GEORGIA DOT RESEARCH PROJECT NO. 14-09

FINAL REPORT

BEST PRACTICES FOR BUDGET-BASED DESIGN

Georgia Department of Transportation

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16. Abstract:
State Departments of Transportation (State DOTs) encounter difficulties in establishing feasible and reliable project budget early in the project development. The lack of a systematic process for establishing baseline budget with the consideration of potential issues (risks) that negatively impact project cost throughout project development presents a major challenge for State DOTs. The overarching objective of this research project is to develop a set of cost estimation and management practices for budget-based design that can aid GDOT project managers and engineers throughout the plan development process (PDP). To achieve the research objective, this report conducted three major tasks: (1) Reviewing state of practice of cost estimation process in other State DOTs; (2) Reviewing state of practice for fixed budget-best value procurement method in other State DOTs; and (3) Conducting statistical analysis to identify important variables capable of explaining variations in submitted bid prices for highway projects in the State of Georgia. Cost estimation and control processes in Minnesota, California, Texas, Ohio, and Washington State DOTs are provided as examples of best practices in establishing reliable baseline cost estimates. Procurement process in Utah, Colorado, and Michigan DOTs are presented as examples of successful utilization of fixed budget-best value procurement method. The results of multivariate regression analysis show that 12 variables, including quantity of the bid item, housing market index, Georgia asphalt cement price index, total bid price, project length, 12-month percent change of Georgia asphalt cement price index, 12-month percent change of Gross Domestic Product (GDP) of the Georgia construction industry, unemployment, total asphalt volume of resurfacing and widening projects, number of bidders, project duration, and number of nearby asphalt plants have explanatory power to explain variations in submitted bid prices for major asphalt line items in the State of Georgia's highway projects. It is also found out that 5 variables, including unemployment, 12-month percent change of Georgia asphalt cement price index, quantity of the bid item, total bid price, and Turner construction cost index have power to explain variations in submitted bid prices for projects in the Transportation Investment Act (TIA) regions.

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EXECUTIVE SUMMARY

State Departments of Transportation (State DOTs) encounter difficulties in establishing feasible and reliable project budget early in the project development. The major challenge that several State DOTs have faced is the lack of a systematic process for establishing baseline budget with the consideration of potential issues (risks) that negatively impact project cost throughout project development. As design advances through various phases, there are several factors affecting the cost estimate, such as right-of-way acquisition, utilities coordination, and scope changes. If these risk factors go unnoticed early in the project development because of limited information related to scope, project site, and design, they can impose a considerable burden on State DOTs and cause cost escalation during project (plan) development process. Considering the new focus by GDOT and other State DOTs on enhanced cost estimation and management process, there is a significant need to make cost estimation a priority and set baseline budget estimate during the planning and concept development phases. This research project will focus on major components of a reliable baseline budget model and their information requirements.

The overarching objective of this research project is to develop a set of cost estimation and management practices for budget-based design that can aid GDOT project managers and engineers throughout the plan development process (PDP). To achieve the research objective, current state of practices in cost estimation and control in several State DOTs

are reviewed and best practices are identified in cost estimation and strategies for cost control. Also, current state of practices in fixed budget-best value procurement method are reviewed and best practices are identified in utilization of this innovative contracting method. Finally, statistical analysis is conducted to investigate the impact of macroeconomic, construction market, and oil market conditions on highway construction costs by analyzing submitted bid prices for major asphalt line items in the State of Georgia's highway projects.

The following recommendations are found out to be effective for enhancing the practice of defining and maintaining the established budget for highway projects:

- State DOTs should establish an integrated process for cost estimation and cost management to establish accurate, reliable, and consistent estimates thorough project development process.
- State DOTs should establish key milestones for estimating, updating, and approving cost estimates as project definition/design advances.
- State DOTs should capture any changes in estimating assumptions to track the basis of cost estimate and control estimated project cost.
- State DOTs are recommended to establish an automated information system to help them maintain, update, and share project information, cost estimates, and changes in project scope, cost, and schedule.

- State DOTs should consider potential issues (risks) that may cause cost escalation during developing baseline cost estimates. Risk analysis tools and inputs from key project stakeholders are necessary for identifying critical risk factors for the project.
- Finally, State DOTs should utilize a quality assurance/quality control (QA/QC) process to verify the final engineer's cost estimate before a project is advertised.

The following recommendations are found out to be effective for enhancing the practice of delivering projects using this innovative contracting strategy:

- State DOTs may consider a fixed budget-best value procurement approach when the full project scope exceeds the baseline cost estimate for the project. For a fixed budget-best value procurement approach, the agency should define the basic configuration scope and should allow the proposers to include the maximum amount of work or additional scope elements in their proposals while staying within the fixed budget.
- A fixed budget-best value approach can be utilized in several project types, such as corridor expansion, bridge deck preservation, and seal coating projects. State DOTs should clearly define additional scope elements beyond the base scope for each project type.
- State DOTs should clearly establish the evaluation criteria to select the proposers for a project. Since the price is fixed for all proposers and this approach allows higher flexibility in proposing design and construction solutions, the agency should

establish rigorous evaluation criteria (e.g., cost, time, and design alternatives) and the weights for the criteria to evaluate the proposals based on the project goals.

Lastly, statistical analysis is conducted to identify important variables capable of explaining variations in submitted bid prices for major asphalt line items in the GDOT's highway projects. Multiple regression analysis is utilized to examine the impact of project characteristics, macroeconomic variables, construction market condition indicators, and oil market parameters on highway construction costs. The main purpose of this research is to examine the effects of several factors representing construction market, economic, and oil market conditions on submitted bid prices. The goal is to develop a regression model with explanatory power to describe variations in submitted bid prices. It is worth noting that the developed regression model can be used for forecasting bid prices for asphalt line items but prediction was not the main objective of this study. Therefore, the results should be used with caution as the forecasting error might be significantly large.

An explanatory model is developed for the State of Georgia's highway projects using multiple regression analysis. Several important variables are identified to have power to explain variations in submitted bid prices for major asphalt line items. The identified variables, in descending order of importance, are: quantity of the bid item, housing market index, Georgia asphalt cement price index, total bid price, project length, 12-month percent change of Georgia asphalt cement price index, 12-month percent change of Gross Domestic Product (GDP) of the Georgia construction industry, unemployment, total asphalt volume of resurfacing and widening projects, number of bidders, project duration, and number of nearby asphalt plants. Among these significant explanatory variables, quantity of the bid item, project length, unemployment, number of bidders, project duration, and number of asphalt plants have negative relationship with submitted bid prices while holding all other variables in the model constant. All other variables have positive influence on submitted bid prices.

Multiple regression analysis is repeated for identifying significant factors that affect variations in submitted bid prices in the regions included in the Transportation Investment Act (TIA). The identified important variables, in descending order of importance, are: unemployment, 12-month percent change of Georgia asphalt cement price index, quantity of the bid item, total bid price, and Turner construction cost index. Among those significant factors in the explanatory model developed for projects in the TIA regions, quantity of the bid item has negative relationship with submitted bid prices while holding all other variables constant. All other variables have positive relationship with submitted bid price.

CHAPTER 1
INTRODUCTION

The Transportation Investment Act (TIA) Referendum was passed in 2012 by Georgia voters in the regions of Central Savannah River Area, Heart of Georgia – Altamaha, and River Valley. These three regions will implement a one percent regional sales tax over a ten-year period to fund transportation improvements. The Office of TIA in Georgia Department of Transportation (GDOT) is responsible for the management of the budget, schedule, execution and delivery of all Projects contained in the Approved Investment Lists. The unique nature of funding for these projects presents significant challenges for the Office of TIA to develop the listed projects according to pre-determined budgets. In other words, the Office of TIA needs to work with the established budgets and schedules for these projects and ensure that these established budgets and schedules remain unchanged throughout the course of project design development. Hence, the Office of TIA needs to develop and utilize a systematic approach for establishing baseline budget and schedule models for its program. The application of this systematic approach is not just limited to the Office of TIA. The budget-based design approach can be considered in the delivery of GDOT's other projects since it can enhance the agency's ability to deliver transportation projects according to their original estimated budgets and schedules. This issue is becoming more and more important with the ever-increasing funding pressure on the agency.

State Departments of Transportation (State DOTs) encounter difficulties in establishing feasible and reliable project budget early in the project development. The major challenge that State DOTs have is the lack of a systematic process that explains required steps and key inputs for establishing baseline budget throughout project development. In addition, as design advances through various phases, there are several factors affecting the cost estimate, such as right-of-way acquisition, utilities coordination, and scope changes. If these risk factors go unnoticed early in the project development because of limited information related to scope, project site, and design, they can impose a considerable burden on State DOT and cause cost escalation during project development process. Thus, State DOTs should have a risk-based approach to identify potential risks and establish strategies to minimize their risks on project cost.

Considering the new focus by GDOT and other State DOTs on enhanced cost estimation and management process, there is a significant need to make cost estimation a priority and set baseline budget estimate during the planning and concept development phases. This research project will focus on major components of a reliable baseline budget model and their information requirements.

The overarching objective of this research project is to develop a set of cost estimation and management practices for budget-based design that can aid GDOT project managers and engineers throughout the plan development process (PDP). To achieve the research objectives, the following tasks have been done, and the report is structured as follows:

Chapter 2- Review state of practice of cost estimation process in other State DOTs

In the first step, the academic/professional literature is reviewed to identify the state of knowledge about establishing baseline budget, developing a project cost management system, and describing a process for project cost control. Current practices of selected State DOTs are reviewed to understand how cost estimation and control are conducted in these State DOTs.

Chapter 3- Review state of practice for fixed budget-best value procurement method in other State DOTs

A critical scanning process is conducted on the FHWA and State DOTs websites to determine their execution process and case studies related to a fixed budget-best value contracting strategy. This procurement method provides an effective strategy to deliver projects under strict budget.

Chapter 4- Conduct statistical analysis to identify important variables capable of explaining variations in submitted bid prices for highway projects

Multiple regression analysis is conducted for investigating the impact of project characteristics, macroeconomic variables, market condition indicators, and oil market parameters on highway construction costs by analyzing the submitted bid prices for highway construction projects in the State of Georgia.

Chapter 5- Conclusions

A summary of research findings is presented.

CHAPTER 2
DEVELOPING AND CONTROLLING BASELINE COST ESTIMATE DURING PROJECT DEVELOPMENT PROCESS

2.1. Introduction

Preconstruction activities conducted as parts of the GDOT's plan development process (PDP) have profound impacts on final project cost and schedule. The ability of the Department to influence project cost and schedule is reduced as the project moves along through the PDP. Critical decisions made in the design development process have direct impacts on the final project cost. Therefore, it is important to establish and create a proper baseline budget model as early as possible during the initial phases of the PDP. This baseline budget model should be monitored and maintained throughout the PDP to guide project managers and engineers to stay within the predetermined budget and schedule (Anderson et al. 2007).

The initial stages of the project development process are critical for establishing the baseline for project budget and schedule (Oberlender and Trost 2001). As the project preconstruction phase advances, the owner's influence on modifying the design and tightening the budget to alter project costs is reduced. Figure 2-1 shows that as project advances through different phases and information becomes available, the ability to change project cost is reduced (Chou 2009). If the project development process is not properly managed, there is a good chance that the owner experiences cost overrun and schedule delay for the project. The major root causes of cost overrun and schedule delay include an unreliable baseline cost estimate, a failure to be aware of uncertainty early in the project development, and lack of appropriate risk-related management practices and analysis tools for managing and controlling the established budget and schedule (Shane et al. 2009; Molenaar et al. 2010).

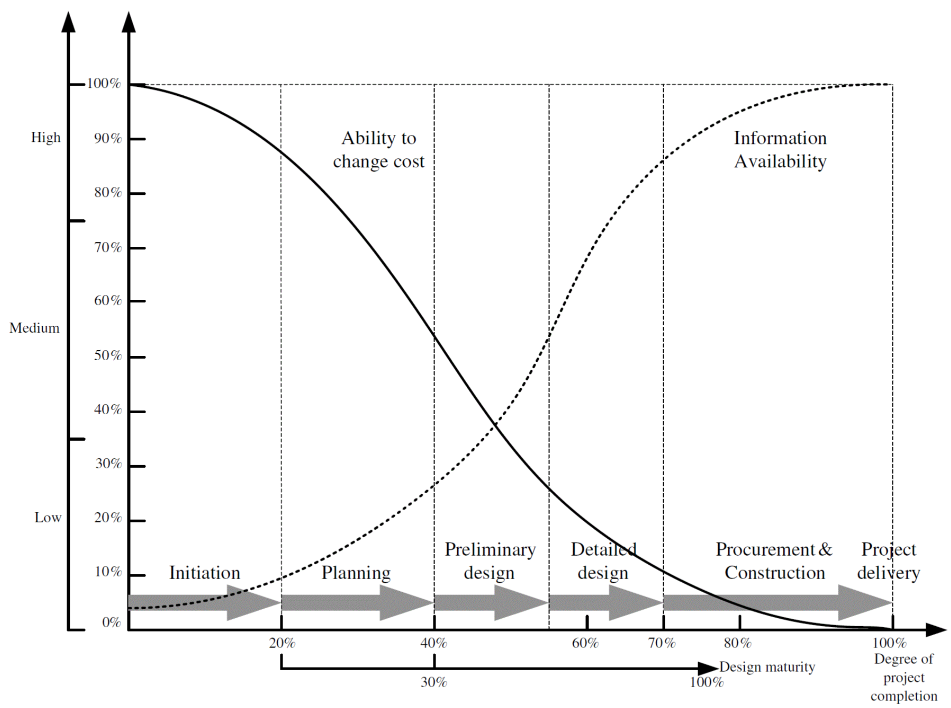


Figure 2-1 Ability to Influence Changes in Cost of a Project

State Departments of Transportation (State DOTs) strive to establish feasible and reliable project budget and schedule early in the project development considering project type and other project-specific characteristics. To establish feasible and reliable project budget, it is critical that an appropriate estimating technique is selected based on the level of project scope definition, the project type, and the complexity of the project (Anderson et al. 2007).

The American Association of State Highway and Transportation Officials (AASHTO) Technical Committee on Cost Estimating (TCCE) provides detailed information about several cost estimating techniques, including conceptual estimating, historical bid-based estimating, cost-based estimating, and risk-based estimating methods.

A conceptual estimating technique is typically used in the planning or early scoping phase where minimal project definition is available. To develop the project cost, this technique requires two key inputs: (a) historical cost data; and (b) project information (e.g., definition, location, and characteristics) matched to cost data.

A historical bid-based estimating technique, as the most common estimating method, is adapted in all phases of project development process, except the planning phase. With this estimating technique, the estimator should identify items, determine item quantities, and select appropriate historical bid prices based on available project information. The key inputs of this technique are project information, historical bid data, and macro-environmental and market condition.

A cost-based estimating technique is usually utilized in preparing the engineer's estimate and at the Plans, Specifications & Estimate (PS&E) phase. Since this technique uses relatively well-defined project information (e.g., a work statement and a set of drawings and specifications) and the latest costs of materials, equipment, and labor, the estimator can expect much more accurate project costs than other methods. Based on identified quantities and assumed production rates, the direct costs of labor, materials, and equipment are calculated using the latest cost data. The key inputs of this technique are historical bid data, labor cost, equipment cost, material cost data, subcontract items, and macro-environment market conditions.

A risk-based estimating technique is an integrated mechanism of risk identification and uncertainty analysis. This technique allows the estimators to estimate an expected value and a range of project costs with consideration of the impact of project risks and uncertainty on the project cost. This estimating technique is utilized in the planning, scoping, and early design phases. The key inputs of this technique include a definition of project complexity and a list of design and estimating assumptions and concerns (Molenaar et al. 2011).

In addition, Harper et al. (2014) concluded that monitoring the cost estimates and the contingency amount has a significant impact on the accuracy of the cost estimates throughout project development process. Through utilizing the questionnaire and interviews, the authors defined five important performance measures for monitoring cost estimates as the following:

1) Bidding accuracy- monitoring the differences between the final plans, specifications, and estimates (PS&E) estimate and previous estimate (i.e., the planning and design estimates) or low bid amounts
2) Estimating accuracy- monitoring the differences between a current cost estimate to previous estimates (i.e., conceptual estimate) or newer, more-developed design estimates (i.e., the final PS &E estimate)
3) Competition effects- monitoring the number of bidders per project let

4) Estimating process- monitoring the total time to complete an estimate at each project development phase where an estimate takes place
5) Contingency amount- tracking the amount or percentage of contingency included in an estimate for a project

The authors also claimed that monitoring cost estimates and contingency amount is critical for controlling cost escalation and avoiding design scope creep (Harper et al. 2014).

Besides establishing feasible and reliable project budget and schedule, State DOTs also face a challenge with respect to controlling project budget and schedule throughout project development process. To control project budget and schedule, State DOTs should identify cost escalation factors early in the project development process. Numerous studies have identified cost escalation factors to increase awareness of the causes of project cost escalation. For example, Arditi et al. (1985) investigated the causes of cost escalation for the public construction projects through conducting a survey. This study identified the important causes of cost escalation as the following: inflation due to economic conditions, availability of materials, project delays due to shortages in resources (e.g., labor and equipment), and deficiencies in cost estimates.

Another study by Akinci and Martin (1998) identified factors causing cost overruns during project development process of construction projects. The authors focused on the external factors that are not controllable by owners and contractors. The factors affecting cost estimates of projects include estimator’s biases, vagueness in scope, design complexity, and project size. Then, they urged that these factors should be identified and considered during developing cost estimates in project development.

More recently, Shane et al. (2009) identified factors that cause cost escalation during project development process through a combination of an in-depth literature review and intense interviews with over 20 transportation agencies. The authors identified twelve cost escalation factors and classified the factors into internal (e.g., bias, delivery/procurement approach, project schedule changes, engineering and construction complexities, scope creep, poor estimating, and inconsistent application of contingencies) and external factors (e.g., local concerns and requirements, effects of inflation, scope changes, market conditions, unforeseen events, and unforeseen conditions). The authors also found out that the identification of the cost escalation factors aids agency/owners, and contractors in developing more accurate cost estimates and establishing better risk mitigation strategies.

With awareness of the cost escalation factors, it is also necessary to monitor and update the project budget and schedule baselines and update them as design advances throughout various phases while controlling and managing cost escalation factors. Any failure in this process can lead to cost underestimation or designing over budget. The major issue is that while projects are being developed, their budgets and schedules often do not meet the expectations (Chou 2010). The underlying reasons for cost overrun and schedule delay include lack of proper procedures for establishing, monitoring, and updating conceptual cost and schedule estimates within the project development process (Anderson et al. 2007).

A well-structured procedure integrated with risk analysis tools is essential for developing more accurate cost estimates and controlling cost escalation during the project development process.

2.2. State of Practice of Cost Estimation Process in Minnesota, California, Texas, Ohio, and Washington State Departments of Transportation

2.2.1. Minnesota Department of Transportation (MnDOT)

2.2.1.1. MnDOT Cost Estimation Process

The Minnesota Department of Transportation (MnDOT) uses a well-structured cost estimation system to prepare cost estimates for highway projects. As shown in Table 2-1, the cost estimation milestones for developing the cost estimate consist of four steps including planning, scoping, design, and letting. Table 2-1 includes major tasks and parties responsible for developing the cost estimate. In the planning phase, MnDOT defines the needs of transportation system improvement and establishes a base for documenting the estimate basis of a project. During the scoping phase, it is critical that all potential issues affecting the project cost and schedule are identified. The baseline cost estimates are developed as an output of the scoping phase. The major tasks in the design and the letting phases are to identify any change in scope, cost, and time, and update and review the baseline cost estimates (MnDOT 2008).

Table 2-1 MnDOT Cost Estimation Milestones

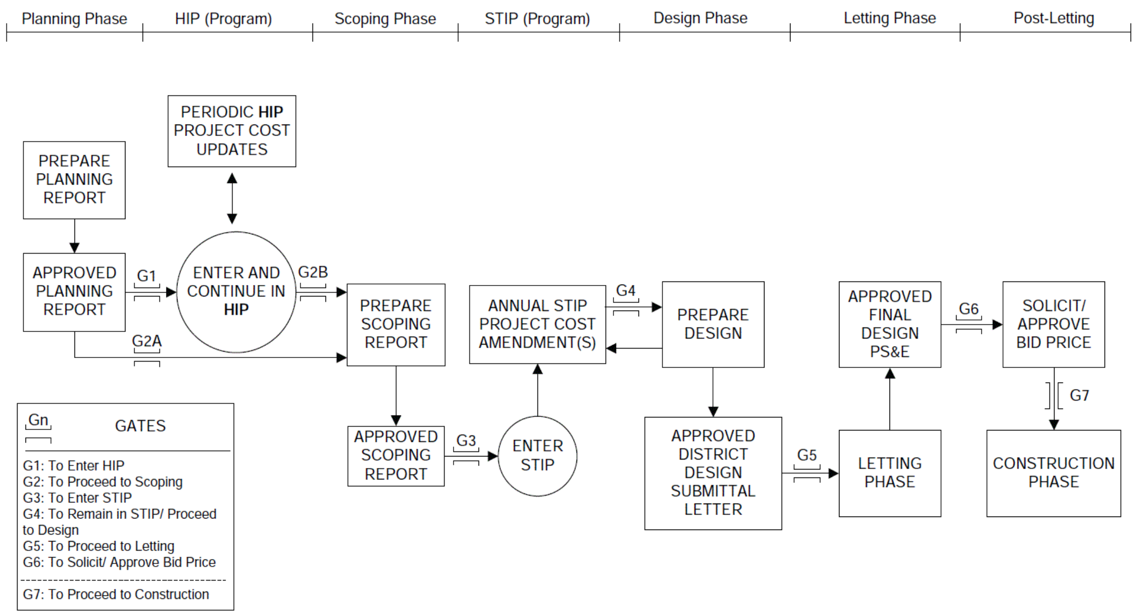
<table>
<tr><th>PDP</th><th colspan="2">Planning (Conceptual Estimating) (1%-15%)</th><th colspan="2">Scoping (Scope Estimating) (10% to 30%)</th><th colspan="2">Design (Design Estimating) (30% to 90%)</th><th colspan="2">Letting (PS&E Estimating) 90%-100%)</th></tr>
<tr><td>Major Tasks</td><td colspan="2">• Identify the needs and deficiencies in the transportation system.
• Prepare a Project Planning Report at the end of the Planning Phase.</td><td colspan="2">• Extensively investigate all potential issues that could affect the cost and schedule of a project.
• Hold a meeting to discuss the project definition.
• Identify and analyze project alternatives
• Prepare a final Scoping Report.
• Develop project cost estimates (baseline cost estimate).</td><td colspan="2">• Identify changes in scope, cost, time throughout the Design process.
• Update the project cost estimate (update baseline cost estimate).</td><td colspan="2">• Prepare the Engineer's Estimate and evaluate contractor bids in relation to the Engineer's estimated cost.
• Review Construction Cost Estimates.</td></tr>
<tr><td rowspan="2">Who</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td></tr>
<tr><td>• Project Manager
• Assistant District Engineer</td><td>• District Engineer
• State Estimation Office
• Functional Groups
• External stakeholders</td><td>• Project Manager
• Assistant District Engineer</td><td>• Commissioner's staff
• District Engineer
• State Estimation Office
• Functional Groups
• External stakeholders</td><td>• Project Manager
• Assistant District Engineer</td><td>• Commissioner's Staff
• District Engineer
• State Estimation Office
• Functional Groups
• External Stakeholders</td><td>• Central Office Estimator</td><td>• District Engineer
• Assistant District Engineer
• District Estimator
• Project Manager
• Functional Groups</td></tr>
</table>

MnDOT puts efforts into developing a reliable estimate basis for more-accurate cost estimation throughout the project development. To develop the accurate cost estimate, a well-defined estimate basis is essential. Table 2-2 describes key inputs for the estimate basis, which are critical sources in developing the cost estimate for each phase of the milestones. As design proceeds, these key inputs should be defined, updated, and documented by the key personnel (e.g., the project manager, functional groups, and the district engineer) for updating cost estimates throughout project development (MnDOT 2008).

