QUANTITATIVE ANALYSIS FOR MODELING UNCERTAINTY IN CONSTRUCTION COSTS OF TRANSPORTATION PROJECTS WITH EXTERNAL FACTORS

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QUANTITATIVE ANALYSIS FOR MODELING UNCERTAINTY IN CONSTRUCTION COSTS OF TRANSPORTATION PROJECTS WITH EXTERNAL FACTORS

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Dedicated to my parents, parents-in-law

My wife, Chaeyun Lee, and my daughter, Claire D. Baek

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LIST OF ABBREVIATIONS

AASHTO	Association of State Highway and Transportation Officials
AIC	Akaike Information Criterion
AICC	Modified Akaike Information Criterion
ANOVA	Analysis of Variance
CCI	Construction Cost Index
CUSUM	Cumulative Sum
df	Degree of Freedom
DHS	Department of Homeland Security
ENR	Engineering News-Record
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
GDP	Gross Domestic Product
GeoPi	GDOT Project Search
GLM	Generalized Linear Modeling
HUD	Housing and Urban Development
LCL	Lower Control Limit
NHCCI	National Highway Construction Cost Index
OLS	Ordinary least squares
Q-Q	Quantile-Quantile
Sig.	Significance Level

SPC	Statistical Process Control
Std. Deviation	Standard Deviation
UCL	Upper Control Limit
VIF	Variance Inflation Factor
WTI	West Texas Intermediate

SUMMARY

Highway construction costs are subject to significant upward and downward variations from project to project and over time. Variations in construction cost disturb transportation agencies in making right investment decisions and estimating accurate construction costs for projects. Transportation agencies face considerable uncertainty in estimating project costs that often leads to significant over- and under-estimation of highway construction costs. The underestimation of project costs can lead to cost overrun, financial problem, and project delay or cancellation. The overestimation of project costs results in an inefficient budget allocation of public funds that could be used on other needed projects. Transportation agencies can also face credibility issues with the public if cost estimation problems remain unresolved. A wide range of variables has been identified in different studies to explain variations in construction cost. There is a value in conducting a research study that attempts to consider a comprehensive list of variables with potentials to explain the variations. The study needs to simultaneously take into account all possible explanatory variables to examine their relations with construction costs. The overarching objective of this research is to assess the effects of several potential variables on explaining variations in submitted unit price bids for major asphalt line items in highway projects.

First, stepwise regression analysis will be utilized to develop an explanatory model for describing variations in the submitted unit price bid. The identified variables used to build the explanatory model are classified into two major tiers. Tier 1 represents project specific factors, such as variables related to project characteristics, project location and its distance to major supply sources and price adjustment clauses. Tier 2 represents global and

external factors, such as variables related to level of activities in local highway construction market, macroeconomic indicators and energy market conditions. Secondly, it is shown that there is a significant spatial correlation between construction project cost and geographical location of the project that a generalized linear modeling approach may overlook. Geographically weighted regression analysis will be conducted to develop explanatory models for describing variations in the submitted unit price bids considering the spatial correlation. Lastly, the effect of natural disasters on highway construction costs will be examined. Cumulative sum (CUSUM) control chart will be utilized to monitor and detect the change in submitted unit price bids for hurricane-impacted and not hurricane-impacted areas.

The primary contributions of this research to the existing body of knowledge are: (1) creation of a multiple regression model to explain variations in submitted unit price bids; (2) creation of local regression models to describe variations in the submitted unit price bids considering the spatial correlation; and (3) empirical assessment of the impact of natural disasters on the variation in the submitted unit price bids. The primary contributions of this research to the state of practice are: (1) enhancing the capability of cost engineers in preparing more-accurate budgets and bids; (2) aiding a bottom-up estimating approach that requires more knowledge about the projects and market; and (3) helping capital project planners set and adjust the timing of the project lettings in the light of market conditions.

CHAPTER 1. INTRODUCTION

1.1 Research Background

Construction cost is subject to significant variation from project to project and over time (Creedy et al. 2010). Variations in construction cost represent a significant challenge for transportation agencies in making right investment decisions and estimating accurate construction costs for projects (Emsley et al. 2002). Transportation agencies face considerable uncertainty in estimating project costs that often leads to significant over- and under-estimation of highway construction costs (Akintoye and MacLeod 1997; Cirilovic et al. 2014). 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 an inefficient budget allocation of public funds that could be used on other needed projects (Creedy et al. 2010; FHWA 2015). Transportation agencies may face credibility issues with the public if cost estimation problems remain unresolved. These variations are also problematic for contractors because they can result in bid loss or profit loss (Shahandashti and Ashuri 2015).

Transportation agencies currently utilize different types of cost estimating techniques, including, parametric, historical percentage, historical bid-based, and cost-based estimating (Anderson et al. 2009). Parametric estimating is primarily used to prepare cost estimates during the early stages of a project, where have very little project scope definition available. According to the National Cooperative Highway Research Program (NCHRP) Report 574 (Anderson et al. 2007), three statistical modeling processes are required to conduct parametric estimation as follows:

1) Project breakdown estimation to determine major cost drivers, called "major items," for the breakdown;
2) Major item quantity estimation to determine appropriate quantities of major items; and
3) Major item price estimation to adjust the calculated values of major items to better reflect estimator knowledge of the project and use the cost estimation system (CES) for recalculating the estimates by using the refined data.

Historical percentage estimating is used for estimating costs for items that are not defined early. This method uses historical cost information from past projects (Anderson et al. 2009). The percentage is calculated based on a relationship between the selected items and a total cost category (e.g., direct construction). Contractor mobilization, construction engineering, and preliminary engineering costs are commonly estimated by using historical percentages (Anderson et al. 2007).

In addition, historical bid-based estimating also uses historical data from recently bid contracts to determine line item costs for a project. Historical bid-based estimation is useful for developing an estimate for line items when cost estimator have adequate historical cost data. The historical bid-based estimation requires the following steps (Anderson et al. 2007):

1) Deciding for how many bids from each project should be included in the data (e.g., low bid, second bid, or three lowest bids).

2) Establishing a timetable that specifies the frequency of data updates (e.g., after each letting, an annual basis, or some other recurring basis).
3) Deciding for what period of time data will be retained in the data base and how far back price data should be considered to determine average prices used in estimates.
4) Determining line-item cost based on the quantities and historical bid data that is adjusted for fitting the current project characteristics and location.

Lastly, cost-based estimating, so-called bottom-up estimating, is an estimating technique to develop project estimates by both estimating the unit cost for items of work to complete the work and taking into account the contract's overhead and profit (Anderson et al. 2009). This technique is commonly utilized for very large and complex projects that are significantly influenced by geographical features, market conditions, and the volatility of material prices. Cost-based estimation requires knowledge about construction methods, supply system, labor market, and method productivity on the project location. A cost-based estimating approach begins with estimating costs about the lowest component level of work as follows (Anderson et al. 2009):

1) Identifying crews, production rates, materials, and equipment for construction items suing a variety of resources (e.g., RS Means Heavy Construction Cost Data or calls with suppliers of materials);
2) Assigning resource requirements for detailed design elements;
3) Estimating agency construction staff support of administering the construction contract; and
4) Summarizing costs at different levels to generate a total cost estimate.

In utilizing these techniques for estimating accurate construction costs, cost estimators and engineers require profound knowledge and experience to use historical cost data, adjust cost estimates, capture cost escalation and inflation. However, state highway agencies have difficulties to develop reliable and accurate cost estimates because of a lack of a systematic methodology to analyze and develop unit prices for transportation projects (Anderson et al. 2009). In addition, Paulsen et al. (2008) claimed that transportation agencies need better tools to capture estimate cost escalation using historical cost data in order to develop accurate cost estimates. In addition, the lack of experienced estimators deteriorates the cost variation for construction projects (Chou et al. 2006). Therefore, this research aims to contribute to the body of knowledge through the examination of the impact of several factors on variation in highway construction cost.

1.2 Research Objectives

This research starts with the following questions: what are the factors that contribute to variation in construction costs?; and how are these factors interacted with construction costs? Thus, this research departs from the comprehensive literature review for identifying the potential factors that might impact construction costs and the development of an explanatory model to investigate relations between construction costs and factors. The explanatory model takes into account a comprehensive list of the factors, which represent construction market, macroeconomic, and oil market conditions, to explain the variation in construction costs. Next, this research examines how the relations between construction costs and the factors vary with geographical locations of projects.

The development of local forms of explanatory models provides a better understanding for spatial heterogeneity of the relations between construction costs and the factors. Lastly, the logical next step is to address the variation in construction costs after large-scale disasters. This research examines the impact of large-scale disasters on the variation in construction costs. Therefore, this research attempts to take into account various aspects of factors, including market conditions, geographical locations of projects, and large-scale disasters, in explaining the variation of construction costs.

The overarching objective of this research is to assess the effects of several potential variables on explaining variations in submitted unit price bids for major asphalt line items in highway projects.

Specific Objectives:

1. Develop an explanatory model to explain variation in the submitted unit price bids
2. Assess the relations between the submitted unit price bids and potential explanatory variables
3. Identify the relative importance of potential explanatory variables
4. Develop a local form of regression for describing variations in the submitted unit price bids
5. Assess the spatial variations of relations between the submitted unit price bids and explanatory variables
6. Monitor the process of variation in the submitted unit price bids after large-scale disasters

7. Identify the significant shifts of variation in the submitted unit price bids after large-scale disasters

1.3 Research Methodology

The following methodologies are used to achieve the objectives of this research

- Multiple regression analysis: developing an explanatory model to explain the variation in the submitted unit price bids and assess the relations between the submitted unit price bids and potential explanatory variables
- Geographically weighted regression analysis: developing a local form of regression and exploring spatial variation in the submitted unit price bids
- Profile monitoring technique (i.e., regression analysis and cumulative sum control chart): monitoring process of the variation in the submitted unit price bids after Hurricane Katrina and Rita.

This research has three primary hypotheses as follows:

1) $\boldsymbol{H_1}$: There will be significant relationship between submitted unit price bids and potential explanatory variable (s).
2) $\boldsymbol{H_2}$: There will be spatial heterogeneity for relationship between submitted unit price bids and explanatory variables.
3) $\boldsymbol{H_3}$: There will be significant change/shift of the process of submitted unit price bids after large-scale disasters.

1.4 Research Motivation

In practice, estimating construction costs during project development highly relies on two major sources: (1) historical cost data and (2) experience and judgement of estimators. For instance, during the planning phase, where there is not enough project information available, the cost engineers and estimators use recent historical cost data to develop cost estimates and rely on experience and their judgement to adjust cost estimates throughout project development. However, transportation agencies face significant staff turnover and the loss of technical expertise and historical knowledge, which aggravate the discrepancies in construction costs. In addition, they lack tools for cost estimating and data tracking and management for cost estimation and management for highway projects (Paulsen 2008; Gransberg et al. 2017). Therefore, it is essential to have tools to aid cost estimators for estimating more accurate construction cost and making right investment decisions for transportation projects.

1.5 Research Contribution

This research aims to contribute to the body of knowledge through the examination of the relative relations of several potential variables on explaining variations in highway construction cost. Examining the variation of construction costs provides useful information that may be used for construction estimate particularly for government organizations or public projects in the planning and programming of the future highway construction projects.

1.6 Organization of Dissertation

This dissertation is organized into seven chapters. It also includes four appendices containing supporting information for this research. Chapter 2 provides the comprehensive review of literature that focuses on construction cost variation. Chapter 3 discusses the dataset used in this research. It describes the details of the data including the submitted unit price bids and potential explanatory variables. In Chapter 4, regression analysis is conducted to develop an explanatory model and explore the relations between submitted unit price bids and potential explanatory variables. Chapter 5 focuses on the spatial variation of the submitted unit price bids and the relationship between the submitted unit price bids and potential explanatory variables. Chapter 6 discusses the impact of Hurricane Katrina and Rita on the submitted unit price bids for highway construction projects. Chapters 4 and 5 use the dataset collected in the State of Georgia for highway construction projects, while Chapter 6 use the dataset collected in the State of Louisiana for highway construction projects. Lastly, a summary, conclusions, and recommendations of this research are discussed in Chapter 7.

CHAPTER 2. LITERATURE REVIEW

2.1 General

This chapter presents a summary of previous studies that have been conducted on cost variation using various types of cost data, including bid price, tender price index, and construction cost index.

2.1.1 Variation in Bid Price

Herbsman (1986) conducted a statistical analysis to develop a forecasting model for construction cost using data gathered from highway projects in the State of Florida between 1968 and 1984. The author concluded that contract prices are significantly affect by input costs of material, labor, and equipment, and the total volume of contracts bid in a particular year. However, the author did not take into account project characteristics and other market condition factors.

Hegazy and Ayed (1998) identified factors affecting highway construction costs by using 18 bids submitted by construction contractors in Newfoundland, Canada. This study found out that the project characteristics including season, location, type of project, contract duration, and contract size significantly impact changes in construction costs. But, this study did not consider other potential factors related to project characteristics, construction market, and economic conditions such as competition in the bidding process, construction demand, and inflation rate.

Wilmot and Cheng (2003) studied 2,827 highway and bridge contracts in the State of Louisiana to examine impacts of project-specific factors and market condition indicators on submitted bid prices using regression analysis. They found out the construction market variables (i.e., prices of materials, labor, and equipment) and the quantity of the pay items are the most influential factors in explaining changes in the price of 5 pay items, embankment, concrete pavement, asphalt pavement, reinforcing steel, and structural concrete. Moreover, the author concluded that project characteristics including contract size, duration, location, and the quarter in which the contract is let have a significant impact on the price of the asphalt pavement pay item. However, the author did not consider other potential factors related to economic and oil market conditions to explain the changes in construction cost.

Li et al. (2008) conducted regression analysis to study the variation of construction using 927 bid prices submitted for public and private commercial and light industrial project in Utah. The authors showed that number of bidders, the value of the project, unemployment rate, and time of the bid opening have significant impact on the submitted bid prices.

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 both the volatility and expected change of the crude oil price has the positive effect on the bid prices. The author also concluded that the price trend in crude oil price (i.e., a difference between futures and spot prices of crude oil) has a statistically larger impact on the unit bid price than the volatility of crude oil price. Considering the effect of the crude oil prices, there is a need to examine the effect of oil market conditions on other oil-intensive bid items such as asphalt cement.

Shrestha and Pradhananga (2010) found out that the project characteristic, number of bidders in the bidding process, has a significant impact on explaining changes in bid prices using 435 bids on 113 public street projects in Clark County, Nevada. The authors concluded that there is a significant negative relationship between the number of bidders and the submitted bid prices. But, the authors did not take into account other significant factors regarding project characteristics and market conditions. For example, as regional projects, hauling distance of materials and the availability of material suppliers may significant impact on the productivity, construction cost, and schedule of a projects.

Mekki Basavaraj (2011) also conducted a regression analysis to explain the variation in unit price of asphalt mix design based on the quantity of the bid item. The author examined 500 bid prices of two asphalt mix designs, type S3 and type S4, used for pavement projects in the state of Oklahoma. The author found out that there is a negative relationship between the bid prices and the quantity of the bid item. However, the author concluded that the quantity of the bid item accounted for only partial variation in bid prices of asphalt mix designs and recommended that other variables be considered for explaining the variation in bid prices.

Wang and Liu (2012) also carried out regression analysis to study the variation of construction costs using bid prices of the asphalt mixture used in 607 highway asphalt resurfacing projects in Kentucky. The authors identified that that number of bidders, Kentucky asphalt price index, Kentucky diesel price index, and the recession factor have significant impacts on the bid prices. The authors also concluded that variation of the oil price can cause significant fluctuation of highway construction costs. But, the authors did not take into account any construction market conditions such as the prices of materials, labor, and equipment and construction demand in other construction industries.

Another study carried out by Shrestha et al. (2014) conducted a regression analysis to examine variation in the bid prices and identify the effect of the quantity of the bid item on the unit price using the bid data of 151 road projects conducted in Clark County, Nevada. The result of this study showed that contractors significantly relied on the quantity of the bid item in developing bid prices. The author found that the quantity of the bid item has a negative relationship with the bid prices. However, the authors did not consider other factors such construction market and economic condition factors that may affect the bid cost.

Ilbeigi et al. (2015) analyzed submitted bid prices of asphalt line items used in highway projects in the State of Georgia to explain variations in construction cost. To explain variation in the bid prices, the authors used several project characteristics, such as quantity of the bid item, total bid price, number of bidders, and project duration, asphalt volume in a particular year, and asphalt cement price index. The authors found out 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 Department of Transportation (GDOT) for asphalt line items. But, the authors lack considerations of other potential factors related to construction market and economic conditions in explaining variation in construction cost.

2.1.2 Variation in Tender Price Index

Akintoye and Skitmore (1993) conducted regression analysis to identify factors affecting the changes in construction cost using tender price index. The authors examined the effects of economic condition and construction demand and supply variables on construction cost. The author found that unemployment level, real interest rate, manufacturing profitability, number of registered construction firms, building cost index, construction productivity, and construction work stoppages are significant factors that lead to changes in construction cost. However, although the authors examined the effect of both construction market and macroeconomic conditions on the changes in the construction cost, the authors did not comprehensively consider other construction market or economic condition factors such as prices of materials and labor wages. In addition, explaining changes in construction cost using tender price index contains limitation in examining the impact of project characteristics.

Akintoye et al (1998) identified the leading indicators for examining and forecasting variation of the United Kingdom tender price index. The authors conducted correlation and regression techniques to identify the leading indicators of construction price movements. The author found that unemployment level, construction output, industrial production, and ratio of price to cost indices in manufacturing are consistent leading indicators of the tender price index.

Ng et al. (2000) conducted a multivariate discriminant analysis to predict the changes in construction costs using the Hong Kong tender price index and the selected economic indicators. The authors indicated that the model with the economic indicator provided high accuracy in predicting the changes in the tender price index. The economic indicators used for developing a multivariate discriminant analysis model include interest rate, building cost, consumer price index, gross domestic product (GDP), construction output, GDP deflator, money supply, and unemployment rate. But, this study did not take into account other important factors regarding to construction market and oil market conditions such as labor wages, material prices, and fuel prices.

Another study carried out by Ng et al. (2004) conducted the integrated approach of regression analysis and time series analysis to forecast variation of Hong Kong tender price index. The authors used several market variables, such as building cost index, composite consumer price index, an implicit gross domestic product deflator, and showed their capability to forecast variation in the tender price index. Wong and Ng (2010) studied variation in Hong Kong tender price index using a vector error correction modeling approach. The author found that GDP, construction output, and building cost index is cointegrated with the tender price index.

2.1.3 Variation in Construction Cost Index

Williams, T. P. (1994) studied changes in construction cost index (CCI) published by the Engineering News-Record (ENR) using several factors, such as percent change of construction cost index, the prime lending rate, and number of housing starts for the month.

In another study conducted by Hwang (2009), the author also analyzed the ENR CCI using dynamic regression analysis. The author developed a dynamic regression model using the interest rate, the number of new residential building units, and the consumer price index to study and predict changes in CCI.

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, and 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. However, since such construction cost index covers the general construction industry, it has a limitation in measuring variation in the construction cost of the particular construction industry such as highway and residential construction industries. In a follow-up work (Shahandashti and Ashuri 2013), the identified leading indicators were utilized to develop multivariate time series models to forecast CCI.

Jiang et al. (2014) developed the vector correction models to identify the relationships between the key influencing factors (i.e., value of construction approval and value of construction completion) of construction demand and supply and the construction price. The authors concluded that the fluctuation in construction demand and supply affects the price levels of construction. But, this study lacks considerations of economic and oil market conditions in explaining changes in the construction price index.

Shahandashti and Ashuri (2015) conducted multivariate time series analysis to study and predict variation in the national highway construction cost index (NHCCI) published by the federal highway administration (FHWA). The authors identified the leading indicators of the National Highway Construction Cost Index (NHCCI) through the granger causality test. The authors concluded that the identified indicators, including average hourly earnings and crude oil price, have power to forecast variation of NHCCI.

2.2 Summary

It can be concluded that various factors affecting construction cost are studied in different studies. First, although several studies that focused on the bid price have primarily attempted to quantify the impact of project related factors and some other factors, they have a lack of focus on market factors related construction market, macroeconomic, and oil market conditions. Next, the studies related to tender price index and construction cost index mainly focused on the market factors, rather than project related factors, for investigating variation in construction costs. Thus, this research attempts to take a comprehensive list of variables into account in explaining variation in construction cost for highway projects.

CHAPTER 3. DATA COLLECTION

3.1 Submitted Unit Price Bids

This research collected submitted unit price bids for major asphalt line items used for pavement projects and examined the effects of several potential factors on the unit price bids. Chapter 4 and 5 used submitted unit price bids for hot mixed recycled asphaltic concrete for multiple regression and geographically weighted regression modeling, while Chapter 6 used submitted unit price bids for superpave asphaltic concrete for profile monitoring.

3.1.1 Hot Mix Recycled Asphaltic Concrete

Data on the submitted unit price bids were collected from resurfacing and widening projects let in state of Georgia between 2008 and 2015. Chapter 4 and 5 used the winnings bids (i.e., the lowest bids) for developing empirical model. The most common asphalt line items for resurfacing and widening projects in the state of Georgia are hot mix recycled concrete (i.e., 9.5 mm, 12.5 mm, and 19 mm Superpave), a mix of reclaimed asphalt pavement, reclaimed asphalt shingles, virgin aggregate, hydrated lime and neat asphalt cement (Floy et al. 2013). Hot mix recycled asphaltic concrete is also the most common asphalt line items used by state departments of transportation (state DOTs) in the United States (Kandhal et al. 1995). Hot mix asphaltic concrete used in resurfacing and widening projects is measured in tons. The variable of interest in this study, the unit price bid, is measured in U.S. dollars per ton of asphalt mixture.

Georgia DOT (GDOT) has divided the state into seven districts that are maintained by seven offices for the districts. Figure 1 depicts the geographical location of the seven districts. For instance, District 1 is located in the North East of the state of Georgia, which has mountainous and rolling terrains. District 3 is located in the Middle West of the state of Georgia, which has a rolling terrain. District 5 is located in South East of the state of Georgia, which has flat and coastal terrains.

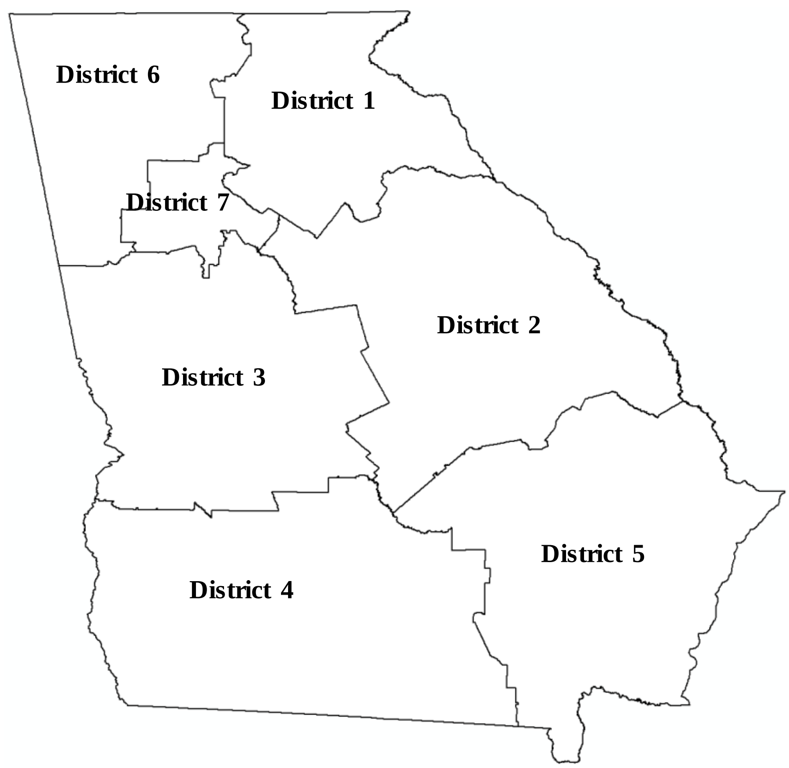


Figure 1 - GDOT District Map

Figure 2 shows monthly values of average unit price bids for asphalt line items from January 2008 to December 2015 in resurfacing and widening projects in three districts in the state of Georgia. Considerable variations can be noticed in unit price bids over time and among the three regions.

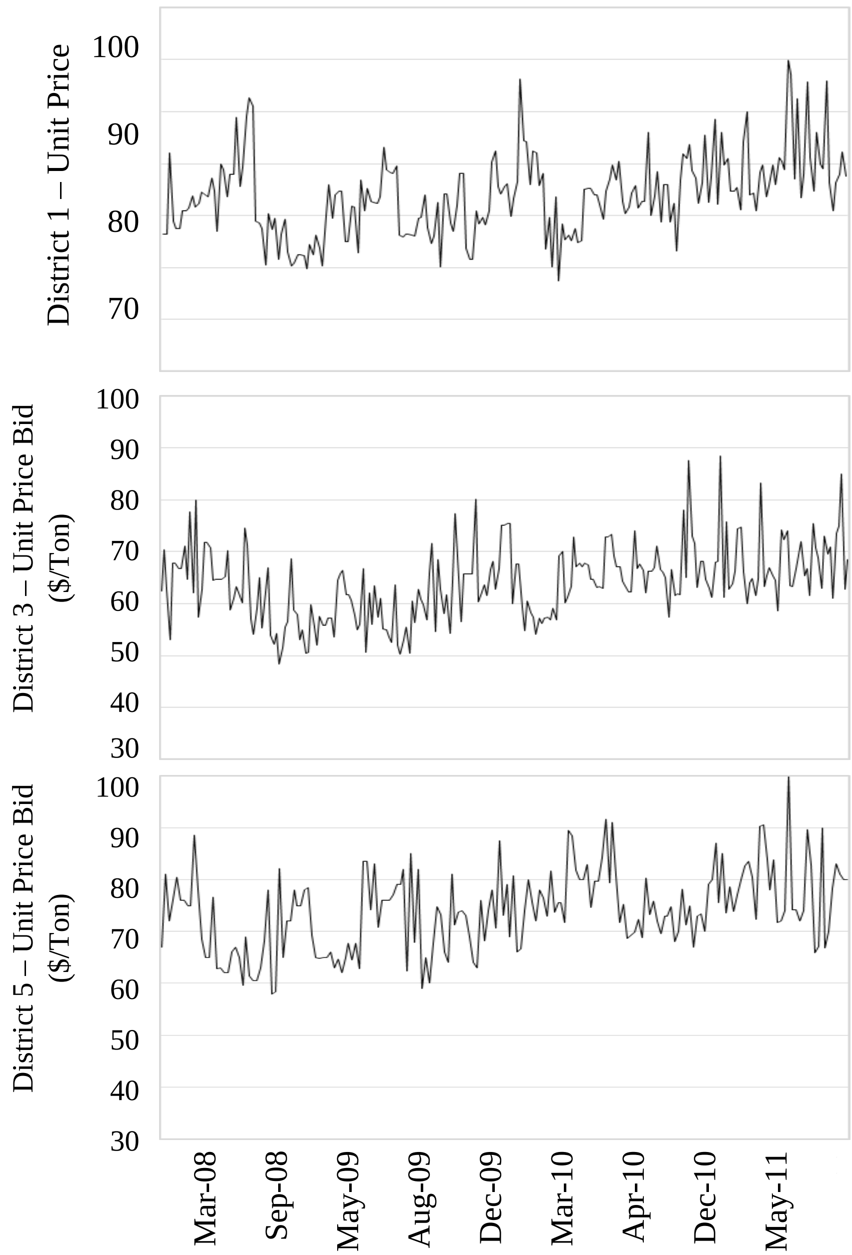


Figure 2 - Average Unit Price Bids for Major Asphalt Line Items over Time in GDOT's Districts 1, 3, and 5

3.1.2 Superpave Asphaltic Concrete

As superpave asphaltic concrete is one of most common asphalt line items for pavement projects in the State of Louisiana, the dataset consists of submitted unit price bids for this line item retrieved from the BidTabs database of Oman Systems. Chapter 6 monitors the process of the winning bids submitted between 2004 and 2015 for highway pavement projects let in the state and refers to submitted unit price bids by construction contractors between 2004 and 2008 to analyze the short-term impact of Hurricanes Katrina and Rita. To investigate the long-term impact of the hurricanes, this research analyzes the submitted unit price bids for superpave asphaltic concrete between 2004 and 2015. In addition, it defines the period between August 29, 2005, and September 18, 2005 as the time during which Hurricanes Katrina and Rita hit the Gulf Coast of the United States.

3.2 Potential Explanatory variables

The relations of the following two major tiers with subgroups of variables are examined in this research. Tier 1 represents project specific variables and Tier 2 represents global and external variables, which are used for explaining the variation in submitted unit price bids in Chapters 4 and 5. In addition, to conduct profile monitoring for examining the impact of large-scale disasters on submitted unit price bids in Chapter 6, this research selected the explanatory variables that most strongly reflect project characteristics and construction market conditions.

3.2.1 Tier 1: Project Specific Variables

Tier 1 contains variables that represent project specific characteristics. There have been several studies that examine the relation between project characteristics and construction costs. A study conducted by Shane et al. (2009) presented that key features of a project, such as duration, number of bidders, and complexity, have significant correlations with construction costs.

Time of year that the project was let is examined with the quarterly dummy variables. Time of year is an important factor in contract's decision making process in submitting bids for highway projects. Since the temperature of hot mixed asphalt is critical to obtaining compaction and longevity of the paved surfaces and patches, contractors should pay special attention to maintaining the certain temperature of the asphalt in manufacturing, delivering, and paving with consideration of the environmental conditions (e.g., ambient temperatures and base temperatures). The ambient temperature is the temperature of the surrounding air in the project site. The base or ground temperature indicates aggregate and existing asphalt temperatures. The ambient and base temperatures can be determined by the geographical locations of projects. For instance, there would be significant difference in the ambient and base temperatures in North Georgia and those in the south or on the coast. Thus, this research considers geographical locations of the project using binary variables that represent GDOT's seven districts.

A common strategy used by state DOTs to deal with material price volatility is to offer price adjustment clauses for fuel, liquid asphalt, cement, steel, and other highway materials in construction contracts. Price adjustment clauses aim to hedge the risk of material prices. Availability of price adjustment clauses in a contract changes the contractor's risk profile that may lead to significant variation in the submitted unit price bid (Skolnik 2011). Georgia department of transportation (GDOT) has implemented the price adjustment clause for asphalt cement since September 2005. Since 2005, GDOT had two revisions for the trigger point and the cap of the price adjustment clause. The first edition of the price adjustment clause was in place from September 2005 to July 2009 with 5% of the trigger point and 50% of the cap. The second edition was from August 2009 to July 2011 with 5% of the trigger point and 125% of the cap and the third and the last edition was from August 2011 to present with 0% of the trigger point and 60% of the cap (GDOT 2014). This research uses binary variables that represent the three types of price adjustment clauses that have been used for asphalt cement in the GDOT's contract as shown in Table 1.

Table 1 - Types of Price Adjustment Clause between 2005 and Present

Years	Types	Description
September 2005 – July 2009	Type I	The trigger point of 5% and the cap of 50%
August 2009 – July 2011	Type II	The trigger point of 5% and the cap of 125% (only eligible for the project that exceeds a duration of 365 days)
August 2011 - Present	Type III	The trigger point of 0% and the cap of 60% (only eligible for the project that exceeds a duration of 365 days)

In addition, Lack of access to the job site and distance from manufacturing plants and source of materials can cause a significant difference in construction costs for highway pavement construction projects (Tran et al. 2014). Terrain type and geographical location are important determinants of changes in construction costs (EU framework 1998; Flyvbjerg et al. 2002).

In this research, the following variables describing project characteristics are considered:

a) **Project Duration**: It is a period between notice to proceed and completion dates (Retrieved from the GDOT GeoPi system) (Days).
b) **Quantity of the Bid Item**: It is a volume of asphalt line item in the submitted bid (Retrieved from the BidTabs database) (Ton).
c) **Total contract Price**: It is the lowest total bid price submitted by highway contractors that bid on the project (Retrieved from the BidTabs database) (Dollars).
d) **Pavement Length**: It is a paving length of the project (Retrieved from the BidTabs database) (Miles).
e) **Number of Pay Items**: It is a proxy variable for project complexity in the procurement process (Rueda Benavides 2013) as contractors need to perform works in as many areas as specified by the pay items in the contract (Retrieved from the online Bid Express system) (Numbers).
f) **Number of Bidders**: It is the number of highway contractors that submitted bids for the project (Retrieved from the BidTabs database) (Numbers).
g) **Terrain of the Project**: It is the geographical feature of the project location. Georgia has four types of terrain: rolling, flat, mountainous, and coastal (GDOT 2009) (Boolean Indicator).

h) **Districts of the Project**: Georgia DOT (GDOT) has divided the State into 7 districts. These districts are used as categorical variables in regression analysis (Retrieved from GDOT Website: Districts) (Boolean Indicator).

i) **Number of Nearby Asphalt Plants (within 50 miles)**: It is calculated as the number of asphalt plants within 50 miles from the center of the project (Retrieved from GDOT Website: Qualified Products List). Distance from an asphalt plant to the paving location should not exceed 50 miles (80km) (ODOT 2016) (Numbers).

j) **Hauling Distance between Asphalt Plant and Project Location**: It is calculated as the hauling distance between the center of the project and the closest asphalt plant to the project location (Retrieved from GDOT Website: Qualified Products List) (Miles).

k) **Hauling Distance between Quarry and Asphalt Plants**: It is calculated as the hauling distance between the closest asphalt plant to the project location and the closest quarry to the asphalt plant (Retrieved from GDOT Website: Qualified Products List) (Miles).

l) **Price Adjustment Clause**: It is price adjustment clauses for fuel, liquid asphalt, cement, steel, and other highway materials in construction contracts (Retrieved from GDOT Section 109-Measurement and Payment) (Boolean Indicator).

