamic adjustment tool for payments.

CHAPTER 3.
CONSTRUCTION EXPENDITURE FLOWS FORECASTING TOOL FOR TRANSPORTATION DESIGN–BUILD PROJECTS

INTRODUCTION

The work on forecasting expenditure cash flow for transportation projects is relatively underrepresented in the literature. Two studies were focused on fitting a mathematical function to model the cash flow of expenditure records of transportation projects. In the first study, Jarrah et al. (2007) classified Texas DOT projects from 2001 to 2003 into 10 groups based on their project types and contract amounts. For each group, Jarrah et al. fitted a single-variable polynomial function to model expenditure cash flows (the single variable was time). In the second study, Liu et al. (2015) fitted several mathematical functions to model the cash flow expenditures of two North Carolina DOT transportation megaprojects, including a linear polynomial model, quadratic polynomial model, cubic polynomial model, quartic polynomial model, exponential model, and rational model. Liu et al. found that, for the two studied megaprojects, quartic polynomial models provided the best fit to model expenditure cash flows.

Linear regression analysis and neural network analysis were also used to estimate the cash flow expenditures of transportation projects. Mills and Tasaico (2005) developed two polynomial regression models using time and project attributes, including number of active contracts, size, duration, engineering type, contract type, region, and weather, as inputs to estimate monthly payments for transportation projects completed by the North Carolina DOT between 2000 and 2002. However, the developed regression models did not show a reasonable accuracy beyond a 12-month forecasting horizon. Chao and Chien (2009) applied neural network analysis to estimate the parameters of polynomial functions that are used to estimate the expenditure curves of six subprojects of the second freeway in Taiwan. Contract amount, duration, type of work, and location were used as the inputs to the neural network models to estimate the coefficients of the developed polynomial functions.

However, none of the existing studies focused on forecasting expenditure cash flow of transportation design–build projects. Design–build has been increasingly used by state DOTs to expedite project delivery and utilize innovative ideas to improve the project performance (USDOT 2006). Cash flow estimating models built based on expenditure records of traditional design–bid–build projects are inherently limited for forecasting the expenditure cash flow of design–build projects. DB projects include payments for several services that do not exist in DBB projects. Most importantly, a DB contract includes a design fee to complete detailed design services for the project, as the engineer of record is part of the DB team. Other services, such as design quality management and construction quality assurance services, are also parts of DB contracts.

The pattern of expenditure is different in DB projects, as design–builders strive to overlap design and construction services as much as possible, in order to expedite project delivery (i.e., packaging of work to facilitate fast-tracking). At the outset of awarding a typical DB contract, only high-level information is available to develop a conceptual cost estimate for the project. Since design has not been finalized, the exact quantities are not determined to develop a detailed cost estimate for the project. This issue represents a big difference between DB and DBB projects that makes estimating the project payouts more difficult for DB projects. Therefore, using expenditure records of design–bid–build projects as inputs to develop a forecasting model for the anticipated expenditure cash flow of a DB project is not appropriate. This research for the first time aims to develop a forecasting model to estimate the expenditure cash flow of transportation design–build projects.

RESEARCH OBJECTIVES

The overarching objective of this chapter is to develop a new expenditure cash flow forecasting model for transportation design–build projects. The proposed forecasting model should be able to generate accurate forecasts with limited training data. In addition, it should be applicable to transportation DB projects with different compositions of tasks. Lastly, the proposed forecasting model should be able to utilize high-level describable attributes and to handle missing values in input, which might be a common problem in the conditions specified in this study.

The existing forecasting models for the design–bid–build projects to be awarded are not suitable for transportation design–build projects. The reasons are threefold. First, existing models rely on a large database, which may not be always accessible. For instance, Mills and Tasaico (2005) used 336 completed projects awarded by the North Carolina DOT between August 2000 and June 2002. Jarrah used 245 completed projects awarded by the Texas DOT between September 2001 and December 2003. On the contrary, in the same time periods, there were only two DB projects awarded by the North Carolina DOT (NCDOT n.d.) and no DB projects awarded by the Texas DOT (TxDOT 2019), correspondingly.

Second, existing models are based on simple curve-fitting of each type of project. However, as transportation owner agencies tend to use design–build to handle project complexity and to transfer risks (Demetracopoulou et al. 2020), a design–build project may comprise tasks of different types, making it hard to classify design–build projects in the way designed for design–bid–build projects. For example, bridge replacement is a project type defined by the Texas DOT, for which Jarrah et al. (2007) fit individual polynomial models to represent. Yet, in addition to the task of bridge replacement, the Northwest Corridor Express Lane project in the state of Georgia, for instance, also includes other types of tasks by definition within the Georgia DOT (GDOT 2015), such as new location roadway, location-specific improvement, and widening.

Third, existing models require too much detailed information, such as for scheduling. As a result of the integrated design–build process, detailed scheduling information of DB projects does not exist at the pre-award phase. Only high-level describable project attributes that are available at the stage of preliminary design could be used as input for the forecasting model, such as contract amount and location. Moreover, there might be missing values in the input data, which is partially due to the unavailability of project classification by types. For example, design speed is crucial for a highway rehabilitation project, but it is not applicable for a pedestrian construction project.

METHODOLOGY

An approach based on case-based reasoning and a genetic algorithm is developed in this project for creating a forecasting model for expenditure cash flow of transportation design–build projects. Case-based reasoning is a data mining technique rooted in the notion that the solution of a new problem comes from the experience of solving previous problems in similar situations (Richter and Weber 2013). To generate a forecast for a new case, case-based reasoning retrieves existing cases with the highest similarities to the new case and then integrates the cash flows of the selected existing cases by taking the weighted average. The population of existing cases increases as the completed cases accumulate.

Data

A database of 33 transportation design–build projects completed between April 2007 and January 2020 in the state of Georgia is used as the basis to create the forecasting model. The 33 projects are listed in Table 15 provides an overview of 19 project-specific attributes that were available for these GDOT projects at the time that the design–build contracts were awarded. These attributes were taken from two sources: DB fact sheets published by GDOT (GDOT 2020) and GeoPI. GeoPI® is a search engine designed to help users locate any GDOT-related data or documentation.

Table 15. Projects used for model development.

Project Name	Project ID
I-85 at KIA Interchange	8232
I-75 Southbound Auxiliary Lane (from I-675 to Eagles Landing Parkway)	8274
SR 400 @ Hammond Drive (Half Diamond Interchange)	8415
SR 204 Spur Bridge Replacement (over Skidaway Narrows)	8651
I-575 @ Ridgewalk Pkwy Interchange	6043
I-20 EB from I-285 to Panola Road (Collector Distributor System)	9542
SR 400/I-85 Connector Ramps	762380-
Jimmy Deloach Connector (South of I-95 to SR 307/Bourne Avenue)	8690
I-75 NB Auxiliary Lane (Eagles Landing Pkwy to I-675 incl Walt Stephens Bridge Replacement)	10126
SR 400 NB Ramp Extension (Abernathy Rd) & SR 400 NB Lane Extension (McFarland to Big Crk Greenway)	10311_10290
I-285 Variable Speed Limit Signs	10782
SR 400 @ Northridge Rd	751580-
I-75 Managed Lanes (SR 155 to I-675/SR 138)	9156_9157
SR 47 @ Little River 10.5 MI SE of Lincolnton	232310-
Safe Routes to Schools (Various Locations)	0010401_0010403_0010394
SR 316 @ Walther Blvd – Grade Separation	10425
Weigh-in-Motion (WIM) Scales – FY 14 incl Mainline WIM Software/Integration	12683
I-285 Ramps @ CR 209/Riverside Drive – Roundabouts	10925
SR 21 @ I-95 Diverging Diamond Interchange (DDI)	12722
SR 400 Widening from McFarland Rd to SR 369	13367
I-85 Managed Lanes Extension (Old Peachtree Road to CR 134/Hamilton Mill Road)	110600-
SR 299 @ I-24 Bridge Replacement (Accelerated Bridge Construction)	11682
FY 16 Bridge Replacement – Batch 1	14174
FY 16 Bridge Replacement – Batch 2	14175
FY 16 Bridge Replacement – Batch 3	14176
FY 16 Bridge Replacement – Batch 4	14177
FY 16 Bridge Replacement – Batch 5	14178
CS 1868/Courtland Street @ CSX RR/MARTA/Decatur Street	752015-
Northwest Corridor	
I-85 Widening CR 134/Hamilton Mill Road to SR 211	110610-
FY 17 Bridge Replacement – Batch 1	15523
FY 17 Bridge Replacement – Batch 2	15524
I-85 Corridor Bridges	15436

The project-specific attributes, as described in table 16, are basic conceptual information about the project scope and its basic design parameters at the time the project is getting under contract, for example, design traffic and design speed. According to the GDOT classification (GDOT 2015), projects can be grouped into seven major project types, i.e., bridge replacement, bridge maintenance, interchange reconstruction, location-specific improvement, systemic improvement, widening, and new location roadway. A design–build project can belong to more than one project type. For example, a project may contain intersection reconstruction and traffic signal upgrades along the road. Of the 33 projects, 13 can be labeled as more than one project type.

Table 16 provides detailed descriptions of 11 project-specific attributes that will be used as inputs in the model to forecast expenditure cash flow of design–build projects. Of these 11 attributes, two variables are numerical attributes, two variables are categorical attributes, and seven variables are binary attributes. A range of possible values for these attributes is also provided in Table 16.

Table 16. Project-specific attributes.

Project-specific Attribute	Description
Contract amount	Numerical, ranging from $1,428,267 to $647,166,673, with mean $48,113,526, extracted from DB fact sheet
Contract duration	Numerical, the period between two dates: notice to proceed date and completion date, ranging from 234 days to 1763 days, with mean 924 days, extracted from DB fact sheet
Regional district	Categorical: {regional district 1 to regional district 7}, GDOT has seven district offices throughout the state of Georgia, as shown in Figure 4 (GDOT 2018c), extracted from GeoPI
Procurement method	Categorical: {one phase low bid, two phase low bid, best value}, extracted from DB fact sheet
Bridge replacement	Binary, a type of project, classified by GDOT, extracted from GeoPI
Bridge maintenance	Binary, a type of project, include bridge painting, and repair & rehabilitation, classified by GDOT, extracted from GeoPI
Interchange reconstruction	Binary, a type of project, classified by GDOT, extracted from GeoPI
Location-specific improvement	Binary, a type of project, including the construction of roundabout & intersections, traffic signals, pedestrian upgrades, lighting, and IT & operational improvements, classified by GDOT, extracted from GeoPI
Systemic improvement	Binary, a type of project, including the construction of guardrail & cable barrier, edge line & centerline rumble strips, sharp curve treatments, sign upgrades, railroad crossing safety, and noise wall, classified by GDOT, extracted from GeoPI
Widening	Binary, a type of project, including the construction of passing lanes and climbing lanes, classified by GDOT, extracted from GeoPI
New location roadway	Binary, a type of project, classified by GDOT, extracted from GeoPI

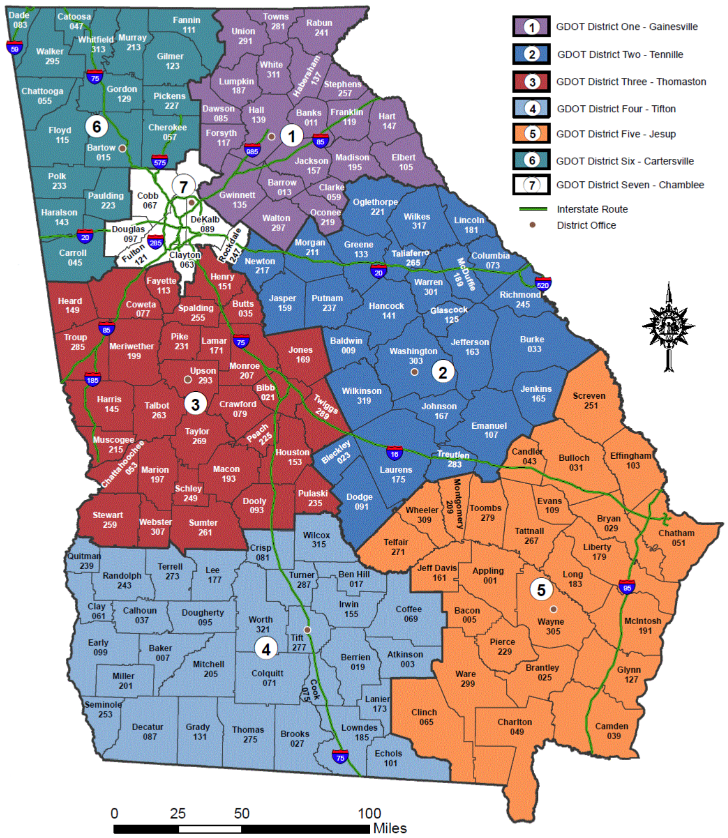


Figure 4. Map. Georgia district map.