Table 2-2 MnDOT Key Inputs for Cost Estimates

Cost Estimation Milestone	Key Inputs
Planning	• Planning Estimate Basis- the accumulated information on project requirements necessary for completing a Planning estimate • Project Characteristics- description of the type of project and complexity of the project related to the concept, including site location information (e.g., urban versus rural) and/or data that are relevant to preparing the cost estimate • Historical Data- cost data from previous project used as a basis for pricing different components of the Total Project Cost Estimates • Functional Group Input- cost estimates provided by different Functional Groups
Scoping	• Project Estimate File- containing the estimate basis that includes project definition requirements and Scoping summary sheet • Project Characteristics- description of the type of project and complexity of the project, including site-specific information and/or data • Historical Data- cost data from previous projects • Functional Group input- cost estimates provided by different functional groups • Market Conditions- understanding of the potential market impact on costs for a project in a given location
Design	• Approved Baseline Cost Estimate Package- including cost estimate summaries, cost estimate details, estimate project definition basis, estimate assumptions, estimate calculations • Updated Project Cost Estimate File- containing the updated estimate basis with specific emphasis on changes in the project requirements • Project Characteristics- description of the type and complexity of the project, including site-specific information • Historical Data- updated cost data from previous projects • Functional Group Input- updated cost estimates provided by different functional groups • Market Conditions- understanding of the potential market impact on costs for a project in a given location in terms of changes from when the baseline cost estimate was prepared
Letting	• Engineer's Estimate Basis File- containing all pertinent information used to prepare an estimate, including the item schedule with quantities • Project Characteristics- description of the type of project and complexity of the project, including site-specific information and/or data • Historical Data- cost data from previous bids and labor, material, and equipment data for different items • Market Conditions- understanding of the potential market impact on construction costs for a given location

MnDOT uses cost estimate review and approval gates to achieve consistent and accurate cost estimates. Figure 2-2 depicts review and approval gates during project development process. At each of these gates, the appropriate management staff (e.g., a project manager, a district engineer, or a Central Office Estimator) should provide an estimate approval before moving the project to the next phase of project development.



Note: HIP= Highway Improvement Plan; STIP= State Transportation Improvement Program

Figure 2-2 MnDOT Cost Estimate Review and Approval Gates

2.2.1.2. MnDOT's Practices for Developing and Controlling Baseline Cost Estimates

Cost Estimation and Cost Management System

The major purpose of an integrated cost estimation and cost management process is to prepare accurate, reliable, and consistent estimates throughout project development process. This practice allows MnDOT to achieve standardization and documentation of project estimating and cost management activities and deliverables, from the planning phase through the letting phase. Figure 2-3 illustrates a work breakdown structure for the cost estimation and cost management process during project development process (MnDOT 2008).

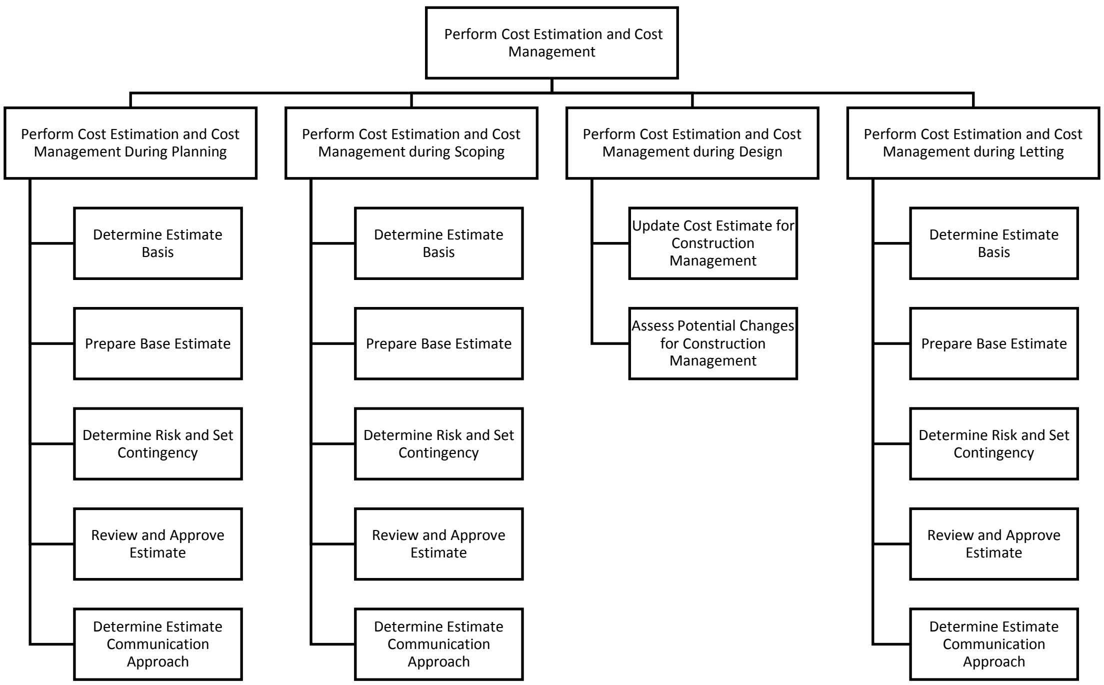


Figure 2-3 MnDOT Cost Estimation and Cost Management Process

The following two steps are performed in all Phases of the MnDOT's project development process:

Step 1. Identify all the existing and desired functions and sub functions relevant to MnDOT cost estimation and cost management process

Step 2. Integrate the desired cost estimation and cost management functions with the pre-construction phases of MnDOT project development process

The entire MnDOT organization (e.g., the commissioner's staff, transportation program committee, district engineer, and central office estimator) provides inputs into the cost estimation process.

One of the unique features of the MnDOT's cost estimation and cost management process is that the process contains risk analysis to develop the cost estimates at each phase of project development process. The activity of "Determine risk and set contingency" allows the project team to:

a. acknowledge uncertainty, risk, and associated contingencies early in the project development process
b. determine the extent of risk analysis based on the project's complexity, local impacts, and other considerations

In addition, the cost estimation and cost management process includes review and approval procedures for the cost estimates. These processes increase the accuracy and completeness of the cost estimates by verifying cost estimate package and data.

Lastly, the activity of "Determine estimate communication approach" enables to establish accountability for all cost estimates and avoid miscommunications about the cost estimates between entities involved in the project.

The following are the major benefits and advantages of the MnDOT's costs estimation and cost management process:

a. A standard process for estimating, managing, and controlling costs

b. Reliable and accurate estimates
c. Improved communication and credibility with external stakeholders
d. Clear accountability for cost estimating and management

Variance Reports on Cost and Schedule

Variance reports are used to capture changes in cost and schedule and provide a mechanism for budget control through tracking changes and alerting project personnel of changes. Three steps are performed in preparation of variance reports:

Step 1. Compare a current estimate with baseline cost estimate
Step 2. If needed, note and explain deviations from the baseline
Step 3. Generate variance reports at key project milestones or when significant changes in the project occur

Variance reports are prepared by the project personnel, particularly the project manager, throughput all phases of project development, most importantly during the design phase. One of the unique features of a variance report is that it is a transparent notification system for alerting project personnel of deviations in project baseline costs and/or schedule. As shown in Figure 2-4, the variance report can provide the detailed project information by using the columns. With this report, the project manager can acknowledge the difference between the baseline cost estimate and the updated cost estimate and track the differences. In addition, the variation report provides an explanation for the cost increase or decrease so that the project manager can efficiently allocate resources including the personnel.

Estimate Reconciliation

SP Number:

Estimate Completion Date:

Project Location:

Project Description:

Reporting Date:

Components	Baseline Cost Estimate				Updated Cost Estimate				Difference				Explanation
	Base	Contingency	Total (Current Yr.)	Construction Year	Base	Contingency	Total (Current Yr.)	Construction Year	Base	Contingency	Total (Current Yr.)	Construction Year	
DIVISION GROUP CATEGORY ELEMENT ITEM													
TOTAL													

Figure 2-4 Template of Variance Reports

The main benefits/advantages of variance reports are:

a. Early identification of differences in project cost and schedule
b. Proper resource allocation

2.2.2. California Department of Transportation (Caltrans)

2.2.2.1. Caltrans Cost Estimation Process

The California Department of Transportation (Caltrans)'s cost estimates are classified into two major estimates: (1) project planning cost estimates; and (2) project design cost estimates. Since project planning cost estimate becomes the baseline cost estimate for a project, the estimator/project team should clearly determine the cost estimate. This cost estimate will be used for project justification, analysis of alternatives, approval, and programming at the planning phase. The following cost estimates are project design cost estimates, which are developed after project approval and with more detailed information of a project (e.g., engineering and environmental studies). As shown in Table 2-3, the two major cost estimates are further divided into several sub cost estimates, which are developed as major tasks are completed at each phase of cost estimation milestones.

Caltrans utilizes two major information sharing systems, the Project Report (PR)/Project Study Report (PSR) and Basic Engineering Estimating System (BEES), to maintain, update, and approve project information, cost estimates, and changes in project scope, costs, and schedule. Caltrans prepares critical information, such as an environmental document, consideration of public comments, and the selection of a preferred alternative, in the project report. This information becomes the estimate basis in developing cost estimates. The BEES assists the project engineer/estimator in preparing the cost estimate in the design phase. The BEES contains critical information, such as contract items, supplemental work, and contingencies used for developing the final engineer's cost estimate (Caltrans 2007a). Through these systems, key stakeholders collaborate to develop the accurate cost estimates during project development process. The key inputs for cost estimating are described in Table 2-4 (Caltrans 2007a).

Table 2-3 Caltrans Cost Estimation Milestones

<table>
<tr><th>1st</th><th colspan="8">Project Planning Cost Estimates</th></tr>
<tr><th>PDP</th><th colspan="2">Project Feasibility Cost Estimate</th><th colspan="2">Project Initiation Cost Estimate</th><th colspan="2">Draft Project Report (PR) Cost Estimate</th><th colspan="2">Project Report (PR) Cost Estimate</th></tr>
<tr><td>Major Tasks</td><td colspan="2">• Prepare project cost information planning studies</td><td colspan="2">• Obtain Additional information (e.g., existing and forecasted traffic volume)
• Evaluate and validate the project cost estimate and assumptions</td><td colspan="2">• Calculate the cost estimate for each project alternative
• Complete Environmental and hazardous waste studies</td><td colspan="2">• Complete the public hearing process, selection of the preferred alternative, and completion of the environmental document</td></tr>
<tr><td rowspan="2">Who</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td></tr>
<tr><td>• Project Engineer
• Project Manager</td><td>• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td><td>• Project Engineer
• Project Manager</td><td>• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td><td>• Project Engineer
• Project Manager</td><td>• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td><td>• Project Engineer
• Project Manager</td><td>• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td></tr>
<tr><th>2nd</th><th colspan="8">Project Design Cost Estimates</th></tr>
<tr><th>PDP</th><th colspan="4">Preliminary Engineer's Cost Estimate</th><th colspan="4">Final Engineer's Cost Estimate</th></tr>
<tr><td>Major Tasks</td><td colspan="4">• Prepare cost estimates using Basic Engineering Estimating System (BEES)
• Update frequently during the design phase as the project construction details, specifications and plans are finalized into a contract document</td><td colspan="4">• Complete the final engineer's cost estimate
• Certify that the estimate is completed and accurate, reflects the true scope of work, and accounts for current market trends</td></tr>
<tr><td rowspan="2">Who</td><td colspan="2">Lead</td><td colspan="2">Support</td><td colspan="2">Lead</td><td colspan="2">Support</td></tr>
<tr><td colspan="2">• Project Engineer
• Project Manager</td><td colspan="2">• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td><td colspan="2">• Project Engineer
• Project Manager</td><td colspan="2">• Headquarters Divisions
• District Right-of-way
• District Director
• External stakeholders</td></tr>
</table>

Note: PDP= Project Development Process

Table 2-4 Caltrans Key Inputs for Cost Estimates

Cost Estimation Milestones	Key Inputs
Project Feasibility Cost Estimate	• Project Information- each function group (e.g., materials, structural design, traffic, and right-of-way) provides the information for developing project information • Existing facilities • High cost items that have impacts on the cost estimates • Contingencies- between 30 and 50%
Project Initiation Cost Estimate	• Appropriate mapping- having accurate maps leads to the reliable estimate basis (e.g., environmental studies) and cost estimates (e.g., the right-of-way cost estimate). • Project Information- including existing and forecasted traffic volume, geotechnical design information, materials and pavement structural section design information, advance planning studies for new structure and modifying existing structures, hazardous waste assessment, potential environmental issues and mitigation, right-of-way and utilities data sheets, traffic handling and transportation management plans, and utilization of existing resources • Contingencies- 25%
Draft Project Report Cost Estimate	• Cost estimates for each competing project alternative • Updated Project Information from the functional groups (e.g., materials, structural design, traffic, and right-of-way) • Contingencies – 20 %
Project Report Cost Estimate	• Public Hearings • Preferred alternative • Environmental document- including the purpose and need for the transportation improvement, project alternatives, public hearing, etc. • Contingencies- 15%
Preliminary Engineer's Cost Estimate	• Project Construction Details • Specifications and Plans • Contract Item prices • Contingencies- up to 10%
Final Engineer's Cost Estimate	• All contract items with Quantities • Certification of Engineer's Estimate for projects with an engineer's estimates greater than $5 million (District Director) • Comparison with Contractor bids received • Contingencies- 5% or less

To have the reliable estimate basis, Caltrans encourages functional groups to provide the information that requires developing cost estimates during project development. In addition, Caltrans has predefined contingency amounts for cost estimates for each cost estimation milestone. Caltrans should certify the accuracy and completeness of the final engineer's estimate for projects greater than $5 million.

2.2.2.2. Caltrans' Practice for Developing and Controlling Baseline Cost Estimates

Quality Assurance (QA)/Quality Control (QC) Certification Practice

The main purpose of the Caltrans' QA/QC certification practice is to certify that the contract cost estimate is complete and accurate while the cost estimates reflect the true scope of the work and account for the most current market trends (Caltrans 2007b). The QA/QC process contains four steps to develop the best estimate possible throughout the Plan Specification and Estimate (PS&E) development phase.

Step 1. Identify roles and responsibilities for QA/QC process.

Step 2. Conduct major activities of the QA/QC process, such as calculating unit quantities, calculating working dates, and verifying all estimates, shown in Table 2-5.

Step 3. Verify all factors used in developing the cost estimates, shown in Table 2-6.

Step 4. Obtain approval of key stakeholders such as the project engineer, the design senior, the central region estimate specialist, and the project manager. A sample template for approval of key stakeholders is shown in Figure 2-5.

Table 2-5 Roles and Responsibilities for QA/QC Process

A=Accountable **I=Input** **S=Signature** **QA=Quality Assurance** **QC=Quality Control**	**Project Engineer (PE)**	**Assistant PE**	**District Estimator**	**Construction Representative**	**Design Senior**	**Specification Writer**	**Project Manager**	**Single Focal Point**	**District Director**
Major Activity	**Responsibility**								
Calculates Unit Quantities	A	QA			QC				
Calculates Working Days	A	QA	I	I	QC				
Determines Unit Prices	A		I/QA	I	QC	I			
Ensures project estimate reflects work required by the plans and specs	A	QA	I		QC	QA			
Ensures project estimate is not inflated or constrained	A		QA		QC				
Ensures project scope and estimate is within budget	I				QC		A	QA	
Prepares Estimate Certification (Supporting Data) form	I/QA		A	I	QC				
Prepares Certification Memo for estimates > $5 Million			A						S
Verifies all estimates	I		I	I	A/S		I		

Table 2-5 represents all entities involved in the QA/QC process and describes their roles and responsibilities. The unique features of the QA/QC certification process allow the project to prepare complete and accurate project estimates corresponding with project scope and budget by verifying critical factors that are considered in developing cost estimates. Table 2-6 lists the factors with the detailed information. In addition, the outcome of this process is a certification of project cost estimates.

The main benefits/advantages of QA/QC certification practice are:

a. Minimal cost changes by reviewing and verifying quantities and the unit costs in comparison with recent bid openings and market trends

b. The higher accuracy of the final cost estimates by verifying assumptions and contingencies

Table 2-6 Critical Factors for QA/QC process

	Factors considered in developing cost estimates
Quality Control	**Assumptions:** How dis assumptions about location (e.g., terrain, distance to construction site, etc.), relative availability of materials, weather conditions, etc., influence the cost estimate? What other elements influence the estimate?
	Source of Unit Prices: What factors were considered to determine unit prices of major items? Provide expenditure authorizations (EAs) of projects considered, unit prices and quantities used. Add specialty items and costs as appropriate.
	Traffic Management Plan: Identify lane closure windows and assumptions about traffic control costs and elements (e.g., number of signs, public outreach, component, night work, etc.).
	Risk Management Plan: Identify risks relating to the development and use basic engineering estimating system (BEES).
	Escalation Factors Used: Explain forecasted variables and assumptions used. Demonstrate forward estimating method.
	Contingencies: Is 5% contingency adequate to address each risk factor? If not, why not? How much more is needed?
	DES Structure verification of Estimate and Quantities: List who prepare calculation data, and verify calculation and data.
Quality Assurance	**Constructability Review:** What is the assumed construction method and what risks are associated with that method? Indicate when reviews occurred and major findings.
	DOE Cost Estimate Review: List Completion data and conclusions of the review.
	Value Analysis Performed: List completion data and any alternatives that impact cost.
	DES Structural Liaison Review: List date and conclusion of Review and name of reviewer
	Independent Estimate Performed: List completion data and variance if any, from Caltrans estimate. If variance, explain how resolved.
Status	**Variance from Programmed Funds (%):** Compare current program cost to PS&E BEES.
	Next Cost Estimate Update: List projected date (three weeks before the California Transportation Commission vote).

Note: DES= Division of Engineering Services; DOE= Division of Equipment

QC/QA Documentation for Estimate Certification

Engineer's Estimate Prepared By:

____ ________

John/Jane Doe, Project Engineer   Date

DES Structures Verification of Estimate and Quantities:

- ❑ See Attached Email
- ❑ See Attached Fax
- ❑ Not Applicable to Project

Engineer's Estimate Checked By:

____ ________

John/Jane Doe, Design Senior   Date

Engineer's Estimate Concurred By:

____ ________

John/Jane Doe, Central Region OE Estimate Specialist   Date

CR PJD Verification of QC/QA Processing:

____ ________

John/Jane Doe, Office Chief, Central Region Design   Date

Recommend Certification:

____ ________

John/Jane Doe, Project Manager   Date

Attachment:
BEES dated __________
DES Structures Verification (if applicable)

Note: OE= Office Engineer; CR= Central Region; PJD= Project Development

Figure 2-5 Template for QA/QC Documentation

2.2.3. Texas Department of Transportation (TxDOT)

2.2.3.1. TxDOT Cost Estimation Process

The Texas Department of Transportation (TxDOT) has five phases of cost estimation process as shown in Table 2-7. In the planning and programming phase, TxDOT develops a preliminary cost estimate, which becomes the baseline cost estimate for a project. Throughout the design and PS&E developments, the preliminary cost estimate will be updated until the agency finalizes the project cost estimate. The preliminary design phase consists of three major design developments, including preliminary schematic, geometric schematic, and value engineering, for review and approval of cost estimate (TxDOT 2014). TxDOT stores all information of the estimate basis and cost estimates in the Design and Construction Information System (DCIS), an automated information system for planning, programming, and developing projects (TxDOT 2006). Through the DCIS, TxDOT updates and shares the cost estimate and the project information with all stakeholders.

Table 2-7 TxDOT Cost Estimation Milestones

PDP	Planning and Programming (10%)		Preliminary Design (30%) (Preliminary Schematics)		Preliminary Design (30-50%) (Geometric Schematics)		Preliminary Design (30-50%) (Value Engineering)		PS&E (100%)	
Major Tasks	• Gather preliminary information • Use Advance Planning Risk Analysis (APRA) tool to measure project scope definition and identify potential risks • Use AASHTO cost estimation program Estimator • Prepare construction and ROW cost estimate • Prepare preliminary estimate (baseline cost estimates)		• Organize design concept conference & prepare design summary report • Prepare preliminary pavement designs • Update construction and ROW cost estimates and corresponding DCIS data • Update cost estimate		• Prepare pavement design report • Perform preliminary hydraulic analysis/design • Determine right of way and access needs • Identify potential utility conflicts • Update project scope • Update cost estimate		• Gather project team experts • Consider redesign of alternatives if needed • Conduct VE study • Make necessary design changes Document design changes • Revise design based on VE study findings • Update cost estimate		• Finalize roadway design • Finalize project design, • Review environmental studies, ROW plans, and utilities relocation requirements • Update APRA • Prepare final engineer's estimate	
Who	Lead	Support	Lead	Support	Lead	Support	Lead	Support	Lead	Support
	• Director of Transportation Planning and Development	• District staff • Project Manager • District Planner • Functional groups • Transportation Planning and Programming Division	• Project Manager	• Environmental coordinator • Design engineers • Roadway design engineer • Functional groups	• Roadway design engineer • Project Manager	• Hydraulic engineer • District pavement engineer	• Roadway design engineer • Project manager	• VE Coordinator • Design Division Engineers & Staff • District Engineer • District Executive Decision Team	• Roadway design engineer • Project Manager	• District design engineer • Hydraulic engineer

Note: ROW= Right of Way; VE= Value Engineering

Table 2-8 TxDOT Key Inputs for Cost Estimates

Cost Estimation Milestones	Key Inputs
Planning and Programming	• An accurate scope of work- including type of work proposed, proposed typical section, existing geometry, earthwork and retaining walls or sloped embankments, drainage issues and possible solution, etc. • The critical elements of the project scope identified with the Advance Planning Risk Analysis (APRA) tool • Recent unit bid prices for similar projects • Contingencies- 6% to 11%
Preliminary Design (Preliminary Schematics)	• Geographic location (i.e., remoteness) and proximity to material sources • Recent bid prices on similar projects • Anticipated difficulty of construction • Presence of restricted work areas or schedules • Project size relative to previous project sizes • Proposed project schedule • Expected construction staging
Preliminary Design (Geometric Schematics)	• Changes in the project scope- including design refinements, route or design alternative selection, utility conflicts, environmental mitigation measure, public involvement, or value engineering analysis findings • Geographic location (i.e., remoteness) and proximity to material sources • Recent bid prices on similar projects • Anticipated difficulty of construction • Presence of restricted work areas or schedules • Project size relative to previous project sizes • Proposed project schedule • Expected construction staging
Preliminary Design (Value Engineering)	• Revised design from Value Engineering Study findings • Geographic location (i.e., remoteness) and proximity to material sources • Recent bid prices on similar projects • Anticipated difficulty of construction • Presence of restricted work areas or schedules • Project size relative to previous project sizes • Proposed project schedule • Expected construction staging
PS&E	• Additional or update data- including the right-of-way maps, as-build construction plans, traffic data, site information, the completed schematic design and project scope

During the TxDOT's cost estimation milestones, several key inputs are required for developing project cost estimates. Table 2-8 describes the key inputs (TxDOT 2014).

As the key information for the cost estimates are obtained at the preliminary design phases (preliminary schematics, geometric schematics, and value engineering), the project manager/estimator should pay careful attention in updating baseline cost and schedule during these phases.

2.2.3.2. TxDOT's Practices for Developing and Controlling Baseline Cost Estimates

Advance Planning Risk Analysis (APRA) – A Spreadsheet-based Tool

The APRA assists the project team/key stakeholders in measuring project scope definition and identifying potential risks/elements that may impact project cost and schedule. TxDOT uses the APRA as a comprehensive checklist to identify potential risks by looking at critical risk elements listed in Table 2-9. The APRA consists of three main sections that include 12 categories that are further broken down into 59 elements (Caldas et al. 2007).