3.2.2 Tier 2: Global and External Variables

Tier 2 contains global and external variables that represent overall construction market, macroeconomic, and energy market conditions. There are significant differences in regional/local economic development condition, population, and market structure. The level of construction activities varies depending on regional/local market conditions (Jiang 2013). Regional/local construction market conditions (e.g., construction demand) are considered as the determinant of construction costs (Jiang 2013). Skitmore (1987) showed that different levels of construction activities in various regions cause significant variations in construction costs. To measure the different levels of construction activities in various levels (local, state, and national levels), this research collected the several variables that represent the levels of construction activities.

According to Schexnayder et al. (2003), price changes in labor and materials place a critical burden on highway agencies and contractors in estimating accurate construction costs. Factors, such as prices of construction materials, wages of construction workers, and level of other construction activities (e.g., the state of residential construction market) influence construction costs. A study conducted by Akintoye and Skitmore (1993) presented that understanding macroeconomic factors affecting the variation in construction costs is crucial for establishing a construction investment strategy for a project. For instance, since the stable supply of labor force lead to a decrease of unemployment, which may results in the level of labor wage rise because of shortages in particular occupations (Wong et al. 2005). Of course, the increase of construction labor wage causes the increase of construction costs. Thus, this research selected three variables that represent employment levels (i.e., number of hires in the construction industry, population, and unemployment).

Highway resurfacing projects are major consumers of oil products, such as asphalt cement and diesel. Changes in the oil price can cause variation in construction costs

(Akintoye and Skitmore 1993; Wang and Liu 2012). Therefore, oil market conditions should be taken into account in pricing construction costs (Damnjanovic and Zhou 2009). The following variables describes construction market, macroeconomic, and energy market conditions:

a) **Total Monthly Asphalt Volume of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County:** It is the sum of the asphalt volume of resurfacing and widening projects awarded in the same month that the project is awarded in the same county as of the project in the State of Georgia (Retrieved from the BidTabs database) (Dollars).

b) **Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County**: It is the number of resurfacing and widening projects awarded in the same month that the project is awarded in the same county as of the project in the State of Georgia (Retrieved from the BidTabs database) (Numbers).

c) **Total Number of Projects Awarded in the Same Month at the State Level**: It is the number of projects awarded in the same month that the project is awarded in the State of Georgia (Retrieved from the Bid Express online bidding system) (Numbers).

d) **Total Dollar Value of Projects Awarded in the Same Month at the State Level**: It is the total dollar value of projects awarded in the same month that the project is awarded in the State of Georgia (Retrieved from the Bid Express online bidding system) (Dollars).

e) **Total Asphalt Volume of Projects Awarded in the Same Month at the State Level**: It is the total asphalt volume of projects awarded in the same month that the project is awarded in the State of Georgia (Retrieved from the GDOT Item Mean Summary) (Dollars).

f) **Common Labor Index**: This index represents and tracks average total wages for laborers, including fringe benefits, in the U.S. construction industry over time (Retrieved from the ENR) (Index).

g) **Construction Cost Index**: This index represents and tracks the local prices of skilled labor and materials, collected in the city of Atlanta, in the construction industry over time. Ashuri and Lu (2010) applied time series analysis to forecast trends in construction cost index (Retrieved from Engineering News-Record) (Index).

h) **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 (Retrieved from the U.S. Bureau of Labor Statistics) (Dollars).

i) **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 (Retrieved from the GDOT Office of Materials) (Index).

j) **Gross Domestic Product (GDP) of the Georgia Construction Industry**: It is the total gross value of construction work in the State of Georgia (Retrieved from U.S. Bureau of Economic Analysis) (Millions of Dollars).

k) **Labor Productivity**: It is the ratio of the highway construction output in the U.S. to the labor hours devoted to the production of that output (provided by U.S. Bureau of Labor Statistics) (Index).

l) **Material Price Index**: This index represents and tracks the average cost of major materials, such as structural steel, in the U.S. construction industry over time (Retrieved from the ENR) (Index).

m) **National Highway Construction Cost Index**: It is a highway construction index that tracks changes in highway construction costs (Retrieved from the FHWA) (Index).

n) **Number of Establishments in Private Construction Industry**: It is the number of private construction establishments in the State of Georgia (Retrieved from the U.S. Bureau of Labor Statistics) (Numbers).

o) **Number of Hires**: It is the total number of additions to the payroll in the U.S. construction industry during the month that the project is awarded, which is provided through the Job Openings and Labor Turnover Survey (Retrieved from the U.S. Bureau of Labor Statistics) (Numbers).

p) **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 in the U.S. This index was utilized by Wang and Ashuri (2016) to forecast construction cost (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

q) **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 in the U.S. (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

r) **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 U.S. construction industry over time (Retrieved from the ENR) (Index).

s) **Value of Construction Put in Place (Pavement)**: It is a monthly estimate of total dollar value of pavement construction work done in the South region, the U.S., measured in Millions of Dollars (Retrieved from the U.S. Census Bureau) (Millions of Dollars).

t) **Value of Construction Put in Place (All construction)**: It is a monthly estimate of total dollar value of construction work done in the State of Georgia measured in Millions of Dollars (Retrieved from the U.S. Census Bureau) (Millions of Dollars).

u) **Average weekly wage (all industry)**: It is an average weekly wage for all industries that covers 98 percent of the U.S. economy. It is measured at the county level in the State of Georgia (Retrieved from the U.S. Bureau of Labor Statistics) (Dollars).

v) **Consumer Price Index (South)**: It is an economic indicator of average change of prices for purchasing consumer goods and services in the South region (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

w) **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. (Retrieved from the Standard Poor’s Dow Jones Indices) (Index).

x) **Inflation rate**: It is the rate of general rising prices for goods and services, and falling of the purchasing power of currency (Retrieved from US Inflation Calculator) (Percentage).

y) **Population**: It is the number of individuals who reside in the State of Georgia. It is measured at the county level (Retrieved from the U.S. Census Bureau) (Numbers).

z) **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 in the U.S. (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

aa) **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 in the U.S. (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

bb) **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 in the U.S. (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

cc) **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 in the U.S. (Retrieved from the U.S. Bureau of Labor Statistics) (Index).

dd) **Unemployment**: It is a count of people who are eligible to work but unable to find a job. It is measured at the county level in the State of Georgia (Retrieved from the U.S. Bureau of Labor Statistics) (Numbers).

ee) **Crude Oil Price of West Texas Intermediate (WTI)**: It is the spot price of unrefined petroleum product in the U.S measured in Dollars per Barrel (Retrieved from the Federal Reserve Bank of St. Louis) (Dollar per Barrel).

ff) **Diesel Retail Price**: It is the spot price of diesel for the Lower Atlantic States (e.g., Georgia) measured in Dollars per Barrel (Retrieved from the U.S. Energy Information Administration) ($ per Gallon).

gg) **Fuel Price Index**: It is an average Statewide selling price of Unleaded Regular Gasoline and Diesel Fuel in Georgia (Retrieved from the GDOT's website) ($ per Gallon).

Table 2 presents summary statistics of the input data including the mean, standard deviation, minimum and maximum of the response and explanatory variables.

Table 2 - Descriptive Statistics of Response and Explanatory Variables

Variables	Mean	Std. Deviation	Minimum	Maximum
Submitted Unit Price Bids for Asphalt Line Items	68.037	8.488	44.470	102.030
Project Specific Variables				
Quantity of the Bid Item	8988.919	9836.928	20.000	105125.000
Total Contract Price	2731815.868	6307494.210	72482.000	63652379.530

Table 2 Continued

Number of Bidders	**3.650**	**1.601**	**1.000**	**10.000**
Number of Pay Items	34.687	44.761	4.000	360.000
Ratio of the Bid Item	42.126	25.081	0.046	92.806
Project Duration	328.918	232.983	88.000	2118.000
Pavement Length	6.836	4.376	0.047	29.727
Quarter 1	0.233	0.423	0	1
Quarter 2	0.340	0.474	0	1
Quarter 3	0.149	0.356	0	1
Quarter 4	0.278	0.448	0	1
Rolling	0.691	0.462	0	1
Flat	0.211	0.408	0	1
Mountainous	0.048	0.214	0	1
Coastal	0.050	0.217	0	1
District 1	0.155	0.362	0	1
District 2	0.168	0.374	0	1
District 3	0.172	0.377	0	1
District 4	0.168	0.374	0	1
District 5	0.135	0.342	0	1
District 6	0.088	0.284	0	1
District 7	0.114	0.318	0	1
2005 Provision	0.218	0.413	0.000	1.000
2009 Provision (Less than 366 days)	0.434	0.496	0.000	1.000
2009 Provision (Greater than or Equal to 366 days)	0.019	0.135	0.000	1.000
2011 Provision (Less than 366)	0.262	0.440	0.000	1.000

Table 2 Continued

2011 Provision (Greater than or Equal to 366 days)	**0.068**	**0.251**	**0.000**	**1.000**
Hauling Distance between Asphalt Plant and Project Location	12.808	7.641	0.151	37.439
Hauling Distance between Quarry and Asphalt Plants	59.170	27.991	0.000	141.962
Number of Nearby Asphalt Plants (within 50 miles)	14.370	12.260	0.000	46.000
Global and External Variables				
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	874735.378	849483.866	7280.000	6948009.560
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	1.975	1.776	1.000	15.000
Total Number of Projects Awarded in the Same Month at the State Level	41.590	26.411	4.000	89.000
Total Dollar Value of Projects Awarded in the Same Month at the State Level	82098830.853	38948967.756	1851745.000	316340893.000
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	39089833.474	24898484.922	42365.000	141027456.023
Asphalt Cement Price Index	488.097	85.690	320.000	750.000
Common Labor Index	18953.766	1135.803	17084.000	21705.000
Construction Cost Index	8918.689	510.367	8090.000	10128.000
Equipment Operator Wages for Paving	14.548	0.640	13.410	15.949

Table 2 Continued

Gross Domestic Product of the Georgia Construction Industry	**15444.462**	**1996.627**	**13762.000**	**20740.672**
Labor Productivity	85.672	5.265	80.961	99.453
Material Price Index	2768.268	141.456	2577.000	3073.000
National Highway Construction Cost Index	1.115	0.077	1.041	1.352
Number of Establishments in Private Construction Industry	292.908	495.982	0.000	2747.667
Number of Hires	354.936	97.244	173.000	522.000
Producer Price Index for Construction Machinery Manufacturing	225.996	9.642	209.500	245.500
Producer Price Index for Construction Sand and Gravel Mining	277.116	14.006	255.200	323.100
Skilled Labor Index	8546.474	465.451	7796.000	9696.000
Value of Construction Put in Place for Pavement	20842.637	1507.176	5586.646	22438.917
Value of Construction Put in Place for All Construction	7476.934	1754.972	1337.167	10224.000
Average weekly wage for All Industry	664.377	166.364	408.667	1428.667
Consumer Price Index (South)	215.811	7.961	203.501	232.269
Dow Jones Industrial Average	12050.622	2324.682	7235.470	17931.750
Inflation Rate	1.876	1.560	-2.100	5.600
Population	142512.337	240670.936	1670.000	1007803.000
Producer Price Index for Gasoline Products	250.553	54.078	114.500	343.800

Table 2 Continued

Producer Price Index for Steel Mill Products	**195.836**	**20.977**	**153.000**	**257.000**
Producer Price Index for No. 2 Diesel Fuel Products	273.761	68.869	139.200	431.900
Producer Price Index for Crude Petroleum Products	242.505	60.659	94.900	384.300
Unemployment	6059.982	10572.476	67.000	53451.000
Crude Oil Prices: West Texas Intermediate (WTI)	87.034	19.908	41.120	133.880
Diesel Retail Prices	3.366	0.656	2.074	4.711
Fuel Price Index	2.950	0.576	1.566	4.042

3.2.3 Potential Variables for Investigating Impact of Hurricane Katrina and Rita on Submitted Unit Price Bids

Potential variables for Chapter 6 were selected based on literature review and regression modeling. With respected to project related factors, the top two variables that were identified in Chapter 4 were collected for monitoring the process of submitted unit price bids after large-scale disasters. In addition, global and external factors were selected based on literature review. A study conducted by Akintoye et al. (1998) found that unemployment has a significant impact on variation in construction costs. Unemployment reflects the changes in market conditions (i.e., macroeconomic conditions), as well as unemployed person in the labor force (Ng. et al. 2000). Want and Liu (2012) showed that oil price is highly related to construction costs of highway resurfacing projects. Furthermore, since the construction industry has limited resources (e.g., labor, materials, and equipment), the boom in other construction industry (e.g., residential or commercial sectors) can lead to insufficient resources for the highway sector. Thus, because building cost index reported by ENR and building permits for new residential construction reported by the U.S Census Bureau reflect the local conditions of the construction market, these variable were selected and collected based on regional and city levels. The following potential variables are used for Chapter 6.

a) **Quantity of the Bid Item**: It is a volume of Superpave asphaltic concrete line items in the submitted bid (Retrieved from the BidTabs database) (Ton).

b) **Total contract Price**: It is the lowest total bid price submitted by highway contractors that bid on the project (Retrieved from the BidTabs database) (Dollars).

c) **Crude Oil Price of West Texas Intermediate (WTI)**: It is the spot price of unrefined petroleum product in the U.S measured in Dollars per Barrel (Retrieved from the Federal Reserve Bank of St. Louis) (Dollar per Barrel).

d) **Building Cost Index**: It is the composite index that measures the overall performance of the building construction industry over time by tracking local prices of skilled labor and materials collected in the city of New Orleans, Louisiana (Retrieved from the ENR) (Index).

e) **Building Permits for New Residential Construction**: It is the number of new housing units in the southern region authorized by building permits for privately-owned residential construction (Retrieved from the U.S. Census Bureau) (Numbers).

CHAPTER 4. DEVELOPING A MULTIPLE REGRESSION MODEL

4.1 Introduction

Based on the above literature review, it can be concluded that a wide range of variables has been identified in different studies to explain variations in construction cost. There is a value in conducting a research study that attempts to consider a comprehensive list of variables with potentials to explain the variations. The study needs to simultaneously take into account all possible explanatory variables to examine their relations with construction costs.

The other gap in the current literature is that the relative importance of potential explanatory variables needs to be measured to identify the most critical factors with the greatest impact on construction cost. This research aims to contribute to the body of knowledge through the examination of the relative relations of several potential variables on explaining variations in highway construction cost.

Examining the relations between submitted unit price bids and a comprehensive list of the potential explanatory variable can aid cost engineers or estimators to develop more accurate cost estimates during project development. Thus, this chapter conducts multiple regression analysis to develop an explanatory model for describing variations in submitted unit price bids and study the relationships between submitted unit price bids and potential explanatory variables.

4.2 Research Objective

The primary objectives of this chapter is as follows:

1. Develop an explanatory model to explain variation in the submitted unit price bids
2. Assess the relations between the submitted unit price bids and potential explanatory variables
3. Identify the relative importance of potential explanatory variables

The main hypothesis of this chapter is as follows:

Null Hypothesis (H_0): there will be no significant relationship between submitted unit price bids and potential explanatory variable (s)

Alternative Hypothesis (H_1): there will be significant relationship between submitted unit price bids and potential explanatory variable (s)

4.3 Research Methodology

This objective of this chapter is to identify the best set of explanatory variables that have capability to explain the submitted unit price bids.

Multiple Linear regression analysis allowed to identify significant factors that affect submitted unit price bids and determine to what extent submitted unit price bids and potential explanatory variables are related. The generic form of linear regression model is as follows (Washington 2010):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p + \varepsilon$$

where Y is the submitted unit price bid, X_p is pth explanatory variable, β_0 is a constant term, β_p is a coefficient for pth explanatory variable, and ε is a normally and independently distributed error term with mean 0 and constant variance σ^2. Ordinary least squares (OLS) estimation is employed for estimating regression model parameters. OLS requires a minimum solution of the squared disturbances (Washington 2010).

To develop a regression model, this research implements the following steps:

1. Inspect input data for identifying outliers;
2. Conduct pairwise correlation between submitted unit price bids as the dependent variable, on one hand, and each of the potential explanatory variables, on the other hand, to assess linear correlation (Note that in some cases, variable transformation (e.g., logarithmic transformation) should be performed if variable transformation better reflects the nature of a relation between the explanatory variable and the submitted unit price bids);
3. Conduct pairwise correlation to diagnose and remove multicollinearity issues between an explanatory variables and other variable (s) using the calculated variance inflation factors (VIFs) for the potential explanatory variables; and
4. Implement a stepwise selection process to identify the best set of explanatory variables.
5. Examine residual plots to check error variance assumptions in regression modeling; and
6. Interpret the results of regression modeling.

An overview of the regression modeling process is depicted in Figure 3.

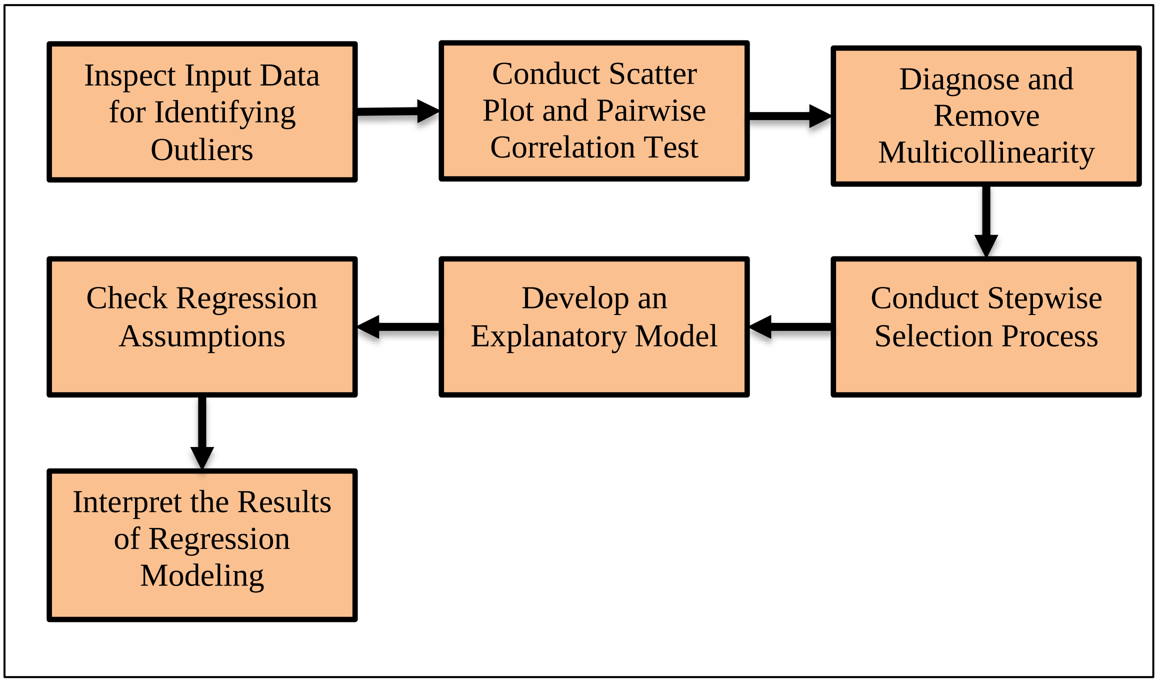


Figure 3 - An Overview of the Regression Modeling Process

4.3.1 *Inspecting input data for identifying outliers*

Abnormal observations (i.e., outliers) should be identified and removed before moving further to develop a reliable regression model. Z-scores are calculated for all observations of submitted unit price bids in the original dataset. If the absolute value of $|z_i|$ is greater than 2.576 (representing 99% confidence level) the i^{th} submitted unit price bid is considered as an outlier and will be removed from further consideration. Based on z-scores, 33 outliers (2.3%) are detected. Thus, 1391 observations are used to develop a multiple regression model.

4.3.2 Conducting pairwise correlation between submitted unit price bid and any of the potential explanatory variables

Pairwise correlation is performed between submitted unit price bids as the dependent variable, on one hand, and each of the potential explanatory variables, on the other hand, to assess the degree of linear relationship. Scatter plot is also used to assess the nature of other relationship forms, such as quadratic, cubic, logarithm, exponential, and power relationships that might exist between the submitted unit price bid and the potential explanatory variable. Whenever appropriate, variable transformation (e.g., logarithmic) is conducted to better reflect the nature of a relationship between the explanatory variable and the submitted unit price bid. Appendix A presents scatter plots between submitted unit price bids and explanatory variables. Moreover, correlation analysis between submitted unit price bids and explanatory variables are presented in Appendix B.

4.3.3 Conduct pairwise correlation to diagnose and remove an explanatory variable that is highly correlated with other variable (s)

Pairwise correlation analysis is conducted to diagnose and remove multicollinearity issues between an explanatory variable and other variables. Significant collinearity between explanatory variables can result in inaccurate estimates of the regression coefficients. If there are very high correlations between explanatory variables (above .80

or .90), the explanatory variable should be removed from the list of explanatory variables. A correlation matrix is presented in Appendix C.

4.3.4 Implementing a stepwise selection process to develop a multiple regression model

A stepwise selection process is performed to identify the best combination of explanatory variables that creates a model with the highest explanatory power. The stepwise selection process starts with no predictors in the stepwise model. By adding a variable at each step, significances of all candidate variables are checked and a variable with largest F-statistic (i.e., *P*-value less than the significance level) is added. At each step of adding a variable, F-statistics for all variables in the model are diagnosed and any variables that are not significant are removed from the model. This process is repeated until all variables in the model are significant and any excluded variables are not significant. This paper uses two significance levels to add and remove variables, F-to-enter criterion with threshold of 0.05 and F-to-remove criterion with threshold of 0.1. The model that contains the best set of variables is selected based on the several model section criteria, including, the Akaike information criterion (AIC) and modified AIC (AICC). These statistics can be calculated using equations (Akaike 1974; Burnham and Anderson 2003; Jafarzadeh et al. 2013):

$$AIC = -2\ln L + 2k$$

$$AICC = AIC + \left\{\frac{[2(k+2)(k+3)]}{(n-k-3)}\right\}$$

where L is the log-likelihood for the model estimated, n is the number of corrected data sets, k in one (the intercept) plus the number of explanatory variables in a given model. The minimum AIC and AICC indicate that the model outperforms other models.

4.3.5 *Check error variance assumptions and multicollinearity issues in the developed regression model*

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

- Independent errors: The scatterplot of residual (i) against residual (i-1) is used to detect whether the residual terms are independent.
- Homoscedasticity: The scatterplot of residuals against predicted values is also used to detect whether the variance of the residual terms is evenly dispersed.
- Normality: The normal probability quantile-quantile (Q-Q) plots of regression residuals are used to assess whether the residuals are normally distributed across a linear line.

Lastly, variance inflation factor (VIF) is calculated for each of the identified explanatory variables, in order to assess multicollinearity issues (Montgomery et al. 2015). The VIF examines whether an explanatory variable has a strong linear relationship with the other explanatory variables. The equation to calculate VIF for variable X_p is:

$$VIF = (1 - R_p^2)^{-1}$$

where R_p^2 is the coefficient of multiple determination when X_p (pth explanatory variable) is regressed on the other explanatory variables in the model (Kutner et al. 2005). Multicollinearity can result in misleading results and erroneous interpretation of the regression model. If the value of VIF is greater than 10 for an explanatory variable, severe multicollinearity exists in the regression model and therefore, the variable needs to be removed from further consideration.

4.3.6 Interpret the results of regression modeling

The relations of potential explanatory variables on the submitted unit price bids are examined using the calculated *P*-value in the developed regression model. Significant explanatory variables are identified at the significance level of $\alpha = 5\%$. The sign and the magnitude of the coefficients of the significant variables show the direction of the relation between the significant explanatory variable and the submitted unit price bid. Explanatory variables need to be standardized, in order to compare their relative impacts on the dependent variable (Washington et al. 2010). Standardized coefficients (i.e., beta coefficients) of explanatory variables are used to determine the relative importance of explanatory variables in the regression model. The higher the absolute value of the beta coefficient is the stronger the relation of the respective explanatory variable is with the submitted unit price bid.

The significance of the developed regression model is measured by two statistical tests, including the *F*-statistic. The *F*-statistic is used for assessing model fit with the null hypothesis that all of the estimated parameters are zero. The *F*-statistic is calculated using the following equation:

$$F = \frac{\sum_{i=1}^{n}(\hat{Y}_i - \bar{Y})/k-1}{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)/n-k},$$

where Y_i is the observed response variable, $\hat{Y}_i$ is the predicted response variable, $\bar{Y}$ is the mean value of actual response variable, k is the number of estimable parameters in the model, and n is the number of corrected data sets (Washington et al. 2010). If the *F*-statistic is statistically significant at the significance level of $\alpha = 5\%$, the null hypothesis is rejected. Adjusted R-squared is a measure of the variation that is explained by a model (Washington et al. 2010). Adjusted R-squared is calculated with the following equation (Washington et al. 2010):

$$Adjusted\ R - squared = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)/n-k}{\sum_{i=1}^{n}(Y_i - \bar{Y})/n-1}.$$

4.4 Results and Discussion

As the first step, outliers in the dataset are detected. Based on z-scores, 33 outliers (2.3%) are detected. Thus, 1391 observations are used to develop a multiple regression model. Variable transformation is conducted based on the results of scatter plot assessment and Pearson correlation test. The natural logarithm transformation is applied on several variables, quantity of bid item, pavement length, Dow Jones industrial average, and unemployment. These variables showed better correlations with the submitted unit price bids after the transformation. In significant and unexpected correlation between submitted unit price bids and explanatory variables are removed from the list of potential explanatory variables. In addition, variables that are not statistically significant at the significance level of $\alpha = 5\%$ and have a weak correlation (i.e., correlation coefficient $r < 0.100$) with submitted unit price bids are excluded from the list of the potential explanatory variables. In addition, an explanatory variable that is highly correlated with other explanatory variable (s) are removed from the list of the potential explanatory variables. From the correlation analysis, 19 potential explanatory variables are selected out of the initial 52 variables for regression modeling.

The stepwise selection process is applied to develop the most appropriate multiple regression model to explain variation in submitted unit price bids. The stepwise process found the best set of explanatory variables throughout 20 steps as shown in Table 3.

Table 3 - Summary of Stepwise Selection Process

Step	Effect Entered	Effect Removed	AIC	AICC	*p*-Value
0	**Intercept**	**-**	9900.337	9900.346	.
1	**Dow Jones Industrial Average (in transformed natural logarithmic form)**	**-**	9597.910	9597.927	<.0001
2	**Number of Nearby Asphalt Plants**	**-**	9490.934	9490.963	<.0001
3	**Quantity of the Bid Item (in transformed natural logarithmic form)**	**-**	9396.646	9396.689	<.0001
4	**Asphalt Cement Price Index**	**-**	9286.703	9286.763	<.0001
5	**District 3**	**-**	9196.383	9196.464	<.0001

Table 3 Continued

6	Total Contract Price	-	**9130.638**	**9130.742**	**<.0001**
7	**District 5**	**-**	9062.759	9062.890	<.0001
8	**Ratio of the Bid Item**	**-**	9008.461	9008.621	<.0001
9	**Number of Bidders**	**-**	8967.040	8967.231	<.0001
10	**National Highway Construction Cost Index**	**-**	8931.236	8931.462	<.0001
11	**Pavement Length (in transformed natural logarithmic form)**	**-**	8891.296	8891.560	<.0001
12	**Coastal**	**-**	8875.836	8876.141	<.0001
13	**Flat**	**-**	8848.776	8849.125	<.0001
14	**-**	**District 5**	8848.908	8849.213	0.1441
15	**District 7**	**-**	8835.303	8835.652	<.0001
16	**Hauling Distance between Quarry and Asphalt Plants**	**-**	8830.980	8831.376	0.0120
17	**Number of Hires**	**-**	8828.314	8828.760	0.0309
18	**Quarter 2**	**-**	8823.719	8824.217	0.0103
19	**Construction Cost Index**	**-**	8821.611	8822.165	0.0428
20	**District 6**	**-**	**8819.471***	**8820.085***	0.0420

Note: * Optimal Value of Criterion; Selection stopped because all candidates for removal are significant at the 0.05 level and no candidate for entry is significant at the 0.1 level.

The selected model, based on AIC is the model at step 20. The identified set of the explanatory variables showed the best overall fit with the AIC of 8819.471 (the lowest value of AIC among the candidate models).

The final regression model contains 12 continuous and 6 binary explanatory variables. Table 4 summarizes the coefficients and the related statistics for the identified explanatory variables in the final stepwise model. All identified variables in the model show statistically significant at the significance level of $\alpha = 5\%$ (i.e., the absolute value of *t*-ratios is greater than 1.96) and capability in explaining variations of submitted unit price bids for asphalt line items.

Table 4 - Results of Multiple Regression Modeling

Rank	Variable	Parameter Estimate	Beta	t ratio	Pr > |t|	VIF
Binary Variable	**Intercept**	-35.714	67.379	-3.810	0.000	0.000
	Quarter 2	-1.407	-1.408	-2.650	0.008	2.702
	Flat	3.384	3.384	7.330	<.0001	1.512
	Mountainous	1.141	1.141	1.510	0.131	1.110
	Coastal	7.080	7.081	8.620	<.0001	1.353
	District 3	-2.457	-2.458	-5.270	<.0001	1.317
	District 6	1.107	1.107	1.900	0.058	1.166
	District 7	2.963	2.963	4.120	<.0001	2.229
1	**Quantity of the Bid Item (in transformed natural logarithmic form)**	-2.266	-3.049	-11.840	<.0001	2.820
2	**Total Contract Price**	3.66×10^{-7}	2.308	11.570	<.0001	1.693
3	**Asphalt Cement Price Index**	0.026	2.263	11.530	<.0001	1.640
4	**Dow Jones Industrial Average (in transformed natural logarithmic form)**	8.320	1.575	5.630	<.0001	3.328

Table 4 Continued

5	Number of Nearby Asphalt Plants	**-0.127**	**-1.563**	**-5.940**	**<.0001**	**2.946**
6	**Ratio of the Bid Item**	0.060	1.501	6.540	<.0001	2.242
7	**Pavement Length (in transformed natural logarithmic form)**	-1.589	-1.170	-6.630	<.0001	1.324
8	**National Highway Construction Cost Index**	15.186	1.164	5.780	<.0001	1.728
9	**Number of Hires**	0.011	1.080	3.880	0.000	3.286
10	**Number of Bidders**	-0.573	-0.917	-4.980	<.0001	1.441
11	**Construction Cost Index**	$1.41{\times}10^{-3}$	0.721	2.000	0.046	5.527
12	**Hauling Distance between Quarry and Asphalt Plants**	0.016	0.434	2.530	0.012	1.256
	Number of Observations			1391		

Note: VIF indicates the variance inflation factor; t ratio is t statistics; Pr > |t| is *p* value (significance level); and Beta is a standard coefficient of the identified variable.

The beta coefficient represents the relative importance of the identified variables in explaining the variation of submitted unit price bids. The identified variables, in descending order of importance, are: (1) the quantity of the bid item; (2) total contract price; (3) asphalt cement price index; (4) Dow Jones Industrial Average; (5) number of nearby asphalt plants; (6) ratio of bid item; (7) pavement length; (8) national highway construction cost index; (9) number of hires; (10) number of bidders; (11) construction cost index; and (12) hauling distance between quarry and asphalt plants. Among the identified explanatory variables in the model, the quantity of the bid item, number of nearby asphalt plants, pavement length, and number of bidders have negative relation with submitted unit price bids for asphalt line items and the remaining variables have the positive association with submitted unit price bids.

Variables related to project location, including terrain types and geographical location of projects, are identified as explanatory variables in the stepwise regression model. The results show that on average, submitted unit price bids for projects in the flat and coastal terrains are higher than those in rolling and mountainous terrains. The results also show that on average, submitted unit price bids in District 7 are higher than those in other districts. Time of year when the project was let was examined using quarterly dummy variables. The results indicated that the second quarter, on average, had the lower submitted unit price bids than other quarters.

Table 5 - ANOVA of the Final Stepwise Regression Model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	55357	2913.53687	89.17	<.0001
Error	1371	44795	32.67347	-	-
Corrected Total	1390	100153	-	-	-

Note: DF indicates the degree of freedom

With regard to a measure of goodness of fit, the result of the *F*-statistics in Table 5 showed F (19, 1371) =89.17 (p-value <.0001), which is statistically significant at the significance level of α = 5%. This *F*-statistic indicates that the null hypothesis (i.e.,

$H_0: \beta_1 = \beta_2 = \beta_t = 0$) is rejected at 5% significance level indicating that overall, a combination of the identified variables used to build the regression model is statistically significant for explaining variation in submitted unit price bids for asphalt line items.

The summary of a regression model is shown in Table 6. The regression model developed in this chapter has the adjusted R-squared of 0.547, indicating the developed model accounted for 54.7% of the variance of submitted unit price bids for asphalt line items.

Table 6 - Summary of Regression Model

Model	**R**	**R-Squared**	**Adjusted R-Squared**	**Std. Error of the Estimate**
	.743	0.553	0.547	5.716

Since the regression analysis is highly dependent on certain assumption, it is critical to check the regression assumptions to validate the developed regression model. Using residual plots, this research validated the regression assumptions, including independent errors, homoscedasticity, and normality. Independency of errors is assessed by plotting residual (*i*) against residual (*i*-1). Figure 4 has a random pattern and no clear relationship between the residual (*i*) and residual (*i*-1), which meets the assumption of independent errors.