In addition to project-specific attributes, several external attributes are also considered in modeling expenditure cash flow of transportation design–build projects. Earlier research conducted by one of the authors (Baek and Ashuri 2019) showed that several variables representing local transportation construction market conditions have significant impact on submitted bid prices for projects. Table 17 represents six external attributes with the greatest impact on submitted bid prices. Two of these attributes represent how busy the local transportation market is on the same month as the design–build contract is executed, total number of projects and total value of projects awarded by GDOT. Data of these two attributes are extracted from Bid Express. Bid Express® is an online system containing information about past proposals, bid prices, and bidders of the Georgia highway projects. The other four attributes represent local transportation market conditions as far as key materials, labor, and equipment: Georgia Fuel Price Index, Georgia Asphalt Cement Price Index (published by the GDOT Office of Materials on a monthly basis), Job Opening and Labor Turnover Index, and Producer Price Index for Construction Machinery Manufacturing (available from the U.S. Bureau of Labor Statistics). Table 17 provides detailed descriptions of these six external attributes that will be used as inputs in our model to forecast expenditure cash flow of design–build projects. All these attributes are numerical; a range of possible values is also provided in Table 17.

Table 17. External attributes.

External Attributes	Description
Georgia fuel price index	Numerical, an average selling price of fuel that is collected from approved local fuel suppliers as reported in GDOT's monthly survey, ranging from $1.73/gal to $3.86/gal, with mean $2.75/gal
Georgia asphalt cement price index	Numerical, an average selling price of asphalt cement that is collected from approved local asphalt cement suppliers as reported in GDOT's monthly survey, ranging from $304/ton to $623/ton, with mean $465/ton
Producer price index for construction machinery manufacturing	Numerical, an index measuring changes in prices received for the output of the construction machinery manufacturing sold to another industry, ranging from 116 to 139, with mean 133
Job opening and labor turnover index	Numerical, an index that represents the number of hires during the entire month as a percent of total employment, ranging from 176 to 566, with mean 358
Monthly number of projects awarded in Georgia	Numerical, the number of projects awarded in each month and in the same county as of the project in the state of Georgia, ranging from 4 projects to 110 projects, with mean 30 projects
Monthly value of projects awarded in Georgia	Numerical, the total dollar value of projects awarded in each month and in the same county as of the project in the state of Georgia, ranging from $1,851,745 to $335,990,273, with mean $124,895,413

Considering the relatively small number of design–build projects in the dataset, case-based reasoning is selected as an appropriate method to develop a forecasting model for expenditure cash flow. Case-based reasoning is a powerful data mining algorithm for cases with a relatively small number of data points and a relatively large number of attributes describing each data point (Richter and Weber 2013). CBR is also found to have flexibility in terms of handling missing data and self-updating with new cases (Arditi and Tokdemir 1999).

Model Development

As Figure 5 shows, the development of the cash flow forecasting model comprises 10 steps. Each step is elaborated in this section.

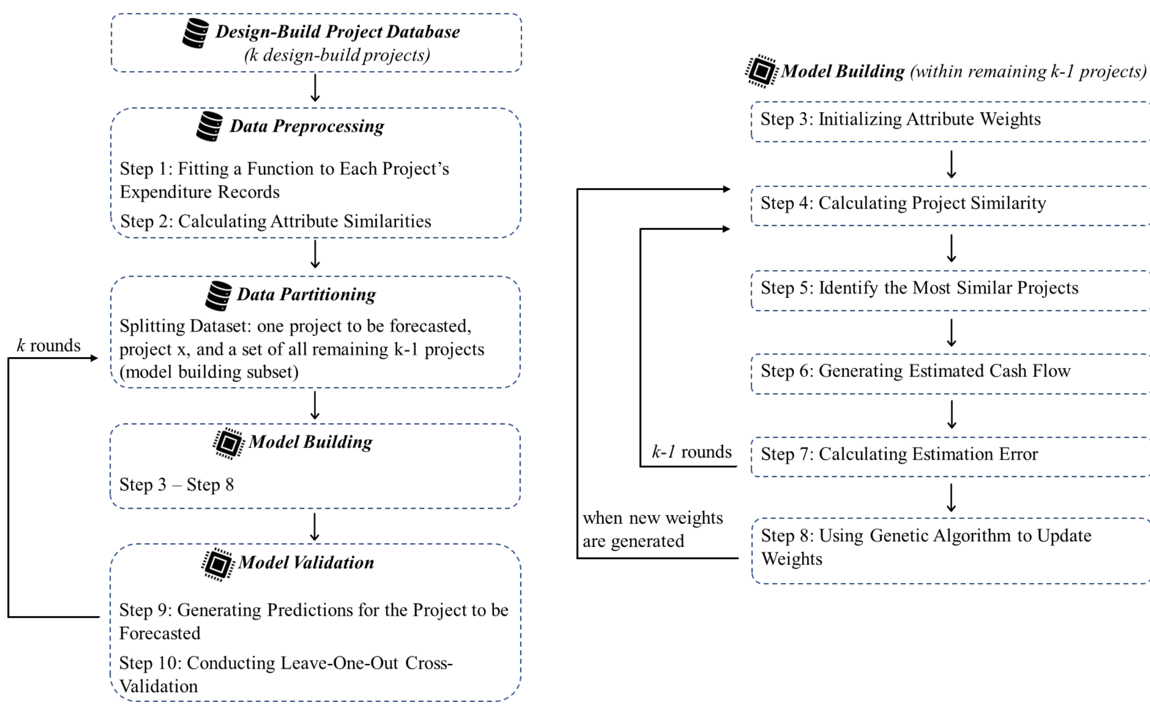


Figure 5. Chart. Model development steps.

Step 1: Finding an appropriate function that best fits the expenditure records of each design–build project in the dataset

First, the cumulative expenditure records of each design–build project are plotted on a graph where the horizontal axis represents project timeline progress as a percentage of total project duration, and the vertical axis represents the cumulative payment as a percentage of total project price. Figure 6 shows the plotted cumulative expenditure records of all 33 design–build projects in the dataset. The projects are labeled as project #3, #10, #23, and #33. Three types of functions are tried to fit to the cumulative expenditure records of design–build projects in the dataset: cubic polynomial, quartic polynomial, and beta functions. It can be seen that the beta function is overall the best fit for cumulative expenditure records for these projects. In addition to providing a high level of accuracy in fitting the plotted points, the formulation of the beta function satisfies the non-decreasing property of a cumulative expenditure function. The beta function is defined by Eq. 1:

$$B(\varphi) = \frac{\int_0^{\varphi} t^{\alpha-1}(1-t)^{\beta-1}\,dt}{\int_0^{1} t^{\alpha-1}(1-t)^{\beta-1}\,dt} \quad (1)$$

where α and β are shape parameters that are estimated for each project, φ is the point in the project timeline (measured by percentage of total project duration) for which the cumulative expenditure $B(\varphi)$ (measured by percentage of total project cost) is calculated by the developed beta function.

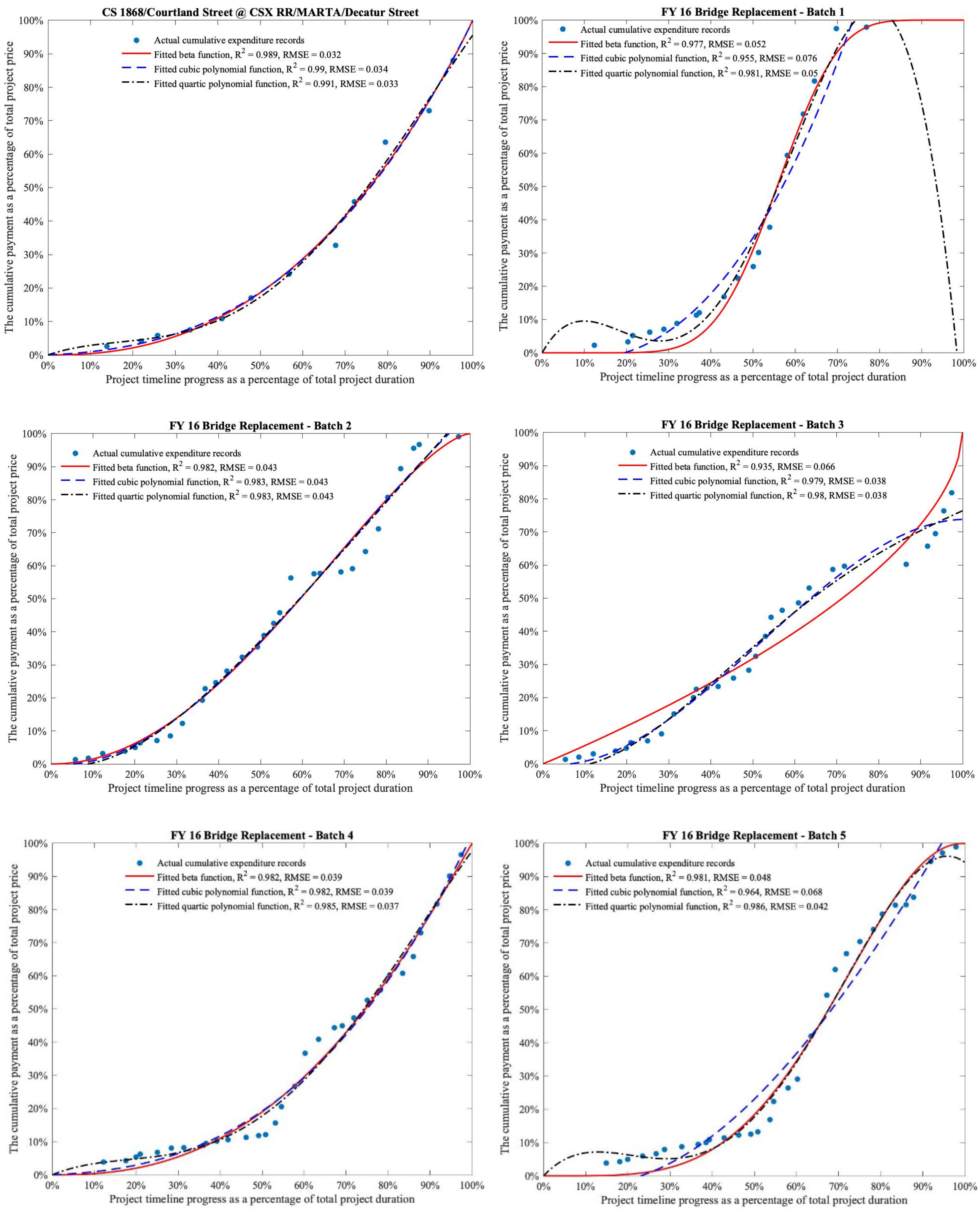


Figure 6. Graphs. Cumulative expenditure curve fitting for the design–build projects.