Table 2-9 APRA Sections, Categories, and Elements

Section 1	**Basis of Project Decision**		
Categories	**A. Project Strategy**	**B. Owner/Operator Philosophies**	**C. Project Requirements**
Elements	A1. Need & Purpose Documentation A2. Investment Studies & Alternatives Assessments A3. Programming & Funding Data A4. Key Team Member Coordination A5. Public Involvement	B1. Design Philosophy B2. Operating Philosophy B3. Maintenance Philosophy B4. Future Expansion & Alteration Consideration	C1. Functional Classification & Use C2. Evaluation of Compliance Requirements C3. Survey of Existing Environmental Conditions C4. Determination of Utility Impacts C5. Value Engineering

Section 2	**Basis of Design**				
Categories	**D. Site Information**	**E. Location & Geometry**	**F. Structures**	**G. Design Parameters**	**H. Installed Equipment**
Elements	D1. Geotechnical Characteristics D2. Hydrological Characteristics D3. Surveys & Planimetrics D4. Permitting Requirements D5. Environmental Documentation D6. Property Descriptions D7. Ownership Determinations D8. Right-of-Way Mapping D9. Constraints Mapping D10. Right-of-Way Site Issues	E1. Horizontal & Vertical Alignment E2. Control of Access E3. Schematic Layouts E4. Cross-Sectional Elements	F1. Bridge Structure Elements F2. Hydraulic Structures F3. Miscellaneous Design Elements	G1. Provisional Maintenance Requirements G2.Constructability	H1. Equipment List H2. Equipment Location Drawings H3. Equipment Utility Requirements

Section 3	**Execution Approach**			
Categories	**I. Acquisition Strategy**	**J. Deliverables**	**K. Project Control**	**Project Execution Plan**
Elements	I1. Long-Lead Parcel & Utility Adjustment Identification I2. Long-Lead/Critical Equipment & Materials Identification I3. Local Public Agencies Utilities Contracts & Agreements I4. Utility Agreement & Joint-Use Contracts I5. Project Delivery Method & Contracting Strategies I6. Design/Construction Plan & Approach I7. Procurement Procedures & Plans I8. Appraisal Requirements I9. Advance Acquisition Requirements	J1. Computer Aided Drafting and Design (CADD)/Model Requirements J2. Documentation/Deliverables	K1. Right-of-Way & Utilities Cost Estimates K2. Design & Construction Cost Estimates K3. Project Cost Control K4. Project Schedule Control K5. Project Quality Assurance & Control K6. Safety Procedures	L1. Environmental Commitments & Mitigation L2. Interagency Coordination L3. Local Public Agency Contractual Agreements L4. Interagency Joint-Use Agreements L5. Preliminary Traffic Control Plan L6. Substantial Completion Requirements

The APRA is a spreadsheet-based tool. Figure 2-6 outlines the project score sheet for project scope evaluation. The following steps are followed in the implementation of the APRA:

Step 1: Use the project assessment sheet and read its corresponding description

Step 2: Discuss issues and review documents if needed

Step 3: Choose only one definition level (0, 1, 2, 3, 4, or 5) for each element. All elements have six pre-assigned scores, one for each of the six possible levels of definition

Step 4: Add each of the element scores within a category to produce a total score for that category

Step 5: Add the three section scores to achieve a total APRA score

SECTION II - BASIS OF DESIGN							
	Definition Level						Score
CATEGORY Element	0	1	2	3	4	5	
D. SITE INFORMATION							
D1. Geotechnical Characteristics							
D2. Hydrological Characteristics							
D3. Surveys & Planimetrics							
D4. Permitting Requirements							
D5. Environmental Documentation							
D6. Property Descriptions							
D7. Ownership Determinations							
D8. Right-of-Way Mapping							
D9. Constraints Mapping							
D10. Right-of-Way Site Issues							
CATEGORY D TOTAL							
E. LOCATION & GEOMETRY							
E1. Horizontal & Vertical Alignment							
E2. Control of Access							
E3. Schematic Layouts							
E4. Cross-Sectional Elements							
CATEGORY E TOTAL							
F. STRUCTURES							
F1. Bridge Structure Elements							
F2. Hydraulic Structures							
F3. Miscellaneous Design Elements							
CATEGORY F TOTAL							
G. DESIGN PARAMETERS							
G1. Provisional Maintenance Requirements							
G2. Constructability							
CATEGORY G TOTAL							

Definition Levels

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

Figure 2-6 Sample of TxDOT's APRA Tool

The APRA is used in planning and programming, and preliminary design phases. The APRA is applied on four gates depicted in Figure 2-7.

a. The first assessment is typically held for projects at the Feasibility and Scoping meeting.
b. The second assessment is typically held for project at a Preliminary Design Conference.
c. The third assessment is typically held for project before preceding to the Plans, Specification, and Estimates development phase.
d. The forth assessment is typically held at the end of the Plans, Specifications, and Estimates development phase, prior to letting.

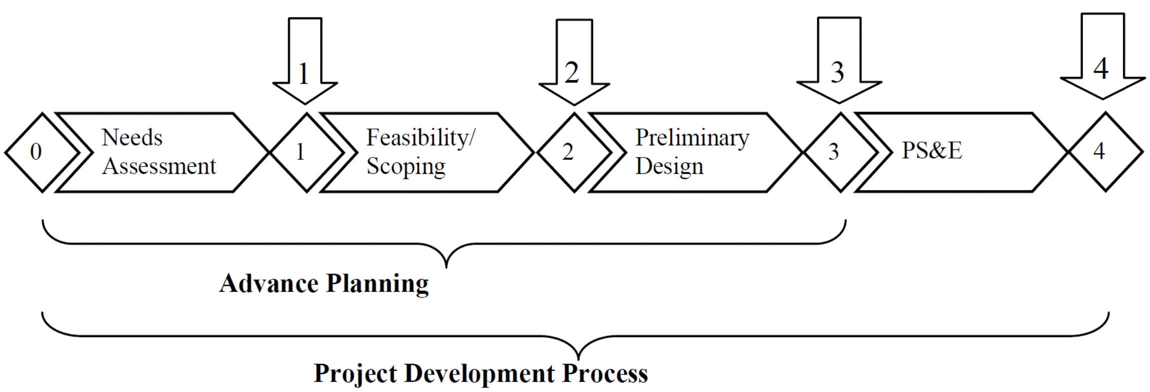


Figure 2-7 APRA Application Points

Table 2-10 APRA Review Gates and Purposes

Gates	1st Gate	2nd Gate	3rd Gate	4th Gate
When	Before proceeding the feasibility and scoping phase /at the feasibility and scoping meetings	Before proceeding the preliminary design phase/at Preliminary Design Conference	Before proceeding the PS&E phase	At the end of PS&E phase
Purpose	• To align the team with project objectives; • To ensure good communication among the decision makers and the project development team; and • To highlight stakeholder expectations to facilitate reasonable engineering estimates.	• To align project objectives and stakeholders' needs; • To identify high priority project deliverables that need to be completed; • To help to eliminate late-project surprises; • To facilitate communication across the project development team and stakeholders.	• To identify risk issues • To develop mitigation plans for risk issues	• To reviewing all risk elements by all stakeholders • To resolve all major issues • To control any residual risk elements

Table 2-10 describes the sub-objectives of the APRA tool at each gate. All major disciplines (e.g., right-of-way, utilities, environmental, design, and planning and programming) participate in the APRA assessment to identify the critical elements of the project scope.

The APRA has several unique features for project development as follows:

- A checklist that a project team can use for determining the necessary steps to follow in defining the project scope
- A listing of standardized scope definition terminology throughout the transportation construction industry
- An industry standard for rating the completeness of the project scope development to facilitate risk analysis and prediction of escalation, potential for disputes, etc.
- A means to monitor progress at various stages during the advance planning phase and the project development process

- A tool to aid in communication and to promote alignment between owners (e.g., TxDOT), design contractors, and other stakeholders by highlighting poorly defined areas in the project scope
- A means through which project team participants can reconcile differences using a common basis for project evaluation
- A training tool for organizations and individuals through the industry
- A benchmarking tool for organizations such as TxDOT to use in evaluating the completion of scope development versus the performance of past projects, both within their organizations and without, in order to predict the probability of the success of future projects.

The main benefits/advantages of the APRA are:

a. The improvement of project performance in terms of both cost and schedule
b. The identification of the project requirements in all major disciplines by quantifying, rating, and assessing the level of scope development

Design Summary Report (DSR) including the Design Conference

The main purpose of the DSR is to document project information and ensure that the project does not overlook potential critical issues in the project scope development (TxDOT 2014).The DSR documents the agreed upon fundamental aspects, concepts, and design criteria of a project and serves as the definition of the project's scope. Key stakeholders need to update design summary throughout all phases of project development process. As project progresses, the DSR needs to be revised and the agency needs to obtain approval from entities and share information with. Project manager and function groups (e.g., right-of-way, utility, and design offices) are responsible for the execution of the ARPA.

As stated earlier, the DSR summarizes information of the key elements that are necessary in developing cost estimates and identifying risks for a project. Figure 2-8 shows a sample of proposed hydraulic elements in the DSR.

The key elements of the DSR are as follows:

- Programming and Funding Data
- Existing Elements
- Advanced Project Development Element
- Proposed Right of Way & Utility Elements
- Proposed Geometric Design Elements
- Proposed Bridge Design Data
- Proposed Hydraulic Elements
- Proposed Pavement Structure Elements
- Proposed Traffic Operations Elements
- Proposed Miscellaneous Elements
- Accelerated Construction Procedures

Functional Classification and Structure Type	Design Frequency (years)					Check 100-yr Flood?
	2	5	10	25	50	
Freeways (main lanes)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐	yes
Bridges	☐	☐	☐	☐	☐	yes
Principal arterials	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐	yes
Small bridges	☐	☐	☐	☐	☐	yes
Major river crossings	☐	☐	☐	☐	☐	yes
Minor arterials and collectors (including frontage roads)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐	yes
Small bridges	☐	☐	☐	☐	☐	yes
Major river crossings	☐	☐	☐	☐	☐	yes
Local roads and streets (off-system projects)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐	yes
Small bridges	☐	☐	☐	☐	☐	yes
Storm drain systems						
Interstate and controlled access highways (main lanes)						yes
inlets and drain pipe	☐	☐	☐	☐	☐	yes
inlets for depressed roadways	☐	☐	☐	☐	☐	yes
Other highways and frontage						
inlets and drain pipe	☐	☐	☐	☐	☐	yes
inlets for depressed roadways	☐	☐	☐	☐	☐	yes
Other	☐	☐	☐	☐	☐	

Figure 2-8 A Sample Hydraulic Element in the Design Summary Report

The main benefits/advantages of the DSR are:

a. The DSR provides reliable basis of estimate for design development and cost estimates based on existing conditions and design elements of a project
b. The DSR aligns key stakeholders to input design criteria and elements
c. The DSR tracks changes in critical elements (ROW, Environmental, Traffic control, etc.) for the project development

2.2.4. Ohio Department of Transportation (ODOT)

2.2.4.1. ODOT Cost Estimation Process

The Ohio Department of Transportation (ODOT) develops cost estimates along with cost estimation milestones shown in Table 2-12. The cost estimation milestones consist of four phases, including planning, preliminary engineering, environmental engineering, and final engineering/right-of-way (ROW), before letting. The baseline cost estimate is developed in the planning phase and updated during the rest of project development process (ODOT 2013). To efficiently develop projects, ODOT classifies transportation projects into five paths to have customized scoping process depending on project size, project complexity, and/or potential impact to the environment. These classifications allow ODOT to have the flexibility in adjusting required tasks to address project needs. The customized scoping process ensures that only necessary work is conducted and that the project is properly planned and developed (ODOT 2013; ODOT 2016). For example, since feasibility study and alternative evaluation report are not necessary in selecting the preferred alternative for a simple improvement project, ODOT can expedite in scoping process by selecting the alternative early in the project development process, at the planning phase. Table 2-11 describes five project paths in detail.

Table 2-11 ODOT Five Project Paths

Paths	Description
Path 1	Path 1 projects are defined as "simple" transportation improvements generated by traditional maintenance and preventative maintenance. They involve minor structure and roadway work with no ROW/utility impacts. These are typically NEPA exempt or CE Level 1 NEPA documents.
Path 2	Path 2 projects are also simple projects (similar to Path 1- minor structure and minor roadway work), however, these jobs can involve ROW/utility impacts. These jobs are typically CE Level 1 documents.
Path 3	Path 3 projects involve a higher level of complexity than projects in Path 1 or 2. They involve projects such as: moderate roadway and structure work, intersection and minor interchange upgrades, minor realignments, reconstruction, median widenings, etc. They can involve utility and ROW impacts including relocations.
Path 4	Path 4 projects involve complex roadway and structure work that may add capacity such as: highway widening, new alignments in suburban or rural settings, reconstruction, access management, complex bridge replacement and/or multiple intersection/interchange alternatives. They may have high utility and/or ROW relocations/impacts. These are typically CE Level 3 or higher level NEPA documents.
Path 5	Path 5 projects have the highest complexity and involve projects like: new capacity-adding alignments in complex urban centers, major highway widenings, reconstructed interchange or new interchange. These projects will have high ROW relocations/impacts, complex utility issues, multiple alternatives and access management issues. These projects are typically higher level NEPA documents and will require additional scoping reviews before acceptance.

Note: CE= Categorical Exclusions; NEPA=National Environmental Policy Act

Table 2-12 ODOT Cost Estimation Milestones

<table>
<tr><th>PDP</th><th colspan="2">Planning (10%)</th><th colspan="2">Preliminary Engineering (Stage 1 Design)</th><th colspan="2">Environmental Engineering (Stage 2 Design)</th><th colspan="2">Final Engineering/ROW (Stage 3 Detailed Design)</th></tr>
<tr><td>Major Tasks</td><td colspan="2">• Develop project concept and scope
• Identify environmental, ROW, utility, and design, geotechnical, engineering issues in the preliminary information package
• Conduct field review
• Prepare base cost estimate including construction, utility, and ROW
• Involve public/stakeholder</td><td colspan="2">• Develop accurate cost estimates for all feasible alternatives
• Conduct feasibility study and NEPA studies
• Analyze alternatives and identify a preferred alternative(s) using the Alternatives Comparison Matrix
• Conduct VE study
• Establish and develop the design parameters to generate an accurate scope, schedule, and budget
• Involve public/stakeholder</td><td colspan="2">• Obtain NEPA and permit approvals
• Refine the level of impacts associated with the preferred alternative
• Conduct VE study
• Prepare environmental mitigation cost estimates
• Develop preliminary ROW and utilities plans and refine estimates
• Update cost estimates and milestone dates
• Involve public/stakeholder</td><td colspan="2">• Finalize design package
• Perform ROW/Utility acquisition
• Update construction, right-of-way acquisition, and utility reimbursement cost estimates
• Involve public/stakeholder</td></tr>
<tr><td rowspan="2">Who</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td></tr>
<tr><td>• Project manager</td><td>• District staff
• Appropriate specialists (functional groups)</td><td>• Project manager</td><td>• Design engineers
• All functional groups (e.g., ROW, Utilities, and Environmental)
• VE Coordinator</td><td>• Project manager</td><td>• VE Coordinator
• All functional groups (e.g., ROW, Utilities, and Environmental)
• Design engineers</td><td>• Project manager</td><td>• District Environmental coordinator
• All functional groups (e.g., ROW, Utilities, and Environmental)
• Design engineers
• Office of Contracts</td></tr>
</table>

Note: PDP= Project Development Process; ROW= Right of Way; VE= Value Engineering; NEPA= National Environmental Policy Act

Table 2-13 provides key inputs for developing cost estimates throughout project development. In the planning phase, ODOT defines the needs of deficiencies in the transportation system through gathering information from functional groups. To update the baseline cost estimate, ODOT uses several major inputs, such as feasibility study, the

Alternative Evaluation Report (AER), and the Value Engineering study, during the preliminary engineering and environmental engineering phases. Lastly, ODOT prepare the PS&E package for developing the final engineer's estimate (ODOT 2013).

Table 2-13 ODOT Key Inputs for Cost Estimates

Cost Estimation Milestones	Key Inputs
Planning (10%)	• Determination of the problem (the transportation problems, and existing and future conditions) • Information from technical studies, the environmental secondary resource review, site visits, and engineering reviews • Definition of the scope work • Goals and objectives for the project • Scope for the preliminary engineering phase (schedule, deliverables, and budget)
Preliminary Engineering (Stage 1 Design)	• Goals, roles, and responsibilities for all project team members • Technical studies • Waterway permit determination • Preferred alternative • Feasibility study • Alternative Evaluation Report (AER)
Environmental Engineering (Stage 2 Design)	• Goals, roles, and responsibilities for all project team members • Technical studies • Environmental field studies and impact analyses • NEPA document • Environmental commitments summary • Waterway permit application • Value Engineering Study • Constructability review • Right-of-way plans
Final Engineering/ROW (Stage 3 Detailed Design)	• Final right-of-way plans and tracings • Completed and submitted plan package • The PS&E package • Final legislation • All pre-bid questions and issues • Federal authorization

Note: NEPA= National Environmental Policy Act; PS&E= Plans, Specifications, and Estimates

2.2.4.2. ODOT's Practices for Developing and Controlling Baseline Cost Estimates

Alternative Evaluation Report (AER)

The AER is used to document all the alternatives and their evaluation to select a preferred alternative. The Alternative Evaluation Report (AER) is applicable in complex Path 3, Path 4, and Path 5 projects as shown in Table 2-14 (ODOT 2016). The AER is prepared when the preferred alternative cannot be defined/chosen in Feasibility study.

Table 2-14 ODOT's Alternative Selection Methods

Project Milestone	**When is information prepared to define the Preferred Alternative?**					
	Path 1	Path 2	Path 3		Path 4	Path 5
			Non-complex	Complex		
Project Initiation	Project's description, method, and footprint	Project's description, method, and footprint				
Feasibility Study		Project's method and footprint	Project's description, method, and footprint	Project's description and footprint	Project's description and footprint	Project's description and footprint
Alternative Evaluation Report				Project's footprint	Project's method and footprint	Project's method and footprint

Note: Description (what will my project involve and where will it be located?); Method (what design standards will apply, how will we build it, and how will traffic be maintained?); Footprint (what are the limits that should be used for environmental clearance, will there be temporary impacts?)

The following steps are conducted by project manager in the district and central offices to develop the AER during the Preliminary Engineering Phase:

Step 1. Discuss environmental and design issues of all the alternatives

Step 2. Summarize the advantages and disadvantages for each alternative

Step 3. Use the combination of both design and environmental factors that contribute to the selection of the preferred alternative

ODOT summarizes all the alternatives in the AER. In Table 2-15, major components of the AER are listed. ODOT evaluates several alternatives based on technical analysis, costs, long-term versus short-term solutions, and stakeholder involvement. To effectively evaluate several alternatives, ODOT uses an alternative comparison matrix to eliminate alternatives and select the feasible alternative among proposed multiple alternatives.

Table 2-15 Components of ODOT's Alternative Evaluation Report

Alternative Evaluation Report Executive Summary	Typical Alternative Evaluation Engineering Element
• Introduction/Background • Alternatives • Traffic Analysis • Roadway Assessment • Drainage Assessment • Geotechnical Assessment • Right of Way Assessment • Utility/Railroad Assessment • Environmental Analysis • Public Involvement • Alternative Comparison • Recommendation	• Field Survey and Mapping • Typical Sections including Lanes, Curbs, Sidewalks, Trees, Lawns, and Shoulder Widths • Alignments (Horizontal and Vertical) • Clearances (Horizontal and Vertical) • Field Survey Information including Topography, Bridges, Utilities, Channels, and Railroads • Geological and Soil Boring Data (Highway/Bridge Foundations) • Drainage • Conceptual Drainage Design including Preliminary Culvert Sizes • Traffic Control • Signal Warrants • Maintenance of Traffic • Conceptual Maintenance of Traffic • Utilities • Right-of-Way, Construction, and Utility Reimbursement Cost Estimates • Locate Waste and Borrow Areas • Railroad Coordination • Value Engineering

The main benefits/advantages of the AER are:

a. ODOT expects to mitigate funding constraint issues by allowing project managers to choose a cost effective alternative

b. ODOT expects to minimize scope changes or issues with the selection of an optimal alternative by considering impacts of technical, engineering, and design issues

2.2.5. Washington State Department of Transportation (WSDOT)

2.2.5.1. WSDOT Cost Estimation Process

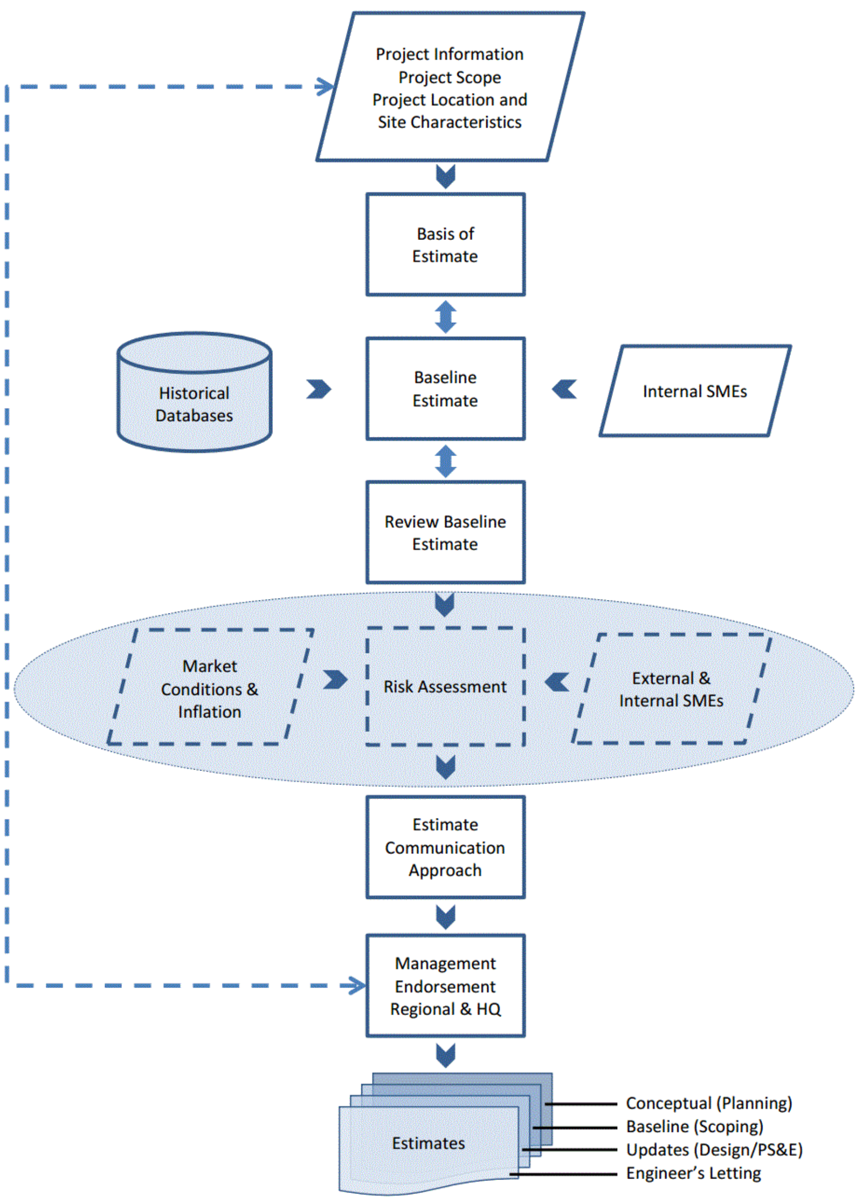
The Washington State Department of Transportation (WSDOT) develops the cost estimates along with cost estimation milestones as shown in Table 2-16. Although the planning phase estimate is developed with limited project information, WSDOT puts efforts into developing the accurate cost estimate by utilizing information collected from project stakeholders, historical projects, and field review. In the scoping phase, WSDOT sets the baseline cost estimates/the project budget. Throughout the design and the PS&E phases, WSDOT updates the cost estimate and refines risks, uncertainty, and assumptions that are used in preparing the cost estimate (WSDOT 2015).

Table 2-16 WSDOT Cost Estimation Milestones

<table>
<tr><th>PDP</th><th colspan="2">Planning</th><th colspan="2">Scoping</th><th colspan="2">Design</th><th colspan="2">PS&E</th></tr>
<tr><td>Major Tasks</td>
<td colspan="2">• Determine the full scope of the project
• Develop a comprehensive list of all of the components for the project
• Conduct a project field review and document potential high-cost items (costs of mitigating hazardous waste and other environmental impact, utility relocation, etc.)
• Review the unit price to reflect current trends.
• Review planning estimates and assumptions</td>
<td colspan="2">• Set the baseline cost estimates
• Document assumptions and scope definitions
• Choose the correct unit costs for items in current dollars
• Justify any changes in the cost of the project
• Ensure major risks to the project
• Conduct a site visit
• Understand the current design standards and their project impact
• Identify the major items of work
• Review the project constructability
• Verify traffic control strategy</td>
<td colspan="2">• Conduct geometric review, general plans review, and preliminary contract review
• Track changes in the estimated cost
• Compare the current budget for the project cost and schedule to the new estimate
• Document each update and provide a written explanation of any significant changes
• Get a quote for materials sources
• Coordinate with the appropriate entities for the review of the cost estimates</td>
<td colspan="2">• Conduct the final independent QA/QC checks of calculations, prices, and assumptions
• Review the basis of estimate for completeness, accuracy, and clarity
• Check quantities of major items and cost drivers
• Review special group estimates for scope and cost
• Review contract special provisions
• Evaluate the potential impact of staging, materials storage, hauling of materials, location of batch plants, and other constructability related issues</td></tr>
<tr><td rowspan="2">Who</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td><td>Lead</td><td>Support</td></tr>
<tr><td>• Project Manager
• Estimator</td>
<td>• Region Planning Manager
• Project Engineer
• Region Plans Office
• Peer Review Team
• Specialty Group</td>
<td>• Project Manager
• Estimator</td>
<td>• Region Plans Office and Programming
• Project Engineer
• Region Plans Office
• Peer Review Team
• Specialty Group</td>
<td>• Project Manager
• Estimator
• Designer</td>
<td>• Assistant State Design Engineer
• Project Engineer
• Project Development Engineer
• Region Plans Office
• Peer Review Team
• Specialty Group</td>
<td>• Project Manager
• Estimator
• Designer</td>
<td>• Construction staff
• Specialty Group
• Region Plans Office
• Peer Review Team
• Project Engineer
• Project Development Engineer</td></tr>
</table>

*PDP= Project Development Process; PS&E= Plans, Specifications, and Estimates; QA/QC= Quality Assurance/Quality Control

WSDOT has a rigorous process to develop the cost estimates for each phase of cost estimation milestones. Figure 2-9 depicts the steps of cost estimating process. For developing the cost estimate, this process allows the estimators to have the reliable estimate basis by using historical databases and internal subject matter experts (SMEs).