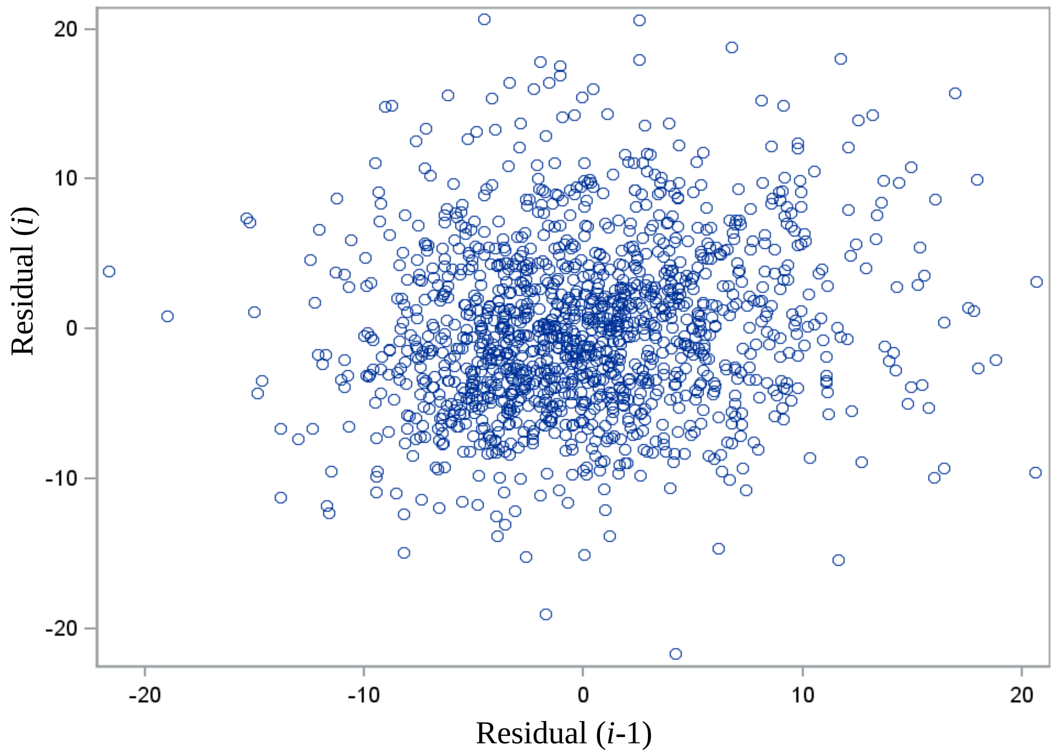


Figure 4 - A Plot of Residual (*i*) and Residual (*i*-1)

Homoscedasticity is measured by a plot of predicted values versus residuals (disturbances). As shown in Figure 5, the residuals do not become systematically larger or smaller across fitted values. It shows constancy of disturbances, which is met an assumption of Homoscedasticity.

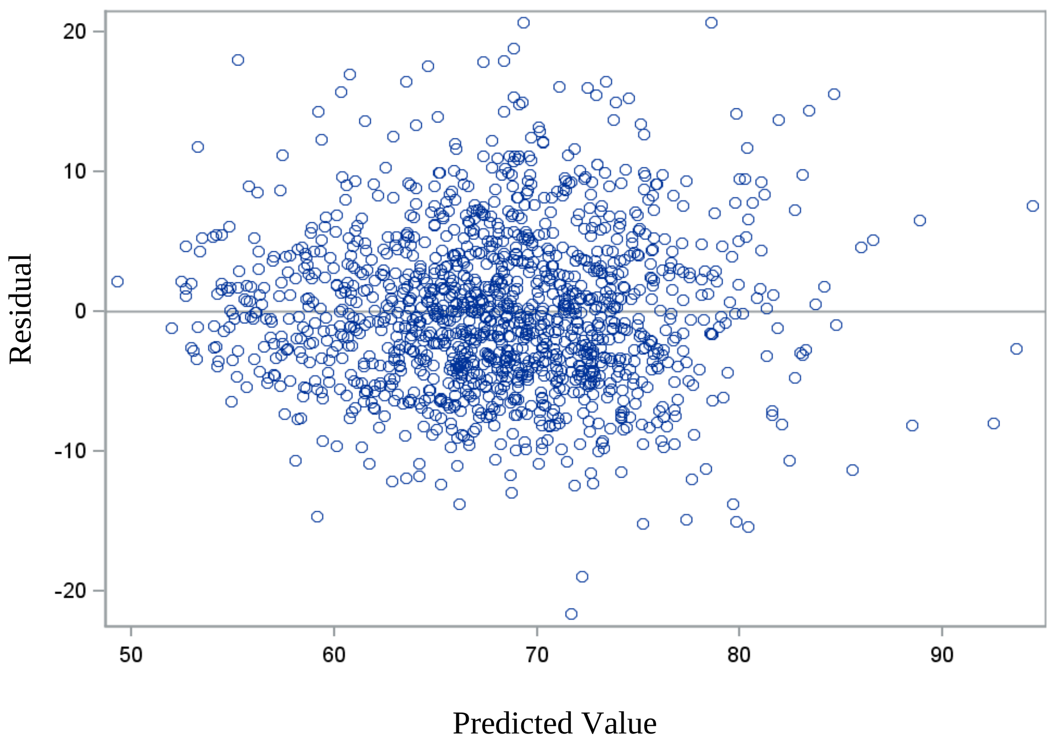


Figure 5 - A Plot of Predicted Values and Residuals

Normality assumption is assessed by normal probability quantile-quantile (Q-Q) plots of the residuals. Figure 6 presents the Q-Q plots of residuals. The Q-Q plots are approximately linear indicating that the error terms are normally distributed, which also meets the normality assumption.

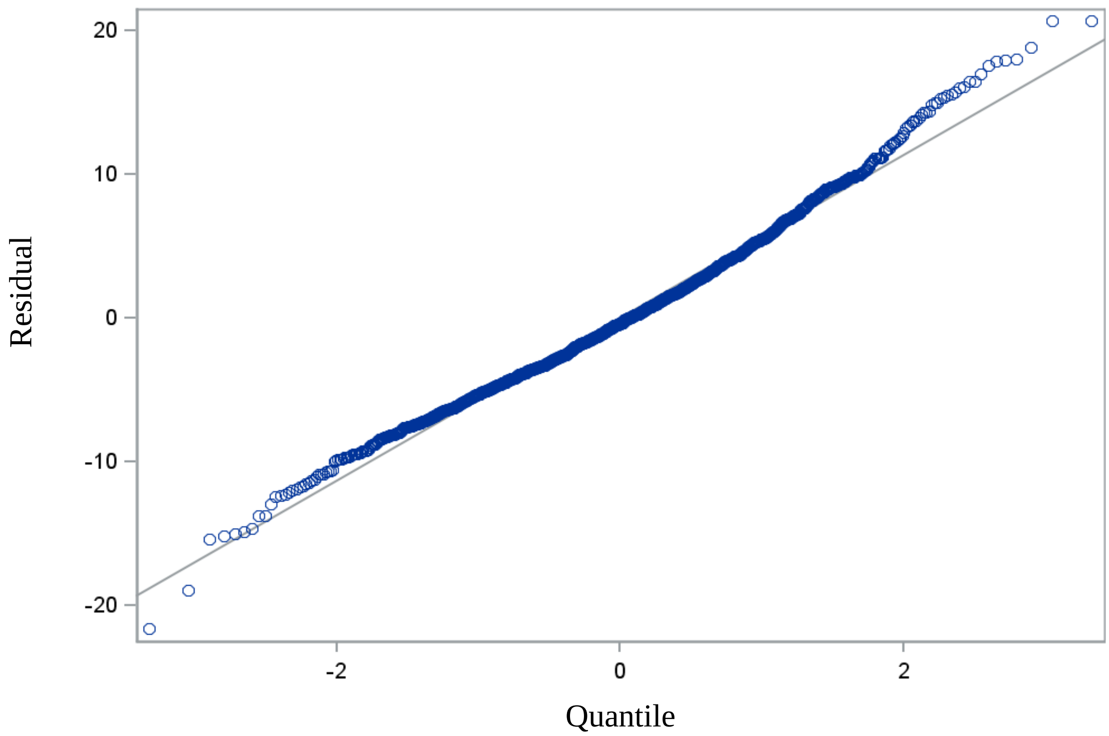


Figure 6 - Q-Q Plots of Regression Residuals

Lastly, the VIF values for each coefficient is diagnosed to check whether multicollinearity exists within the explanatory variables of the developed model. As the VIF values for the identified explanatory variables in Table 4 are not greater than 10, there is no multicollinearity issues in the regression model.

Turning to specific estimation results, the developed explanatory model contains several important explanatory variables, including quantity of the bid item, total contract price, asphalt cement price index, Dow Jones Industrial Average, number of nearby asphalt plants, ratio of the bid item, pavement length, national Highway construction cost index, number of hires, number of bidders, construction cost index, and hauling distance between quarry and asphalt plants.

It is found that the quantity of the bid item and pavement length, have negative relations with the submitted unit price bids. These findings represent the significance of economy of scale in explaining the variations in submitted unit price bids. The larger the volume of hot mix asphalt concrete is the lower the submitted unit price bid is for the project. Similarly, the longer the pavement length is the lower the submitted unit price bid is for the pavement project. The identified negative relations are consistent with the results of Wilmot and Cheng's (2003) study that showed the significance of the economy of scale in reducing unit price bids.

It is shown that total contract price and ratio of bid item have positive relations with the submitted unit price bid. The number of bidders is determined as an explanatory variable with a negative relation with the submitted unit price bid. The higher the degree of competition in the bidding process the lower the unit price bid. The effect of competition on bidding price is confirmed in several other studies (Shrestha and Pradhananga 2010; Wang and Liu 2012).

It is concluded that the percentage changes in the trigger point and the cap of the clause had no statistically significant effect on the variation in the submitted unit price bid for asphalt line items. In addition, there is no statistical evidence of any relation between the presence of a price adjustment clause in the contract and the variation in the submitted unit price bid. This finding is consistent with the results of Ilbeigi et al.'s (2015) study that did not find any significant relation between offering the price adjustment clause in the contract and the submitted unit price bid.

It is found that the number of nearby asphalt plants has a negative relation with the submitted unit price bid, while hauling distance between quarry and asphalt plant has a positive relation with the submitted unit price bid. These results show that the availability of suppliers and accessibility to materials sources are advantageous for reduced construction prices.

It is shown that the several indicators of construction market conditions, including construction cost index, asphalt cement price index, national highway construction cost index, and the number of hires, have positive relations with the submitted unit price bid. The positive relation between submitted unit price bids and asphalt cement price index indicates that increasing the cost of construction materials increases the submitted unit price bids for asphalt line items. This finding is consistent with the results of Wang and Liu's (2012) study.

In addition, since resources in the construction industry are limited and transferable from one market to another (Skitmore et al. 2006), the boom in other construction sectors, represented by the growth of construction cost index, can cause insufficient resources in the highway construction industry. Thus, it is expected that an increase in construction cost index increases the submitted unit price bids for asphalt line items. National highway construction cost index is also identified as significant factors for explaining variation in submitted unit price bids. An increase in highway construction cost index indicates the increase in the prices of highway construction costs, which lead to the higher submitted unit price bids.

Furthermore, the growth in the number of hires in the construction industry leads to an increase in the submitted unit price bids. The growth in the number of hires in construction industry indicates more work. The identified relation between the number of hires and the submitted unit price bids is consistent with the results of a study conducted by Ashuri et al. (2012) that showed the positive relation between employment level in construction and the ENR's construction cost index. Overall, it can be concluded that submitted unit price bids for asphalt line items are, on average, higher in the booming construction market.

It is found that Dow Jones Industrial Average has a positive relation with the submitted unit price bid. The growth in Dow Jones Industrial Average is an indication of increasing economic activities because of the development and expansion of new dwellings, businesses, and infrastructure systems. Thus, as Dow Jones Industrial Average increases, the construction market is more likely to be active and it leads to an increase in the submitted unit price bids because of limited resources available in the market.

4.5 Conclusions

It is concluded that the following variables have statistically significant relations with submitted unit price bids (in descending order of importance in explaining the variation of the submitted unit price bid): (1) quantity of the bid item; (2) total contract price; (3) asphalt cement price index; (4) Dow Jones Industrial Average; (5) number of nearby asphalt plants; (6) ratio of the bid item; (7) pavement length; (8) national Highway construction cost index; (9) number of hires; (10) number of bidders; (11) construction cost index; and (12) hauling distance between quarry and asphalt plants. Among the identified explanatory variables in the model, the quantity of the bid item, number of nearby asphalt plants, project length, and number of bidders have negative relations with submitted unit price bids for asphalt line items and the remaining variables have positive associations with submitted unit price bids.

The results of stepwise regression analysis can help estimators and capital project planners to think outside the box and consider the contextual information in estimating construction cost. The research findings showed that the identified variables contain useful information for explaining most of the variability in construction cost. This new knowledge has great implications for cost estimators and investment planners since the identified factors represent the macroeconomic and market context in which the construction cost is changing. The proposed formulation can help cost estimators analyze the effects of changes in the identified explanatory variables on the anticipated unit price bid submitted by the highway contractor.

CHAPTER 5. SPATIAL MODELING FOR SUBMITTED UNIT PRICE BIDS

5.1 Introduction

Previous studies show a significant correlation between the cost and geographical location of a construction project. Thus, the objective of this chapter is to develop a local form of regression models to explore spatial variation of relationship between submitted unit price bids and potential explanatory variables.

The generalized linear modeling (GLM) approach overlooks the spatial correlation between the unit price bids and the geographical location of a project, leading to over or underestimating the significance of explanatory variables. Thus, state DOTs must be capable of analyzing uncertainty related to the impact of geographical variability of the construction market and economic conditions on construction costs.

Several studies have emphasized spatial correlation in estimations of construction costs. For instance, Zhang et al. (2014) used surface interpolation methods to analyze cost indexes for studying spatial correlation with geographical locations and found a significant spatial correlation between cost indexes and specific geographical locations. They concluded that an adjustment in cost data increased the accuracy of cost estimates for construction projects. Another study carried out by Zhang et al. (2016) analyzed RSMean's city cost index (CCI) to develop location adjustment factors for realistic cost estimates and concluded that improvement in the geographical interpretation of CCI by incorporating local economic conditions increases the accuracy of cost estimates for a construction project.

Migliaccio et al. (2009) also used the RSMeans' CCI national reference data to conduct a spatial analysis and showed a strong spatial correlation between proximity and CCI value. Migliaccio et al. (2012) also used spatial analysis to explain the spatial patterns of construction costs with socioeconomic variables such as the population, the population growth percentile, and the household growth rate. The authors concluded that the impact of each covariate differed from state to state.

Although previous studies indicate a significant spatial correlation between the cost and geographical location of a construction project, they do not analyze the geographical variation in actual construction projects or the impact of covariates such as project characteristics, construction market, and economic conditions on construction costs in a geographical manner. In addition, few have focused on the spatial heterogeneity of the relationships between construction cost and potential explanatory variables.

5.2 Research Objectives

The main objective of this chapter is to explain variations in submitted unit price bids for asphalt line items used in highway construction projects by incorporating external factors: construction market and economic condition factors. To achieve this main objective, this chapter also has the following sub-objectives:

1. To explore spatial variation in submitted unit price bids for asphalt line items
2. To develop explanatory models for describing variations in submitted unit price bids
3. To identify spatial correlation between submitted unit price bids and external factors

The main hypothesis Tests of this chapter are as follows:

Alternative hypothesis (H_1): Submitted unit price bids significantly differ across various

Alternative hypothesis (H_2): there will be spatial heterogeneity for relationship between submitted unit price bids and explanatory variables.

5.3 Research Methodology

Spatial analysis is conducted to examine spatial variation in submitted unit price bids, as well as spatial heterogeneity for relationships between the submitted unit price bids and explanatory variables.

To develop a regression model, this research implements the following steps:

1. Conduct Hot spot analysis for exploring spatial variation in the submitted unit price bids
2. Implement a stepwise selection process for identifying key variables
3. Conduct bandwidth selection process for identifying the optimal number of nearest neighbors
4. Develop local models using geographically weighted regression analysis
5. Assess spatial heterogeneity of relationship between the submitted unit price bids

Hot spot analysis is used to measure spatial variation in submitted unit price bids and geographical location of a project. Hot spot analysis is a statistical method for assessing geographical clustering, which identifies the locations of statistically significant high- and low-value clusters of construction costs by evaluating each feature within the context of neighboring features and against all features in the dataset. To identify the statistical significance of a particular area, the hot spot analysis computes the Getis-Ord Gi* statistic using the following equations (Khan et al. 2008; Kondo 2016):

$$G_i^* = \frac{\sum_{j=1}^{N} w_{i,j} x_j - \bar{X} \sum_{j=1}^{N} w_{i,j}}{s\sqrt{\frac{\left[N \sum_{j=1}^{N} w_{i,j}^2 - \left(\sum_{j=1}^{N} w_{i,j}\right)^2\right]}{N-1}}},$$

$$\bar{X} = \frac{\sum_{j=1}^{N} x_j}{N},$$

$$S = \sqrt{\frac{\sum_{j=1}^{N} X_j^2}{N} - \bar{X}^2}, \text{ and}$$

$$w_{i,j}(d) = \begin{cases} 1, if\ d_{i,j} < d,\ \ for\ all\ i, j \\ 0, otherwise \end{cases},$$

where G_i^* is z-score value including the value at site i, x_j is the attribute value of feature j, $w_{i,j}$ is the spatial weight between feature i and j, and n is equal to the total number of features. The spatial weight matrix $w_{i,j}$ is estimated based on the default neighborhood search threshold, which is 15 miles (or 24247. 251 meters).

The aim of this chapter is to study a spatial correlation between the cost and geographical location of a construction project—a correlation that a generalized linear modeling (GLM) approach may overlook. Using geographically weighted regression (GWR) analysis, this chapter develops explanatory models for describing variations in submitted unit price bids. GWR enables the identification of parameters for each location in space and complex spatial variations in parameter estimates (Brunsdon et al. 1996). While the relationships between a dependent variable and explanatory variable (s) in GLM are assumed to be constant across the geographical area, the relationships in the GWR model vary over space (Guo et al. 2008). The GWR model is expressed as (Fotheringham et al. 1998):

$$Y = \beta_0(u_i, v_i) + \sum_{1}^{p} \beta_p(u_i, v_i) X_p + \varepsilon$$

where Y is the submitted unit price bid, u_i and v_i are location coordinates for each observation i, X_p is pth explanatory variable, β_0 is a constant term, β_p is a coefficient for pth explanatory variable, and ε is a normally and independently distributed error. Using

GWR, the parameter estimates for each explanatory variable *X* are obtained for each geographical location *i*. To estimates the coefficients of the GWR model, the following matrix expression is used:

$$\widehat{\beta_i} = (X^T W_i X)^{-1} X^T W_i y$$

where *X* is the matrix of the explanatory variable with a column of 1s for the intercept, *y* is the submitted unit price bid, $\widehat{\beta_i} = (\beta_{i0}, \ldots \beta_{im})^T$ is the vector of *m*+1 local regression coefficients, and W_i is the diagonal matrix denoting the geographical weighting of each observed data of regression point *i*.

The geographical weight matrix W_i is calculated with A kernel function based on the proximities between regression point *i* and the *N* data points around it. To define the geographical weight matrix W_{ij}, Gaussian kernel function can be used with the following equation (Fotheringham et al. 1998; Nakaya et al. 2014):

$$W_{ij} = \exp\left(-\frac{d_{ij}^2}{{b_{i(t)}}^2}\right)$$

where d_{ij} is the distance between the regression point *i* and locations *j*, *b* is a bandwidth size defined by distance metric measure. The bandwidth is defined by a fixed number of nearest neighbors (i.e., an adaptive bandwidth method), which allows to use the *t*-th nearest neighbor distance for each regression location (Nakaya et al. 2014). The optimal number of nearest neighbors is computed on the bandwidth selection process and identified using the Akaike information criterion (AIC) and modified AIC (AICC).

A linear regression model is developed for explaining variation in submitted unit price bids for asphalt line items and compared with geographically weighted regression model for evaluating the model performance. To evaluate the model performance, the Akaike information criterion (AIC) and modified AIC (AICC) are used.

5.4 Results and Discussion

5.4.1 Hot Spot Analysis

To diagnose the presence of significant spatial variation between submitted unit price bids and geographical location of the projects, this research entails a hotspot analysis. As shown in Figure 7, the hot spot analysis showed significant variation in submitted unit price bids in four areas, thereby rejecting the null hypothesis. Submitted unit price bids in hot spot areas, mostly Areas 1, 2, and 3, are significantly higher than the overall mean of submitted unit price bids at a 99% confidence level. One explanation for this finding is that Areas 2 and 3 have difficulty procuring important resources such as labor, materials, and equipment. Another explanation is that very few asphalt plants are located in southern Georgia. In addition, Area 1 is a mountainous terrain, which might decrease the level of productivity on projects and increase the unit prices on submitted bids for asphalt line items. Conversely, submitted unit price bids in cold spot areas, mostly Area 4, are significantly lower than the overall mean of unit prices. One explanation for this finding is that Area 4 has better accessibility to procuring asphalt cement and aggregates from North Georgia. Thus, Area 4 receives relatively lower submitted unit price bids than other districts. One conclusion from these findings is that significant spatial variation exists between unit price bids and geographical locations, which rejects the null hypothesis of this test.

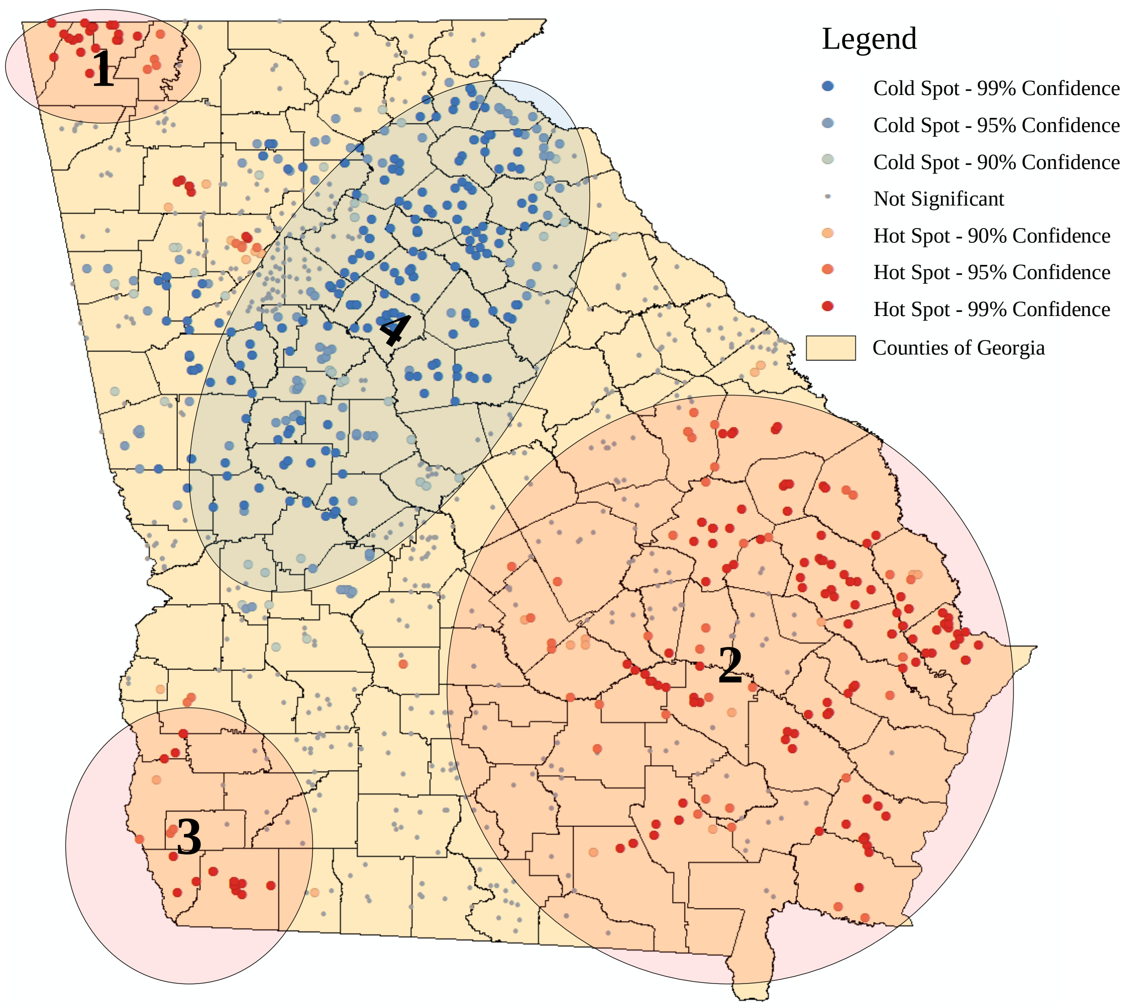


Figure 7 - Hot Spot Analysis for Spatial Variation in Submitted Unit Price Bids

5.4.2 Geographically Weighted Regression (GWR)

This research entails a stepwise selection procedure for identifying key variables for regression modeling. A stepwise selection procedure is implemented with the continuous explanatory variables. Table 7 presents the summary of the stepwise selection process. Based on the values of AIC and AICC, the model at step 12 is selected where AIC is 9018. 659 and AICC is 9018.964.

Table 7 - Summary of Stepwise Selection Process

Step	Effect Entered	Effect Removed	AIC	AICC	Pr > |t|
0	**Intercept**	-	9900.337	9900.346	.
1	**Dow Jones Industrial Average (in transformed natural logarithmic form)**	-	9597.910	9597.927	<.0001
2	**Number of Nearby Asphalt Plants**	-	9490.934	9490.963	<.0001
3	**Quantity of the Bid Item (in transformed natural logarithmic form)**	-	9396.646	9396.689	<.0001
4	**Asphalt Cement Price Index**	-	9286.703	9286.763	<.0001
5	**Total Contract Price**	-	9225.230	9225.311	<.0001
6	**Ratio of the Bid Item**	-	9167.867	9167.971	<.0001
7	**Hauling Distance between Quarry and Asphalt Plants**	-	9120.045	9120.175	<.0001

Table 7 Continued

8	National Highway Construction Cost Index	-	**9085.889**	**9086.049**	**<.0001**
9	**Pavement Length (in transformed natural logarithmic form)**	-	9047.191	9047.382	<.0001
10	**Number of Bidders**	-	9026.078	9026.305	<.0001
11	**Construction Cost Index**	-	9023.082	9023.346	0.0255
12	**Number of Hires**	-	**9018.659***	**9018.964***	**0.0114**

Note: * Optimal Value of Criterion; Selection stopped because all candidates for removal are significant at the 0.05 level and no candidate for entry is significant at the 0.1 level.

The optimal subset model includes 12 significant variables—Dow Jones Industrial Average, number of nearby asphalt plants, quantity of the bid item, asphalt Cement price index, total contract price, ratio of the bid item, hauling distance between quarry and asphalt plants, national highway construction cost index, pavement length, number of bidders, construction cost index, and number of hires—for regression modeling.

The bandwidth selection process is conducted to identify the optimal number of nearest neighbors of the regression point. Table 8 provides the summary of bandwidth selection process. Based on the AIC and AICC, the best bandwidth size is 54, which is used for calculating the weighting function for GWR.

Table 8 - Summary of Bandwidth Selection Process

Iteration	Bandwidth (Number of Neighbors)	AIC	AICC
1*	**54.093***	**8522.411***	**8562.455***
2	82.551	8602.494	8621.387
3	100.139	8645.073	8658.071
4	128.597	8694.846	8703.253
5	82.551	8602.494	8621.387
6	71.681	8576.987	8601.410
7	64.963	8556.727	8586.092
8	60.811	8541.382	8574.255
10	58.245	8534.904	8569.856
11	56.659	8530.779	8568.165
12	55.679	8525.581	8564.190

*Note: limits are between 1 and 1391; * indicates the optimal bandwidth size.

The results of the generalized linear regression and GWR models are presented in Table 9. In the generalized linear regression model, the identified variables have the power to explain variation in the submitted unit prices at a 95% confidence level (i.e., |t-ratio|>1.96 and *p*-value < 0.05). Overall, the developed generalized regression model explains 47.4% of the variation in submitted unit prices for asphalt line items. In addition, with the identified variables from the stepwise select process, this work applies GWR analysis to estimate local variable coefficients for each location. Table 9 also provides the results of GWR analysis including the mean, minimum, maximum, 1st quartile, median, and 3rd quartile of the coefficients of the local models. The coefficients of the identified variables show significant variability with regard to the impact of the identified variables on submitted unit price bids. The results of the analysis indicate that the GWR models can explain 64.8 % of the variation in submitted unit prices for asphalt line items. Based on the model criterion, adjusted R-squared (i.e., the higher value of adjusted R-squared) and AIC (i.e., the minimum value of AIC), the GWR models outperform the generalized linear regression model.

The results suggested that across the study region submitted unit price bids are negatively related to quantity of the bid item, pavement length, number of bidders, and number of nearby asphalt plants, while other identified variables are positive relationships with the submitted unit price bids.

Table 9 - Results of Generalized Linear and GWR Models

Model	**Generalized Linear Model**		**GWR Model**					
Variable	**Parameter Estimate**	**t ratio**	**Mean**	**Min.**	**Max.**	**1st Quartile**	**Median**	**3rd Quartile**
Intercept	68.037	412.180	65.067	48.510	73.779	63.972	65.404	66.740
Quantity of the Bid Item (in transformed natural logarithmic form)	-3.403	-12.440	-3.390	-6.483	-1.227	-4.019	-3.297	-2.487

Table 9 Continued

Total Contract Price	**2.292**	**10.720**	**2.462**	**0.440**	**7.754**	**1.585**	**2.164**	**3.401**
Asphalt Cement Price Index	2.147	10.220	1.795	-1.972	3.202	1.535	1.821	2.212
Ratio of the Bid Item	1.689	6.900	1.623	-0.322	3.126	1.196	1.802	2.262
Dow Jones Industrial Average (in transformed natural logarithmic form)	1.520	5.060	1.490	-1.951	3.578	0.987	1.565	2.244
Number of Nearby Asphalt Plants	-1.455	-7.490	-1.891	-18.644	8.449	-3.953	-1.618	0.295
National Highway Construction Cost Index	1.374	6.360	1.378	-0.065	3.061	0.886	1.237	1.910
Hauling Distance between Quarry and Asphalt Plants	1.231	7.240	0.454	-1.048	1.891	0.054	0.407	0.813
Construction Cost Index	1.179	3.050	1.356	-1.876	4.767	0.475	1.137	2.237

Table 9 Continued

Pavement Length (in transformed natural logarithmic form)	**-1.160**	**-6.180**	**-1.021**	**-3.214**	**2.003**	**-1.579**	**-1.108**	**-0.725**
Number of Bidders	-0.881	-4.640	-0.356	-3.027	1.515	-0.713	-0.190	0.217
Number of Hires	0.512	2.530	0.816	-0.941	2.405	0.308	0.909	1.297
R-Squared	0.479				0.703			
Adjusted R-Squared	0.474				0.648			
AIC	9018.659				8522.411			
Number of Observations	1391				1391			

The major advantage of GWR is that the spatial patterns between the dependent variable and explanatory variable can be easily mapped and visualized (Bitter et al. 2007). To visually examine the spatial variations of relationships between submitted unit price bids and key identified variables, this chapter employs a spatial interpolation tool, the natural neighbor, on the coefficients of the variables and *p*-values (at the significance level of α = *5%*) of the identified variables. Figure 8 and 9 depict spatial variation in the relationship between submitted unit price bids and the identified variables and their significance. The results of the spatial interpolation for the identified variables suggest that significant variation in the parameters exists.

The quantity of the bid item exhibits a significant negative relationship with the submitted unit price bids in all the regions in Georgia. The density parameter of the quantity of the bid items appears to become more negative in the northern and eastern regions of Georgia. A possible explanation for this result is that since contractors have the better accessibility of the material sources in the northern region and through ports in the coastal regions of Georgia, contractors can take an advantage of the accessibility of the material sources and economy of scale in purchasing materials in these areas. Thus, the relationship between the submitted unit price bids and the quantity of the bid item is more significant in the urban and the northern areas of Georgia.

The ratio of the bid item shows a positive relationship with the submitted unit price bids in the northern and the eastern regions of Georgia. The density parameter of the ratio of the bid item become more positive in these regions. Ground conditions (i.e., soil nature) are a critical factor that influences construction costs (Al-Tabtabai et al 1999). Because of less productivity in the mountainous terrain (Chong et al. 2011), constructing the asphalt intensive projects (i.e., the higher ratio of the bid item in the highway contract) in the mountainous areas is burdensome for construction contractors. Thus, the change of ratio of the bid item has the higher impact on the submitted unit price bids in the mountainous terrain than those in other terrains.

In addition, the total contract price is positively related to the submitted unit price bids in most regions of Georgia. The density parameter of the total contract price becomes less positive in the middle and southern regions of Georgia, where have the higher population (i.e., population > 150,000) (U.S. Census Bureau 2010). This result indicates that the projects become more complex as they become larger so the projects become difficult (Dunston et al. 2000; Bordat et al. 2004). In the urban setting, the larger size of pavement projects is a critical challenge because the difficulty of traffic control (often traffic lanes are usually closed, restricted, or detoured to a surrounding roadway to conduct pavement projects) (Woodroffe and Ariaratnam 2008), which can lead to an increase in submitted unit price bids.

