Development of Risk Management Strategies for State DOTs to Effectively Deal with Volatile Prices of Transportation Construction Materials

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DEVELOPMENT OF RISK MANAGEMENT STRATEGIES FOR STATE DOTS TO EFFECTIVELY DEAL WITH VOLATILE PRICES OF TRANSPORTATION CONSTRUCTION MATERIALS

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16. Abstract:
Volatility in price of critical materials used in transportation projects, such as asphalt cement, leads to considerable uncertainty about project cost. This uncertainty may lead to price speculation and inflated bid prices submitted by highway contractors to protect themselves against possible price increases. One of the most common risk sharing strategies widely used by transportation agencies is price adjustment clauses (PAC) that divide potential upside and downside risk of material prices between contractors and owners. However, it is not clear whether offering PAC reduces risk premium of bids submitted by highway contractors. The research objective of this study is to explore whether offering PAC for asphalt cement can explain the variation of submitted bids for asphalt line items by highway contractors. Data on 3,749 highway projects bid out in the State of Georgia from January 1998 to July 2013 were collected to analyze the impacts of PAC on bid prices. Multivariate regression analysis was conducted to evaluate the effect of several factors, such as project size, number of bidders, asphalt cement price, and availability of PAC on unit price bids submitted by highway contractors for major asphalt line items. The results show that a linear combination of several explanatory variables such as quantity of the item, total bid price, and asphalt cement price index can explain the variations of the submitted bid prices appropriately. Eligibility for the PAC program is not a statistically significant explanatory variable in most of the models. In addition, several time series models were created to forecast the short-term variation of the asphalt cement price in Georgia.

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EXECUTIVE SUMMARY

Significant volatility in the price of asphalt cement is one of the most important challenges of state Departments of Transportation (state DOTs) and contractors in transportation projects. Considerable volatility in the price of asphalt cement can lead to uncertainty about project cost. This uncertainty may lead to price speculation and inflated bid prices submitted by highway contractors to secure themselves against possible price increases. One of the most common risk sharing strategies widely used by transportation agencies is price adjustment clauses (PAC) that divide potential upside and downside risk of material prices between contractors and owners. A survey by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction in 2009 indicates that 40 State Departments of Transportation (DOTs) offer PAC for asphalt cement. Georgia Department of Transportation (GDOT) has been offering PAC for the asphalt cement since September 2005. Although PACs are aimed at eliminating extra risk premiums and hence reducing contractors' submitted bid prices, offering these clauses freezes the scarce financial resources of state DOTs that otherwise could be used in other much-needed projects and has significant financial burden on state DOTs' limited budgets. Considering the significant magnitude of price adjustment clauses for asphalt cement line items, it is imperative to examine the financial implications of offering PAC for asphalt cement line items in transportation projects. The significance of PAC on explaining the variation of submitted bid prices for asphalt line items is not clear. The research objective of this study is to examine whether offering PAC for asphalt cement can explain the variation of submitted bids by highway contractors for major asphalt line items. Data on 3,749 highway projects bid out in the state of Georgia from January 1998 to July 2013 were collected to analyze the impact of PAC on bid prices. Multivariate linear regression analysis was conducted to model the variations of the submitted bid

prices for seven major asphalt mixture line items. Several variables were considered as possible explanatory variables for variations in submitted bid prices, for example, duration of the project, quantity of the item, total bid price, asphalt cement price index in the bid date, number of bidders, and eligibility for the PAC program. Several linear regression models were created to explain variations in submitted unit price bids for 7 major asphalt line items.

Multivariate linear regression analysis was used to model the variations of the submitted bid prices for seven major asphalt line items. The results of the regression models identify which explanatory variables are statistically significant to explain the variations of the submitted bid prices of major asphalt line items. The linear regression models were developed using the entire dataset from January 1998 to July 2013. The results indicate that:

1. There is a linear relationship between the response variable (bid price) and a combination of several explanatory variables, such as quantity, total bid price, and asphalt cement price index.
2. Although the quality of the model varies in each line item, linear regression is capable of capturing and explaining the majority of variations in the submitted bid prices.
3. The results in all seven models for major asphalt line items are very consistent with one another, i.e., a similar set of explanatory variables was identified to explain the variation of submitted bid prices for all seven asphalt line items.
4. Overall, the most powerful explanatory variables for explaining the variations of the submitted bid prices are the quantity of the line item, total bid price of the projects, asphalt cement price index at the bid date, and letting in the period of September 2005 to August 2009.

5. Eligibility of the projects for the PAC is not a statistically significant explanatory variable in any models but the model for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) for which this variable has a positive significant coefficient indicating that the expected bid prices for this line item in eligible projects are higher than those in ineligible projects.

Since the contractors' size might affect their bid decisions, the regression analysis was repeated using three sample datasets of contractors: big, medium, and small contractors. The results specify that:

1. Although the quality of the model varies in each line item and across the sample datasets, linear regression is capable of capturing and explaining the majority of variations in the submitted bid price.
2. The main variables explaining the variation of bid prices in a project within a subgroup are similar to those observed in the models using the entire dataset.
3. Eligibility for the PAC is statistically significant in explaining the variations of the bid prices in three asphalt line items for the big contractor dataset. The expected bid price for line items 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL) and 402-3130 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL) in PAC-eligible projects is lower than those in PAC-ineligible projects. However, similar to the results of the model developed for the entire dataset of submitted bids, the expected value of the bid prices for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in PAC-eligible projects is higher than those in PAC-ineligible projects.
4. Eligibility for the PAC is statistically significant in explaining the variations of the bid prices in only one of the line items (402-1812: Recycled Asphaltic Concrete Leveling,

BM&HL) for the dataset of medium-size contractors. The expected value of the bid prices for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in PAC-eligible projects is higher than those in PAC-ineligible projects.

5. Eligibility for the PAC program is not found statistically significant in explaining the variation of the bid price in any of the line items for the dataset of small contractors.

Finally, since the specific provisions of the PAC for asphalt cement in the state of Georgia changed significantly in August 2009, several regression models were created for the projects with let dates after August 2009. The results show that:

1. Except one line item that does not have enough observations, a linear relationship between the response variable (bid price) and a combination of several explanatory variables can be identified.
2. Although the quality of regression models varies in each line item, linear regression is capable of capturing and explaining the majority of variations in the bid prices.
3. The most powerful explanatory variables that are statistically significant to explain the variations of the submitted bid prices are similar to those observed in the models using the entire datasets and the models for big, medium, and small contractors.
4. Similar to the results of the models using the entire dataset, eligibility for the PAC is statistically significant in explaining the variations of the bid prices for only one of the line items (402-1812: Recycled Asphaltic Concrete Leveling, BM&HL) in the group of projects with let date after August 2009. The expected value of the bid prices for this line item for PAC-eligible is higher than those in PAC-ineligible projects.

The primary contributions of this research are: (a) the creation of several multivariate regression models that are able to explain the variations of highway contractors' submitted bid prices for major asphalt line items; and (b) the empirical assessment of whether offering price adjustment clauses contributes to the variations of contractors' submitted bid prices for major asphalt line items in highway projects. It is expected that this work contributes to the transportation community by helping capital planners of transportation agencies systematically evaluate the financial impact of state DOTs' price adjustment clauses on the cost of their highway construction projects.

CHAPTER 1
INTRODUCTION

1.1. INTRODUCTION

Significant volatility in the price of asphalt cement is one of the most important challenges of state Departments of Transportation (state DOTs) and contractors in transportation projects. On top of regular inflation, the volatility of the global oil market directly affects the price of asphalt cement and thereby causes fluctuations in the cost of transportation projects through the rise and fall of oil prices (Carroll and Cox 2010). The volatility in the price of asphalt cement may lead to uncertainty about project cost. Cost uncertainty may increase the risk of contractors in fixed-price contracts and consequently, may lead to price speculation and inflated bid prices submitted by contractors to secure their profits against possible price increases (Damnjanovic et al. 2009). Eckert and Eger (2005) indicate that state DOTs often overpay for projects under the fixed-price contracts that transfer the material price risk to contractors, due to increased risk premiums and hidden contingencies in contractors' submitted bids. Transportation officials in Kentucky, New Hampshire, Pennsylvania, and Washington state DOTs believed that they may have paid more money to contractors than actual added costs, due to increased material prices (Holmgren et al. 2010).

A common strategy widely used by state DOTs for handling the issue of extra risk premiums in submitted bids and avoiding overpayment to contractors is to offer price adjustment clauses (PACs) in contracts. PACs are risk-sharing strategies between owners and contractors to divide the risk of upward and downward movements of material prices between the two parties. State DOTs may benefit from this shift in risk allocation through contractors' willingness to submit lower bids (Skolnik 2011). Most state DOTs in the United States have employed PACs in their transportation contracts. In 2009, a survey done by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction, Contract Administration Section, indicates that 40 state DOTs offer PACs for asphalt cement. Furthermore, the results from a Delphi survey of transportation experts show that PAC is among the top ten programs widely used as cost reduction methods (Damnjanovic et al. 2009).

Although PACs are aimed at eliminating extra risk premiums and hence reducing contractors' submitted bid prices, offering these clauses freezes the scarce financial resources of state DOTs that otherwise could be used in other much-needed projects and has significant financial burden on state DOTs' limited budgets. For example, the Georgia Department of Transportation (GDOT) paid more than 69 million dollars to contractors between 2007 and 2012 in price adjustment clauses for just asphalt cement line items in its transportation projects. Considering the significant magnitude of price adjustment clauses for asphalt cement line items, it is imperative to examine the financial implications of offering the PAC for asphalt cement line items in transportation projects. The impact of PAC on submitted bid prices is not clear. Eckert and Eger (2005) interviewed Florida, North Carolina, South Carolina, and Tennessee DOTs and found out that these state DOTs were satisfied with their PAC programs for asphalt cement line items. However, none of these state DOTs had done any quantitative research to provide any empirical evidence for the financial impact of PACs on contractors' submitted bid prices. In 2011, Skolnik conducted a survey on 400 highway contractors and uncovered that there is a consensus among surveyed contractors that offering PACs is beneficial to all stakeholders in the market. Nearly all responding contractors mentioned that they would add contingencies to their bids in the absence of PACs.

Further, Skolnik (2011) used regression analysis to compare submitted bid prices in four states with PACs (i.e. Illinois, Tennessee, Missouri, and Oregon) and those prices in four other states with no PACs (i.e. Arkansas, California, Michigan, and Texas). Skolnik indicated that the analysis results were mixed and non-conclusive across state DOTS and among all PAC-eligible line items; and hence, further empirical research is needed to assess the impact of PACs on submitted contractors' bid prices. Particularly, Skolnik recommended conducting separate studies for each state DOT and for each PAC-eligible line item, such as asphalt cement, since the characteristics of price adjustment clauses and the conditions of highway construction market are different from state to state and from line item to line item.

The research objective of this study is to examine the effect of offering PACs by state DOTs on the variations of contractors' submitted bid prices for major asphalt line items in highway projects. To achieve this objective, the remainder of this report is structured, as follows. Chapter one introduces the PAC, previous studies about it, and the current implementation of the PAC program for asphalt cement in the State of Georgia. Chapter two investigates the characteristics and volatility in the price of asphalt cement in Georgia. Several time series forecasting models are created to improve the forecasting of asphalt price in this chapter. Chapter three describes the characteristics of the comprehensive dataset consisting of detailed information about the transportation projects in the State of Georgia used in this research. Chapter four explains multiple steps involved in modeling the variations of contractors' submitted bid prices for major asphalt line items. Chapter five interprets the results of the statistical models.

The primary contributions of this research to the body of knowledge are: (a) the creation of several multivariate regression models that are able to explain the variations of highway contractors' submitted bid prices for major asphalt line items; and (b) the empirical assessment of whether offering price adjustment clauses contributes to explaining the variation of contractors' submitted bid prices for major asphalt line items in highway projects. It is expected that this work contributes to the transportation community by helping capital planners of transportation agencies systematically evaluate the financial impact of state DOTs' price adjustment clauses on the cost of their highway construction projects.

1.2. LITERATURE REVIEW

1.2.1. Price Adjustment Clause (PAC)

For the first time in the U.S., the Price Adjustment Clause (PAC) was used during World War I to manage rapidly increasing price of coal (Baron and De Bondt 1979). In the 1970s, electric utilities faced significant increases in the price of fuel inputs, which resulted in many utility investors having to absorb unexpected increases in fuel costs. Motivated by the concern that these costs would be ultimately borne by consumers, 43 out of 50 states either adopted or expanded existing Fuel Adjustment Clauses (FACs) by 1974 (Golec 1990).

In contrary to the widespread application of adjustment clauses in the electric utility industry, the impact of this clause was controversial and in the late 1970s and during 1980s, poor efficiency resulted from the PAC program was a hot topic. Baron and De Bondt (1979) observed that fuel adjustment clauses can lead to inefficiency problems related to the choice of technology and its selection of fuel supply sources because if utilities can shift all fuel cost increases to consumers, then there is no incentive to select the lowest cost fuel supply.

Kaserman and Tepel (1982) found that FACs can lead to unnecessarily high utility company costs because of an adverse aggregate input price effect. They examined the influence of automatic FAC on the prices paid by electric utilities for aggregate fuel input. They asserted that the direct correlation between output price and aggregate fuel cost might lead to higher prices for aggregate fuel inputs than the price in the absence of adjustment clauses.

Gollop and Karlson (1978) empirically analyzed the effects of the utility's ability to recover costs through an automatic fuel adjustment mechanism on the average cost. They found that the adjustment clause might lead to higher fuel costs because of inefficiency. They suggested that frequent monitoring of fuel adjustment clause provisions can prevent inefficient behavior while allowing utilities to recover quickly increasing input costs during times of high inflation. Later, in 1982, Isaac examined the effects of fuel adjustment clause on the input choice of electric utilities and confirmed that adjustment mechanism can lead to inefficiencies in input choices. However, it can help to preserve the financial integrity of electric utilities too. Kendrick (1975) examined the impacts of adjustments clauses in the telecommunications industry and concluded that the mechanism should consist of efficiency incentives to ensure good productivity.

Since 1974, the other industries, such as building and highway construction, have gradually offered PAC for selected commodities to handle the problem of inflated bids. (Holmgren et al 2010). The vast majority of transportation agencies in the U.S. currently employ PACs. In 2009, a survey by the AASHTO Subcommittee on Construction, Contract Administration Section, showed that only 3 agencies, Arkansas, Michigan, and Texas DOTs, do not employ PACs in their contracts. Furthermore, 40 state DOTs offer the PAC for asphalt cement and 41 state DOTs offer the PAC for fuel (AASHTO 2009). Figure 1-1 shows the distribution of the PAC programs based on the eligible materials.

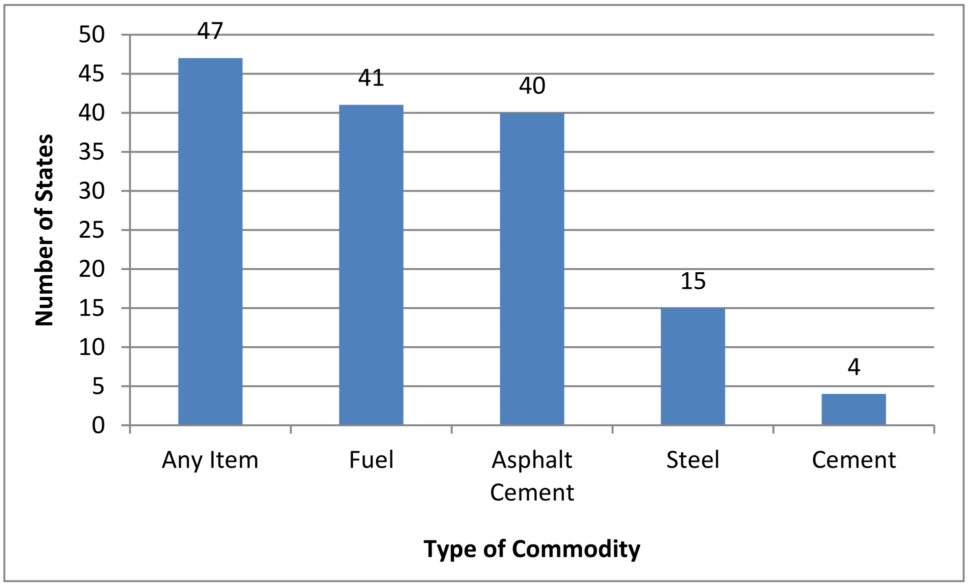

Figure 1-1: Number of states that offer PAC (Source: Skolnik 2011)

Although the primary purpose of all PAC programs across the U.S. is to shift the risk of material price fluctuations from contractor to state DOTs and consequently eliminate the possibility of risk premiums in contractors' submitted bids, different transportation agencies use various design elements in their PAC programs. The most important design elements are type of the eligible materials, calculation of index, material usage factors, trigger points, presence of opt-in or opt-out, and formulas to calculate the price adjustment.

The trigger points refer to the percent changes in material prices that initiate the application of relevant adjustment clauses. The distribution of the trigger point is broad. A large group of state DOTs uses 5-7.5% as the trigger value. Skolnik (2011) surveyed the AASHTO members to develop Figure 1-2 that depicts the distribution of the trigger point for various eligible line items.

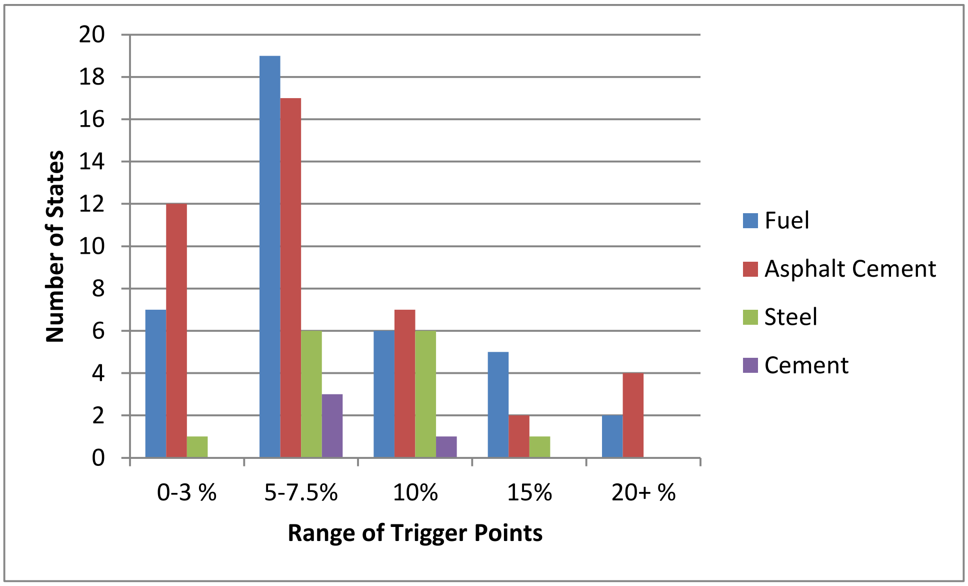

Figure 1-2: Trigger points for price escalation (Skolnik 2011)

Opt-in or opt-out indicates whether the contractor has the right to accept or decline the PAC after the contract is awarded. The results of the survey of the AASHTO members (2009) indicate that only a small percentage of states with PACs also have opt-in clauses, which give the right to contractors to decide whether to accept the PAC. Figure 1-3 shows the number of state DOTs that have an opt-in policy.

Also, some state DOTs, such as New York, Iowa, and Montana, apply a dollar value rather than a percent for the trigger values. For example, New York DOT applies adjustment for fuel when the fuel price is changed by at least 10 cents per gallon (Holmgren et al. 2010).

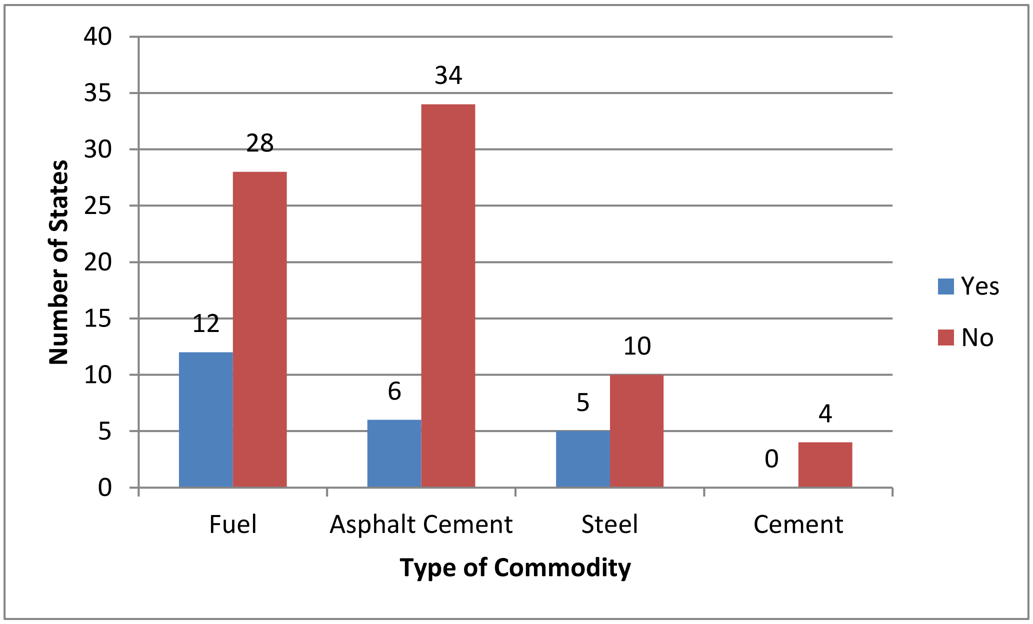

Figure 1-3: Number of states that have an opt-in policy for various line items (Source: Skolnik 2011)

Some state DOTs always offer PACs for all projects while some State DOTs offer PACs under specific conditions for some projects. Figure 1-4 shows the percentages of different contract conditions for PAC exclusion in the state DOTs that offer PACs. It can be seen that just over half of state DOTs exclude projects from these clauses for specific pay items, 38 percent of state DOTs exclude projects based on minimum pay item quantities, 23 percent of state DOTs exclude projects by dollar amount, 17 percent of state DOTs exclude projects by project duration, and 17 percent of state DOTs exclude only designated projects. No state DOT reported to exclude the project because it is funded solely at the state level. It can be concluded that projects are generally excluded from using the PAC due to the type of specific pay item or a measure of small size in dollar, pay item quantity or duration. Specific pay items are most likely not included due to small amounts of fuel or construction inputs consumed or lack of reliable data at the level of usage for those pay items.

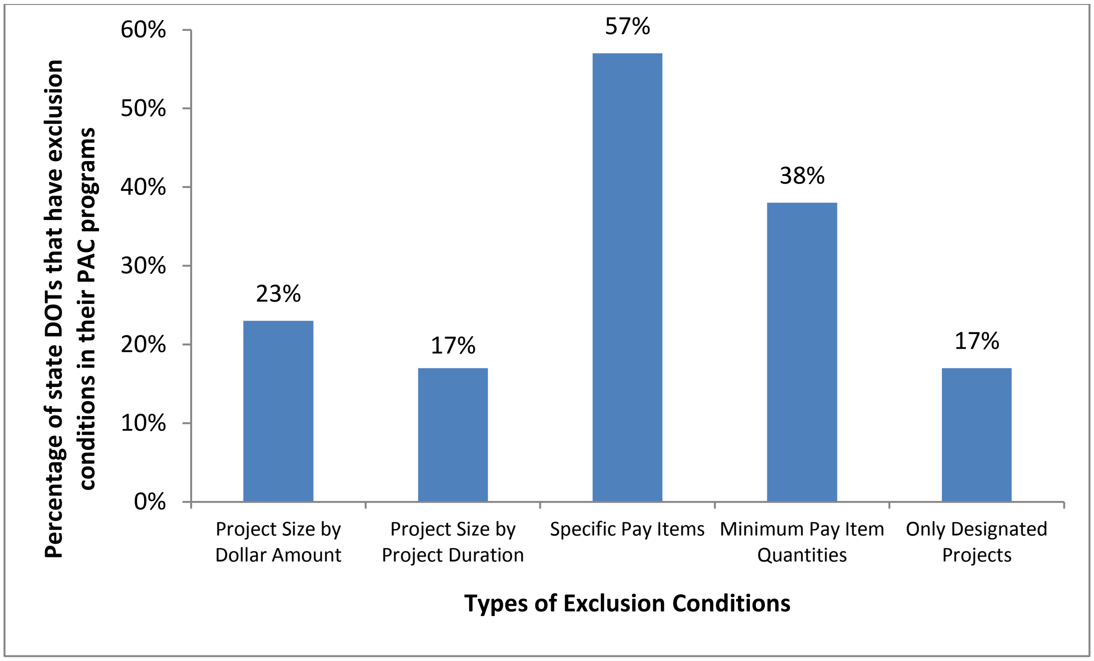

Figure 1-4: The distribution of state DOTs that have exclusion conditions in their PAC programs (Source: Skolnik 2011)

The benefits of offering PAC and consequently shifting the risk from contractors to state DOTs is not restricted to cost reduction. Skolnik (2011) conducted a survey of 50 state DOTs and 400 highway construction contractors to identify possible benefits, beneficiaries, and barriers for the successful implementation of the PAC. The results indicate that the most important benefits of the PAC from the state DOTs' viewpoints are:

- Better bid prices (78% of respondents noted this benefit.)
- Contractor stability (56% of respondents noted this benefit.)
- Increased number of bidders (24% of respondents noted this benefit.)
- Fewer bid retraction (2% of respondents noted this benefit.)

Also, the percent of the State DOT respondents that reported perceived benefits for offering the PAC for various commodities are:

- Fuel (60%)
- Asphalt Cement (63%)
- Cement (Most state DOTs do not offer the PAC for cement. Of the 10% that do, half perceived significant benefits.)
- Steel – A large number of state DOTs do not offer the PAC for steel. Of the 39 percent that do, 13% perceived significant benefits.)

Moreover, the percent of the State DOT respondents that reported perceived benefits for offering the PAC for various industry stakeholders are:

- Prime Contractors (81%)
- Subcontractors (70%)
- State DOTs (61%)
- Suppliers (60%)
- Others (2% of the respondents perceived significant benefit for taxpayers.)
- On the other hand, the percent of the contractor respondents that reported perceived benefits for offering the PAC for various commodities are:
- Asphalt Cement (91%)
- Fuel (72%)
- Steel (72%)
- Cement (58%)

Also, the percent of the contractor respondents that reported perceived benefits for offering the PAC for various industry stakeholders are:

- State DOTs (82%)
- Prime Contractors (83%)
- Subcontractors (84%)
- Suppliers (78%)

Identification of the most important barriers to successfully implement the PAC is critical. The results of the survey by Skolnik (2011) indicate that the most important barriers to successfully implement the PAC from the viewpoint of state DOTs are:

- Administrative cost
- Contractor resistance
- Process of creating the policy
- Updated fuel usage factors
- Costs of the programs do not justify the benefits

However, the most cited barriers by contractors are:

- Timing on invoices versus the index payment calculations. This problem involves a discrepancy in the date the materials are purchased and the index date used by state DOTs.
- A high trigger value for index payments is also a complaint of some contractors.
- Incorrect index values, either due to outdated indexes or incorrect calculations.

Eckert and Eger (2005) mentioned a list of possible barriers to successfully implement the PAC as follows:

- Contracts must have a set-aside contingency funding to be able to address indexed adjustments. These funds, whether used or not, are tied to a contract (i.e., not available to other work) until closed.
- Risk management is not well understood by most, and therefore, the long-run benefits may not be understood.
- Suppliers could be artificially raising prices that will impact index without the state knowing it.
- It is extremely difficult to track payments under the index process over the years. Adjustments increase the complexity of the tracking process.
- It is difficult to assure that the prices quoted by suppliers for the index are true monthly prices for asphalt concrete.

1.2.2. Evaluating the PAC

As mentioned before, impacts of the price adjustment clause and appropriate strategies to successfully implement the PAC in different industries, such as transportation projects, is a debatable topic. The precise evaluation of the PAC helps state DOTs adjust their strategies. Holmgren et al. (2010) mentioned that within the last few years, 18 state DOTs have made minor changes to the way the fuel adjustment is calculated. Holmgren et al. (2010) suggested that usage factors should be reviewed and recalculated every three years, price changes should be routinely monitored, and the effects of different variables on the price should be frequently reexamined.

Both qualitative and quantitative analyses have been used to evaluate the effectiveness of PAC programs.

1.2.2.1. Qualitative Analysis

In 2005, Eckert and Eger contemplated the implementation of the PAC program for Georgia DOT. They conducted phone interviews with Georgia's five surrounding state DOTs, Alabama, Florida, North Carolina, South Carolina, and Tennessee, and interviewed a representative from the GDOT. The purpose of the interview was to address the GDOT's perspective on the issues related to the fixed bid process, lessons learned in the fixed bid process, and to assess the costs and benefits associated with the fixed bid process. Further, three other state DOTs, Mississippi, Arkansas, and Illinois, were interviewed using the comments received from the questionnaires and comments heard from the neighboring state DOTs.

The results of the surveyed neighboring state DOTs showed that four out of the five neighboring state DOTs are satisfied with the asphalt cement price index process. However, none of them has done a benefit/cost analysis that could determine the fiscal impact of the PAC or the impact of the current index process on the supply of asphalt cement. Alabama DOT's concern was that the state DOT sets the price and the suppliers immediately adjust their prices to the state average price bringing into question the competitive advantage of the price index concept. Alabama DOT was not convinced that the PAC helps the state; and in fact, the PAC may cost the state more than having a fixed bid system.

In an evaluation of ways to reduce construction cost and increase competition, Damnjanovic et al. (2009) identified factors, strategies, and methods to reduce construction cost in two categories at project and program levels. A Delphi analysis was utilized to formulate a group judgment about the effectiveness of the methods. Based on the results, the PAC was ranked the 8th at the program level.

The results of the survey of 400 highway contractors indicate that there is a consensus among surveyed contractors that the PACs are beneficial to all stakeholders, for all commodities, and to the market overall (Skolnik 2011). Nearly all responding contractors claim that they add contingencies to their bids in the absence of PACs. Approximately 91% of contractors add contingencies to their bid prices when there is no PAC in place to cover the material price risk. Approximately 38 percent of contractors are less likely to bid projects when there is no PAC. 64 percent of contractors noted that the PAC has no effect on the number of projects they bid. 58% indicated that the PAC lowers their bid prices. Approximately 28 percent postulate that the PAC does not affect their bid prices while 13 percent assume higher prices.71 percent of contractors believed that their risk is lower, of which 31 percent believed their risk is significantly lower. However, approximately 18 percent believed their risk is higher with the presence of PACs.