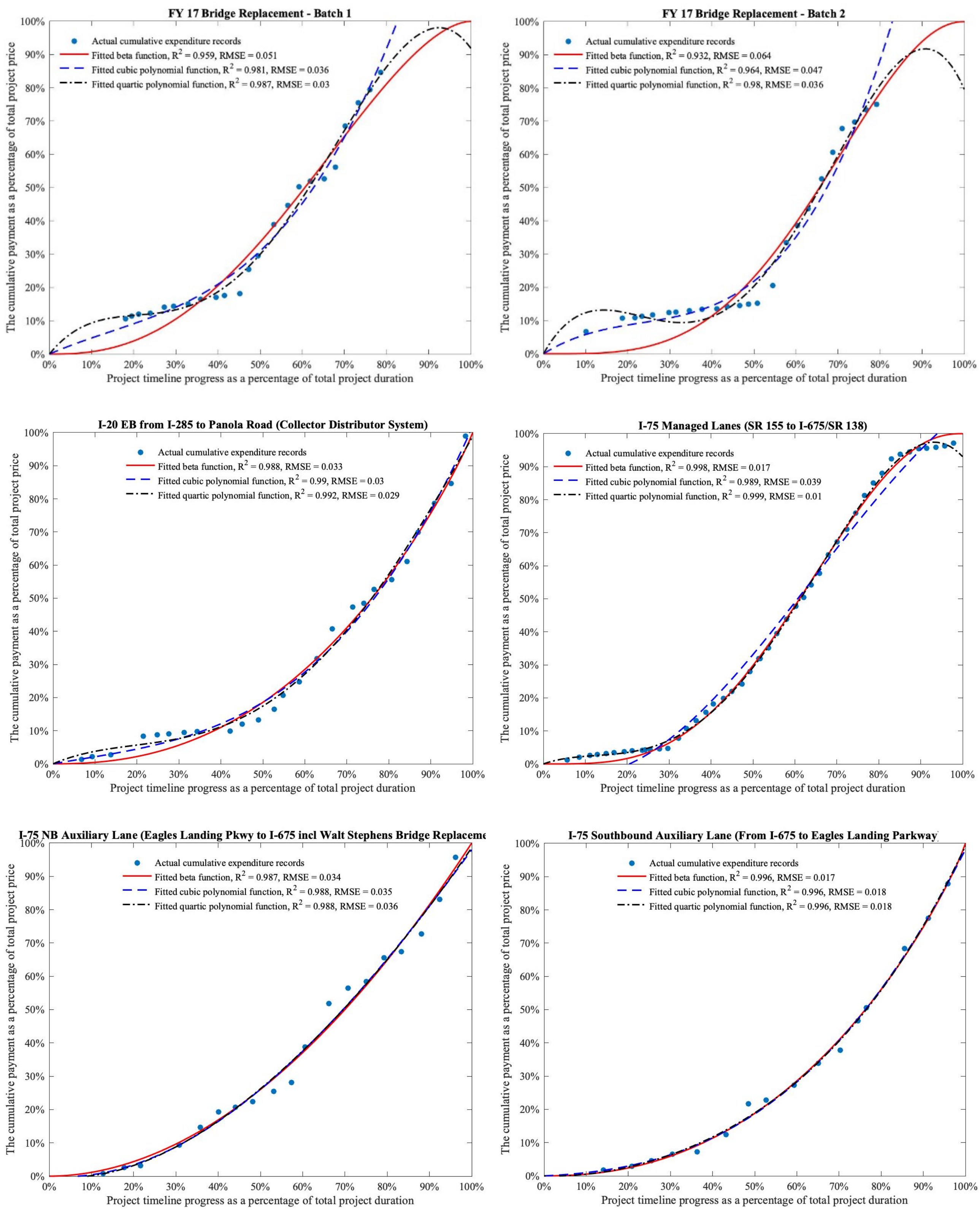


Figure 6 (Continued). Graphs. Cumulative expenditure curve fitting for the design–build projects.

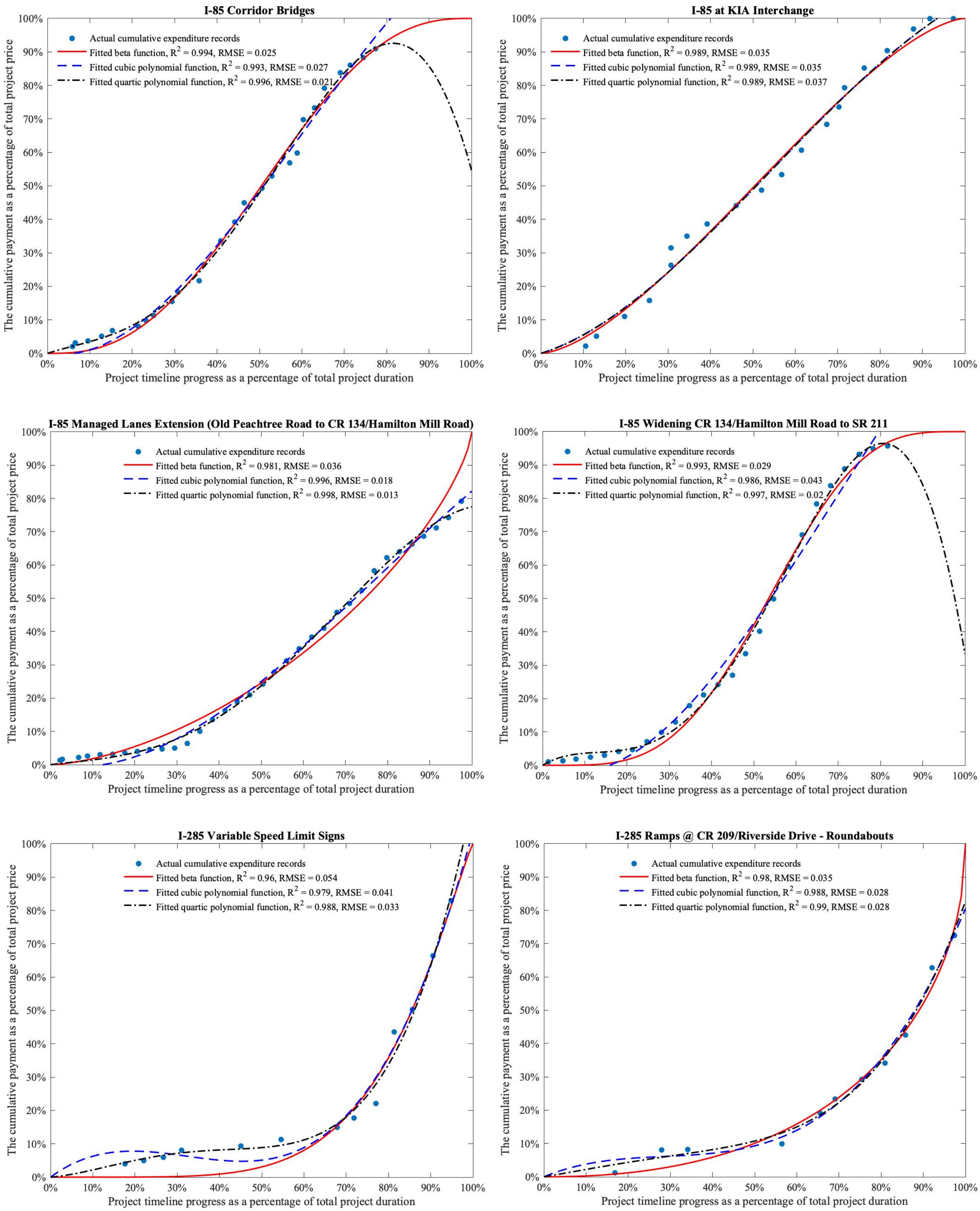


Figure 6 (Continued). Graphs. Cumulative expenditure curve fitting for the design–build projects.

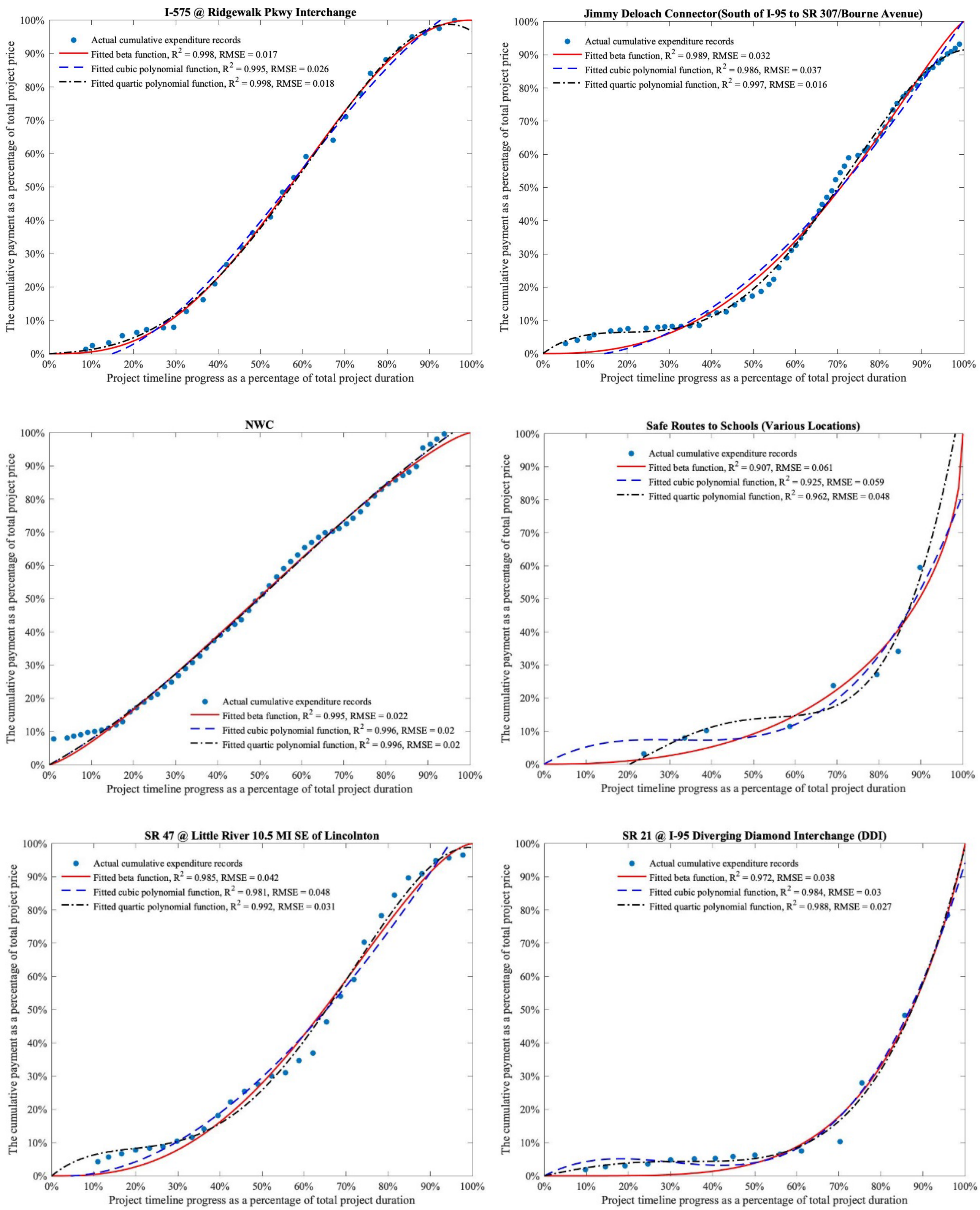


Figure 6 (Continued). Graphs. Cumulative expenditure curve fitting for the design–build projects.