Note: HQ= Headquarters

Figure 2-9 WSDOT Cost Estimating Process for Each Phase of PDP

The potential benefit of this process is implementing risk assessment for each phase cost estimate. WSDOT considers factors of market conditions and inflation for the cost estimate, as well as inputs from external and internal SMEs to capture the effect of uncertainties on project cost and schedule (WSDOT 2015).

WSDOT defines the key inputs for developing cost estimates as shown in Table 2-17. WSDOT emphasizes on documenting the estimate basis (e.g., project description, risks, and changes in scope/design) to communicate with key stakeholder and convey key information from one phase to the next of project development (WSDOT 2015).

Table 2-17 WSDOT Key Inputs for Cost Estimates

Cost Estimation Milestones	Key Inputs	
Planning	• Description of the project including lead agency, responsible person, estimating processing software, etc. • Purpose, timing, and location of the project • The basic scope of the project (e.g., mission/design, estimate type, project type, and wetlands issues) • The primary estimating methodology for the cost estimate • Design basis including information that describe the types and status of engineering and design deliverables for preparing the estimates, as well as any design assumption	• Planning basis including descriptions of the project management, engineering, design, and construction approaches Cost basis including methods and sources for determining listed item pricing • Description of allowances, assumptions, exclusions, exceptions • Risks (i.e., all threats and opportunities) in preparing the cost estimate • Estimate quality assurance • Reconciliation for any differences in the cost estimate • List of all parties in preparing the cost estimate
Scoping	• Description of the project • Purpose, timing, and location of the project • The basic scope of the project • The primary estimating methodology for the cost estimate • Basis of design, planning, and cost	• Description of allowances, assumptions, exclusions, exceptions • Risks (i.e., all threats and opportunities) in preparing the cost estimate • Estimate quality assurance • Reconciliation for any differences in the cost estimate • List of all parties in preparing the cost estimate
Design	• Description of the project • Purpose, timing, and location of the project • The basic scope of the project • The primary estimating methodology for the cost estimate • Basis of design, planning, and cost • Description of allowances, assumptions, exclusions, exceptions	• Risks (i.e., all threats and opportunities) in preparing the cost estimate • Estimate quality assurance • Documentation reconciliation for any differences in the cost estimate • List of all parties in preparing the cost estimate
PS&E	• Description of the project • Purpose, timing, and location of the project • The basic scope of the project • The primary estimating methodology for the cost estimate • Basis of design, planning, and cost • Description of allowances, assumptions, exclusions, exceptions	• Risks in preparing the cost estimate • Estimate quality assurance • Reconciliation for any differences in the cost estimate • List of all parties in preparing the cost estimate • Quantities of major items and cost drivers • Contract special provisions • Potential impact of staging, materials storage, hauling of materials, location of batch plants, and other constructability related issues.

2.2.5.2. WSDOT's Practices for Developing and Controlling Baseline Cost Estimates

Cost Risk Assessment (CRA) and Cost Estimate Validation Process (CEVP) Workshop

The CRA and CEVP are systematic project review and risks assessment processes to identify and describe cost and schedule risks associated with the project (WSDOT 2012). CEVP is an intense workshop in which a team of top engineers and risk managers from local and national private firms and public agencies examine a transportation project and review project details with WSDOT engineers. The CEVP can be used in all projects in excess of $100 million. The CRA has the similar process and objective, but less intense than the CEVP. The CRA can be applicable in all projects in excess of $25 million. Seven-step process of the CRA and CEVP consists of the following:

Step 1. Select the project and method.

Step 2. Structure the project team effort.

Step 3. Define and evaluate the base cost estimate and schedule.

Step 4. Assess uncertainty and risk.

Step 5. Quantify uncertainty in the project cost and schedule.

Step 6. Apply probabilistic analysis and document.

Step 7. Implement and measure risk response actions, monitor, and control.

The CRA and CEVP are applied in the late-planning phase and early stages of the PS&E phase as represented in Figure 2-10. Participants in CRA and CEVP workshops are listed in Table 2-18.

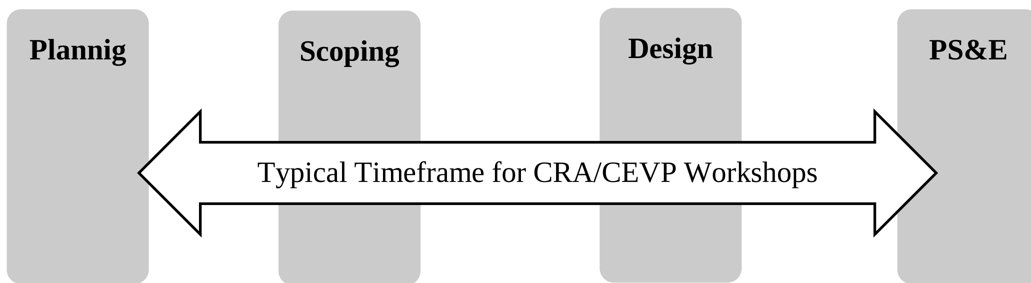


Figure 2-10 Timing of CRA/CEVP Workshops

Table 2-18 Roles and Responsibilities of CRA and CEVP Workshop Team

Workshop Team		Roles and Responsibilities
Project Team Members	Project Manager	Prepare project resource (decision maker)
	Estimator	Prepare and document project estimate
	Scheduler	Prepare and document project schedule
	Lead Designer	Prepare primary resource for design questions
	Key Technical Experts	Specialty groups as needed
Subject Matter Experts (SMEs)	Project Team Experts	Internal SMEs work with external SMEs to review and validate project cost and schedule estimates. They provide objective review and comment regarding project issues, risks and uncertainty. At the end of the workshop, the SMEs should provide a brief (i.e. one page) summary of their thoughts about the workshop.
	Agency Experts (HQ et al.)	
	Other Stakeholders	
	External Consultants	
Cost-Risk Team Members	Risk Lead	Conducts risk elicitation and manages meeting during risk elicitation; performs, or directs the performance of the statistical analysis.
	Risk Lead Assistant	Assists with risk elicitation and meeting management during risk elicitation
	Cost Lead	Conducts Base Cost and Schedule Review and validation; manages the meeting during the review
	Cost Lead Assistant	If needed, assists the cost lead position, as appropriate.
	Cost Risk Estimating Management (CREM) Workshop Coordinator	Coordinates the agenda and participants' discussions, works with the project manager to insure the success of the workshop

The CRA and CEVP methods have the following unique capabilities:

a. Define and review or validate cost and schedule base estimates using a Lead Cost and Schedule Reviewer, Subject Matter Experts, and WSDOT specialists.

b. Document assumptions and constraints used in developing the estimated project cost and schedule range.

c. Replace (or greatly reduce) the traditional project "contingency" with key identifiable risks that can be more clearly understood and managed.

d. Under the direction of a risk lead, identify and quantify key events in a project that can cause a significant deviation from the base cost or schedule. This identification and quantification should begin prior to the workshop through Advance Elicitation meetings.
e. Perform a Monte Carlo simulation analysis to model the collective impact of base and risk issues for the complete project as a system to produce an estimate of a reasonable range and distribution.
f. Discuss and develop concepts for responses to risks to the schedule that could impact the cost of the project. Promote pro-active risk management by project teams. Provide the project team with actionable information on risk events that allow them to manage the risks (threats/opportunities) on an on-going basis, via mitigation strategies to better control project costs and schedules.
g. Perform "post-mitigation" analysis to ascertain the effectiveness of planned and/or implemented risk response actions.

The main benefits/advantages of CRA and CEVP are:

a. The improved communication with the public
b. The improved team communication
c. The increased ability to quantify risks and develop strategic risk management plans for the identified risk.
d. The more realistic cost ranges

2.3. Summary of the Recommended Best Practices for Cost Estimation and Control

Changes in estimated project cost is one of the major concerns of State DOTs throughout project development from concept to completion of a project. This chapter reviewed the current state of practices in cost estimation and control in several State DOTs and identified best practices in cost estimation and strategies for cost control. The following recommendations are found out to be effective for enhancing the practice of defining and maintaining the established budget for highway projects.

State DOTs should establish an integrated process for cost estimation and cost management to establish accurate, reliable, and consistent estimates thorough project development process. A cost management process is essential for managing project costs, evaluating the basis of project estimate, and identifying and analyzing project issues (risks) at any phase of the project development process. A systematic process should be in place to collect critical inputs from key stakeholders and validate key information items to arrive at a reliable basis for all components of project cost estimate. For example, Minnesota DOT enhances the accuracy and completeness of the cost estimates by verifying cost estimate package and data. The MnDOT's practice also contains risk analysis to identify risk factors and establish contingency. The MnDOT's project managers utilize this integrated cost management system to mitigate risk and refine contingency for project cost estimates at each phase of the project development process.

State DOTs should establish key milestones for estimating, updating, and approving cost estimates as project definition/design advances. Establishing key milestones for cost estimates are indispensable for improving the consistency and accuracy of the cost estimates. For example, Caltrans identifies several cost estimation milestones in different phases of project initiation, preliminary design, and detailed design development. Roles and responsibilities are clearly defined for different project participants from project management team and functional groups to provide information needed for updating and controlling project estimate. Example of specific tasks assigned to the project team are: visiting a project site, selecting a preferred alternative, and preparing project plans and specifications. Minnesota DOT has also developed cost estimate review and approval gates consisting of 7 gates for reviewing and approving cost estimate with approved project information items (e.g., a scope report) from appropriate project management staff.

State DOTs should capture any changes in estimating assumptions to track the basis of cost estimate and control estimated project cost. During the project development process, State DOTs often experience cost increase or decrease. It is recommended that all changes are documented and any deviations from the baseline cost estimate are justified. Information about the change in cost estimate and reasons behind it should be described and shared with other key stakeholders. For example, Minnesota DOT utilizes a reporting system called “Variance Report” for documenting the difference between baseline and updated cost estimates and alerting project participants about deviations in project definition and estimated cost. Variance reports allow project managers to explain cost increase or decrease based on important cost items and scope elements of the project. Variance reports help project managers reconcile deviation in the baseline project definition and budget.

State DOTs are recommended to establish an automated information system to help them maintain, update, and share project information, cost estimates, and changes in project scope, cost, and schedule. As highway construction projects require handling massive amount of project information and data provided by numerous parties, it is difficult to handle the project information and data during a relatively long time span of project development. Thus, a database management system is essential for maintaining, updating, sharing project information and cost estimates. For example, Caltrans has developed the Project Report (PR)/Project Study Report (PSR) and Basic Engineering Estimating System (BEES) for sharing project information. With the PR/PSR, Caltrans is able to summarize key information points about the project, such as scoping study, cost, and overall impact of alternatives to obtain approval for the project to proceed and support development of costs estimates. The Caltrans' BEES program helps project manager/estimator prepare more reliable cost estimates in the design phase. Texas DOT has also developed the Design Summary Report (DSR) that helps the agency prepare a reliable basis for cost estimation by documenting key elements of fundamental aspects, concepts and design criteria of the project. In addition, the DSR allows project managers and estimators to track critical elements (e.g., right-of-way, environmental, and traffic control) throughout the project development. Oregon DOT uses a similar concept called the Alternative Evaluation Report (AER) to describe all design alternatives and explain the evaluation process to select the most preferred alternative. Detailed information items about utilities and site conditions, right-of-way, and environmental assessment are available in the AER that help Oregon DOT's project managers prepare a more reliable basis for cost estimation.

State DOTs should consider potential issues (risks) that may cause cost escalation during developing baseline cost estimates. Risk analysis tools and inputs from key project stakeholders are necessary for identifying critical risk factors for the project. For example, Texas DOT has utilized the Advance Planning Risk Analysis (APRA) system for measuring project scope definition and identifying potential risk factors that may impact project cost and schedule. The APRA helps Texas DOT monitor progress of scope development and identify potential issues and risks in major components of a project at various stages during the project development process. Washington State DOT uses a couple of systematic project review and risk assessment workshops called the Cost Risk Assessment (CRA) and the Cost Estimate Validation Process (CEVP) workshops to identify and describe cost and schedule risks of a project. WSDOT uses these workshops to assess and quantify the impacts of the identified risk factors on project cost and schedule. CRA and CEVP workshops enable the project team to establish proactive risk management for controlling baseline project budget.

Finally, State DOTs should utilize a quality assurance/quality control (QA/QC) process to verify the final engineer's cost estimate before a project is advertised. The final validation process is necessary for checking if the cost estimates reflect the true scope of the work and the most current market conditions. For example, Caltrans utilizes a QA/QC certification practice to evaluate project cost estimates and maintain consistency of cost estimates at the program level. The Caltrans' QA/QC process integrates with value analysis and constructability review. Project managers coordinate with other stakeholders to verify all information items and risk factors used in developing project cost estimates, including assumptions, sources of unit price, and a risk management plan.

It is expected that State DOTs realize significant improvements in their cost estimation process by utilizing the identified best practices described above. The major benefits of the identified best practices are as follows.

1. Uniformity and consistency of cost estimates with a well-structured cost estimation system
2. Enhancement of the project scope definition and identification of critical issues/risk areas in major components of a project
3. Maximization of information and the knowledge of a multidisciplinary team through various levels of the review process
4. A closer estimation of the contingency amount by using risk management tools that may differ by project size and complexity

5. Verification of the final engineer’s cost estimate through a final quality assurance/quality control (QA/QC) process

CHAPTER 3
FIXED BUDGET-BEST VALUE PROCUREMENT METHOD

3.1. Introduction

The highway construction industry in the United States faces significant challenges in rehabilitating aging infrastructure and meeting growing traffic volumes with limited funding. Thus, delivering projects within available funds become far more critical in the highway construction industry. Amid increasing complexity of projects and funding constraints, State Departments of Transportation (State DOTs) have utilized best value procurement methods, such as fixed budget-best value, to maximize the value of dollars expended for their projects. The best value procurement methods can include several evaluation criteria, such as price, schedule, and technical factors, in request for proposals (RFPs). With best value procurement methods, State DOTs can select key factors that match or meet the project's specific requirements (Scott et al. 2006). Based on the key evaluation factors, State DOT selects the proposal that most closely meets or exceeds the owner's expectations and project's requirements.

Fixed budget-best value, also known as "design-to-costs", allows State DOTs to generate the greatest amount of work while achieving the best value for dollars expended (FHWA 2013). This approach encourages the proposers to submit the proposals with the best value that they are able to achieve while staying within the defined budget. As a variation of best value procurement methods, a fixed budget-best value approach provides State DOTs a choice for selecting evaluation and selection criteria, such as project scope, qualifications, and schedule that meet or exceed their project requirements. The National Cooperative Highway Research Program (NCHRP) Project 10-61 provides an example of the fixed price-best value algorithm as follows:

$$Algorithm: Award\ T_{max}, Fixed\ P$$

T=Technical Score

P=Project Price

Using this algorithm, State DOT selects the proposal that obtains the maximum technical score while fulfilling the premise of the fixed budget. The technical score can be calculated based on several types of parameters (e.g., time, qualifications, and design) that the owner requires for the project goal (Scott et al. 2006). As the fixed budget-best value evaluates the proposal by using project scope, qualifications, schedule, and non-cost factors, this approach can be typically applied on design-build projects. As many highway construction projects have suffered from significant cost overrun, this approach provides an attractive alternative for procuring a project with a tight budget.

3.2. State of Practice for Fixed Budget-Best Value Procurement Method in Utah, Colorado, Idaho, and Michigan Departments of Transportation

Under the provisions of Special Experimental Project No. 14 (SEP 14) (FHWA 2016), several state departments of transportation currently utilize the fixed budget-best value approach to maximize the use of their available funds. To document state of practice of a fixed budget-best value contracting strategy, a comprehensive review of academic and professional literature was conducted. In addition, a critical scanning process was conducted on the FHWA and State DOTs websites to determine their execution process and case studies related to a fixed budget-best value contracting strategy. The results of scanning indicate that use of a fixed budget-best value approach was successfully utilized in several State DOTs, including the Idaho, Michigan, Utah, and Colorado DOTs.

3.2.1. Utah Department of Transportation (UDOT)

The Utah Department of Transportation (UDOT) defines the fixed budget-best value/fixed price-best value in the context of the following three objectives (UDOT 2016):

- Knowing funding limitation
- Maximizing scope for the price
- Encouraging innovation

With this procurement method, UDOT aims to maximize the amount of work under a single contract while spending all authorized funding for the contract. In addition, UDOT encourages the proposers to develop innovative solutions to achieve the State's goal (UDOT 2013). Since the fixed budget-best value approach provides higher flexibility in design and construction methods and techniques than that in traditional procurement methods, such as low bid, UDOT utilizes this method in design-build projects. The selection process of the fixed budget-best value follows a similar process of best value design-build procurement as follows (UDOT 2016):

A. Develop and approve projects goals: The process begins with understanding of the major factors impacting the project based on environmental study information or other known issues. During this process, the project team and Regional Leadership should clearly define the project goals based on scope, schedule, budget, and impacts to the public. Based on the project goals, the project team and Regional Leadership apply relative weights to goals and develop evaluation criterial for each scored goal. The project goals and evaluation criteria should be refined by the Selection Committee throughout project development. Finally, the project team and Regional Leadership request approval of the project goals and evaluation criteria from the Selection Committee.

B. Receive and Evaluate Proposals: Once the project goals and evaluation criteria are approved by the Selection Committee, the proposals will be received and evaluated by the Selection Committee.

a. Analysis Committee identifies the added values, risks, strengths, and weaknesses of proposers
b. Evaluation Committee offers one-one meetings with each proposer
c. Selection Committee meets with the Evaluation Committee early in the process to discuss the project and agrees on purpose and objective of the project. Next, through the review of blinded technical and blinded price proposals, the Selection Committee determines overall best value selection and provides a written and blinded justification of best value selection.

To measure quantitative and qualitative benefits of proposals, UDOT uses evaluation adjectives, such as “HIGH”, “MEDIUM”, and “LOW”, which indicate the relative significance to UDOT. The example of evaluation factors for project definition is shown in Table 3-1.

Table 3-1 Example of Evaluation Factors and Category

Evaluation Factor	Evaluation Category
HIGH	• Number of I-15 lane and shoulder miles added or improved, by type and level of improvement. • Number of interchanges reconstructed or improved and level of improvement • Operational metrics of mainline, at and between interchanges • Operational metrics of mainline transitions to existing facilities • Level of improvement to regional mobility associated with mainline improvements using the results from the transportation demand management (TDM), as listed below: ○ Vehicle miles traveled (VMT) ○ Vehicle hours traveled (VHT) ○ Average speed ○ Total delay ○ User costs ○ Percent VMT with volume-to-capacity (V/C) greater than or equal to 1 (for all links excluding centroid connectors) • Level of improvement of the interchange operations using the results from the microscopic simulation software (VISSIM) models for traffic flow as listed below: ○ Delay ○ Speed ○ Density ○ Travel time index ○ Queuing
MEDIUM	• Other operational improvements including the following: ○ Number and nature of decision points ○ Length of weave areas ○ Width and location of shoulders and refuge areas ○ Number of bicycle/pedestrian conflicts with traffic ○ Provision of clear zones • Number of intersections improved and level of improvement
LOW	• For areas between American Fork Main Street and Provo Center Street • Operational metrics in cross street transitions to existing facilities • Extent and functionality of non-motorized improvements

3.2.1.1. An Example of Fixed Budget-Best Value from UDOT

The first fixed budget-best value project in UDOT was the 24-mile I-15 Corridor Expansion (I-15 CORE) project in 2008. The major challenge of this project was the budget cut from $2.6 billion to $1.7 billion. Using a fixed budget-best value approach and proactive risk management, UDOT was able to deliver all the basic configuration scope with additional elements while spending $1.1 billion, which was less than the State legislature approved budget. I-15 CORE project is an exceptionally successful example of a fixed-price-best value procurement method. All proposers submitted more scope with innovative solutions for design and construction and did not exceed the approved budget. The winning proposal provided fastest schedule, more lane miles, fewer lane closures, and additional inch of pavement that has longer life and lower life cycle costs (UDOT 2013 ;WSDOT 2013).

The evaluation criteria for I-15 CORE were:

- Technical, must-have requirements
- Pass/Fail elements
- Project goals and values

The scores for three categories were given as the following:

- 60% project definition (scope)
- 20% maintenance of traffic
- 20% schedule

Overall, UDOT verified that a fixed budget-best value approach is an effective contracting strategy in maximizing the amount of work while staying within the approved budget.

3.2.2. Colorado Department of Transportation (CDOT)

The Colorado Department of Transportation (CDOT) also utilizes a fixed budget-best value (or fixed price-best proposal) procurement method when the agency has a budget constraint and wants to maximize the scope of work. This method provides proposers with flexibility in selecting the technical approach and scope for a project within the defined budget. In addition to the basic configurations, CDOT usually defines additional scope elements, known as “Additional Requested Elements (AREs)”, so that proposers can have options to select. As more AREs are included in proposals while staying within the budget, the proposers will obtain the higher evaluation score. To achieve the project goal, the agency should carefully define the budget and the AREs for a project. The selection process for a fixed budget-best value approach is as follows (CDOT 2016):

A. Develop Evaluation Procedure: the process begins with determining the project goals. CDOT should determine the project goals by using best value parameters including cost, time, scope, technical design consideration, and construction operation consideration (such as Maintenance of Traffic (MOT) and Public Involvement (PI) parameters). The best value scoring parameters are shown in Table 3-2.

Table 3-2 Relating Project Goals and Values to Best Value Scoring Parameters

Project Goals	Possible Best Value Parameters
Maximize operational capacity	• Project technical approach and commitments • AREs
Maximize use of available funds	• AREs • Additional Proposal scope commitments
Manage impacts during construction, or Minimize inconvenience to the traveling public, or Minimize inconvenience to the stakeholders	• MOT approach and commitments • PI approach and commitments • Time of completion • Duration of construction impacts
Complete the project on or before a set date	• Time of completion • Time to obtain key schedule milestones
Provide a high-quality project	• Quality Management Plan approach and commitments • Technical approach and commitments
Safety of the public and workers	• Safety Management Plan approach and commitments
Maximize project durability or Minimize life cycle costs of project	• Maintenance Level of Service commitments • Low-maintenance structures • Low-maintenance pavement • Other low-maintenance designs

B. Receive and Evaluate Proposals: each evaluator reviews and assesses individual statements of qualifications (SOQs)/Proposals using the overall criteria set and records observations using provided evaluation forms.

   a. Each evaluator determines an adjectival rating for each evaluator category using the adjectival evaluation and scoring guide as shown in Table 3-3. Each evaluator uses a best value evaluation formula to determine total score. Each parameter is then assigned specific scoring criteria. The maximum of the total proposal score is 100 points. Table 3-4 shows Alternative Algorithms to calculate total score.

b. The Evaluation Committee and technical advisors meet and discuss the submitted SOQs/Proposals and the evaluation forms. The Evaluation Committee then determines the final score for each proposal.

c. CDOT provides the opportunity for one-one meetings for each proposer that requests a meeting within the allowed time period.