1.2.2.2. Quantitative Analysis

Eckert and Eger (2005) established a numerical comparison between the prices of asphalt cement from 2001 to 2003 in the five neighboring states of Georgia that had the PAC and those prices in Georgia that did not have any PAC program at that time. They also compared the prices of hot mixed asphalt in two categories of “All Superpave” and “Superpave 12.5 mm” in Georgia and its neighboring states. Results showed that Georgia, on average, has the lowest quoted price for asphalt cement. However, the volatility of the price of asphalt cement in Georgia, as measured by the standard deviation, is higher than that in Alabama, Florida, and Tennessee. These quantitative findings showed that the price risk premium - defined as the increase in price due to the probability that prices will rise over time in fixed bid long-term contracts - was not detected within the 2001-

2003 time period in submitted bids for asphalt cement in Georgia. Some of the suppliers indicated that the lack of a price difference may be due to the fact that the suppliers have been guaranteeing the price of asphalt cement in long-term contracts for the state of Georgia. The suppliers noted that they will quote the price of asphalt cement in the future for up to three years by providing a ceiling price to the contractors (Eger and Guo 2008).

Skolnik (2011) analyzed the most important two benefits of implementing PAC program quantitatively, reduction in submitted bid prices and increase in competition. Statistical analysis was conducted using data from the comprehensive Bid-Tabs database collected by Oman Systems, Inc. The bid prices were compared in two different groups of states from 2007 to 2009. The first group contains Arkansas, California, Michigan, and Texas that did not have the PAC at that time (Control Group). The second group contains Illinois, Tennessee, Missouri, and Oregon that had the PAC at that time. All those 8 states use standard pay items that use unit price and have large enough bid data points.

The bid prices in these eight states were used in a regression analysis model to determine significant factors influencing bid prices. The basic regression model has the bid price as the dependent variable and several explanatory variables including the presence of the PAC, the quantity of the pay item requested for the job, and the relevant price index. In addition, several indicator variables, such as trigger points and the presence of opt-in clause were later added to the basic regression model. In the first set of regressions, the group of four states with the PAC of any type was compared to the control group of the four states with no PAC. In a second set of regressions, each state with the PAC was compared individually to the group of four control states with no PAC. A separate regression analysis was conducted for each state with a PAC for the pay item category.

In the second set of the regression model, number of bidders as a variable was analyzed. The regression has the number of bidders as the dependent variable and several explanatory variables including average job size, number of firms, change in employment, and price adjustment clause effect. Regression coefficients were calculated for all lettings, periods of rising prices, and periods of falling prices. The results show that the PAC coefficients are variable with no consistent pattern. Overall, the statistical analysis conducted in this study cannot conclusively answer the central question of whether these clauses result in lower prices or increase the number of bidders.

Considering these results, Skolnik recommended that availability of index, validity of index, methods for measuring quantities, impact of changing price, contractor’s ability to control price, and cost of administering program for eligibility of a commodity should be included in the PAC. Also, regarding the design elements, Skolnik suggested excluding opt-in provisions and considering trigger point between 0 to 10 percent because higher trigger points may reduce the effectiveness of the PAC. One of the most important achievements of Skolnik’s research is that the effectiveness of offering PAC in different states is not same. This difference might be based on the different design elements of PACs in different states or different market conditions. Thus, it is necessary to study the effect of the PAC implementation in each state, separately.

Kosmopoulou and Zhou (2011) conducted an empirical study to analyze the effects of offering the PAC for asphalt cement in Oklahoma. They used the information of all public projects of Oklahoma Department of Transportation (ODOT) from 2003 to 2009 for their study. The results of the Difference-in-Difference (DID) regression analysis and Regression Discontinuity Design (RDD) indicated that in general, submitted bids for eligible projects are 5% lower than those submitted bids for ineligible projects. Furthermore, ODOT received approximately 12.7% lower bids on PAC-eligible items compared to PAC-ineligible items.

1.2.2.3. Suggestions and Guidelines

In 2006, Carrol et al. studied the current practices of Fuel Price Adjustment in the southern region states. They suggested establishing price adjustment for both gasoline and diesel fuels by the Georgia Department of Transportation. They recommended not applying price adjustment for any projects less than six months. A trigger point of 20% change in the current fuel price compared to the letting date was recommended. Furthermore, they suggested establishing quantity thresholds for each item that receives the fuel price adjustment.

1.3. PRICE ADJUSTMENT CLAUSE IN GEORGIA

Georgia Department of Transportation (GDOT) has been offering PAC for asphalt cement in transportation projects since September 2005. GDOT has changed the provision of PAC for asphalt cement two times, in 2009 and 2011. The main objectives of all three provisions of PAC for asphalt cement are the same. However, they are different in design elements, trigger points, and restrictions.

1.3.1. PAC Provision of 2005

GDOT developed the PAC provision for asphalt cement for the first time in September 15, 2005. Based on this provision, if the asphalt cement price for the current month is greater than the asphalt cement price for the month in which the project was let to contract, the contractor will be paid an amount calculated in accordance with the following formula:

$$\mathrm{PA} = \left(\frac{\mathrm{APM} - \mathrm{APL}}{\mathrm{APL}} - 0.05\right) \times \mathrm{TMT} \times \mathrm{APL}$$

where:

PA = Price Adjustment.

APM = the “Monthly Asphalt Cement Price (Georgia Base Asphalt Price)” for the month the hot mix asphalt/bituminous tack/bituminous surface treatment is placed.

APL = the “Monthly Asphalt Cement Price (Georgia Base Asphalt Price)” for the month that the project was let.

TMT = Total Monthly Tonnage of asphalt cement computed by the Engineer based on the Hot Mix Asphaltic Concrete of the various types per ton.

On the other hand, if the asphalt cement price for the current month is less than the asphalt cement price for the month in which the project was let to contract, the Department will deduct an amount calculated in accordance with the following formula.

$$\mathrm{PA} = \left(\frac{\mathrm{APM} - \mathrm{APL}}{\mathrm{APL}} + 0.05\right) \times \mathrm{TMT} \times \mathrm{APL}$$

According to the above formulas, no price adjustment shall be made until the APM is greater than 5% above or below the APL. This 5% trigger point is one of the most important design elements of the PAC program.

Based on this provision of the PAC, the monthly asphalt cement price index is determined based on both National Base Asphalt Price (NBAP) and Local Base Asphalt Price (LBAP). NBAP is calculated based on the arithmetic average of the previous four weeks “Posted Price Asphalt Cement” for the “East Coast market-GA/FL” as listed in the “Asphalt Weekly Monitor®” published by “Poten and Partners.” However, LBAP is calculated based on the arithmetic average posted price of asphalt cement from the Department’s monthly survey obtained from approved asphalt cement suppliers of bituminous materials to the Department projects and the suppliers’ asphalt terminals after removing the highest and the lowest price.

The other important characteristics of the PAC are the criteria to be eligible for the clause and restrictions. The restrictions of this provision are as follows:

- A price adjustment shall not be made on any hot mix asphalt placed between the letting date and 180 days after the letting date.
- Cut-back, tack-coat, and surface treatment projects are not eligible for price adjustment.
- There is a cap of 50% above the APL for any price adjustment.
- After original contract time has expired, no further asphalt cement price adjustment will be made. The Asphalt Cement Price Adjustment for any hot mix asphalt placed after the original Contract Time expires will be computed based on the Monthly Asphalt Cement Price at the time the Contract Time has expired or the Monthly Asphalt Cement Price at the time the Contract was let, whichever is less.

1.3.2. PAC Provision of 2009

GDOT established a new provision for price adjustment in August 21, 2009. The most important differences between the second version and the first one are the cap of the price adjustment and the eligibility criteria of the projects. In this second version, GDOT increased the cap from 50% to 125%. Thus, after August 21, 2009, any volatility of asphalt cement price index from 5% to 125% is covered by the PAC program. Furthermore, no price adjustment will be made on any project with less than 366 calendar days from the contract letting date to the specified completion date. The duration between the original completion date and the letting date was not a criterion for eligibility of the projects for the PAC program in the 2005 version. However, for all eligible projects based on the provision of 2005, a price adjustment was not made between the letting date and 180 days after the letting date.

1.3.3. PAC Provision of 2011

Two years later, in August 19, 2011, GDOT revised the PAC program and established the third provision. The 5% trigger point was canceled in the third version. Thus, the price adjustment is determined as follow:

$$\mathrm{PA} = \left(\frac{\mathrm{APM} - \mathrm{APL}}{\mathrm{APL}}\right) \times \mathrm{TMT} \times \mathrm{APL}$$

Another change in the third version compared to the second one is the reduction of the cap from 125% to 60%. Furthermore, the calculation of the asphalt cement price index is only based on the Georgia Base Asphalt Price (GBAP), which is determined based on the arithmetic average of posted prices of asphalt cement from the Department's monthly survey obtained from approved asphalt cement suppliers of bituminous materials to the Department projects and the suppliers' asphalt terminals after removing the highest and the lowest price.

CHAPTER 2
CHARACTERISTICS OF ASPHALT CEMENT PRICE INDEX

2.1. INTRODUCTION

Asphalt cement is the most important and critical input commodity in transportation projects. Sharp increases in the price of asphalt cement is often argued as a major reason for increasing highway construction costs (Zhou and Damnjanovic 2011; Skolnic 2011; Damnjanovic and Zhou 2009; Gallagher and Riggs 2006; Wilmot and Cheng 2003). Although price of asphalt cement increases over the long term, it is subject to considerable short-term variations. This volatility in the price can lead to serious problems for both owner organizations and contractors. As noted in the previous chapter, the PAC is offered to manage the consequences of this volatility in the price. Figure 2-1 shows asphalt cement price index in the state of Georgia from September 1995 to July 2013.

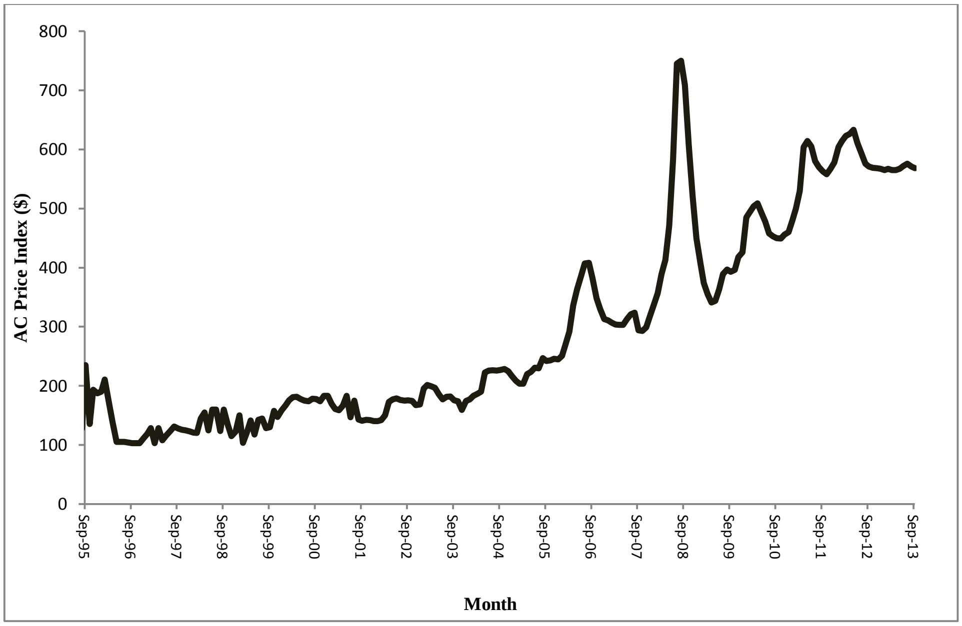

Figure 2-1: Asphalt cement price index in Georgia

Since the asphalt cement price index has an undeniable role in the PAC, identifying the characteristics and properties of this index is important. However, there is little knowledge about how the asphalt price index fluctuates over time. This gap in knowledge makes it difficult for transportation agencies to assess the financial impacts of price adjustment clauses on budgeted project costs under uncertainty about Asphalt Cement Price Index. The objective of this chapter is to create appropriate time series models for estimating and forecasting fluctuations in Asphalt Cement Price Index. After investigation on characteristics of historical time series data of monthly asphalt cement price index, several univariate time series models are created. The accuracy and predictability of these time series models are examined using actual Asphalt Cement Price Index data, which were not used in model creation efforts.

2.2. Time Series Analysis

A time series is a set of data points that are recorded at uniform time intervals. Time series methods are used to extract meaningful characteristics of the data and forecast future values based on the previous data. The most important difference of time series methods compared to causal methods, such as regression models is that they do not need any explanatory variables. In many cases, future values of economy-related explanatory variables are not available and hence, time series models have a considerable advantage over causal methods. In this research, the time series dataset consists of monthly asphalt cement price index in the state of Georgia. As noted earlier in the first chapter, GDOT determines the index based on the average of prices from around 15 different suppliers after removing the minimum and maximum prices.

2.2.1. Time Series Data Characteristics: Autocorrelation, Stationary and Seasonality

The first step to create time series models is to investigate whether the series data is autocorrelated or not. If the time series data were not autocorrelated, the time series model cannot be applied. The Box-Pierece test is used to investigate the autocorrelation. In Box-Pierce test, the null hypothesis is that the data are not autocorrelated. The results of the test indicate that the p-value of the test is very small (less than 2.2×10^{-16}). Thus, the time series dataset of asphalt cement price index is autocorrelated.

A time series is stationary if its statistical properties do not depend on time. Figure 2-2 shows auto correlation function plot that indicates a strong increasing trend in the monthly index. This is an indicator of nonstationary property since the mean value is clearly not constant. In addition, to investigate the nonstationary properties of the time series data more rigorously, KPSS test (Kwiatkowski et. al. 1992) was conducted. The null hypothesis is that the time series is stationary around a deterministic trend. The results of the test indicate that the p-value is 0.01. Since p-value is smaller than the significance level, the null hypothesis is rejected and the monthly asphalt cement price index is nonstationary.

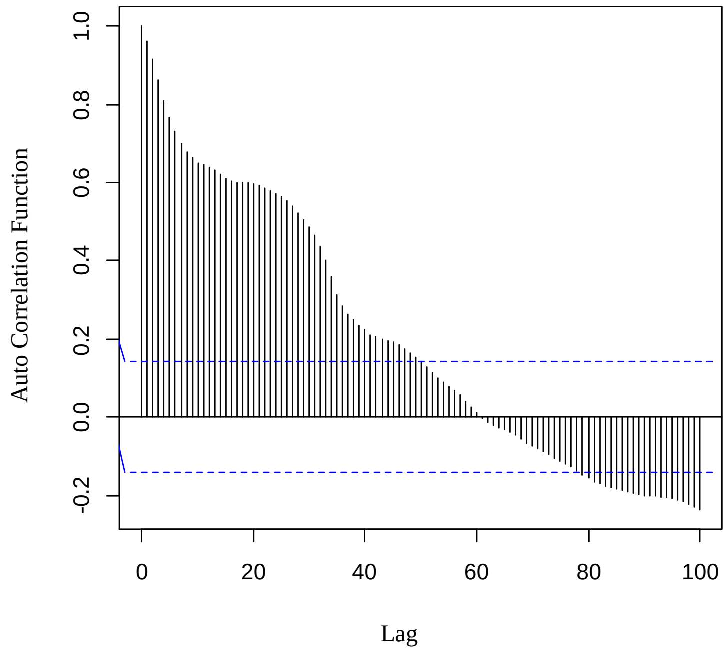

Figure 2-2: Auto Correlation Function (ACF) plot of the AC price index

The other important property of a time series dataset is seasonality that displays certain cyclical or periodic behaviors over time. Figure 2-3 shows the first difference auto correlation function plot indicating that the dataset might have seasonality property.

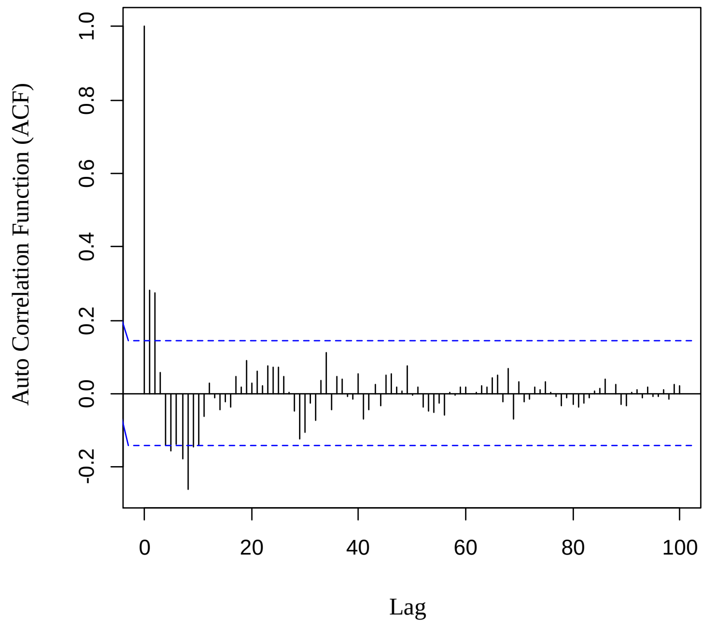

Figure 2-3: First difference ACF plot of the AC price index

2.2.2. Time Series Forecasting Models

In this chapter, Holt ES, Holt-Winters ES, ARIMA, and Seasonal ARIMA time series models are created to model the variations of monthly asphalt cement price index and forecast the trend. Each time series model has its unique assumptions and formulation. Table 2-1 shows the basic assumptions of each model.

Time series forecasting consists of two major modeling steps: in-sample model fitting and out-of-sample forecasting. In-sample model fitting does not forecast future path of a variable. It uses historical data to estimate model parameters and fit the model with actual data. Out-of-sample forecasting attempts to forecast future values of a variable by using the time series model and its parameters that were created via in-sample model fitting based on the historical data. In this research, the characteristics of Asphalt Cement (AC) price index dataset were examined with underlying assumptions of these methods. Also, the accuracy of in-sample model fitting and out-of-sample forecasting models is assessed by three common statistical error measures: Mean

Absolute Percentage Error (MAPE), Mean Square Error (MSE), and Mean Absolute Error (MAE). Formulation of these error measures are as follows:

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\frac{\left|\hat{Y}(t) - \tilde{Y}(t)\right|}{\tilde{Y}(t)} \times 100\%$$

$$MSE = \frac{1}{N}\sum_{t=1}^{N}(\hat{Y}(t) - \tilde{Y}(t))^2$$

$$MAE = \frac{1}{N}\sum_{t=1}^{N}\left|\hat{Y}(t) - \tilde{Y}(t)\right|$$

Where $\hat{Y}$ is the fitted value for in-sample model fitting (or forecasted value for out-of-sample forecasting) and $\tilde{Y}$ is the actual value.

Table 2-1: Assumptions of time series models

Time Series Models	Modeling Assumptions
Holt ES	Underlying data show trends
Holt-Winters ES	Underlying data show trends & seasonality
ARIMA	Underlying data are nonstationary and Model residuals are white noise
Seasonal ARIMA	Underlying data are nonstationary & seasonal and Model residuals are white noise

2.2.2.1. Holt Exponential Smoothing (Holt ES)

The Holt ES method is recommended to handle time series data that display trends (Brockwell and Davis 2002). Since the increasing trend in asphalt cement price index can be observed, this method is used in this research. The Holt ES method models the time series based on level and trend smoothing (Gardner 1985). Level smoothing estimates the monthly level factor of the price index, while trend smoothing estimates the trend factor or the average monthly growth rate of the index. The optimum value for level smoothing weight (α) and trend smoothing (β) should be determined to minimize the MSE. The optimal values for α and β are 0.971 and 0.03101 with p-values of less than 0.0001 and 0.0008, respectively. The error measures of the Holt ES model are MAPE=5.61%, MSE=1421.6, and MAE=23.773. Figure 2-4 shows the results of this time series model. The fitted values for in-sample model fitting are shown in red.

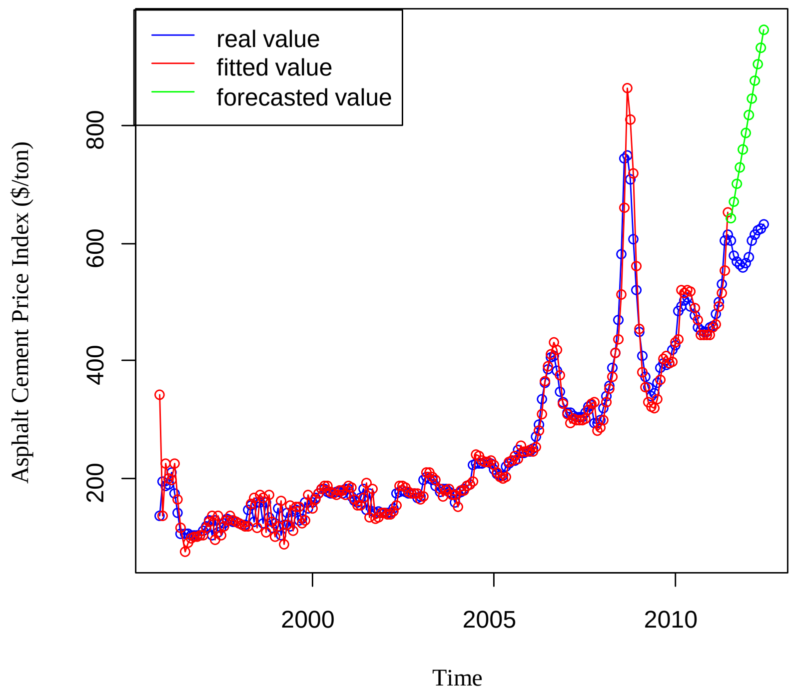

Figure 2-4: Results of Holt ES model

2.2.2.2. Holt-Winters Exponential Smoothing (Holt-Winters ES)

For time series that shows trends and seasonality, Winters (1960) recommended a generalized version of Holt ES method in which beside level smoothing and trend smoothing, a new factor called seasonal smoothing estimates the value of seasonal growth rate. Similar to the Holt ES method, the optimal value of factors should be calculated to minimize the MSE of the forecasted values. The results show that the optimal values of those three factors are a=0.89901, b=0.035, and c=0.779 with p-values of <0.0003, <0.00014, and <0.0079, respectively. The error measures of the Holt-Winters ES model is MAPE=6.0095%, MSE=1346.8090, and MAE=26.78317. Figure 2-5 shows the results of this time series model. The fitted values for in-sample model fitting are shown in red.

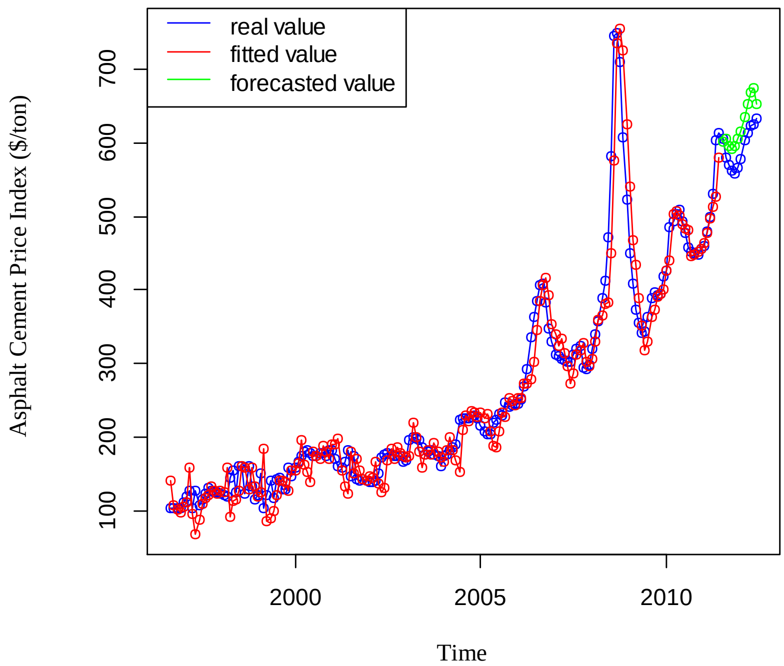

Figure 2-5: Results of Holt-Winter ES model

2.2.2.3. Auto-Regressive Integrated Moving-Average (ARIMA)

Autoregressive Integrated Moving Average (ARIMA) is recommended to model time series data displaying nonstationary behaviors (Box and Jenkins 1970). This method is based on the combination of two time series approaches, autoregressive (AR) and moving average (MA). In this method, the first step is to create a stationary time series dataset that can be applied by a sequential differencing operation on the original dataset. In order to make the time series dataset of price index stationary, the first difference of the dataset has been taken. The results of the KPSS test and the Augmented Dickey-Fuller (ADF) test on the first difference of the original dataset show that the first difference dataset is stationary.

ARIMA model has three parameters: p and q that show the order of AR and MA parts of the model and d that represents the difference order required to transform the original dataset to a stationary time series dataset. As mentioned before, the first difference of the dataset is stationary. Thus, d is equal to 1. To determine p and q, ACF and Partial Autocorrelation Function (PACF) can be used (Brockwell and Davis 2002). If ACF and PACF values of a time series are equal to zero at all lag levels, the time series is a white noise. If the PACF graph of a time series cuts off after lag p and its ACF graph dies down, then the time series is AR (p). If the ACF graph of a time series cuts off after lag q and its PACF graph dies down, then the time series is MA (q). If both ACF and PACF graphs of a time series die down, then the time series is ARIMA. Figure 2-6 shows the ACF and PACF graphs of the transformed data. Based on Figure 2-6, p and q are 2 and 1, respectively. Moreover, the forecasting package of the R software was used to determine the values for p and q. The calculation was based on considering different values for these two orders and calculating the respective value of Bayesian Information Criterion (BIC) for different combinations of the two parameters. The outputs of the analysis indicate that ARIMA (2,1,1) can be selected as the initial best model.

The next step is to determine the coefficients and develop the ARIMA model. AR and MA coefficients are determined based on the Maximum Likelihood Estimation (MLE) approach. The results show that the $\emptyset(1) = 1.6153, \emptyset(2) = -0.7518$, and $\theta(1) = -0.8738$.

Since the residuals of the ARIMA model must be a white noise time series dataset (i.e., sampled from a random variable with 0 and finite variance $\sigma^2 < \infty$), the Ljung-Box Q test and standardized residuals evaluation were conducted. The results indicate that:

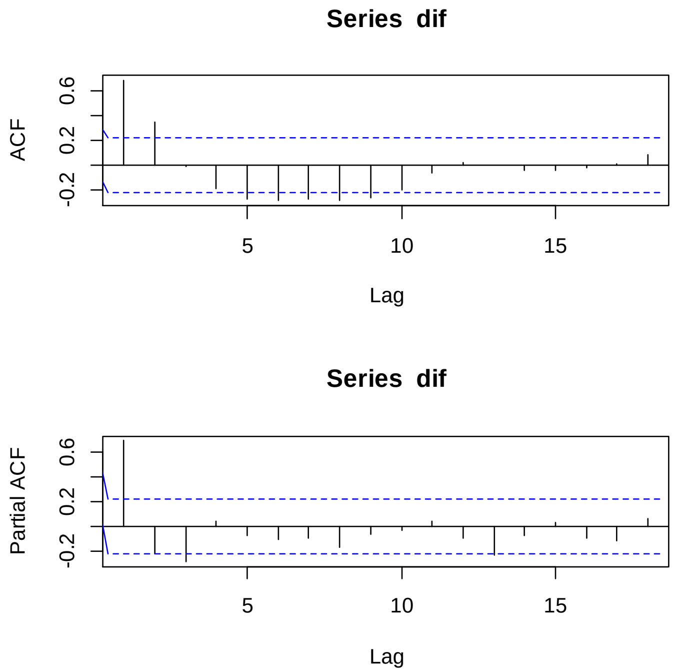

Figure 2-6: ACF and partial ACF of first difference

(1) The standardized residuals do not show clusters of volatility.

(2) The autocorrelation function (ACF) shows no significant autocorrelation between the residuals.

(3) The p-values for the Ljung-Box statistics are all large indicating that the residuals do not show any particular pattern.

The error measures of the ARIMA model is $MAPE = 3.19\%, MSE = 602.505$, and $MAE = 14.5767$.

Figure 2-7 shows the results of this time series model. The fitted values for in-sample model fitting are shown in red.

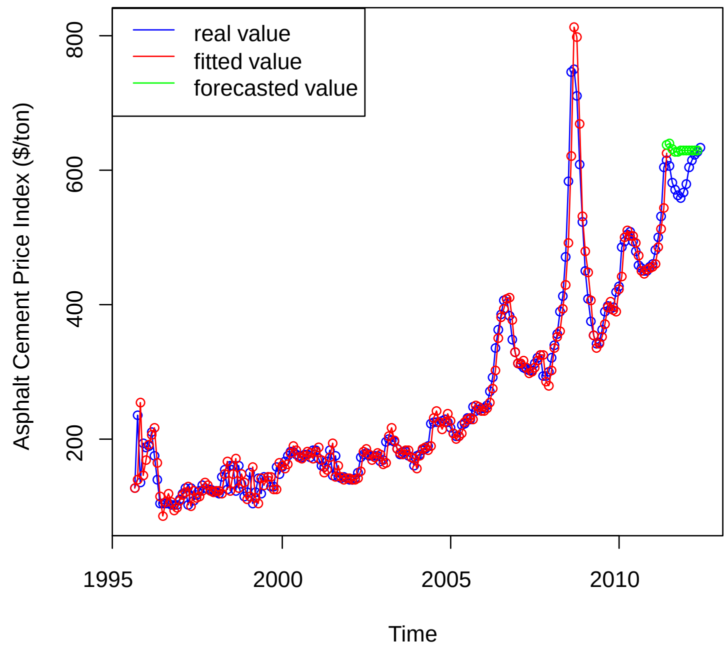

Figure 2-7: Results of ARIMA(2,1,2) model

2.2.2.4. Seasonal Auto-Regressive Integrated Moving-Average (Sesonal ARIMA)

In order to capture seasonality in time series data, Seasonal ARIMA model is introduced to extend ARIMA model. In addition to parameters p, q, and d that are required to define a regular ARIMA model, parameters P, Q, and D are used to describe the seasonal ARIMA model. Parameters P and Q are integers describing the orders of AR and MA seasonal parts of the ARIMA model, respectively, and parameter D is an integer representing the difference order required to remove the seasonality of the transformed stationary dataset.

First, seasonal differencing and the necessary test should be conducted to check whether differenced dataset is stationary or not. Seasonal period of asphalt cement price index is considered 12 months. Thus, D is equal to 1 and one cycle differencing is sufficient to reach a stationary dataset. Parameters P and Q of the seasonal ARIMA model are identified by observing the behaviors of the sample ACF and PACF time series plots of the transformed dataset at multiples of lag 12. According to the visual rules for model type selection, both P and Q are 0. The initial seasonal ARIMA model is (2,1,1)(0,1,0). The initialization process for parameters p and q were conducted by computing the Bayesian Information Criterion (BIC) values for various combinations of p and q in the seasonal ARIMA model as described in Brockwell and Davis (2002). Several seasonal ARIMA models were tried to find the best combination of p and q with the lowest BICs. The results show that Seasonal ARIMA (2,1,1)(0,1,2) provides the lowest BIC. Furthermore, based on the MLE approach, the coefficients of the seasonal ARIMA model are determined as the following:

$AR\ (1) = 1.6605, AR(2) = -0.7835, MA(1) = -1.000, SMA(1) = -0.9982, SMA(2) = -0.0016$. The error measures of the seasonal ARIMA model are:

$MAPE = 2.91\%, MSE = 455.59$, and $MAE = 13.41$.

Figure 2-8 shows the results of this time series model. The fitted values for in-sample model fitting are shown in red.