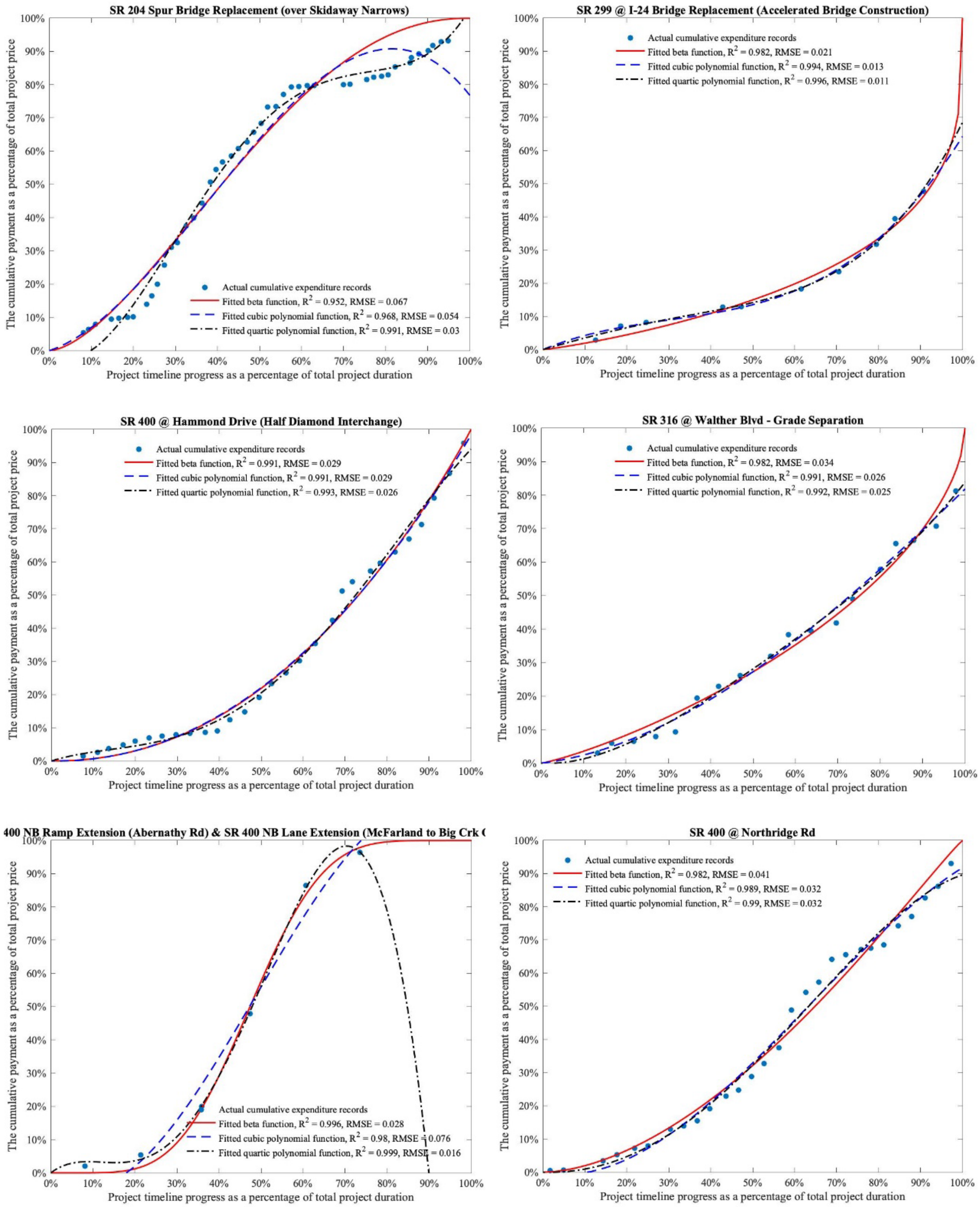


Figure 6 (Continued). Graphs. Cumulative expenditure curve fitting for the design–build projects.

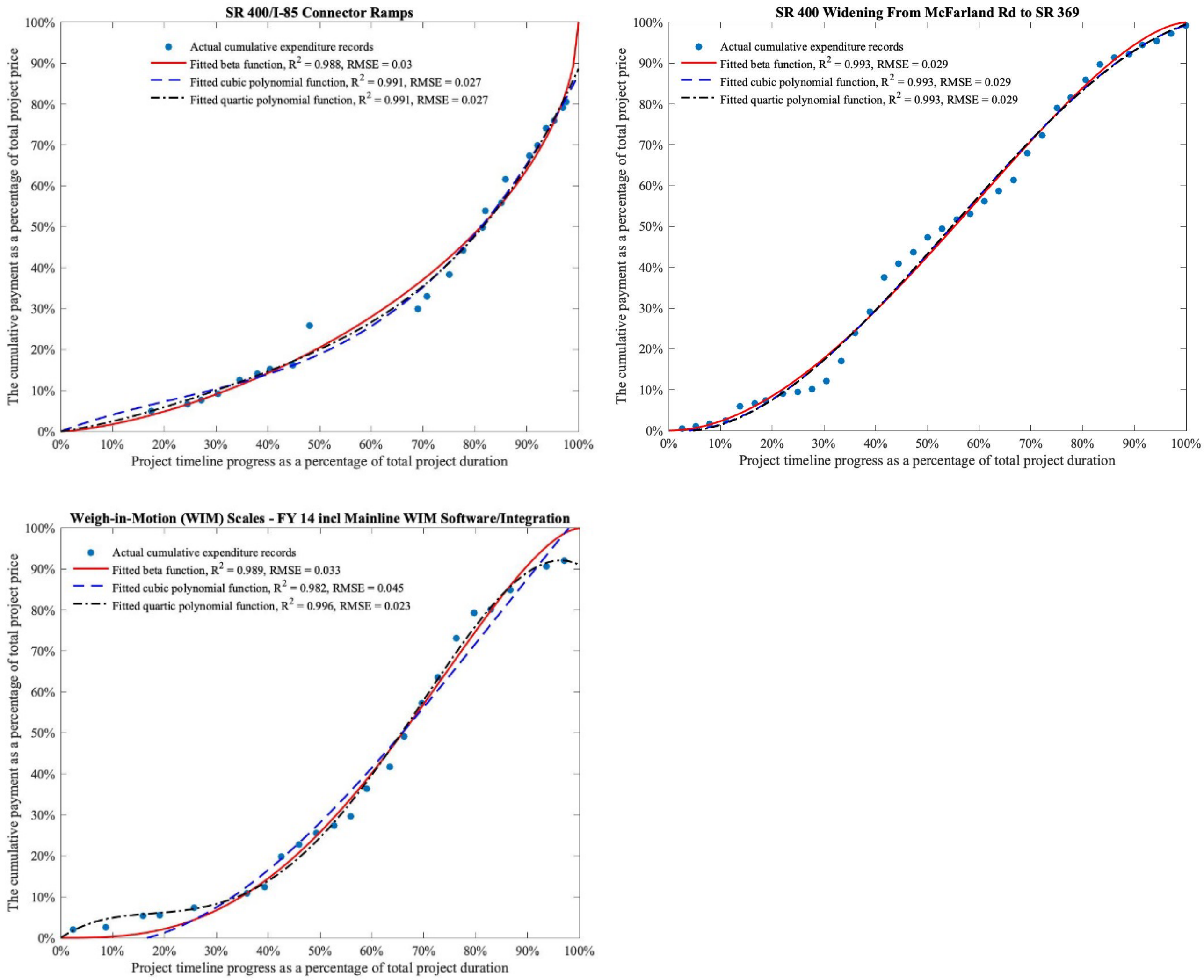


Figure 6 (Continued). Graphs. Cumulative expenditure curve fitting for the design–build projects.

Step 2: Calculating Attribute Similarities

The case-based reasoning algorithm uses the similarity between a project and other projects in the dataset to forecast the expenditure cash flow for the project. Higher project similarities imply higher similarities in cash flows. Project similarity is obtained by taking the weighted average of attribute similarity values. Attribute similarities are values ranging from 0 to 100 where a large value indicates high-level similarity. There are two types of project attributes in the model: numerical attributes and categorical attributes (including binary variables). When comparing the similarity of attribute *s* between project *i* and project *j*, the value is defined as Eq. 2 if attribute *s* is numerical, and the value is defined as Eq. 3 if attribute *s* is categorical. Attribute similarities are calculated between each project attribute of any two projects in the dataset.

$$AS_{s,i,j} = \left(1 - \frac{|AV_{s,i} - AV_{s,j}|}{AV_{s,max} - AV_{s,min}}\right) \times 100 \tag{2}$$

$$AS_{s,i,j} = \begin{cases} 100 & \text{if } AV_{s,i} = AV_{s,j} \\ 0 & otherwise \end{cases} \tag{3}$$

where $AS_{s,i,j}$ = the similarity of attribute *s* between project *i* and project *j*; $AV_{s,i}$ = the value of attribute *s* in project *i*; $AV_{s,max}$ = the maximum value of attribute *s* in all the projects in the dataset; and $AV_{s,min}$ = the minimum value of attribute *s* in all the projects in the dataset.

Step 3: Initializing Attribute Weights

The overall project similarity is the weighted average of the calculated attribute similarities in the previous step. The computed attribute similarities are rolled up to determine the project similarity using appropriate weights. Finding the right weights is an optimization problem that needs to be solved. The weights are decision variables in this optimization problem. The objective function is to minimize the difference between the predicted expenditure curve and the actual expenditure cash flow curve. The initial sets of attribute weights are randomly generated with values between 0 and 100.

Suppose there are *k* design–build projects in the dataset. In this step, the *k* projects are split into two subsets. The first subset contains only one project, denoted by project *x* hereafter. The second subset contains all the remaining $k-1$ projects that will be used for building the forecasting model. The second subset is referred to as the model building subset hereafter. The $k-1$ projects are used to determine an optimal set of attribute weights by which the overall error of cash flow estimating for $k-1$ projects is minimized. The optimal set of attribute weights will be applied on the project to be forecasted (project *x*), in order to predict its expenditure cash flow curve.

Step 4: Calculating Project Similarities

Consider a project in the model building subset, project *y*. Suppose project *z* is another project in the model building subset. The similarity between projects *y* and z is defined as Eq. 4, i.e., the weighted average of attribute similarities calculated in step 2 with the attribute weights selected in step 3.

$$PS_{y,z} = \frac{\sum_{s=1}^{m}(w_s \times AS_{s,y,z})}{\sum_{s=1}^{m} w_s} \qquad \text{Eq. (4)}$$

where $PS_{y,z}$ = the project similarity between project *y* and project *z*; w_s = the weight for attribute *s*; and m = the total number of project attributes. Using the same set of attribute weights, project similarities are calculated between any two projects in the model building subset.

Step 5: Identifying the Most Similar Projects to Project y in the Model Building Subset

Projects in the model building subset with the highest project similarities to project y are selected to retrieve information for estimating the expenditure cash flow of project y. The top five similar projects with the greatest values of project similarities PS calculated in step 4 are identified. The cumulative expenditure cash flows of these five projects are used to estimate the cumulative cash flow of project y. Choosing the top five similar cases in the dataset is a recommended approach in the case-based reasoning literature, as five has been identified as an appropriate number of similar cases for building the prediction model (Ahna et al. 2017). The estimated results will be examined to ensure that selecting the top five similar cases leads to the best possible estimation for cumulative expenditure curves. The retrieval process described in this step is conducted for each of the $k-1$ projects in the model building subset.

Step 6: Generating Estimated Cash Flow

The value of cumulative expenditure for project y is calculated at any point of time using the corresponding values of the top similar projects in the model building subset. Calculated project similarities are used as weights applied to the corresponding cumulative expenditure values of the top five similar projects. At any point in time during the project timeline *(t)*, estimated cumulative expenditure for project *y*, denoted by $CE_{Estimated}^{(t)}$, is calculated using Eq. 5.

$$CE_{Estimated}^{(t)} = \frac{\sum_{r=1}^{5}(PS_{y,r} \times CE_r^{(t)})}{\sum_{r=1}^{5} PS_{y,r}} \tag{5}$$

where $CE_r^{(t)}$= cumulative expenditure of the cash flow of the r^{th} retrieved project at time *(t)*; $PS_{y,r}$ = the project similarity between project *y* and the r^{th} retrieved project. The estimating process described in this step is performed on each of the *k−1* projects in the model building subset.

Step 7: Calculating Estimation Error

The estimation error for project *y* is measured by mean absolute error (MAE) using Eq. 6.

$$MAE = \int_0^{100\%} \left| CE_{Estimated}^{(t)} - CE_{Actual}^{(t)} \right| dt \tag{6}$$

where $CE_{Estimated}^{(t)}$ = cumulative expenditure during the project timeline *(t)* of the estimated cash flow; and $CE_{Actual}^{(t)}$ = cumulative expenditure during the project timeline *(t)* of the actual cash flow. The MAE described in this step is calculated for each of the *k−1* projects in the model building subset. The overall error of each set of attribute weights is computed by taking the average value of MAE for all *k−1* estimated cash flows.

Step 8: Using Genetic Algorithm to Search for the Optimal Set of Attribute Weights

The space of attribute weights needs to be searched to find an optimal set of attribute weights that provides the lowest reasonable estimation error across all projects in the model building subset. A genetic algorithm is used to evolve the initial sets of attribute weights and search for the optimal set of attributes. The genetic algorithm has good capability to handle nonlinear optimization problems (Pal and Shiu 2004). The solution domain of the genetic algorithm is the sets of attribute weights. The fitness value of each set of attribute weights is its overall estimation error calculated in step 7. Fitness proportionate selection is used as the selection method of the genetic algorithm, in which the probability of each existing set of attribute weights to breed a new generation of weights is inversely proportional to its overall estimation error. Crossover and mutation are used as the genetic operators of the genetic algorithm to generate a new generation of weights. Crossover and mutation rates are set at 0.9 and 0.01, respectively. For each newly generated set of attribute weights, steps 4–7 are repeated. The genetic algorithm stops when the number of maximum generations is reached. In this study, the maximum generation is set as 500, following the rule of thumb given in the literature (Ahmed and Deb 2013, Zhang et al. 2009). Upon completion of this step, an optimal set of attribute weights is found for providing the best estimates for expenditure cash flows of $k-1$ projects in the model building subset.