Table 3-3 Adjectival Evaluation and Scoring Guide

Adjective	Description	Percentage of Max. Score
Excellent (E)	SOQ/Proposal supports an extremely strong expectation of successful project performance if ultimately selected as the contractor. SOQ indicates significant strengths and/or a number of minor strengths and no weaknesses. Submitter provides a consistently outstanding level of quality.	90-100%
Very Good (VG)	SOQ/Proposal indicates significant strengths and/or a number of minor strengths and no significant weaknesses. Minor weaknesses are offset by strengths. There exists a small possibility that, if ultimately selected as the contractor, the minor weaknesses could slightly adversely affect successful project performance.	75-89%
Good (G)	SOQ/Proposal indicates significant strengths and/or a number of minor strengths. Minor and significant weaknesses exist that could detract from strengths. While the weaknesses could be improved, minimized, or corrected, it is possible that if ultimately selected as the contractor, the weaknesses could adversely affect successful project performance.	51-74%
Fair (F)	SOQ/Proposal indicates weaknesses, significant and minor, which are not offset by significant strengths. No significant strengths and few minor strengths exist. It is probable that if ultimately selected as the contractor, the weaknesses would adversely affect successful project performance.	25-50%
Poor (P)	SOQ/Proposal indicates existence of significant weaknesses and/or minor weaknesses and no strengths. SOQ indicates a strong expectation that successful performance could not be achieved if ultimately selected as the contractor.	0-24%

Table 3-4 CDOT Design-Build Alternative Algorithms to Determine Total Evaluation Score

Alternative Algorithm	Formula	Result
Technical Score Adjusted by Price	Total Score = Ts x (GMP/Pp)	The highest score determines the apparent best value.
Proposal Price Score Adjusted by Technical Score	Total Score = Pp/Ts	The lowest score determines the apparent best value.
Qualitative Technical Score plus Quantitative Price Score	Total Score = Ts + (Pmax x Plow/Pp)	The highest score determines the apparent best value.
Qualitative Technical Score plus Quantitative Price Score (based on defined dollars per point)	Total Score = Ts + [Pmax – ((Pp – Plow)/($ per Pt))]	The highest score determines the apparent best value.

Note: Ts = Technical Proposal score: the sum of all other best value scoring elements, including AREs; Pmax = Maximum Proposal price points; Pp = Proposal price; Plow = Lowest Proposal price; $ Per Pt Factor = A defined dollar amount per point value; GMP = Guaranteed Maximum Price

3.2.2.1. An Example of Fixed Budget-Best Value from CDOT

CDOT utilized a fixed budget-best value approach in the $1.67 billion Transportation-Expansion (T-REX) design-build project in 1999. The scope of this projects is to add 19 miles of double-track light rail, build 13 stations with park-n-Rides, add 13 light rain vehicles to the Regional Transportation District (RTD)'s fleet, and construct a new light rail maintenance facility in Englewood. The project goals of this project are as follows (CDOT 2003):

- To minimize inconvenience to the public
- To meet or beat the total program budget of $1.67 billion
- To provide for a quality project
- To meet or beat the schedule to be fully operational by June 30, 2008

CDOT achieved the significant schedule and cost saving because of the innovative funding and design-build/fixed budget-best value approach. The winning proposal was selected based on a best-value evaluation process by looking at technical and price proposals. The Innovative contracting strategy enabled CDOT to complete project within schedule and under the approved budget.

3.2.3. Idaho Transportation Department (ITD)

The Idaho Transportation Department (ITD) also started to conduct an experiment with a fixed budget-best value (or fixed Price-best design) approach under the provision, Special Experimental Project No. 14 (SEP 14). ITD uses this contracting strategy in a design-build delivery method to yield a greater amount of work than the low-bid method and not an additional element of work. Thus, ITD selected a proposer who submits maximum scope or quantity of work within the approved budget. The selection process of the ITD's fixed budget- best value approach is as follows (ITD 2014):

A. Develop Evaluation Procedure: the process begins with defining the project goals for the project. Next, the project team needs to develop project scope, estimated cost, and maximum time allowed for the project. Based on the project goals and other information, the evaluation criteria and process need to be developed.

B. Receive and Evaluate Proposals: proposers submit technical and price proposals concurrently. ITD should keep price proposal confidently until technical proposals have been evaluated, scored, and reviewed by higher levels.

   a. The Evaluation Committee evaluates technical and price proposal by using Pass/Fail and Scored Criteria. Pass/Fail Criteria include formatting, executive summary, legal, and financial aspects of proposals, as well as participant experience. Next, Score Criteria consist of organizational structure, project management, maintenance of traffic, and project-specific technical and quality factors (i.e., design and construction qualifications, innovation, design and construction quality, and time of completion).

b. The Selection Committee discusses and reviews the evaluation of technical and price proposal with the Evaluation Committee and documents the results of the evaluation.

c. The Contracting Officer approves the evaluation of the technical and price proposal and summary of scores and feedback from evaluators.

3.2.3.1. Examples of Fixed Budget-Best Value from ITD

ITD tried fixed budget-best value with several project types (i.e., bridge deck preservation, resurfacing, and seal coating projects). Table 3-5 provides examples of project types in State of Idaho that the fixed budget-best value procurement method has been utilized in. For example, in 2010, ITD used fixed budget-best value in a bridge deck preservation project. ITD required the bidders to determine the total number of square yards of deck preservation that they could accomplish for the fixed budget of $700,000. ITD selected the bidder who submitted bid with the largest square yardage of 27,641 squad yards. In 2015, ITD had a fixed budget of $651,500 for the roadway resurfacing projects between MP36.783 and MP48.869 in Idaho. The contractors were required to bid a tonnage of crushed aggregate base that is excavated or blasted from the source, crushed, placed, and compacted. The range of the tonnage was between 14,115 and 41,448 tons. ITD procured the contract to the bidder who submitted the biggest tonnage, 41,448 tons. In 2016, ITD also used the fixed budget-best value approach for sealcoating projects in District 4 of the

State of Idaho. The bidders bid how many square yards they could sealcoat for the fixed budget of $2,948,000. The range of the square yards is between 1,433,897 and 1,616,228.07 square yards. The winning bid was the bidder who submitted the bid with the 1,616,228.07 square yards. Using a fixed budget-best value, ITD achieves equal to or better than the base concept.

Table 3-5 Example of Fixed Budget-Best Value Projects in State of Idaho

Construction Year	Budget	Work Type	Winning Bid
2010	$700,000	Bridge Deck Preservation Projects	The largest square yardage (27,641 sq. yd.)
2015	$651,500	Roadway Resurfacing Projects	the biggest tonnage (41,448 tons)
2016	$2,948,000	Sealcoating Projects	The largest square yardage (1,616,228.07 sq. yd.)

3.2.4. Michigan Department of Transportation (MDOT)

The Michigan Department of Transportation (MDOT) uses a fixed budget-best value (or fixed price-variable scope) to maximize the amount of work within a maximum budget. Thus, the contractor providing the most scope/work for the established budget is awarded the contract. MDOT classifies projects into three types that can be procured by a fixed budget-best value approach (MDOT 2015):

- Type 1: projects receive bids by the units of work that can be completed for a State fixed price. The selected contractor is the bidder that proposed the most units of work for the given fixed price. Type 1 has been used for HMA crack seal, chip seal, and fog seal projects, bid by the lane mile.

- Type 2: projects receive bid by the units of work that can be completed for a maximum price. Contractors bid units of work, and may also bid a price for that work which is below the maximum price. The selected contractor is first determined by the bidder that proposes the most units of work, for their determined maximum price. If two or more contractors propose the same amount of work, then the successful bidder is determined by which of those contractors proposed the lowest maximum price. Type 2 has been used for bridge deck epoxy overlay work, bid by the square yard.
- Type 3: projects receive bids through a traditional low bid process. The contractor provides unit prices for pay items provided in the schedule of items. The selected contractor is determined by the lowest submitted bid. The project is awarded at the low bid price.

With Type 1, the proposer submits the maximum amount work while spending all authorized funding. On the other hand, the Type 2 projects allow MDOT and proposers to adjust the maximum price depending on the maximum amount of work submitted by proposers. The Type 3 project will go through normal low bid process. It allows to add work until final construction costs equal to the engineer's estimate (Youngs 2013).

MDOT considers a combination of technical and price factors to select the winning bid in a fixed budget-best value approach. The selection process for a fixed budget-best value method is as follows:

A. Develop and approve projects goals: the project manager prepares a proposal evaluation plan that details the process and criteria to be used during technical proposal evaluation. The Selection Team develops scoring criteria for the technical portion of the evaluation.

B. Receive and Evaluate Proposals:

    a. The proposals will be reviewed by a Selection team consisting of the project manager, staff from the region/Transportation Service Center, the Innovative Contracting Unit, The Central Selection Review Team (CSRT), as well as other technical experts.

    b. The project manager and deputy project manager (DPM) review the technical proposals by using the Pass/Fail criteria in the RFP and score the proposals. The project manager provides the Selection Team with the submitted proposals and the results of the technical proposal review.

    c. The Selection Team reviews the technical proposal and determines the score for each proposal with justification.

    d. The project manager provides CSRT with the information of final review and approval. The final results are posted after approving the scores.

3.2.4.1. Examples of Fixed Budget-Best Value from MDOT

MDOT also utilized the fixed budget-best value contracting strategy in several projects to achieve the maximum amount of work within the fixed budget for the project. In 2012, MDOT used this innovative approach for crack sealing work in Hillsdale, Ingham, Jackson, and Lenawee counties in the state of Michigan. The scope of this project included a maximum of 103.78 miles of hot mix asphalt crack treatment and Overband crack filing on 15 segments of various roadways in Michigan. Three bidders submitted the bids with the maximum number of roadbed miles of work that could be completed for the established project budget of $387,000. To evaluate proposals, MDOT had two evaluation criteria: past performance and maximum amount of work. MDOT awarded the contract to the bidder who submitted the maximum length of 74.43 roadbed miles, which was longer than the Department's estimate of 70.62 miles (MDOT 2012).

3.4. Summary of the Recommended Best Practices for Fixed Budget-Best Value Procurement Method

State DOTs experience crucial funding limitations for delivering much-needed construction and rehabilitation projects that are necessary for maintaining the quality of transportation infrastructure systems. Innovative contracting strategies, such as a fixed budget-best value procurement method, can help State DOTs complete a project within an established budget. This chapter reviewed the current state of practices in fixed budget-best value procurement method and identified best practices in utilization of this innovative contracting method. The following recommendations are found out to be effective for enhancing the practice of delivering projects using this innovative contracting strategy.

State DOTs may consider a fixed budget-best value procurement approach when the full project scope exceeds the baseline cost estimate for the project. For a fixed budget-best value procurement approach, the agency should define the basic configuration scope and should allow the proposers to include the maximum amount of work or additional scope elements in their proposals while staying within the fixed budget. For example, several State DOTs, including Utah, Idaho, and Michigan DOTs typically let the proposers submit the maximum amount of work that they can achieve with the established budget. State DOTs then procure the contract to the proposer who proposes the maximum amount of work within the established budget. In contrast, Colorado DOT defines specific additional scope elements, known as "Additional Requested Elements (AREs)", in the RFP to enable the proposers to select additional scope elements beyond the base scope of a project within the fixed budget. The agency evaluates whether the proposers have incorporated the additional elements in accordance with project design requirements.

A fixed budget-best value approach can be utilized in several project types, such as corridor expansion, bridge deck preservation, and seal coating projects. State DOTs should clearly define additional scope elements beyond the base scope for each project type. For example, Utah DOT used the fixed budget-best value approach in the I-15 Corridor Expansion (I-15 Core) project, which is addable for the scope of work in terms of lane miles. UDOT selected the proposal that provided more lane miles for the corridor expansion. Idaho DOT used this contracting strategy in bridge deck preservation and sealcoating projects. Idaho DOT procured the contract to the bidder who submitted the largest square yardage for the preservation.

State DOTs should clearly establish the evaluation criteria to select the proposers for a project. Since the price is fixed for all proposers and this approach allows higher flexibility in proposing design and construction solutions, the agency should establish rigorous evaluation criteria (e.g., cost, time, and design alternatives) and the weights for the criteria to evaluate the proposals based on the project goals. For example, Utah DOT uses evaluation adjectives (i.e., “High”, “Medium”, and “Low”) to measure quantitative and qualitative benefits of the submitted proposals for a project. “High” indicates that the proposal covers more scope elements for a project with respect to quality and quantity of a project. Utah DOT assigns higher points to a proposal with a "High" category. Colorado DOT establishes best value scoring parameters based on project goals. For instance, if the project goal is to maximize operational capacity, CDOT uses project technical approach and commitments, as well as AREs as primary parameters to evaluate the proposals for a project.

The fixed budget-best value approach maximizes improvements within the defined budget and provides incentives to proposers to utilize the full budget. This approach increases competition and exploits the budget as much as possible that can result in maximum improvements for the project. The fixed budget-best value has several advantages and disadvantages. The major advantage of this approach is that it can be a good tool for controlling costs and keeping a project within budget. However, the agencies may get less work done than originally planned if the budget is too tight. In addition, this approach may require more time for evaluating proposal and have challenges in selecting the contractor if selection criteria are not clearly defined and defendable. Several advantages and disadvantages of the fixed budget-best value procurement are summarized as follows (Scott et al. 2006; WSDOT 2013):

- Advantages:
    1. Allows the agency to achieve the maximized amount of work within an established budget.

2. Provides proposers with significant flexibility in structuring their proposals; i.e., whether to only submit the basic configuration or to include various levels of additional scope elements.
3. Allows the agency to communicate its desired additional scope through the outcomes it values; for example, additional mainline capacity, direct connections between certain roadways or longer pavement life.
4. Allows proposers to develop highest-value, creative solution for fixed construction budget.
5. Fosters competition and innovation as the value-based approach.

- Disadvantages:
  1. Provides the agency with challenges in determining and splitting work for the bidding purpose that accurately corresponds to the established budget.
  2. Requires the agency to define exactly how it will evaluate additional scope beyond the high/low value definition otherwise provided during meetings with the contractor.
  3. Limits the flexibility and range of what is actually proposed due to difficulty in defining more specific evaluation criteria.
  4. Limits creativity of the proposers to respond and use innovative approaches that achieve desired goals if the agency specifically prescribes what additional elements it desires beyond the basic configuration.

CHAPTER 4
STATISTICAL ANLYSIS FOR EXPLAINING VARIATIONS IN SUBMITTED BID PRICES FOR ASPHALT LINE ITEM IN HIGHWAY PROJECTS

4.1. Introduction

Highway construction costs are subject to significant variation from project initiation to project completion. Variation in construction cost disturbs transportation agencies in making investment decisions and preparing accurate engineer's cost estimates for their projects. The underestimation of project costs can lead to cost overrun, financial problem, and project delay or cancellation (Peng 2006). The overestimation of project costs results in inefficient budget allocation of public funds that could be used on other needed projects (FHWA 2015). State Departments of Transportation (State DOTs) may face credibility issues with the public if cost estimation problems remain unresolved. Therefore, construction cost variation should be treated properly for delivering projects that have been programmed and committed.

Variation in construction costs depends on several factors, such as the current volume of construction in the project location, inflation rate, and the cost of material, labor, and equipment. The impact of these factors varies based on project characteristics (e.g., type of projects, complexity of projects, geographical location of projects, and project size) and its surrounding environment (e.g., macroeconomic, market conditions, and competitive bidding environment). The combined effects of these factors impose considerable uncertainty in pricing construction costs for State DOTs. According to the American Association of State Highway and Transportation Officials Technical Committee on Cost Estimating (TCCE) publication (2011), macroeconomic variables, such as prices of materials and labor, and market condition factors, such as competition and contractors' work volume, are key inputs for preparing cost estimates and structuring letting strategies. According to the Federal Highway Administration (FHWA) (2015), market conditions are major drivers of over- and under-estimation of highway construction costs. This report also noted that most State DOTs have low capability to capture volatile market conditions in their cost estimating process. There is no consistent approach to deal with inflation and escalation factors in preparing costs estimates (Actis 2010). Developing a systematic method to deal with uncertainty in market conditions represents a great challenge in managing variation in construction costs. Major critical factors in regard to not only project characteristics, but also macroeconomic and market conditions, should be identified and properly considered in the cost estimation of construction projects.

Several studies identified factors affecting variation in construction costs. Chua and Li (2000) focused on market condition factors affecting contractors' decisions in unit price bidding. Through conducting a survey of 153 top contractors in Singapore, the authors identified four major factors, competition, risk, company's position in bidding, and need for work, as influential factors on bid prices. Wilmot and Cheng (2003) conducted an empirical analysis for testing impacts of project-specific factors and market condition indicators on submitted bid prices to the Louisiana DOT. They identified factors that affect the price of 5 pay items, embankment, concrete pavement, asphalt pavement, reinforcing steel, and structural concrete, through studying 2,827 highway and bridge contracts in the State of Louisiana. The authors used several independent variables, such as project location, quantity of pay items, and labor costs to explain the variation in the submitted bid price for 5 pay items. Through conducting multivariate regression analysis, the study found that the most influential factors are the price of the resources (i.e., materials, labor, and equipment) and the quantity of the pay items. Moreover, contract size, duration, location, and the quarter in which the contract is let were found to have a significant impact on the price of the asphalt pavement pay item.

Shrestha and Pradhananga (2010) examined the effect of competitive bidding on variations in bid prices using 435 bids on 113 public street projects in Clark County, Nevada. Through a correlation analysis, the authors concluded that there is a significant negative correlation between the number of bidders and the submitted bid prices. Another study carried out by Shrestha et al. (2014) analyzed the bid data of 151 road projects conducted in Clark County, Nevada, to examine the relationship between the unit price bids and the quantity of the unit item. The results of correlation analysis show that an increase in the quantities lowers the unit price bids.

Hegazy and Ayed (1998) identified factors affecting construction costs by using 18 bids submitted by construction contractors. This study found that season, location, type of project, contract duration, and contract size significantly impact construction costs. Damnjanovic and Zhou (2009) examined the impact of the crude oil prices on excavation bid item of 5,180 highway construction projects let in the State of Texas. The authors identified that the crude oil price has the positive effect on the bid prices. Ilbeigi et al. (2015) analyzed submitted bid prices in the State of Georgia to explain variations in construction cost. The authors identified that quantity of the line item, total contract price of the project, and asphalt cement price index are influential factors that explained variations in bid prices submitted to Georgia DOT for asphalt line items.

Lastly, Ashuri et al. (2012) conducted Granger causality tests to capture and predict construction cost variations using construction cost index (CCI) published by the Engineering News-Record (ENR). The authors concluded that economic conditions including consumer price index, producer price index, money supply, gross domestic product (GDP), crude oil prices, and construction market conditions including building permits, housing starts, and employment level in construction are the leading indicators of CCI and can help predict future CCI trends.

In this study, variation of submitted bid prices for major asphalt line items were investigated. The major objective was to assess the effects of several potential variables on explaining the variation of submitted bid prices. Potential factors were grouped into 4 major categories: (1) Project characteristics; (2) Construction market conditions; (3) Macroeconomic conditions; and (4) Oil market conditions. Historical bid data submitted for major asphalt line items from resurfacing and widening projects in the State of Georgia were used to examine the relationships in this study.

4.2. Methodology

The primary goal of this chapter is to model the variation in the unit prices of asphalt line items (i.e., hot mix recycled asphalt concrete) by using several factors that may have potential to explain the variation. The potential factors are related to project-specific variables, and macroeconomic, construction market, and oil market conditions. This chapter utilizes multiple regression analysis to develop an explanatory model for describing variations of submitted bid prices. Regression analysis is used to establish the nature of the relationship between the unit prices and the potential factors and explain the variation in the submitted bid prices with combination of significant factors.

The following steps are followed in the methodology of multiple linear regression (MLR) analysis:

1. Inspect data for identifying outliers
2. Conduct pairwise correlation between submitted bid price as the dependent variable, on one hand, and each of the potential explanatory variables, on the other hand, to assess if linear correlation (in some cases variable transformation (e.g., logarithmic)) should be performed if the variable transformation better reflects the nature of relationship between the explanatory variable and the submitted bid price
3. Develop a multiple regression model to describe variations in submitted bid prices using the information embedded in the potential explanatory variables

4. Interpret the results of regression modeling

5. Examine residual plots to check error variance assumptions in regression modeling

4.2.1. Modeling the Variations of the Submitted Bid Prices

4.2.1.1. Inspect Data for Identifying Outliers

Since large data are typically exposed to uncertainty regarding calculation, writing, or coding errors, abnormal and suspected outliers should be diagnosed and removed before developing a reliable regression model. The detected outliers should be omitted from further consideration in model development. z-scores are calculated for all observations of submitted bid prices in the original dataset as follows.

$$z_i = \frac{y_i - \mu}{\sigma} \quad i = 1,2, \ldots, N$$

where y_i is the i^{th} observation in the dataset of submitted bid prices, μ is the mean value of all observations of submitted bid prices, and σ is the standard deviation of submitted bid prices. If the absolute value of z_i is greater than 2.576 (representing 99% confidence level), the i^{th} submitted bid price will be considered as an outlier and will be removed from further consideration.

4.2.1.2. Conduct Pairwise Correlation between Submitted Bid Price and Potential Explanatory Variables

Pairwise correlation is performed between submitted bid price as the dependent variable, on one hand, and each of the potential explanatory variables, on the other hand, to assess the degree of linear correlation. This initial correlation assessment is used to examine the significance of association between the submitted bid price and any of the explanatory variables. Scatter plot is also used to assess the nature of the relationship. In addition to linear correlation, other forms of correlation, such as quadratic, cubic, logarithm, exponential, and power relationships might exist between the submitted bid price and the potential explanatory variable. Scatter plots are useful methods to detect these other forms of relationships. Whenever appropriate, variable transformation (e.g., logarithmic) is conducted to better reflect the nature of relationship between the explanatory variable and the submitted bid price. The transformed variable is used in regression analysis.

4.2.1.3. Develop a Multiple Regression Model to Describe Variations in Submitted Bid Prices

Ordinary least squares (OLS) regression modeling is used to explain variations in submitted bid prices based on a combination of the explanatory variables. Analysis of Variance (ANOVA) is conducted to determine whether the developed regression model is statistically significant (i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model). The fitness of the model is examined by calculating the adjusted R-squared of the model. The higher the R-squared, the greater the model is in explaining the variation of submitted bid prices. Variance inflation factor (VIF) is calculated for each of the identified explanatory variables, in order to assess multicollinearity issues in the regression model (Montgomery et al. 2015). Multicollinearity can result in misinterpretation of the regression modeling results. The significance of the model coefficients is examined using the calculated p-value for each explanatory variable in the model.

4.2.1.4. Interpret the Results of Regression Modeling

The effects of potential explanatory variables on the submitted bid prices are examined using the calculated p-value in the developed regression model. Significant explanatory variables are identified at the significance level of α = 5%. The sign and the magnitude of the coefficients of the significant variables show the direction of the effects of the significant explanatory variables on the submitted bid price. The results of regression analysis are used to examine whether and how a potential variable has the power to explain variations in submitted bid prices.

Explanatory variables have different measurement units. Thus, there is a limitation in comparing the relative impacts of explanatory variables on the dependent variable. The following equation is used to convert all continuous explanatory variables to standardized variables that have the same scale with the expected value of 0 and variance of 1 (Washington et al. 2010):

$$X_i' = \frac{X_i - \overline{X_i}}{s(X_i)} \qquad i = 1,2, \ldots, N$$

where X'_i is the standardized form of the i^{th} input variable, X_i is the i^{th} input variable, $\overline{X_i}$ is the average value of X_i, and $s(X_i)$ is the sample standard deviation of X_i. MLR analysis using the standardized variables produces the beta/standardized coefficients for the explanatory variables. The beta coefficient of each explanatory variable is used to determine the relative importance of the explanatory variables in the regression model. The higher the absolute value of the beta coefficient, the stronger the effect of the respective explanatory variable is on the submitted bid prices.

Note that categorical variables will not be considered for transformation. Standardization is not applicable to categorical variables to determine the relative significance of these factors, compared to other non-categorical factors, on submitted bid prices. This issue can be explained as follows. First, categorical variables cannot be increased by a standard deviation because they are the dichotomous variables, coded as 0 and 1. Estimated coefficients of categorical variables show difference in average level of submitted bid prices between two categories (Jacoby 2005). Standardizing categorical variables prohibits us from interpreting the difference between the impacts of different categorical variables.

4.2.1.5. Examining Residual Plots to Check Error Variance Assumptions

Once a regression model is developed, the regression assumptions should be checked. The following assumptions should be examined (Field 2009):

- Independent errors: the residual terms should not be correlated. If the assumption of independence is violated, the confidence intervals and significant tests of the model will be invalid. The scatterplot of standardized residuals against predicted values is useful for detecting independence.
- Homoscedasticity: the variance of the residual term should be constant and evenly dispersed. If the assumption of homoscedasticity is violated, the confidence interval and significance tests are not valid. The scatterplot of standardized residuals against predicted values is also useful for detecting heteroscedasticity.