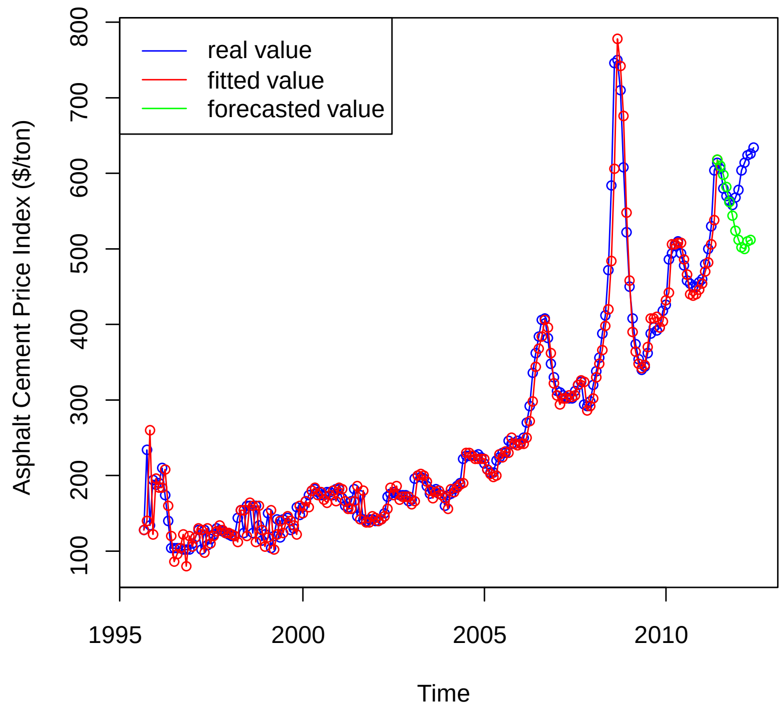

Figure 2-8: Results of seasonal ARIMA model

2.2.3. Out of Sample Forecasting

Out-of-sample forecasting predicts future values of price index by predictive time series models that are developed based on the historical data. Out-of-sample forecasting models use the subset of monthly asphalt cement price index from October 2005 to June 2011 to forecast price index after June 2011. Figures 2-4 to 2-8 show the results of the out-of-sample forecasting models in green. The predictability of time series models was investigated by three error measures: MAPE, MSE, and MAE. Table 2-2 presents the error measures of the out-of-sample time series models.

Table 2-2: Error measures of Out-of-Sample forecasting

Error Measure	Holt ES	Holt-Winters ES	ARIMA	Seasonal ARIMA
MAPE	4.0%	6.3%	11.6%	12.5%
MSE	867.67	2070.67	5972.1	7103.31
MAE	23.16	37.00	69.67	73.43

The results indicate that for in-sample forecasting, the Seasonal ARIMA model has the best ability to capture the seasonality property of the data. However, for out-of-sample forecasting, the error measures of seasonal ARIMA are considerably higher than the others and the Holt ES is the most accurate model.

It can be concluded that the described time series methods are applicable for modeling variations of the asphalt cement price index and developing in-sample forecasting models since the index dataset meets the underlying assumptions of these methods. It is shown that the seasonal ARIMA model is the best time series model for in-sample forecasting of the price index while the Holt ES model is the most-accurate time series approach for out-of-sample forecasting of asphalt cement price index in Georgia.

CHAPTER 3
DATASET DEVELOPMENT

3.1. INTRODUCTION

The project dataset contains information on 3,749 projects with different asphalt quantities from 1/23/1998 to 7/19/2013. The information on prices and quantities are distributed across 19 asphalt line items. Each studied project can have between one to seven line items. The projects are also distributed geographically in seven districts throughout the state of Georgia. In this chapter, the distribution of data among different categories is analyzed and some basic statistical measures are performed on each category of data. First, the general characteristics of the projects are studied, e.g., number of asphalt line items, location, duration, and size (value and quantity). Second, the market conditions and the changes in the competitive bidding environment over time are discussed.

3.2. PROJECT CHARACTERISTICS

Project characteristics are a set of quantitative values, such as project bidding date, location, duration, total bid price, and total asphalt quantity that specifies a unique project in the dataset. These properties can distinguish the projects from each other and help group the projects with similar characteristics.

3.2.1. Asphalt Mixture line items

Since the main question of this study is about the assessment of the effects of the price adjustment clauses on the bidding behavior of the contractors, it is useful to first study the changes in bidding price (USD per Ton) for each line item throughout the time horizon of the study. The bidding prices may be affected by internal factors, such as size and location of a project, as well as external factors, such as market conditions and competitive bidding environment. Table 3-1 shows the description of main line items and the number of observations in each line item.

Table 3-1: Major line items

Line Item	Description	Number of Observations
402-3190	Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL	1432
402-3130	Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL	1177
402-3121	Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL	1178
402-1812	Recycled Asphaltic Concrete Leveling, BM&HL	3023
402-1802	Recycled Asphaltic Concrete Patching, BM&HL	1007
402-3113	Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL	132
402-4510	Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL	328

Figures 3-1 to 3-7 show the changes in bid prices for these seven main line items whose data were available over time. The historic data for other line items were either not available for the whole period of the study or not sufficient for performing proper statistical analysis. As indicated by red lines in the figures, there are three policy changes in 2005, 2009, and 2011, which represent the introduction of three types of price adjustment clauses for asphalt cement.

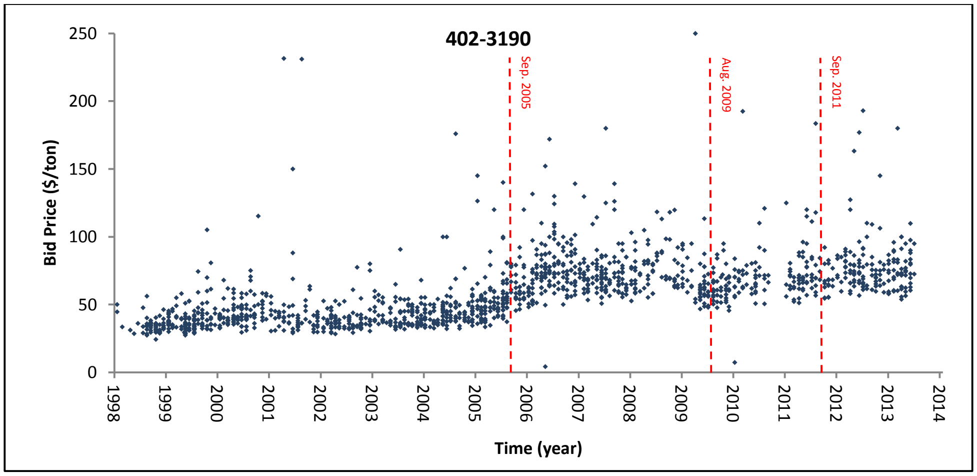

Figure 3-1: Bidding price fluctuations over time for the line item 402-3190

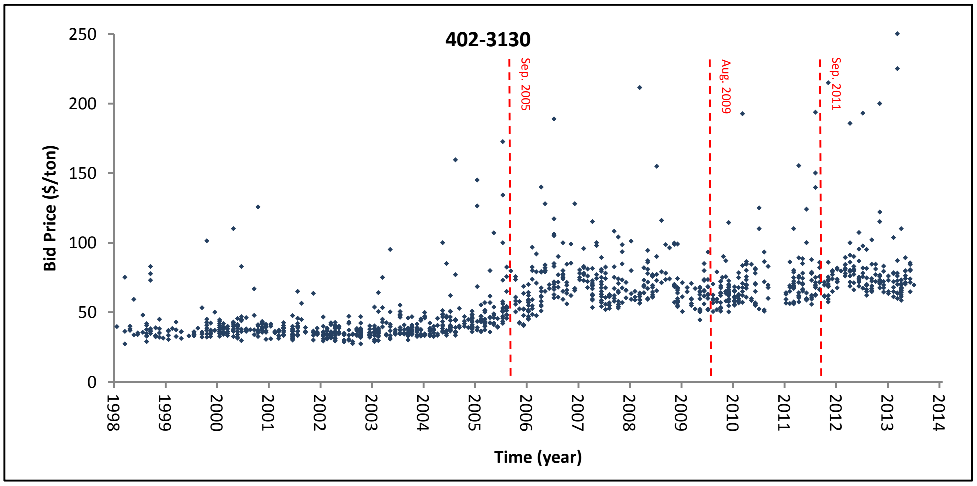

Figure 3-2: Bidding price fluctuations over time for the line item 402-3130

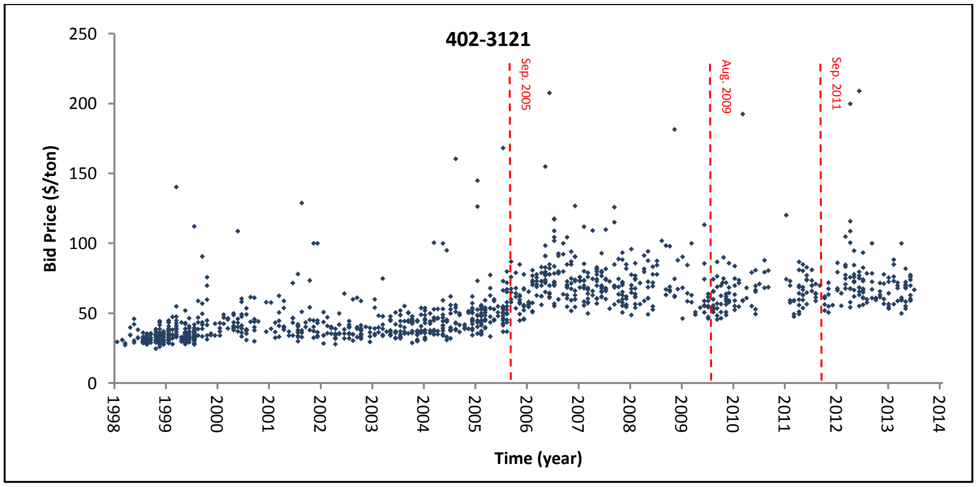

Figure 3-3: Bidding price fluctuations over time for the line item 402-3121

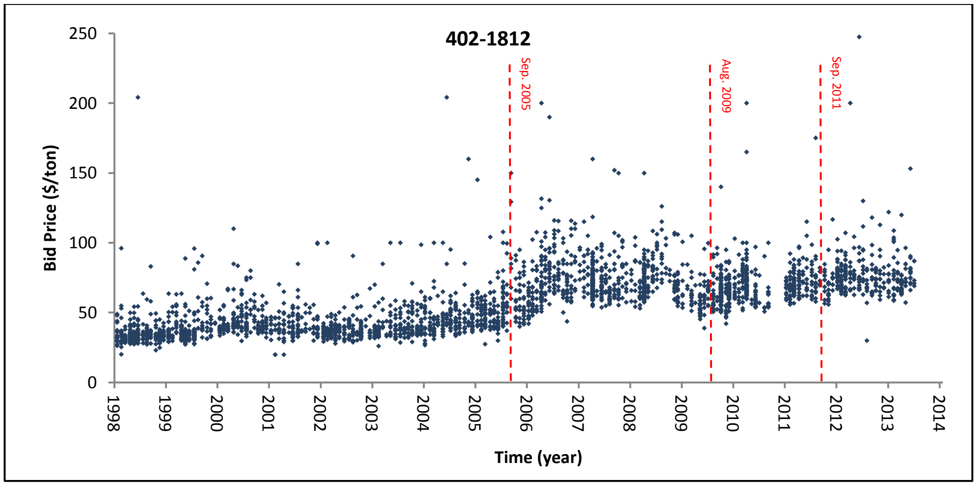

Figure 3-4: Bidding price fluctuations over time for the line item 402-1812

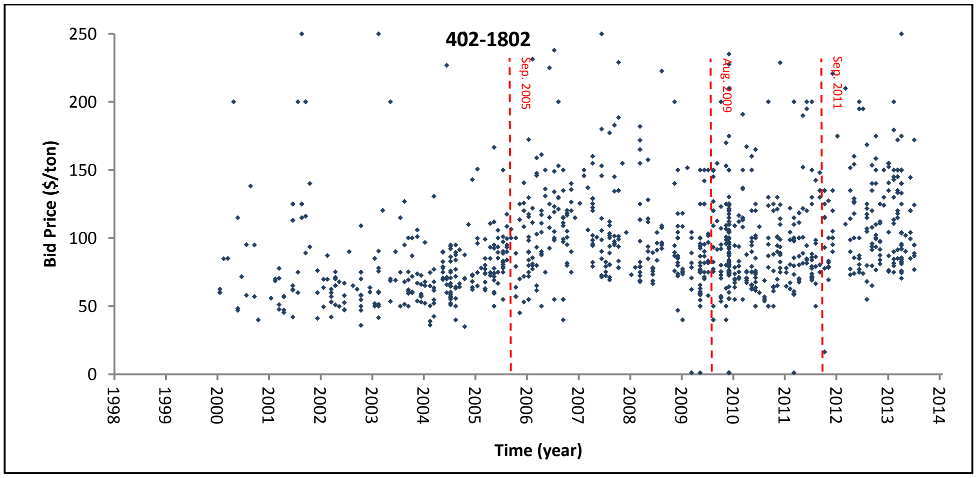

Figure 3-5: Bidding price fluctuations over time for the line item 402-1802

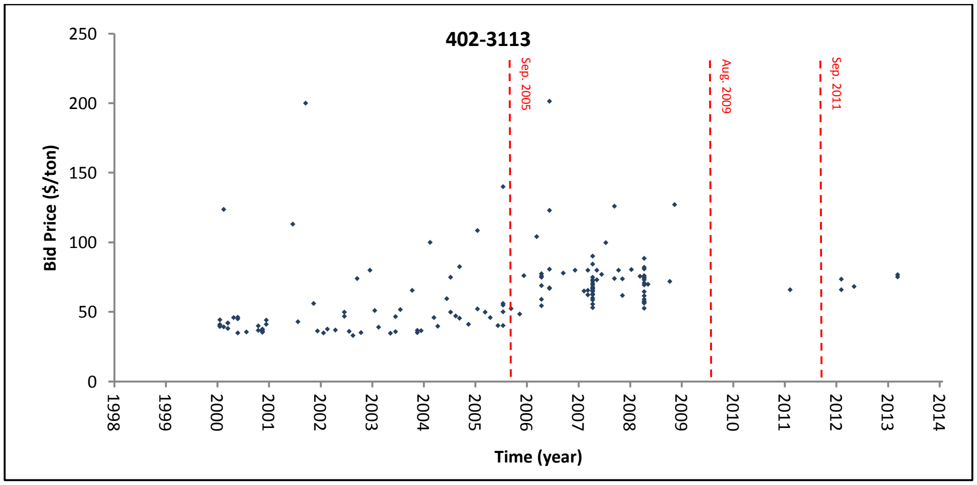

Figure 3-6: Bidding price fluctuations over time for the line item 402-3113

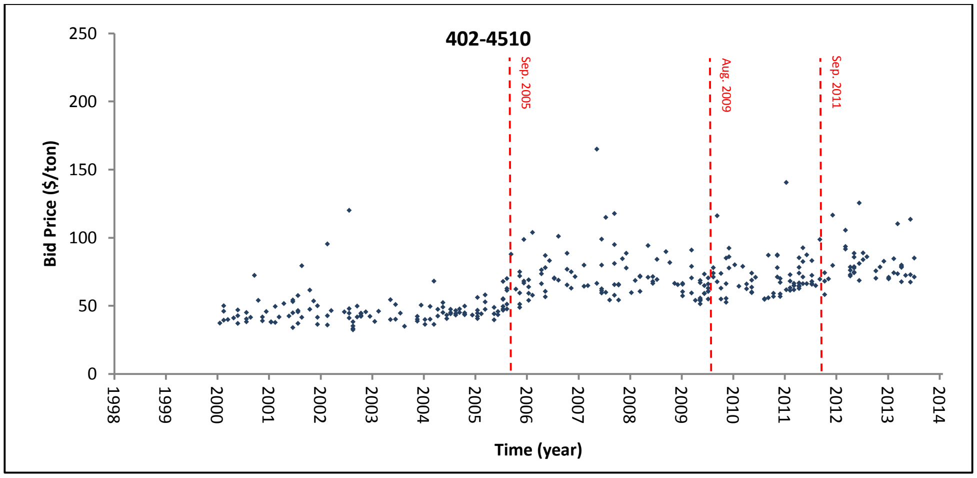

Figure 3-7: Bidding price fluctuations over time for the line item 402-4510

These seven main line items constitute the majority of asphalt work both in terms of monetary value and quantity. Figure 3-8 and Figure 3-9 show how the combined value and quantity of these seven line items have changed over time compared to the value and quantity of the entire asphalt line items, respectively.

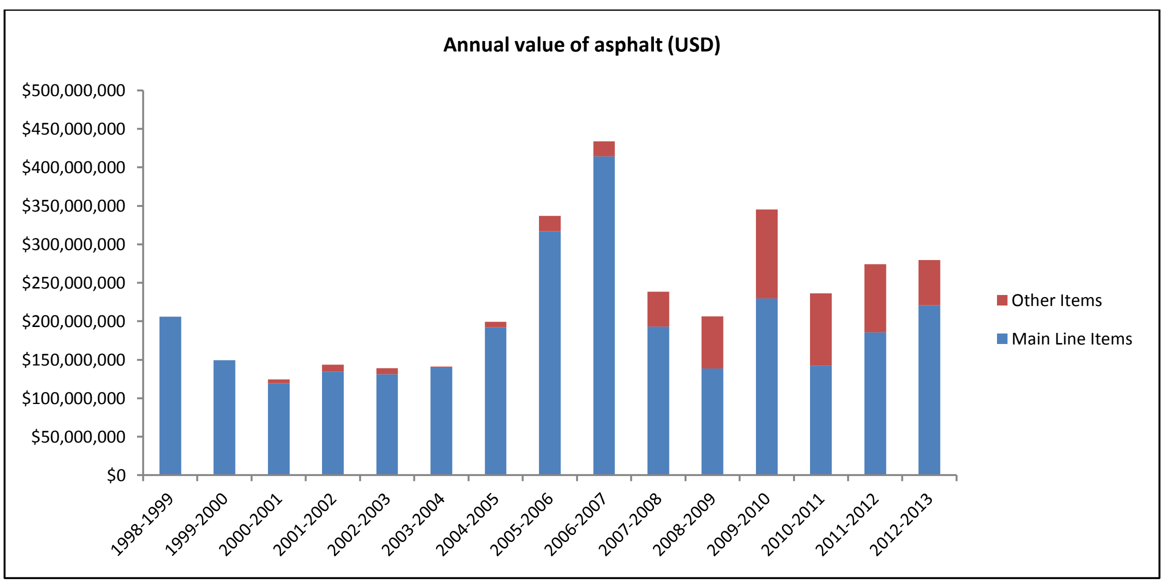

Figure 3-8: Annual value of asphalt based on the share of main line items

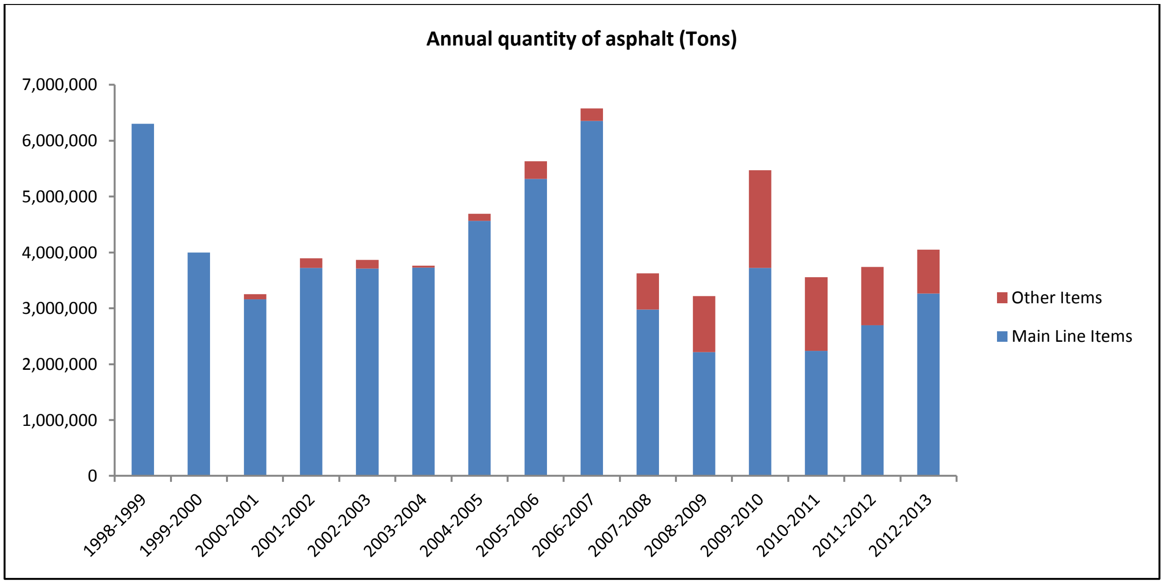

Figure 3-9: Annual quantity of asphalt based on the number of line items

Projects may vary in terms of the number of asphalt line items. Each project can have one to seven different line items depending on the complexity and specifications of the project. Each contractor submits a separate bid for each line item within a single project. Besides meeting other qualifications criteria, the winner of the bid is usually the contractor who submits the minimum bid for all line items within the project. Figure 3-10 shows the change in distribution of the awarded projects over time in terms of number of line items. As shown in this graph, the projects with one to four line items constitute the majority of the awarded projects over time. It is important to note that since the dataset for few line items is dated back to 1998, only projects with those line items were taken into account for early years. Although the number of the projects with more than four line items is small compared to the projects with few line items, the value of the projects with more than four line items comprises a considerable share in total value of awarded projects in each year (Figure 3-11).

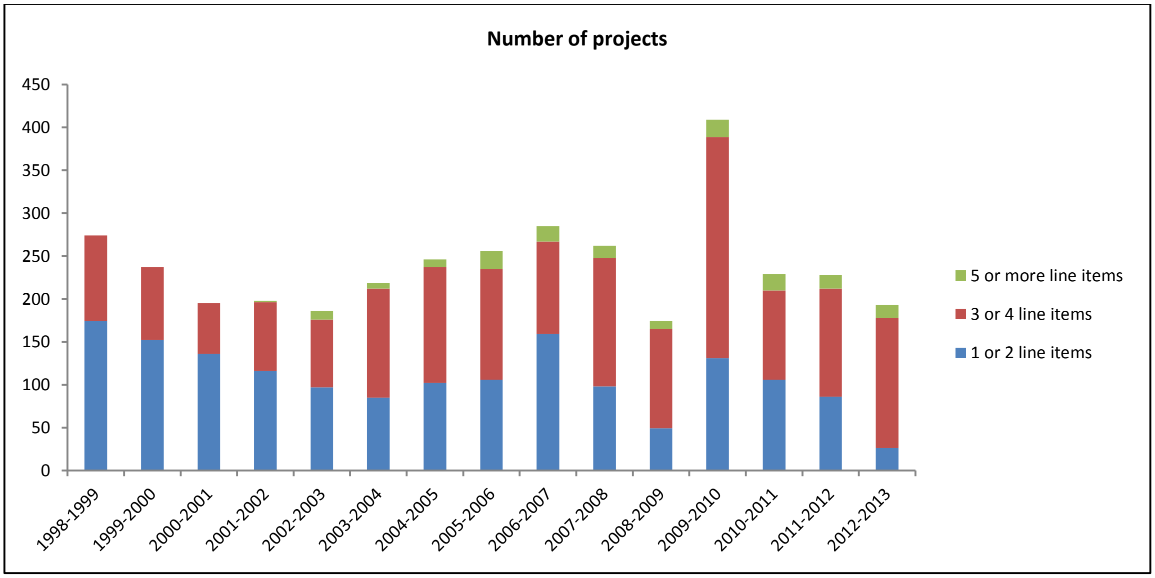

Figure 3-10: Annual number of awarded projects based on the number of line items

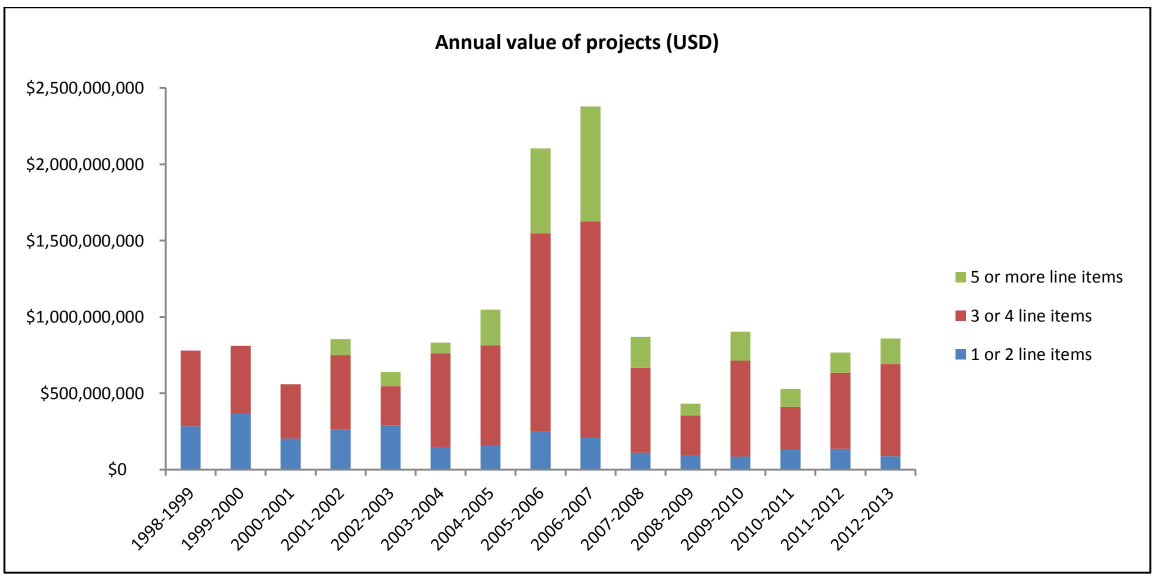

Figure 3-11: Annual value of awarded projects based on the number of line items

3.2.2. Location

The Georgia Department of Transportation has seven district offices throughout the state of Georgia. The map of these district offices is shown in Figure 3-12. The distribution of projects among these seven districts varies by time. Figure 3-13 shows how the number of awarded projects in each district has been changed over the past 15 years. Total annual values of awarded projects are shown in Figure 3-14. The share of the total annual values of the projects in the northern districts (districts one and six), the central districts (districts two and three), and the southern districts (districts four and five) are approximately equal to each other, i.e., 20-30% each year.

The share of the total annual values of the projects in the metro Atlanta district (i.e., district seven) is approximately 10-15% each year. Figure 3-15 depicts the distribution of the annual quantity of asphalt line items in these seven districts. District seven has the lowest share of asphalt quantity among all districts.

Figure 3-12: Seven districts of the Georgia Department of Transportation (GDOT)

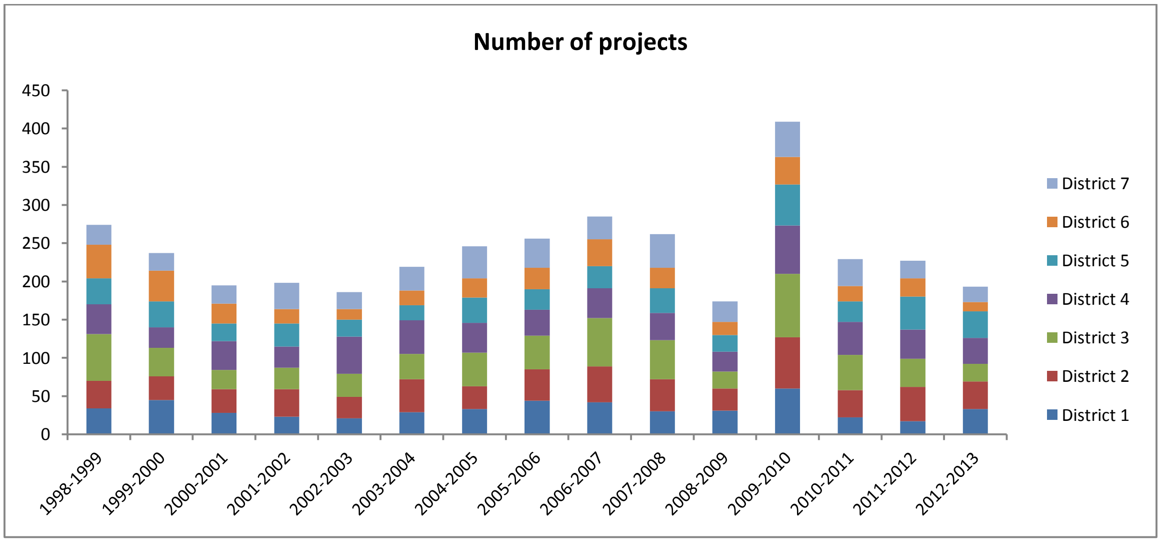

Figure 3-13: Annual number of awarded projects based on the location

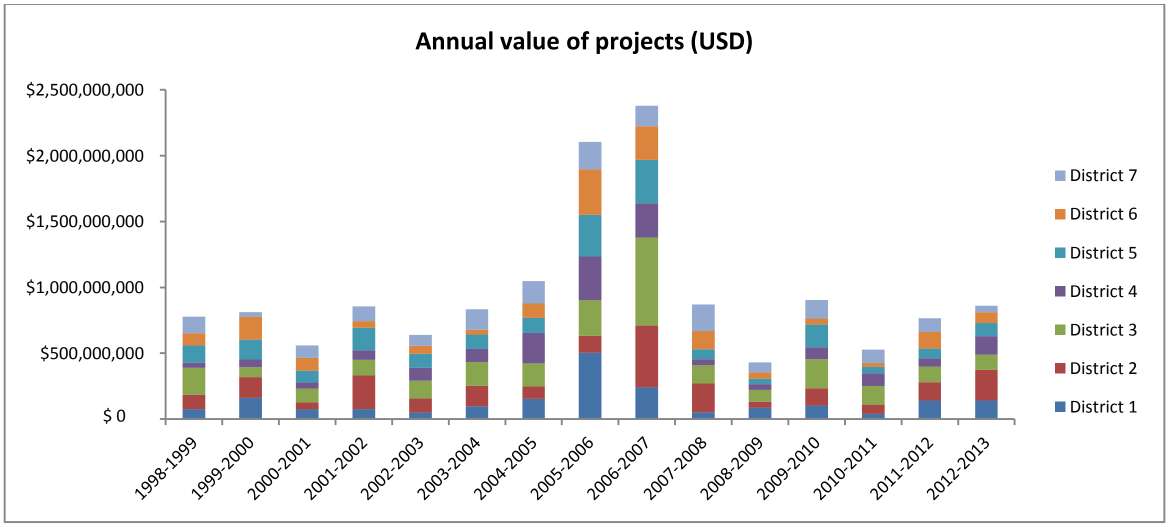

Figure 3-14: Annual value of awarded projects based on the location

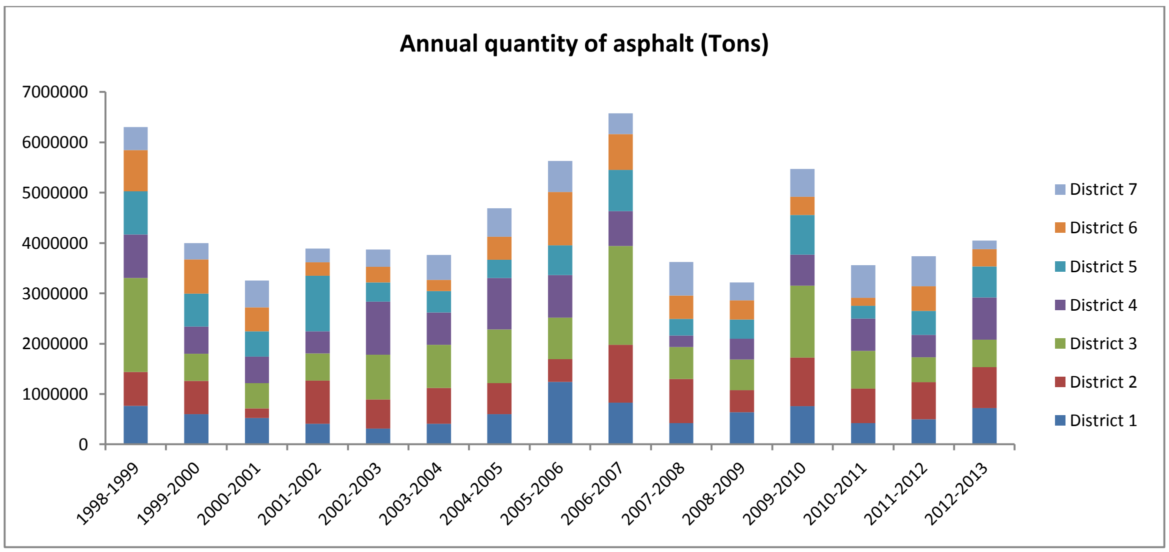

Figure 3-15: Annual asphalt quantity of awarded projects based on the location

3.2.3. Duration

Since the price adjustment clause (PAC) has targeted the projects with duration more than one year, the dataset can be divided between short (i.e., project duration less than one year) and long (i.e., project duration longer than one year) projects. As shown in Figure 3-16, the composition of the annual number of projects has shifted dramatically after 2008-09 with the share of short projects surging from only 13% in 2007-08 to approximately 70% in 2009-10. This trend, however, cannot be observed in the annual value of the projects. Although the share of short projects has increased dramatically since 2008-09, long projects, as shown in Figure 3-17, still dominate the market in terms of total value of the projects.