Step 9: Applying the Optimal Weights to Predict the Expenditure Curve of Project x

The optimal set of attribute weights obtained in step 8 is used to forecast the cash flow expenditure curve of project *x*. The optimal weights are used to calculate the project similarities between project *x* and each of the $k-1$ projects in the model building subset using Eq. 4. The top five similar projects to project x are identified based on the greatest values of project similarities, and the value of cumulative expenditure for project *x* is calculated at any point in time using the corresponding values of these similar projects in the model building subset. The MAE measure described in Eq. 5 is used to calculate the error of forecasting the cash flow expenditure of project *x*.

Step 10: Conducting Leave-One-Out Cross-Validation

A leave-one-out cross-validation (LOOCV) method is used to assess the accuracy of the developed case-based reasoning model. Completion of steps 3–9 results in the forecasted expenditure cash flow of one project in the dataset, project *x*. The same steps 3–9 will be repeated to forecast cash flow expenditure curves of the other $k-1$ projects in the dataset. In all, *k* rounds of the developed partitioning-training-forecasting process are conducted to predict expenditure cash flows of all projects in the dataset.

RESULTS

The expenditure cash flow curve of each design–build project in the dataset is forecasted using information from the other 32 design–build projects in the dataset. Thirty-three forecasts are made using the developed case-based reasoning model, in order to evaluate the accuracy of the forecasting method. Figure 7 shows forecasted cumulative expenditure cash flow for all 33 design–build projects in the dataset. The values of shape parameters α and β are specified for each forecasted beta function in the graph. The forecasted error term, i.e., MAE, is also identified for each predicted cumulative expenditure curve. Figure shows the distribution of MAE values of all predictions and associated minimum value, maximum value, and standard deviation.

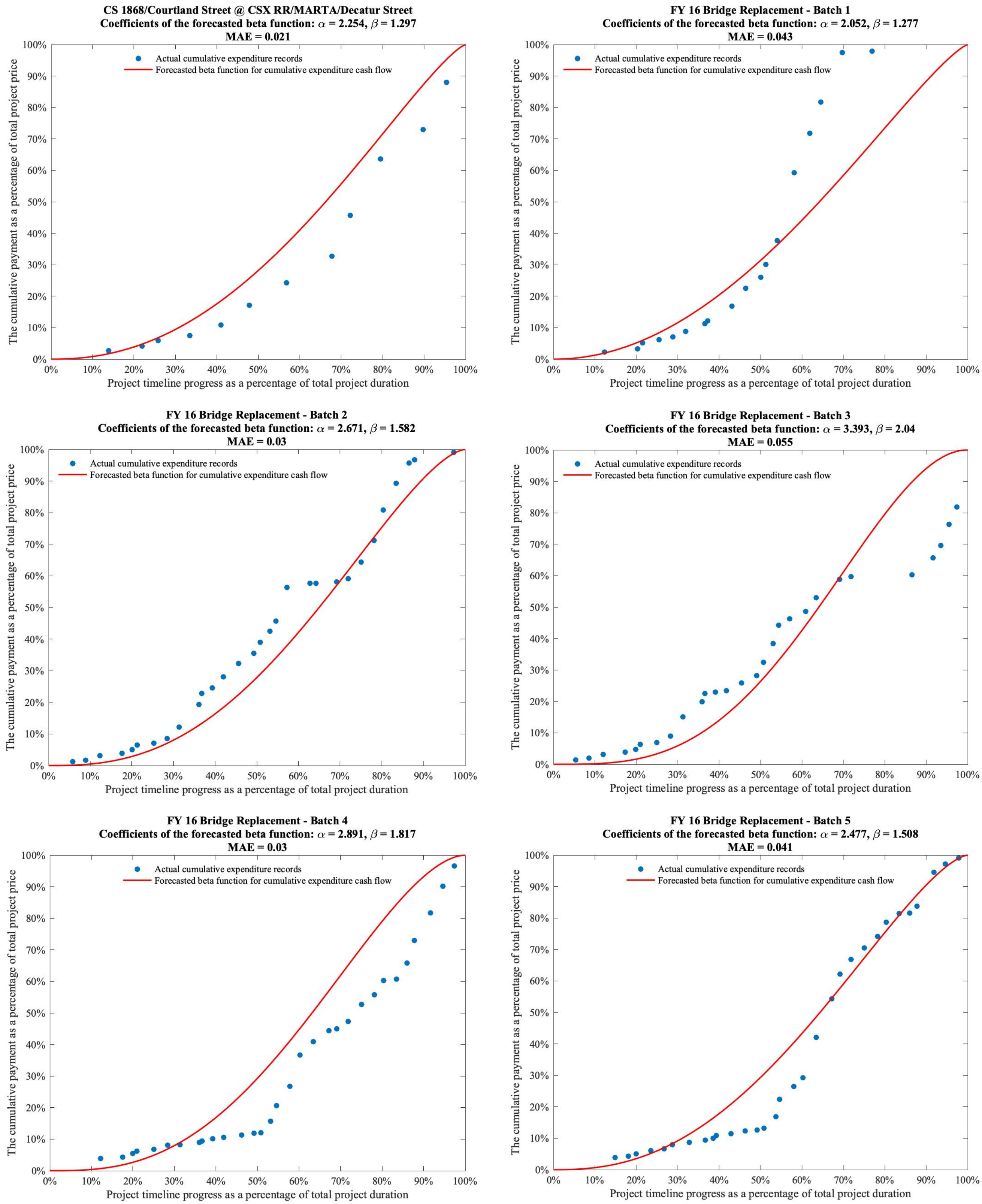


Figure 7. Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.

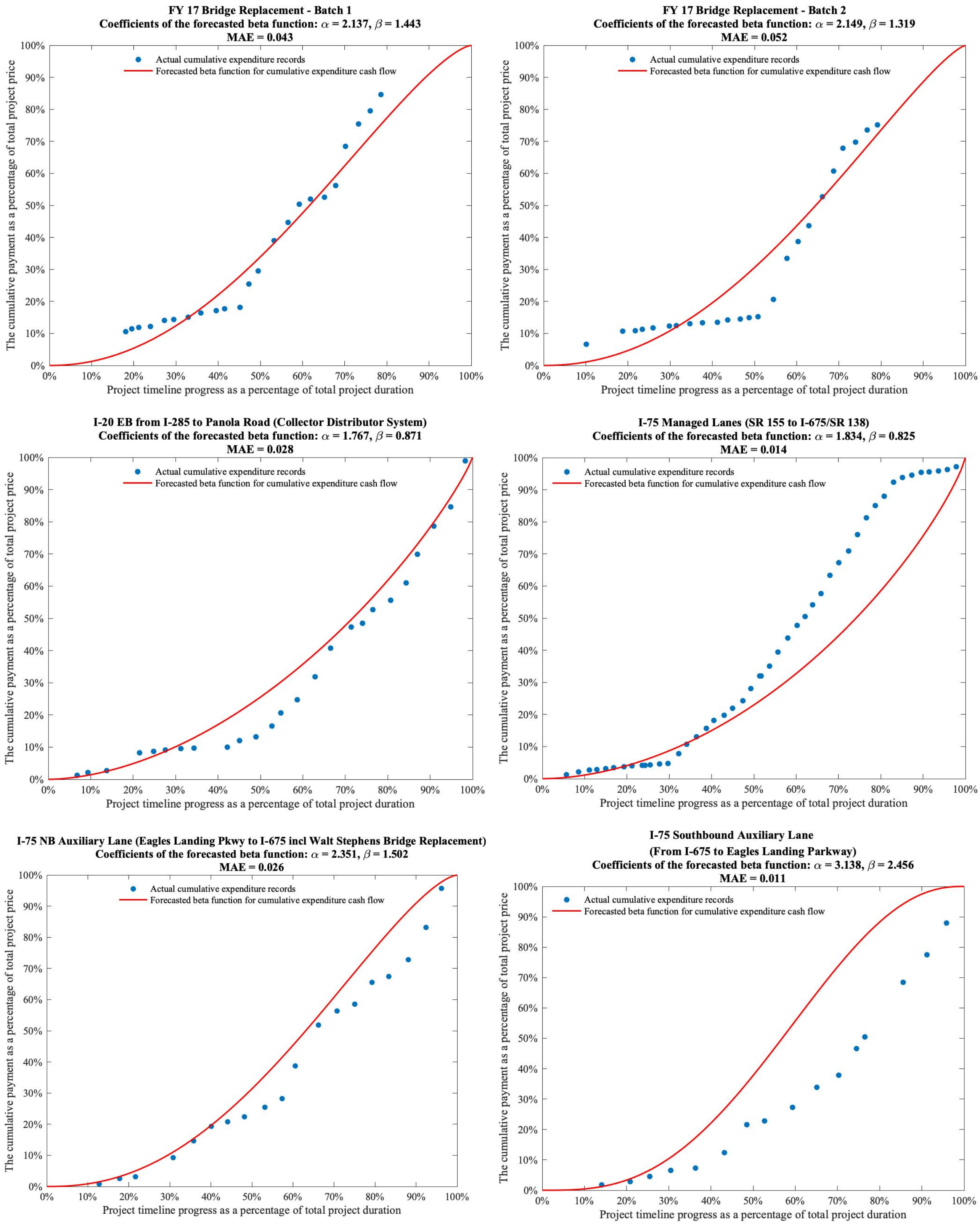


Figure 7 (Continued). Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.

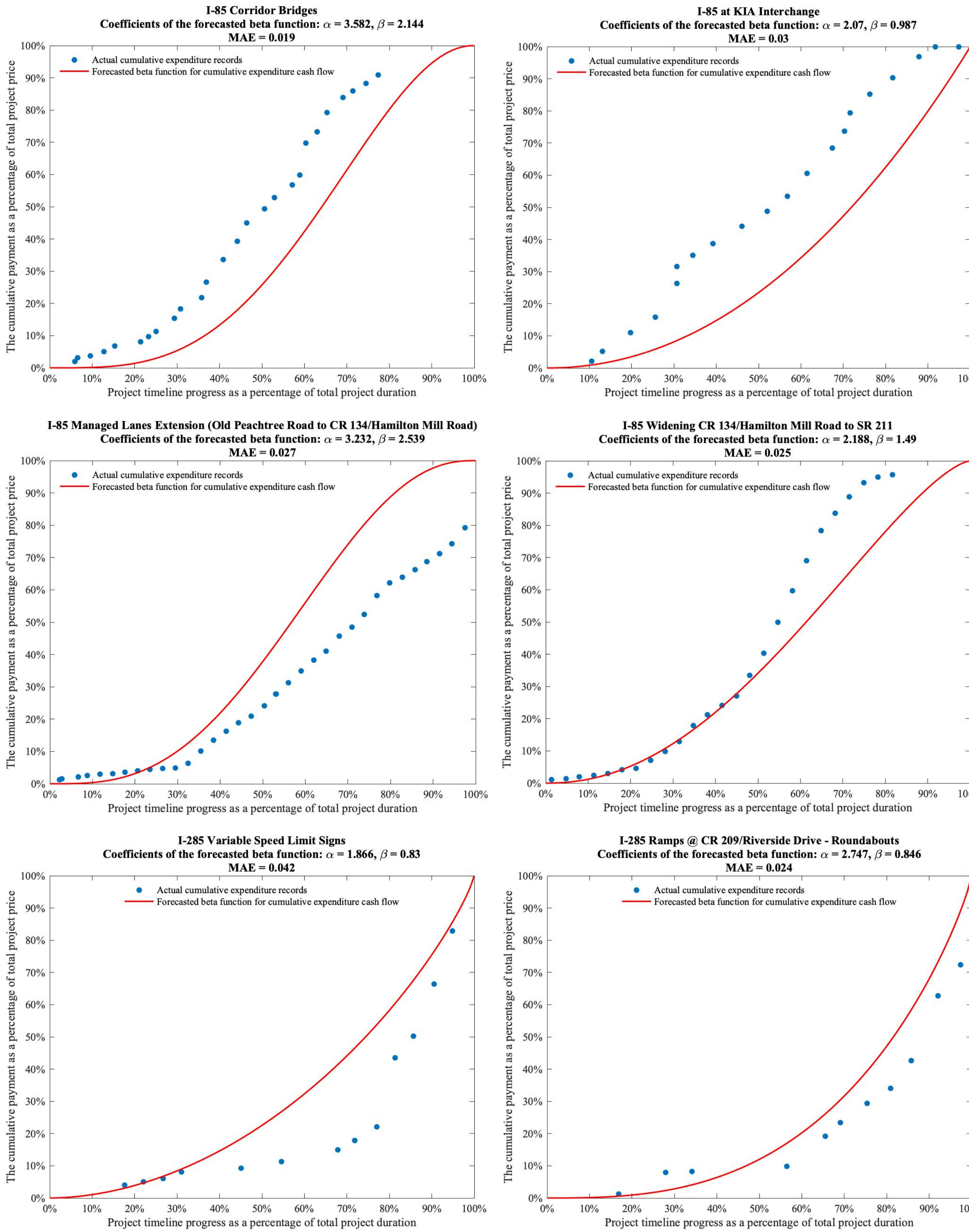


Figure 7 (Continued). Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.