- Normality: the residuals in the model should be random, normally distributed variables with a mean of 0. The histogram and the normal probability–probability (P-P) plot of regression standardized residuals are useful for testing normality.

4.3. Dataset Development

4.3.1. Data Compilation Process

Data compilation process includes extraction of data corresponding to the research problem, critical evaluation of data sources, assessment of data quality, and compilation of data. Figure 4-1 depicts the compilation process of data. Raw historical bid data are retrieved from the BidTabs database of Oman Systems. Historical bid data include information about unique project identification number (project ID), unit price bids for main asphalt line items, volume of asphalt line items, total bid price (contract amount), number of bidders, and winning bids. Several other software systems used by the Georgia DOT for contract administration are also utilized as data sources to: (a) cross-validate the quality of the collected data from the BidTabs; and (b) retrieve further information about project characteristic. Unit price bids retrieved from the BidTabs database are rechecked for accuracy with another sources of bid data, Bid Express®, Construction Administration System (CAS), SiteManager (SM), and the GDOT transportation project information (TransPi). Bid Express® is an online system containing information about past proposals, bid prices, and bidders of the Georgia highway projects. CAS and SM are software systems used by GDOT for contract administration. In addition, information about the geographical location of the project including the map of the project is accessed via the GDOT TransPi. Project-specific information collected from the above multiple sources is stored in a centralized database.

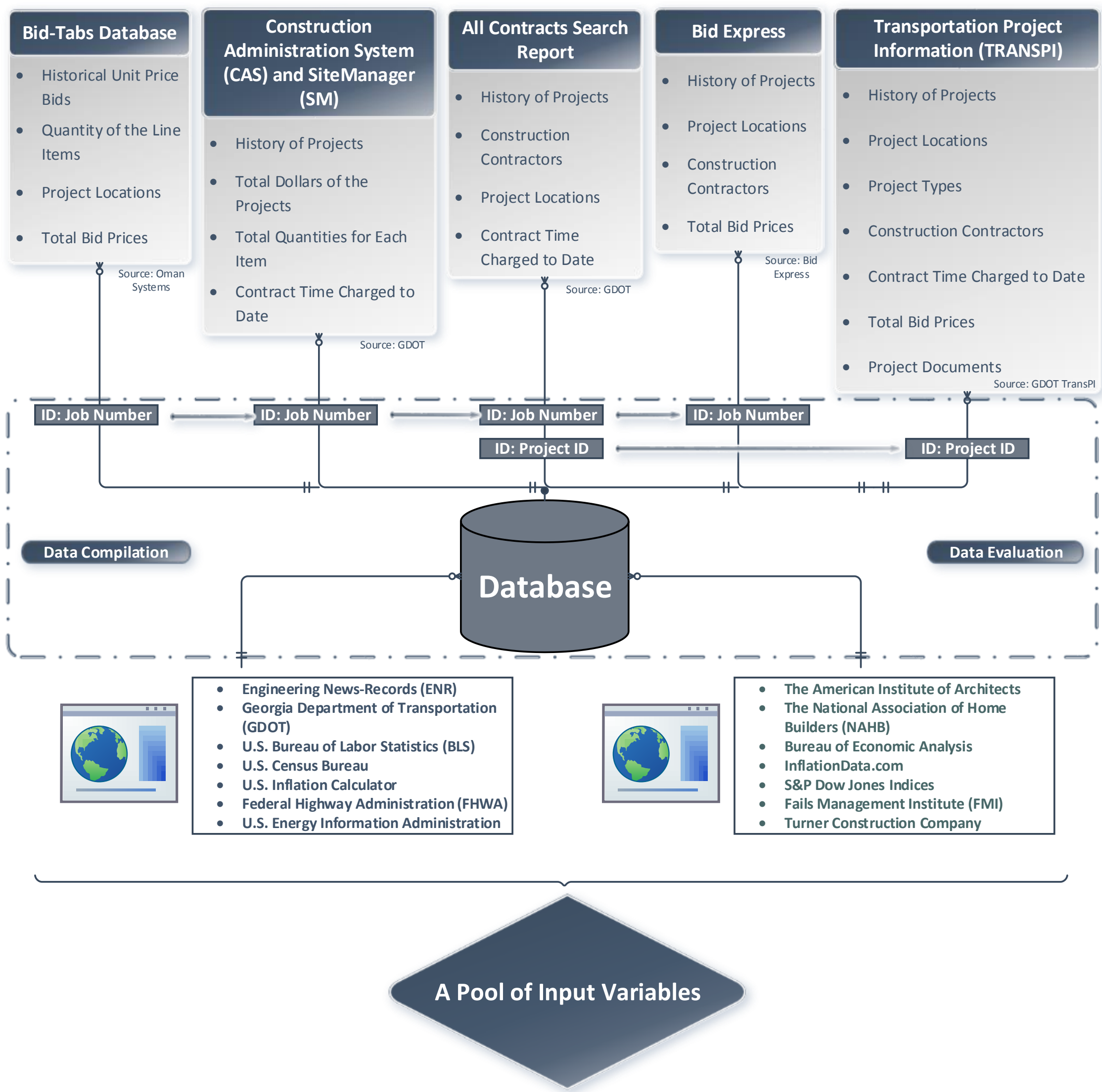


Figure 4-1 Data Compilation Process for Multiple Regression Analysis

4.3.2. Submitted Unit Prices for Asphalt Line Items

Hot mix recycled asphaltic concrete, as one of asphalt line items, is the most common pavement material used by State DOTs in the United States (Kandhal et al. 1995).

Submitted bid prices for asphalt line items from 1,424 projects let in the State of Georgia between 2008 and 2015 are used in this research. Descriptive statistics of submitted unit prices are described in Table 4-1.

Table 4-1 Descriptive Statistics of Submitted Unit Prices for Hot Mix Recycle Asphaltic Concrete

	Total	**Resurfacing**	**Widening**
Number of Projects	1,424	1,310	114
Mean ($/Ton)	69.02	68.43	75.74
Median ($/Ton)	67.75	67.30	73.50
Min ($/Ton)	40.25	40.25	51.97
Max ($/Ton)	354.53	354.53	155.37

4.3.3. Factors affecting Variation in the Submitted Bid Prices

Table 4-2 provides a summary of explanatory variables that are identified with potential impacts on submitted bid prices. The identified potential explanatory variables are categorized into 4 groups: (1) Project characteristics; (2) Construction market conditions; (3) Macroeconomic conditions; and (4) Oil market conditions.

Table 4-2 Summary of Potential Explanatory Variables

Category	Factors	Unit	Region/ Industry	Source
Project Characteristics (11 Variables)	Project Duration	Day	Project Level	Bid-Tabs database of Oman Systems & GDOT TransPi
	Quantity of the Bid Item	Ton	Project Level	Bid-Tabs database of Oman Systems
	Terrain of the Project	Terrain Types	Project Level	GDOT (2009)
	District of the Project	Districts	Project Level	Bid-Tabs database of Oman Systems
	Total Bid Price	$	Project Level	Bid-Tabs database of Oman Systems
	Project Length	Miles	Project Level	Bid Express
	Number of Nearby Asphalt Plants (within 50 miles)	No.	Project Level	GDOT TransPi & GDOT Office of Materials and Testing
	Hauling Distance between Asphalt Plant and Project Location	Miles	Project Level	GDOT TransPi & GDOT Office of Materials and Testing
	Hauling Distance between Quarry and Asphalt Plant	Miles	Project Level	GDOT TransPi & GDOT Office of Materials and Testing
	Number of Bidders	No.	Project Level	Bid-Tabs database of Oman Systems
	Number of Pay Items	No.	Project Level	Bid Express
Construction Market Conditions (30 Variables)	Total Asphalt Volume of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County	$	County/Construction	Bid-Tabs database of Oman Systems
	Total Number of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County	No.	County/Construction	Bid-Tabs database of Oman Systems
	Total Number of Projects Awarded in the Current Month at the Level of the State of Georgia	No.	Georgia/Construction	Bid Express
	Total Dollar Value of Projects Awarded in the Current Month at the Level of the State of Georgia	$	Georgia/Construction	Bid Express
	Total Asphalt Volume of Projects Awarded in the Current Month at the Level of the State of Georgia	$	Georgia/Construction	GDOT Item Mean Summary
	Architecture Billings Index	IDX	South/Construction	The American Institute of Architects
	Building Permits for New Residential Construction	No.	South/Construction	U.S. Census Bureau
	ENR Building Cost Index	IDX	Atlanta/Construction	Engineering News-Record (ENR)
	ENR Common Labor Index	IDX	National/Construction	Engineering News-Record (ENR)
	ENR Construction Cost Index	IDX	Atlanta/Construction	Engineering News-Record (ENR)

Category	Factors	Unit	Region/ Industry	Source
Construction Market Conditions (Cont'd)	ENR Material Price Index	IDX	National/Construction	Engineering News-Record (ENR)
	ENR Skilled Labor Index	IDX	National/Construction	Engineering News-Record (ENR)
	Equipment Operator Wages, Paving, Mean Hourly Wage, Georgia	$	Georgia/Construction	U.S. Bureau of Labor Statistics
	Georgia Asphalt Cement Price Index	$/Ton	Georgia/Construction	GDOT
	Job Opening and Labor Turnover Index (Hires)	Thousands	National/Construction	U.S. Bureau of Labor Statistics
	Housing Market Index	IDX	South/Construction	National Association of Home Builders/ Wells Fargo
	National Highway Construction Cost Index	IDX	National/Construction	Federal Highway Administration
	Producer Price Index (Construction machinery manufacturing)	IDX	National/Construction	U.S. Bureau of Labor Statistics
	Producer Price Index (Construction sand and gravel mining)	IDX	National/Construction	U.S. Bureau of Labor Statistics
	Turner Construction Cost Index	IDX	National/Construction	Turner Construction Company
	Value of Construction Put in Place (Pavement)	Thousands of $	South/Construction	U.S. Census Bureau
	Value of Construction Put in Place (All construction)	Thousands of $	Georgia/Construction	U.S. Census Bureau
	FMI Nonresidential Construction Index	IDX	National/Construction	Fails Management Institute (FMI)
	Labor Productivity	IDX	National/Construction	U.S. Bureau of Labor Statistics
	Number of Establishments in Private Construction Industry	No.	County/Construction	U.S. Bureau of Labor Statistics
	Gross Domestic Product (GDP) of the Georgia Construction Industry	Millions of $	Georgia/Construction	Bureau of Economic Analysis
	12 Month Percent Change of Georgia Asphalt Cement Price Index	%	Georgia/Construction	GDOT
	12 Month Percent Change of Gross Domestic Product (GDP) of the Georgia Construction Industry	%	Georgia/Construction	Bureau of Economic Analysis
	12 Month Percent Change of Job Opening and Labor Turnover Index (Hires)	%	National/Construction	U.S. Bureau of Labor Statistics
	12 Month Percent Change of Value of Construction Put in Place (Pavement)	%	Georgia/Construction	U.S. Census Bureau

Category	Factors	Unit	Region/ Industry	Source
Macroeconomic Conditions (10 Variables)	Dow Jones Industrial Average	IDX.	National/Industry	S&P Dow Jones Indices
	Inflation Rate	%	National/Industry	USInflationcalculator.com
	Average Weekly Wage (all industry)	IDX	County/Industry	U.S. Bureau of Labor Statistics
	Consumer Price Index (south)	IDX	South/Industry	U.S. Bureau of Labor Statistics
	Producer Price Index (Gasoline products)	IDX	National/Industry	U.S. Bureau of Labor Statistics
	Producer Price Index (Steel mill products)	IDX	National/Industry	U.S. Bureau of Labor Statistics
	Producer Price Index (No. 2 diesel fuel products)	IDX	National/Industry	U.S. Bureau of Labor Statistics
	Producer Price Index (Crude petroleum products)	IDX	National/Industry	U.S. Bureau of Labor Statistics
	Unemployment	No.	County/Industry	U.S. Bureau of Labor Statistics
	12 Month Percent Change of Unemployment	%	County/Industry	U.S. Bureau of Labor Statistics
Oil Market Conditions (4 Variables)	Crude Oil Price	$/Barrel	National/Industry	InflationData.com
	Diesel Retail Prices	$/Gallon	South/Industry	U.S. Energy Information Administration
	Georgia Fuel Price Index	$/Gallon	Georgia/Industry	GDOT
	12 Month Percent Change of Georgia Fuel Price Index	%	Georgia/Industry	GDOT

Note: No. = number; IDX. = index; S.Y. = square yard of surface area; %= Percentage

4.3.3.1. Project Characteristics

Project characteristics are unique features of each project, such as asphalt quantity of the project, duration, total bid price, and project bidding date. Collectively, these unique features represent project characteristics. Two categorical variables are used to classify projects: (a) terrain type; and (b) Georgia DOT district.

1. Project Duration: It is period between 2 dates: notice to proceed date and completion date.
2. Quantity of the Bid Item: It is volume of the asphalt line items.
3. Terrain of the Project: It is the geographical feature of the project location. Georgia has four types of terrain, rolling, flat, mountainous, and coastal. Figure 4-2 shows the terrain types in the Georgia map (GDOT 2009). These terrain types are used as categorical variables in the regression analysis. Descriptive statistics of the submitted bid prices based on terrain types are described in Table 4-3. Coastal terrain in Georgia has relatively higher average unit prices compared to other terrain types.

Table 4-3 Descriptive Statistics of the Submitted Bid Prices based on Georgia Terrain Types

Terrain	Rolling	Flat	Mountainous	Coastal
Number of Projects	999	281	70	74
Mean ($/Ton)	67.09	72.72	68.86	81.21
Median ($/Ton)	66.10	72.00	68.02	77.31
Min. ($/Ton)	40.25	52.37	51.59	56.87
Max. ($/Ton)	170.85	116.86	125.00	354.53

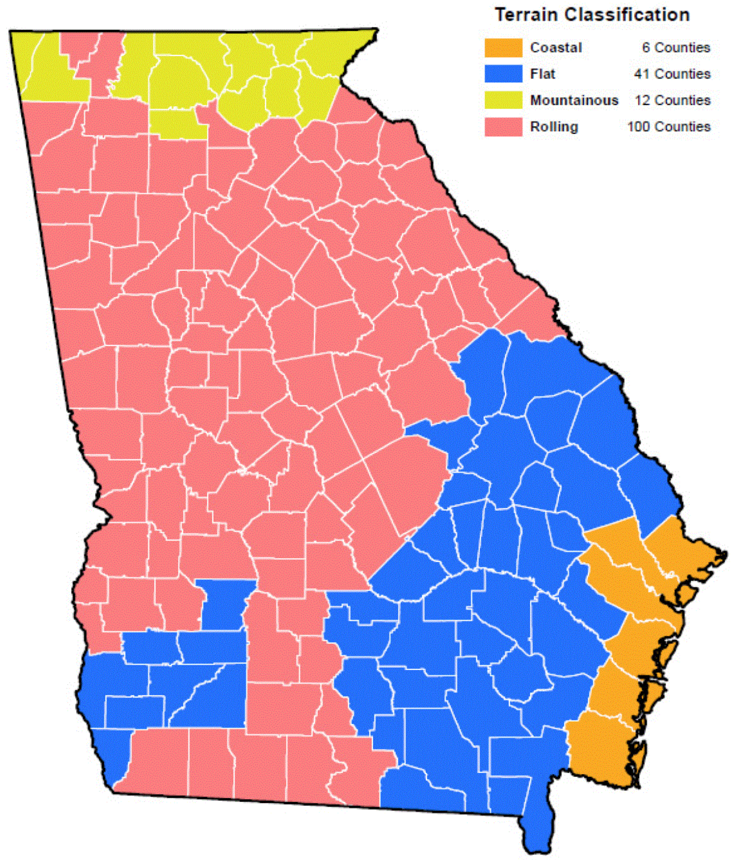


Figure 4-2 Georgia Terrain Map

4. Districts of the Project: GDOT has 7 district offices throughout the State of Georgia as shown in Figure 4-3 (GDOT 2014). These districts are used as categorical variables in the regression modelling. In addition, descriptive statistics of the submitted bid prices in different districts are summarized in Table 4-4. Districts 4 and 5 have relatively higher average unit prices for asphalt line items compared to other Districts.

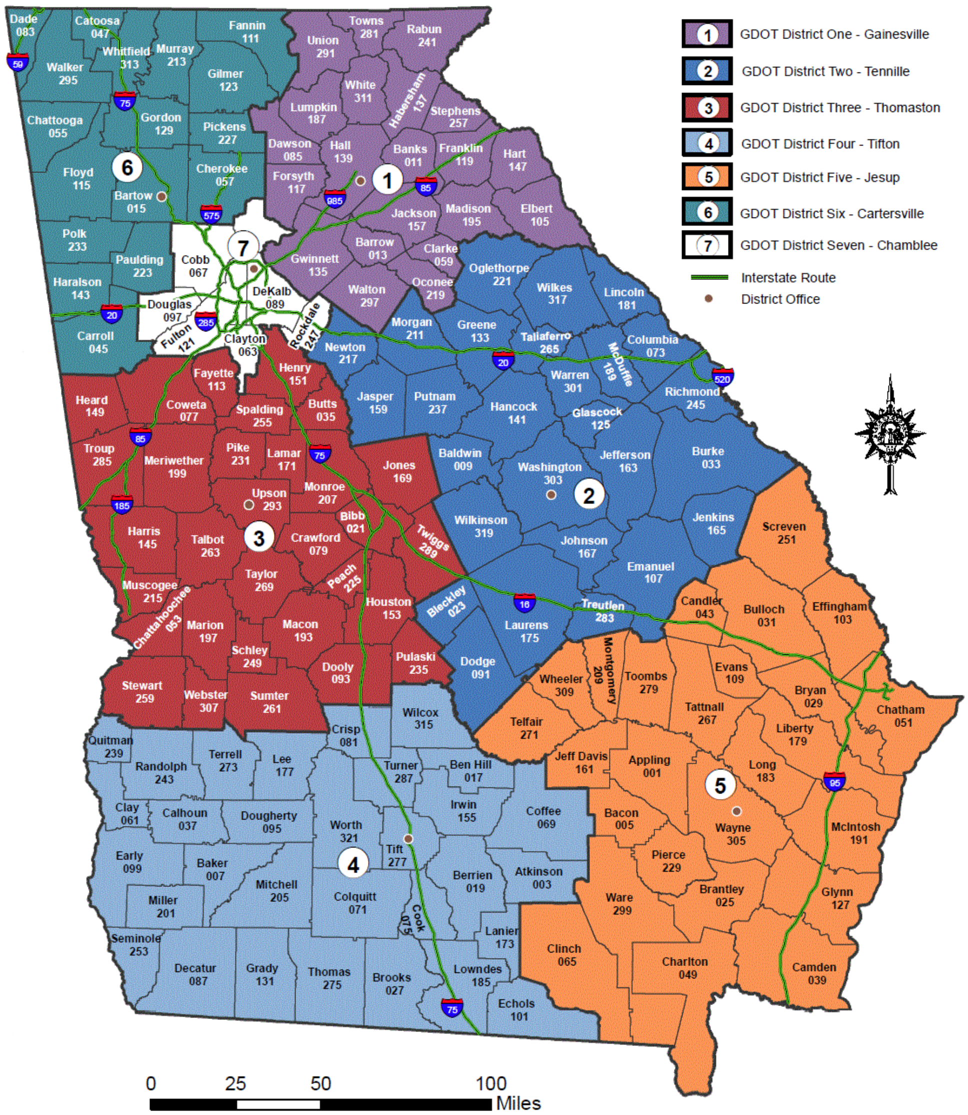


Figure 4-3 Georgia District Map

Table 4-4 Descriptive Statistics of the Submitted Bid Prices based on Seven Districts

Districts	**District 1**	**District 2**	**District 3**	**District 4**	**District 5**	**District 6**	**District 7**
Number of Projects	219	241	242	237	195	126	164
Mean ($/Ton)	65.45	69.68	64.16	71.35	75.80	69.50	68.18
Median ($/Ton)	64.00	68.25	36.73	70.46	74.00	68.17	67.13
Min. ($/Ton)	47.41	50.66	42.00	50.00	52.42	50.24	40.25
Max. ($/Ton)	170.85	111.63	101.02	116.86	354.53	110.18	155.37

5. Total Bid Price: It is the lowest total bid price that is submitted by contractors on the project. Total bid price represents the size of the project.
6. Project Length: It is an approximate length of the project. Project length is another indicator of the size of the project.
7. Number of Nearby Asphalt Plants (within 50 miles): It is the number of asphalt plants within 50-mile radius of the center of the project. Since distance from an asphalt plant to the paving location should not exceed 50 miles (80km) (ODOT 2016), the number of asphalt plants are counted within 50 miles from the project location. The annual number of certified asphalt plants in Georgia is provided in Table 4-5. In addition, Figure 4-4 shows the geographical distribution of asphalt plants in Georgia.

Table 4-5 Annual Number of Asphalt Plants in Georgia

Year	**2008**	**2010**	**2012**	**2014**	**2016**
Number of Certified Asphalt Plants	118	113	106	108	103

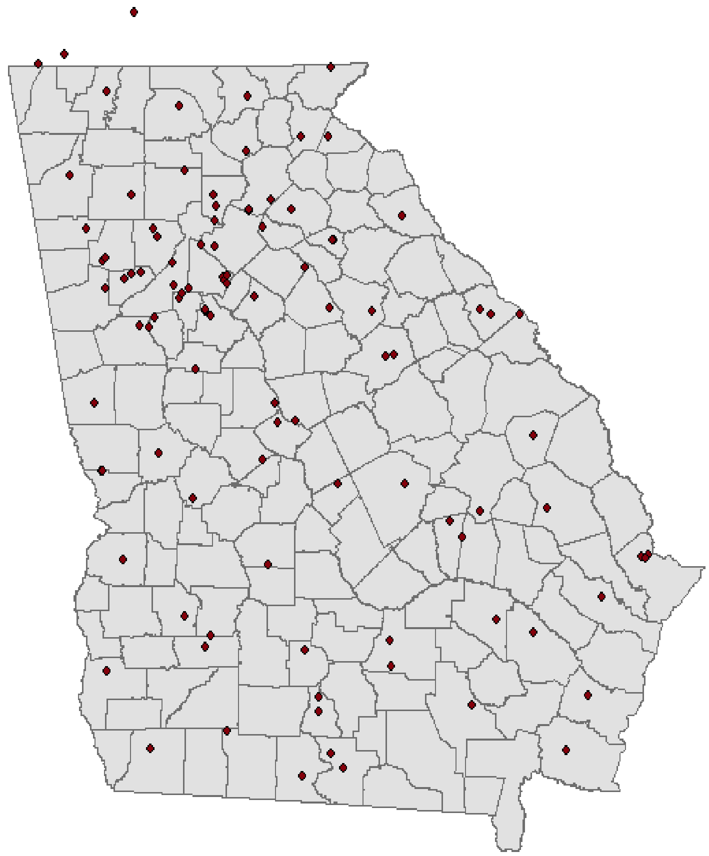


Figure 4-4 Locations of Active Asphalt Plants in Georgia in 2016

8. Hauling Distance between Asphalt Plant and Project Location: It is the hauling distance between project location and the closest asphalt plant to the project location.

9. Hauling Distance between Quarry and Asphalt Plant: It is the hauling distance between the closest asphalt plant to the project location and the closest quarry to the asphalt plant.

10. Number of Bidders: It is the number of bidders submitting bids for the project. This variable is a market indicator that represents the market competitiveness for the project.

11. Number of Pay Items: It is the number of pay items in the contract for which the contractor submits a unit bid prices. This variable is an indicator of project complexity.

4.3.3.2. Construction Market Conditions

Market conditions for the construction industry can be described by several factors (e.g., prices of construction materials and labor, and construction cost indexes). Rapidly changing market conditions represent significant challenge for public and private sectors in pricing construction cost. The following variables are considered in this study to represent construction market conditions:

1. Total Asphalt Volume of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County: It is the sum of the asphalt volume of resurfacing and widening projects awarded in each month and in the same county as of the project in the State of Georgia. This factor represents the activity level of paving construction in the area close to the project location.
2. Total Number of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County: It is the number of resurfacing and widening projects awarded in each month and in the same county as of the project in the State of Georgia.
3. Total Number of Projects Awarded in the Current Month at the Level of the State of Georgia: It is the number of projects awarded in each month and in the same county as of the project in the State of Georgia.