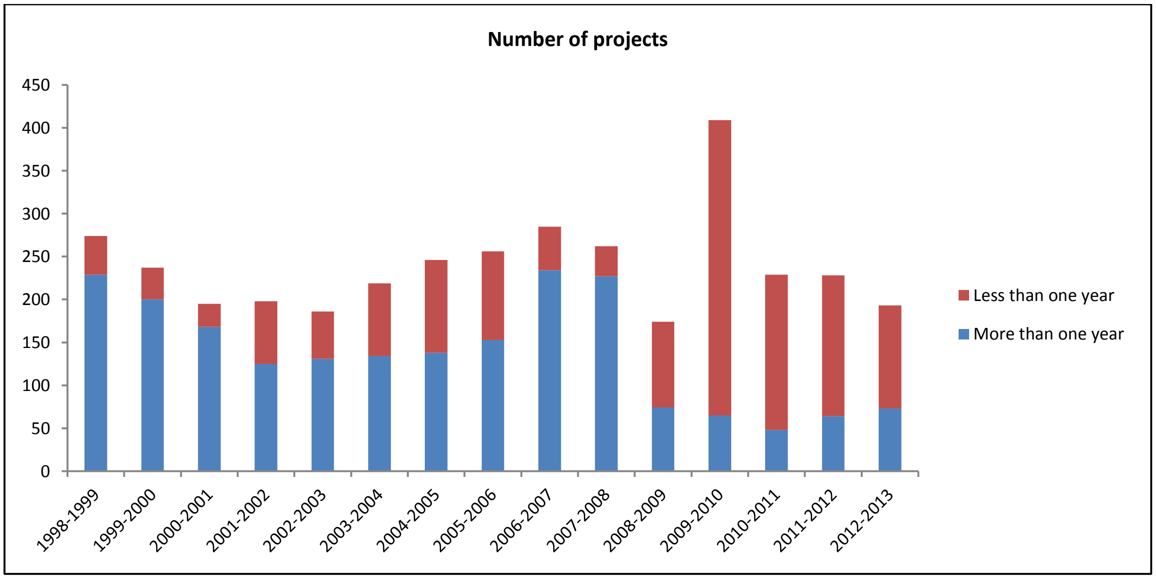

Figure 3-16: Annual number of awarded projects based on the duration of the projects

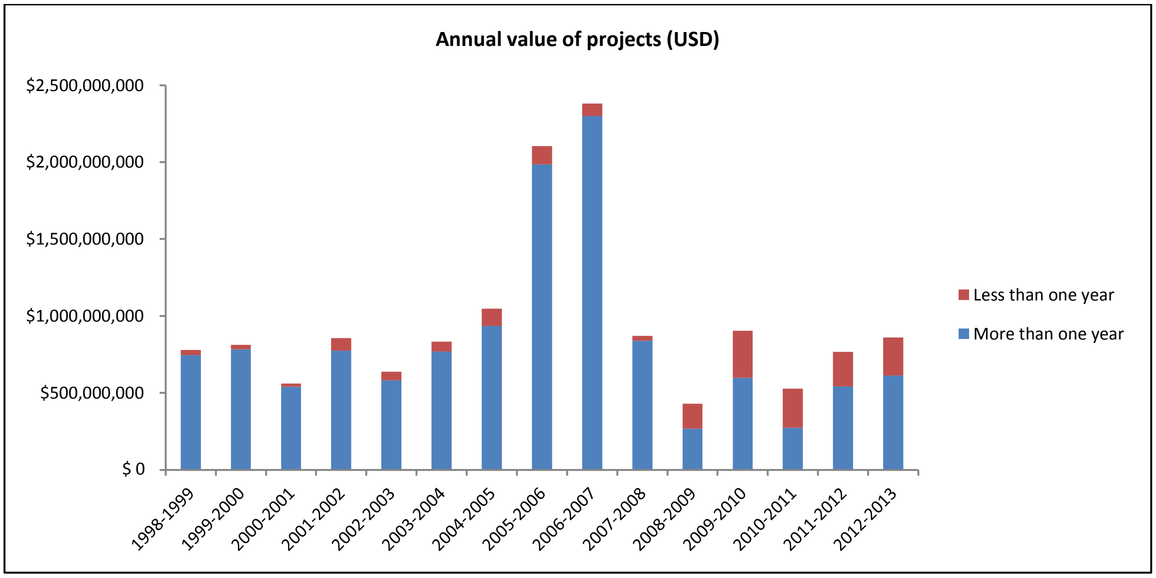

Figure 3-17: Annual value of awarded projects based on the duration of the projects

3.2.4. Size of the Project

Projects in the dataset vary greatly in size. While the projects worth more than $10 million historically comprise less than 10% of total number of projects (Figure 3-18), they account for more than a half of annual value of the projects (Figure 3-19). Although the annual number of projects with the value less than $1 million is between 20% and 50% of total number of awarded projects, their contribution to the annual value of the projects is less than 10% in most years.

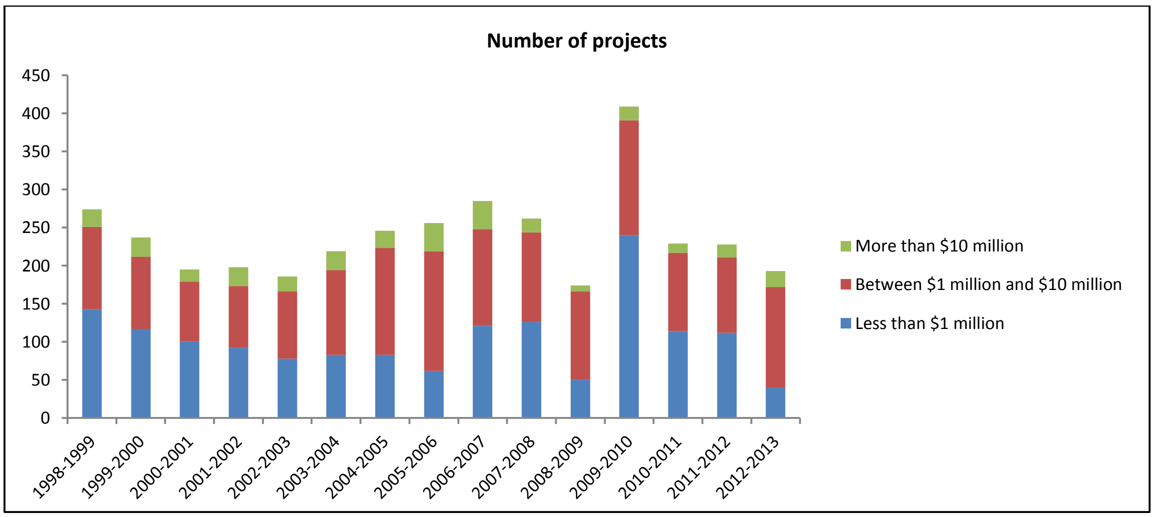

Figure 3-18: Annual number of awarded projects based on the size of the projects

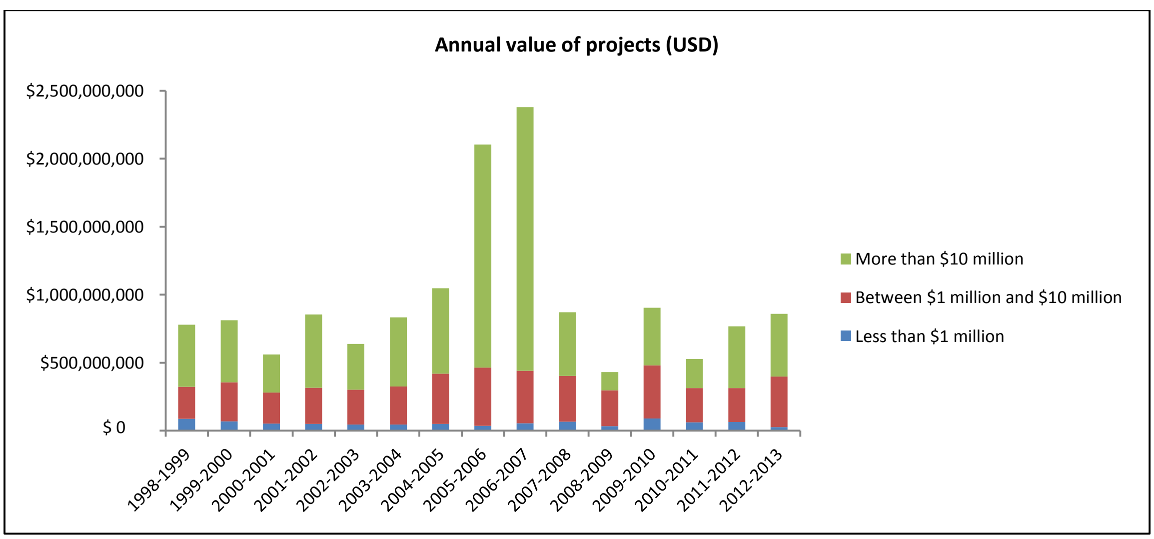

Figure 3-19: Annual value of awarded projects based on the size of the projects

3.2.4. Quantity of asphalt

Similar pattern can be recognized in the distribution of asphalt quantity in the projects. There are few projects with quantities of asphalt being more than one million tons (Figure 3-20) and yet, these projects constitute the majority of the annual project value (Figure 3-21). Projects with the medium quantity of asphalt line items between 500,000 and one million tons show a steady trend both in terms of the number of the awarded projects and the total value of the projects; there are approximately 100 projects in this range every year with the total value of about $500,000 per annum.

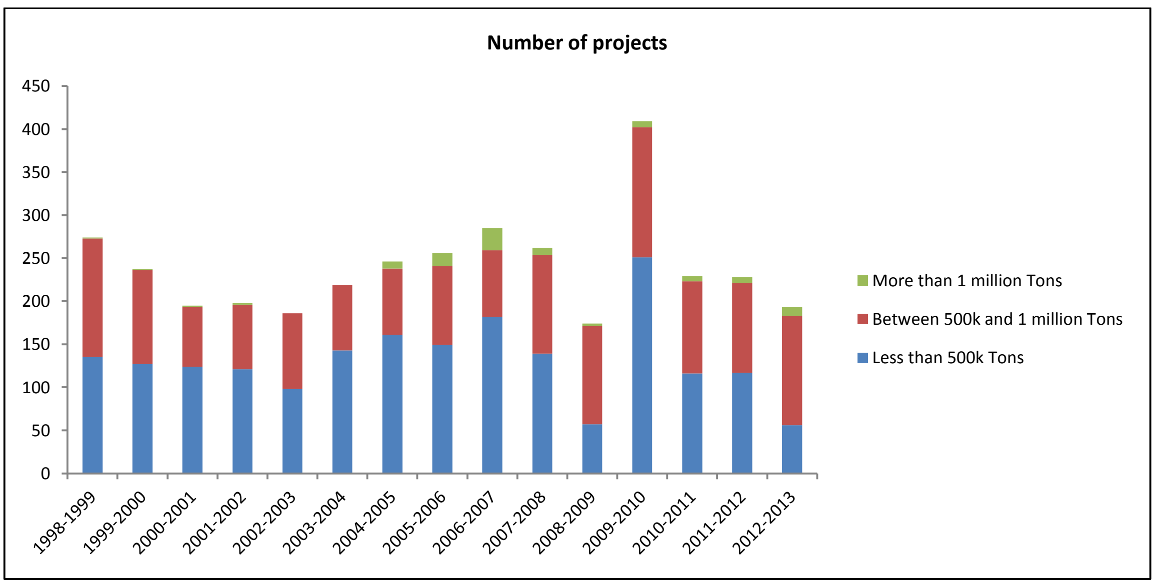

Figure 3-20: Annual number of awarded projects based on the quantity of asphalts in the projects

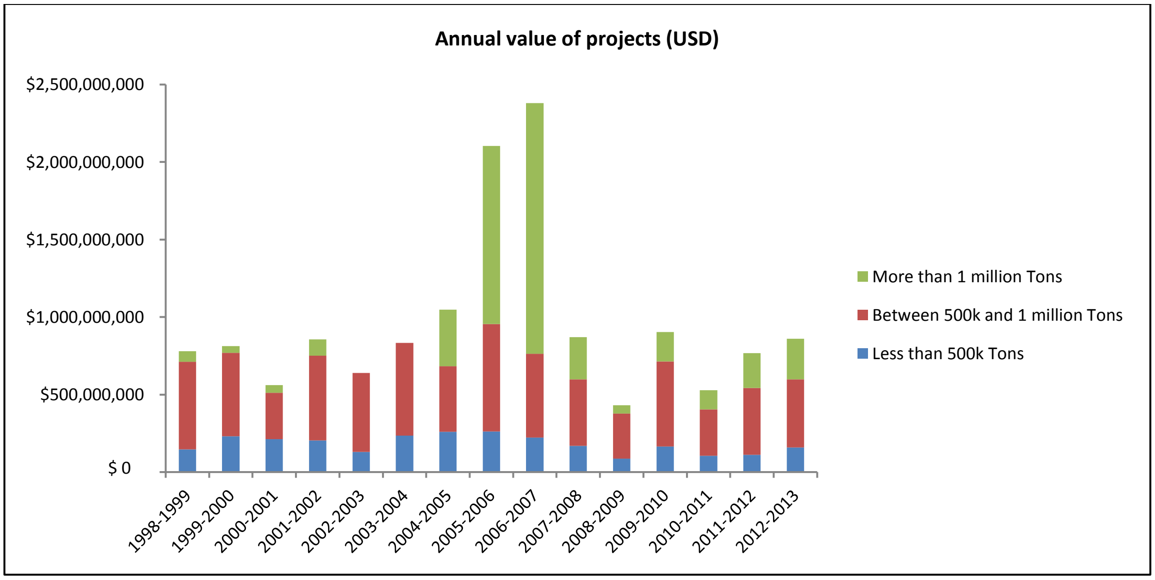

Figure 3-21: Annual value of awarded projects based on the quantity of asphalts in the projects

3.3. MARKET CHARACTERISTICS

Market characteristics are those variables that act exogenously outside the project's characteristics. These variables explain the environment that the project was bid out.

3.3.1. Total number of projects

The number of awarded projects each year is an indicator of the capacity of the market. As shown in Figure 3-22 on average, there are approximately 200 to 250 projects awarded each year in Georgia. Asphalt projects experienced a sharp drop in 2008-09 but recovered quickly in the following year. The number has been stabilized around 200 projects in the most recent few years.

3.3.2. Total value of the projects

Total value of the projects per year is another indicator for the size of the market. It shows the designated budget for the asphalt projects in that year. As shown in Figure 3-23, this number surged between 2005 and 2007 to reach its peak at approximately $2.5 billion and then, dropped to its lowest level in 2008-09.

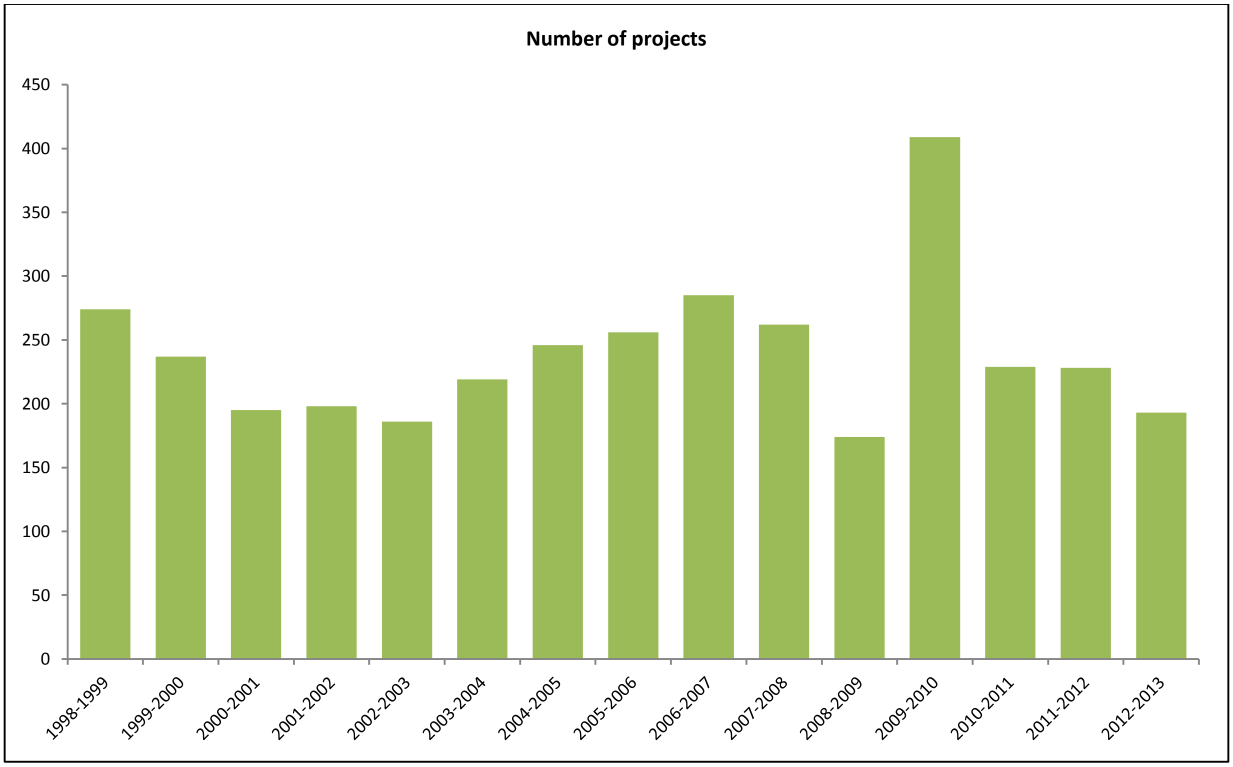

Figure 3-22: Annual number of awarded projects

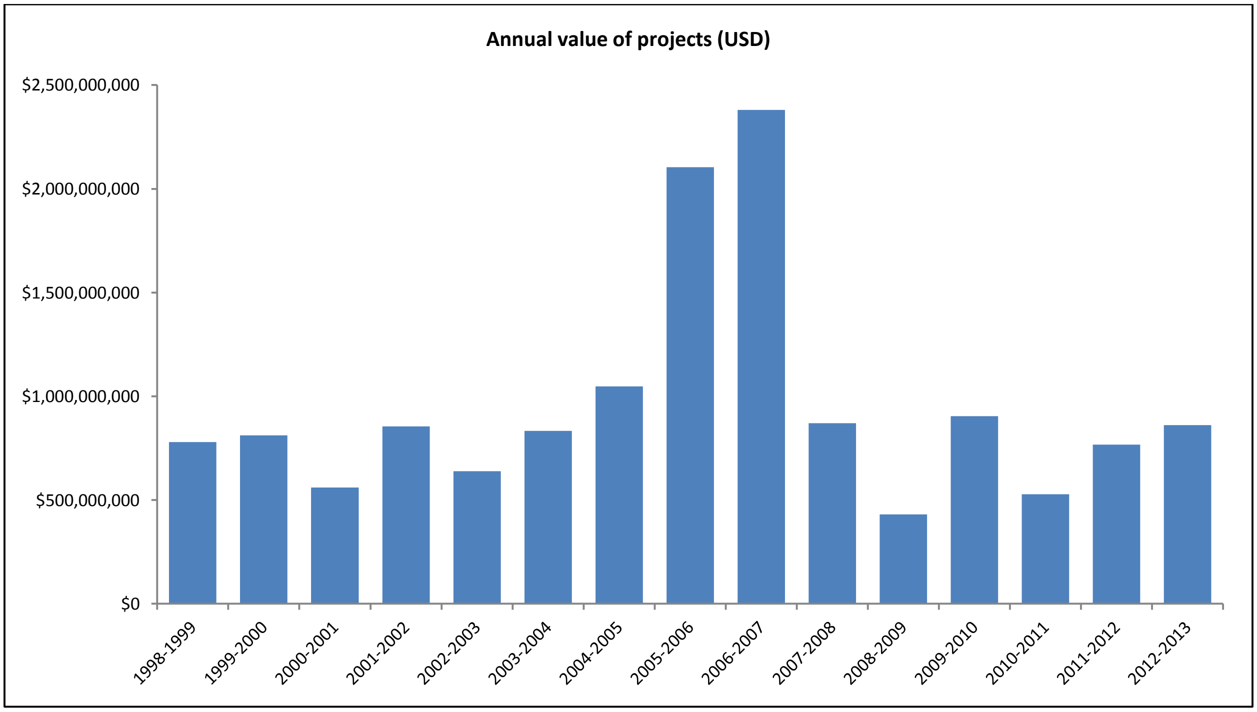

Figure 3-23: Annual value of awarded projects

3.3.3. Competition

The number of bidders for a project can be a good indicator of the competitiveness in the market for the project. As shown in Figure 3-24, the number of projects with 1 or 2 bidders has been gradually decreasing in recent years. Figure 3-25 shows an interesting observation about the surge in the total value of the projects in 2005-07. While the market was booming, the number of projects with 1 or 2 bidders was also on the rise. This trend has been reversed substantially since 2008 and the number of projects with 1 or 2 bidders dropped significantly.

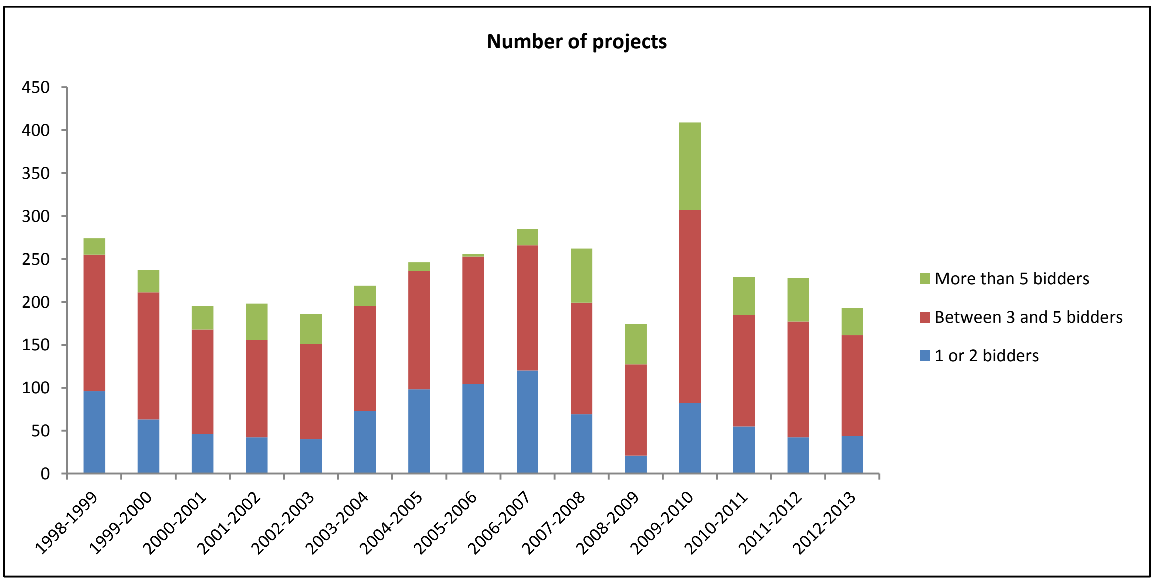

Figure 3-24: Annual number of awarded projects based on the number of bidders per project

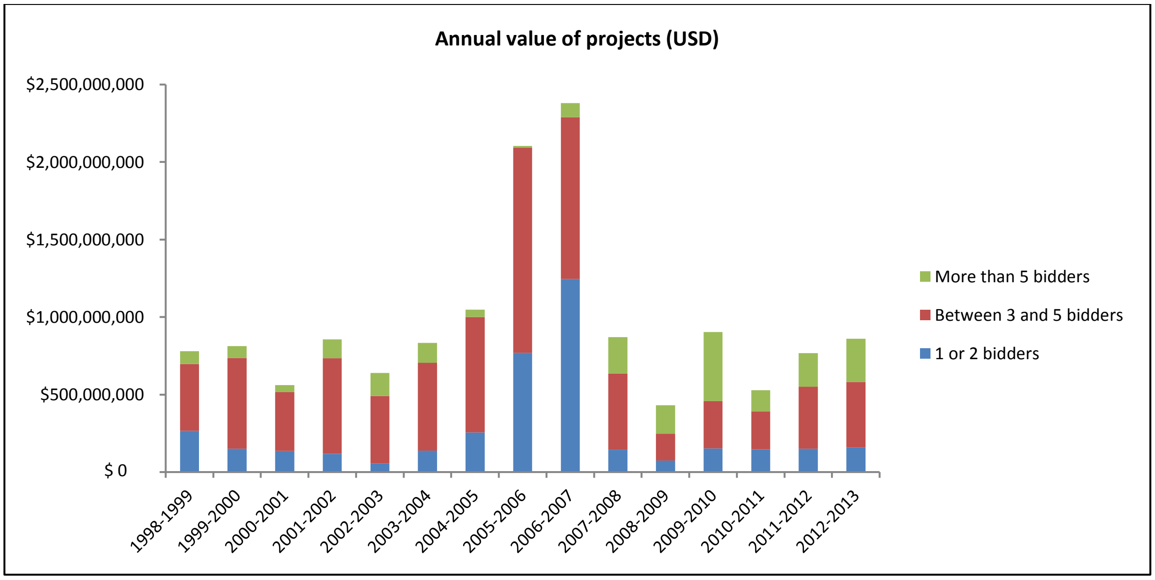

Figure 3-25: Annual value of awarded projects based on the number of bidders per project

3.3.4. Contractors-size

Besides the size of the market, the size of the contractors may also be a determining factor in shaping the competition in the market. While large contractors may be less vulnerable to external factors, such as abrupt changes in asphalt cement price, small contractors may be more exposed to the high price risk. Figures 3-26 and 3-27 show the annual number and annual value of awarded projects to large contractors, respectively, and compare them with those awarded to other contractors.

3.3.5. Contractors-Project size

Projects can be divided into three categories: small projects with the value less than $1 million, medium projects with the value between $1 and $10 million, and large projects with the value more than $10 million. Figures 3-28 and 3-29 show how small projects were awarded to the two groups of contractors (i.e., large contractors and others).