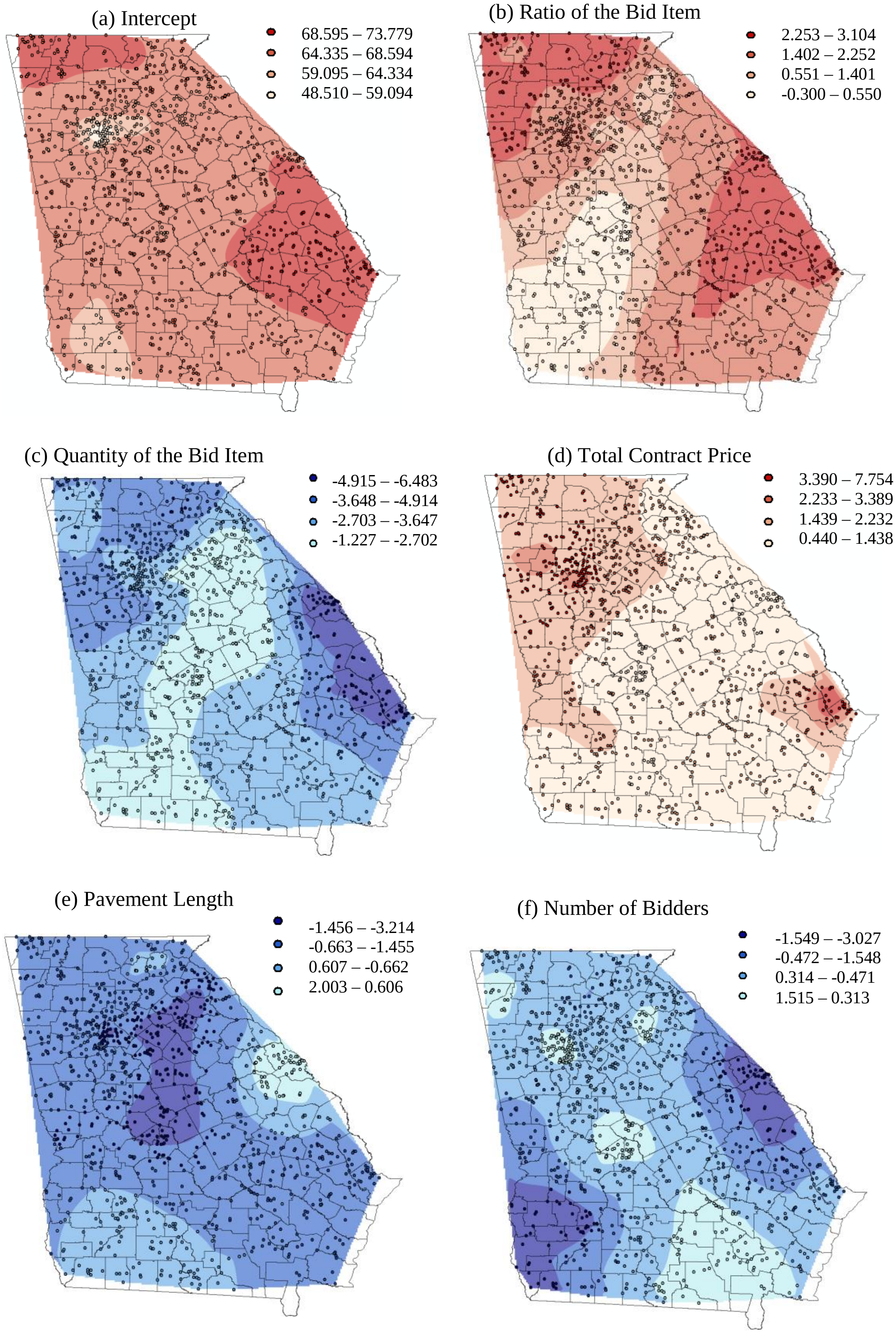
Pavement Length has a negative relationship with submitted unit price bids in the northern, middle, and southeastern regions of Georgia. The density parameter of the pavement length appears to become more negative in the middle region of Georgia. In addition, although the relationship between the number of bidders and submitted unit price bids is significantly positive in some parts of the southwestern and eastern regions of Georgia, they do not show this relationship in the northern, middle, and southern regions of Georgia.

The number of nearby asphalt plants has a negative relationship with submitted unit price bids in the northern, northeastern, middle, and southern regions of Georgia. The density parameter of the number of nearby asphalt plants become more negative in the southern region of Georgia. Hauling distance between quarry and asphalt plants have a positive relationship with submitted unit price bids in the western and southeastern regions of Georgia. The density parameter of hauling distance between quarry and asphalt plants appears to become more positive in the southeastern region. According to Walker and Weber (1987), when supplier competition is low, the supplier may take advantage of this opportunity to exploit limited alternatives available to the contractors, which consequently increase the price of materials. Thus, since the major asphalt plants and quarries are located in the northern region of Georgia, changes in available material suppliers or potential hauling distance of materials in the southern region of Georgia have the more significant impact on the submitted unit price bids for asphalt line items than those in other areas.

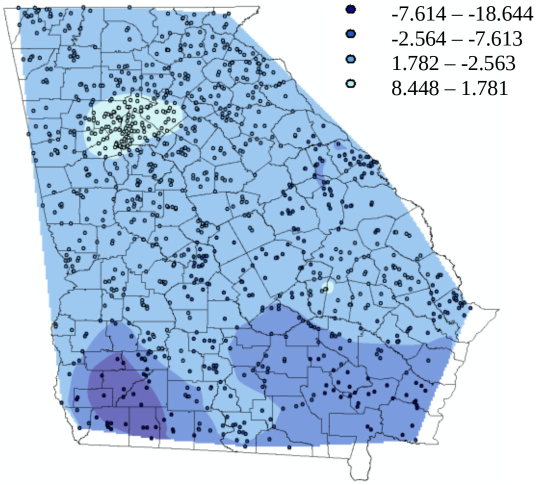
Asphalt cement price index has a positive relationship with submitted unit price bids in most regions of Georgia. Asphalt cement price index is more strongly correlated in the northeastern, middle, and southwestern regions of Georgia than in other regions. It is found that asphalt cement price index has a higher positive impact on the submitted unit price bids in the rural area of Georgia than those in the urban areas. Dow Jones Industrial Average has a positive relationship with submitted unit price bids in the northern and southeastern regions of Georgia. The density parameter of Dow Jones Industrial Average appears to become more positive in the northern region of Georgia.

In addition, the number of hires of the construction industry has a positive relationship with submitted unit price bids in the southern region of Georgia. The density parameter of the number of hires appears to become more positive in the southern region of Georgia, where are mainly the rural areas of Georgia. According to the study carried out by Bai et al. (2011), they found that with a growth in the construction sector, larger cities/urban areas attract more population than small cities and towns. As the growth in the number of hires in the construction industry indicates that there are more works in the construction sectors, it is expected that the growth of labor markets can cause significant population migration and labor mobility from rural to urban (Bencivenga and Smith 1997; Fang and Dewen 2008). The increase of labor mobility and population migration from rural to urban leads to labor shortages for construction projects (Teixeira and Mishel 1992), which results in poor productivity and an increase of construction costs (Kaming et al. 1997). Thus, the relationship between the submitted unit price bids and the number of hires in the construction industry becomes more positive in the rural regions of Georgia.

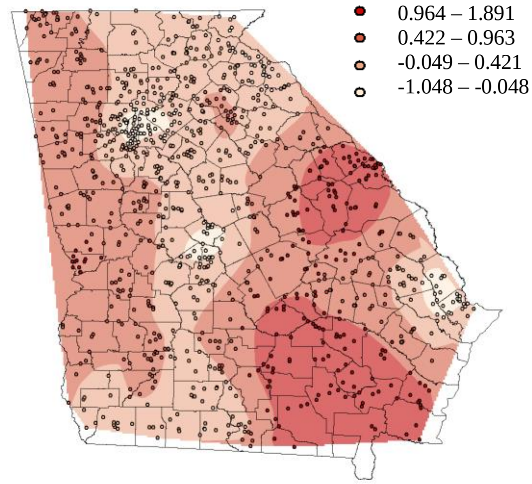
National highway construction cost index has a positive relationship with submitted unit price bids in the northern and middle regions of Georgia. National highway construction cost index is more strongly correlated in the northeastern region of Georgia. Moreover, construction cost index has a positive relationship with submitted unit price bids in the northeastern and middle regions of Georgia. The parameter of the construction cost index tends to be higher in the urban areas (i.e., Atlanta and Augusta) of Georgia. Changes in the overall construction market conditions are more influential to construction costs in the higher population areas (population >85,000). The relationship between the submitted unit price bids and construction market factors (i.e., national highway construction cost index and ENR construction cost index) are more significant in the northern region of Georgia.


(a) Intercept
68.595 – 73.779
64.335 – 68.594
59.095 – 64.334
48.510 – 59.094
(b) Ratio of the Bid Item
2.253 – 3.104
1.402 – 2.252
0.551 – 1.401
-0.300 – 0.550
(c) Quantity of the Bid Item
-4.915 – -6.483
-3.648 – -4.914
-2.703 – -3.647
-1.227 – -2.702
(d) Total Contract Price
3.390 – 7.754
2.233 – 3.389
1.439 – 2.232
0.440 – 1.438
(e) Pavement Length
-1.456 – -3.214
-0.663 – -1.455
0.607 – -0.662
2.003 – 0.606
(f) Number of Bidders
-1.549 – -3.027
-0.472 – -1.548
0.314 – -0.471
1.515 – 0.313

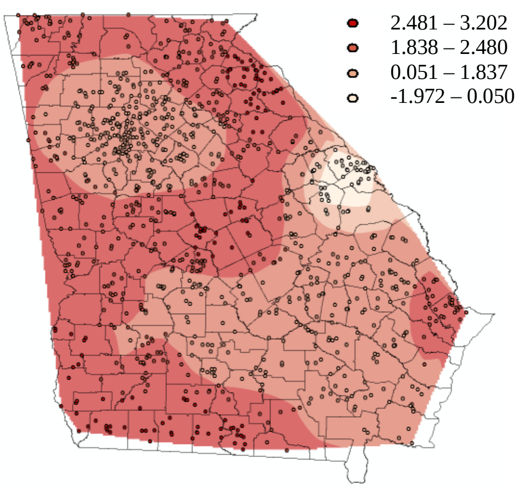
(g) Number of Nearby Asphalt Plants



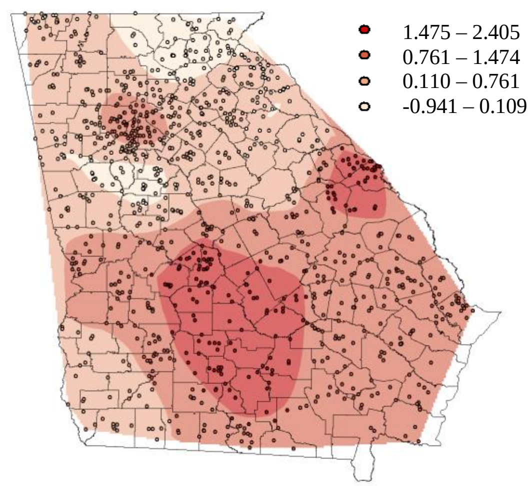
(h) Hauling Distance between Quarry and Asphalt Plants



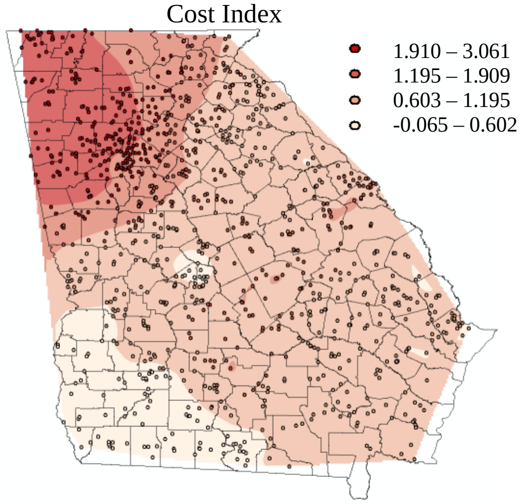
(i) Asphalt Cement Price



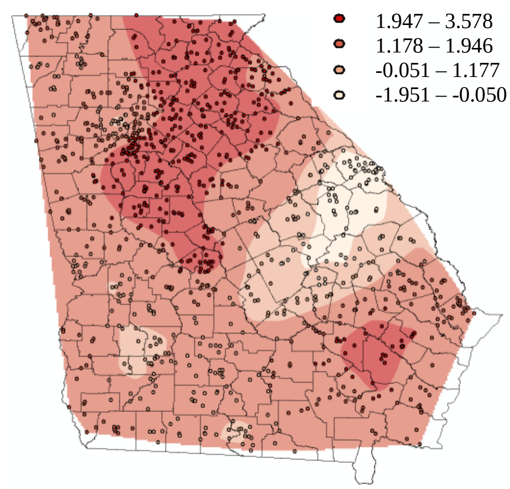
(j) Number of Hires



(k) National Highway Construction Cost Index



(l) Dow Jones Industrial Average



(m) Construction Cost Index

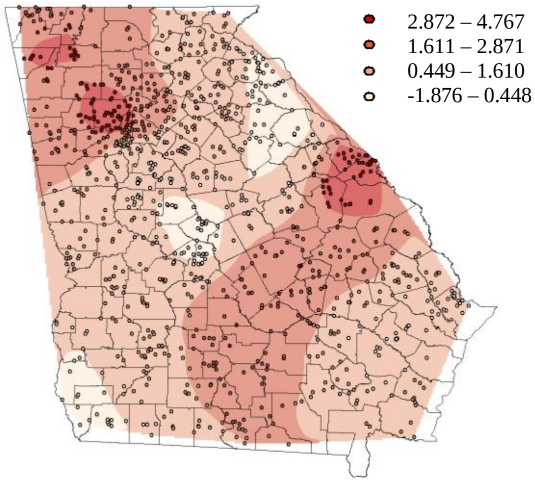
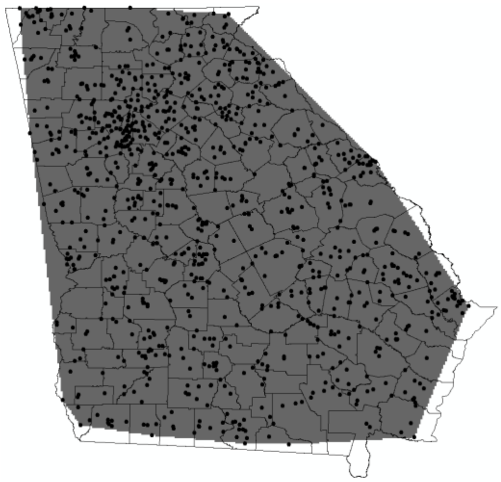
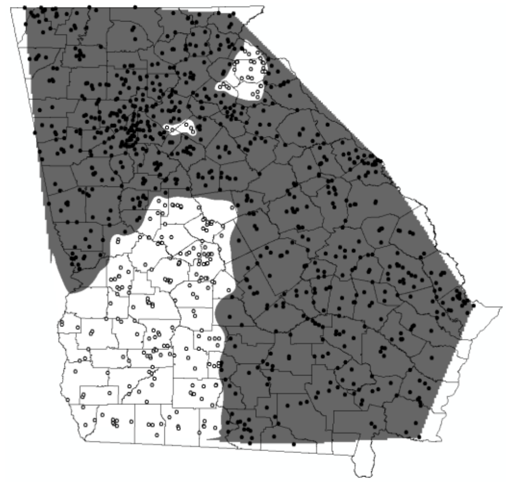


Figure 8 - Spatial Interpolation for Identified Variables: (a) Intercept; (b) Ratio of the Bid Item; (c) Quantity of the Bid Item; (d) Total Contract Price; (e) Pavement Length; (f) Number of Bidders; (g) Number of Nearby Asphalt Plants; (h) Hauling Distance between Quarry and Asphalt Plants; (i) Asphalt Cement Price; (j) Number of Hires; (k) National Highway Construction Cost Index; (l) Dow Jones Industrial Average; and (m) Construction Cost Index

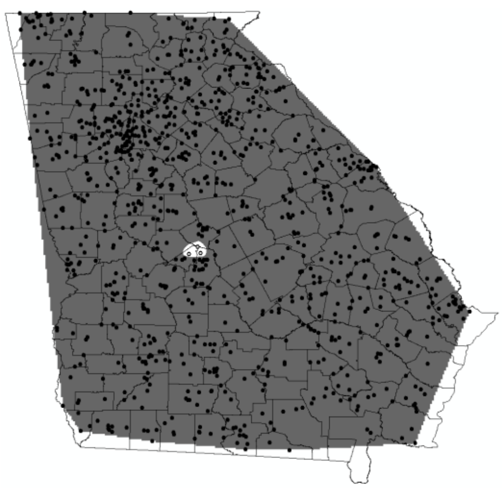
Intercept



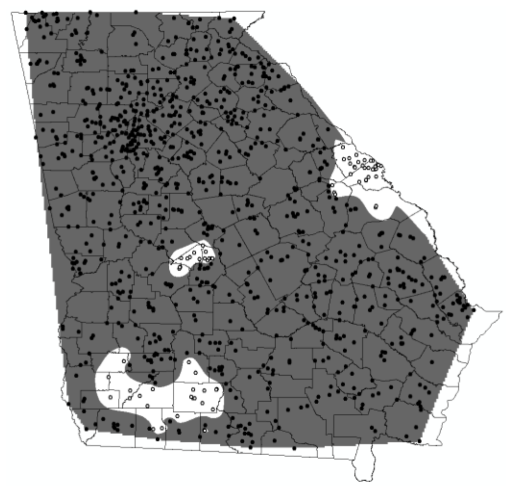
Ratio of the Bid Item



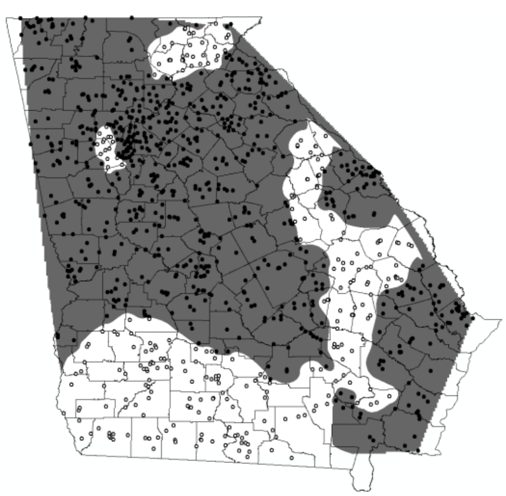
Quantity of the Bid Item



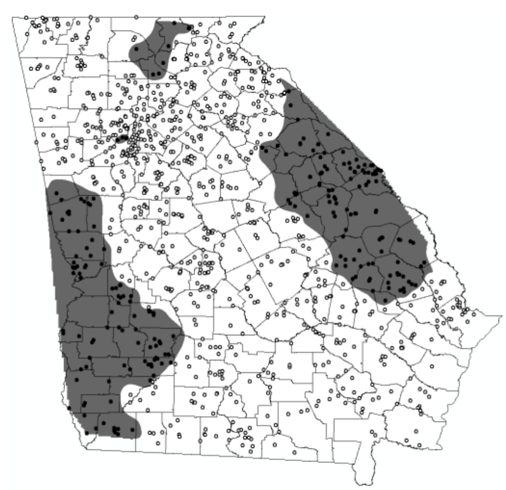
Total Contract Price



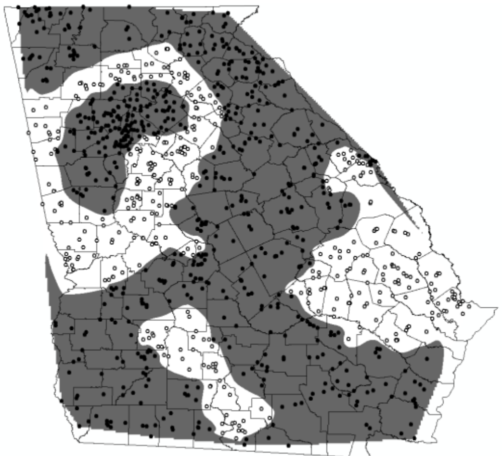
Pavement Length



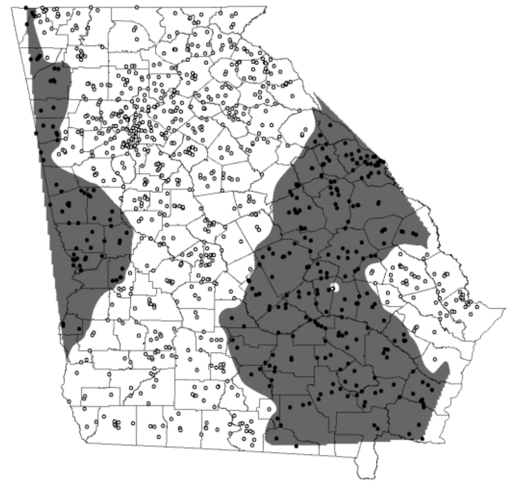
Number of Bidders



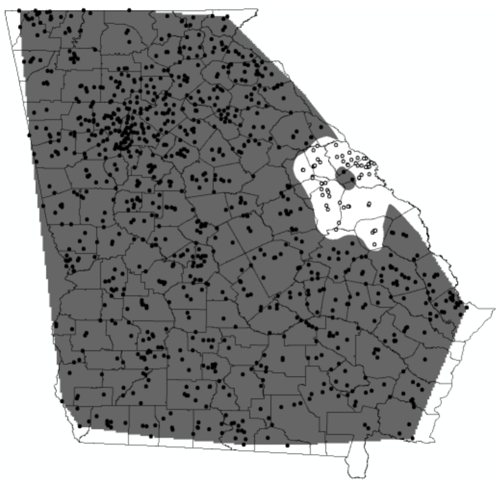
Number of Nearby Asphalt Plants



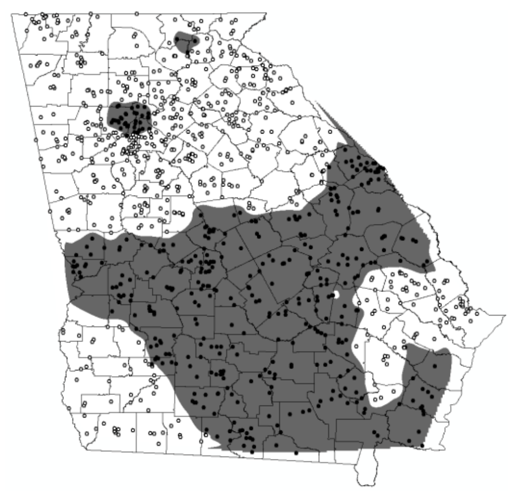
Hauling Distance between Quarry and Asphalt Plants



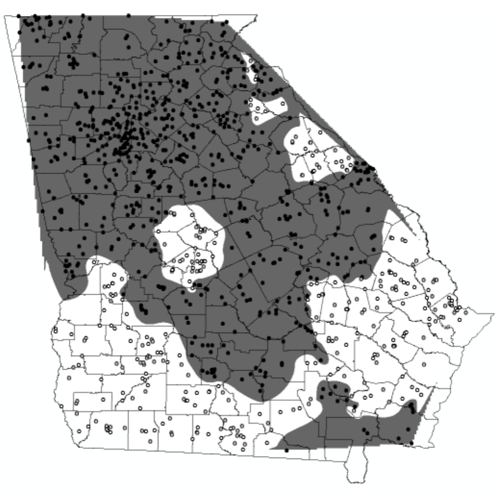
Asphalt Cement Price Index



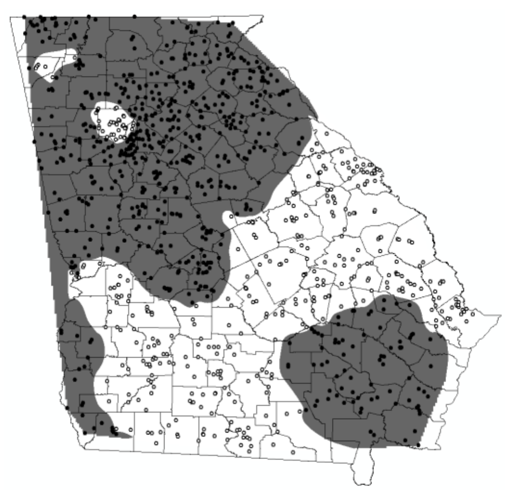
Number of Hires



National Highway Construction Cost



Dow Jones Industrial Average



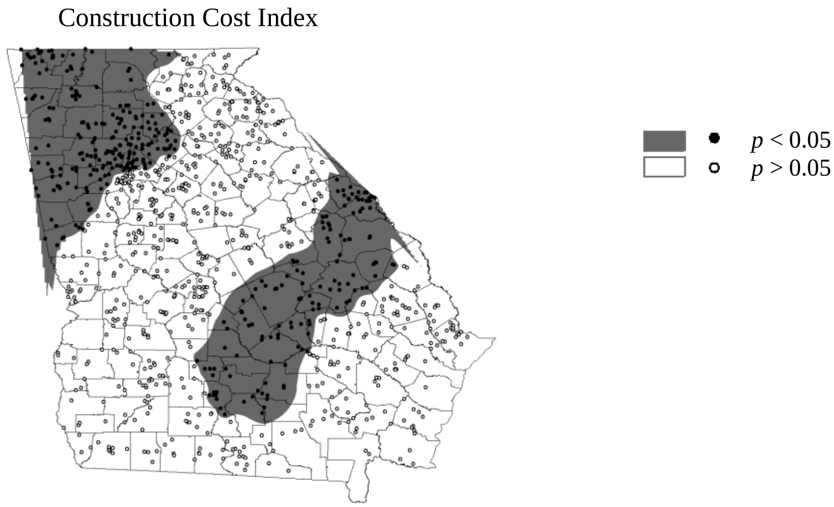


Figure 9 - Spatial Interpolation for *p*-values of Identified Variables

The unexplained spatial variation of the relationships between submitted unit price bids and the identified explanatory variables may be attributed to natural variation in the project environment and the unobservable local market conditions of the project location. In addition, unlike global modeling approaches such as generalized linear models, which have a fixed parameter across the study area, parameter estimates for identified variables in GWR models vary across the geographical locations of the projects (or individual observations). Thus, interpreting the variation of the parameter estimates of GWR models can be difficult because of the complex nature of the GWR analysis (Pirdavani et al. 2014). However, in this research, the parameter estimates of the developed GWR models have similar signs as expected.

The major advantage of GWR in comparison with MLR is its capability for estimating local coefficients of regression model, which vary across the study area. However, GWR is more likely to have multicollinearity in local coefficients than does

MLR. A study conducted by Wheeler and Calder (2007) showed that the regression model produces more accurate inferences on the regression coefficients than does GWR because of the presence of explanatory variable collinearity. It is difficult to measure how much the explanatory variable contributes to the model. In other word, the developed GWR models in this chapter have a limitation in conducting multiple hypothesis testing about the parameters (Chen et al. 2012). Thus, this chapter focused on developing a local form of explanatory models using GWR that have explanatory power for variation in submitted unit price bids.

In addition, GWR has a limitation in using categorical variables in the modeling process because categorical variables can cause a serious multicollinearity issue in the model. Including the dummy/binary variables for a categorical variable (e.g., terrain type and districts) can cause "redundant" locally when the categories are spatially clustered in some areas with some categories missing in other areas (Zhang et al. 2011). GWR analysis in Chapter 5 avoided the binary variables for the categorical variables (i.e., time of year, types of price adjust clauses, terrain type, and districts) that were used for MLR analysis in Chapter 4. Thus, Chapter 5 was not able to test hypothesis related to any categorical variables.

5.5 Conclusion

The overall contribution of this chapter to the body of knowledge is a preliminary understanding of the relationship between construction costs and the geographical location of a project and spatial relationships between construction costs and external covariates, including project characteristics, construction markets, and economic conditions.

The study used GWR (geographically weighted regression) to spatially examine variations in submitted unit prices for bid line items. The identified variables—the ratio of the bid item, the quantity of the bid item, the total contract price, pavement length, the number of bidders, number of nearby asphalt plants, hauling distance between quarry and asphalt plants, the asphalt cement price index, the number of hires, national highway construction cost index, Dow Jones Industrial Average, and construction cost index—showed power to explain variation in submitted unit prices. The identified variables in this chapter are the same as the significant variables identified in the MLR analysis of Chapter 4 except the binary variables, which were not included in the GWR analysis due to the multicollinearity issue.

Furthermore, the average relationship between the submitted unit price bids and explanatory variables in the GWR models showed the same relationships that were shown in the MLR model of Chapter 4. For instance, quantity of the bid item, number of nearby asphalt plants, pavement length, and number of bidders have negative relations with submitted unit price bids, while the remaining variables have positive relations with the submitted unit price bids for asphalt line items. Unlike the MLR model in Chapter 4, a global model for a study area, the developed GWR models consist of set of local regression models, which have various local coefficients depending on the geographical location of the projects. Therefore, this research did not identify the relative importance for the identified variables in the GWR models.

In addition, this chapter used to a spatial interpolation tool to examine the significance of spatial correlations between submitted unit price bids and the identified variables and concluded that when cost estimators use the identified variables for estimating construction costs, they should assign various weights to the identified variables with the spatial relationships. This chapter proved that the use of GWR analysis provides the greater capability of describing variations in submitted unit price bids for highway construction projects.

In addition, the proposed approach provides insight into the exploration of geographical variation in a graphical manner. The findings of this chapter should help state DOTs determine more accurate construction costs by considering the geographical locations of the projects. For instance, to adjust the preliminary cost projections for a project, they could use a cost estimator that takes the spatial patterns of construction costs into account. By employing a cost estimator that uses spatial relationships between construction costs and important variables, a state DOT is able to adjust and prepare bids prior to letting a project.

CHAPTER 6. PROFILE MODELING TO EXAMINE VARIATION IN THE SUBMITTED UNIT PRICE BIDS AFTER DEVASTATING NATURAL DISASTERS

6.1 Introduction

Hurricanes Katrina and Rita hit the Gulf of Mexico coast in August and September 2005, respectively, and devastated a great deal of property in Louisiana, Mississippi, and Alabama. According to the Department of Homeland Security (DHS) (2006), the storm surge and flooding caused by Hurricane Katrina caused 1,326 deaths, displaced more than 700,000 people from the Gulf Coast regions, 273,000 of whom were evacuated to shelters, and destroyed approximately 300,000 homes. Such large-scale disasters cause extensive destruction and damage to the infrastructure and buildings (Hallegatte and Przyluski 2010) and disorder in social and economic activity, both of which impose a significant burden on entities responsible for implementing construction and reconstruction projects. For instance, aaccording to Hayat and Amaratunga (2011), there is a significant challenge in conducting roadway projects after large-scale disasters because of difficulties in developing accurate project design and acquiring property for roadway projects in disaster environment.

In the aftermath of a large-scale disaster, an unprecedented increase in the demand for construction and the disruption of transportation and resource supply systems generate considerable uncertainty that leads to inaccurate cost estimates for construction projects and inappropriate investment decisions (Mendell 2006; Senter 2006). In addition, construction projects under such uncertainty often experience cost overruns, financial problems, and project delays or cancellations (Peng 2006). These problems call for research that improves our understanding of changes in construction costs after a natural disaster.

Several studies have investigated the impact of natural disasters on the construction industry. For example, a study by Guimaraes et al. (1993) examined changes in economic activity in the aftermath of Hurricane Hugo, which struck the U.S coast in South Carolina in 1989. The authors found that construction income significantly increased after the hurricane and suggested that the main causes of the increase were greater regional activity in construction sectors (e.g., residents and businesses) and greater financial flow in the form of disaster relief and insurance claims to communities. In another study, Chang et al. (2011) found that construction agencies often face difficulty procuring skilled construction labor and materials for implementing reconstruction projects after large-scale disasters. The resource availability for post-disaster reconstruction can cause significant cost changes for reconstruction projects. From a survey of building contractors, the authors identified influential factors (e.g., quantity of resources required, competency of resourcing manager and qualification of contractors, general economic environment, and resource transportation cost) that affected resource availability for housing recovery construction after the 2008 Wenchuan earthquake in China.

To explain construction cost changes for residential and commercial properties after the 2002 to 2010 hurricane seasons in Florida and the other states on the Atlantic and Gulf of Mexico coasts, Olsen and Porter (2013) developed an exploratory model that found that these regions underwent significant cost changes after large storms. The authors concluded that labor costs were a major driver of construction cost changes for repairing residential and commercial properties. Cheng and Wilmot (2009) studied the impact of Hurricanes Katrina and Rita on the Louisiana highway construction cost index, consisting of six major bid items. They also concluded that the index in the hurricane-impacted area significantly increased after the hurricanes and declined during the subsequent two quarters while the index in the non-hurricane-impacted area declined after the hurricane.

However, the studies mentioned above have not examined the effects of natural disasters on the costs of highway construction, which suggests the need for an empirical analysis of such costs. In addition, little literature discusses process shift of construction costs for highway projects after large-scale disasters. Therefore, the aim of this chapter is to detect process shifts in the submitted unit price bids and determine the recovery period of the submitted unit price bids after larger-scale disasters.

6.2 Research Objectives

The overarching objective of this research is to analyze the impact of Hurricane Katrina and Rita on submitted unit price bids for superpave asphaltic concrete line items. To do so, this paper has the following sub-objectives:

1) To monitor the changes in submitted unit price bids for hurricane-impacted and non-hurricane-impacted areas
2) To detect process shifts in submitted unit prices after Hurricanes Katrina and Rita

3) To investigate the long-term impact of Hurricanes Katrina and Rita on variations among submitted unit prices

The following hypothesis is used in this chapter:

Null hypothesis (*H_0*): the process of submitted unit price bids remains in control at the target value μ_0 after Hurricane Katrina and Rita.

Alternative hypothesis (*H_1*): the process of submitted unit price bids significantly is in the out of control state (i.e.,$\mu_1 > \mu_0$ or $\mu_1 < \mu_0$) after Hurricane Katrina and Rita.

6.3 Hurricane-Impacted Areas

Figure 10 shows the 64 parishes in Louisiana, highlighted in gray, devastated by Hurricanes Katrina and Rita. The federal government declared these parishes, listed on Federal Emergency Management Agency (FEMA)'s official website (FEMA 2015a; FEMA 2015b), disaster areas. Hurricane Katrina impacted nine parishes, including Jefferson, Orleans, Plaquemines, St. Bernard, St. Charles, St. John the Baptist, St. Tammany, and Tangipahoa in the southeastern region in the state of Louisiana, and Hurricane Rita also impacted nine parishes, including Calcasieu, Cameron, Iberia, Lafourche, St. Charles, St. John the Baptist, St. Mary, Terrebonne, and Vermilion in the southern regions in the state. Thus, focusing on these parishes, this paper monitors changes in submitted unit price bids for highway construction projects after Hurricane Katrina and Rita.