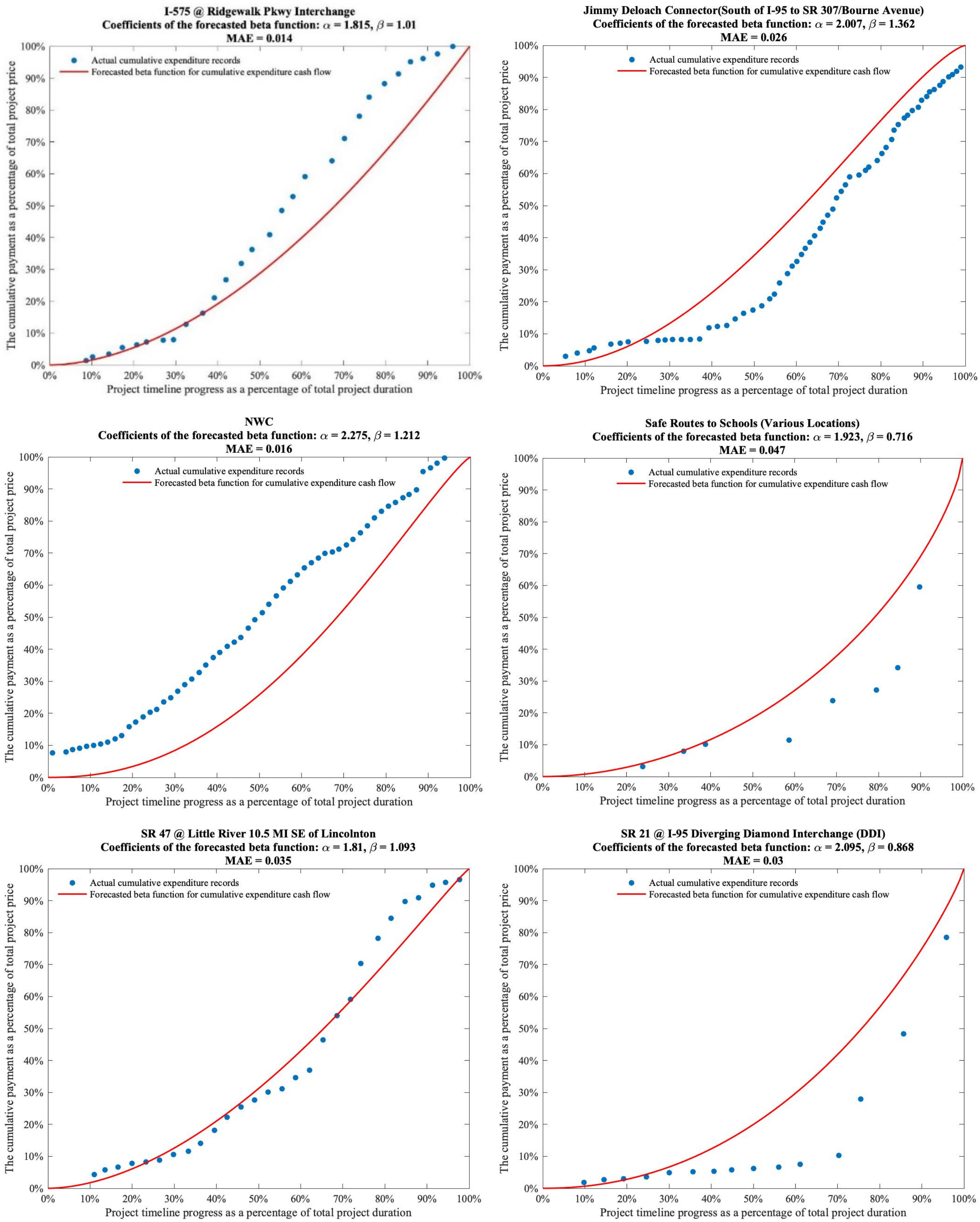


Figure 7 (Continued). Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.

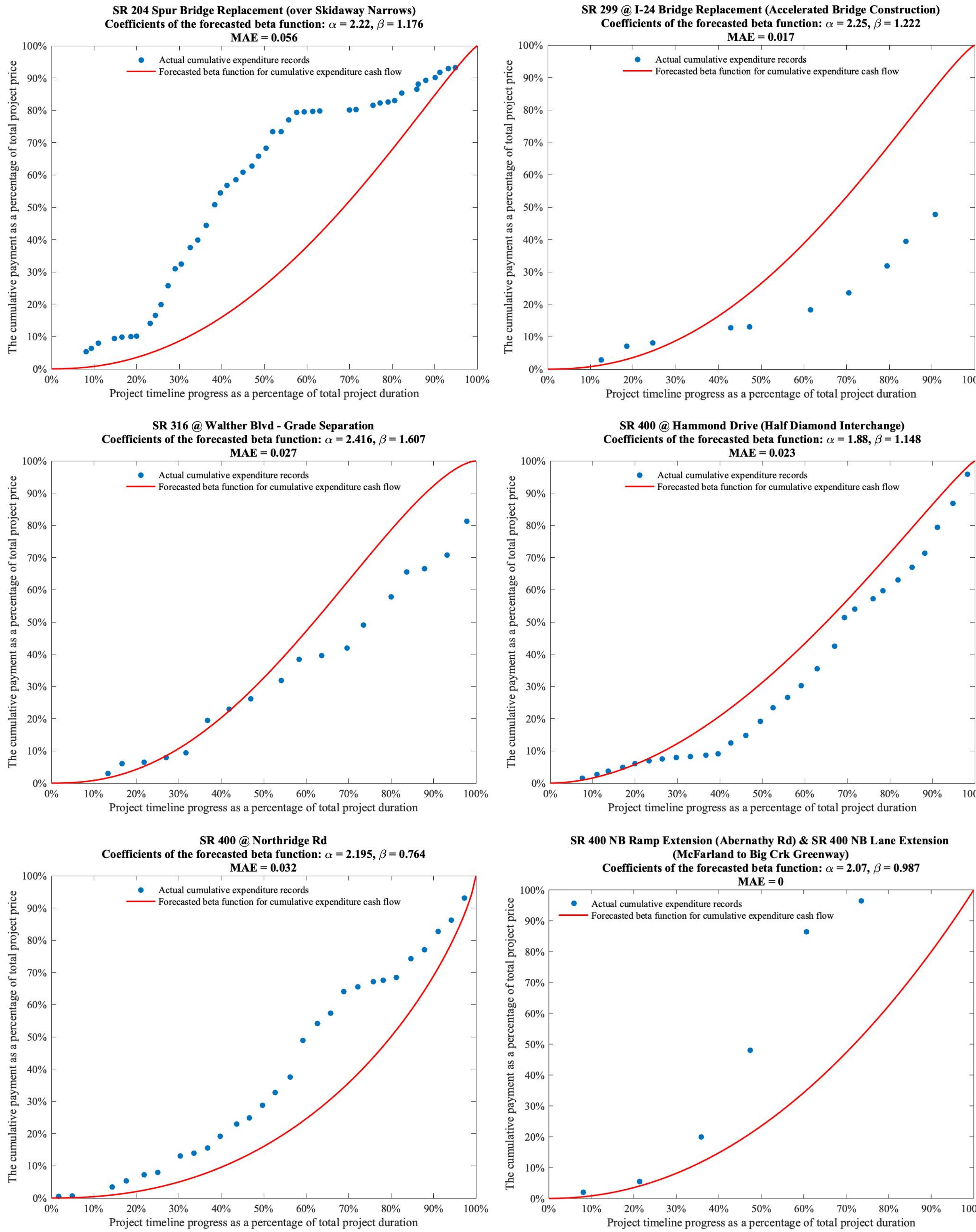
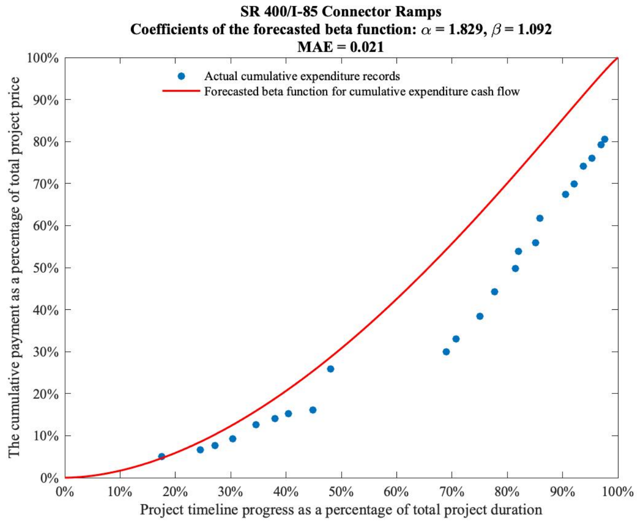
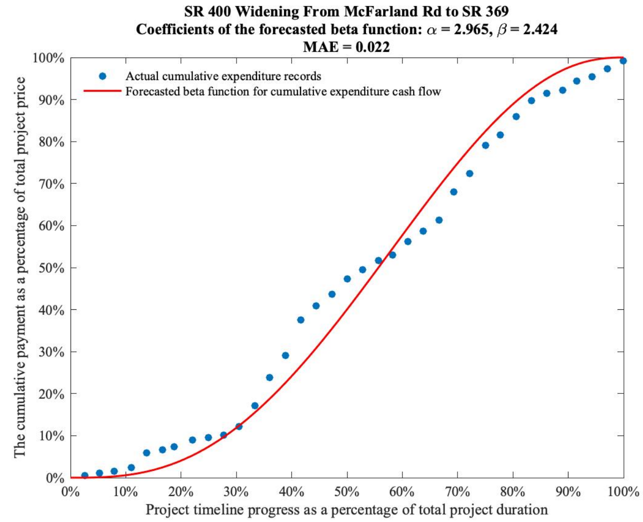


Figure 7 (Continued). Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.





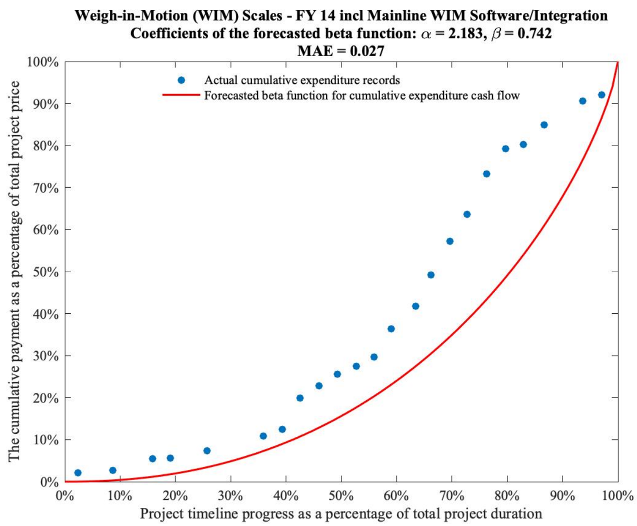


Figure 7 (Continued). Graphs. Forecasted cumulative expenditure cash flow for the design–build projects.