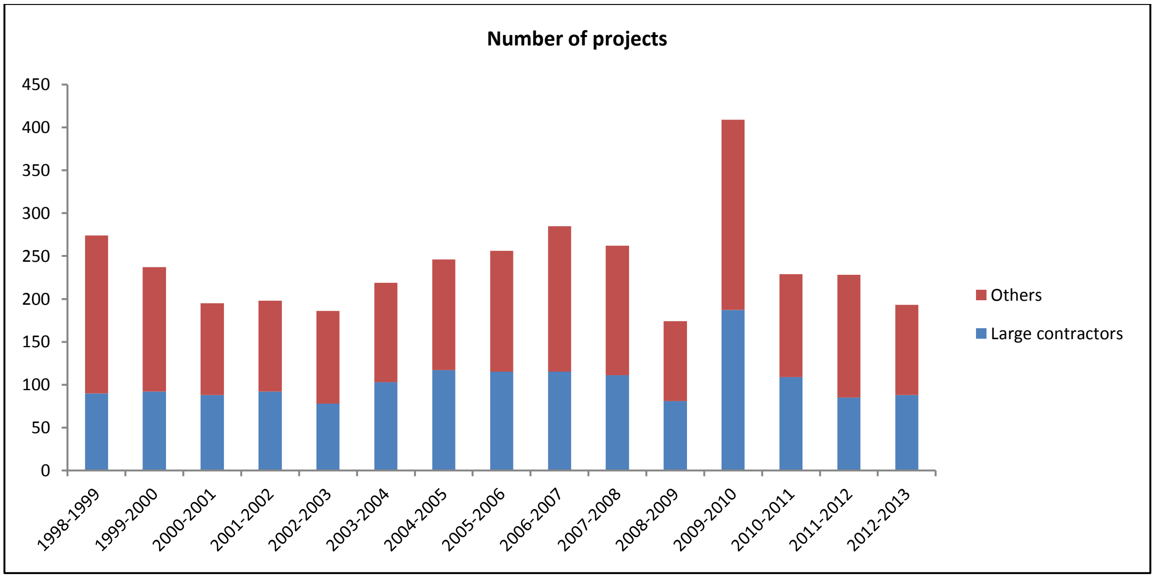

Figure 3-26: Annual number of awarded projects to large contractors and others

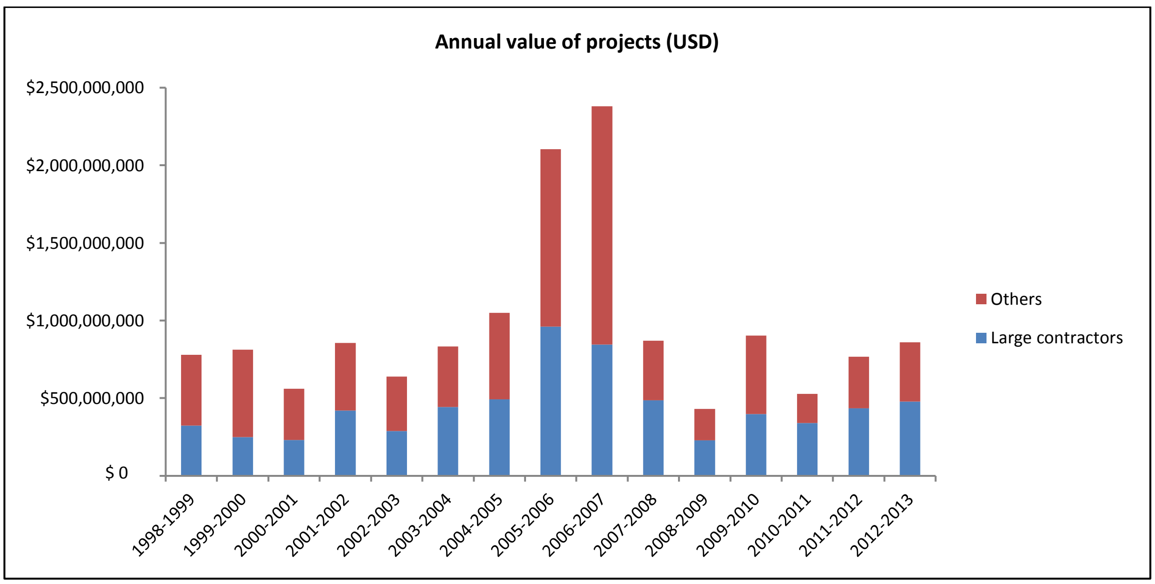

Figure 3-27: Annual value of awarded projects to large contractors and others

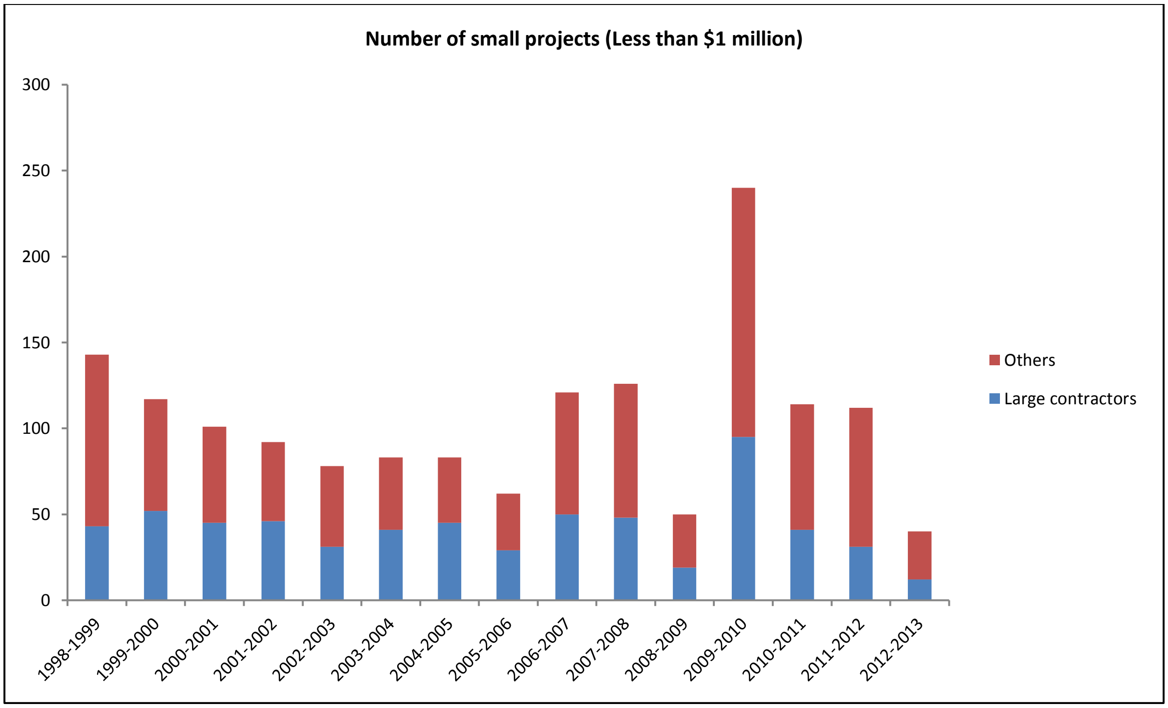

Figure 3-28: Annual number of Small projects awarded to large contractors and others

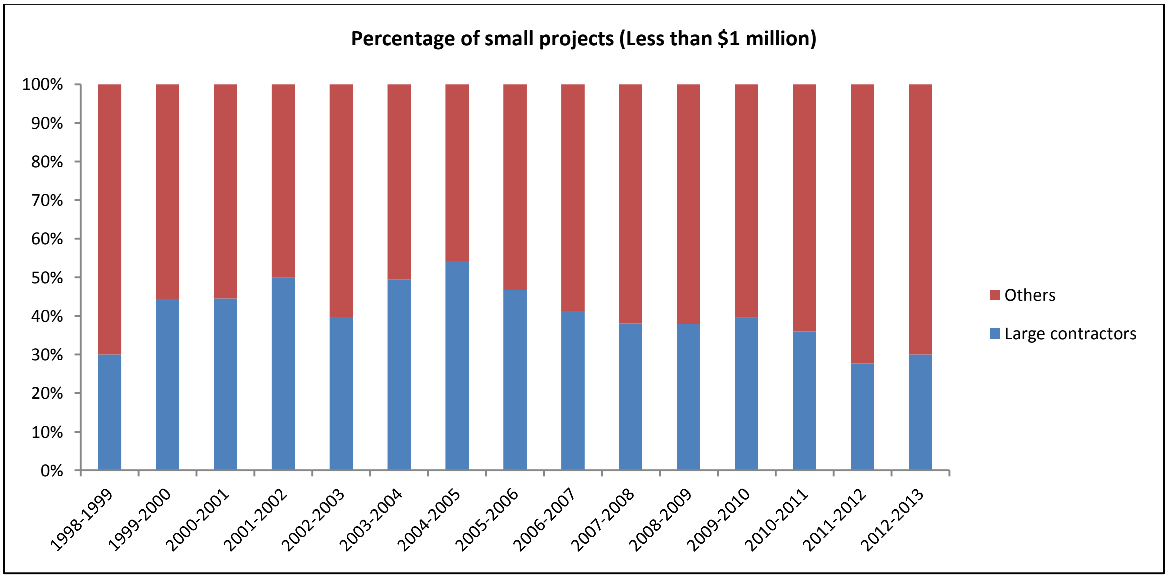

Figure 3-29: Percentage of small projects awarded to large contractors and others

Figures 3-30 and 3-31 show how medium projects were awarded to the two groups of contractors (i.e., large contractors and others).

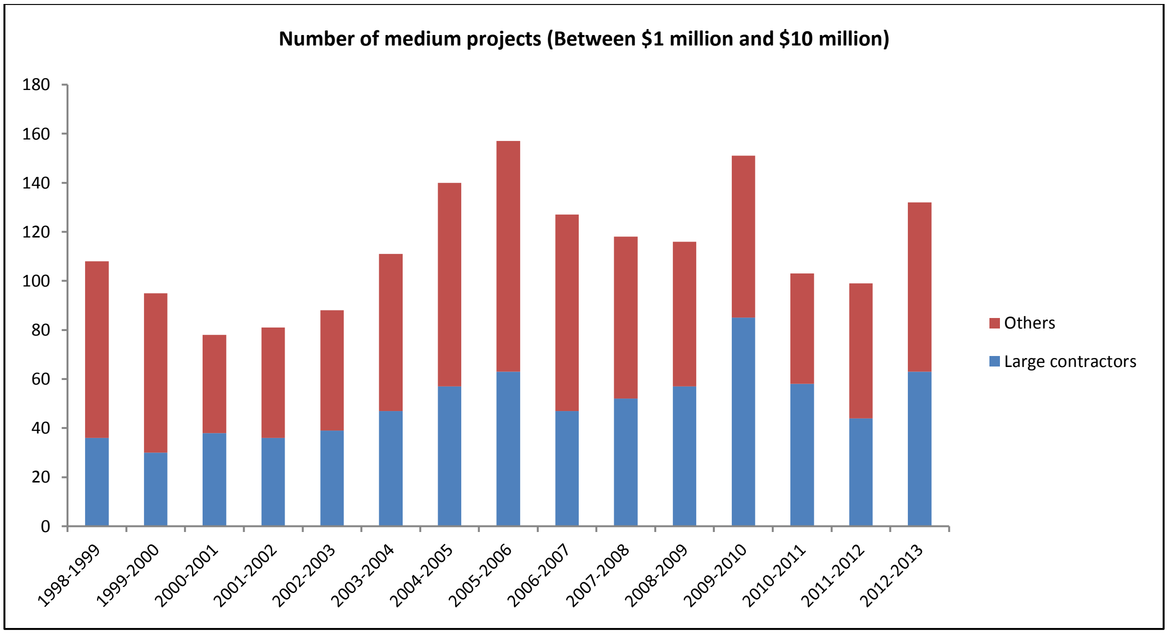

Figure 3-30: Annual number of medium projects awarded to large contractors and others

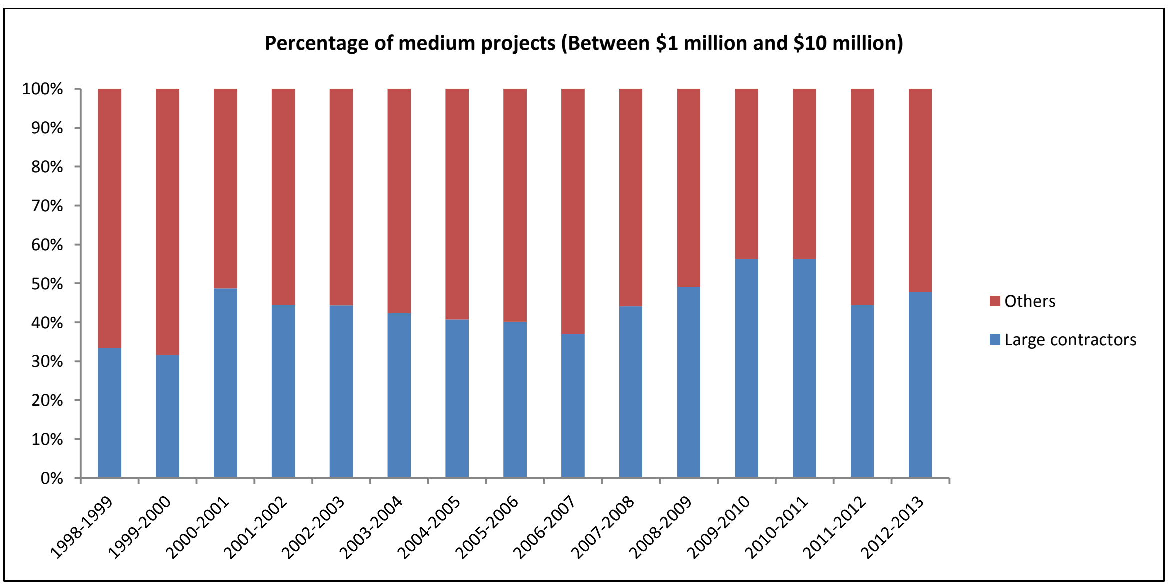

Figure 3-31: Percentage of medium projects awarded to large contractors and others

Figures 3-32 and 3-33 show how large projects were awarded to the two groups of contractors (i.e., large contractors and others).

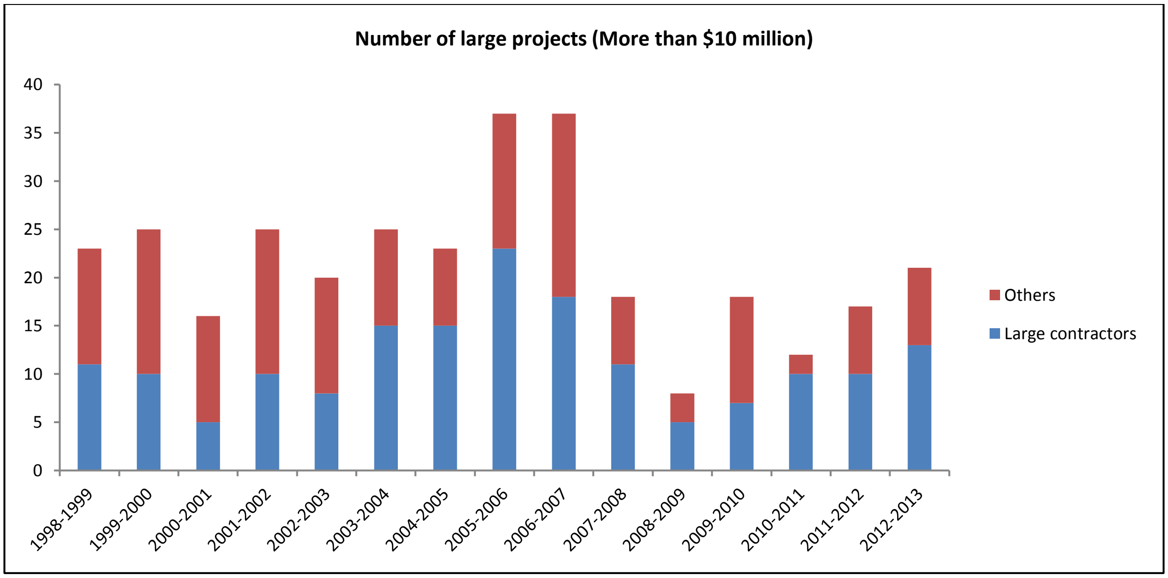

Figure 3-32: Annual number of large projects awarded to large contractors and others

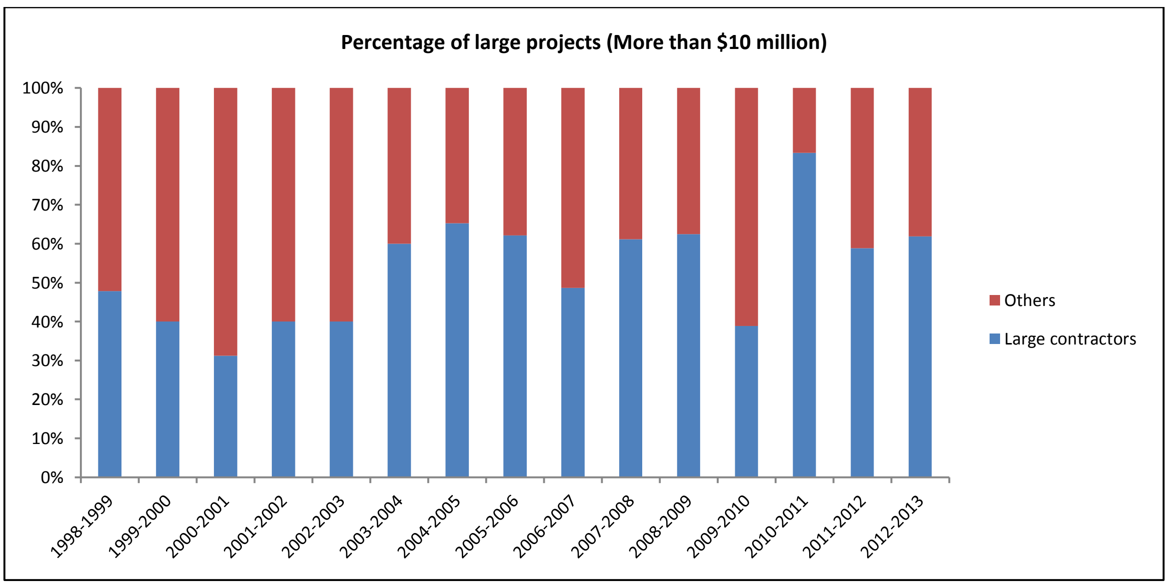

Figure 3-33: Percentage of large projects to large contractors and others

CHAPTER 4
MODELING THE VARIATIONS OF BID PRICES

4.1. INTRODUCTION

In this chapter, multivariate regression analysis is used to identify significant explanatory variables that can explain variations in contractors' submitted bids for major asphalt line items. First, analyses were conducted using the entire dataset from 1998 to 2013. Then, since the contractor size and their abilities to handle the price volatility might be important, the analyses were repeated separately within three groups of contractors in the dataset: big, medium, and small contractors. Finally, since the criteria to determine the eligible projects for PAC program were changed significantly in August 2009, the analyses were repeated using only the dataset after August 2009 to study the effects of offering PAC on the submitted bid prices.

Several steps were followed to create multivariate regression analysis models:

1- Conduct literature review and interview transportation cost professionals to identify a potential list of explanatory variables for modeling the variations of contractors' submitted bids (e.g., project duration, number of bidders, quantity of asphalt line items, average price of asphalt cement, and availability of price adjustment clauses in the contract).
2- Develop a dataset of actual contractors' submitted bid prices for major asphalt line items in highway projects and gather information about the potential explanatory variables for these projects.
3- Identify unusual observations (i.e., outliers) in the dataset using a statistical test based on standardized residuals and remove (or refine) theses data points from the dataset.

4- Develop scatter plots among the contractors' submitted bids and potential explanatory variables and conduct the Pearson correlation test to determine whether any nonlinear relationships (e.g., quadratic, cubic, logarithm, exponential, or power) exist between the submitted bid prices and any of the potential explanatory variables and if needed, apply respective variable transformation.
5- Apply backward elimination algorithm to create the best subset multivariate regression model using information from potential explanatory variables to describe variations of the contractors' submitted bids.
6- Evaluate the explanatory power of the multivariate regression models using the Analysis of Variance (ANOVA) test.
7- Diagnose multicollinearity in the developed multivariate regression model using the Variance Inflation Factor (VIF) test to examine whether the model is reliable and the results are not misleading.
8- Analyze the residuals of the multivariate regression model to examine the appropriateness of the modeling assumptions.
9- Interpret the multivariate regression models and analyze the results.

4.2. DEFINING THE VARIABLES

An extensive literature review and interviews with transportation cost professionals were conducted to identify a potential list of explanatory variables for modeling the variations of contractors' submitted bid prices. Twenty four variables were identified as potential explanatory variables as follows.

1- ***Duration of the project:*** Duration of a project may be an important effective factor to determine the bid price. Sonmez (2008), Lowe et al. (2006), and Trost (2003) considered duration of the project to model the costs of construction projects. The unit of the duration in this research is days.
2- ***Quantity of the line item:*** Quantity of the line item may be an important factor to determine its price. Carr (1989) noted that the cost of an activity can be a variable based on the quantity of the activity.
3- ***Total bid price:*** Total proposal bid price or contract value shows the size of the project. Ahmad and Minkarah (1998) revealed that bidding decisions are affected by different criteria including the project size.
4- ***Relative value of the line item:*** This variable shows the relative dollar value of the line item compared to the total bid price of the project by calculating the ratio of the total price of the item over the total bid price. This variable is an indicator of the relative importance of the line item compared to the other line items in the project. Our interviews of the transportation cost professionals indicated the importance of this factor in explaining the variations of the submitted bids.
5- ***Number of the bidders:*** Number of bidders is an indicator of competition in the market. Carr (2005) presented a quantitative analysis of the impacts of competition on project bid

prices and concluded that as the level of competition in the market decreases, the project bid prices increase.

Asphalt cement is one of the most important input commodities in transportation projects. Liu (2012) statistically showed that there is a direct relationship between asphalt cement price and submitted bid prices of the asphalt mixtures. The following two explanatory variables are used to investigate the relationship between the price of asphalt cement and submitted bid prices of the seven major asphalt line items.

6- ***Asphalt cement price index at the bid date:*** GDOT determines the asphalt cement price index based on the arithmetic average of asphalt cement from the department's monthly survey with approved asphalt cement suppliers. The maximum and minimum prices are excluded from the calculation of the index.

7- ***Rate of change of the asphalt cement price index:*** Rate of change of asphalt cement price index shows the expected trend for future prices that may impact contractors' submitted bid prices for asphalt line items. This variable is determined for each month based on the slope of the trend line fitted to the last three monthly price indices.

Seven binary variables also were considered to capture the effects of location of the projects.

8 - 14- ***Location of the projects:*** Considering the availability of resources, distance to the asphalt plants, and weather conditions, location of a project may affect the bid price. Ahmad and Minkarah (1988) conducted a comprehensive questionnaire survey among 400 general contractors. The results indicated that the location of the project is one of the criteria that can affect the bid/no-bid decisions and bid prices. GDOT has divided the state to seven different districts. In this research, for each district, a binary variable has been defined. Value 1 for the district binary variable indicates that the project is located in the district.

15- ***Eligibility of the projects for PAC:*** This is a binary variable that indicates whether a project is eligible for PAC or not. GDOT has been offering PAC for asphalt cement since September 2005. The criteria for eligibility of the projects have been changed several times since 2005. This variable considers a project eligible for PAC if the project was eligible based on the valid provision on its bid date.

Three other binary variables were also considered to capture the effects of changes in the specific provisions of the PAC in the state of Georgia over time.

16- ***Letting from September 2005 to August 2009 (Period 09/05 to 08/09):*** This variable is one for all projects with let dates between September 2005 and August 2009 and is zero, otherwise.

17- ***Letting from September 2009 to August 2011 (Period 09/09 to 08/11):*** This variable is one for all projects with letting date between September 2009 and August 2011 and is zero, otherwise.

18- ***Letting after August 2011 (Period after 09/11):*** This variable is one for all projects with letting date after August 2011 and is zero, otherwise.

Information about available projects in the market might affect the contractors' bidding behavior. Akintoye (2000) identified market conditions as one of the main factors influencing bid prices. GDOT announces its upcoming new projects each fiscal year (from July 1 to June 30) in advance. Thus, the number of the future available projects, the dollar values of these projects, and the total quantity of asphalt projects might affect contractors' decisions to whether it bids on a specific project and how much it bids for asphalt line items. The following six variables were used to take into account the information about current and upcoming asphalt projects in the project's district and the other Georgia districts.

19- ***Annual Number of Projects in the District:*** This variable is the total number of current and upcoming projects in the project's district in the fiscal year that the project was let.

20- ***Annual Value of the Projects in the District:*** This variable is the total annual dollar value of all current and upcoming projects in the project's district in the fiscal year that the project was let.

21- ***Annual Quantity of Asphalt Mixtures in the District:*** This variable is the total quantity of current and upcoming asphalt mixtures in the project's district in the fiscal year that the project was let.

22- ***Annual Number of Projects in Other Districts:*** This variable is the total number of current and upcoming projects in the other districts in the fiscal year that the project was let.

23- ***Annual Value of the Projects in Other Districts:*** This variable is the total annual dollar value of all current and upcoming projects in the other districts in the fiscal year that the project was let.

24- ***Annual Quantity of Asphalt Mixture in Other Districts:*** This variable is the total quantity of current and upcoming asphalt mixtures in the other districts in the fiscal year that the project was let.

4.3. MODELING THE VARIATIONS OF THE SUBMITTED BID PRICES

In this section, the regression models for each line item are created using the set of identified potential explanatory variables. At first step, unusual observations are detected and removed from the dataset to develop more accurate regression models. Significant explanatory variables and best subsets for each line item are determined using backward and forward procedures. Then, model evaluation, multicollinearity diagnosis, and residuals analysis are conducted to check the reliability of the models.

4.3.1. Detecting Unusual Observations

Outliers should be identified and removed from the dataset since the unusual observations are distant from other observations and therefore, make the results of regression analysis unreliable. A statistical test based on standardized residuals and leverage values (Neter et al. 1996) was used to detect unusual observations and remove them from the dataset. In general, a data point can be considered unusual if the absolute value of the standardized residual is greater than 2 or if the leverage value is more than 3 times the number of model coefficients divided by the number of observations. Table 4-1 shows the number of removed unusual observations from the dataset for each asphalt line item. It can be seen that just a small fraction of the data points were identified as outliers for these asphalt line items. Most unusual observations were from projects with very small quantity of asphalt mixtures. The remaining data points were large enough to conduct meaningful statistical analysis.

Table 4-1: Number of unusual observations for each major asphalt line item

Line Item	Description	Number of Observations	Number of Unusual Observations	Percentage of Removed data
402-3190	Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL	1432	88	6.14%
402-3130	Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL	1177	73	6.20%
402-3121	Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL	1178	47	3.99%
402-1812	Recycled Asphaltic Concrete Leveling, BM&HL	3023	105	3.47%
402-1802	Recycled Asphaltic Concrete Patching, BM&HL	1007	44	4.37%
402-3113	Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL	132	15	11.36%
402-4510	Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL	328	17	5.18%

4.3.2. Developing Scatter Plots and Variable Transformation

Scatter plots among the identified potential explanatory variables and contractors' submitted bid prices were developed to determine whether any nonlinear relationships (e.g., quadratic, cubic, logarithm, exponential, or power) exist between the submitted bid prices and any of the potential explanatory variables. The results indicated that using natural logarithm of quantity and contract value, instead of these variables in their original forms, lead to more appropriate model. Furthermore, Pearson correlation coefficients between submitted bid prices and the potential explanatory variables were calculated. Pearson correlation is a measure of the linear dependency between two variables giving a value between +1 and -1, where +1 is total positive correlation, 0 shows no correlation, and -1 indicates total negative correlation. Pearson correlation is calculated as:

$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \sigma_Y}$$

where, cov is the covariance, σ_X and σ_Y are the standard deviation of X and Y, respectively.

The results of Pearson correlation calculation indicated that natural logarithm of quantity and contract values have higher correlations with the submitted bid prices than the correlations of not transformed quantity and contract values with the submitted bid prices, respectively.

4.3.3. Finding the Best Subset

A best subset regression model was created to explain the variations of submitted bid prices for each main asphalt line item using the information available in the potential explanatory variables. A backward elimination algorithm (Webster 2013) was applied to determine the best combination (i.e., subset) of potential explanatory variables that can best model the variations of submitted bid prices for the asphalt line item. Tables 4-3, 4-5, 4-7, 4-9, 4-11, 4-12, 4-15, and 4-17 show the coefficients of the best subset regression models created for explaining the variations of the submitted bid prices of the seven asphalt line items. All specified coefficients are significant at 5% level of significance and hence, respective variables (with non-zero coefficients) contribute to explaining the variations of submitted bids for asphalt line items.

4.3.4. Evaluating the Models

Multivariate regression models should be evaluated by Analysis of Variance (ANOVA) test (Webster 2013). ANOVA tests were conducted to examine the significance of the developed regression models for the seven asphalt line items. The results of the ANOVA test show whether the linear relationship between the response and selected explanatory variables is statistically significant or not.

4.3.5. Diagnosing Multicollinearity

If two or more explanatory variables in a multivariate regression model are highly correlated, the results might be misleading. Variance Inflation Factor (VIF) was used to diagnose any multicollinearity issues in the developed models. In general, a VIF of 10 or larger indicates a problem based on multicollinearity (Webster 2013).

4.3.6. Analyzing the Residuals

In this research, the residual analysis is conducted using Q-Q plots, histograms of frequency of the residuals, and scatter plots of the residuals against fitted values and observations orders. A Q-Q plot is a plot of the quintiles of the observed and normal distributions against each other. If the Q-Q plot of the residuals against normal distribution is a straight line, the residuals follow a normal distribution. In addition to Q-Q plots, histogram of the frequency of the residuals can be helpful to check the normality of the residuals visually. Furthermore, data are considered independent if no specific pattern or trend is observed in the scatter plots of residuals against fitted values and observation orders.

4.4. Results of the Regression Models Using the Entire Dataset

As noted earlier, the first step regression models for each major asphaltic line item were created. The entire dataset consists of the information of all transportation projects in Georgia from January 1998 to July 2013.

4.4.1. Results for item 402-3190: Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL

The backward procedure was conducted for the line item 402-3190. Table 4-3 shows the results of the regression analysis. Considerably large adjusted R-squared indicates that most of the observations are fitted to the regression line. Column two shows the coefficients of the explanatory variables in the linear regression model. A positive coefficient shows a direct relationship between the response and explanatory variable indicating that the expected bid price increases as the value of the explanatory variable increases. On the contrary, a negative coefficient shows an inverse relationship indicating that the bid price is expected to decrease as the value of the explanatory variable increases. The fourth column shows the t-statistics for each explanatory variable. Higher absolute value of the t-statistic indicates higher explanatory power of the variable to model the variations of the response variable. In Table 4-3, the statistically significant explanatory variables are ranked based on the absolute values of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, let date between September 2005 and August 2009, asphalt cement price index in the bid date, and relative value of the line item.

The results specify that the coefficient of the explanatory variable, quantity, is negative. Thus, the expected value of submitted bid price decreases as the quantity of this item increases. Similarly, the expected value of the bid price decreases as the number of bidders variable increases. On the contrary, some other explanatory variables, such as total bid price, asphalt cement price index, and relative value of the line item have positive coefficients indicating that the expected value of the bid price increases as the value of each of these variables increases. Coefficients of the three binary variables for project let dates are positive. Therefore, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period 09/05-08/09 has the highest explanatory power among these three binary variables.

Eligibility for the PAC is not a statistically significant factor to explain the variations of the bid prices at 5% significance level. However, it should be noted that this variable was eliminated in the last iteration of the backward procedure for having the p-value of 0.069 and a negative coefficient. Thus, if a higher significance level (e.g. 10%) was selected, this variable would be significant too.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, multicollinearity does not undermine the validity of the regression model for this line item. The results of ANOVA tests (Table 4-2) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression models. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-2: Results of the ANOVA test for item 402-3190

Source	DF	SS	MS	F	P
Regression	14	384366	27455	545.75	0.000
Residual Error	1410	70932	50		
Total	1424	455298			

Figure 4-1 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and no considerable pattern or trend is observed in the scatter plots of residuals against fitted values and observation orders.