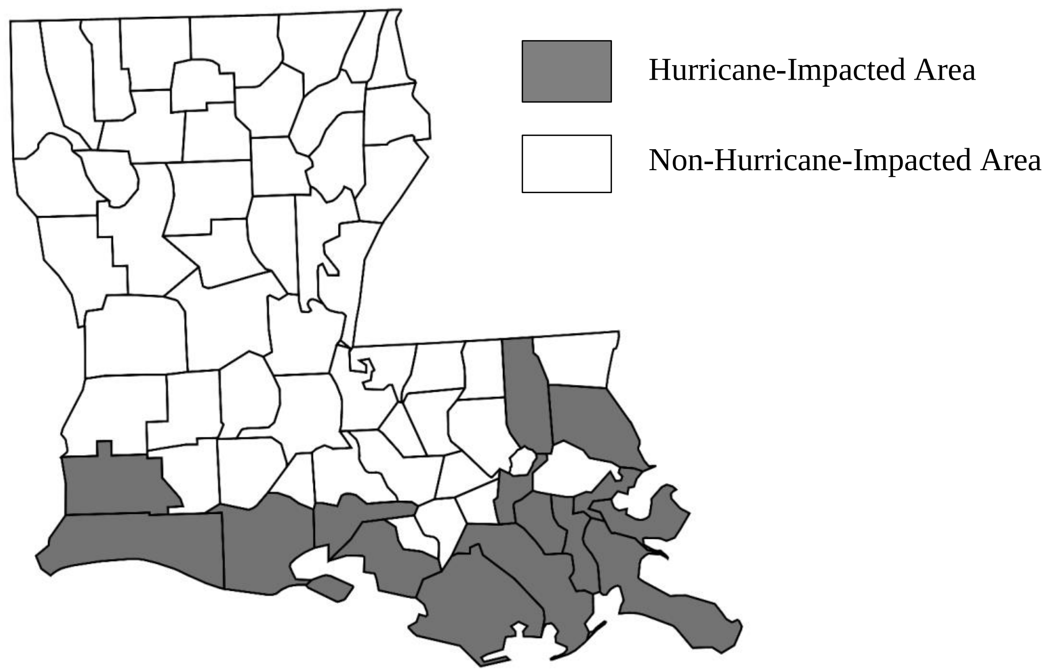


Figure 10 - Parishes Impacted by Hurricanes Katrina and Rita

6.4 Research Methodology

This chapter adopt statistical process control (SPC) for monitoring and detecting changes in submitted unit price bids after Hurricanes Katrina and Rita in the state of Louisiana. SPC is a statistical method for the quality control of a process. For this research, a cumulative sum (CUSUM) control chart, one of the tools of SPC, is selected for monitoring and detecting changes in submitted unit price bids. CUSUM is a powerful tool for detecting a small shift in a process (Montgomery 2009).

Two types of control chart application are used in this chapter. Phase I analyzes the set of process data at one by contracting control limits to determine if the process has been in control over the period of time. In phase II, where it is assumed that the process is reasonably table, process shifts caused by assignable causes can be detected using control chart applications (e.g., cumulative sum). In this chapter, phase II process monitoring is utilized for the short-term analysis of Hurricane Katrina and Rita to detect process shift in the submitted unit price bids after Hurricane Katrina and Rita. Phase I process monitoring is used for the long-term analysis of the hurricanes to determine if the process has been in control over the period of time (Montgomery 2009).

SPC techniques have been developed in practical situations in which a process/product is functionally dependent on one or more explanatory variables. In such cases, a profile monitoring technique that takes into account functional relationships between the process and explanatory variables is applicable to the monitoring process (Montgomery 2009). A profile-monitoring technique uses residuals from a developed regression model to monitor the process. In addition, monitoring regression residuals with the CUSUM control chart instead of using original data values enhances sensitivity to small shifts (Montgomery 2009). Thus, this paper applies CUSUM control charts to regression residuals for hurricane-impacted and non-hurricane-impacted areas and investigates the impact of Hurricanes Katrina and Rita on variations among submitted unit price bids for superpave asphaltic concrete line items. Lastly, to monitor the long-term impact of Hurricanes Katrina and Rita, this chapter uses a dataset between 2004 and 2015 in our CUSUM control chart analysis, following the steps of the research methodology:

1. Developing regression models for the hurricane- and non-hurricane-impacted areas before the hurricanes hit the Gulf Coast

2. Examining the relationships between submitted unit price bids and explanatory variables
3. Computing residuals by subtracting the submitted unit price bids from the predicted values for the entire dataset (i.e., the dataset before and after Hurricanes Katrina and Rita)
4. Applying CUSUM control charts to the residuals for both areas
5. Diagnosing CUSUM control charts to detect any shifts in the regression residuals and out-control signals after Hurricanes Katrina and Rita for the hurricane- and non-hurricane-impacted areas
6. Investigating the long-term impact of Hurricanes Katrina and Rita on the variability of the submitted unit price bids

6.5 Results and Discussion

6.5.1 Short-Term Impact of Hurricanes Katrina and Rita

Ordinary least squares regression modeling is applied for developing regression models with the submitted bid prices and explanatory variables. To determine the linear relationships between the submitted unit price bids and explanatory variables, a scatter plot assessment and Pearson correlation tests were conducted. Natural logarithms were used for transforming the quantity of bid items among the explanatory variables. Tables 10 and 11 list the results of the regression analysis using the submitted unit price bids before Hurricanes Katrina and Rita and project-related and construction market variables for the hurricane- and non-hurricane-impacted areas.

From the results of the regression model of the hurricane-impacted area, the quantity of bid items and level of unemployment exhibit a strong relationship with the submitted unit price bids at a significance level (*p*-value) of 0.05 while holding all other variables constant. From the results of the regression model of the non-hurricane-impacted area, the quantity of bid items and the total contract price significantly impact the submitted unit price bids at a significance level (*p*-value) of 0.05 while holding all other variables constant. The quantity of bid items from both regression models exhibits a negative relationship with submitted unit price bids. Variance inflation factors (VIFs) are less than 10. Therefore, the model has no multicollinearity issue.

Table 10 - Results of the Regression Analysis for the Hurricane- and Non-Hurricane-Impacted Areas

Model	Hurricane-Impacted Area			Non-Hurricane-Impacted Area		
	Parameter Estimate	**t ratio (Pr > |t|)**	**VIF**	**Parameter Estimate**	**t ratio (Pr > |t|)**	**VIF**
Constant	216.259	2.904 (0.005)		237.336	3.358 (0.001)	
Quantity of the Bit Item (in transformed natural logarithmic form)	-8.621	-6.523 (0.000)	1.209	-18.763	-20.165 (0.000)	1.148
Total Contract Price	2.284×10^{-7}	1.118 (0.267)	1.280	1.486×10^{-6}	4.526 (0.000)	1.120
Unemployment	0.002	2.888 (0.005)	1.084	-0.001	-1.791 (0.075)	1.024
Crude Oil Price	0.491	0.878 (0.383)	4.029	0.384	0.814 (0.417)	4.300
Building Cost Index, New Orleans	-0.024	-0.964 (0.338)	2.865	-0.015	-0.659 (0.511)	2.891

Table 10 Continued

Building Permits for New Residential Construction, South	**-0.040**	**-0.641 (0.524)**	**2.276**	**0.015**	**0.287 (0.774)**	**2.241**

Adjusted R Squared	0.415 (41.5%)	0.711 (71.1%)
Number of Observations	Before Hurricanes: 73 (used for Regression modeling) After Hurricanes: 144	Before Hurricanes: 169 (used for Regression modeling) After Hurricane: 303

The results of the ANOVA for the regression models, listed in Table 11, indicate that the regression models for both the hurricane- and non-hurricane-impacted areas statistically significant.

Table 11 - ANOVA Test for the Regression Models for the Hurricane- and Non-Hurricane-Impacted Areas

Model	Hurricane-Impacted Area					Non-Hurricane-Impacted Area				
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	16042.572	6	2673.762	9.509	.000	179172.326	6	29862.054	70.024	.000
Residual	18558.361	66	281.187			69085.521	162	426.454		
Total	34600.933	72				248257.848	168			

Regression residuals were calculated for the entire dataset before and after Hurricane Katrina and Rita by subtracting the submitted unit price bids from the predicted values, computed by the estimated regression equations. Then, to monitor the process of the submitted unit price bids, the CUSUM control chart was applied to the regression residuals. CUSUM control charts can be created by plotting the cumulative sums of the deviations of the residuals from the target value (μ_0). Creating a CUSUM control chart requires the construction of a tabular CUSUM, which entails the use of one-sided upper and lower CUSUMs, denoted by C^+ and C^-, which are computed by the following equations (Montgomery 2009):

$$C_i^+ = \max[0, e_i - (\mu_0 + K) + C_{i-1}^+]$$

$$C_i^- = \max[0, (\mu_0 - K) - e_i + C_{i-1}^-]$$

where e_i is the residual of the regression (i.e., $Y_i - \hat{Y}_i$), the starting values are $C_0^+ = C_0^- = 0$, μ_0 (target value) is the in-control values/residuals of the mean before Hurricanes Katrina and Rita, and *K* is the reference value, calculated at $K = |\mu_1 - \mu_0|/2$, where μ_1 is the out-of-control values/residuals of the mean after Hurricanes Katrina and Rita. While the upper CUSUM, C_i^+, detects an increase in the submitted unit price bids for asphalt line items, the lower CUSUM, C_i^-, detects a decrease in the submitted unit price bids. In addition, the CUSUM control chart consists of upper and lower control limits, which are estimated by decision interval *H*. The upper and lower control limits are defined as follows (Montgomery 2009):

$$Upper\ Control\ Limit\ (UCL) = H\sigma$$

$$Lower\ Control\ Limit\ (LCL) = -H\sigma$$

where a reasonable value for *H* is 5 and σ is the standard deviation of the in-control values. Thus, the upper and lower control limits for the hurricane- and non-hurricane-impacted areas were ± 80.274 and ± 101.393, respectively. If C_i^+ and C_i^- exceed both upper and lower control limits, the process is defined as an out control state, indicating that a significant increase or decrease in the submitted unit price bids. Determining the recovery period require the number of consecutive periods in which CUSUM C_i^+ or C_i^- have been nonzero prior to the first period that is out of state after Hurricanes Katrina and Rita (Montgomery 2009).

Figures 11 and 12 plot the CUSUM from calculations by equations mentioned above. Figure 11 presents the results of the CUSUM control chart for the hurricane-impacted area, which showed a significant increase in the submitted unit price bids for superpave asphaltic concrete line items detected immediately after Hurricanes Katrina and Rita. This finding is consistent with the previous study conducted by Cheng and Wilmot (2009). A submitted unit price bid for a project let in October 2005 was the first observation in the out-of-control state after Hurricanes Katrina and Rita. Thus, the null hypothesis is rejected and there is statistical difference in submitted unit price bids after Hurricane Katrina and Rita. In addition, the submitted unit price bids in the hurricane-impacted area started to shift in July 2005. According to the third quarterly cost report of *Engineering News Report* (ENR) (2005), a boom in cleanup and reconstruction activity in the hurricane-impacted area immediately after Hurricanes Katrina and Rita caused a shortage of materials and skilled labor that led to price increases in construction resources. In addition, the severe supply disruptions caused by the shutdown of the energy infrastructure (e.g., oil refineries), cement plants, and transport systems such as rails, roads, and bridges for construction resources along with the damage they sustained in the aftermath of Hurricanes Katrina and Rita resulted in significant cost increases in construction materials (Kowal et al. 2006), which led to higher bids for construction projects. The recovery period was not identifiable in the analysis of the short-term impact of Hurricanes Katrina and Rita.

Figure 12 shows the CUSUM control chart for the non-hurricane-impacted area. Although significant variability in the submitted unit price bids occurred in the aftermath of Hurricanes Katrina and Rita, none of the CUSUM C_i^+ or C_i^- were out of control until March 2006. The non-hurricane-impacted area experienced a shift in the submitted unit price bid in March 2006, when the first out-of-control state in the non-hurricane-impacted area also occurred, which indicated that the null hypothesis is rejected. Thus, the non-hurricane-impacted area experienced a significant increase in submitted unit price bids during the six months following Hurricanes Katrina and Rita.

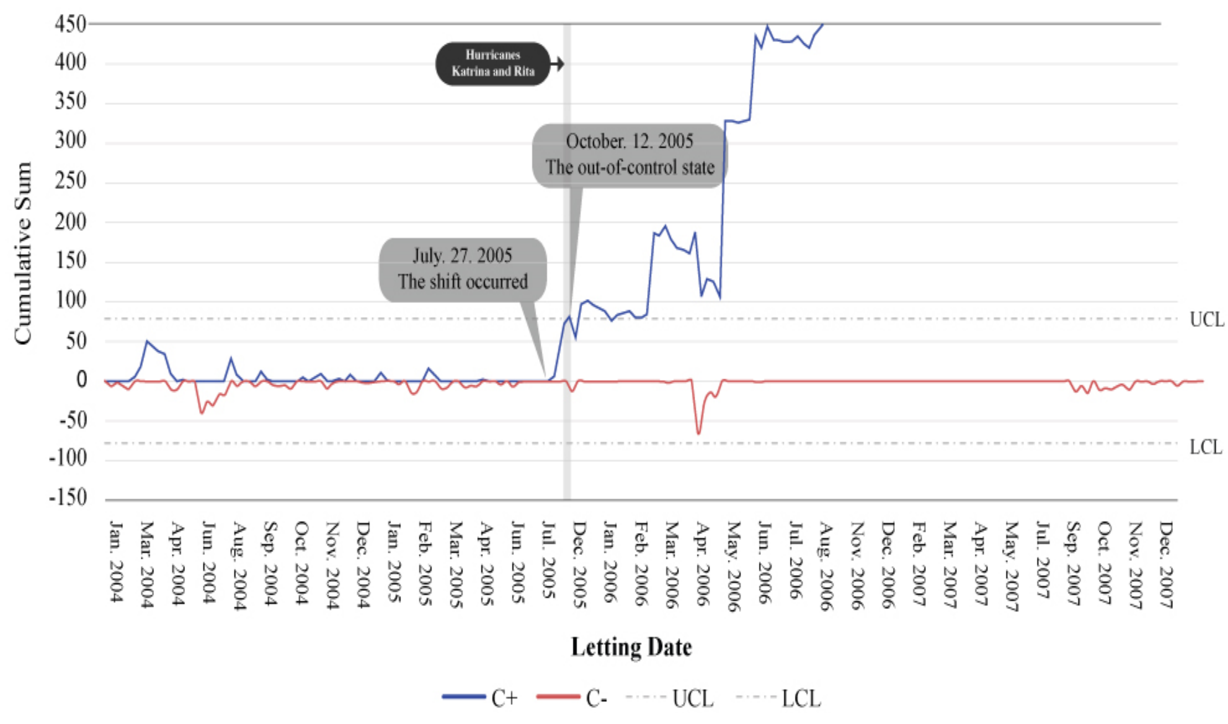


Figure 11 - CUSUM Control Chart for the Hurricane-Impacted Area

Figures 11 and 12 illustrate a major shift between March and July 2006 that occurs in both the hurricane- and non-hurricane-impacted areas. The major cause of this shift is a boom in reconstruction activity. A year after Hurricanes Katrina and Rita hit the Gulf of Mexico, more than 38,000 building permits were issued for rebuilding residential property (Liu et al. 2006). Moreover, approximately $5 billion in federal grants went to the state of Louisiana for aid in rebuilding damaged housing and other infrastructures on May 2006 (U.S. Department of State 2006). The federal support and the massive building permits that prompted a boom in reconstruction activities led to increased demand for construction services, which in turn, caused higher bids for higher projects let in the entire state of Louisiana. The CUSUM control chart for non-hurricane-impacted areas was not able to detect the recovery period in the short-term analysis of Hurricanes Katrina and Rita.

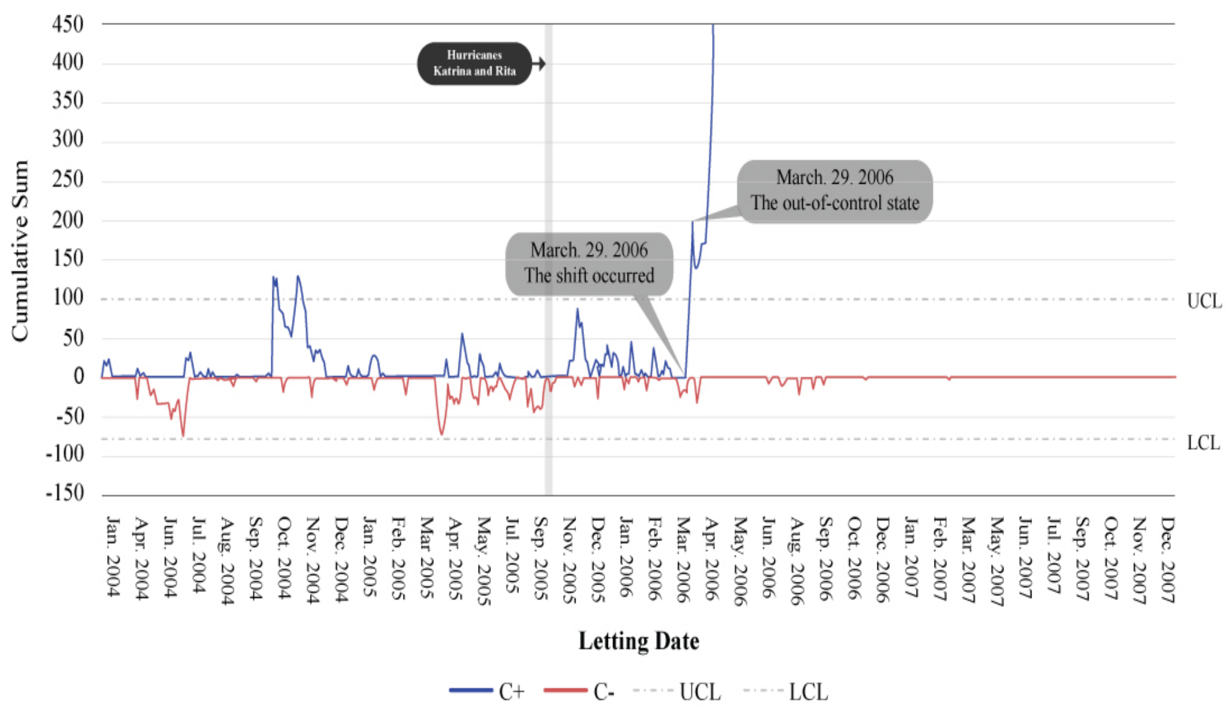


Figure 12 - CUSUM Control Chart for the Non-Hurricane-Impacted Area

6.5.2 *Long-Term Impact of Hurricane Katrina and Rita*

The CUSUM control chart was used to diagnose the long-term impact of Hurricanes Katrina and Rita. A regression model was developed using submitted unit price bids for highway projects let throughout the state of Louisiana between 2004 and 2015 with the key explanatory variables. The results of the regression model appear in Tables 12 and 13. The identified variables show power to explain variations among the submitted unit price bids for Superpave asphaltic concrete with a 95% significance level (*P*-value<0.05).

Table 12 - Results of the Regression Analysis for Submitted Unit Price Bids between 2004 and 2015

Model	Parameter Estimate	t ratio (Pr > |t|)	VIF
Constant	195.796	14.437 (0.000)	
Quantity of the Bit Item (in transformed natural logarithmic form)	-19.474	-52.501 (0.000)	1.022
Total Contract Price	3.790×10^{-7}	7.193 (0.000)	1.028
Unemployment	3.951×10^{-4}	2.029 (0.042)	1.024
Crude Oil Price	0.109	2.751 (0.006)	1.306
Building Cost Index, New Orleans	0.019	5.443 (0.000)	1.680
Building Permits for New Residential Construction, South	-0.330	-7.344 (0.000)	1.683
Adjusted R Squared	0.456 (45.6%)		
Number of Observations	3815		

In addition, the ANOVA test concluded that the developed model was statistically significant at a 95% confidence (*P*-value<0.05).

Table 13 - ANOVA Test for the Regression Models for the Submitted Unit Price Bids between 2004 and 2015

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	6773715.917	6	1128952.653	534.342	.000
Residual	8045509.112	3808	2112.791		
Total	14819225.03	3814			

After accounting for the variability explained by the identified variables in the regression model, the residuals from the developed regression model were used to develop a CUSUM control chart for measuring the variability among the submitted unit price bids, shown in Figure 13. Five standard deviations (5 sigma) are depicted in Figure 13 as the upper- and lower-control limits (i.e., 229.64 and -229.64, respectively) to identify the significance level of the variability.

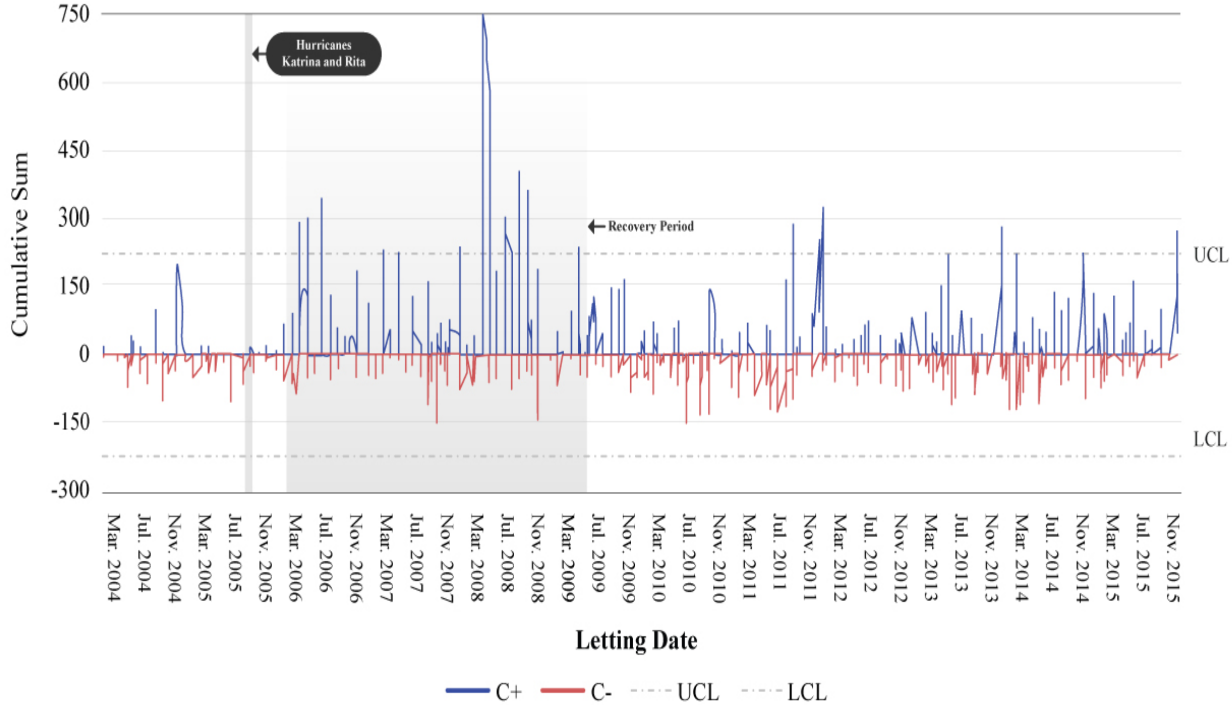


Figure 13 - CUSUM Control Chart for Submitted Unit Price Bids in the State of Louisiana between 2004 and 2015

The first out-of-control signal on the CUSUM control chart is detected on April 26, 2006, and then a shift likely occurs after Hurricane Katrina and Rita between February 22, 2006 and March 29, 2006. In addition, significant variability in the submitted unit price between March 2006 and December 2006 is noticeable. The U.S. Department of Housing and Urban Development (HUD) approved $368.4 million to fund rebuilding plans that would meet the infrastructure needs of the state and $10.8 billion to fund Louisiana's Road Home Program (U.S. Department of State 2006). The rebuilding plans led to a significant increase in construction demand and a shortage of construction resources (e.g., materials, workers, equipment) in the state, which may have resulted in the significant variability among submitted unit price bids. Furthermore, according to a study conducted by Kates et al. (2006), the period of the restoration process for electricity, gas, public transportation, schools, hospitals, and food stores was 40 weeks (until June of 2006). After the completion of the restoration process, the reconstruction process gained momentum in the reestablishment of the infrastructure, housing, and jobs for the destroyed areas (Kate et al. 2006).

During the Atlantic hurricane season in 2008, Louisiana experienced two devastating hurricanes, Hurricanes Gustave (Category 4) and Ike (Category 4), which may have caused additional variability in the submitted unit price bids. After the great recession of 2008 and 2009, the variability subsides with unit price bids returning to their normal/pre-hurricane levels between June 2009 and August 2011. Therefore, the recovery period for the submitted unit price bids after Hurricanes Katrina and Rita occurred between February 2006 and June 2009, approximately 170 weeks.

6.6 Conclusion

Hurricanes Katrina and Rita significantly impacted submitted unit price bids for superpave asphaltic concrete line items used on highway pavement projects. In this chapter, a profile monitoring technique was used to investigate short- and long-term effects of these hurricanes on submitted unit price bids. In a short-term analysis, significant shifts in the submitted unit price bids before and after the hurricanes for both hurricane- and non-hurricane-impacted areas were detected. Results of a CUSUM control chart indicated that after Hurricanes Katrina and Rita hit the Gulf of Mexico, unit price bids for asphalt line items in the hurricane-impacted area significantly increased immediately after the hurricanes, and those in the non-hurricane-impacted area significantly increased six months after the hurricanes.

Furthermore, the long-term impact of these hurricanes on the submitted unit price bids between 2004 and 2015 was investigated. It is concluded that the variability among submitted unit price bids subsided; that is, bids returned to their normal levels in June 2009. We expect that these findings will help estimators and capital project planners set and adjust the costs of their highway construction projects and the timing of project letting while avoiding increases in construction demand and disruptions in transportation and resource supply systems during recovery and reconstruction in the aftermath of large-scale disasters.

Transportation agencies should ensure that post-disaster reconstruction, as well as new construction, is placed on safe ground and built on time and within budget. The results of this chapter will enable both construction agencies to improve their understanding of variations in construction costs after large-scale disasters and transportation agencies to more accurately estimate the cost of rebuilding highway projects. They should also help them make more-informed investment decisions for highway recovery programs in the aftermath of large-scale disasters. It is expected that the proposed framework can be generalized to the monitoring of other line items after large-scale disasters.

CHAPTER 7. CONCLUSION AND CONTRIBUTION

7.1 Conclusion

This research aimed to investigate the impact of potential explanatory variables on variation construction costs. The main objectives of this research were as follows:

1. Investigate the relations between the submitted unit price bids and potential explanatory variables

2. Assess the spatial variations of relations between the submitted unit price bids and explanatory variables

3. Monitor the process of variation in the submitted unit price bids after large-scale disasters

Chapter 4 developed a regression model to explain variation in submitted unit price bids and study the relations between the submitted unit price bids and potential explanatory variables. The developed regression model statistically showed the capability to explain variation in the submitted unit price bids and demonstrated the significant relations between the submitted unit price bids and explanatory variables. Chapter 4 identified several important variables, in descending order of importance, including: (1) the quantity of the bid item; (2) total contract price; (3) asphalt cement price index; (4) Dow Jones Industrial Average; (5) number of nearby asphalt plants; (6) ratio of bid item; (7) pavement length; (8) national highway construction cost index; (9) number of hires; (10) number of bidders; (11) construction cost index; and (12) hauling distance between quarry and asphalt plants. It is also found that the quantity of the bid item, the number of nearby asphalt plants, pavement length, and number of bidders have significant negative relationships on the submitted unit price bids, while the remaining variables are positively related to the submitted unit price bids for asphalt line items.

Chapter 4 found new variables that were not empirically examined in the previous studies. First, this research used types of price adjustment clauses to measure the impact of percent changes of trigger points and caps of price adjustment clauses on submitted unit price bids. In previous studies, they focused more on impact of inclusion of price adjustment clauses on the construction costs. Although the percent changes of trigger points and caps of price adjustment clauses for asphalt cement were not included in the explanatory model as significant variables, this finding enables transportation agencies to redesign the clauses for better controlling the price volatility of asphalt cement.

Next, this research included number of nearby asphalt plants, hauling distance between asphalt plant and project location, and hauling distance between quarry and asphalt plants for measuring impact of availability of suppliers and accessibility to materials sources on the submitted unit price bids and found that number of nearby asphalt plants and hauling distance between quarry and asphalt plants have significant impact on the unit price bids for asphalt line items. An interesting point to note is that hauling distance between asphalt plant and project location was not identified as an important variable for explaining the variation in the submitted unit price bids. In addition, equipment operator wages for paving was not included in the final model. To better explain the variability of the submitted unit price bids, it is essential to collect data/variables that can represent equipment operator wages for paving at the project level.

Chapter 5 explored the spatial variation in the submitted unit price bids and the spatial pattern of relationship between the submitted unit price bids and explanatory variables. Hot spot analysis showed that significant spatial variation between submitted unit price bids and geographical location of the projects. The results of this chapter found that submitted unit price bids in southern Georgia are relatively higher than those in the northern and middle regions of Georgia. The local models developed by geographically weighted regression analysis outperformed the generalized linear regression model. In addition, there is the presence of spatial heterogeneity of relationship between submitted unit price bids and explanatory variables.

Chapter 6 examined the impact of Hurricane Katrina and Rita on the submitted unit price bids for Superpave asphaltic concrete line items. The short- and long-term effects of Hurricane Katrina and Rita were examined using a profile monitoring technique. In a short-term analysis, significant shifts in the submitted unit price after the hurricanes were detected for both hurricane-and non-hurricane-impacted areas. The results of this chapter indicated that submitted unit price bids in the hurricanes impacted area increased immediately after the hurricanes, and those in the non-hurricane-impacted areas increased six months after the hurricanes. In a long-term analysis, it is concluded that submitted unit price bids in the State of Louisiana subsided and returned to their normal levels in June 2009. Therefore, the recovery period for the submitted unit price bids after Hurricanes Katrina and Rita occurred between February 2006 and June 2009, approximately 170 weeks.

7.2 Implications of the Results

The findings of this research and their implications are summarized as the following:

- One of the most interesting findings of our research is related to the assessment of price adjustment clauses in the highway construction industry. Skolnik (2011) conducted a survey of state DOT officials and highway industry professionals and found out that a common perception is that the inclusion of price adjustment clauses in contracts has the impact on submitted bid prices. Also, Skolnik found that changes in the trigger value of the clauses impact the variability of submitted bid prices. However, our empirical study shows no significant relationships between the inclusion of price adjustment clauses and submitted unit price bids for highway construction contracts. We also did not find any statistically significant relationships between changes of the trigger point of the clauses and submitted unit price bids for asphalt line items. This finding should be considered by highway agencies in: (a) questioning the effectiveness of offering price adjustment clauses for asphalt line items in their highway projects; and (b) designing effective price adjustment clauses with appropriate trigger points and risk sharing mechanisms for asphalt line items.
- This research has found significant evidences for economy of scale in contractors' submitted unit price bids for highway projects. The economy of scale exists in regard to both the quantity of the bid item and the pavement length. As the quantity of the bid item in a highway project increases the submitted unit price bid decreases. Also, as the pavement length increases the unit price bid decreases. These findings have important implications for transportation agencies in defining the scope of

highway projects. For instance, highway agencies may think of any opportunities to combine smaller resurfacing or widening projects in order to potentially receive lower unit price bids.

- This research found that availability of asphalt providers and input material suppliers are significant variables to explain the variability of submitted bid prices. The result is consistent with the previous studies (Al-Tabtabai et al. 1999; Alavi and Tavares 2009; Damnjanovic et al. 2009; Tran et al. 2014; and Shrestha et al. 2017) that show the importance of availability of material suppliers and hauling distances. However, the existing studies have not exactly examined the impact of availability of asphalt plants and material suppliers on highway construction costs. Our empirical study found an increase in the number of nearby asphalt plant is related to decrease in the submitted unit price bids. The increase in hauling distance between quarry and asphalt plants is related to increase in the submitted unit price bid. Highway cost estimators should evaluate the availability and the capacity of nearby asphalt plants and materials sources, in order to make appropriate adjustments in developing reliable cost estimates for highway projects.
- This research also found that the submitted unit price bids significantly fluctuated over the period of the recovery time. The agencies may want to postpone major projects unless they are critical and urgent.

7.3 Research Contribution

This research contributes to the body of knowledge in three aspects. The first contribution is the creation of regression models, including multiple regression and geographically weighted regression, which aids transportation agencies in estimating highway construction cost especially in the early stage of the project. Transportation agencies are interested in better utilization of historical data in developing more reliable cost estimates (Turochy el al. 2001; Anderson et al. 2006). State DOTs need better tools to estimate cost escalation using historical cost data (Paulsen et al. 2008). The regression models proposed in this research assist parametric estimating through employing a set of variables related to project features (e.g., work types, length, and construction cost index).

The second contribution is the identification of important factors affecting variation of submitted unit price bids by examining a comprehensive set of potential variables. According to Anderson et al. (2009), many state DOTs lack a systematic methodology to analyze and develop unit prices for construction and maintenance projects. Typically, state DOTs rely on experience and engineering judgment to adjust unit prices in response to a variety of factors, such as project complexity, market conditions, and material prices. This research identified a set of new variables, such as number of asphalt plants, construction cost index, and Down Jones Industrial Average, that are useful in explaining the variability of highway construction cost. The identified factors and their relative importance help cost engineers/estimators make better decisions in estimating/adjusting unit prices for work items and preparing bids for construction contracts. Furthermore, the spatial variation of relationships between the unit prices and the identified factors provides cost engineers/estimators in local government agencies/district offices with more detailed information for assigning weights to the identified factors in estimating and adjusting unit price bids according a geographic location of a project.