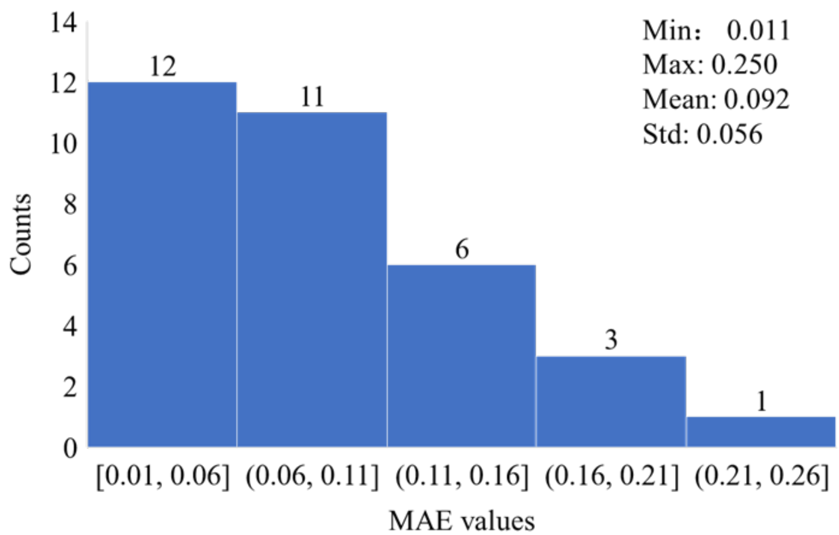


Figure 8. Graph. Distribution of MAE values of predictions.

Figure shows the connection of the 33 completed transportation design–build projects involved in this study, on the basis of their mutual similarities. Each node represents a project, and each arrow represents a connection. For a project to be forecasted, only the five most similar existing projects would be used to build connections. For an arrow, the start node denotes the project to be forecasted, while the end node denotes an existing project to be used for generating prediction. As shown in figure, the connections between projects are evenly distributed, which implies that the proposed algorithm is capable of capturing the inherent similarities between seemingly unrelated design–build projects.

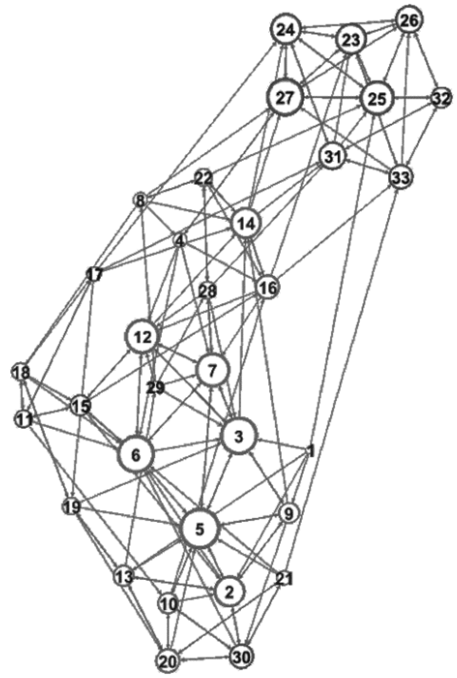


Figure 9. Image. Map of project network based on similarities.

Other configurations can be examined to assess how changes in the number of similar projects may impact the accuracy of the proposed forecasting model. Table 18 summarizes the accuracy level of the forecasting method under different scenarios for configurations of similar projects, i.e., using the top three, five, seven, and nine similar projects for predicting the cash flow. The results show that the mean value of MAE is higher when the top seven or nine similar projects are used for forecasting. The accuracy levels of the top three or five similar projects are fairly close to each other, but the accuracy range for the top five is lower than that for the top three. Therefore, five is considered the appropriate number of similar projects in the developed case-based reasoning method for cash flow forecasting. This number is consistent with some other applications of a case-based reasoning method in the literature (Ahna et al. 2017, Kwon et al. 2019).

Table 18. Comparison of different retrieval configurations.

Retrieval Configuration	Maximum MAE	Minimum MAE	Mean MAE	Standard Deviation of MAE
3 similar projects	0.240	0.015	0.095	0.052
5 similar projects	0.224	0.017	0.096	0.046
7 similar projects	0.223	0.024	0.111	0.038
9 similar projects	0.225	0.029	0.119	0.038

In the literature, researchers developed different forecasting models for projects of different sizes (measured by contract amount and contract duration) (Mills and Tasaico 2005, Jarrah et al. 2007). Therefore, the authors of this study calculate the correlations between forecast accuracy and project size to examine if the proposed CBR model has consistent performance over projects of different sizes. As shown in table 19, the forecast accuracy of the proposed CBR model has weak correlations with either contract amount or contract duration. In other words, the accuracy of predictions generated by the proposed model is independent of the size of the transportation design–build projects. However, due to the limited existing completed transportation design–build projects, the results of the Pearson correlation test are not statistically significant. More completed projects are required to validate the results of the Pearson correlation test.

Table 19. Pearson correlation test on the relations of prediction accuracy and project size.

Relations	Correlation Coefficient	Degree of Freedom	p-value
Contract amount vs. forecast error	0.056	31	0.757
Contract duration vs. forecast error	−0.052	31	0.772

CHAPTER 4. USER MANUAL OF THE DEVELOPED EXCEL VISUAL BASIC FOR APPLICATION (VBA) TOOL

PURPOSE OF THE TOOL

The purpose of the Excel Visual Basic for Application tool is to provide a data-driven forecasting model on construction expenditure cash flow. Project managers can use this tool to help decision-making in the practice of project planning and in the practice of progress management and cash flow management. The prediction on expenditure cash flow generated by this tool happens in the construction phase and does not contain the cost incurred outside the owner–developer contract, such as the cost of preliminary engineering and agent fees.

This tool is designed for design–build and design–build–finance projects. After entering high-level, describable project attributes that are available for the projects to be awarded, the user could have predictions on the periodic payment obligations, cumulative payment obligations, and amount financed by the design–builders. This tool sets up a public funding module by enabling users to manually enter the Fiscal Year available funding. This VBA tool is a stepping-stone for intelligent project management. It aims at serving project managers with data-driven predictions, which are complementary to the experience and expert judgement of project managers.

STRUCTURE OF THE TOOL

The tool has three pages, which are introduced below.

HOME PAGE (figure)

The Home page contains links to the Input Data page, the Results page, and this user manual. When opening the tool, only the "*Input data*" button is activated.

- Click the "*Input data*" button to enter project attributes. Successful completion of the Data Entry form brings back the home page and activates the "*Predict the expenditure cash flow*" button.
- Click the "*Predict the expenditure cash flow*" button to activate the "*Results*" button.
- Click the "*Results*" button to access the Cash Flow Prediction Results sheet.
- Click the "*Erase Info and Start Over*" button to erase all information of the current project and start over with another project. Note: Save the previous project information manually.
- Click the "*Manual*" button to open and close the Manual page.

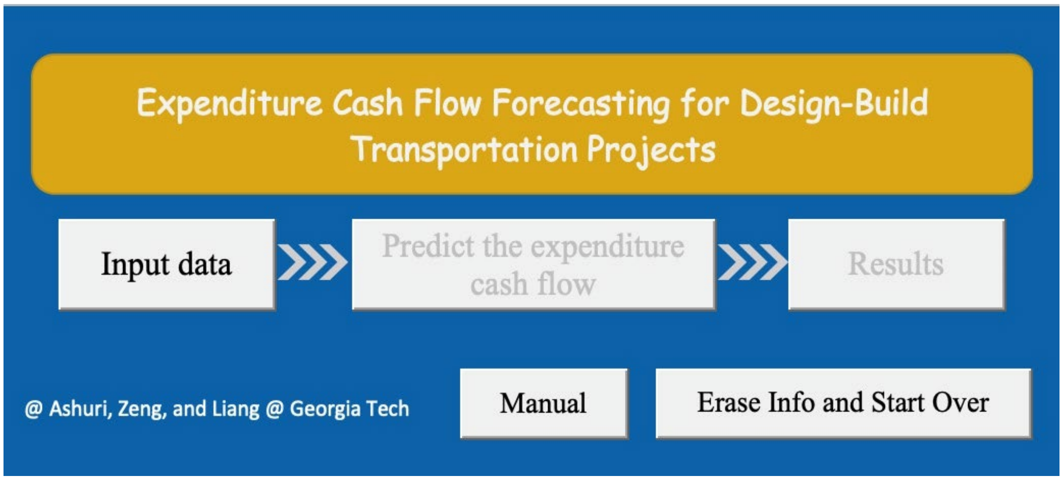


Figure 10. Screen capture. Home page.

Input Data Page

The Input Data page allows entry of project identification information and attributes through manual entry fields, drop-down menus, and links (figure).

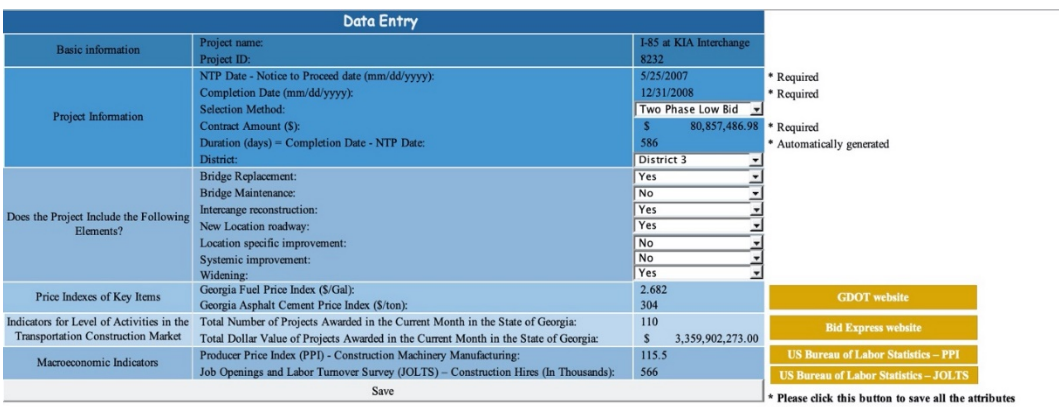


Figure 11. Screen capture. Input Data page.

Following are detailed instructions on the project attributes to be input.

- *Basic Information*
    - This section is for notation only and includes the *Project name* and *Project ID*. The input values will not impact the calculation and prediction results.
- *Project Information*
    - *NTP Date*, *Completion Date*, and *Contract Amount* are required.
    - All other attributes are optional. Note: Complete and accurate input helps to generate accurate prediction results.
    - A project may run along more than one district. Select the *District* in which the majority of the project lies.
- *Does the Project Include the Following Elements?*
    - Related information can be found in the Concept Report, Preliminary Field Plan Review (PFPR) Report, and Final Field Plan Review (FFPR) Report.
- *Price Indexes of Key Items*
    - Related information can be found from the GDOT website (figure), whose link is provided next to the input cells. (Use the project letting date to retrieve the data.)

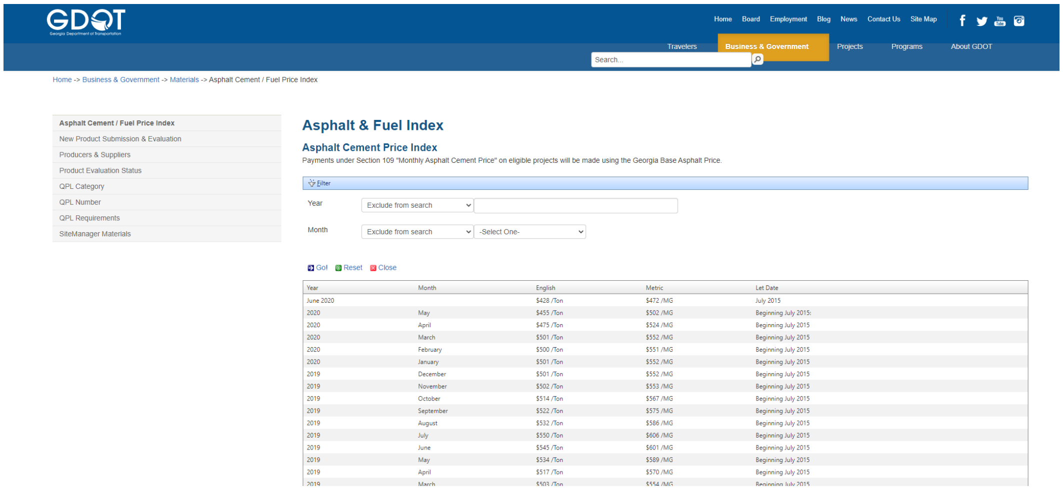


Figure 12. Screen capture. GDOT website for asphalt and fuel index.