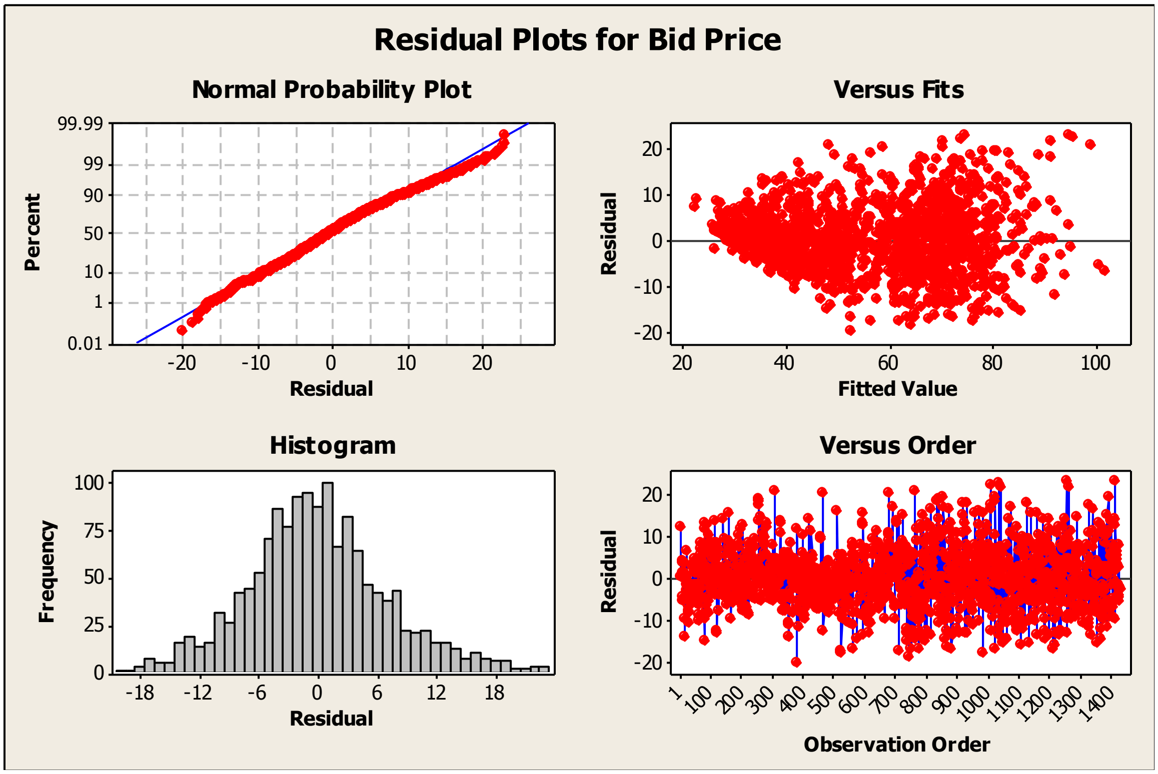

Figure 4-1: Residual plots for item 402-3190

Table 4-3: Results of regression analysis for item 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	11.943	3.61	0.000	
1	Natural Logarithm of Quantity of the Item	-7.294	-30.94	0.000	4.167
2	Natural Logarithm of Total Bid Price of the Project	5.263	18.17	0.000	3.964
3	Bid Date: Between Sept 05 and Aug 09	14.432	17.96	0.000	3.561
4	AC Index at the Bid Date	0.053	17.37	0.000	6.703
5	Relative value of the Line Item	24.446	10.57	0.000	2.335
6	Annual Value of Projects in Other Districts	10^{-8}	8.06	0.000	3.744
7	Location of the Project: District 5	4.560	7.43	0.000	1.15
8	Bid Date: Between Aug 09 and Aug 11	7.619	6.25	0.000	3.563
9	Number of Bidders	-0.587	-5.88	0.000	1.382
10	Bid Date: After Aug 11	6.155	4.54	0.000	5.627
11	Annual Quantity of Asphalt Mixture in other Districts	-1.5×10^{-6}	-4.43	0.000	3.004
12	Location of the Project: District 3	-1.808	-3.33	0.001	1.345
13	Annual Number of Projects in the District	0.062	3.08	0.002	1.577
14	Location of the Project: District 4	1.576	2.67	0.008	1.329
-	Duration of the project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in Other Districts	-	-	-	-
S	**7.09272**				
R-Sq	**84.4%**				
R-Sq (adj)	**84.3%**				

4.4.2. Results for item 402-3130: Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL

Table 4-5 shows the results of the regression analysis. Similar to the previous line item, the adjusted R-squared is considerably large indicating that most of the submitted bid prices are fitted to the regression line. Also, ranking the explanatory variables based on their absolute values of the t-statistics specifies that the most powerful significant variables in this model are quantity, asphalt cement price index in the bid date, total bid price, let date between September 2005 and August 2009, and relative value of the line item. Since the coefficient of the explanatory variable quantity is negative, the expected bid price decreases as the quantity increases. Conversely, some other explanatory variables such as asphalt cement price index in the bid date, total bid price, and relative value of the line item have a positive coefficient indicating that the bid price is expected to increase as the value of each of these variables increases.

Similar to the previous line item, considering the coefficients of the three binary variables for project let dates of the projects, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period 09/05-08/09 has the highest explanatory power among these three binary variables.

Eligibility for the PAC program is not a statistically significant explanatory variable for modeling the variations of the bid prices for this line item.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, the regression model for this line item does not have any problem caused by multicollinearity.

The results of ANOVA tests (Table 4-4) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression models. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-4: Results of the ANOVA test for item 402-3130

Source	DF	SS	MS	F	P
Regression	13	315015	24232	694.26	0.000
Residual Error	1151	40174	35		
Total	1164	355189			

Figure 4-2 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and no considerable pattern or trend is observed in the scatter plots of residuals against fitted values and observation orders.

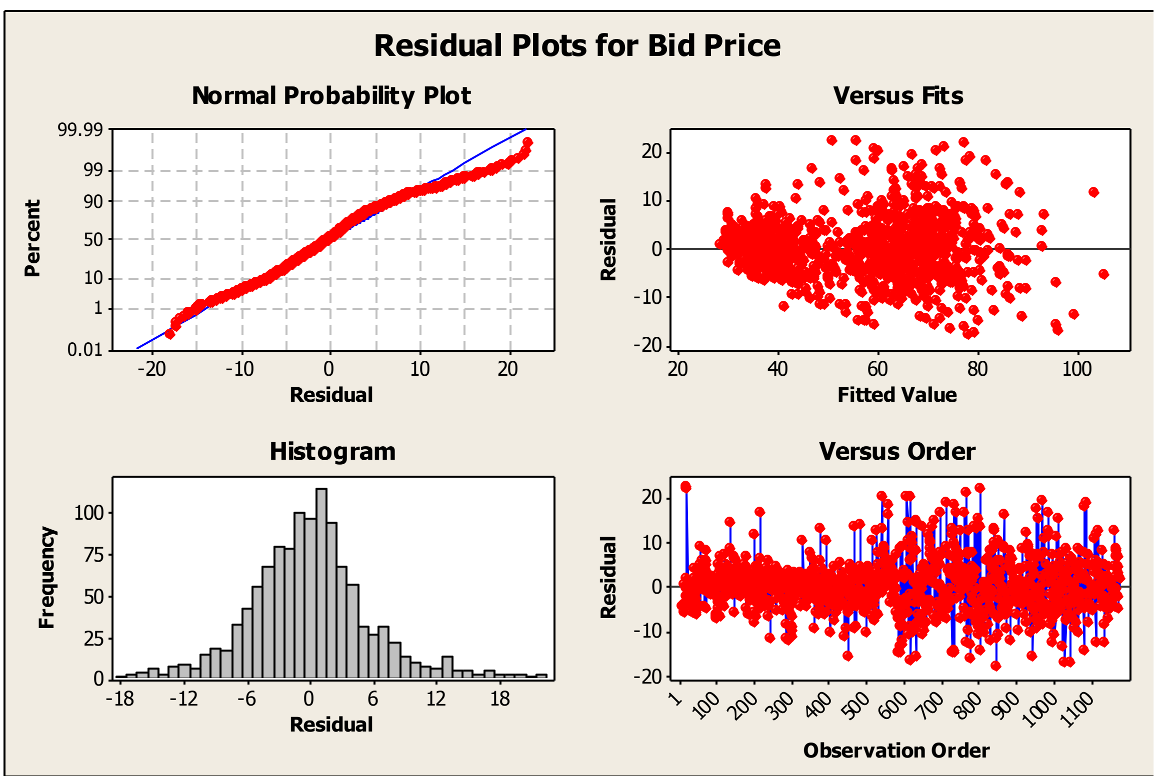

Figure 4-2: Residual plots for item 402-3130

Table 4-5: Results of regression analysis for item 402-3130 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	16.347	5.980	0.000	
1	Natural Logarithm of Quantity of the Item	-6.422	-25.420	0.000	4.668
2	AC Index at the Bid Date	0.053	19.260	0.000	6.557
3	Natural Logarithm of Total Bid Price of the Project	4.499	17.610	0.000	4.009
4	Bid Date: Between Sept 05 and Aug 09	12.363	16.740	0.000	3.322
5	Relative value of the Line Item	14.488	9.760	0.000	5.175
6	Annual Value of Projects in Other Districts	10^{-9}	7.150	0.000	1.593
7	Bid Date: Between Aug 09 and Aug 11	7.032	6.930	0.000	3.856
8	Bid Date: After Aug 11	7.810	6.510	0.000	5.698
9	Number of Bidders	-0.626	-6.240	0.000	1.249
10	Location of the project: District 5	3.146	5.770	0.000	1.114
11	Location of the project: District 3	-1.993	-3.760	0.000	1.172
12	Location of the project: District 1	-1.786	-3.370	0.001	1.145
13	Annual Number of Projects in the District	0.048	2.750	0.006	1.429
-	Duration of the project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in Other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**5.90789**				
R-Sq	**88.7%**				
R-Sq (adj)	**88.6%**				

4.4.3. Results for item 402-3121: Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL

Table 4-7 shows the results of the regression analysis. Since the adjusted R-squared is considerably large, most of the submitted bid prices are fitted to the regression line. Ranking the explanatory variables based on their absolute values of their respective t-statistics specifies that the most powerful variables in this model are quantity, let date between September 2005 and August 2009, asphalt cement price index in the bid date, total bid price, and relative value of the line item. The negative coefficient of the explanatory variable, quantity, indicates that the expected bid price decreases as the quantity increases. On the contrary, some other powerful significant explanatory variables, such as asphalt cement price index and total bid price have positive coefficient indicating that the bid price is expected to increase as the value of each of these variables increases.

Furthermore, considering the coefficients of the three binary variables for let date of the projects, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period 09/05-08/09 has the highest explanatory power among these three binary variables.

Eligibility for the PAC program is not a statistically significant explanatory variable for modeling the variations of the bid prices for this line item.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, the regression model for this line item does not have any problem caused by multicollinearity.

The results of ANOVA tests (Table 4-6) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-6: Results of the ANOVA test for item 402-3121

Source	DF	SS	MS	F	P
Regression	14	302272	21591	499.5	0.000
Residual Error	1163	50271	43		
Total	1177	352543			

Figure 4-3 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and there is no considerable pattern or trend observed in the scatter plots of residuals against fitted values and observation orders.

Table 4-7: Results of regression analysis for item 402-3121 (Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	15.063	3.780	0.000	
1	Natural Logarithm of Quantity of the Item	-6.168	-25.020	0.000	4.683
2	Bid Date: Between Sept 05 and Aug 09	14.320	16.650	0.000	3.671
3	AC Index at the Bid Date	0.050	15.400	0.000	7.149
4	Natural Logarithm of Total Bid Price of the Project	4.590	12.890	0.000	6.561
5	Relative value of the Line Item	16.178	8.000	0.000	3.929
6	Annual Value of Projects in Other Districts	10^{-8}	7.590	0.000	3.408
7	Bid Date: Between Aug 09 and Aug 11	7.935	6.470	0.000	3.094
8	Location of the project: District 5	3.527	5.790	0.000	1.106
9	Number of Bidders	-0.443	-4.300	0.000	1.444
10	Bid Date: After Aug 11	4.630	3.140	0.002	5.581
11	Annual Quantity of Asphalt Mixture in other Districts	-6.5×10^{-7}	-2.360	0.019	2.534
12	Location of the project: District 3	-1.177	-2.330	0.020	1.144
13	Location of the project: District 4	1.486	2.240	0.025	1.201
14	Duration of the project	-0.003	-2.230	0.026	2.860
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in Other Districts	-	-	-	-
S	**6.57459**				
R-Sq	**85.7%**				
R-Sq (adj)	**85.6%**				

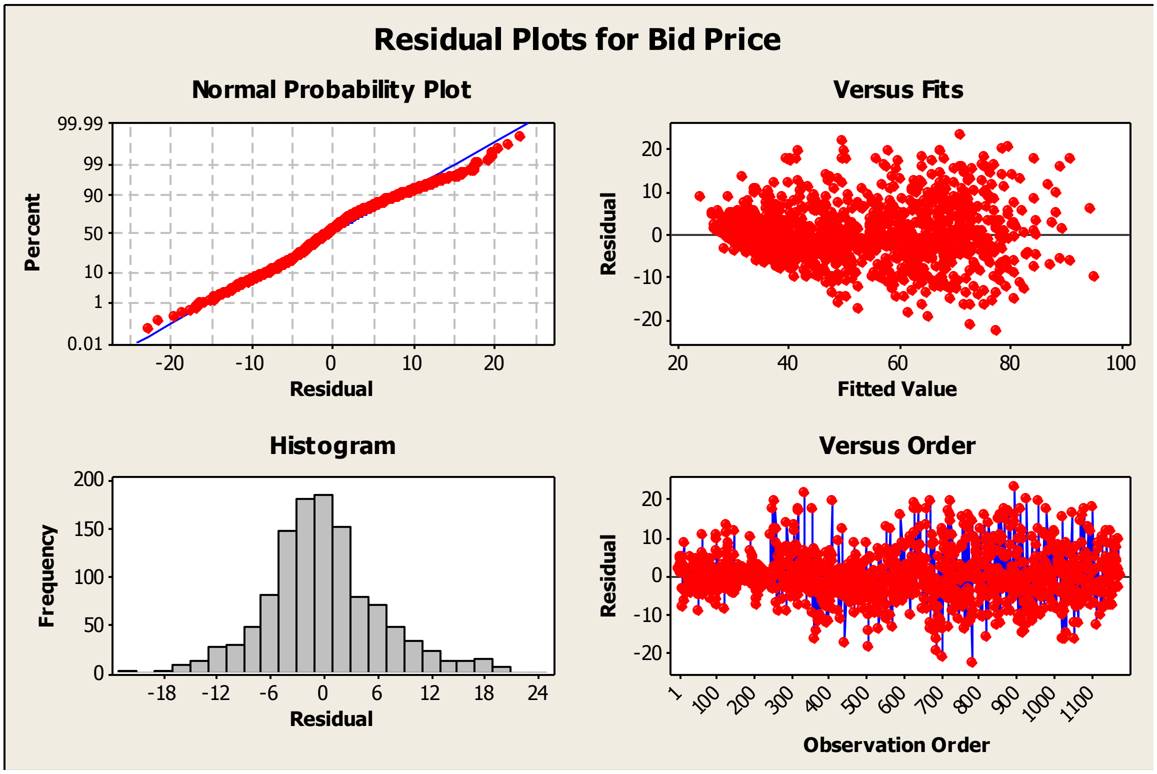

Figure 4-3: Residual plots for item 402-3121

4.4.4. Results for item 402-1812: Recycled Asphaltic Concrete Leveling, BM&HL

Table 4-9 shows the results of the regression analysis. Similar to the previous line items, the adjusted R-squared is considerably large indicating that most of the submitted bid prices are fitted to the regression line. Furthermore, ranking the explanatory variables based on their absolute values of their respective t-statistics specifies that the most powerful variables in this model are quantity, total bid price, asphalt cement price index in the bid date, relative value of the line item, and let date between September 2005 and August 2009. Again, the coefficient of the explanatory variable, quantity, is negative indicating that the expected bid prices for this line item decrease as the quantity increases. On the other hand, some other powerful significant variables such as total bid price, asphalt cement price index, and relative value of the line item have positive coefficients indicating that the bid price is expected to increase as the value of each of these variables increases.

Considering the coefficients of the three binary variables for let date of the projects, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period September 2005-August 2009 has the highest explanatory power among these three binary variables.

On the contrary to the previous line items, eligibility for the PAC program is a statistically significant explanatory variable to explain the variations of the submitted bid prices for this line item. However, the positive coefficient of this explanatory variable indicates that the expected bid prices are higher for eligible project.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, the regression model for this line item does not have any problem caused by multicollinearity.

The results of ANOVA tests (Table 4-8) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-8: Results of the ANOVA test for item 402-1812

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	18	789514	43862	843.79	0.000
Residual Error	2861	148720	52		
Total	2879	938233			

Table 4-9: Results of regression analysis for item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	10.271	4.760	0.000	
1	Natural Logarithm of Quantity of the Item	-6.009	-38.060	0.000	3.338
2	Natural Logarithm of Total Bid Price of the Project	4.312	25.250	0.000	2.582
3	AC Index at the Bid Date	0.058	23.860	0.000	8.283
4	Relative value of the Line Item	43.155	16.140	0.000	3.505
5	Bid Date: Between Sept 05 and Aug 09	9.390	9.960	0.000	9.412
6	Annual Value of Projects in Other Districts	10^{-8}	8.370	0.000	3.610
7	Bid Date: Between Aug 09 and Aug 11	6.924	7.860	0.000	5.865
8	Location of the project: District 5	3.441	7.830	0.000	1.200
9	Location of the project: District 3	-3.339	-7.560	0.000	1.569
10	Rate of Change of the AC Index	0.062	6.790	0.000	1.252
11	Number of Bidders	-0.507	-6.370	0.000	1.167
12	Eligibility of the Projects for PAC	4.234	6.060	0.000	5.851
13	Bid Date: After Aug 11	5.550	5.030	0.000	6.614
14	Location of the project: District 6	-1.941	-3.980	0.000	1.214
15	Annual Number of Projects in the District	0.060	3.250	0.001	3.455
16	Annual Quantity of Asphalt Mixture in the District	-1.8×10^{-6}	-2.870	0.004	2.554
17	Location of the project: District 2	-1.071	-2.730	0.006	1.218
18	Annual Quantity of Asphalt Mixture in other Districts	-5.9×10^{-7}	-2.550	0.011	2.745
-	Duration of the project	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
S	**7.20983**				
R-Sq	**84.1%**				
R-Sq (adj)	**84.0%**				

Figure 4-4 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and there is no considerable pattern or trend observed in the scatter plots of residuals against fitted values and observation orders.

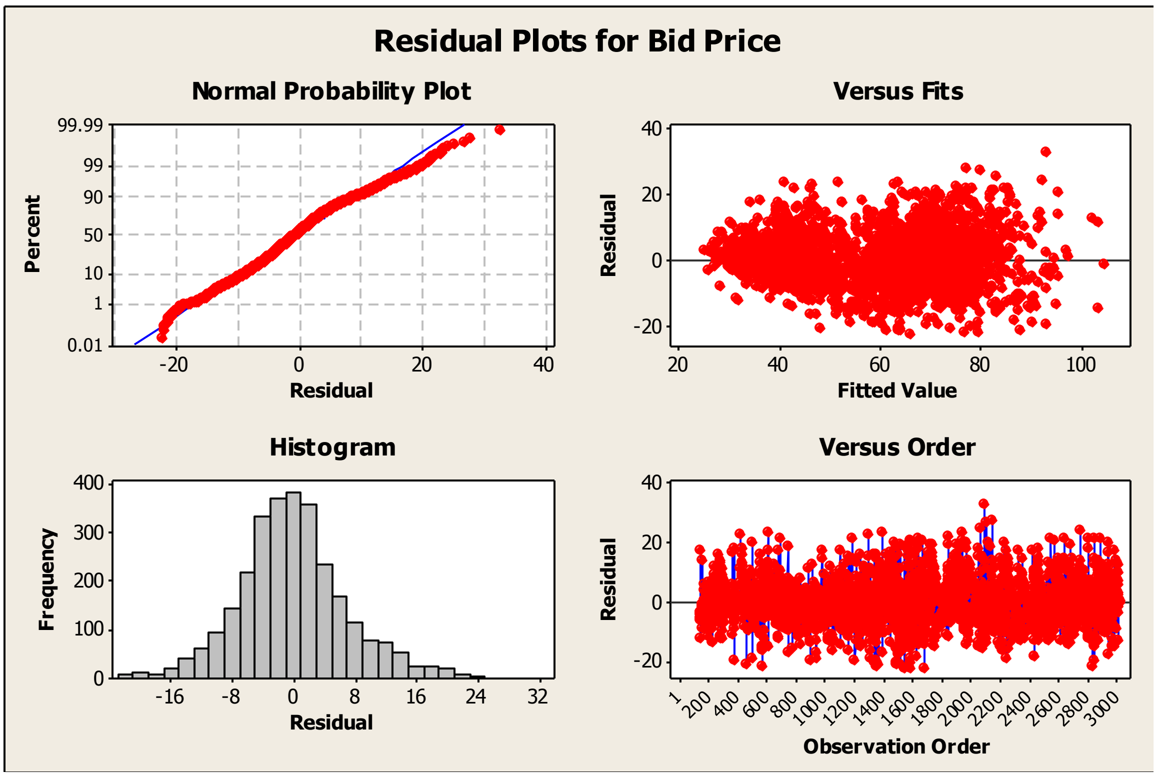

Figure 4-4: Residual plots for item 402-1812

4.4.5. Results for item 402-1802: Recycled Asphaltic Concrete Patching, BM&HL

Table 4-11 shows the results of the regression analysis. Adjusted R-squared is not very large compared to the models of other line items. Ranking the explanatory variables based on their absolute values of their respective t-statistics specifies that the most powerful variables in this model are quantity, asphalt cement price index in the bid date, total bid price, relative value of the line item, and let date between September 2005 and August 2009. The negative coefficient of the explanatory variable, quantity, indicates that the expected bid price decreases as the quantity increases. On the contrary, some other powerful significant explanatory variables such as asphalt cement price index and total bid price have positive coefficient indicating that the bid price is expected to increase as the value of each of these variables increases.

Considering the three binary variables for let date of the projects, the expected submitted bid price for a project increases if the project was awarded between September 2005 and August 2009.

Eligibility for the PAC program is not a statistically significant explanatory variable to model the variations of the bid prices for this line item.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, the regression model for this line item does not have any problem caused by multicollinearity.

The results of ANOVA tests (Table 4-10) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-10: Results of the ANOVA test for item 402-1802

Source	DF	SS	MS	F	P
Regression	10	588749	58875	130.7	0.000
Residual Error	996	448647	450		
Total	1006	1037396			

Table 4-11: Results of regression analysis for item 402-1802 (Recycled Asphaltic Concrete Patching, BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	53.950	5.020	0.000	
1	Natural Logarithm of Quantity of the Item	-14.031	-22.660	0.000	2.027
2	AC Index at the Bid Date	0.060	12.540	0.000	1.166
3	Natural Logarithm of Total Bid Price of the Project	6.373	8.110	0.000	1.350
4	Relative value of the Line Item	59.727	6.940	0.000	2.018
5	Bid Date: Between Sept 05 and Aug 09	10.014	6.090	0.000	1.248
6	Location of the project: District 6	-9.337	-4.500	0.000	1.145
7	Annual Value of Projects in other Districts	10^{-8}	4.110	0.000	1.824
8	Annual Value of Projects in the District	3×10^{-8}	3.440	0.001	1.658
9	Number of Bidders	-1.378	-3.120	0.002	1.157
10	Location of the project: District 5	6.100	2.210	0.027	1.127
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in Other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**21.2238**				
R-Sq	**56.8%**				
R-Sq (adj)	**56.3%**				

Figure 4-5 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and there is no considerable pattern or trend observed in the scatter plots of residuals against fitted values and observation orders.

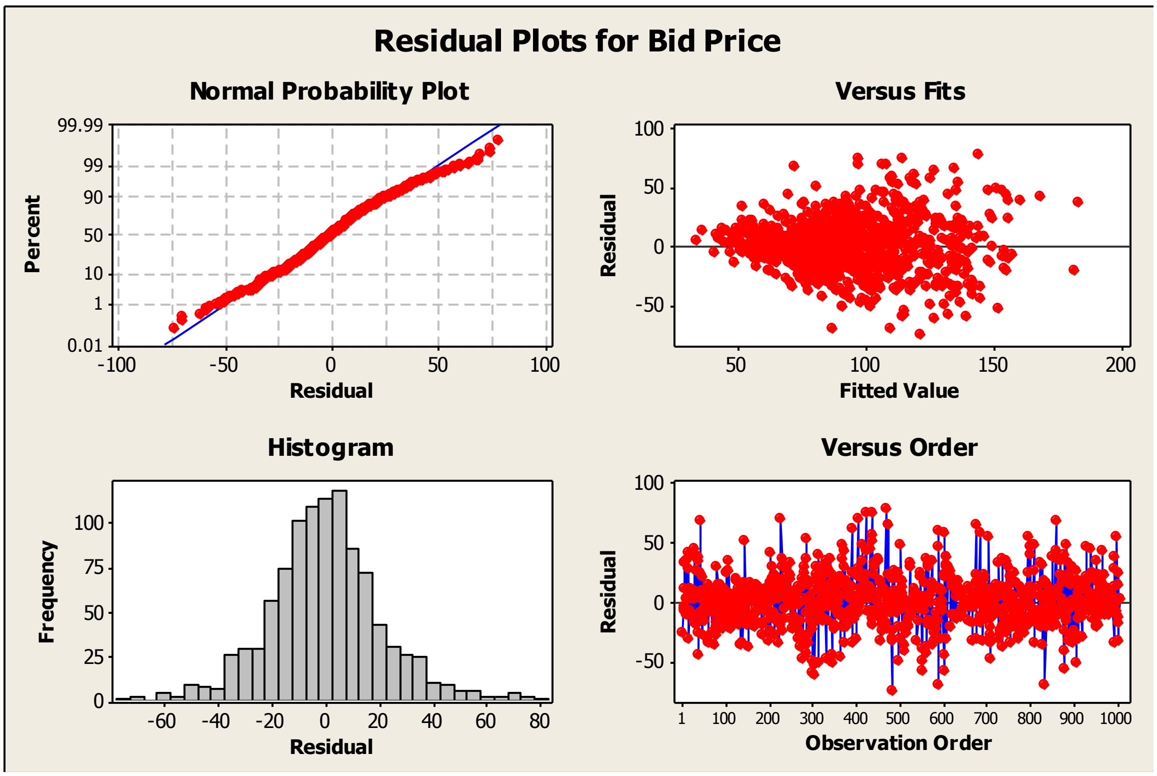

Figure 4-5: Residual plots for item 402-1802

4.4.6. Results for item 402-3113: Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL

Table 4-12 shows the results of the regression analysis. Considerably large adjusted R-squared indicates that most of the observations are fitted to the regression line. Also, ranking the explanatory variables based on their absolute values of their respective t-statistics specifies that the most powerful variables in this model are let date between September 2005 and August 2009, quantity, asphalt cement price index in the bid date, total bid price, and location of the projects in district six. The negative coefficient of the explanatory variable, quantity, indicates that the expected bid price decreases as the quantity increases. On the contrary, other powerful significant explanatory variables such as asphalt cement price index and total bid price have positive coefficients indicating that the bid price is expected to increase as the value of each of these variables increases.

Binary variables for project let dates between August 2009 and August 2011 and after August 2011 are not statistically significant. However, let dates between September 2005 and August 2009 are significant with a positive coefficient. Therefore, the expected submitted bid price for a project increases if the project was awarded between September 2005 and August 2009.

It should be noted that letting between September 2005 and August 2009 and eligibility for PAC program are highly correlated to each other (Pearson correlation coefficient is 1). It means that all projects in the dataset within the timeframe of September 2005 to August 2009 were eligible for the PAC program. Therefore, those two explanatory variables cannot participate in the model together and one of them should be excluded. Since the coefficient of the variable is positive and considerably large, considering the results of the other line items, it is probable that the letting date in the first period of 2005 and 2009 is the significant explanatory variable.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, multicollinearity does not undermine the validity of the regression model for this line item.

The results of ANOVA tests (Table 4-13) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model.

Table 4-12: Results of regression analysis for item 402-3113 (Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	27.256	3.900	0.000	
1	Bid Date: Between Sept 05 and Aug 09	15.063	9.110	0.000	1.616
2	Natural Logarithm of Quantity of the Item	-3.815	-7.920	0.000	1.444
3	AC Index at the Bid Date	0.049	6.890	0.000	1.484
4	Natural Logarithm of Total Bid Price of the Project	2.607	5.300	0.000	1.292
5	Location of the project: District 6	9.947	4.300	0.000	1.124
6	Location of the project: District 5	6.290	3.710	0.000	1.169
-	Duration of the project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Relative value of the Line Item	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**7.46685**				
R-Sq	**79.8%**				
R-Sq (adj)	**78.9%**				

Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-13: Results of the ANOVA test for item 402-3113

Source	DF	SS	MS	F	P
Regression	6	27594.2	4599	82.49	0.000
Residual Error	125	6969.2	55.8		
Total	131	34563.4			

Figure 4-6 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and there is no considerable pattern or trend observed in the scatter plots of residuals against fitted values and observation orders.

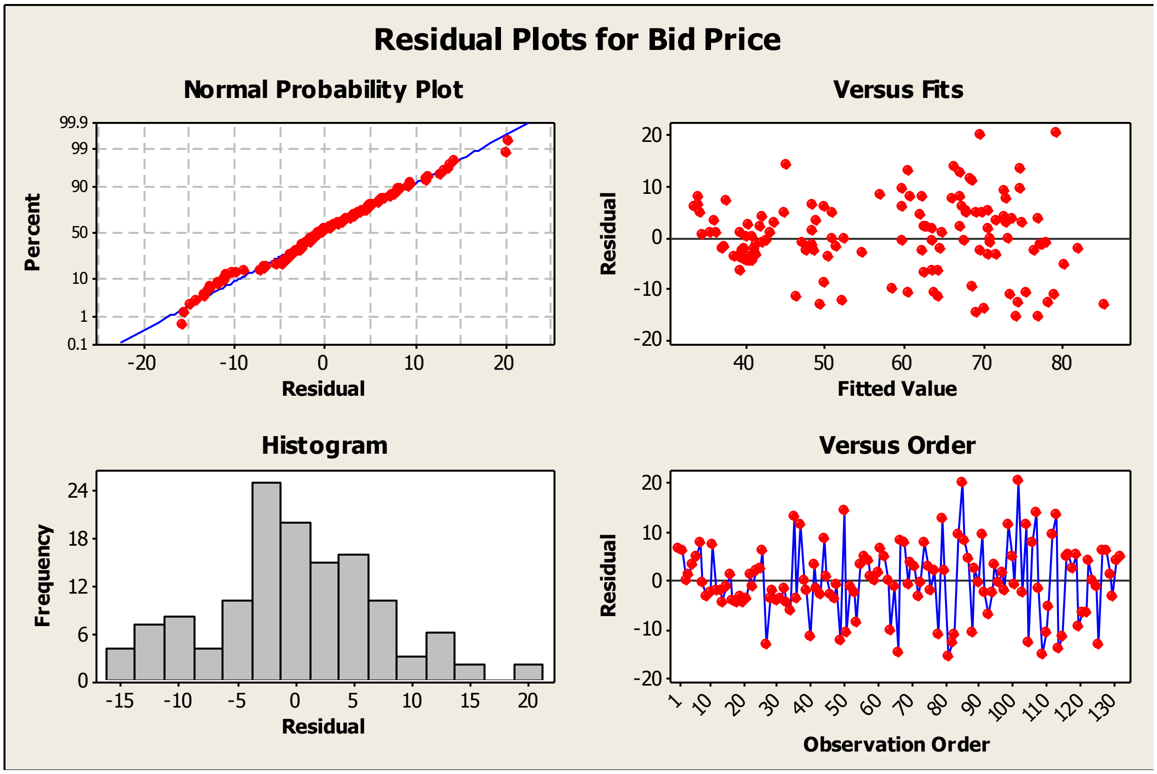

Figure 4-6: Residual plots for item 402-3113

4.4.7. Results for item 402-4510: Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL

Table 4-15 shows the results of the regression analysis. Considerably large adjusted R-squared indicates that most of the observations are fitted to the regression line. Ranking the explanatory variables based on their absolute values of their respective t-statistics specifies that the most powerful variables in this model are quantity, asphalt cement price index at the bid date, let date between September 2005 and August 2009, total bid price, and annual value of the projects in other districts. The negative coefficient of the explanatory variable, quantity, indicates that the expected bid price decreases as the quantity increases. On the contrary, other powerful significant explanatory variables such as asphalt cement price index and total bid price have positive coefficient indicating that the bid price is expected to increase as the value of each of these variables increases.