The third contribution is the identification of shift changes in submitted unit price bids in the aftermath of large-scale disasters. State DOTs face a significant challenge in estimating construction costs after large-scale disasters because of difficulties in measuring the extent of cost variation and identifying a short-term or long-term impacts of the disasters on construction costs (Cheng and Wilmot 2009). Capital project planners and cost engineers/estimators can have a better understanding of variation in submitted unit price bids after large-scale disasters, which aid to estimate more accurate construction costs and set or adjust timing of project letting while avoiding the unprecedented increase in the demand for construction and the disruption of transportation and resource supply systems.

Therefore, this research provides the necessary formulations in which the contextual information can be used to enhance the capability of cost engineers in preparing more-accurate budgets and bids. The empirical findings based on the actual project conditions aid a bottom-up estimating approach that requires more knowledge about the projects and markets. Furthermore, since the cost engineers are required to adjust construction costs as the project moves forward, the identified factors can be tracked, reviewed, and used for adjusting construction costs, instead of having to rely on the conventional approach, which is based on a fixed percentage escalation throughout the project development. In addition, increased demand/boom in the construction markets leads to the increased unit price bid. These findings suggest that the identified factors help capital project planners set and adjust the timing of project lettings while avoiding the boom in the local and state-wide market, if possible.

To practically utilize the proposed parametric model in this research, careful consideration should be given to three major elements. First, a credible database (e.g., Trn•sport of the American Association of State Highway and Transportation Officials and Bid Tabs of Oman Systems) is required for organizing and retaining information on completed projects (Bajaj et al. 2002; Anderson et al. 2007). Collecting and maintaining data should be based on the time to adjust the dollar-valued costs for inflation (Anderson et al. 2007; AASHTO 2013; FHWA 2015). Next, cost drivers/variables that impact the cost of various items of work should be identified. The identified cost drivers/variables should accurately reflect the particular situation being studied and estimated. Since this research identified significant factors affecting unit price bids for asphalt line items, the identified factors that represent project characteristics and market conditions can be incorporated into statistical modeling for pavement projects. Lastly, to improve the accuracy of cost estimates, adjustment of any of the calculated values can be made based on estimator knowledge of the project (Anderson et al. 2007). For instance, the important variables/cost-sensitive parameters that were identified in this research can be monitored to adjust the cost of the work item for managing cost escalation resulting from either scope or market changes.

The proposed parametric model, however, has three main challenges. First, a collaborative effort is essential for assembling, refining, and updating data, which are the most time-consuming processes (Membah and Asa 2015). Insufficient or inaccurate data can lead to the loss of the accuracy of the proposed model. Next, estimating project costs with the proposed parametric model may need large-scale assumption for unquantifiable or unknown project detail (e.g., construction method and productivity), compared to other estimating estimation techniques (e.g., cost-based estimation) (Anderson et al. 2007). Lastly, estimation environment/culture and data availability that may differ from organization to organization may hinder state highway agencies from utilizing the proposed parametric model and may also require them to calibrate statistical equation using their own data to ensure proper results (Turochy et al. 2001). Thus, transportation agencies can internally develop the parametric model using the framework proposed in this research that meets their unique estimation needs.

To enhance the quality of the parametric estimation model, it is essential for collecting additional data related to differences in construction management techniques of individual organizations and productivity/technology and policy for individual projects. For instance, since an increase of paving productivity can result in a significant increase of profitability for contactors, changes in paving productivity can significantly impact the variation in construction cost for pavement projects (Schmitt et al. 1997).

7.4 Limitations and Future Research

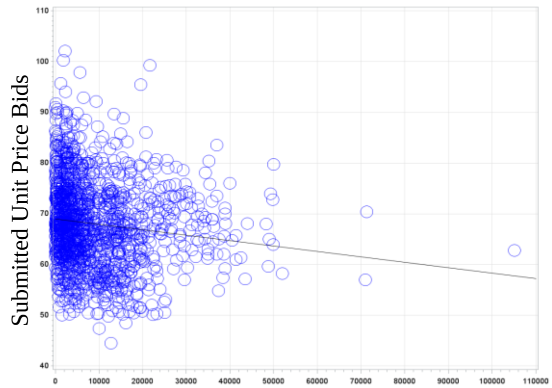
The major limitation of this research is that some variables, such as CCI, fuel price index, and NHCCI, are only available at the National or State level, not at the level of the nearby project area. The lack of data at the project level may introduce some limitations to model the variability of submitted price bids. Availability of finer data sources at the project level can enhance the quality of our model.

Another limitation of this research is that this research has no access to the engineer's estimate and the final construction costs of the projects (i.e., the actual unit price paid by the state highway agency) because of confidentiality reasons. Thus, this research has a limit in validating the proposed model with the engineer's estimate and the final cost of project. However, in future research, empirical analysis for modeling cost discrepancies among different types of cost data (i.e., engineer's estimate, submitted unit price, and actual unit price) with consideration for global and external factors allows cost engineers/estimators to estimate more accurate cost estimates and efficiently manage cost overrun during both project development and construction processes.

In future work, other modeling approaches, such as machine learning and artificial intelligence algorithms, should be utilized to enhance forecasting. However, the downside of these approaches is that these black box models are not good for identifying explanatory variables and explaining the effects of the variables on the submitted unit price bids.

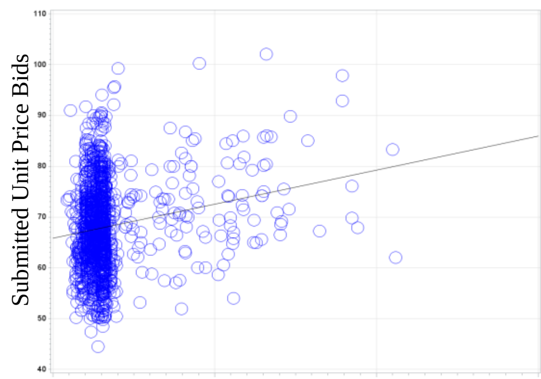
The framework proposed in this research can be used to examine variation in other major line items (e.g., structure concrete, excavation, and structural steel) and adopted to other state DOTs to improve the understanding of the impact of the project characteristics and market conditions on construction costs.

APPENDIX A. SCATTER PLOTS BETWEEN SUBMITTED UNIT PRICE BIDS AND EXPLANATORY VARIABLES

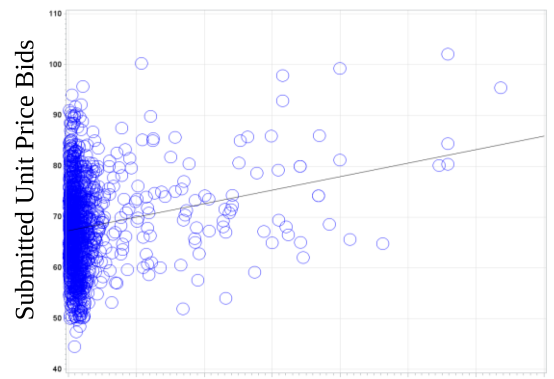


Quantity of the Bid Item

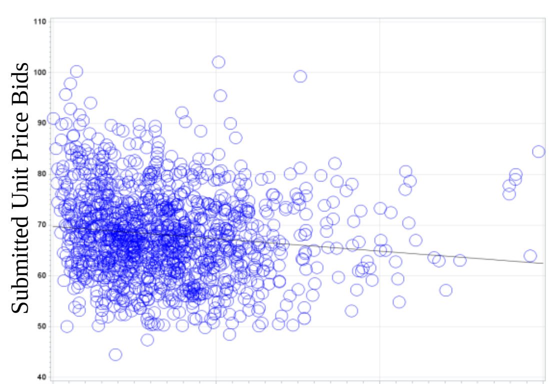
Ratio of the Bid Item



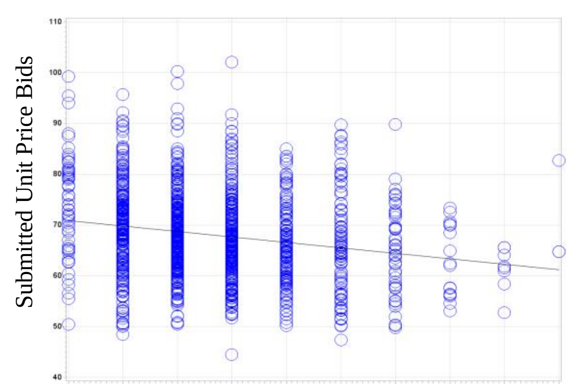
Project Duration



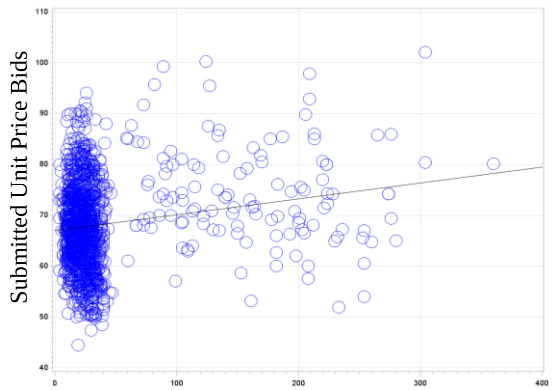
Total Contract Price



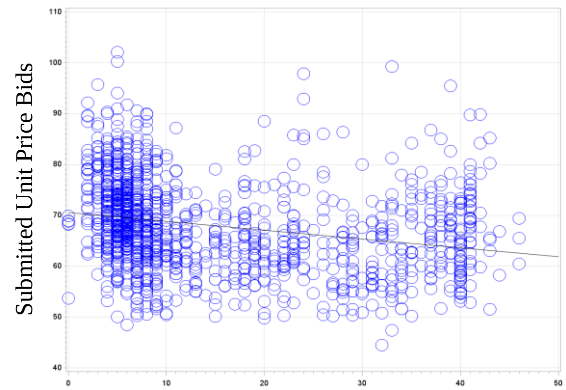
Pavement Length



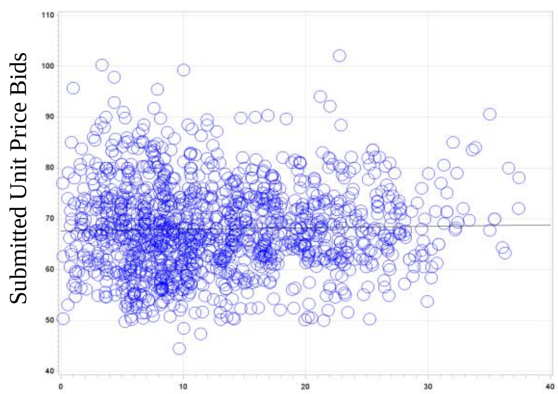
Number of Bidders



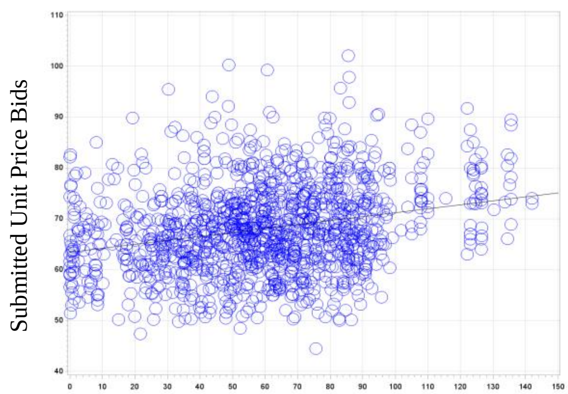
Number of Pay Items



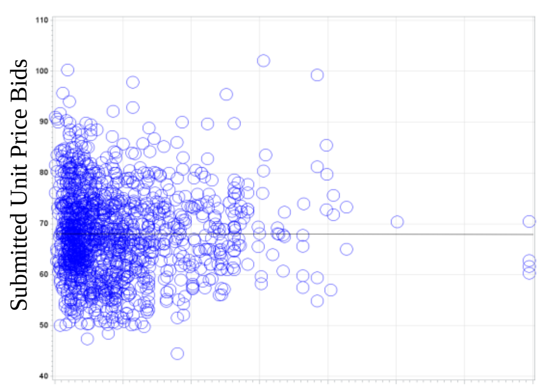
Number of Nearby Asphalt Plants



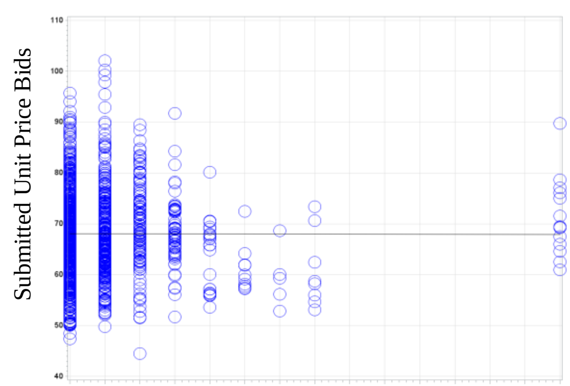
Hauling Distance between Asphalt Plant and Project Location



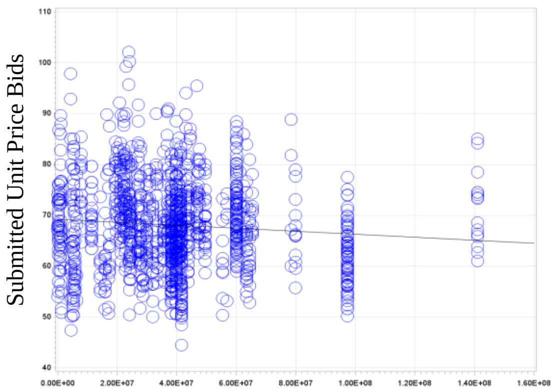
Hauling Distance between Quarry and Asphalt Plants



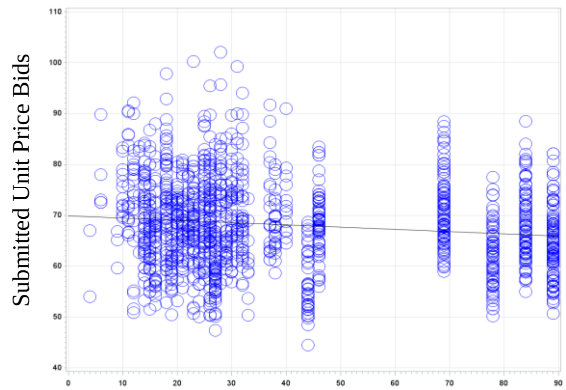
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County



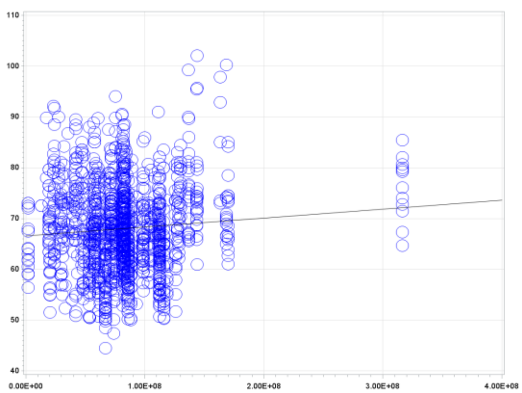
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County

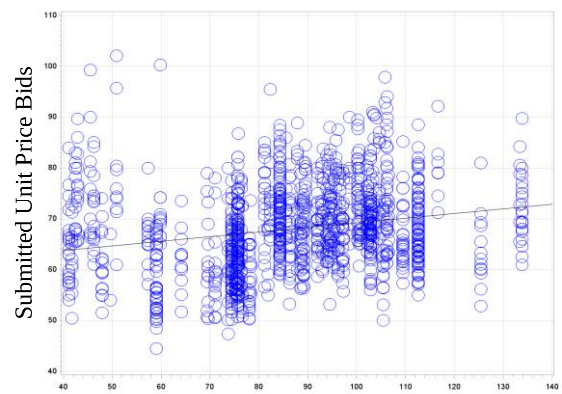


Total Asphalt Size of Projects Awarded in the Same Month at the State Level

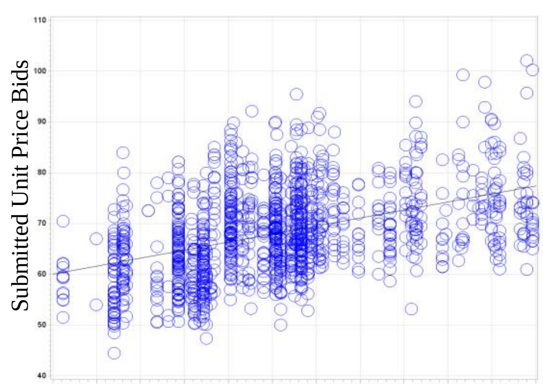


Total Number of Projects Awarded in the Same Month at the State Level

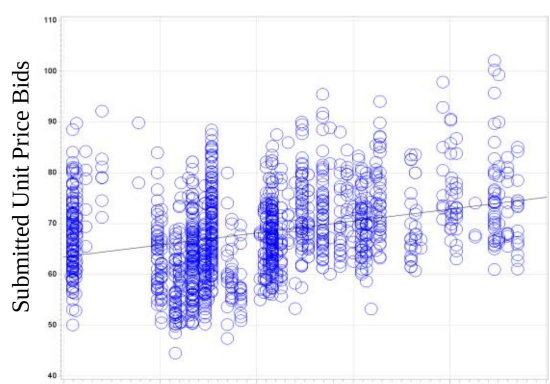

Total Dollar Value of Projects Awarded in the Same Month at the State Level



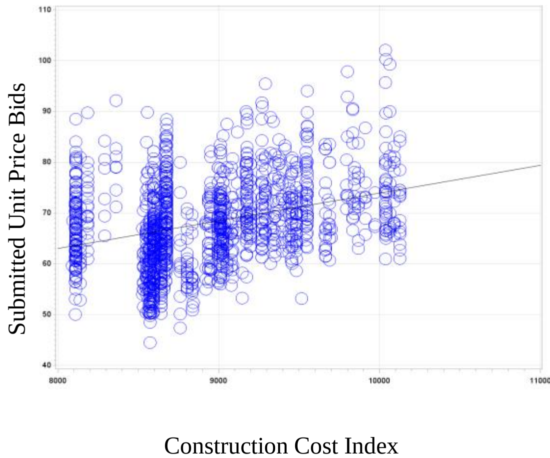
Crude Oil Price of West Texas Intermediate

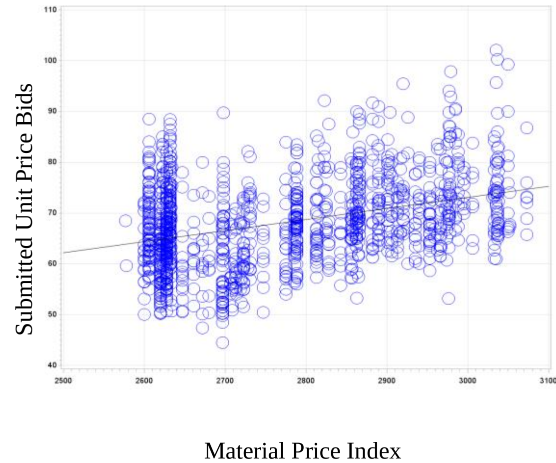


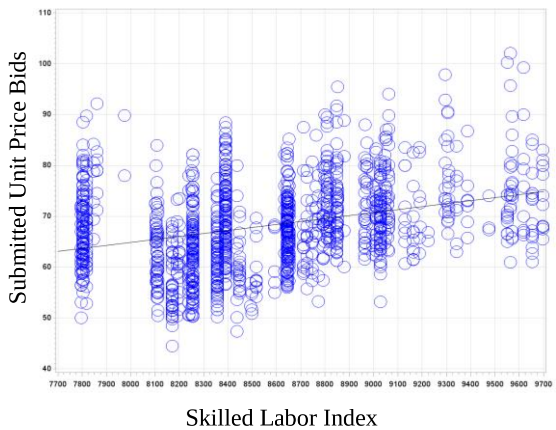
Dow Jones Industrial Average

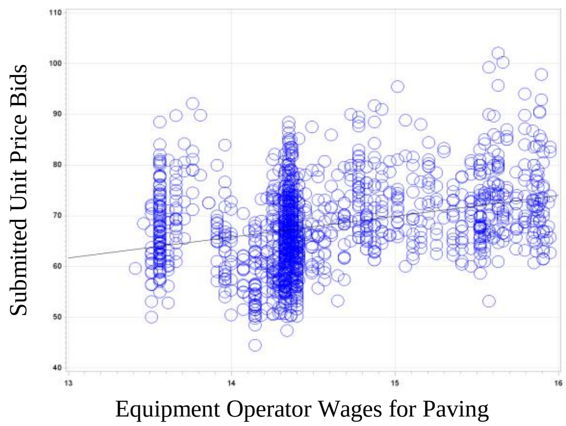


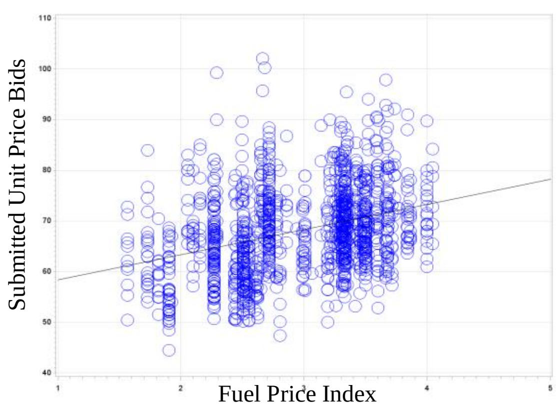
Common Labor Index

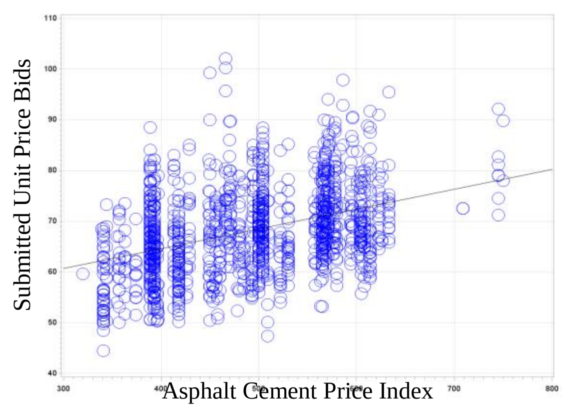

Submitted Unit Price Bids
Construction Cost Index

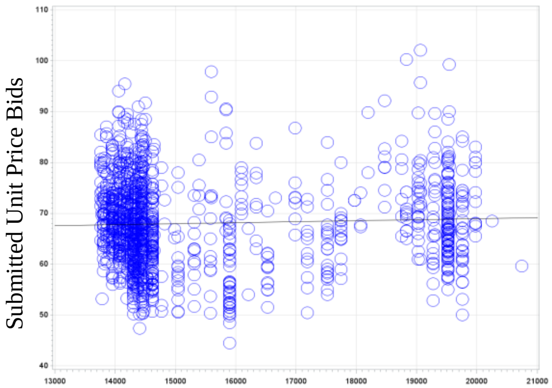

Submitted Unit Price Bids
Material Price Index


Submitted Unit Price Bids
Skilled Labor Index

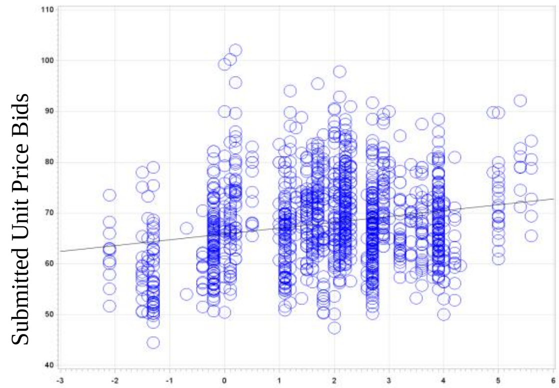

Submitted Unit Price Bids
Equipment Operator Wages for Paving


Submitted Unit Price Bids
Fuel Price Index

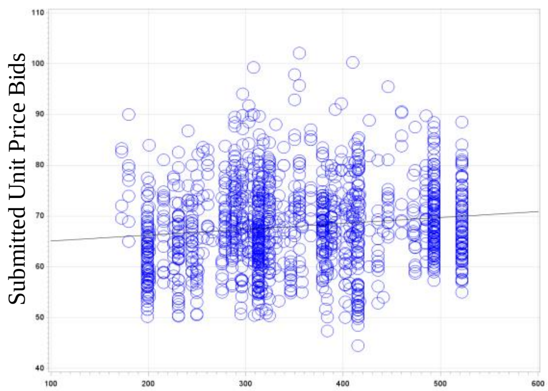

Submitted Unit Price Bids
Asphalt Cement Price Index



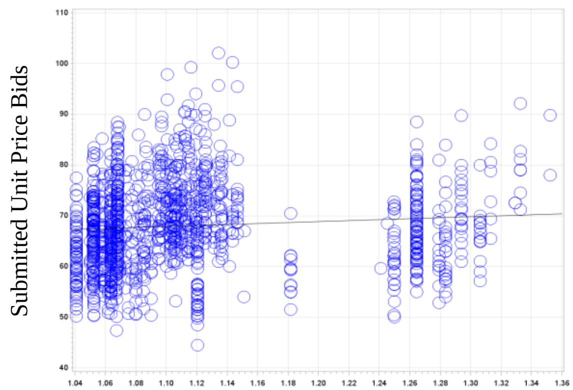
Gross Domestic Product of the Georgia Construction Industry



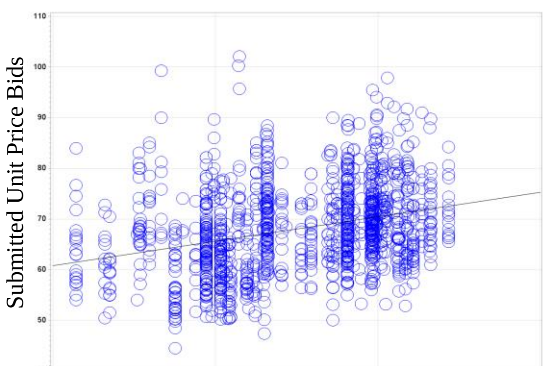
Inflation Rate



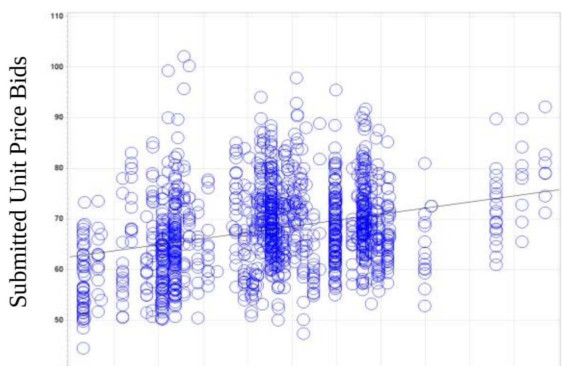
Number of Hires



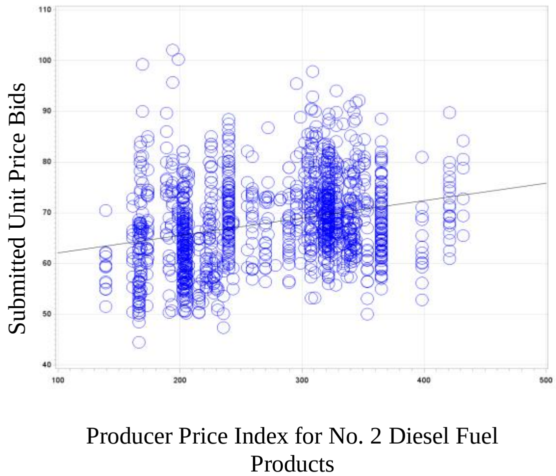
National Highway Construction Cost Index

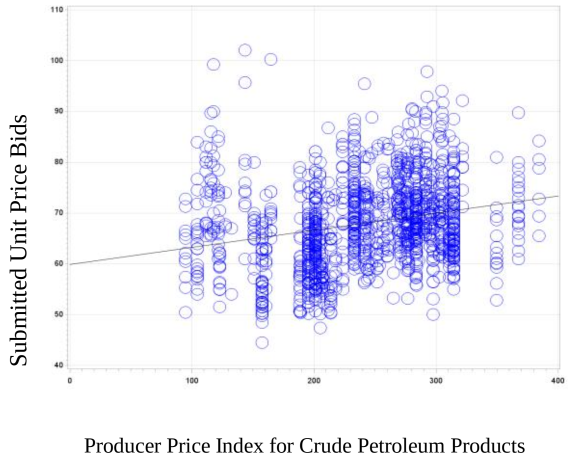


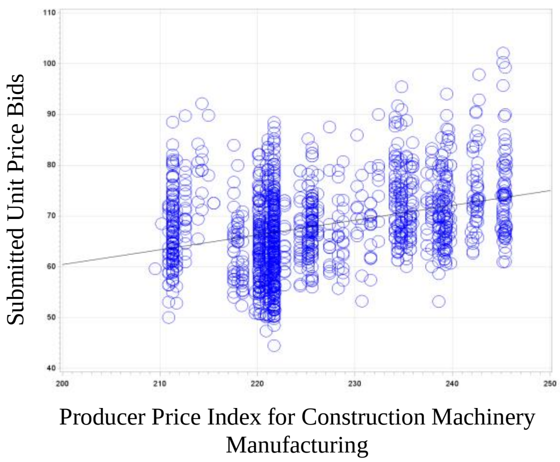
Producer Price Index for Gasoline Products

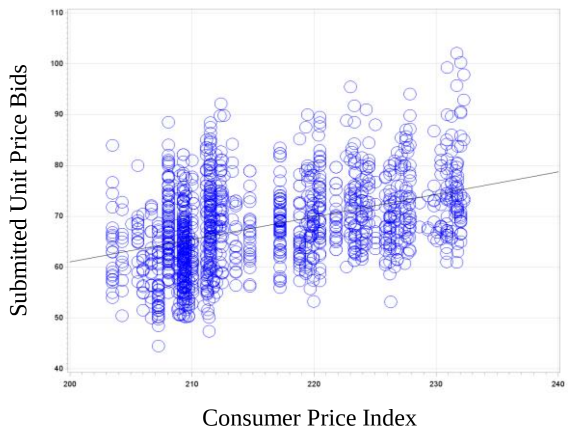


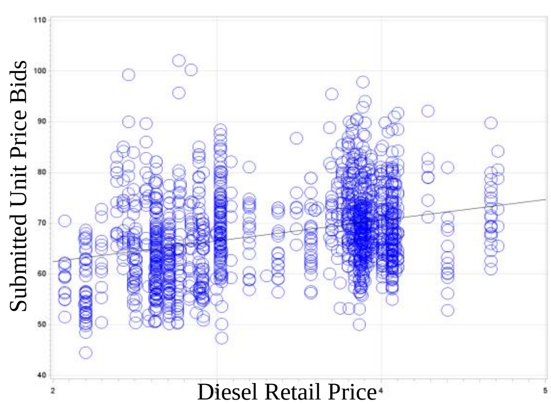
Producer Price Index for Steel Mill Products


Submitted Unit Price Bids
Producer Price Index for No. 2 Diesel Fuel Products

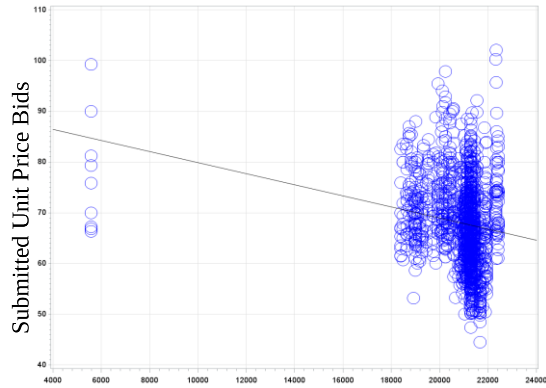

Submitted Unit Price Bids
Producer Price Index for Crude Petroleum Products


Submitted Unit Price Bids
Producer Price Index for Construction Machinery Manufacturing

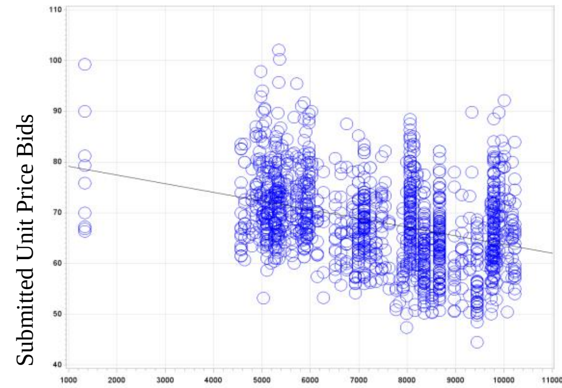

Submitted Unit Price Bids
Consumer Price Index


Submitted Unit Price Bids
Diesel Retail Price

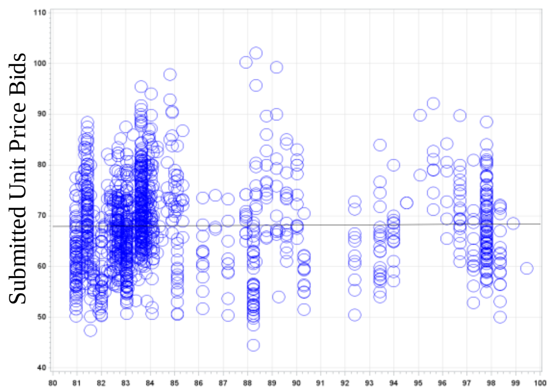

Submitted Unit Price Bids
Unemployment



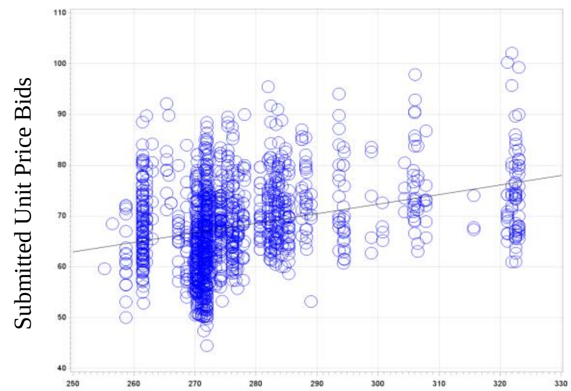
Value of Construction Put in Place for Pavement