- *Indicators for Level of Activities in the Transportation Construction Market*
    - *Total Number of Projects Awarded in the Current Month in the State of Georgia* cannot be less than 1.
    - *Total Dollar Value of Projects Awarded in the Current Month in the State of Georgia* cannot be less than the number for Construction Amount ($) on the Data Entry page.
    - Related information can be found from the BidExpress website, whose link is provided next to the input cells. (Use the project letting date to retrieve the data.) Note: The GDOT Office of Construction Bidding Administration can help provide related information (i.e., the project letting date, total number of projects awarded in the current month in the State of Georgia, and total dollar value of projects awarded in the current month in the State of Georgia).

- *Macroeconomic Indicators*
    - Related information can be found from the U.S. Bureau of Labor Statistics website, whose link is provided next to the input cells. (Use the project letting date to retrieve the data.)
    - To retrieve PPI data, select the US Bureau of Labor Statistics – PPI link and follow these steps:
        - Select "*Multi-screen Data Search*" under Industry Data on the Featured PPI Databases page (figure 13).

Figure 13. Screen capture. Retrieving PPI data (1).

- Select "33312- Construction machinery manufacturing" by clicking on it once (figure 14).

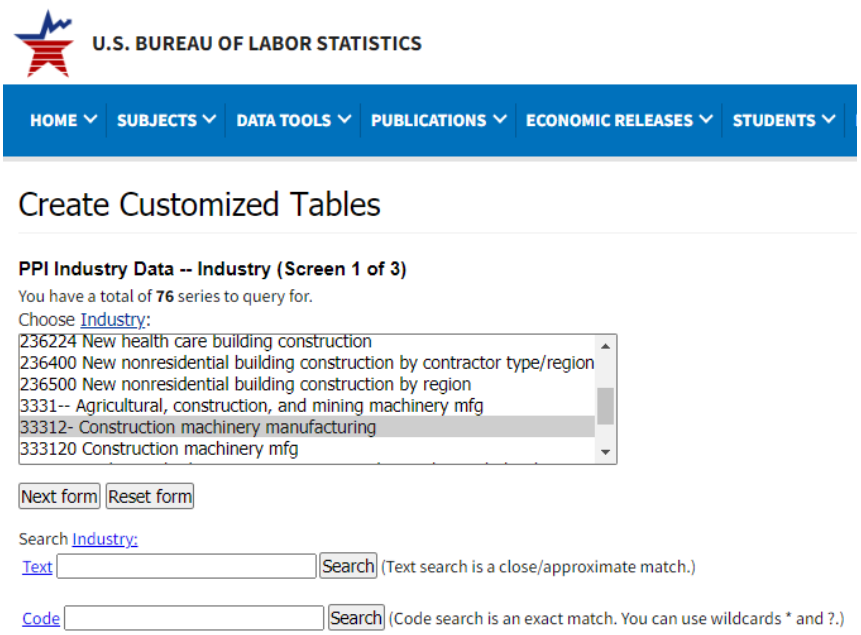


Figure 14. Screen capture. Retrieving PPI data (2).

- Select "33312- Construction machinery manufacturing" by clicking on it once (figure 15).

Figure 15. Screen capture. Retrieving PPI data (3).

- Click the "*Next form*" button.

○ To retrieve JOLTS data, select the US Bureau of Labor Statistics – JOLTS link and follow these steps:

  - Under Job Openings and Labor Turnover Survey (JOLTS), select "*Multi-screen Data Search*" (figure 16).

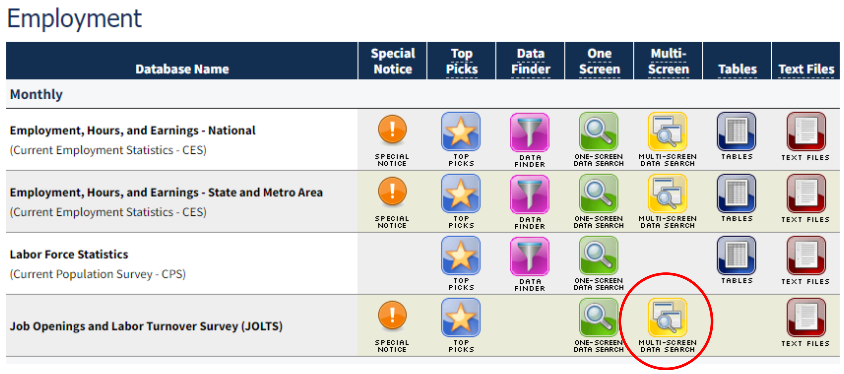


Figure 16. Screen capture. Retrieving JOLTS data (1).

- Select "230000 Construction" by clicking on it once (figure 17).

Figure 17. Screen capture. Retrieving JOLTS data (2).

- Click the "*Next form*" button.

- Select “00 Total US” (figure 18).

Figure 18. Screen capture. Retrieving JOLTS data (3).

- Select “HI Hires” (figure 19).

Figure 19. Screen capture. Retrieving JOLTS data (4).

- Select “L Level- In Thousands” (figure 20).

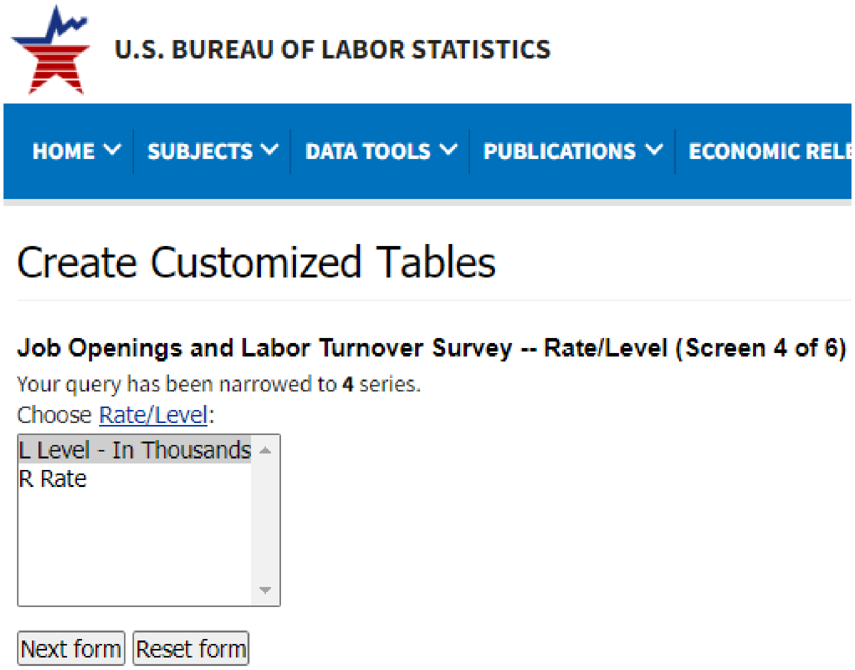


Figure 20. Screen capture. Retrieving JOLTS data (5).

- Select the checkbox for “Not Seasonally Adjusted” (figure 21).

Figure 21. Screen capture. Retrieving JOLTS data (6).

- Click the “*Retrieve data*” button.

- After filling the cells, click the “*Save*” button to go to the next step.

Cash Flow Prediction Results Page (figure 22)

The Cash Flow Prediction Results page allows the user to check and customize the prediction results. To get the results, follow the three steps shown in figure 22:

- Step 1: Enter the Public Funding Available for each Fiscal Year.
- Step 2: Select the unit for Timeline (i.e., Month, Quarter, or Year).
- Step 3: Click the “*Calculate*” button.

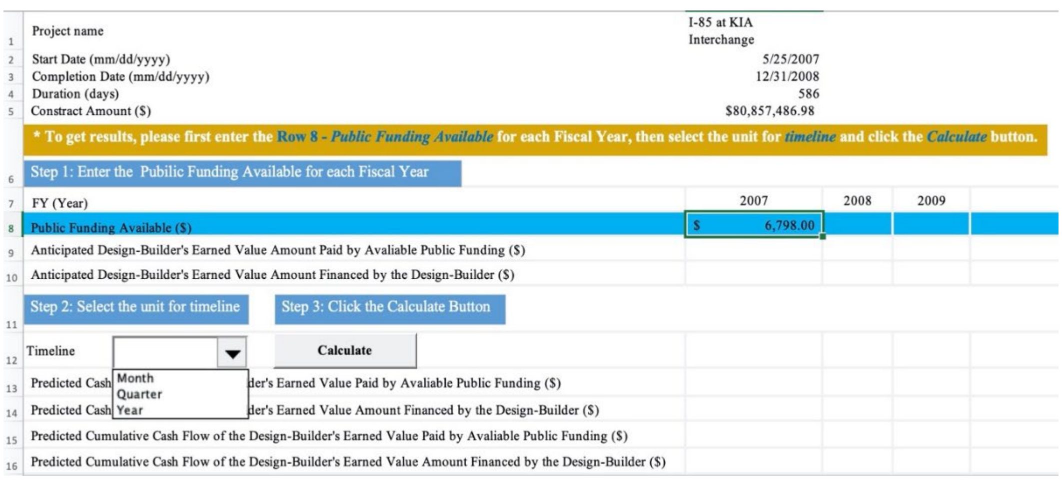


Figure 22. Screen capture. Cash Flow Prediction Results page.

For more information about the tool, contact Dr. Baabak Ashuri at the Georgia Institute of Technology:

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CHAPTER 5. CONCLUSIONS

This research aims to develop a forecasting model for expenditure cash flow for the GDOT design and construction program, taking into account flexibilities offered by innovative project delivery methods, such as design–build, design–build–finance, and public–private partnerships. To achieve the research objective, current state of the practice regarding the schedule of values and progress payments of DB and other innovative project delivery for highway projects in several state DOTs are reviewed and best practices are identified. Moreover, an expenditure cash flow forecasting model is developed for transportation DB projects via a case-based reasoning approach. The developed model can generate accurate forecasts with limited training data and high-level describable project attributes, and it can handle inputs with missing data. An Excel Visual Basic for Application Tool is developed for project managers by using the proposed CBR model.

The following recommendations are found to be effective for managing progress payment of highway projects:

- A well-established SOV helps the Department develop a project-specific basis for reviewing and approving the design–builder's work and developing a periodic pay estimate throughout the project.

- An updated SOV that accommodates any changes in the scope of work is essential to smooth execution of the progress payment and a successful DB project.
- A detailed/updated payment breakdown for progress payments helps the Department approve/disapprove the payment to the contractor and reduce disputes.
- Including early completion incentives in the DB RFP can encourage the design–builder to not only finish the project on time but also minimize the impact on the communities in which the projects are constructed.
- A well-defined cost-loaded critical path method schedule enables the Department to establish the expected cash flow for the life of the project.
- Establishing and providing specific bid items that are eligible for price adjustments in a contract provides the Department with a more accurate and dynamic adjustment tool for payments.

Forecasting on future construction expenditure flow is the basis of determining the capability of project letting. However, the features of transportation design–build projects make the existing forecasting models for projects to be awarded not applicable. To narrow the gap, the authors proposed a CBR model with three characteristics: (1) having the capability to make an accurate forecast, even with limited existing completed projects as a training set; (2) having the flexibility to accommodate the complexity of transportation design–build projects, even if the project comprises various types of tasks; and (3) having the capability to provide accurate forecasts by using easily accessible high-level describable project attributes, even with missing data. Thirty-three completed design–build projects awarded by GDOT prior to January 2020 were used to test the model.

The proposed CBR model features three advantages. First, unlike the curve-fitting–based models in the literature, the forecasting performance of the proposed model is not impacted by contract amount and contract duration, which implies wider applicability and better accountability. Second, compared with the curve-fitting–based models, the proposed model has the capability to generate forecasts based on up-to-date project records. Third, the proposed similarity-based model enables better interpretability in comparison with the neural network models in the literature. The proposed model is based on the inherent connections between project features and expenditure flows, which overcomes the lack of interpretability of the existing black box machine learning methods.

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