4. Total Dollar Value of Projects Awarded in the Current Month at the Level of the State of Georgia: It is the total dollar value of projects awarded in each month and in the same county as of the project in the State of Georgia.
5. Total Asphalt Volume of Projects Awarded in the Current Month at the Level of the State of Georgia: It is the total asphalt volume of projects awarded in the current year at the level of the State of Georgia.
6. Architecture Billings Index: It is a leading economic indicator for forecasting nonresidential construction activity for the future 9 to 12 months. This index is prepared by the American Institute of Architects (AIA) through gathering billings data from architectural firm leaders.
7. Building Permits for New Residential Construction: It is the number of new housing units authorized by building permits, for new privately-owned residential construction.
8. ENR Building Cost Index: This index represents and tracks average cost of skilled labor and materials in the building construction industry over time.
9. ENR Common Labor Index: This index represents and tracks average total wages for laborers, including fringe benefits, in the construction industry over time.
10. ENR Construction Cost Index: This index represents and tracks average cost of skilled labor and materials in the construction industry over time.
11. ENR Material Price Index: This index represents and tracks average cost of major materials, such as structural steel, in the construction industry over time.

12. ENR Skilled Labor Index: This index represents and tracks average total wages for skilled laborers (such as carpenters, bricklayers, and iron workers), including fringe benefits, in the construction industry over time.
13. Equipment Operator Wages (Paving): It is a mean hourly wage of an equipment operator, such as asphalt paving machine operators, in the State of Georgia.
14. Georgia Asphalt Cement Price Index: It is an average selling price of asphalt cement that is collected from approved local asphalt cement suppliers as reported in the GDOT's monthly survey.
15. Gross Domestic Product (GDP) of the Georgia Construction Industry: It is the total market value of goods and services provided by the Georgia construction industry.
16. Job Opening and Labor Turnover Index (Hires): It is an index that represents the number of hires during the entire month as a percent of total employment.
17. Housing Market Index: It is an indicator for the single-family housing market. The data are collected through the survey by asking respondents to rate market conditions for the sale of new homes at the present time and in the next six months.
18. National Highway Construction Cost Index: It is a highway construction index to track pure price-changes in highway construction costs.
19. Producer Price Index (Construction machinery manufacturing): It is an index measuring changes in prices received for the output of the construction machinery manufacturing sold to another industry.

20. Producer Price Index (Construction sand and gravel mining): It is an index measuring changes in prices received for the output of the construction sand and gravel mining sold to another industry.
21. Turner Construction Cost Index: It is a cost index on a main basis of labor rates, productivity, and material prices in the non-residential building construction market in the U.S.
22. Value of Construction Put in Place (Pavement): It is an estimate of total dollar value of State and local pavement construction work done each month in the U.S. measured in Millions of Dollars.
23. Value of Construction Put in Place (All construction): It is an estimate of total dollar value of construction work done each month in the State of Georgia measured in Millions of Dollars.
24. Fails Management Institute (FMI) Nonresidential Construction Index: It is an index measuring nonresidential construction activity. The index is developed based on the survey of national contractors in several regions or around the U.S.
25. Labor Productivity: It is the ratio of the output of goods and services to the labor hours devoted to the production of that output.
26. Number of Establishments in Private Construction Industry: It is the number of private construction establishments in the State of Georgia.
27. 12 Month Percent Change of Georgia Asphalt Cement Price Index: It is a measure of trends in the Georgia asphalt cement price index by comparing a value in the

current month with a value in the corresponding month last year. The 12-month percent change shows how much of the downturn or rise in asphalt cement prices in the Georgia is.

28. 12 Month Percent Change of Gross Domestic Product (GDP) of the Georgia Construction Industry: It is a measure of trends in GDP of the Georgia construction industry by comparing a value in the current month with a value in the corresponding month last year. The 12-month percent change of GDP shows how much of the downturn or rise in GDP of the Georgia construction industry is.
29. 12 Month Percent Change of Job Opening and Labor Turnover Index (Hires): It is a measure of trends in the labor market of the construction industry by comparing a value in the current month with a value in the corresponding month last year. The 12-month percent change of Job Opening and Labor Turnover shows how much of the downturn or rise in hires of the construction industry is.
30. 12 Month Percent Change of Value of Construction Put in Place (Pavement): It is a measure of trends in the total value of construction put in place for pavement projects by comparing a value in the current month with a value in the corresponding month last year. The 12-month percent change shows how much of the downturn or rise in the total value of construction put in place for pavement projects in the South regions (e.g., Georgia, Alabama, and Florida) is.

4.3.3.3. Macroeconomic Conditions

Macroeconomic conditions can be described by GDP and unemployment. Macroeconomic conditions have significant impact on investment in the construction industry. The following macroeconomic variables are considered in this study:

1. Dow Jones Industrial Average: It is a stock market index that reveals trading activities covering various industries among 30 large publicly-owned companies in the U.S.
2. Inflation rate: It is the rate of general rising prices for goods and services, and falling of the purchasing power of currency.
3. Average weekly wage (all industry): It is an average weekly wage for all industries that covers 98 percent of the U.S. economy. This measure is available at the county level.
4. Consumer Price Index (south): It is an economic indicator of average change of prices for purchasing consumer goods and services.
5. Producer Price Index (Gasoline products): It is an index that measures the average change over time in selling prices of gasoline related products and power by domestic producers of goods and services.
6. Producer Price Index (Steel mill products): It is an index that measures the average change over time in selling prices of steel related products and power by domestic producers of goods and services.

7. Producer Price Index (No. 2 diesel fuel products): It is an index that measures the average change over time in selling prices of No. 2 diesel related products and power by domestic producers of goods and services.
8. Producer Price Index (Crude petroleum products): It is an index that measures the average change over time in selling prices of crude petroleum related products and power by domestic producers of goods and services.
9. Unemployment: It is a count of people who are eligible to work but unable to find a job.
10. 12 Month Percent Change of Unemployment: It is a measure of trends in the number of unemployed people by comparing a value in the current month with the value in the same month last year. The 12-month percent change shows how much of the downturn or rise in unemployment is in the State of Georgia.

4.3.3.4. Oil Market Conditions

Oil market affects unit bid prices for major asphalt line items. Volatility in oil market should be considered in pricing construction costs and managing risks related to oil/fuel prices (Damnjanovic and Zhou 2009). The following variables represent oil market condition in this study:

1. Crude Oil Price: It is the spot price of unrefined petroleum product measured in Dollars per Barrel.
2. Diesel Retail Prices: It is the spot price of diesel measured in Dollars per Barrel.

3. Georgia Fuel Price Index: It is an average statewide selling price of Unleaded Regular Gasoline and Diesel Fuel.
4. 12 Month Percent Change of Georgia Fuel Price Index: It is a measure of trends in the Georgia fuel price index by comparing a value in the current month with a value in the corresponding month last year. The 12-month percent change shows how much of the downturn or rise in fuel prices in the Georgia is.

4.4. Results of the Multiple Regression Modeling

As the first step, the outliers in the dataset are detected. Based on the z-scores, 33 outliers (2.3%) are detected as shown in Table 4-6. Thus, 1391 observations are used to develop a multiple regression model.

Table 4-6 Results of Outlier Inspection

Bid Item	**Number of Observations**	**Detected Outliers**	**Percentage of Removed Data**
Recycled Asphaltic Concrete	1424	33	2.3%

Variable Transformation: Scatter plots and Pearson correlation analysis are used to examine whether any variable transformation is helpful to enhance the quality of regression analysis. The correlation of the submitted bid price with each of the potential explanatory variables is calculated, once with the variable in its original form and once with the transformed variables in its logarithmic form. It is found that the following variables are better transformed into their logarithmic forms before they are included in regression analysis because the correlation of these variables with the submitted bid price is higher when the variables are in the logarithmic form: the quantity of the item, project length, building permits for new residential construction, Dow Jones Industrial Average, housing market index, producer price index for No. 2 diesel fuel related products, and unemployment.

Multiple regression model is developed for explaining variations in submitted unit prices for major asphalt line items. The entire dataset consists of the information of resurfacing and widening projects let in the State of Georgia from January 2008 to December 2015. Ordinary least squares (OLS) regression is developed with 55 potential factors. Multicollinearity issues are also reexamined using Variance inflation factors (VIF). The results of VIF diagnosis indicated that several factors represent a multicollinearity issue in the regression modeling since the respective VIF values for these variables are greater than 10. The variables that have multicollinearity issues are: architecture billings index, building permits for new residential construction, Dow Jones Industrial Average, ENR building cost index, ENR common labor index, ENR construction cost index, ENR material price index, ENR skilled labor index, equipment operator wages for paving, Georgia fuel price index, Gross Domestic Product (GDP) of the Georgia construction industry, producer price index for gasoline related products, producer price index for steel related products, producer price index for No. 2 diesel related products, producer price index for crude petroleum related products, producer price index for construction machinery manufacturing, producer price index for construction sand and gravel mining, Turner construction cost index, consumer price index, diesel retail prices, value of construction put in place for pavement projects, value of construction put in place for all construction projects, FMI nonresidential construction index, and labor productivity in highway, street, and bridge construction. These 23 variables are, therefore, removed from the final model. The results of this model are presented in Table 4-7.

Table 4-7 Coefficients of the Final Regression Model

<table>
<tr><th colspan="3" rowspan="2">Model</th><th colspan="2">Unstandardized Coefficients</th><th>Standardized Coefficients</th><th rowspan="2">t</th><th rowspan="2">Sig.</th><th rowspan="2">VIF</th></tr>
<tr><th>B</th><th>Std. Error</th><th>Beta</th></tr>
<tr><td colspan="2"></td><td>(Constant)</td><td>54.734</td><td>5.130</td><td></td><td>10.668</td><td>0.000</td><td></td></tr>
<tr><td rowspan="9">Categorical Variable</td><td rowspan="3">Terrain</td><td>Flat</td><td>2.289</td><td>0.565</td><td>0.107</td><td>4.052</td><td>0.000</td><td>2.114</td></tr>
<tr><td>Mountainous</td><td>3.344</td><td>0.811</td><td>0.085</td><td>4.123</td><td>0.000</td><td>1.277</td></tr>
<tr><td>Coastal</td><td>5.748</td><td>1.014</td><td>0.147</td><td>5.667</td><td>0.000</td><td>2.026</td></tr>
<tr><td rowspan="6">District</td><td>District 2</td><td>3.660</td><td>0.665</td><td>0.161</td><td>5.501</td><td>0.000</td><td>2.578</td></tr>
<tr><td>District 3</td><td>0.166</td><td>0.663</td><td>0.007</td><td>0.25</td><td>0.802</td><td>2.608</td></tr>
<tr><td>District 4</td><td>4.083</td><td>0.749</td><td>0.18</td><td>5.451</td><td>0.000</td><td>3.279</td></tr>
<tr><td>District 5</td><td>5.654</td><td>0.886</td><td>0.228</td><td>6.378</td><td>0.000</td><td>3.836</td></tr>
<tr><td>District 6</td><td>3.365</td><td>0.709</td><td>0.113</td><td>4.749</td><td>0.000</td><td>1.690</td></tr>
<tr><td>District 7</td><td>1.880</td><td>0.841</td><td>0.071</td><td>2.235</td><td>0.026</td><td>2.991</td></tr>
<tr><td rowspan="15">Rank</td><td>1</td><td>Natural Logarithm of Quantity of Bid Item</td><td>-1.561</td><td>0.180</td><td>-0.247</td><td>-8.652</td><td>0.000</td><td>2.459</td></tr>
<tr><td>2</td><td>Natural Logarithm of Housing Market Index</td><td>4.347</td><td>0.669</td><td>0.236</td><td>6.497</td><td>0.000</td><td>3.966</td></tr>
<tr><td>3</td><td>Georgia Asphalt Cement Price Index</td><td>0.023</td><td>0.004</td><td>0.234</td><td>6.214</td><td>0.000</td><td>4.277</td></tr>
<tr><td>4</td><td>Total Bid Price</td><td>2.834×10^{-7}</td><td>4.061×10^{-8}</td><td>0.211</td><td>6.979</td><td>0.000</td><td>2.738</td></tr>
<tr><td>5</td><td>Natural Logarithm of Project Length</td><td>-2.223</td><td>0.273</td><td>-0.193</td><td>-8.134</td><td>0.000</td><td>1.690</td></tr>
<tr><td>6</td><td>12 Month Percent Change of Georgia Asphalt Cement Price Index</td><td>0.037</td><td>0.012</td><td>0.141</td><td>2.984</td><td>0.003</td><td>6.681</td></tr>
<tr><td>7</td><td>12 Month Percent Change of Gross Domestic Product (GDP) of the Georgia Construction Industry</td><td>0.091</td><td>0.034</td><td>0.110</td><td>2.659</td><td>0.008</td><td>5.191</td></tr>
<tr><td>8</td><td>Natural Logarithm of Unemployment</td><td>-0.582</td><td>0.242</td><td>-0.097</td><td>-2.410</td><td>0.016</td><td>4.834</td></tr>
<tr><td>9</td><td>Total Asphalt Volume of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County</td><td>9.055×10^{-7}</td><td>2.856×10^{-7}</td><td>0.089</td><td>3.170</td><td>0.002</td><td>2.392</td></tr>
<tr><td>10</td><td>Number of Bidders</td><td>-0.427</td><td>0.127</td><td>-0.081</td><td>-3.363</td><td>0.001</td><td>1.724</td></tr>
<tr><td>11</td><td>Project Duration</td><td>-0.003</td><td>0.001</td><td>-0.069</td><td>-2.238</td><td>0.025</td><td>2.88</td></tr>
<tr><td>12</td><td>Average Weekly Wage (all industry)</td><td>0.003</td><td>0.002</td><td>0.065</td><td>1.557</td><td>0.120</td><td>5.161</td></tr>
<tr><td>13</td><td>Total Number of Projects Awarded in the Current Month at the Level of the State of Georgia</td><td>0.021</td><td>0.011</td><td>0.064</td><td>1.927</td><td>0.054</td><td>3.320</td></tr>
<tr><td>14</td><td>Number of Establishments in Private Construction Industry</td><td>0.001</td><td>0.001</td><td>0.064</td><td>1.827</td><td>0.068</td><td>3.743</td></tr>
<tr><td>15</td><td>Crude Oil Price</td><td>0.027</td><td>0.020</td><td>0.063</td><td>1.319</td><td>0.187</td><td>6.782</td></tr>
</table>

Model			Unstandardized Coefficients		Standardized Coefficients	t	Sig.	VIF
			B	Std. Error	Beta			
Rank (Cont'd)	**16**	Number of Nearby Asphalt Plants (within 50 miles)	-0.041	0.017	-0.060	-2.374	0.018	1.903
	17	Job Opening and Labor Turnover Index (Hires)	0.005	0.003	0.057	1.851	0.064	2.802
	18	12 Month Percent Change of Unemployment	0.017	0.012	0.056	1.408	0.159	4.675
	19	12 Month Percent Change of Job Opening and Labor Turnover Index (Hires)	-0.029	0.016	-0.046	-1.801	0.072	1.975
	20	Total Number of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County	-0.201	0.126	-0.042	-1.594	0.111	2.103
	21	12 Month Percent Change of Georgia Fuel Price Index	1.996×10^{-4}	1.531×10^{-4}	0.027	1.304	0.192	1.321
	22	Inflation Rate	0.144	0.253	0.026	0.566	0.571	6.524
	23	Total Dollar Value of Projects Awarded in the Current Month at the Level of the State of Georgia	3.807×10^{-9}	5.654×10^{-9}	0.017	0.673	0.501	2.024
	24	Hauling Distance between Asphalt Plant and Project Location	0.013	0.023	0.011	0.549	0.583	1.308
	25	Hauling Distance between Quarry and Asphalt Plants	0.003	0.006	0.010	0.503	0.615	1.188
	26	Monthly GA Total Asphalt Volume	2.263×10^{-9}	7.658×10^{-9}	0.007	0.295	0.768	1.517
	27	National Highway Construction Cost Index	-0.351	4.116	-0.003	-0.085	0.932	4.156
	28	Number of Pay Items	1.089×10^{-5}	1.748×10^{-4}	0.001	0.062	0.950	1.192
	29	12 Month Percent Change of Value of Construction Put in Place (Pavement)	0.001	0.024	0.001	0.036	0.971	1.276

Note: Sig. = Significance Probability (p-value)

The beta coefficient for each variable is calculated to determine the relative importance of explanatory variables in the regression model. Reviewing the absolute values of beta coefficients and significance probabilities of each variable in the developed regression model indicates that the most important factors in explaining submitted bid prices are quantity of the bid item, followed by housing market index, Georgia asphalt cement price index, total bid price, project length, 12-month percent change of Georgia asphalt cement price index, 12-month percent change of Gross Domestic Product (GDP) of the Georgia construction industry, unemployment, total asphalt volume of resurfacing and widening projects, number of bidders, project duration, and number of nearby asphalt plants. The results of the regression analysis also indicate that quantity of the bid item, project length, unemployment, number of bidders, project duration, and number of asphalt plants have negative relationship with submitted bid prices while holding all other variables in the model constant.

Georgia has 4 types of terrain, including rolling, flat, mountainous, and coastal terrain. Terrain type is included as categorical variable in the regression model. The results of regression analysis conclude that submitted bid prices in flat, mountainous, and coastal terrain are higher than those in rolling terrain, on average, while holding all other variables constant. Submitted bid prices in coastal terrain are relatively higher than those in other terrain types, on average.

GDOT has 7 district offices throughout the State of Georgia. Seven categorical variables are used in regression analysis. The results show that submitted bid prices in all other districts are higher than those in District 1, on average, while holding all other factors in the model constant. Submitted bid prices in District 5 showed relatively higher than those in other districts, on average.

The final regression model with selected explanatory variables has adjusted R-Squared of 0.538 with F (38, 1352) = 43.543 and p < .001. As it can be seen in Table 4-8, the regression model can explain approximately 53.8% of variations in submitted bid prices for major asphalt line items. The results of ANOVA tests are provided in Table 4-9. The null hypothesis is rejected at 1% significance level indicating at least one of the coefficients of the identified explanatory variables is not zero in the regression model. Overall, a combination of variables used in the regression model is statistically significant for explaining variations in submitted bid prices.

Table 4-8 Model Summary of the Final Regression Model

R	R Squared	Adjusted R Squared	Std. Error of the Estimate
0.742	0.550	0.538	5.771535

Table 4-9 ANOVA of the Final Regression Model

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	55116.571	38	1450.436	43.543	0.000
Residual	45035.965	1352	33.311		
Total	100152.527	1390			

Note: df= Degree of Freedom; F= F Statistic; Sig. = Significance Probability

Figure 4-5 depicts the histogram of standardized residuals for the regression model that is used to diagnose the regression model for the normality assumption. The histogram of standardized residuals is appeared normal and bell-shaped. This histogram suggests that the normality assumption is not violated in the regression modeling.

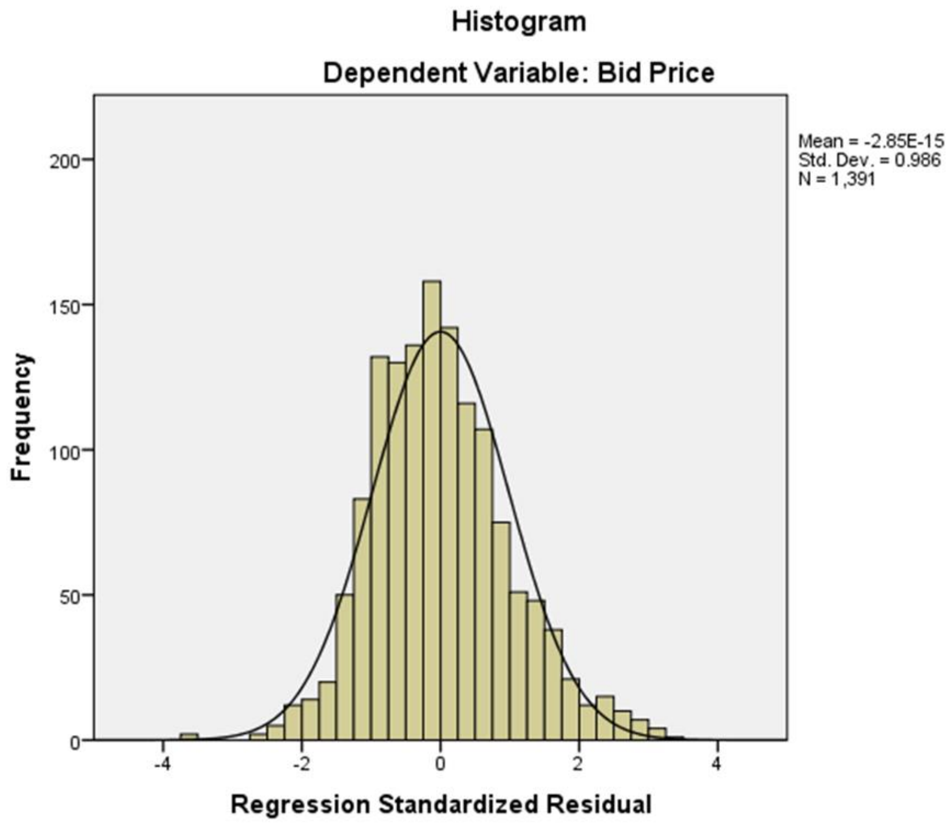


Figure 4-5 Histogram of Standardized Residuals for the Regression Model

Figure 4-6 depicts the normal probability-probability (P-P) plot based on the calculated standardized residuals. If the residuals are normally distributed, the residuals should fall on the diagonal line. In Figure 4-6, the residual plot (the normal probability plot) is appeared to generally follow a straight line. This result indicates that the normality assumption is met.

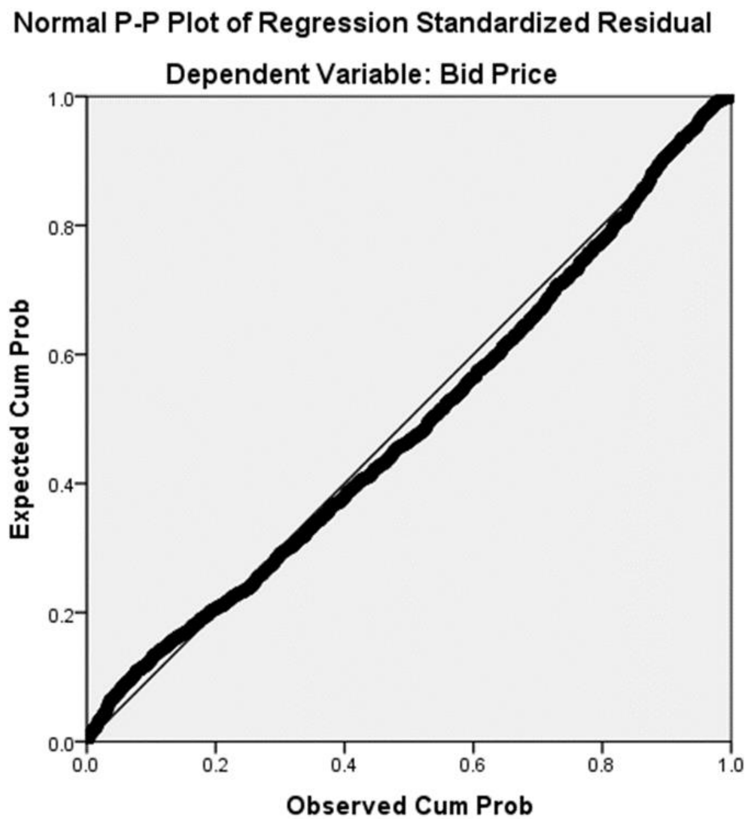


Figure 4-6 Normal P-P Plot of Standardized Residuals for the Regression Model

Figure 4-7 shows the scatterplot of standardized residuals against predicted values. If residuals are homoscedastic, then the spread of the residuals should balance evenly around zero on the Y-axis. The scatterplot has a random pattern centered on the line of zero standard residual value and there is no clear relationship between the residuals and the predicted values. Thus, the assumptions of homoscedasticity and independence are met.