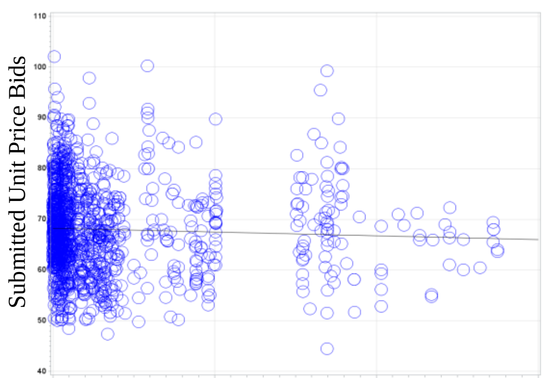
Value of Construction Put in Place for All construction



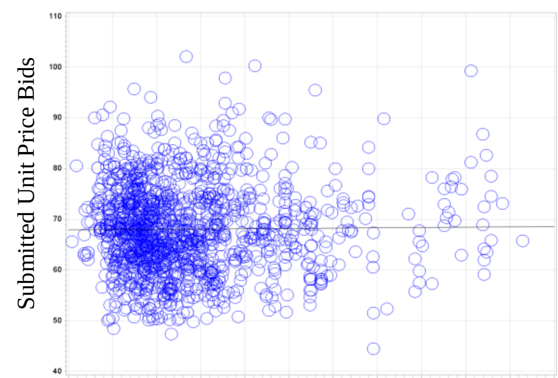
Labor Productivity



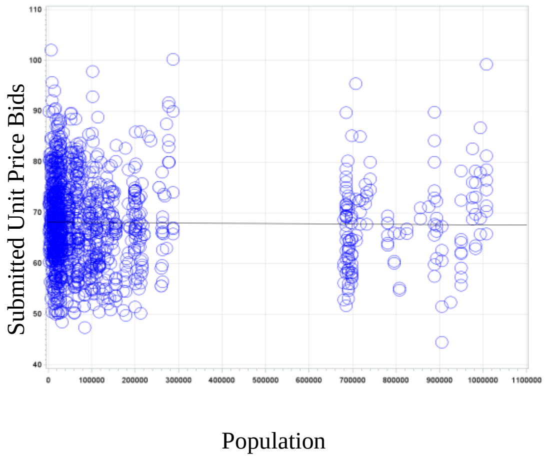
Producer Price Index for Construction Sand and Gravel Mining



Number of Establishments in Private Construction Industry



Average Weekly Wage for All Industry


Submitted Unit Price Bids
110
100
90
80
70
60
50
40
0
100000
200000
300000
400000
500000
600000
700000
800000
900000
1000000
1100000
Population

APPENDIX B. CORRELATION ANALYSIS BETWEEN SUBMITTED UNIT PRICE BIDS AND POTENTIAL EXPLANATORY VARIABLES

Variables	Submitted Unit Price Bids	Pr > |t|
Quantity of the Bid Item	-0.124***	<.0001
Ratio of the Bid Item	-0.125***	<.0001
Project Duration	0.183***	<.0001
Total Contract Price	0.198***	<.0001
Project Length	-0.125***	<.0001
Number of Bidders	-0.203***	<.0001
Number of Pay Items	0.165***	<.0001
Number of Nearby Asphalt Plants	-0.249***	<.0001
Hauling Distance between Asphalt Plant and Project Location	0.026	0.3285
Hauling Distance between Quarry and Asphalt Plants	0.256***	<.0001
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.003	0.9214
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.003	0.9153
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.086***	0.0013
Total Number of Projects Awarded in the Same Month at the State Level	-0.138***	<.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	0.080***	0.0029
Crude Oil Price of West Texas Intermediate	0.214***	<.0001
Dow Jones Industrial Average	0.432***	<.0001
Common Labor Index	0.314***	<.0001

Construction Cost Index	0.328***	<.0001
Material Price Index	0.364***	<.0001
Skilled Labor Index	0.322***	<.0001
Equipment Operator Wages for Paving	0.310***	<.0001
Fuel Price Index	0.336***	<.0001
Asphalt Cement Price Index	0.395***	<.0001
Gross Domestic Product of the Georgia Construction Industry	0.047*	0.0830
Inflation Rate	0.210***	<.0001
Number of Hires	0.132***	<.0001
National Highway Construction Cost Index	0.087***	0.0012
Producer Price Index for Gasoline products	0.306***	<.0001
Producer Price Index for Steel mill products	0.297***	<.0001
Producer Price Index for No. 2 diesel fuel products	0.279***	<.0001
Producer Price Index for Crude petroleum products	0.239***	<.0001
Producer Price Index for Construction Machinery Manufacturing	0.331***	<.0001
Consumer Price Index	0.415***	<.0001
Diesel Retail Price	0.315***	<.0001
Unemployment	-0.070***	0.0090
Value of Construction Put in Place for Pavement	-0.194***	<.0001
Value of Construction Put in Place for All construction	-0.354***	<.0001
Labor Productivity	0.014	0.5978
Producer Price Index for Construction Sand and Gravel Mining	0.310***	<.0001
Number of Establishments in Private Construction Industry	-0.045	0.0951
Average Weekly Wage for All Industry	0.012	0.6560
Population	-0.013	0.6164

Note: ***, **, and * indicates significance at 1%, 5%, and 10% level, respectively.

APPENDIX C. CORRELATION ANALYSIS AMONG POTENTIAL EXPLANATORY VARIABLES

	Submitted Unit Price Bids	Ratio of the Bid Item	Project Duration	Quantity of the Bid Item (in transformed natural logarithmic form)	Total Contract Price
Submitted Unit Price Bids	1.00000	-0.12562 <.0001	0.18333 <.0001	-0.18534 <.0001	0.19786 <.0001
Ratio of the Bid Item	-0.12562 <.0001	1.00000	-0.36004 <.0001	0.49775 <.0001	-0.34764 <.0001
Project Duration	0.18333 <.0001	-0.36004 <.0001	1.00000	0.17146 <.0001	0.72710 <.0001
Quantity of the Bid Item_in transformed natural logarithmic form	-0.18534 <.0001	0.49775 <.0001	0.17146 <.0001	1.00000	0.25488 <.0001
Total Contract Price	0.19786 <.0001	-0.34764 <.0001	0.72710 <.0001	0.25488 <.0001	1.00000
Pavement Length (in transformed natural logarithmic form)	-0.20422 <.0001	0.08029 0.0027	-0.18545 <.0001	0.33878 <.0001	0.03826 0.1539
Number of Bidders	-0.20290 <.0001	-0.08243 0.0021	0.09014 0.0008	-0.12017 <.0001	-0.00152 0.9550
Number of Pay Items	0.16500 <.0001	-0.41033 <.0001	0.86822 <.0001	0.19188 <.0001	0.81465 <.0001
Number of Nearby Asphalt Plants	-0.24933 <.0001	-0.04948 0.0650	0.07063 0.0084	0.06626 0.0134	0.04883 0.0687
Hauling Distance between Asphalt Plant and Project Location	0.02622 0.3285	0.11961 <.0001	-0.09626 0.0003	0.02420 0.3671	-0.06508 0.0152
Hauling Distance between Quarry and Asphalt Plants	0.25595 <.0001	0.01896 0.4799	0.00822 0.7594	-0.00038 0.9886	0.01088 0.6853
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.00265 0.9214	0.02103 0.4332	0.15651 <.0001	0.50417 <.0001	0.34188 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.00285 0.9153	-0.28201 <.0001	-0.06028 0.0246	-0.33371 <.0001	-0.06637 0.0133
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.08603 0.0013	0.02820 0.2933	-0.17661 <.0001	-0.13490 <.0001	-0.10805 <.0001
Total Number of Projects Awarded in the Same Month at the State Level	-0.13774 <.0001	0.03387 0.2069	-0.24063 <.0001	-0.46504 <.0001	-0.23376 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	0.07978 0.0029	-0.07576 0.0047	0.24198 <.0001	0.05745 0.0321	0.25738 <.0001
Crude Oil Price of West Texas Intermediate	0.21421 <.0001	-0.07978 0.0029	-0.00875 0.7443	-0.20212 <.0001	-0.11316 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.44335 <.0001	-0.08799 0.0010	0.25133 <.0001	0.11736 <.0001	0.23587 <.0001
Common Labor Index	0.31395 <.0001	-0.06177 0.0212	0.23995 <.0001	0.26760 <.0001	0.29338 <.0001
Construction Cost Index	0.32822 <.0001	-0.06472 0.0158	0.25486 <.0001	0.28426 <.0001	0.29953 <.0001
Material Price Index	0.36402 <.0001	-0.07257 0.0068	0.30201 <.0001	0.33659 <.0001	0.29885 <.0001
Skilled Labor Index	0.32219 <.0001	-0.06021 0.0247	0.22947 <.0001	0.25957 <.0001	0.28729 <.0001
Equipment Operator Wages for Paving	0.30991 <.0001	-0.05809 0.0303	0.27091 <.0001	0.26911 <.0001	0.28457 <.0001
Fuel Price Index	0.33642 <.0001	-0.08809 0.0010	0.10229 0.0001	-0.02022 0.4512	0.03279 0.2216
Asphalt Cement Price Index	0.39503 <.0001	-0.05423 0.0432	0.12856 <.0001	0.14367 <.0001	0.11115 <.0001

Gross Domestic Product of the Georgia Construction Industry	0.04650 0.0830	0.00641 0.8112	0.10436 <.0001	0.03118 0.2452	0.06181 0.0212
Inflation Rate	0.20994 <.0001	-0.05474 0.0412	-0.07308 0.0064	-0.18056 <.0001	-0.10323 0.0001
Number of Hires	0.13209 <.0001	-0.01416 0.5978	0.00695 0.7957	-0.18619 <.0001	-0.02866 0.2855
National Highway Construction Cost Index	0.08700 0.0012	-0.00387 0.8853	0.12086 <.0001	0.04551 0.0898	0.00500 0.8523
Producer Price Index for Gasoline products	0.30596 <.0001	-0.08552 0.0014	0.07986 0.0029	-0.04164 0.1206	0.01527 0.5694
Producer Price Index for Steel mill products	0.29686 <.0001	-0.07004 0.0090	-0.00449 0.8670	-0.10240 0.0001	-0.06229 0.0202
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.29032 <.0001	-0.07687 0.0041	0.05542 0.0388	-0.09000 0.0008	-0.03833 0.1531
Producer Price Index for Crude petroleum products	0.23931 <.0001	-0.07667 0.0042	0.01112 0.6786	-0.16624 <.0001	-0.09081 0.0007
Producer Price Index for Construction Machinery Manufacturing	0.33103 <.0001	-0.06776 0.0115	0.26659 <.0001	0.27215 <.0001	0.29272 <.0001
Consumer Price Index	0.41516 <.0001	-0.08516 0.0015	0.28304 <.0001	0.23794 <.0001	0.28995 <.0001
Diesel Retail Price	0.31490 <.0001	-0.08481 0.0015	0.08706 0.0012	-0.05192 0.0529	-0.00950 0.7234
Unemployment (in transformed natural logarithmic form)	-0.10669 <.0001	-0.05511 0.0399	0.09857 0.0002	0.09364 0.0005	0.07231 0.0070
Value of Construction Put in Place for Pavement	-0.19369 <.0001	0.05228 0.0512	-0.15387 <.0001	-0.11395 <.0001	-0.16196 <.0001
Value of Construction Put in Place for All construction	-0.35417 <.0001	0.07256 0.0068	-0.22509 <.0001	-0.21703 <.0001	-0.26115 <.0001
Labor Productivity	0.01416 0.5978	0.00022 0.9935	0.09925 0.0002	0.01975 0.4617	-0.00033 0.9901
Producer Price Index for Construction Sand and Gravel Mining	0.31027 <.0001	-0.05717 0.0330	0.27908 <.0001	0.27358 <.0001	0.33239 <.0001
Number of Establishments in Private Construction Industry	-0.04477 0.0951	-0.02816 0.2940	0.09211 0.0006	0.09125 0.0007	0.06259 0.0196
Average Weekly Wage for All Industry	0.01195 0.6560	-0.02206 0.4110	0.14266 <.0001	0.14023 <.0001	0.11941 <.0001
Population	-0.01344 0.6164	-0.03223 0.2296	0.07907 0.0032	0.08481 0.0015	0.06181 0.0211

	Pavement Length (in transformed natural logarithmic form)	Number of Bidders	Number of Pay Items	Number of Nearby Asphalt Plants	Hauling Distance between Asphalt Plant and Project Location
Submitted Unit Price Bids	-0.20422 <.0001	-0.20290 <.0001	0.16500 <.0001	-0.24933 <.0001	0.02622 0.3285
Ratio of the Bid Item	0.08029 0.0027	-0.08243 0.0021	-0.41033 <.0001	-0.04948 0.0650	0.11961 <.0001
Project Duration	-0.18545 <.0001	0.09014 0.0008	0.86822 <.0001	0.07063 0.0084	-0.09626 0.0003
Quantity of the Bid Item (in transformed natural logarithmic form)	0.33878 <.0001	-0.12017 <.0001	0.19188 <.0001	0.06626 0.0134	0.02420 0.3671
Total Contract Price	0.03826 0.1539	-0.00152 0.9550	0.81465 <.0001	0.04883 0.0687	-0.06508 0.0152
Pavement Length (in transformed natural logarithmic form)	1.00000	-0.15143 <.0001	-0.21678 <.0001	-0.14542 <.0001	0.20256 <.0001
Number of Bidders	-0.15143 <.0001	1.00000	0.09284 0.0005	0.44751 <.0001	-0.17547 <.0001
Number of Pay Items	-0.21678 <.0001	0.09284 0.0005	1.00000	0.03684 0.1697	-0.09327 0.0005
Number of Nearby Asphalt Plants	-0.14542 <.0001	0.44751 <.0001	0.03684 0.1697	1.00000	-0.39504 <.0001
Hauling Distance between Asphalt Plant and Project Location	0.20256 <.0001	-0.17547 <.0001	-0.09327 0.0005	-0.39504 <.0001	1.00000
Hauling Distance between Quarry and Asphalt Plants	-0.01854 0.4896	-0.09354 0.0005	0.01202 0.6541	-0.18554 <.0001	0.03616 0.1777
Total Monthly Asphalt Size of Resurfacing and	0.33575 <.0001	-0.04819 0.0724	0.17569 <.0001	0.21577 <.0001	-0.07700 0.0041

Widening Projects Awarded in the Same Month at the Level of the County					
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.02590 0.3344	0.23474 <.0001	-0.09473 0.0004	0.30455 <.0001	-0.16218 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.10694 <.0001	0.01457 0.5871	-0.11405 <.0001	0.02064 0.4419	-0.00655 0.8072
Total Number of Projects Awarded in the Same Month at the State Level	-0.08715 0.0011	0.07262 0.0067	-0.26653 <.0001	-0.07696 0.0041	0.04753 0.0764
Total Dollar Value of Projects Awarded in the Same Month at the State Level	-0.17256 <.0001	-0.03814 0.1551	0.26392 <.0001	0.02767 0.3024	-0.05429 0.0429
Crude Oil Price of West Texas Intermediate	0.07410 0.0057	-0.02129 0.4276	-0.11893 <.0001	0.00542 0.8399	0.02127 0.4281
Dow Jones Industrial Average (in transformed natural logarithmic form)	-0.05058 0.0593	-0.13052 <.0001	0.21497 <.0001	-0.00741 0.7826	-0.02984 0.2660
Common Labor Index	-0.06443 0.0162	-0.12865 <.0001	0.28824 <.0001	-0.04024 0.1336	-0.02046 0.4457
Construction Cost Index	-0.05451 0.0421	-0.13163 <.0001	0.29524 <.0001	-0.03394 0.2058	-0.02409 0.3693
Material Price Index	-0.00045 0.9867	-0.13237 <.0001	0.29920 <.0001	0.00058 0.9826	-0.03972 0.1387
Skilled Labor Index	-0.05869 0.0286	-0.13247 <.0001	0.27846 <.0001	-0.04695 0.0801	-0.01770 0.5094
Equipment Operator Wages for Paving	-0.09368 0.0005	-0.09951 0.0002	0.30163 <.0001	-0.03133 0.2429	-0.01357 0.6130
Fuel Price Index	0.06243 0.0199	-0.08865 0.0009	0.02639 0.3254	-0.00912 0.7341	0.01553 0.5628
Asphalt Cement Price Index	0.04219 0.1157	-0.08841 0.0010	0.11727 <.0001	-0.05771 0.0314	0.02156 0.4216
Gross Domestic Product of the Georgia Construction Industry	0.01114 0.6782	0.01532 0.5680	0.03025 0.2596	0.12156 <.0001	-0.08028 0.0027
Inflation Rate	0.05289 0.0486	-0.00596 0.8242	-0.12132 <.0001	-0.00384 0.8861	0.00369 0.8906
Number of Hires	0.00563 0.8339	0.00385 0.8860	-0.06000 0.0252	0.03958 0.1401	-0.00937 0.7269
National Highway Construction Cost Index	0.05964 0.0261	0.01743 0.5161	0.00586 0.8271	0.10489 <.0001	-0.06557 0.0145
Producer Price Index for Gasoline products	0.06391 0.0171	-0.09159 0.0006	0.00906 0.7357	-0.02363 0.3785	0.02897 0.2803
Producer Price Index for Steel mill products	0.12167 <.0001	-0.04567 0.0886	-0.09153 0.0006	0.01831 0.4950	-0.00501 0.8519
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.09083 0.0007	-0.08399 0.0017	-0.04911 0.0671	-0.01987 0.4590	0.02131 0.4272
Producer Price Index for Crude petroleum products	0.07900 0.0032	-0.03488 0.1935	-0.09476 0.0004	-0.01019 0.7041	0.02237 0.4045
Producer Price Index for Construction Machinery Manufacturing	-0.06457 0.0160	-0.10958 <.0001	0.29563 <.0001	-0.04006 0.1353	-0.01807 0.5007
Consumer Price Index	-0.04458 0.0965	-0.13318 <.0001	0.28218 <.0001	-0.01851 0.4903	-0.02269 0.3977
Diesel Retail Price	0.08891 0.0009	-0.08664 0.0012	-0.01948 0.4679	0.00111 0.9670	0.00633 0.8135
Unemployment (in transformed natural logarithmic form)	-0.22876 <.0001	0.31679 <.0001	0.10222 0.0001	0.68229 <.0001	-0.50223 <.0001
Value of Construction Put in Place for Pavement	0.02518 0.3480	0.10694 <.0001	-0.13149 <.0001	0.04453 0.0969	0.01476 0.5823
Value of Construction Put in Place for All construction	0.04804 0.0733	0.14415 <.0001	-0.25135 <.0001	0.07502 0.0051	0.00047 0.9861
Labor Productivity	0.05982 0.0257	0.01380 0.6069	-0.01403 0.6012	0.11220 <.0001	-0.06941 0.0096
Producer Price Index for Construction Sand and Gravel Mining	-0.09234 0.0006	-0.10089 0.0002	0.31711 <.0001	0.01038 0.6989	-0.04919 0.0666

Number of Establishments in Private Construction Industry	-0.16092 <.0001	0.23908 <.0001	0.06505 0.0152	0.69259 <.0001	-0.35559 <.0001
Average Weekly Wage for All Industry	-0.19863 <.0001	0.19860 <.0001	0.12068 <.0001	0.62999 <.0001	-0.36666 <.0001
Population	-0.17704 <.0001	0.23509 <.0001	0.04934 0.0658	0.71808 <.0001	-0.35738 <.0001

	Hauling Distance between Quarry and Asphalt Plants	Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	Total Asphalt Size of Projects Awarded in the Same Month at the State Level	Total Number of Projects Awarded in the Same Month at the State Level
Submitted Unit Price Bids	0.25595 <.0001	-0.00265 0.9214	-0.00285 0.9153	-0.08603 0.0013	-0.13774 <.0001
Ratio of the Bid Item	0.01896 0.4799	0.02103 0.4332	-0.28201 <.0001	0.02820 0.2933	0.03387 0.2069
Project Duration	0.00822 0.7594	0.15651 <.0001	-0.06028 0.0246	-0.17661 <.0001	-0.24063 <.0001
Quantity of the Bid Item (in transformed natural logarithmic form)	-0.00038 0.9886	0.50417 <.0001	-0.33371 <.0001	-0.13490 <.0001	-0.46504 <.0001
Total Contract Price	0.01088 0.6853	0.34188 <.0001	-0.06637 0.0133	-0.10805 <.0001	-0.23376 <.0001
Pavement Length (in transformed natural logarithmic form)	-0.01854 0.4896	0.33575 <.0001	-0.02590 0.3344	-0.10694 <.0001	-0.08715 0.0011
Number of Bidders	-0.09354 0.0005	-0.04819 0.0724	0.23474 <.0001	0.01457 0.5871	0.07262 0.0067
Number of Pay Items	0.01202 0.6541	0.17569 <.0001	-0.09473 0.0004	-0.11405 <.0001	-0.26653 <.0001
Number of Nearby Asphalt Plants	-0.18554 <.0001	0.21577 <.0001	0.30455 <.0001	0.02064 0.4419	-0.07696 0.0041
Hauling Distance between Asphalt Plant and Project Location	0.03616 0.1777	-0.07700 0.0041	-0.16218 <.0001	-0.00655 0.8072	0.04753 0.0764
Hauling Distance between Quarry and Asphalt Plants	1.00000	0.02262 0.3992	0.00304 0.9098	-0.09669 0.0003	-0.06473 0.0158
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.02262 0.3992	1.00000	0.20166 <.0001	-0.13435 <.0001	-0.32938 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.00304 0.9098	0.20166 <.0001	1.00000	0.00069 0.9796	0.15836 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.09669 0.0003	-0.13435 <.0001	0.00069 0.9796	1.00000	0.42173 <.0001
Total Number of Projects Awarded in the Same Month at the State Level	-0.06473 0.0158	-0.32938 <.0001	0.15836 <.0001	0.42173 <.0001	1.00000
Total Dollar Value of Projects Awarded in the Same Month at the State Level	-0.03195 0.2337	0.10820 <.0001	-0.05024 0.0610	0.15532 <.0001	0.18536 <.0001
Crude Oil Price of West Texas Intermediate	0.06808 0.0111	-0.05592 0.0370	0.25973 <.0001	-0.14863 <.0001	0.02017 0.4522
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.12028 <.0001	0.15207 <.0001	-0.06282 0.0191	-0.08358 0.0018	-0.29142 <.0001
Common Labor Index	0.10527 <.0001	0.20274 <.0001	-0.23691 <.0001	-0.08374 0.0018	-0.50123 <.0001

Construction Cost Index	0.10807 <.0001	0.22108 <.0001	-0.23068 <.0001	-0.10474 <.0001	-0.53778 <.0001
Material Price Index	0.11114 <.0001	0.28800 <.0001	-0.17655 <.0001	-0.19667 <.0001	-0.66088 <.0001
Skilled Labor Index	0.11025 <.0001	0.19605 <.0001	-0.23265 <.0001	-0.08082 0.0026	-0.50399 <.0001
Equipment Operator Wages for Paving	0.11082 <.0001	0.18343 <.0001	-0.24092 <.0001	-0.08452 0.0016	-0.44647 <.0001
Fuel Price Index	0.09727 0.0003	0.05793 0.0307	0.12885 <.0001	-0.21229 <.0001	-0.27605 <.0001
Asphalt Cement Price Index	0.11406 <.0001	0.12729 <.0001	-0.09401 0.0004	-0.19257 <.0001	-0.55230 <.0001
Gross Domestic Product of the Georgia Construction Industry	-0.03696 0.1683	0.09736 0.0003	0.11890 <.0001	0.01426 0.5953	0.10450 <.0001
Inflation Rate	0.03556 0.1850	-0.07635 0.0044	0.19249 <.0001	0.03647 0.1740	0.01094 0.6836
Number of Hires	-0.04509 0.0927	-0.03123 0.2444	0.19069 <.0001	-0.03228 0.2290	0.25728 <.0001
National Highway Construction Cost Index	-0.01622 0.5455	0.09068 0.0007	0.14465 <.0001	-0.12008 <.0001	-0.04286 0.1101
Producer Price Index for Gasoline products	0.08587 0.0013	0.03972 0.1387	0.11980 <.0001	-0.20549 <.0001	-0.24577 <.0001
Producer Price Index for Steel mill products	0.05910 0.0275	0.04970 0.0639	0.24550 <.0001	-0.23076 <.0001	-0.25176 <.0001
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.08169 0.0023	0.00507 0.8500	0.16288 <.0001	-0.20982 <.0001	-0.16056 <.0001
Producer Price Index for Crude petroleum products	0.07684 0.0041	-0.03990 0.1370	0.21947 <.0001	-0.17488 <.0001	-0.04329 0.1065
Producer Price Index for Construction Machinery Manufacturing	0.11519 <.0001	0.19409 <.0001	-0.23435 <.0001	-0.10042 0.0002	-0.51119 <.0001
Consumer Price Index	0.12480 <.0001	0.22030 <.0001	-0.14472 <.0001	-0.15104 <.0001	-0.51549 <.0001
Diesel Retail Price	0.08958 0.0008	0.04579 0.0878	0.16781 <.0001	-0.21965 <.0001	-0.23392 <.0001
Unemployment (in transformed natural logarithmic form)	-0.04356 0.1044	0.27394 <.0001	0.30711 <.0001	-0.02203 0.4117	-0.15065 <.0001
Value of Construction Put in Place for Pavement	-0.07199 0.0072	-0.10296 0.0001	0.09124 0.0007	0.14160 <.0001	0.19570 <.0001
Value of Construction Put in Place for All construction	-0.13034 <.0001	-0.16081 <.0001	0.21281 <.0001	0.13796 <.0001	0.48164 <.0001
Labor Productivity	-0.03111 0.2462	0.07671 0.0042	0.15132 <.0001	-0.06434 0.0164	0.06738 0.0120
Producer Price Index for Construction Sand and Gravel Mining	0.07181 0.0074	0.23374 <.0001	-0.20432 <.0001	-0.03081 0.2509	-0.40593 <.0001
Number of Establishments in Private Construction Industry	-0.04443 0.0977	0.27462 <.0001	0.27675 <.0001	0.00413 0.8776	-0.13176 <.0001
Average Weekly Wage for All Industry	-0.01391 0.6042	0.29332 <.0001	0.24592 <.0001	-0.02483 0.3548	-0.19368 <.0001
Population	-0.04224 0.1153	0.30998 <.0001	0.36655 <.0001	-0.00924 0.7306	-0.14298 <.0001

	Total Dollar Value of Projects Awarded in the Same Month at the State Level	Crude Oil Price of West Texas Intermediate	Dow Jones Industrial Average (in transformed natural logarithmic form)	Common Labor Index	Construction Cost Index
Submitted Unit Price Bids	0.07978 0.0029	0.21421 <.0001	0.44335 <.0001	0.31395 <.0001	0.32822 <.0001

Ratio of the Bid Item	-0.07576 0.0047	-0.07978 0.0029	-0.08799 0.0010	-0.06177 0.0212	-0.06472 0.0158
Project Duration	0.24198 <.0001	-0.00875 0.7443	0.25133 <.0001	0.23995 <.0001	0.25486 <.0001
Quantity of the Bid Item (in transformed natural logarithmic form)	0.05745 0.0321	-0.20212 <.0001	0.11736 <.0001	0.26760 <.0001	0.28426 <.0001
Total Contract Price	0.25738 <.0001	-0.11316 <.0001	0.23587 <.0001	0.29338 <.0001	0.29953 <.0001
Pavement Length (in transformed natural logarithmic form)	-0.17256 <.0001	0.07410 0.0057	-0.05058 0.0593	-0.06443 0.0162	-0.05451 0.0421
Number of Bidders	-0.03814 0.1551	-0.02129 0.4276	-0.13052 <.0001	-0.12865 <.0001	-0.13163 <.0001
Number of Pay Items	0.26392 <.0001	-0.11893 <.0001	0.21497 <.0001	0.28824 <.0001	0.29524 <.0001
Number of Nearby Asphalt Plants	0.02767 0.3024	0.00542 0.8399	-0.00741 0.7826	-0.04024 0.1336	-0.03394 0.2058
Hauling Distance between Asphalt Plant and Project Location	-0.05429 0.0429	0.02127 0.4281	-0.02984 0.2660	-0.02046 0.4457	-0.02409 0.3693
Hauling Distance between Quarry and Asphalt Plants	-0.03195 0.2337	0.06808 0.0111	0.12028 <.0001	0.10527 <.0001	0.10807 <.0001
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.10820 <.0001	-0.05592 0.0370	0.15207 <.0001	0.20274 <.0001	0.22108 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.05024 0.0610	0.25973 <.0001	-0.06282 0.0191	-0.23691 <.0001	-0.23068 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	0.15532 <.0001	-0.14863 <.0001	-0.08358 0.0018	-0.08374 0.0018	-0.10474 <.0001
Total Number of Projects Awarded in the Same Month at the State Level	0.18536 <.0001	0.02017 0.4522	-0.29142 <.0001	-0.50123 <.0001	-0.53778 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	1.00000	-0.18482 <.0001	0.23116 <.0001	0.23097 <.0001	0.21958 <.0001
Crude Oil Price of West Texas Intermediate	-0.18482 <.0001	1.00000	0.35303 <.0001	-0.20993 <.0001	-0.18329 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.23116 <.0001	0.35303 <.0001	1.00000	0.69305 <.0001	0.70830 <.0001
Common Labor Index	0.23097 <.0001	-0.20993 <.0001	0.69305 <.0001	1.00000	0.99658 <.0001
Construction Cost Index	0.21958 <.0001	-0.18329 <.0001	0.70830 <.0001	0.99658 <.0001	1.00000
Material Price Index	0.14179 <.0001	-0.03403 0.2046	0.71044 <.0001	0.87693 <.0001	0.91364 <.0001
Skilled Labor Index	0.21763 <.0001	-0.18621 <.0001	0.70566 <.0001	0.99746 <.0001	0.99386 <.0001
Equipment Operator Wages for Paving	0.25263 <.0001	-0.14788 <.0001	0.67726 <.0001	0.94840 <.0001	0.94637 <.0001
Fuel Price Index	-0.08970 0.0008	0.86845 <.0001	0.58864 <.0001	0.16099 <.0001	0.19767 <.0001
Asphalt Cement Price Index	-0.13871 <.0001	0.29941 <.0001	0.44498 <.0001	0.52528 <.0001	0.56128 <.0001
Gross Domestic Product of the Georgia Construction Industry	0.10446 <.0001	-0.01039 0.6987	0.17188 <.0001	-0.28540 <.0001	-0.25359 <.0001
Inflation Rate	-0.17390 <.0001	0.76532 <.0001	0.29882 <.0001	-0.25063 <.0001	-0.22652 <.0001
Number of Hires	0.13616 <.0001	0.43942 <.0001	0.12046 <.0001	-0.31161 <.0001	-0.29802 <.0001
National Highway Construction Cost Index	-0.08687 0.0012	0.23858 <.0001	0.04783 0.0745	-0.42086 <.0001	-0.35930 <.0001
Producer Price Index for Gasoline products	-0.08774 0.0011	0.88824 <.0001	0.54752 <.0001	0.14465 <.0001	0.17675 <.0001
Producer Price Index for Steel mill products	-0.26421 <.0001	0.76906 <.0001	0.33802 <.0001	-0.06723 0.0121	-0.01969 0.4630

Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	-0.15316 <.0001	0.93263 <.0001	0.51346 <.0001	-0.02056 0.4435	0.01919 0.4745
Producer Price Index for Crude petroleum products	-0.17410 <.0001	0.99070 <.0001	0.39653 <.0001	-0.13980 <.0001	-0.11037 <.0001
Producer Price Index for Construction Machinery Manufacturing	0.22279 <.0001	-0.15975 <.0001	0.68655 <.0001	0.97172 <.0001	0.97707 <.0001
Consumer Price Index	0.22310 <.0001	0.12262 <.0001	0.85873 <.0001	0.92280 <.0001	0.93822 <.0001
Diesel Retail Price	-0.14669 <.0001	0.90413 <.0001	0.55190 <.0001	0.04689 0.0804	0.09238 0.0006
Unemployment (in transformed natural logarithmic form)	0.06590 0.0140	-0.06072 0.0235	0.01284 0.6324	0.07025 0.0088	0.07194 0.0073
Value of Construction Put in Place for Pavement	-0.09638 0.0003	-0.12708 <.0001	-0.35732 <.0001	-0.35706 <.0001	-0.36842 <.0001
Value of Construction Put in Place for All construction	-0.17796 <.0001	-0.04118 0.1248	-0.74222 <.0001	-0.93223 <.0001	-0.93302 <.0001
Labor Productivity	-0.01161 0.6652	0.19907 <.0001	0.05991 0.0255	-0.45497 <.0001	-0.40442 <.0001
Producer Price Index for Construction Sand and Gravel Mining	0.33084 <.0001	-0.32277 <.0001	0.71194 <.0001	0.92471 <.0001	0.92367 <.0001
Number of Establishments in Private Construction Industry	0.05942 0.0267	-0.01038 0.6990	0.08051 0.0027	0.03227 0.2290	0.04264 0.1119
Average Weekly Wage for All Industry	0.11958 <.0001	-0.08014 0.0028	0.20896 <.0001	0.22720 <.0001	0.23463 <.0001
Population	0.06028 0.0246	0.00306 0.9093	0.11371 <.0001	0.07521 0.0050	0.08544 0.0014