Similar to all other line items, coefficients of the three binary variables for project let dates are positive. Therefore, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period 09/05-08/09 has the highest explanatory power among these three binary variables.

Similar to all other line items but 402-1812, eligibility for the PAC program is not a statistically significant explanatory variable for modeling the variations of the bid prices for this line item.

Since the calculated values of the VIF indexes for all the significant explanatory variables are less than 10, the regression model for this line item does not have any problem caused by multicollinearity.

The results of ANOVA tests (Table 4-14) indicate that the null hypothesis is strongly rejected at 1% significance level, i.e., at least one of the coefficients of the identified explanatory variables is not zero in the regression model. Thus, the linear relationship between the submitted bid price for this line item and the identified explanatory variables is statistically significant and the model has statistically significant explanatory power to explain the variations of submitted bid prices.

Table 4-14: Results of the ANOVA test for item 402-4510

Source	DF	SS	MS	F	P
Regression	12	64096.4	5341.4	156.87	0.000
Residual Error	311	10589.6	34.1		
Total	323	74686			

Figure 4-7 depicts the residual plots of the regression model. This figure indicates no violation of the basic assumptions of a regression model. It can be seen that the Q-Q plot of the residuals against normal distribution is close to a straight line, the histogram of the frequency of the residuals is similar to a normal distribution, and there is no considerable pattern or trend is observed in the scatter plots of residuals against fitted values and observation orders.

Table 4-15: Results of regression analysis for item 402-4510 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL)

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	48.384	9.710	0.000	
1	Natural Logarithm of Quantity of the Item	-4.838	-15.980	0.000	1.264
2	AC Index at the Bid Date	0.060	13.660	0.000	4.640
3	Bid Date: Between Sept 05 and Aug 09	10.027	8.970	0.000	2.417
4	Natural Logarithm of Total Bid Price of the Project	1.987	7.220	0.000	1.176
5	Annual Value of Projects in other Districts	10^{-8}	5.490	0.000	6.209
6	Location of the project: District 5	7.226	5.400	0.000	1.168
7	Annual Number of Projects in the District	0.152	4.350	0.000	1.648
8	Location of the project: District 7	3.088	4.200	0.000	1.198
9	Bid Date: After Aug 11	7.375	3.830	0.000	4.287
10	Annual Quantity of Asphalt Mixture in other Districts	-3.2×10^{-6}	-3.730	0.000	5.499
11	Bid Date: Between Aug 09 and Aug 11	5.864	3.500	0.001	4.028
12	Number of Bidders	-0.577	-2.770	0.006	1.301
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Relative value of the Line Item	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Eligibility of the Projects for PAC	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in Other Districts	-	-	-	-
S	**5.83524**				
R-Sq	**85.8%**				
R-Sq (adj)	**85.3%**				

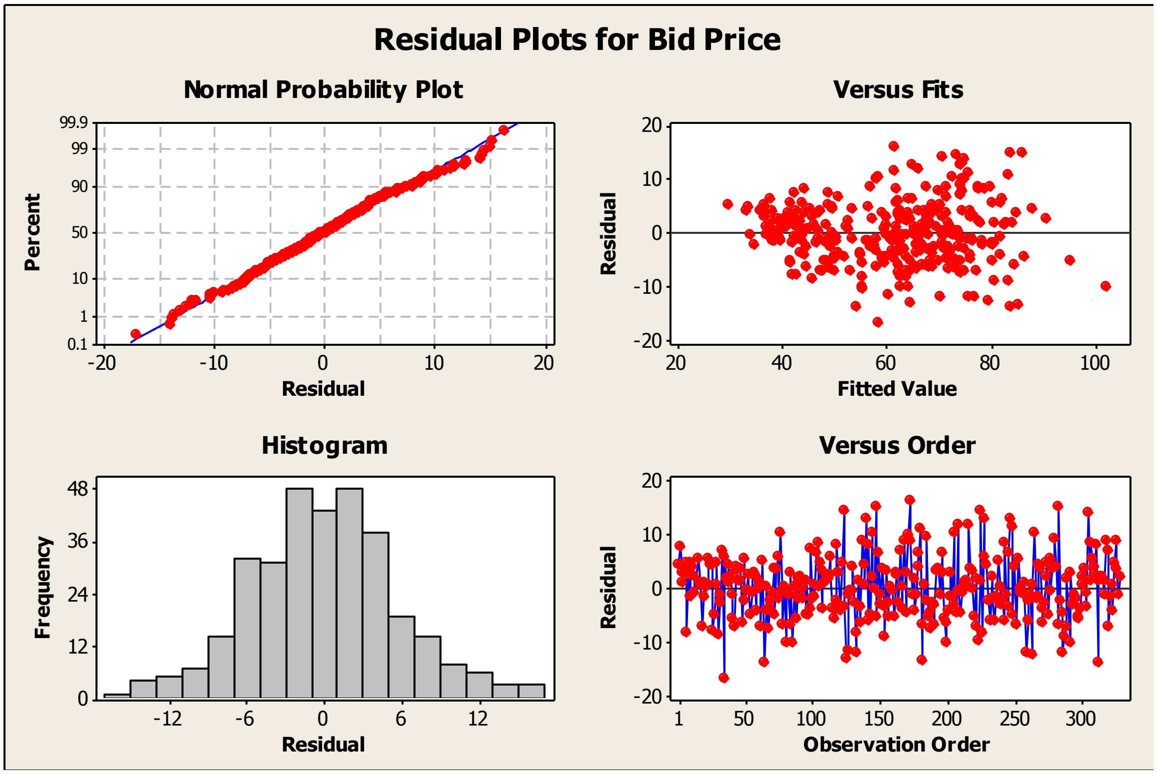

Figure 4-7: Residual plots for item 402-4510

4.5. RESULTS OF THE REGRESSION MODELS FOR BIG, MEDIUM, AND SMALL CONTRACTORS

Contractor's size is an important factor affecting the contractor's bid/no-bid decision and its approach to determine the bid price. Drew and Skitmore (1992) showed that there is a relationship between the size of bidders and the contract value. Furthermore, the contractor's approach to handle the risk of material price volatility might be different for different contractors based on their abilities to handle the material price risk. Big contractors may be able to hedge their positions in the volatile market of asphalt cement through advanced purchase of materials using cash in hand. In this section, three different sample datasets consisting of big, medium, and small contractors were developed. Classification of the contractors into big, medium, and small contractors was driven by the information received from the Georgia DOT's cost professionals. This classification takes into account the number of asphalt plants owned by the contractor, the contractor's annual level of asphalt production, and the contractor's participation rate in the GDOT's bids. Regression models were created for all seven important line items and for each category of big, medium, and small contractors.

4.5.1. Results for Big Contractors

4.5.1.1. Item 402-3190: Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL

The results of the regression model are ranked based on the absolute value of the t-statistics that show the explaining power of the identified variables. Table 4-16 shows the results of the regression model for line item 402-3190 submitted by big contractors. The results indicate that the most powerful explanatory variables to model the variations of this line item are quantity, total bid price, let date between September 2005 and August 2009, asphalt cement price index at the bid date, and let date between August 2009 and August 2011.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.1). The signs of the coefficients of the common significant variables in these two regression models are exactly similar to each other. For instance, the coefficients of the three binary variables for project let dates are positive. Therefore, the expected submitted bid price for a project increases if the project was awarded after September 2005. Relatively speaking, the period 09/05-08/09 has the highest explanatory power among these three binary variables.

However, the PAC was identified as a significant variable with a negative coefficient in explaining the variations of the big contractors' submitted bid prices for this line item, i.e., the expected big contractor's bid price is lower for PAC-eligible projects than that for non PAC-eligible projects. This finding is different from the results of the regression model developed for this line item using the entire dataset for which the PAC was not identified as a significant variable in explaining the variations of submitted bid prices.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-16: Results of regression analysis for big contractors: item 402-3190

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	13.831	2.84	0.005	
1	Natural Logarithm of Quantity of the Item	-6.493	-17.600	0.000	3.844
2	Natural Logarithm of Total Bid Price	4.918	11.320	0.000	4.135
3	Bid Date: Between Sept 05 and Aug 09	17.626	9.990	0.000	6.693
4	AC Index at the Bid Date	0.044	8.980	0.000	7.498
5	Bid Date: Between Aug 09 and Aug 11	11.674	5.970	0.000	4.137
6	Relative Value of the Line Item	21.920	5.940	0.000	2.381
7	Annual Value of the Projects in other Districts	10^{-8}	5.560	0.000	3.647
8	Number of Bidders	-0.833	-5.160	0.000	1.286
9	Bid Date: After Aug 11	11.074	4.880	0.000	7.145
10	Eligibility of the Projects for PAC	-3.925	-2.960	0.003	5.009
11	Annual Quantity of Asphalt Mixture in other Districts	-1.2×10^{-6}	-2.460	0.014	2.738
12	Location of the project: District 5	2.508	2.150	0.032	1.069
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
S	**6.70053**				
R-Sq	**82.2%**				
R-Sq (adj)	**81.8%**				

4.5.1.2. Item 402-3130: Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL

Table 4-17 shows the results of the regression models for this line item submitted by big contractors. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, asphalt cement price index at the bid date, total bid price, let date between September 2005 and August 2009, and relative value of the line item.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.2).

The signs of the coefficients of the common significant variables in these two regression models such as quantity, total bid price, AC index at bid date, and number of bidders, are exactly similar to each other.

However, the PAC was identified as a significant variable with a negative coefficient in explaining the variations of the big contractors' submitted bid prices for this line item, i.e., the expected big contractor's bid price is lower for PAC-eligible projects than that for non PAC-eligible projects. This finding is different from the results of the regression model developed for this line item using the entire dataset for which the PAC was not identified as a significant variable in explaining the variations of submitted bid prices.

It should be noted that based on the t-statistic, this variable has the least explanatory power among the significant variables in the model. Also, since the p-value of this variable is 0.042, eligibility for PAC is accepted as a marginally significant variable.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-17: Results of regression analysis for big contractors: item 402-3130

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	7.806	2.290	0.022	
1	Natural Logarithm of Quantity of the Item	-5.749	-18.120	0.000	4.402
2	AC Index at the Bid Date	0.048	16.360	0.000	5.786
3	Natural Logarithm of Total Bid Price	4.528	14.130	0.000	4.766
4	Bid Date: Between Sept 05 and Aug 09	12.568	10.390	0.000	7.120
5	Relative Value of the Line Item	15.080	8.510	0.000	5.617
6	Annual Value of the Projects in other Districts	10^{-9}	7.770	0.000	1.490
7	Bid Date: After Aug 11	8.723	6.470	0.000	5.108
8	Location of the project: District 5	4.645	5.680	0.000	1.088
9	Bid Date: Between Aug 09 and Aug 11	5.729	5.000	0.000	3.736
10	Number of Bidders	-0.489	-3.980	0.000	1.249
11	Location of the project: District 6	2.421	3.770	0.000	1.207
12	Annual Number of Projects in the District	0.064	3.010	0.003	1.598
13	Eligibility of the Project for PAC	-1.978	-2.040	0.042	5.473
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**4.60745**				
R-Sq	**90.7%**				
R-Sq (adj)	**90.5%**				

4.5.1.3. Item 402-3121: Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL

Table 4-18 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, letting between September 2005 and August 2009, asphalt cement price index at bid date, and annual value of the projects in other districts.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.3).

The signs of the coefficients of the common significant variables in these two regression models such as quantity of the item, AC index at bid date, relative value of the line item, and number of bidders are exactly similar to each other. Furthermore, similar to the model using the entire dataset, eligibility of the project for the PAC program is not a statistically significant explanatory variable in this model.

The results of the ANOVA test for evaluation of the model and VIF test for detecting multicollinearity were conducted and the results indicate that the model has statistically significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Furthermore, residual analysis specifies no violation of the basic assumptions of a regression model.

Table 4-18: Results of regression analysis for big contractors: item 402-3121

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	14.448	2.730	0.007	
1	Natural Logarithm of Quantity of the Item	-6.405	-15.980	0.000	4.100
2	Natural Logarithm of Total Bid Price	4.802	10.100	0.000	4.780
3	Bid Date: Between Sept 05 and Aug 09	12.106	8.480	0.000	3.509
4	AC Index at the Bid Date	0.042	7.780	0.000	7.990
5	Annual Value of the Projects in other Districts	10^{-8}	6.130	0.000	3.293
6	Relative Value of the Line Item	19.291	5.680	0.000	3.620
7	Number of Bidders	-0.804	-4.790	0.000	1.386
8	Bid Date: Between Aug 09 and Aug 11	8.424	4.130	0.000	3.522
9	Bid Date: After Aug 11	6.299	2.640	0.009	6.249
10	Location of the project: District 5	3.281	2.500	0.013	1.030
11	Annual Quantity of Asphalt Mixture in other Districts	-8.8×10^{-7}	-2.050	0.041	2.447
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
S	**6.39893**				
R-Sq	**83.3%**				
R-Sq (adj)	**82.8%**				

4.5.1.4. Item 402-1812: Recycled Asphaltic Concrete Leveling, BM&HL

Table 4-19 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, asphalt cement price index at bid date, total bid price, annual value of projects in other districts, and relative value of the line item.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.4).

The signs of the coefficients of the common significant variables in these two regression models are exactly similar to each other.

The PAC was identified as a significant variable with a positive coefficient in explaining the variations of the big contractors' submitted bid prices for this line item, i.e., the expected big contractor's bid price is higher for PAC-eligible projects than that for non PAC-eligible projects. This finding is similar to the results of the regression model developed for this line item using the entire dataset for which the PAC was identified as a significant variable in explaining the variations of submitted bid prices.

The results of the ANOVA test for evaluation of the model and VIF test for detecting multicollinearity were conducted and the results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Furthermore, residual analysis specifies no violation of the basic assumptions of a regression model.

Table 4-19: Results of regression analysis for big contractors: item 402-1812

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	10.749	3.910	0.000	
1	Natural Logarithm of Quantity of the Item	-5.374	-22.040	0.000	4.327
2	AC Index at the Bid Date	0.056	18.250	0.000	7.191
3	Natural Logarithm of Total Bid Price	4.016	16.500	0.000	3.023
4	Annual Value of the Projects in other Districts	10^{-9}	9.810	0.000	1.713
5	Relative Value of the Line Item	39.381	8.520	0.000	4.473
6	Number of Bidders	-0.901	-7.740	0.000	1.341
7	Bid Date: Between Sept 05 and Aug 09	9.282	7.370	0.000	9.474
8	Bid Date: Between Aug 09 and Aug 11	7.023	7.030	0.000	4.395
9	Rate of Change of the AC Index	0.072	6.240	0.000	1.169
10	Location of the project: District 3	-2.933	-5.500	0.000	1.222
11	Location of the project: District 6	-3.002	-4.790	0.000	1.177
12	Bid Date: After Aug 11	5.351	3.770	0.000	5.536
13	Eligibility of the Project for PAC	3.196	3.280	0.001	6.364
14	Location of the project: District 4	-2.128	-3.080	0.002	1.246
15	Location of the project: District 2	-1.446	-2.940	0.003	1.381
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**6.49167**				
R-Sq	**85.4%**				
R-Sq (adj)	**85.2%**				

4.5.1.5. Item 402-1802: Recycled Asphaltic Concrete Patching, BM&HL

Table 4-20 shows the results of the regression models for this line item ranked based on the absolute value of their t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, let date between September 2005 and August 2009, annual value of the projects in other districts, asphalt cement price index at bid date, and total bid price.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.5).

The signs of the coefficients of the common significant variables in these two regression models are exactly similar to each other. Furthermore, similar to the model developed using the entire data set, eligibility of the project for the PAC program is not a statistically significant explanatory variable to explain the variations of the submitted bid prices.

It should be noted that let date between September 2005 and August 2009 and eligibility for the PAC program are highly correlated to each other in this model (Pearson correlation coefficient is 0.928). Thus, based on the multicollinearity diagnosis, they cannot be used in the model together. Therefore, it is not clear which one is significant. However, since the coefficient of the variable is positive and considerably large, considering the results of the other line items, it is probable that the let date between September 2005 and August 2009 is the significant explanatory variable.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-20: Results of regression analysis for big contractors: item 402-1802

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	62.400	5.700	0.000	
1	Natural Logarithm of Quantity of the Item	-12.678	-18.140	0.000	2.321
2	Bid Date: Between Sept 05 and Aug 09	14.903	8.980	0.000	1.412
3	Annual Value of the Projects in other Districts	10^{-8}	7.300	0.000	1.528
4	AC Index at the Bid Date	0.044	7.070	0.000	1.990
5	Natural Logarithm of Total Bid Price	5.067	6.450	0.000	1.319
6	Annual Number of Projects in the District	0.277	5.280	0.000	1.527
7	Relative Value of the Line Item	39.326	5.150	0.000	2.239
8	Number of Bidders	-2.198	-4.620	0.000	1.283
9	Bid Date: After Aug 11	9.389	3.660	0.000	2.162
10	Location of the project: District 6	-5.871	-2.630	0.009	1.266
11	Location of the project: District 5	9.673	2.500	0.013	1.186
12	Location of the project: District 4	11.194	2.170	0.030	1.178
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**15.5971**				
R-Sq	**68.5%**				
R-Sq (adj)	**67.9%**				

4.5.1.6. Item 402-3113: Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL

Table 4-21 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, asphalt cement price index at bid date, letting between September 2005 and August 2009, and annual quantity of asphalt mixtures in other districts.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.6).

The signs of the coefficients of the common significant variables in these two regression models are exactly similar to each other.

Similar to the previous item, let date between September 2005 and August 2009 and eligibility of the project for the PAC program are highly correlated to each other (Pearson correlation coefficient is 1). Thus, based on the multicollinearity diagnosis, they cannot be used in the model. Therefore, it is not clear which one is significant. However, since the coefficient of the variable is positive and considerably large, considering the results of the other line items, it is probable that the let date between September 2005 and August 2009 is the significant explanatory variable.

After eliminating PAC eligibility variable, the ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-21: Results of regression analysis for big contractors: item 402-3113

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	-5.81	-0.43	0.670	
1	Natural Logarithm of Quantity of the Item	-5.036	-6.28	0.000	3.018
2	AC Index at the Bid Date	0.065	6.10	0.000	2.304
3	Natural Logarithm of Total Bid Price	4.431	4.77	0.000	3.299
4	Bid Date: Between Sept 05 and Aug 09	8.527	3.93	0.000	1.914
5	Annual Quantity of Asphalt Mixture in other Districts	2.76×10^{-6}	2.99	0.004	1.477
6	Relative Value of the Line Item	17.451	2.99	0.004	4.434
7	Location of the project: District 6	8.113	2.10	0.040	1.847
-	Duration of the Project	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
S	**6.67277**				
R-Sq	**82.0%**				
R-Sq (adj)	**80.1%**				

4.5.1.7. Item 402-4510: Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL

Table 4-22 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, quantity, let date between September 2005 and August 2009, total bid price, and annual value of projects in other districts.

We can compare the regression model developed for this line item using big contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.7).

The signs of the coefficients of the common significant variables in these two regression models are exactly similar to each other. Furthermore, similar to the model for this line item using the entire dataset, eligibility of the projects for the PAC program is not statistically significant to model the variations of the submitted bid prices for this line item.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-22: Results of regression analysis for big contractors: item 402-4510

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	36.050	5.520	0.000	
1	AC Index at the Bid Date	0.060	13.460	0.000	4.084
2	Natural Logarithm of Quantity of the Item	-4.629	-12.900	0.000	1.348
3	Bid Date: Between Sept 05 and Aug 09	9.747	8.360	0.000	2.361
4	Natural Logarithm of Total Bid Price	2.803	6.420	0.000	2.504
5	Annual Value of the Projects in other Districts	10^{-8}	5.030	0.000	6.534
6	Annual Number of Projects in the District	0.161	4.180	0.000	1.660
7	Annual Quantity of Asphalt Mixture in other Districts	-3.2×10^{-6}	-3.390	0.001	5.756
8	Bid Date: After Aug 11	6.729	3.380	0.001	3.752
9	Location of the project: District 5	7.786	3.370	0.001	1.104
10	Duration of the Project	-0.005	-2.620	0.009	2.581
11	Location of the project: District 7	1.957	2.510	0.013	1.193
12	Bid Date: Between Aug 09 and Aug 11	3.795	2.200	0.029	3.874
13	Number of Bidders	-0.500	-2.000	0.046	1.408
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Relative Value of the Line Item	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
S	**5.32192**				
R-Sq	**86.4%**				
R-Sq (adj)	**85.6%**				

4.5.2. Results for Medium Contractors

4.5.2.1. Item 402-3190: Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL

Similar to the previous section, the results of the regression models are ranked based on the absolute value of their respective t-statistics which shows the explaining power of the explanatory variables. Table 4-23 shows the results of the regression models for item 402-3190 for sample category of medium contractors. The results indicate that the most powerful explanatory variables to model the variation of the submitted bid prices for this line item are let date between September 2005 and August 2009, quantity, let date between August 2009 and August 2011, asphalt cement price index at bid date, and let date after 2011.

We can compare the regression model developed for this line item using medium contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.1) and model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.1). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to one another.

Similar to the model of big contractors, the PAC was identified as a significant variable with a negative coefficient in explaining the variations of the medium contractors' submitted bid prices for this line item, i.e., the expected medium contractor's bid price is lower for PAC-eligible projects than that for non PAC-eligible projects. This finding is different from the results of the regression model developed for this line item using the entire dataset for which the PAC was not identified as a significant variable in explaining the variations of submitted bid prices.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-23: Results of regression analysis for medium contractors: item 402-3190

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	28.325	4.410	0.000	
1	Bid Date: Between Sept 05 and Aug 09	27.807	10.160	0.000	7.302
2	Natural Logarithm of Quantity of the Item	-3.044	-7.650	0.000	1.909
3	Bid Date: Between Aug 09 and Aug 11	18.106	6.570	0.000	3.444
4	AC Index at the Bid Date	0.041	6.270	0.000	5.794
5	Bid Date: After Aug 11	18.896	6.270	0.000	5.578
6	Eligibility of the Project for PAC	-9.722	-4.710	0.000	4.706
7	Natural Logarithm of Total Bid Price	2.151	3.970	0.000	1.770
8	Location of the project: District 2	-3.533	-2.360	0.020	1.081
-	Rate of Change of the AC Index	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Relative Value of the Line Item	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**5.24377**				
R-Sq	**91.7%**				
R-Sq (adj)	**91.1%**				

4.5.2.2. Item 402-3130: Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL

Table 4-24 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, let date between September 2005 and August 2009, quantity, changing rate of the asphalt cement price index, and total bid price.

We can compare the regression model developed for this line item using medium contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.2) and model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.2). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the medium contractors' submitted bid prices for this line item. This finding is different from the results of the regression model developed for this line item using big contractors' bid data for which the PAC was identified as a significant variable in explaining the variations of submitted bid prices.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-24: Results of regression analysis for medium contractors: item 402-3130

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	23.115	4.140	0.000	
1	AC Index at the Bid Date	0.080	26.320	0.000	1.784
2	Bid Date: Between Sept 05 and Aug 09	13.210	10.180	0.000	1.538
3	Natural Logarithm of Quantity of the Item	-2.957	-8.550	0.000	1.996
4	Rate of Change of the AC Index	-0.173	-5.720	0.000	1.496
5	Natural Logarithm of Total Bid Price	1.830	3.750	0.000	1.772
6	Bid Date: Between Aug 09 and Aug 11	3.869	2.960	0.004	1.775
7	Location of the project: District 3	-6.089	-2.860	0.005	1.085
8	Annual Quantity of Asphalt Mixture in other Districts	1.2×10^{-6}	2.410	0.018	1.354
9	Location of the project: District 1	-5.219	-2.250	0.026	1.036
-	Bid Date: After Aug 11	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Relative Value of the Line Item	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
S	**4.48031**				
R-Sq	**94.1%**				
R-Sq (adj)	**93.6%**				

4.5.2.3. Item 402-3121: Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL

Table 4-25 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, let date between September 2005 and August 2009, quantity, total bid price, and annual quantity of the projects in other districts.

We can compare the regression model developed for this line item using medium contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.3) and model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.3). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to one another.

Similar to the previous regression models for this line item using the entire dataset and big contractors' sample dataset, eligibility for the PAC program is not a statistically significant explanatory variable in this model too.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-25: Results of regression analysis for medium contractors: item 402-3121

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	28.633	3.800	0.000	
1	AC Index at the Bid Date	0.061	13.970	0.000	1.585
2	Bid Date: Between Sept 05 and Aug 09	11.741	7.240	0.000	1.193
3	Natural Logarithm of Quantity of the Item	-3.865	-6.980	0.000	2.633
4	Natural Logarithm of Total Bid Price	2.147	3.510	0.001	2.009
5	Annual Quantity of Asphalt Mixture in other Districts	2.1×10^{-6}	3.020	0.004	1.523
6	Annual Quantity of Asphalt Mixture in the District	-4.9×10^{-6}	-2.410	0.018	1.175
-	Relative Value of the Line Item	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Location of the project: District 1	-	-	-	-
-	Location of the project: District 2	-	-	-	-
-	Location of the project: District 3	-	-	-	-
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
S	**4.81251**				
R-Sq	**92.5%**				
R-Sq (adj)	**91.7%**				

4.5.2.4. Item 402-1812: Recycled Asphaltic Concrete Leveling, BM&HL

Table 4-26 shows the results of the regression models for this line item ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are let date between September 2005 to August 2009, asphalt cement price index at bid date, quantity, let date between August 2009 and August 2011, and let date after 2011.

We can compare the regression model developed for this line item using medium contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.4) and model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.4). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the medium contractors' submitted bid prices for this line item. This finding is different from the results of the regression model developed for this line item using the entire dataset and big contractors' bid data for which the PAC was a significant variable with a positive coefficient.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-26: Results of regression analysis for medium contractors: item 402-1812

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	29.314	7.120	0.000	
1	Bid Date: Between Sept 05 and Aug 09	16.758	15.780	0.000	2.812
2	AC Index at the Bid Date	0.055	13.820	0.000	7.063
3	Natural Logarithm of Quantity of the Item	-4.178	-10.260	0.000	4.482
4	Bid Date: Between Aug 09 and Aug 11	12.297	8.960	0.000	3.841
5	Bid Date: After Aug 11	13.025	7.150	0.000	5.926
6	Rate of Change of the AC Index	0.101	6.120	0.000	1.250
7	Natural Logarithm of Total Bid Price	2.288	5.500	0.000	3.074
8	Relative Value of the Line Item	23.729	4.610	0.000	3.587
9	Location of the project: District 2	-3.008	-4.120	0.000	1.045
10	Location of the project: District 3	-3.131	-3.030	0.003	1.050
11	Number of Bidders	-0.604	-3.020	0.003	1.090
12	Location of the project: District 1	-9.293	-2.600	0.010	1.040
-	Location of the project: District 4	-	-	-	-
-	Location of the project: District 5	-	-	-	-
-	Location of the project: District 6	-	-	-	-
-	Location of the project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**4.95042**				
R-Sq	**93.2%**				
R-Sq (adj)	**93.0%**				

4.5.2.5. Item 402-1802: Recycled Asphaltic Concrete Patching, BM&HL

Table 4-27 shows the results of the regression models for this line item ranked based on the absolute value of the t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, asphalt cement price index at bid date, letting between September 2005 and August 2009, relative value of the item, and total bid price.

We can compare the regression model developed for this line item using medium contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.5) and model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.5). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to one another.

Similar to the previous regression models for this line item using the entire dataset and big contractors' sample dataset, eligibility for the PAC program is not a statistically significant explanatory variable in this model too.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-27: Results of regression analysis for medium contractors: item 402-1802

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	7.590	0.170	0.863	
1	Natural Logarithm of Quantity of the Item	-13.167	-6.780	0.000	2.141
2	AC Index at the Bid Date	0.102	5.400	0.000	1.501
3	Bid Date: Between Sept 05 and Aug 09	32.706	4.890	0.000	1.494
4	Relative Value of the Line Item	223.770	2.970	0.004	2.236
5	Natural Logarithm of Total Bid Price	7.905	2.330	0.023	1.637
-	Bid Date: After Aug 11	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 5	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**18.0197**				
R-Sq	**60.5%**				
R-Sq (adj)	**57.8%**				

4.5.2.6. Item 402-3113: Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL

Since enough observations for the determined medium size contractors are not available, creating the regression model for this line item is not possible.

4.5.2.7. Item 402-4510: Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL

Since enough observations for the determined medium size contractors are not available, developing the regression model is not possible.

4.5.3. Results for Small Contractors

4.5.3.1. Item 402-3190: Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL

Similar to the previous sections, the results of the regression models are ranked based on the absolute value of their respective t-statistics which shows the explaining power of the explanatory variables. Table 4-28 shows the results of the regression models for item 402-3190 submitted by small contractors. The results indicate that the most powerful explanatory variables to model the variations of the submitted bid prices for this item are asphalt cement price index at bid date , let date between September 2005 and August 2009, quantity, total bid price and let date between August 2009 and August 2011.

We can compare the regression model developed for this line item using small contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.1), model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.1) and model developed for this line item using medium contractors' submitted bid data (as described in Section 4.5.2.1). The signs of the coefficients of the common significant variables in these regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the small contractors' submitted bid prices for this line item. This finding is different from the results of the regression model developed for this line item using big and medium contractors' bid data for which the PAC was identified as a significant variable in explaining the variations of submitted bid prices.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-28: Results of regression analysis for small contractors: item 402-3190

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	-8.500	-0.610	0.544	
1	AC Index at the Bid Date	0.072	14.120	0.000	1.274
2	Bid Date: Between Sept 05 and Aug 09	14.177	7.770	0.000	1.080
3	Natural Logarithm of Quantity of the Item	-8.653	-6.820	0.000	5.677
4	Natural Logarithm of Total Bid Price	7.608	5.180	0.000	5.769
5	Bid Date: Between Aug 09 and Aug 11	13.187	4.800	0.000	1.225
6	Number of Bidders	-2.374	-4.740	0.000	1.226
7	Relative Value of the Line Item	33.373	4.080	0.000	2.888
-	Bid Date: After Aug 11	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 5	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**6.20088**				
R-Sq	**88.9%**				
R-Sq (adj)	**87.5%**				

4.5.3.2. Item 402-3130: Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL

Table 4-29 shows the results of the regression models for this line item ranked based on the absolute values of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, let date between September 2005 and August 2009, and asphalt cement price index at bid date.