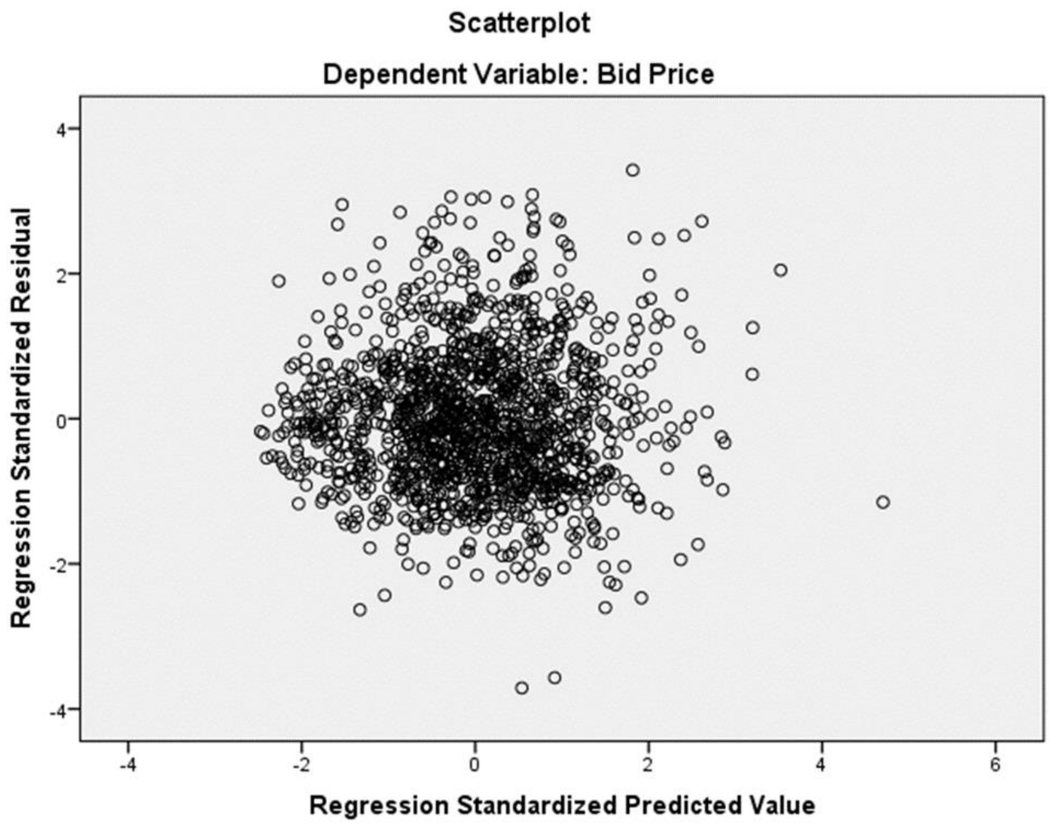


Figure 4-7 Scatterplot of Standardized Residuals vs. Predicted Values

4.5. Results of the Multiple Regression Modeling for Projects in TIA Regions

Regression analysis is conducted for modeling variations in submitted bid prices in the three Regional Commissions in the State of Georgia: Central Savannah River Area, Heart of Georgia Altamaha, and River Valley where the Transportation Investment Act (TIA) is implemented for improving the local transportation system. These regions are depicted in Figure 4-8. A specific regression model is created to identify significant factors that can explain variations in submitted bid prices just using the data from the TIA regions. The dataset used in this analysis is submitted unit prices for asphalt line items used in resurfacing and widening projects let in these three regions from 2008 to 2015.

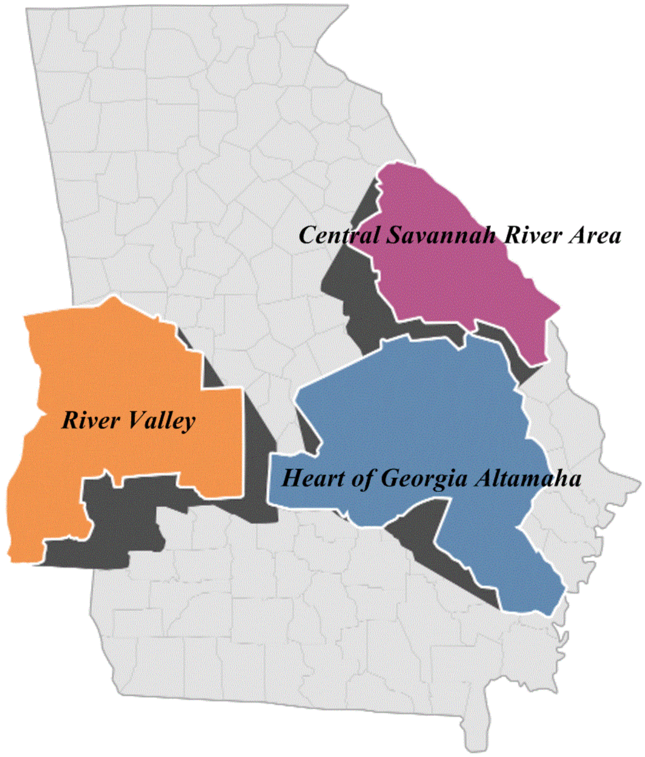


Figure 4-8 Three Regional Commissions for TIA

Since this section focuses on TIA regions, categorical variables for Districts are excluded from the analysis. In addition, as TIA regions do not contain any mountainous terrain, this terrain variable is also excluded from the regression analysis. Regression modeling is done to explain variations in submitted bid prices in TIA regions using information from 21 remaining factors.

Variable Transformation: Scatter plots and Pearson correlation analysis are used to examine whether any variable transformation is helpful to enhance the quality of regression analysis. The correlation of the submitted bid price with each of the potential explanatory variables is calculated, once with the variable in its original form and once with the transformed variable in its logarithmic form. It is found that Total Asphalt Volume of Resurfacing and Widening Projects is better transformed into its logarithmic form before it is included in regression analysis because the correlation of the variable with the submitted bid price is higher when the variable is in the logarithmic form.

Ordinary least squares (OLS) regression is developed with 54 factors. Multicollinearity issues are found in the results (i.e., VIF is less than 10 for all explanatory variables). The variables that contain multicollinearity issues are: building permits for new residential construction, crude oil price, Dow Jones Industrial Average, ENR building cost index, ENR common labor index, ENR construction cost index, ENR material price index, ENR skilled labor index, equipment operator wages for paving, Georgia fuel price index, Gross Domestic Product (GDP) of the Georgia Construction Industry, housing market index, national highway construction cost index, producer price index for gasoline related products, producer price index for No. 2 diesel fuel related products, producer price index for crude petroleum related products, producer price index for construction machinery manufacturing, producer price index for construction sand and gravel mining, consumer price index, diesel retail prices, value of construction put in place for pavement projects, value of construction put in place for all construction projects, FMI nonresidential construction index, labor productivity in highway, street, and bridge construction, and 12-month percent change of value of construction put in place for pavement projects. These 23 variables are removed from the final model. The regression results are shown in Table 4-10.

Table 4-10 Coefficients of the Final Regression Model Developed Based on Projects in TIA Regions

Model			Unstandardized Coefficients		Standardized Coefficients	t	Sig.	VIF
			B	Std. Error	Beta			
		(Constant)	35.064	17.731		1.978	0.049	
	Terrain	Flat	7.197	0.724	0.441	9.948	0.000	1.241
		Coastal	12.895	2.260	0.242	5.706	0.000	1.140
Rank	1	Unemployment	0.001	3.892×10^{-4}	0.342	2.917	0.004	8.711
	2	12 Month Percent Change of Georgia Asphalt Cement Price Index	0.048	0.024	0.202	2.025	0.044	6.279
	3	Quantity of the Bid Item	-1.782×10^{-4}	7.414×10^{-5}	-0.197	-2.403	0.017	4.244
	4	Total Bid Price	2.537×10^{-7}	1.119×10^{-7}	0.190	2.267	0.024	4.449
	5	Architecture Billings Index	0.309	0.198	0.181	1.564	0.119	8.447
	6	Number of Establishments in Private Construction Industry	-0.011	0.007	-0.178	-1.569	0.118	8.125
	7	Georgia Asphalt Cement Price Index	0.015	0.008	0.168	1.823	0.069	5.361
	8	Project Duration	-0.005	0.003	-0.128	-1.408	0.160	5.266
	9	Turner Construction Cost Index	0.023	0.012	0.128	1.986	0.048	2.611
	10	Job Opening and Labor Turnover Index (Hires)	0.009	0.005	0.113	1.783	0.076	2.557
	11	Natural Logarithm of Total Asphalt Volume of Resurfacing and Widening Projects	-0.952	0.658	-0.107	-1.447	0.149	3.488
	12	Total Dollar Value of Projects Awarded in the Current Month at the Level of the State of Georgia	1.786×10^{-8}	9.970×10^{-9}	0.097	1.791	0.074	1.872
	13	Total Number of Projects Awarded in the Current Month at the Level of the State of Georgia	0.027	0.023	0.094	1.163	0.246	4.108
	14	Number of Bidders	-0.500	0.277	-0.084	-1.805	0.072	1.358
	15	Hauling Distance between Quarry and Asphalt Plants	0.022	0.012	0.083	1.920	0.056	1.193
	16	12 Month Percent Change of Gross Domestic Product (GDP) of the Georgia Construction Industry	0.055	0.080	0.072	0.690	0.491	6.929
	17	Total Number of Resurfacing and Widening Projects Awarded in the Current Month at the Level of the County	-0.603	0.490	-0.066	-1.232	0.219	1.815
	18	Inflation Rate	-0.341	0.497	-0.065	-0.687	0.493	5.595
	19	Average Weekly Wage (all industry)	-0.004	0.004	-0.057	-1.066	0.287	1.815

Model			Unstandardized Coefficients		Standardized Coefficients	t	Sig.	VIF
			B	Std. Error	Beta			
Rank (Cont'd)	**20**	12 Month Percent Change of Unemployment	-0.016	0.023	-0.052	-0.712	0.477	3.324
	21	Number of Pay Items	0.001	0.001	0.048	1.141	0.255	1.136
	22	Total Asphalt Volume of Projects Awarded in the Current Month at the Level of the State of Georgia	1.396×10^{-8}	1.728×10^{-8}	0.040	0.808	0.420	1.553
	23	Value of Construction Put in Place (Pavement)	1.702×10^{-4}	2.726×10^{-4}	0.031	0.624	0.533	1.575
	24	Project Length	-0.039	0.105	-0.023	-0.374	0.708	2.361
	25	12 Month Percent Change of Georgia Fuel Price Index	-1.394×10^{-4}	3.438×10^{-4}	-0.019	-0.405	0.685	1.336
	26	Number of Nearby Asphalt Plants (within 50 miles)	0.016	0.041	0.017	0.393	0.694	1.245
	27	Producer Price Index (Steel mill products)	-0.006	0.047	-0.015	-0.131	0.896	8.051
	28	Hauling Distance between Asphalt Plant and Project Location	0.013	0.044	0.013	0.298	0.766	1.272
	29	12 Month Percent Change of Job Opening and Labor Turnover Index (Hires)	0.001	0.030	0.002	0.027	0.978	2.006

Note: Sig. = Significance Probability (p-value)

Reviewing the absolute values of beta coefficients and significance probabilities of each variable in the developed regression model indicates that 5 most important factors in explaining submitted bid prices in descending order of importance are: unemployment, 12-month percent change of Georgia asphalt cement price index, quantity of the bid item, total bid price, and Turner construction cost index. The results of the regression analysis also suggest that quantity of the bid item has negative relationship with submitted bid prices while holding all other variables constant.

Terrain types in TIA regions are rolling, flat, and coastal terrain. Submitted bid prices in flat and coastal terrain are higher than those in the rolling terrain, on average, while holding all other variables constant. Submitted bid prices in coastal terrain are far higher than those in other terrain types in TIA regions, on average.

The final regression model with selected explanatory variables is developed for explaining variations in submitted bid prices in TIA regions. Table 4-11 shows a summary of regression modeling in TIA regions. The final model can explain approximately 42% of variations in submitted bid prices using information from 30 explanatory variables. It is shown in Table 4-12 that the overall model is found to be statistically significant ($F = 9.559$, $p<0.001$).

Table 4-11 Model Summary of the Final Regression Model Developed Based on Projects in TIA Regions

R	R-Square	Adjusted R-Square	Std. Error of the Estimate
0.685	0.469	0.420	5.92246

Table 4-12 ANOVA of the Final Regression Model Developed Based on Projects in TIA Regions

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	10393.507	31	335.274	9.559	0.000
Residual	11785.379	336	35.076		
Total	22178.886	367			

Note: df= Degree of Freedom; F= F Statistic; Sig. = Significance Probability

Figure 4-9 depicts the histogram of standardized residuals for the regression model that is used to diagnose the regression model for the normality assumption. The histogram of standardized residuals is appeared normal and bell-shaped. This histogram suggests that the normality assumption is not violated in the regression modeling.

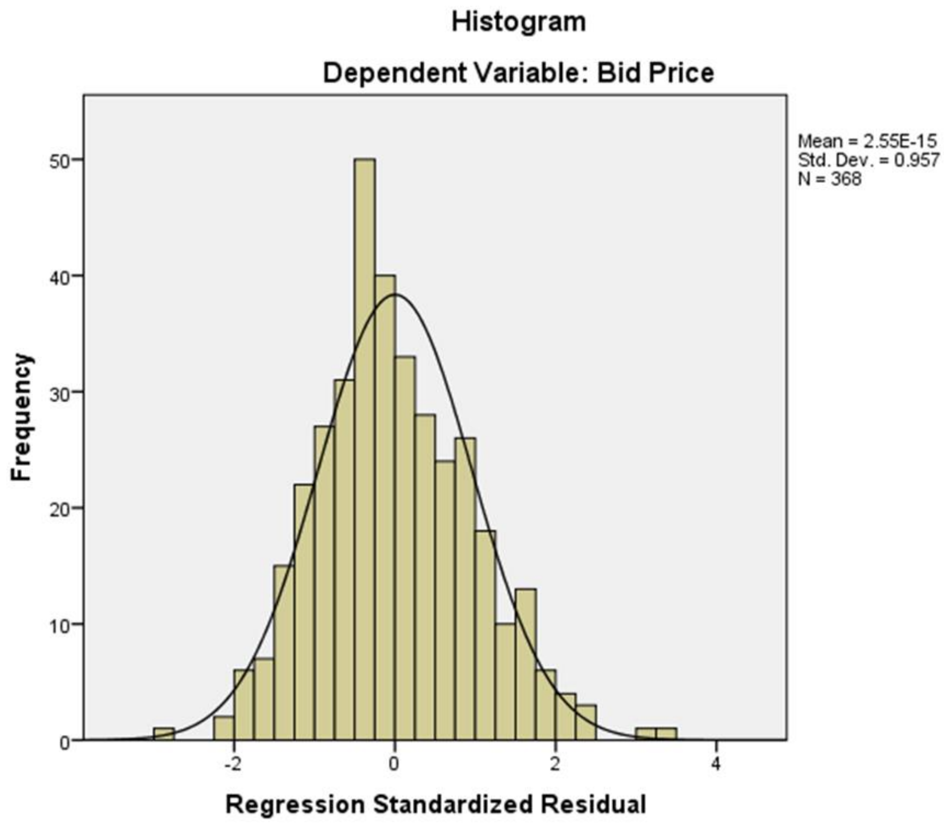


Figure 4-9 Histogram of Standardized Residuals for the Regression Model Developed Based on Projects in TIA Regions

Figure 4-10 depicts the normal probability-probability (P-P) plot based on the calculated standardized residuals. If the residuals are normally distributed, the residuals should fall on the diagonal line. In Figure 4-10, the residual plot (the normal probability plot) is appeared to generally follow a straight line. This result indicates that the normality assumption is met.

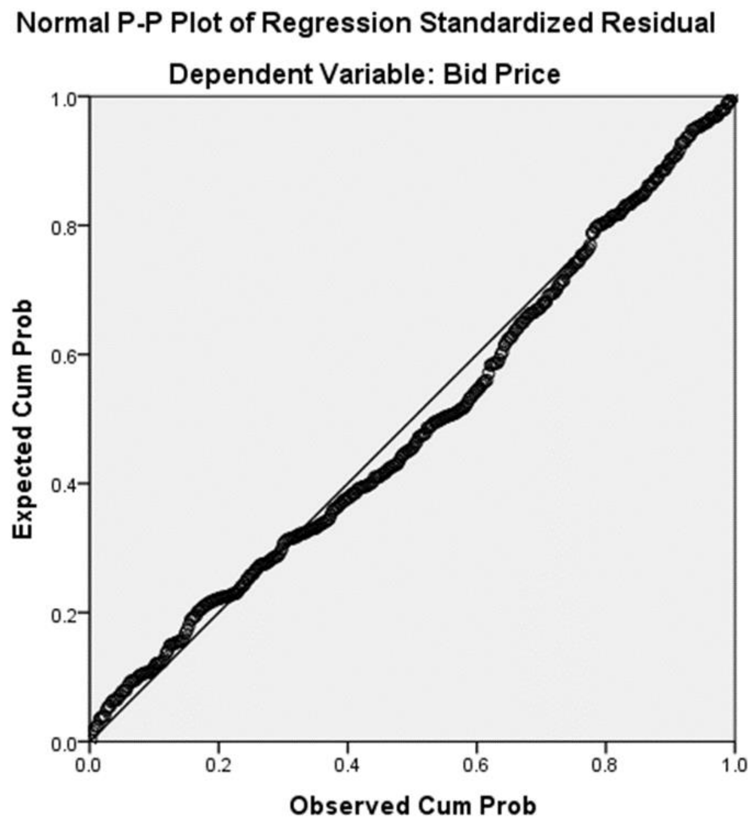


Figure 4-10 Normal P-P Plot of Standardized Residuals for the Regression Model Developed Based on Projects in TIA Regions

Figure 4-11 shows the scatterplot of standardized residuals against predicted values. If residuals are homoscedastic, then the spread of the residuals should balance evenly around zero on the Y-axis. The scatterplot has a random pattern centered on the line of zero standard residual value and there is no clear relationship between the residuals and the predicted values. Thus, the assumptions of homoscedasticity and independence are met.

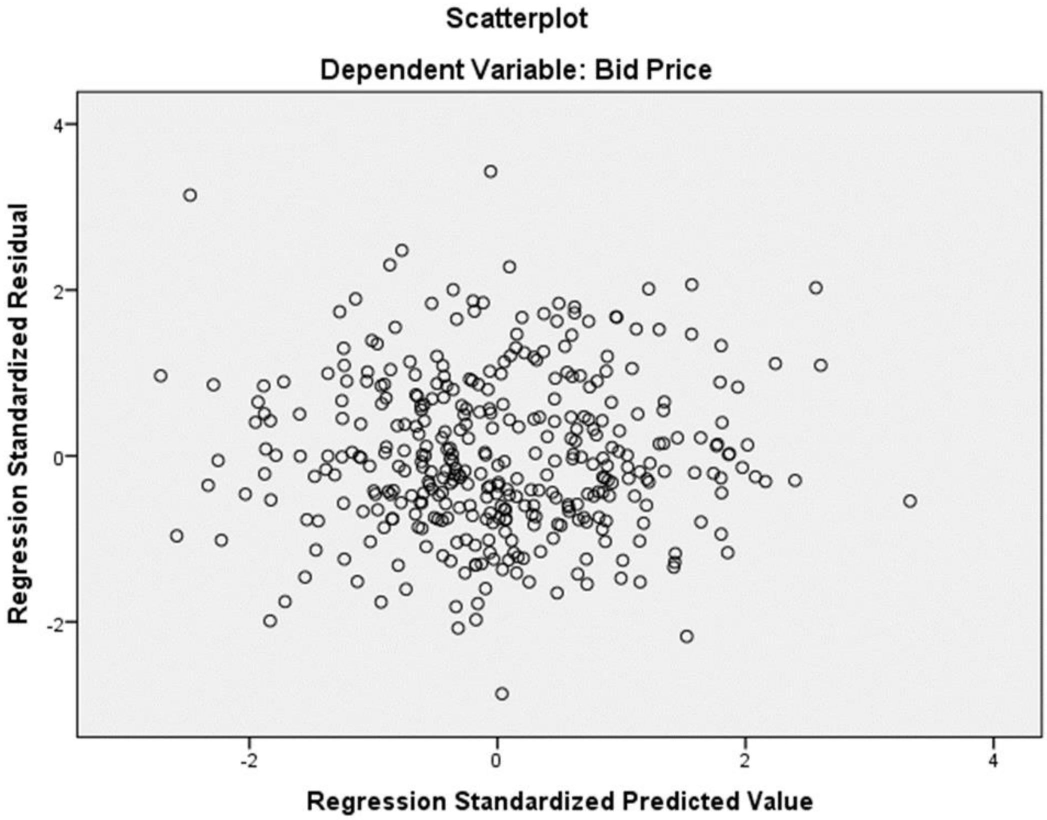


Figure 4-11 Scatterplot of Standardized Residuals vs. Predicted Values for the Regression Model Developed Based on Projects in TIA Regions

CHAPTER 5
CONCLUSIONS

This research aims to present a set of cost estimation and management practices for budget-based design that can aid GDOT project managers and engineers throughout the plan development process (PDP). To achieve the research objective, current state of practices in cost estimation and control in several State DOTs are reviewed and best practices are identified in cost estimation and strategies for cost control. Also, current state of practices in fixed budget-best value procurement method are reviewed and best practices are identified in utilization of this innovative contracting method. Finally, statistical analysis is conducted to investigate the impact of macroeconomic, construction market, and oil market conditions on highway construction costs by analyzing submitted bid prices for major asphalt line items in the State of Georgia's highway projects.

The following recommendations are found out to be effective for enhancing the practice of defining and maintaining the established budget for highway projects:

- State DOTs should establish an integrated process for cost estimation and cost management to establish accurate, reliable, and consistent estimates thorough project development process.
- State DOTs should establish key milestones for estimating, updating, and approving cost estimates as project definition/design advances.

- State DOTs should capture any changes in estimating assumptions to track the basis of cost estimate and control estimated project cost.
- State DOTs are recommended to establish an automated information system to help them maintain, update, and share project information, cost estimates, and changes in project scope, cost, and schedule.
- State DOTs should consider potential issues (risks) that may cause cost escalation during developing baseline cost estimates. Risk analysis tools and inputs from key project stakeholders are necessary for identifying critical risk factors for the project.
- Finally, State DOTs should utilize a quality assurance/quality control (QA/QC) process to verify the final engineer's cost estimate before a project is advertised.

The following recommendations are found out to be effective for enhancing the practice of delivering projects using this innovative contracting strategy:

- State DOTs may consider a fixed budget-best value procurement approach when the full project scope exceeds the baseline cost estimate for the project. For a fixed budget-best value procurement approach, the agency should define the basic configuration scope and should allow the proposers to include the maximum amount of work or additional scope elements in their proposals while staying within the fixed budget.
- A fixed budget-best value approach can be utilized in several project types, such as corridor expansion, bridge deck preservation, and seal coating projects. State DOTs

should clearly define additional scope elements beyond the base scope for each project type.

- State DOTs should clearly establish the evaluation criteria to select the proposers for a project. Since the price is fixed for all proposers and this approach allows higher flexibility in proposing design and construction solutions, the agency should establish rigorous evaluation criteria (e.g., cost, time, and design alternatives) and the weights for the criteria to evaluate the proposals based on the project goals.

Lastly, statistical analysis is conducted to identify important variables capable of explaining variations in submitted bid prices for major asphalt line items in the GDOT's highway projects. Multiple regression analysis is utilized to examine the impact of project characteristics, macroeconomic variables, construction market condition indicators, and oil market parameters on highway construction costs. The main purpose of this research is to examine the effects of several factors representing construction market, economic, and oil market conditions on submitted bid prices. The goal is to develop a regression model with explanatory power to describe variations in submitted bid prices. It is worth noting that the developed regression model can be used for forecasting bid prices for asphalt line items but prediction was not the main objective of this study. Therefore, the results should be used with caution as the forecasting error might be significantly large.

An explanatory model is developed for the State of Georgia's highway projects using multiple regression analysis. Several important variables are identified to have power to explain variations in submitted bid prices for major asphalt line items. The identified variables, in descending order of importance, are: quantity of the bid item, housing market index, Georgia asphalt cement price index, total bid price, project length, 12-month percent change of Georgia asphalt cement price index, 12-month percent change of Gross Domestic Product (GDP) of the Georgia construction industry, unemployment, total asphalt volume of resurfacing and widening projects, number of bidders, project duration, and number of nearby asphalt plants. Among these significant explanatory variables, quantity of the bid item, project length, unemployment, number of bidders, project duration, and number of asphalt plants have negative relationship with submitted bid prices while holding all other variables in the model constant. All other variables have positive influence on submitted bid prices.

Multiple regression analysis is repeated for identifying significant factors that affect variations in submitted bid prices in the regions included in the Transportation Investment Act (TIA). The identified important variables, in descending order of importance, are: unemployment, 12-month percent change of Georgia asphalt cement price index, quantity of the bid item, total bid price, and Turner construction cost index. Among those significant factors in the explanatory model developed for projects in the TIA regions, quantity of the bid item has negative relationship with submitted bid prices while holding all other variables constant. All other variables have positive relationship with submitted bid price.

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