	Material Price Index	Skilled Labor Index	Equipment Operator Wages for Paving	Fuel Price Index	Asphalt Cement Price Index
Submitted Unit Price Bids	0.36402 <.0001	0.32219 <.0001	0.30991 <.0001	0.33642 <.0001	0.39503 <.0001
Ratio of the Bid Item	-0.07257 0.0068	-0.06021 0.0247	-0.05809 0.0303	-0.08809 0.0010	-0.05423 0.0432
Project Duration	0.30201 <.0001	0.22947 <.0001	0.27091 <.0001	0.10229 0.0001	0.12856 <.0001
Quantity of the Bid Item (in transformed natural logarithmic form)	0.33659 <.0001	0.25957 <.0001	0.26911 <.0001	-0.02022 0.4512	0.14367 <.0001
Total Contract Price	0.29885 <.0001	0.28729 <.0001	0.28457 <.0001	0.03279 0.2216	0.11115 <.0001
Pavement Length (in transformed natural logarithmic form)	-0.00045 0.9867	-0.05869 0.0286	-0.09368 0.0005	0.06243 0.0199	0.04219 0.1157
Number of Bidders	-0.13237 <.0001	-0.13247 <.0001	-0.09951 0.0002	-0.08865 0.0009	-0.08841 0.0010
Number of Pay Items	0.29920 <.0001	0.27846 <.0001	0.30163 <.0001	0.02639 0.3254	0.11727 <.0001
Number of Nearby Asphalt Plants	0.00058 0.9826	-0.04695 0.0801	-0.03133 0.2429	-0.00912 0.7341	-0.05771 0.0314
Hauling Distance between Asphalt Plant and Project Location	-0.03972 0.1387	-0.01770 0.5094	-0.01357 0.6130	0.01553 0.5628	0.02156 0.4216
Hauling Distance between Quarry and Asphalt Plants	0.11114 <.0001	0.11025 <.0001	0.11082 <.0001	0.09727 0.0003	0.11406 <.0001
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.28800 <.0001	0.19605 <.0001	0.18343 <.0001	0.05793 0.0307	0.12729 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.17655 <.0001	-0.23265 <.0001	-0.24092 <.0001	0.12885 <.0001	-0.09401 0.0004
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.19667 <.0001	-0.08082 0.0026	-0.08452 0.0016	-0.21229 <.0001	-0.19257 <.0001

Total Number of Projects Awarded in the Same Month at the State Level	-0.66088 <.0001	-0.50399 <.0001	-0.44647 <.0001	-0.27605 <.0001	-0.55230 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	0.14179 <.0001	0.21763 <.0001	0.25263 <.0001	-0.08970 0.0008	-0.13871 <.0001
Crude Oil Price of West Texas Intermediate	-0.03403 0.2046	-0.18621 <.0001	-0.14788 <.0001	0.86845 <.0001	0.29941 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.71044 <.0001	0.70566 <.0001	0.67726 <.0001	0.58864 <.0001	0.44498 <.0001
Common Labor Index	0.87693 <.0001	0.99746 <.0001	0.94840 <.0001	0.16099 <.0001	0.52528 <.0001
Construction Cost Index	0.91364 <.0001	0.99386 <.0001	0.94637 <.0001	0.19767 <.0001	0.56128 <.0001
Material Price Index	1.00000	0.87356 <.0001	0.83873 <.0001	0.35695 <.0001	0.67932 <.0001
Skilled Labor Index	0.87356 <.0001	1.00000	0.93578 <.0001	0.19030 <.0001	0.53752 <.0001
Equipment Operator Wages for Paving	0.83873 <.0001	0.93578 <.0001	1.00000	0.19030 <.0001	0.53163 <.0001
Fuel Price Index	0.35695 <.0001	0.19030 <.0001	0.19030 <.0001	1.00000	0.59964 <.0001
Asphalt Cement Price Index	0.67932 <.0001	0.53752 <.0001	0.53163 <.0001	0.59964 <.0001	1.00000
Gross Domestic Product of the Georgia Construction Industry	-0.07008 0.0089	-0.29024 <.0001	-0.33413 <.0001	-0.07599 0.0046	-0.36791 <.0001
Inflation Rate	-0.08472 0.0016	-0.20922 <.0001	-0.27357 <.0001	0.72104 <.0001	0.32908 <.0001
Number of Hires	-0.20245 <.0001	-0.30333 <.0001	-0.30828 <.0001	0.34023 <.0001	-0.05172 0.0538
National Highway Construction Cost Index	-0.01901 0.4787	-0.42846 <.0001	-0.37443 <.0001	0.17554 <.0001	-0.02424 0.3664
Producer Price Index for Gasoline products	0.31541 <.0001	0.17348 <.0001	0.17146 <.0001	0.97927 <.0001	0.56457 <.0001
Producer Price Index for Steel mill products	0.21536 <.0001	-0.03576 0.1825	-0.12227 <.0001	0.80671 <.0001	0.62231 <.0001
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.21221 <.0001	0.00953 0.7226	0.00944 0.7250	0.94534 <.0001	0.48745 <.0001
Producer Price Index for Crude petroleum products	0.04501 0.0933	-0.11337 <.0001	-0.08012 0.0028	0.90534 <.0001	0.37050 <.0001
Producer Price Index for Construction Machinery Manufacturing	0.90265 <.0001	0.96794 <.0001	0.96519 <.0001	0.21774 <.0001	0.56382 <.0001
Consumer Price Index	0.91709 <.0001	0.92708 <.0001	0.90621 <.0001	0.48749 <.0001	0.63090 <.0001
Diesel Retail Price	0.30616 <.0001	0.07495 0.0052	0.07464 0.0053	0.95992 <.0001	0.54443 <.0001
Unemployment (in transformed natural logarithmic form)	0.07289 0.0065	0.06612 0.0136	0.06334 0.0181	-0.02977 0.2672	0.00322 0.9046
Value of Construction Put in Place for Pavement	-0.38609 <.0001	-0.36355 <.0001	-0.40794 <.0001	-0.27303 <.0001	-0.28536 <.0001
Value of Construction Put in Place for All construction	-0.84040 <.0001	-0.94189 <.0001	-0.91362 <.0001	-0.39201 <.0001	-0.61604 <.0001
Labor Productivity	-0.11332 <.0001	-0.46020 <.0001	-0.44899 <.0001	0.08601 0.0013	-0.28605 <.0001
Producer Price Index for Construction Sand and Gravel Mining	0.82353 <.0001	0.91376 <.0001	0.86878 <.0001	0.02331 0.3850	0.33022 <.0001
Number of Establishments in Private Construction Industry	0.08931 0.0009	0.02885 0.2822	0.01245 0.6426	0.01046 0.6968	-0.03132 0.2431
Average Weekly Wage for All Industry	0.24738 <.0001	0.22418 <.0001	0.20557 <.0001	0.01336 0.6185	0.05491 0.0406
Population	0.12700 <.0001	0.07239 0.0069	0.05301 0.0481	0.03933 0.1426	0.00737 0.7837

	Gross Domestic Product of the Georgia Construction Industry	Inflation Rate	Number of Hires	National Highway Construction Cost Index	Producer Price Index for Gasoline products

Submitted Unit Price Bids	0.04650 0.0830	0.20994 <.0001	0.13209 <.0001	0.08700 0.0012	0.30596 <.0001
Ratio of the Bid Item	0.00641 0.8112	-0.05474 0.0412	-0.01416 0.5978	-0.00387 0.8853	-0.08552 0.0014
Project Duration	0.10436 <.0001	-0.07308 0.0064	0.00695 0.7957	0.12086 <.0001	0.07986 0.0029
Quantity of the Bid Item (in transformed natural logarithmic form)	0.03118 0.2452	-0.18056 <.0001	-0.18619 <.0001	0.04551 0.0898	-0.04164 0.1206
Total Contract Price	0.06181 0.0212	-0.10323 0.0001	-0.02866 0.2855	0.00500 0.8523	0.01527 0.5694
Pavement Length (in transformed natural logarithmic form)	0.01114 0.6782	0.05289 0.0486	0.00563 0.8339	0.05964 0.0261	0.06391 0.0171
Number of Bidders	0.01532 0.5680	-0.00596 0.8242	0.00385 0.8860	0.01743 0.5161	-0.09159 0.0006
Number of Pay Items	0.03025 0.2596	-0.12132 <.0001	-0.06000 0.0252	0.00586 0.8271	0.00906 0.7357
Number of Nearby Asphalt Plants	0.12156 <.0001	-0.00384 0.8861	0.03958 0.1401	0.10489 <.0001	-0.02363 0.3785
Hauling Distance between Asphalt Plant and Project Location	-0.08028 0.0027	0.00369 0.8906	-0.00937 0.7269	-0.06557 0.0145	0.02897 0.2803
Hauling Distance between Quarry and Asphalt Plants	-0.03696 0.1683	0.03556 0.1850	-0.04509 0.0927	-0.01622 0.5455	0.08587 0.0013
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.09736 0.0003	-0.07635 0.0044	-0.03123 0.2444	0.09068 0.0007	0.03972 0.1387
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.11890 <.0001	0.19249 <.0001	0.19069 <.0001	0.14465 <.0001	0.11980 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	0.01426 0.5953	0.03647 0.1740	-0.03228 0.2290	-0.12008 <.0001	-0.20549 <.0001
Total Number of Projects Awarded in the Same Month at the State Level	0.10450 <.0001	0.01094 0.6836	0.25728 <.0001	-0.04286 0.1101	-0.24577 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	0.10446 <.0001	-0.17390 <.0001	0.13616 <.0001	-0.08687 0.0012	-0.08774 0.0011
Crude Oil Price of West Texas Intermediate	-0.01039 0.6987	0.76532 <.0001	0.43942 <.0001	0.23858 <.0001	0.88824 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.17188 <.0001	0.29882 <.0001	0.12046 <.0001	0.04783 0.0745	0.54752 <.0001
Common Labor Index	-0.28540 <.0001	-0.25063 <.0001	-0.31161 <.0001	-0.42086 <.0001	0.14465 <.0001
Construction Cost Index	-0.25359 <.0001	-0.22652 <.0001	-0.29802 <.0001	-0.35930 <.0001	0.17675 <.0001
Material Price Index	-0.07008 0.0089	-0.08472 0.0016	-0.20245 <.0001	-0.01901 0.4787	0.31541 <.0001
Skilled Labor Index	-0.29024 <.0001	-0.20922 <.0001	-0.30333 <.0001	-0.42846 <.0001	0.17348 <.0001
Equipment Operator Wages for Paving	-0.33413 <.0001	-0.27357 <.0001	-0.30828 <.0001	-0.37443 <.0001	0.17146 <.0001
Fuel Price Index	-0.07599 0.0046	0.72104 <.0001	0.34023 <.0001	0.17554 <.0001	0.97927 <.0001
Asphalt Cement Price Index	-0.36791 <.0001	0.32908 <.0001	-0.05172 0.0538	-0.02424 0.3664	0.56457 <.0001
Gross Domestic Product of the Georgia Construction Industry	1.00000	0.15949 <.0001	0.31915 <.0001	0.79782 <.0001	-0.15809 <.0001
Inflation Rate	0.15949 <.0001	1.00000	0.33653 <.0001	0.30646 <.0001	0.68605 <.0001

Number of Hires	0.31915 <.0001	0.33653 <.0001	1.00000	0.33991 <.0001	0.37860 <.0001
National Highway Construction Cost Index	0.79782 <.0001	0.30646 <.0001	0.33991 <.0001	1.00000	0.09675 0.0003
Producer Price Index for Gasoline products	-0.15809 <.0001	0.68605 <.0001	0.37860 <.0001	0.09675 0.0003	1.00000
Producer Price Index for Steel mill products	0.05705 0.0334	0.79519 <.0001	0.35821 <.0001	0.35623 <.0001	0.78283 <.0001
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.02642 0.3248	0.77968 <.0001	0.38428 <.0001	0.30687 <.0001	0.94232 <.0001
Producer Price Index for Crude petroleum products	-0.04411 0.1001	0.76410 <.0001	0.42650 <.0001	0.22382 <.0001	0.92393 <.0001
Producer Price Index for Construction Machinery Manufacturing	-0.27575 <.0001	-0.23440 <.0001	-0.29604 <.0001	-0.33284 <.0001	0.19698 <.0001
Consumer Price Index	-0.15461 <.0001	0.01894 0.4804	-0.09549 0.0004	-0.19987 <.0001	0.46068 <.0001
Diesel Retail Price	0.04117 0.1249	0.75567 <.0001	0.35747 <.0001	0.33443 <.0001	0.94504 <.0001
Unemployment (in transformed natural logarithmic form)	0.01402 0.6014	-0.06334 0.0182	-0.06740 0.0119	-0.00906 0.7358	-0.04405 0.1005
Value of Construction Put in Place for Pavement	0.12089 <.0001	-0.02753 0.3049	0.04475 0.0953	0.05033 0.0606	-0.25426 <.0001
Value of Construction Put in Place for All construction	0.37635 <.0001	0.05374 0.0451	0.22238 <.0001	0.41245 <.0001	-0.38444 <.0001
Labor Productivity	0.91507 <.0001	0.25317 <.0001	0.37766 <.0001	0.93564 <.0001	0.01872 0.4854
Producer Price Index for Construction Sand and Gravel Mining	0.04602 0.0862	-0.30544 <.0001	-0.22051 <.0001	-0.21722 <.0001	-0.01887 0.4820
Number of Establishments in Private Construction Industry	0.20130 <.0001	-0.01371 0.6095	0.03211 0.2313	0.14886 <.0001	-0.01396 0.6028
Average Weekly Wage for All Industry	0.12380 <.0001	-0.07576 0.0047	-0.09801 0.0003	0.05120 0.0562	-0.01785 0.5059
Population	0.16535 <.0001	-0.01360 0.6123	0.02515 0.3487	0.11961 <.0001	0.01493 0.5780

	Producer Price Index for Steel mill products	Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	Producer Price Index for Crude petroleum products	Producer Price Index for Construction Machinery Manufacturing	Consumer Price Index
Submitted Unit Price Bids	0.29686 <.0001	0.29032 <.0001	0.23931 <.0001	0.33103 <.0001	0.41516 <.0001
Ratio of the Bid Item	-0.07004 0.0090	-0.07687 0.0041	-0.07667 0.0042	-0.06776 0.0115	-0.08516 0.0015
Project Duration	-0.00449 0.8670	0.05542 0.0388	0.01112 0.6786	0.26659 <.0001	0.28304 <.0001
Quantity of the Bid Item (in transformed natural logarithmic form)	-0.10240 0.0001	-0.09000 0.0008	-0.16624 <.0001	0.27215 <.0001	0.23794 <.0001
Total Contract Price	-0.06229 0.0202	-0.03833 0.1531	-0.09081 0.0007	0.29272 <.0001	0.28995 <.0001
Pavement Length (in transformed natural logarithmic form)	0.12167 <.0001	0.09083 0.0007	0.07900 0.0032	-0.06457 0.0160	-0.04458 0.0965
Number of Bidders	-0.04567 0.0886	-0.08399 0.0017	-0.03488 0.1935	-0.10958 <.0001	-0.13318 <.0001
Number of Pay Items	-0.09153 0.0006	-0.04911 0.0671	-0.09476 0.0004	0.29563 <.0001	0.28218 <.0001
Number of Nearby Asphalt Plants	0.01831 0.4950	-0.01987 0.4590	-0.01019 0.7041	-0.04006 0.1353	-0.01851 0.4903

Hauling Distance between Asphalt Plant and Project Location	-0.00501 0.8519	0.02131 0.4272	0.02237 0.4045	-0.01807 0.5007	-0.02269 0.3977
Hauling Distance between Quarry and Asphalt Plants	0.05910 0.0275	0.08169 0.0023	0.07684 0.0041	0.11519 <.0001	0.12480 <.0001
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.04970 0.0639	0.00507 0.8500	-0.03990 0.1370	0.19409 <.0001	0.22030 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.24550 <.0001	0.16288 <.0001	0.21947 <.0001	-0.23435 <.0001	-0.14472 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.23076 <.0001	-0.20982 <.0001	-0.17488 <.0001	-0.10042 0.0002	-0.15104 <.0001
Total Number of Projects Awarded in the Same Month at the State Level	-0.25176 <.0001	-0.16056 <.0001	-0.04329 0.1065	-0.51119 <.0001	-0.51549 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	-0.26421 <.0001	-0.15316 <.0001	-0.17410 <.0001	0.22279 <.0001	0.22310 <.0001
Crude Oil Price of West Texas Intermediate	0.76906 <.0001	0.93263 <.0001	0.99070 <.0001	-0.15975 <.0001	0.12262 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.33802 <.0001	0.51346 <.0001	0.39653 <.0001	0.68655 <.0001	0.85873 <.0001
Common Labor Index	-0.06723 0.0121	-0.02056 0.4435	-0.13980 <.0001	0.97172 <.0001	0.92280 <.0001
Construction Cost Index	-0.01969 0.4630	0.01919 0.4745	-0.11037 <.0001	0.97707 <.0001	0.93822 <.0001
Material Price Index	0.21536 <.0001	0.21221 <.0001	0.04501 0.0933	0.90265 <.0001	0.91709 <.0001
Skilled Labor Index	-0.03576 0.1825	0.00953 0.7226	-0.11337 <.0001	0.96794 <.0001	0.92708 <.0001
Equipment Operator Wages for Paving	-0.12227 <.0001	0.00944 0.7250	-0.08012 0.0028	0.96519 <.0001	0.90621 <.0001
Fuel Price Index	0.80671 <.0001	0.94534 <.0001	0.90534 <.0001	0.21774 <.0001	0.48749 <.0001
Asphalt Cement Price Index	0.62231 <.0001	0.48745 <.0001	0.37050 <.0001	0.56382 <.0001	0.63090 <.0001
Gross Domestic Product of the Georgia Construction Industry	0.05705 0.0334	0.02642 0.3248	-0.04411 0.1001	-0.27575 <.0001	-0.15461 <.0001
Inflation Rate	0.79519 <.0001	0.77968 <.0001	0.76410 <.0001	-0.23440 <.0001	0.01894 0.4804
Number of Hires	0.35821 <.0001	0.38428 <.0001	0.42650 <.0001	-0.29604 <.0001	-0.09549 0.0004
National Highway Construction Cost Index	0.35623 <.0001	0.30687 <.0001	0.22382 <.0001	-0.33284 <.0001	-0.19987 <.0001
Producer Price Index for Gasoline products	0.78283 <.0001	0.94232 <.0001	0.92393 <.0001	0.19698 <.0001	0.46068 <.0001
Producer Price Index for Steel mill products	1.00000	0.85266 <.0001	0.78710 <.0001	-0.05217 0.0517	0.20619 <.0001
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.85266 <.0001	1.00000	0.95740 <.0001	0.03452 0.1982	0.31471 <.0001
Producer Price Index for Crude petroleum products	0.78710 <.0001	0.95740 <.0001	1.00000	-0.08138 0.0024	0.19587 <.0001
Producer Price Index for Construction Machinery Manufacturing	-0.05217 0.0517	0.03452 0.1982	-0.08138 0.0024	1.00000	0.93808 <.0001

Consumer Price Index	0.20619 <.0001	0.31471 <.0001	0.19587 <.0001	0.93808 <.0001	1.00000
Diesel Retail Price	0.86696 <.0001	0.98854 <.0001	0.93175 <.0001	0.11023 <.0001	0.38528 <.0001
Unemployment (in transformed natural logarithmic form)	-0.01995 0.4572	-0.07163 0.0075	-0.06409 0.0168	0.05996 0.0253	0.05463 0.0416
Value of Construction Put in Place for Pavement	-0.09083 0.0007	-0.20925 <.0001	-0.16552 <.0001	-0.40019 <.0001	-0.42297 <.0001
Value of Construction Put in Place for All construction	-0.11063 <.0001	-0.22294 <.0001	-0.12107 <.0001	-0.93346 <.0001	-0.93792 <.0001
Labor Productivity	0.22033 <.0001	0.23156 <.0001	0.17020 <.0001	-0.39329 <.0001	-0.25130 <.0001
Producer Price Index for Construction Sand and Gravel Mining	-0.18174 <.0001	-0.15023 <.0001	-0.27158 <.0001	0.89697 <.0001	0.85795 <.0001
Number of Establishments in Private Construction Industry	0.04115 0.1251	-0.01036 0.6994	-0.01933 0.4712	0.02701 0.3141	0.06141 0.0220
Average Weekly Wage for All Industry	-0.00873 0.7448	-0.03022 0.2600	-0.06995 0.0091	0.21797 <.0001	0.22695 <.0001
Population	0.06321 0.0184	0.01208 0.6525	-0.00339 0.8995	0.06763 0.0116	0.10486 <.0001

	Diesel Retail Price	Unemployment (in transformed natural logarithmic form)	Value of Construction Put in Place for Pavement	Value of Construction Put in Place for All construction	Labor Productivity
Submitted Unit Price Bids	0.31490 <.0001	-0.10669 <.0001	-0.19369 <.0001	-0.35417 <.0001	0.01416 0.5978
Ratio of the Bid Item	-0.08481 0.0015	-0.05511 0.0399	0.05228 0.0512	0.07256 0.0068	0.00022 0.9935
Project Duration	0.08706 0.0012	0.09857 0.0002	-0.15387 <.0001	-0.22509 <.0001	0.09925 0.0002
Quantity of the Bid Item (in transformed natural logarithmic form)	-0.05192 0.0529	0.09364 0.0005	-0.11395 <.0001	-0.21703 <.0001	0.01975 0.4617
Total Contract Price	-0.00950 0.7234	0.07231 0.0070	-0.16196 <.0001	-0.26115 <.0001	-0.00033 0.9901
Pavement Length (in transformed natural logarithmic form)	0.08891 0.0009	-0.22876 <.0001	0.02518 0.3480	0.04804 0.0733	0.05982 0.0257
Number of Bidders	-0.08664 0.0012	0.31679 <.0001	0.10694 <.0001	0.14415 <.0001	0.01380 0.6069
Number of Pay Items	-0.01948 0.4679	0.10222 0.0001	-0.13149 <.0001	-0.25135 <.0001	-0.01403 0.6012
Number of Nearby Asphalt Plants	0.00111 0.9670	0.68229 <.0001	0.04453 0.0969	0.07502 0.0051	0.11220 <.0001
Hauling Distance between Asphalt Plant and Project Location	0.00633 0.8135	-0.50223 <.0001	0.01476 0.5823	0.00047 0.9861	-0.06941 0.0096
Hauling Distance between Quarry and Asphalt Plants	0.08958 0.0008	-0.04356 0.1044	-0.07199 0.0072	-0.13034 <.0001	-0.03111 0.2462
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.04579 0.0878	0.27394 <.0001	-0.10296 0.0001	-0.16081 <.0001	0.07671 0.0042
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.16781 <.0001	0.30711 <.0001	0.09124 0.0007	0.21281 <.0001	0.15132 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.21965 <.0001	-0.02203 0.4117	0.14160 <.0001	0.13796 <.0001	-0.06434 0.0164
Total Number of Projects Awarded in the Same Month at the State Level	-0.23392 <.0001	-0.15065 <.0001	0.19570 <.0001	0.48164 <.0001	0.06738 0.0120
Total Dollar Value of Projects Awarded in the	-0.14669 <.0001	0.06590 0.0140	-0.09638 0.0003	-0.17796 <.0001	-0.01161 0.6652

Same Month at the State Level					
Crude Oil Price of West Texas Intermediate	0.90413 <.0001	-0.06072 0.0235	-0.12708 <.0001	-0.04118 0.1248	0.19907 <.0001
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.55190 <.0001	0.01284 0.6324	-0.35732 <.0001	-0.74222 <.0001	0.05991 0.0255
Common Labor Index	0.04689 0.0804	0.07025 0.0088	-0.35706 <.0001	-0.93223 <.0001	-0.45497 <.0001
Construction Cost Index	0.09238 0.0006	0.07194 0.0073	-0.36842 <.0001	-0.93302 <.0001	-0.40442 <.0001
Material Price Index	0.30616 <.0001	0.07289 0.0065	-0.38609 <.0001	-0.84040 <.0001	-0.11332 <.0001
Skilled Labor Index	0.07495 0.0052	0.06612 0.0136	-0.36355 <.0001	-0.94189 <.0001	-0.46020 <.0001
Equipment Operator Wages for Paving	0.07464 0.0053	0.06334 0.0181	-0.40794 <.0001	-0.91362 <.0001	-0.44899 <.0001
Fuel Price Index	0.95992 <.0001	-0.02977 0.2672	-0.27303 <.0001	-0.39201 <.0001	0.08601 0.0013
Asphalt Cement Price Index	0.54443 <.0001	0.00322 0.9046	-0.28536 <.0001	-0.61604 <.0001	-0.28605 <.0001
Gross Domestic Product of the Georgia Construction Industry	0.04117 0.1249	0.01402 0.6014	0.12089 <.0001	0.37635 <.0001	0.91507 <.0001
Inflation Rate	0.75567 <.0001	-0.06334 0.0182	-0.02753 0.3049	0.05374 0.0451	0.25317 <.0001
Number of Hires	0.35747 <.0001	-0.06740 0.0119	0.04475 0.0953	0.22238 <.0001	0.37766 <.0001
National Highway Construction Cost Index	0.33443 <.0001	-0.00906 0.7358	0.05033 0.0606	0.41245 <.0001	0.93564 <.0001
Producer Price Index for Gasoline products	0.94504 <.0001	-0.04405 0.1005	-0.25426 <.0001	-0.38444 <.0001	0.01872 0.4854
Producer Price Index for Steel mill products	0.86696 <.0001	-0.01995 0.4572	-0.09083 0.0007	-0.11063 <.0001	0.22033 <.0001
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	0.98854 <.0001	-0.07163 0.0075	-0.20925 <.0001	-0.22294 <.0001	0.23156 <.0001
Producer Price Index for Crude petroleum products	0.93175 <.0001	-0.06409 0.0168	-0.16552 <.0001	-0.12107 <.0001	0.17020 <.0001
Producer Price Index for Construction Machinery Manufacturing	0.11023 <.0001	0.05996 0.0253	-0.40019 <.0001	-0.93346 <.0001	-0.39329 <.0001
Consumer Price Index	0.38528 <.0001	0.05463 0.0416	-0.42297 <.0001	-0.93792 <.0001	-0.25130 <.0001
Diesel Retail Price	1.00000	-0.04697 0.0799	-0.24004 <.0001	-0.27654 <.0001	0.24533 <.0001
Unemployment (in transformed natural logarithmic form)	-0.04697 0.0799	1.00000	-0.03005 0.2627	-0.04277 0.1108	-0.01521 0.5709
Value of Construction Put in Place for Pavement	-0.24004 <.0001	-0.03005 0.2627	1.00000	0.57585 <.0001	0.08860 0.0009
Value of Construction Put in Place for All construction	-0.27654 <.0001	-0.04277 0.1108	0.57585 <.0001	1.00000	0.46813 <.0001
Labor Productivity	0.24533 <.0001	-0.01521 0.5709	0.08860 0.0009	0.46813 <.0001	1.00000
Producer Price Index for Construction Sand and Gravel Mining	-0.07471 0.0053	0.08549 0.0014	-0.29128 <.0001	-0.79069 <.0001	-0.19793 <.0001
Number of Establishments in Private Construction Industry	0.02020 0.4517	0.77183 <.0001	0.01251 0.6411	0.01220 0.6493	0.16423 <.0001
Average Weekly Wage for All Industry	0.00698 0.7947	0.79872 <.0001	-0.10797 <.0001	-0.18593 <.0001	0.05962 0.0262
Population	0.04486 0.0944	0.81155 <.0001	-0.02153 0.4224	-0.03813 0.1552	0.12896 <.0001

	Producer Price Index for Construction Sand and Gravel Mining	Number of Establishments in Private Construction Industry	Average Weekly Wage for All Industry	Population
Submitted Unit Price Bids	0.31027 <.0001	-0.04477 0.0951	0.01195 0.6560	-0.01344 0.6164
Ratio of the Bid Item	-0.05717 0.0330	-0.02816 0.2940	-0.02206 0.4110	-0.03223 0.2296

Project Duration	0.27908 <.0001	0.09211 0.0006	0.14266 <.0001	0.07907 0.0032
Quantity of the Bid Item (in transformed natural logarithmic form)	0.27358 <.0001	0.09125 0.0007	0.14023 <.0001	0.08481 0.0015
Total Contract Price	0.33239 <.0001	0.06259 0.0196	0.11941 <.0001	0.06181 0.0211
Pavement Length (in transformed natural logarithmic form)	-0.09234 0.0006	-0.16092 <.0001	-0.19863 <.0001	-0.17704 <.0001
Number of Bidders	-0.10089 0.0002	0.23908 <.0001	0.19860 <.0001	0.23509 <.0001
Number of Pay Items	0.31711 <.0001	0.06505 0.0152	0.12068 <.0001	0.04934 0.0658
Number of Nearby Asphalt Plants	0.01038 0.6989	0.69259 <.0001	0.62999 <.0001	0.71808 <.0001
Hauling Distance between Asphalt Plant and Project Location	-0.04919 0.0666	-0.35559 <.0001	-0.36666 <.0001	-0.35738 <.0001
Hauling Distance between Quarry and Asphalt Plants	0.07181 0.0074	-0.04443 0.0977	-0.01391 0.6042	-0.04224 0.1153
Total Monthly Asphalt Size of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	0.23374 <.0001	0.27462 <.0001	0.29332 <.0001	0.30998 <.0001
Total Number of Resurfacing and Widening Projects Awarded in the Same Month at the Level of the County	-0.20432 <.0001	0.27675 <.0001	0.24592 <.0001	0.36655 <.0001
Total Asphalt Size of Projects Awarded in the Same Month at the State Level	-0.03081 0.2509	0.00413 0.8776	-0.02483 0.3548	-0.00924 0.7306
Total Number of Projects Awarded in the Same Month at the State Level	-0.40593 <.0001	-0.13176 <.0001	-0.19368 <.0001	-0.14298 <.0001
Total Dollar Value of Projects Awarded in the Same Month at the State Level	0.33084 <.0001	0.05942 0.0267	0.11958 <.0001	0.06028 0.0246
Crude Oil Price of West Texas Intermediate	-0.32277 <.0001	-0.01038 0.6990	-0.08014 0.0028	0.00306 0.9093
Dow Jones Industrial Average (in transformed natural logarithmic form)	0.71194 <.0001	0.08051 0.0027	0.20896 <.0001	0.11371 <.0001
Common Labor Index	0.92471 <.0001	0.03227 0.2290	0.22720 <.0001	0.07521 0.0050
Construction Cost Index	0.92367 <.0001	0.04264 0.1119	0.23463 <.0001	0.08544 0.0014
Material Price Index	0.82353 <.0001	0.08931 0.0009	0.24738 <.0001	0.12700 <.0001
Skilled Labor Index	0.91376 <.0001	0.02885 0.2822	0.22418 <.0001	0.07239 0.0069
Equipment Operator Wages for Paving	0.86878 <.0001	0.01245 0.6426	0.20557 <.0001	0.05301 0.0481
Fuel Price Index	0.02331 0.3850	0.01046 0.6968	0.01336 0.6185	0.03933 0.1426
Asphalt Cement Price Index	0.33022 <.0001	-0.03132 0.2431	0.05491 0.0406	0.00737 0.7837
Gross Domestic Product of the Georgia Construction Industry	0.04602 0.0862	0.20130 <.0001	0.12380 <.0001	0.16535 <.0001
Inflation Rate	-0.30544 <.0001	-0.01371 0.6095	-0.07576 0.0047	-0.01360 0.6123
Number of Hires	-0.22051 <.0001	0.03211 0.2313	-0.09801 0.0003	0.02515 0.3487
National Highway Construction Cost Index	-0.21722 <.0001	0.14886 <.0001	0.05120 0.0562	0.11961 <.0001
Producer Price Index for Gasoline products	-0.01887 0.4820	-0.01396 0.6028	-0.01785 0.5059	0.01493 0.5780
Producer Price Index for Steel mill products	-0.18174 <.0001	0.04115 0.1251	-0.00873 0.7448	0.06321 0.0184
Producer Price Index for No. 2 diesel fuel products (in transformed natural logarithmic form)	-0.15023 <.0001	-0.01036 0.6994	-0.03022 0.2600	0.01208 0.6525
Producer Price Index for Crude petroleum products	-0.27158 <.0001	-0.01933 0.4712	-0.06995 0.0091	-0.00339 0.8995
Producer Price Index for Construction Machinery Manufacturing	0.89697 <.0001	0.02701 0.3141	0.21797 <.0001	0.06763 0.0116
Consumer Price Index	0.85795 <.0001	0.06141 0.0220	0.22695 <.0001	0.10486 <.0001
Diesel Retail Price	-0.07471 0.0053	0.02020 0.4517	0.00698 0.7947	0.04486 0.0944
Unemployment (in transformed natural logarithmic form)	0.08549 0.0014	0.77183 <.0001	0.79872 <.0001	0.81155 <.0001
Value of Construction Put in Place for Pavement	-0.29128 <.0001	0.01251 0.6411	-0.10797 <.0001	-0.02153 0.4224

Value of Construction Put in Place for All construction	-0.79069 <.0001	0.01220 0.6493	-0.18593 <.0001	-0.03813 0.1552
Labor Productivity	-0.19793 <.0001	0.16423 <.0001	0.05962 0.0262	0.12896 <.0001
Producer Price Index for Construction Sand and Gravel Mining	1.00000	0.10638 <.0001	0.27546 <.0001	0.13480 <.0001
Number of Establishments in Private Construction Industry	0.10638 <.0001	1.00000	0.77580 <.0001	0.93442 <.0001
Average Weekly Wage for All Industry	0.27546 <.0001	0.77580 <.0001	1.00000	0.87157 <.0001
Population	0.13480 <.0001	0.93442 <.0001	0.87157 <.0001	1.00000

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