We can compare the regression model developed for this line item using small contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.2), model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.2) and model developed for this line item using medium contractors' submitted bid data (as described in Section 4.5.2.2). The signs of the coefficients of the common significant variables in these regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the small contractors' submitted bid prices for this line item. This finding is different from the results of the regression model developed for this line item using big contractors' bid data and is similar to the results of the regression models developed for this line item using entire data set and medium contractors' bid data.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-29: Results of regression analysis for small contractors: item 402-3130

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	37.708	5.510	0.000	
1	Natural Logarithm of Quantity of the Item	-4.235	-8.430	0.000	1.470
2	Bid Date: Between Sept 05 and Aug 09	15.586	8.090	0.000	2.479
3	AC Index at the Bid Date	0.060	7.200	0.000	6.198
4	Location of the Project: District 3	-11.729	-4.770	0.000	1.111
5	Bid Date: Between Aug 09 and Aug 11	13.009	4.740	0.000	3.231
6	Natural Logarithm of Total Bid Price	2.478	4.550	0.000	1.503
7	Number of Bidders	-1.676	-4.410	0.000	1.104
8	Bid Date: After Aug 11	10.244	2.760	0.007	8.197
9	Location of the Project: District 2	-11.273	-2.140	0.036	1.068
-	Rate of Change of the AC Index	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Relative Value of the Line Item	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 5	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**5.06345**				
R-Sq	**90.9%**				
R-Sq (adj)	**89.7%**				

4.5.3.3. Item 402-3121: Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL

Table 4-30 shows the results of the regression models for this line item using small contractors' bid data. The significant explanatory variables are ranked based on the absolute value of the t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, let date between September 2005 and August 2009, quantity, number of bidders, and let date between August 2009 and August 2011.

We can compare the regression model developed for this line item using small contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.3), model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.3) and model developed for this line item using medium contractors' submitted bid data (as described in Section 4.5.2.3). The signs of the coefficients of the common significant variables in these regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the small contractors' submitted bid prices for this line item. This finding is similar to the results of the regression model developed for this line item using entire data set, big contractors' bid data, and medium contractors' bid data.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-30: Results of regression analysis for small contractors: item 402-3121

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	19.130	0.970	0.335	
1	AC Index at the Bid Date	0.077	11.410	0.000	2.255
2	Bid Date: Between Sept 05 and Aug 09	14.650	7.080	0.000	1.347
3	Natural Logarithm of Quantity of the Item	-7.605	-4.680	0.000	13.194
4	Number of Bidders	-3.887	-4.630	0.000	3.549
5	Bid Date: Between Aug 09 and Aug 11	15.336	4.590	0.000	1.769
6	Natural Logarithm of Total Bid Price	6.900	3.660	0.001	11.961
7	Location of the Project: District 3	-38.140	-3.320	0.002	3.813
8	Relative Value of the Line Item	31.140	2.920	0.005	6.332
9	Location of the Project: District 2	-26.420	-2.460	0.018	6.577
10	Location of the Project: District 4	-24.130	-2.350	0.023	23.737
11	Location of the Project: District 6	-21.770	-2.160	0.036	18.508
12	Location of the Project: District 5	-21.450	-2.070	0.044	41.685
-	Eligibility of the Project for PAC	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**5.82707**				
R-Sq	**91.7%**				
R-Sq (adj)	**89.5%**				

4.5.3.4. Item 402-1812: Recycled Asphaltic Concrete Leveling, BM&HL

Table 4-31 shows the results of the regression models for this line item using small contractors' bid data. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, let date between September 2005 and August 2009, quantity, let date between August 2009 and August 2011, and total bid price.

We can compare the regression model developed for this line item using small contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.4), model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.4) and model developed for this line item using medium contractors' submitted bid data (as described in Section 4.5.2.4). The signs of the coefficients of the common significant variables in these regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the small contractors' submitted bid prices for this line item. This finding is similar to the results of the regression model developed for this line item using the medium contractors' bid data. However, eligibility of the project for the PAC program was identified as a significant variable with a positive coefficient in the regression models using the entire data set and big contractors' bid data.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-31: Results of regression analysis for small contractors: item 402-1812

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	1.892	0.260	0.793	
1	AC Index in the Bid Date	0.080	25.400	0.000	1.262
2	Bid Date: Between Sept 05 and Aug 09	12.738	10.210	0.000	1.671
3	Natural Logarithm of Quantity of the Item	-4.446	-6.050	0.000	6.141
4	Bid Date: Between Aug 09 and Aug 11	6.788	5.260	0.000	1.455
5	Natural Logarithm of Total Bid Price	3.628	4.890	0.000	3.732
6	Location of the Project: District 5	4.175	3.960	0.000	1.265
7	Location of the Project: District 3	-4.397	-3.380	0.001	1.230
8	Annual Quantity of Asphalt Mixture in other Districts	10^{-9}	3.080	0.002	1.514
9	Relative Value of the Line Item	22.020	2.070	0.040	4.223
-	Rate of Change of the AC Index	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
S	**6.11843**				
R-Sq	**85.7%**				
R-Sq (adj)	**85.0%**				

4.5.3.5. Item 402-1802: Recycled Asphaltic Concrete Patching, BM&HL

Table 4-32 shows the results of the regression models for this line item using small contractors' bid data. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, relative value of the item, and number of bidders.

We can compare the regression model developed for this line item using small contractors' submitted bid data with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.5), model developed for this line item using big contractors' submitted bid data (as described in Section 4.5.1.5) and model developed for this line item using medium contractors' submitted bid data (as described in Section 4.5.2.5). The signs of the coefficients of the common significant variables in these regression models are exactly similar to one another.

The PAC was not identified as a significant variable in explaining the variations of the small contractors' submitted bid prices for this line item. This finding is similar to the results of the regression model developed for this line item using the entire data set, big contractors' bid data and medium contractors' bid data.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-32: Results of regression analysis for small contractors: item 402-1802

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	-136.450	-2.830	0.006	
1	Natural Logarithm of Quantity of the Item	-27.964	-11.630	0.000	2.008
2	Natural Logarithm of Total Bid Price	24.537	6.720	0.000	1.754
3	Relative Value of the Line Item	602.400	5.690	0.000	2.564
4	Number of Bidders	4.559	2.930	0.005	1.020
-	Bid Date: Between Sept 05 and Aug 09	-	-	-	-
-	Bid Date: Between Aug 09 and Aug 11	-	-	-	-
-	Bid Date: After Aug 11	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	AC Index at the Bid Date	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 5	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of the Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of the Projects in other Districts	-	-	-	-
-	Annual Value of the Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**19.4882**				
R-Sq	**70.0%**				
R-Sq (adj)	**68.3%**				

4.5.3.6. Item 402-3113: Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL

Since enough observations for the determined small size contractors are not available, developing the regression model is not possible.

4.5.3.7. Item 402-4510: Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL

Since enough observations for the determined small size contractors are not available, developing the regression model is not possible.

4.6. RESULTS OF THE REGRESSION MODELS USING DATASET AFTER AUGUST 2009

GDOT has been offering price adjustment clauses for asphalt cement since September 2005. GDOT updated the provision of the PAC program in August 2009 and later in August 2011. During the first period, which is from September 2005 to August 2009, there was no limitation and restriction for the PAC eligibility based on the duration of the projects. However, since August 2009, only projects with more than 366 days from the let date to the original completion date have been eligible for the PAC program. This new regulation may affect the impacts of the PAC program. Thus, in this section, the regression models for all seven major line items are recreated by only using the dataset of projects awarded after August 2009.

4.6.1. Item 402-3190: Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL

Table 4-33 shows the results of the regression models for item 402-3190 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, location of the project in district 5, location of the project in district 4, and asphalt cement price index at bid date.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.1). The signs of the coefficients of the common significant variables in these regression models are exactly similar to each other.

The PAC was not identified as a significant variable in explaining the variations of the submitted bid prices after August 2009 for this line item. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-33: Results of regression analysis for item 402-3190 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	31.126	3.710	0.000	
1	Natural Logarithm of Quantity of the Item	-7.219	-12.340	0.000	5.023
2	Natural Logarithm of Total Bid Price	4.850	6.680	0.000	4.344
3	Location of the Project: District 5	8.067	6.500	0.000	1.134
4	AC Index at the Bid Date	0.038	6.490	0.000	1.096
5	Location of the Project: District 4	6.848	5.410	0.000	1.258
6	Relative Value of the Item	27.447	3.920	0.000	2.405
7	Number of Bidders	-0.535	-2.640	0.009	1.365
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**7.43758**				
R-Sq	**57.9%**				
R-Sq (adj)	**57.0%**				

4.6.2. Item 402-3130: Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL

Table 4-34 shows the results of the regression models for item 402-3130 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, asphalt cement price index at bid date, total bid price, and location of the projects in district 5.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.2). The signs of the coefficients of the common significant variables in these regression models are exactly similar to each other.

The PAC was not identified as a significant variable in explaining the variations of the submitted bid prices after August 2009 for this line item. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-34: Results of regression analysis for item 402-3130 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	35.208	6.550	0.000	
1	Natural Logarithm of Quantity of the Item	-5.525	-12.380	0.000	4.646
2	AC Index at the Bid Date	0.046	9.370	0.000	1.114
3	Natural Logarithm of Total Bid Price	3.785	8.020	0.000	3.090
4	Location of the Project: District 5	6.035	6.860	0.000	1.185
5	Number of Bidders	-0.759	-3.840	0.000	1.548
6	Relative Value of the Item	8.611	3.080	0.002	4.782
7	Location of the Project: District 4	3.259	3.010	0.003	1.297
8	Location of the Project: District 1	-2.264	-1.980	0.049	1.142
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**6.06144**				
R-Sq	**65.0%**				
R-Sq (adj)	**64.1%**				

4.6.3. Item 402-3121: Recycled Asphaltic Concrete 25MM SP, GP 1/2 BM&HL

Table 4-35 shows the results of the regression models for item 402-3121 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, total bid price, asphalt cement price index at bid date, location of the projects in district 5, and location of the projects in district 4.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.3). The signs of the coefficients of the common significant variables in these regression models are exactly similar to each other.

The PAC was not identified as a significant variable in explaining the variations of the submitted bid prices after August 2009 for this line item. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-35: Results of regression analysis for item 402-3121 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	2.062	0.250	0.805	
1	Natural Logarithm of Quantity of the Item	-9.631	-12.800	0.000	9.750
2	Natural Logarithm of Total Bid Price	7.569	9.430	0.000	6.002
3	AC Index at the Bid Date	0.035	6.480	0.000	1.051
4	Location of the Project: District 5	8.332	6.190	0.000	1.178
5	Location of the Project: District 4	8.639	5.810	0.000	1.132
6	Relative Value of the Item	71.470	5.540	0.000	4.082
7	Location of the Project: District 2	3.151	2.640	0.009	1.210
8	Location of the Project: District 7	2.508	2.100	0.037	1.304
-	Number of Bidders	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**6.23095**				
R-Sq	**68.9%**				
R-Sq (adj)	**67.7%**				

4.6.4. Item 402-1812: Recycled Asphaltic Concrete Leveling, BM&HL

Table 4-36 shows the results of the regression models for item 402-1812 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, location of the project in district 5, asphalt cement price index at bid date, relative value of the item, location of the projects in district 4, and eligibility for PAC.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.4). The signs of the coefficients of the common significant variables in these regression models are exactly similar to each other.

The PAC was identified as a significant variable with a positive coefficient in explaining the variations of the contractors' submitted bid prices after August 2009 for this line item, i.e., the expected bid price after August 2009 is higher for PAC-eligible projects than that for non PAC-eligible projects. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-36: Results of regression analysis for item 402-1812 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	43.231	7.940	0.000	
1	Natural Logarithm of Quantity of the Item	-6.163	-17.760	0.000	4.878
2	Location: District 5	9.016	12.320	0.000	1.322
3	Relative Value of the Item	46.943	11.120	0.000	3.767
4	Location of the Project: District 4	7.087	9.100	0.000	1.704
5	Eligibility of the Project for PAC	8.565	8.380	0.000	3.278
6	AC Index at the Bid Date	0.035	7.930	0.000	2.179
7	Natural Logarithm of Total Bid Price	3.264	7.250	0.000	5.711
8	Annual Quantity of Asphalt Mixture in the District	1.19×10^{-5}	4.750	0.000	9.338
9	Annual Number of Projects in the District	-0.167	-4.480	0.000	8.090
10	Location of the Project: District 2	2.708	4.160	0.000	1.242
11	Annual Value of Projects in the District	-4×10^{-8}	-4.100	0.000	3.758
12	Rate of Change of the AC Index	0.062	2.770	0.006	1.494
13	Duration of the Project	-0.005	-2.580	0.010	3.375
14	Number of Bidders	-0.342	-2.440	0.015	1.417
15	Annual Value of Projects in other Districts	10^{-9}	2.200	0.028	1.393
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 3	-	-	-	-
-	Location of the Project: District 6	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**6.53229**				
R-Sq	**61.2%**				
R-Sq (adj)	**60.5%**				

4.6.5. Item 402-1802: Recycled Asphaltic Concrete Patching, BM&HL

Table 4-37 shows the results of the regression models for item 402-1802 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are quantity, asphalt cement price index at bid date, relative value of the item, and total bid price.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.5). The signs of the coefficients of the common significant variables in these three regression models are exactly similar to each other.

The PAC was not identified as a significant variable in explaining the variations of the submitted bid prices after August 2009 for this line item. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-37: Results of regression analysis for item 402-1802 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	73.520	4.160	0.000	
1	Natural Logarithm of Quantity of the Item	-14.543	-15.400	0.000	2.737
2	AC Index at the Bid Date	0.085	5.470	0.000	1.386
3	Relative Value of the Item	61.970	4.120	0.000	2.270
4	Natural Logarithm of Total Bid Price	4.174	3.360	0.001	1.511
5	Location of the Project: District 3	-10.539	-3.320	0.001	1.658
6	Location of the Project: District 6	-13.283	-3.270	0.001	1.439
7	Annual Quantity of Asphalt Mixture in the District	1.32×10^{-5}	2.900	0.004	1.869
8	Location of the Project: District 1	-7.430	-2.300	0.022	1.540
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Location of the Project: District 2	-	-	-	-
-	Location of the Project: District 4	-	-	-	-
-	Location of the Project: District 5	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
S	**20. 6991**				
R-Sq	**60.9%**				
R-Sq (adj)	**60.2%**				

4.6.6. Item 402-3113: Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL

Since there are not enough observations for this line item in the dataset after August 2009, creating the regression model is not possible.

4.6.7. Item 402-4510: Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL

Table 4-38 shows the results of the regression models for item 402-4510 using bid data after August 2009. The significant explanatory variables are ranked based on the absolute value of their respective t-statistics. The results indicate that the most powerful explanatory variables in this model are asphalt cement price index at bid date, quantity, relative value of the item, location of the project in district 5, and location of the projects in district 4.

We can compare the regression model developed for this line item using the bid data after August 2009 with the regression model developed for the same line item using the entire dataset of submitted bid data (as described in Section 4.4.7). The signs of the coefficients of the most important common significant variables in these three regression models are exactly similar to each other.

The PAC was not identified as a significant variable in explaining the variations of the submitted bid prices after August 2009 for this line item. This finding is similar to the results of the regression model developed for this line item using the entire dataset.

The ANOVA test was conducted for the evaluation of the regression model and the VIF test was performed to detect any multicollinearity issue in the model. The results indicate that the model has significant explanatory power and the regression model for this line item does not have any problem caused by multicollinearity. Further, the results of residual analysis specify no violation of the basic assumptions of regression modeling.

Table 4-38: Results of regression analysis for item 402-4510 using the dataset after August 2009

Ranking	Variable	Coefficient	t-Statistic	P-Value	VIF
	Constant	69.935	12.310	0.000	
1	AC Index at the Bid Date	0.054	7.350	0.000	1.083
2	Natural Logarithm of Quantity of the Item	-2.494	-4.630	0.000	1.717
3	Relative Value of the Item	-11.397	-4.630	0.000	1.635
4	Location of the Project: District 5	9.256	4.360	0.000	1.152
5	Location of the Project: District 4	6.531	2.900	0.005	1.142
6	Location of the Project: District 6	-5.367	-2.400	0.018	1.133
7	Location of the Project: District 1	-3.224	-2.240	0.028	1.259
8	Location of the Project: District 3	-3.078	-2.110	0.037	1.288
-	Natural Logarithm of Total Bid Price	-	-	-	-
-	Number of Bidders	-	-	-	-
-	Duration of the Project	-	-	-	-
-	Rate of Change of the AC Index	-	-	-	-
-	Location of the Project: District 1	-	-	-	-
-	Location of the Project: District 7	-	-	-	-
-	Eligibility of the Project for PAC	-	-	-	-
-	Annual Number of Projects in the District	-	-	-	-
-	Annual Value of Projects in the District	-	-	-	-
-	Annual Quantity of Asphalt Mixture in the District	-	-	-	-
-	Annual Number of Projects in other Districts	-	-	-	-
-	Annual Value of Projects in other Districts	-	-	-	-
-	Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-
S	**5.38482**				
R-Sq	**70.4%**				
R-Sq (adj)	**68.1%**				

CHAPTER 5
ANALYSIS OF THE RESULTS

5.1. INTRODUCTION

The results of chapter four indicate that the linear regression model is a reliable approach to model the variations of submitted bid prices for main asphalt line items. In this chapter, the results of regression models, created in the previous chapter, are analyzed. Significant explanatory variables and their coefficients in different models are compared to each other to check whether the explanatory variables show a consistent pattern in all models. The effects of offering PAC on explaining the variations of contractors' submitted bid prices for main asphalt line items are investigated across all models.

5.2. COMPARATIVE ANALYSIS OF THE RESULTS OF THE REGRESSION MODELS CREATED FOR THE SEVEN MAIN ASPHALT LINE ITEMS USING THE ENTIRE DATASET

In the previous chapter, the variations of the submitted bid prices for seven major asphalt line items were modeled using multivariate linear regression. Table 5-1 compares the coefficients of the explanatory variables in the models created for main asphalt line items using the entire dataset.

The results indicated that the quantity is a significant explanatory variable to model the variations of the submitted bid prices in all seven models. In all models, the coefficient of this variable is negative indicating that the bid prices are expected to decrease as the quantity increases. The quantity has the most explanatory power in the six out of the seven models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, 402-1802, and 402-4510); and in the other model (i.e., model for line item 402-3113), it is the second most important variable, to explain the variations of bid prices. Thus, quantity of the line items can be considered as one of the most significant factors that can describe the variations of submitted bids for the seven major asphalt line items.

Table 5-1: Coefficients of the variables in the models using the entire dataset

Variables	402-3190	402-3130	402-3121	402-1812	402-1802	402-3113	402-4510
Natural Logarithm of Quantity for the Item	-7.294	-6.422	-6.168	-6.009	-14.031	-3.815	-4.838
Natural Logarithm of Total Bid Price	5.263	4.499	4.590	4.312	6.373	2.607	1.987
AC Index at the Bid Date	0.053	0.053	0.050	0.058	0.060	0.049	0.060
Number of Bidders	-0.587	-0.626	-0.443	-0.507	-1.377	-	-0.576
Relative Value of the Line Item	24.446	14.488	16.178	43.155	59.727	-	-
Duration of the Project	-	-	-0.002	-	-	-	-
Rate of Change of the AC Index	-	-	-	0.062	-	-	-
Eligibility of the project for PAC	-	-	-	4.234	-	-	-
Bid Date: Between Sept. 05 and Aug. 09	14.432	12.363	14.320	9.390	10.014	15.063	10.027
Bid Date: Between Aug. 09 and Aug. 11	7.619	7.032	7.935	6.924	-	-	5.864
Bid Date: After Aug. 11	6.155	7.810	4.630	5.550	-	-	7.375
Location of the Project: District 1	-	-1.786	-	-	-	-	-
Location of the Project: District 2	-	-	-	-1.071	-	-	-
Location of the Project: District 3	-1.808	-1.993	-1.177	-3.339	-	-	-
Location of the Project: District 4	1.576	-	1.486	-	-	-	-
Location of the Project: District 5	4.560	3.146	3.527	3.441	6.100	6.290	7.226
Location of the Project: District 6	-	-	-	-1.941	-9.337	9.947	-
Location of the Project: District 7	-	-	-	-	-	-	3.088
Annual Number of Projects in the District	0.062	0.048	-	0.060	-	-	0.152
Annual Value of Projects in the District	-	-	-	-	3×10^{-8}	-	-
Annual Quantity of Asphalt Mixture in the District	-	-	-	-1.8×10^{-6}	-	-	-
Annual Number of Projects in other Districts	-	-	-	-	-	-	-
Annual Value of Projects in other Districts	10^{-8}	10^{-9}	10^{-8}	10^{-9}	10^{-8}	-	10^{-8}
Annual Quantity of Asphalt Mixture in other Districts	-1.5×10^{-6}	-	-6.5×10^{-7}	-5.9×10^{-7}	-	-	-3.2×10^{-6}
R-Sq (adj)	**84.3%**	**88.6%**	**85.6%**	**84.0%**	**56.3%**	**78.9%**	**85.3%**

The total bid price is a significant explanatory variable in all seven models with a positive coefficient indicating that the expected bid prices for major asphalt line items are relatively greater for large projects than those for small projects. The total bid price is the second most powerful explanatory variable in two models (i.e., models for line items 402-3190, 402-1812), the third most powerful explanatory variable in two other models (i.e., models for line items 402-3130, 402-1802), and is the fourth important variable in three other models (i.e., models for line items 402-3121, 402-3113, 402-4510).

Asphalt cement price index at the bid date is always a significant explanatory variable with a positive coefficient in all seven models indicating that the expected value of bid prices for main asphalt line items increases as the asphalt cement price index increases. This variable is among the most important explanatory variables in all seven models. Thus, asphalt cement price index at the bid date can describe the variation of the submitted bid prices for the seven major asphalt line items. The asphalt cement price index is the second most powerful explanatory variable in three models (i.e., models for line items 402-3130, 402-1802, and 402-4510), the third most powerful explanatory variable in three other models (i.e., models for line items 402-3121, 402-1812, and 402-3113), and is the fourth important variable in the other model (i.e., model for line item 402-3190).

The number of bidders is a statistically significant explanatory variable with a negative coefficient in all models but one (i.e., the model for line item 402-3113). The negative coefficient of this variable in these six models indicates that the expected bid price decreases as the number of bidders increases. Although the number of bidders is a significant variable in six out of the seven models, this variable does not make it to the list of the top five powerful explanatory variables in all models.

The relative value of the asphalt line item is a significant variable with positive coefficients in five out of the seven models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, and 402-1802). The expected bid price for any of these asphalt line items increases as the relative value of the line item increases. Considering relatively large t-statistics for this variable in all five models, the relative value of the asphalt line item can describe the variations of the five main asphalt line items.

The project duration is not a statistically significant explanatory variable for all models except for the model for line item 402-3121. Even for the model developed for the line item (402-3121), the t-statistics for the project duration is relatively low and hence, the project duration does not have considerably high explanatory power to explain the variation of submitted bid prices for main asphalt line items.

Although asphalt cement price index is a significant explanatory variable in all seven models, the change rate of the index is only significant in one of the models developed (for line item 402-1812). It can be concluded that the trend of the asphalt cement price is not a significant variable to describe the variations in the submitted bid prices for most asphalt line items.

The bid date between September 2005 and August 2009 is a significant binary variable for all models with positive sign, i.e., the expected bid price of any asphalt line item increases if the project was let during the period of September 2005 and August 2009. Similar conclusions can be made for the other two binary variables, the bid date between August 2009 and August 2011 and the bid date after August 2011, except that these two variables are not significant for the two of the models developed (for line items 402-1802 and 402-3113).

Variables representing the location of the project do not show any similar effects on explaining the variations of submitted bid prices for different asphalt line items. The binary variable representing district 5 is the only variable that is significant for all models with positive coefficients, i.e., the expected bid price for projects in district 5 is relatively higher than those in the other districts. The binary variable representing district 3 is significant in the four out of the seven models (i.e., models for line items 402-3190, 402-3130, 402-3121, and 402-1812) with negative coefficients, i.e., the expected bid price for projects in district 3 is relatively lower than those in the other districts for asphalt line items 402-3190, 402-3130, 402-3121, and 402-1812. However, none of the location variables have considerable large t-statistics even if they are identified to be statistically significant for modeling the variations of the bid prices. Overall, location is not a powerful explanatory variable to describe the variations of submitted bid prices for main asphalt line items.

Not very large t-statistics for the six explanatory variables related to the available projects in the project district and in other districts indicate that these variables do not have considerable explanatory power compared to the other variables. Annual number of projects in the district is significant with a positive coefficient in four models. However, number of projects in other districts is not significant in any models. Annual value of new projects in other districts is significant in six models. However, annual value of new projects in the districts is significant for only one line item. Finally, annual quantity of asphalt mixture in other districts is significant in four models with negative coefficients. Conversely, this quantity in the district is significant in only one model.

The annual value of projects in other districts is a significant variable for all models except the model for line item 402-3113. However, the coefficients of this variable in all models are very small and respective t-statistics are not substantially large. Hence, the annual value of projects in other districts does not have much power to explain the variations of the submitted bids for main asphalt line items.

Annual number of projects in the district is a significant variable in the four of the seven models, (i.e., models for line items 402-3190, 402-3130, 402-1812, and 402-4510), all with small coefficients and low t-statistics. Similarly, annual quantity of asphalt mixture in other districts is a significant variable in the four of the seven models, (i.e., models for line items 402-3190, 402-3121, 402-1812, and 402-4510), all with small coefficients and low t-statistics. Hence, both variables do not have much power to explain the variations of the submitted bids for main asphalt line items.

Annual value of projects and annual quantity of asphalt mixture in the district are significant in just one of the seven models. Annual value of projects in the district is only significant in the model for line item 402-1802 and annual quantity of asphalt mixture in the district is only significant in the model for line item 402-1812. Their respective t-statistics are not substantially large. Hence, both variables do not have much power to explain the variations of the submitted bids for main asphalt line items. It was found that the annual number of projects in other districts is not a significant variable in any of the models.

Finally, eligibility for the PAC is not a statistically significant explanatory variable in all models except the model developed for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in which the binary variable, eligibility of the project for PAC, becomes significant with positive sign, i.e., the expected bid price for asphalt line item 402-1812 is greater in PAC-eligible projects than that in PAC-ineligible projects. However, the t-statistics of the PAC variable is not substantially large. Thus, eligibility of the project for the PAC program does not have much power to explain the variations of the submitted bid prices for this line item.

5.3. COMPARATIVE ANALYSIS OF THE RESULTS OF THE REGRESSION MODELS CREATED FOR THE SEVEN MAIN ASPHALT LINE ITEMS BASED ON THE CONTRACTOR'S SIZE (BIG, MEDIUM, AND SMALL CONTRACTORS)

5.3.1. Big Contractors

Table 5-2 compares the coefficients of the explanatory variables in the models created for main asphalt line items using big contractors' bid data.

The results indicated that the quantity is a significant explanatory variable to model the variations of the submitted bid prices in all seven models. In all models, the coefficient of this variable is negative indicating that the bid prices are expected to decrease as the quantity increases. The quantity has the most explanatory power in the six out of the seven models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, 402-1802, and 402-3113); and in the other model (i.e., model for line item 402-4510), it is the second most important variable, to explain the variations of bid prices. Thus, quantity of the line items can be considered as one of the most significant factors that can describe the variations of submitted bids for the seven major asphalt line items.

The total bid price is a significant explanatory variable in all seven models with a positive coefficient indicating that the expected bid prices for major asphalt line items are relatively greater for large projects than those for small projects. The total bid price is the second most powerful explanatory variable in two models (i.e., models for line items 402-3190, 402-3121), the third most powerful explanatory variable in three other models (i.e., models for line items 402-3130, 402-

1812, 402-3113), the fourth important variable in one other model (i.e., model for line item 402-4510) and fifth important variable in the other model (i.e., model for line item 402-1802).

Asphalt cement price index at the bid date is always a significant explanatory variable with a positive coefficient in all seven models indicating that the expected value of bid prices for main asphalt line items increases as the asphalt cement price index increases. This variable is among the most important explanatory variables in all seven models. Thus, asphalt cement price index at the bid date can describe the variation of the submitted bid prices for the seven major asphalt line items. The asphalt cement price index is the most powerful explanatory variable in one model (i.e., model for line item 402-4510), the second most powerful explanatory variable in three models (i.e., models for line items 402-3130, 402-1812, and 402-3113), the fourth most powerful explanatory variable in three other models (i.e., models for line items 402-3190, 402-3121, and 402-1802).

The number of bidders is a statistically significant explanatory variable with a negative coefficient in all models but one (i.e., the model for line item 402-3113). The negative coefficient of this variable in these six models indicates that the expected bid price decreases as the number of bidders increases. Although the number of bidders is a significant variable in six out of the seven models, this variable does not make it to the list of the top five powerful explanatory variables in all models.

The relative value of the asphalt line item is a significant variable with positive coefficients in six out of the seven models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, 402-1802, and 402-3113). The expected bid price for any of these asphalt line items increases as the relative value of the line item increases. Considering relatively large t-statistics for this variable in all six models, the relative value of the asphalt line item can describe the variations of the six main asphalt line items.

The project duration is not a statistically significant explanatory variable for all models except for the model for line item 402-4510. Even for the model developed for the line item (402-4510), the t-statistics for the project duration is relatively low and hence, the project duration does not have considerably high explanatory power to explain the variation of submitted bid prices for main asphalt line items.

Although asphalt cement price index is a significant explanatory variable in all seven models, the change rate of the index is only significant in one of the models developed (for line item 402-1812). It can be concluded that the trend of the asphalt cement price is not a significant variable to describe the variations in the submitted bid prices for most asphalt line items.

The bid date between September 2005 and August 2009 is a significant binary variable for all models with positive sign, i.e., the expected bid price of any asphalt line item increases if the project was let during the period of September 2005 and August 2009. Similar conclusions can be made for the other two binary variables, the bid date between August 2009 and August 2011 and the bid date after August 2011, except that the bid date between August 2009 and August 2011 is not significant for the models developed for line items 402-1802 and 402-3113 and the bid date after August 2011 is not significant for the model developed for line item 402-3113.

Variables representing the location of the project do not show any similar effects on explaining the variations of submitted bid prices for different asphalt line items. The binary variable representing district 5 is the only variable that is significant for five models (i.e., 402-3190, 402-3130, 402-3121, 402-1802, and 402-4510) with positive coefficients, i.e., the expected bid price for projects in district 5 is relatively higher than those in the other districts. However, none of the location variables have considerable large t-statistics even if they are identified to be statistically significant for modeling the variations of the bid prices. Overall, location is not a powerful explanatory variable to describe the variations of submitted bid prices for main asphalt line items.

Not very large t-statistics for the six explanatory variables related to the available projects in the project district and in other districts indicate that these variables do not have considerable explanatory power compared to the other variables. Annual number of projects in the district is significant with a positive coefficient in three models. However, number of projects in other districts is not significant in any models. Annual value of new projects in other districts is significant in six models. However, annual value of new projects in the districts is not significant in any models. Finally, annual quantity of asphalt mixture in other districts is significant in four models. Conversely, this quantity in the district is not significant in any models.

The annual value of projects in other districts is a significant variable for all models except the model for line item 402-3113. However, the coefficients of this variable in all models are very small and respective t-statistics are not substantially large. Hence, the annual value of projects in other districts does not have much power to explain the variations of the submitted bids for main asphalt line items.

Annual number of projects in the district is a significant variable in the three of the seven models, i.e., models for line items 402-3130, 402-1802, and 402-4510, all with low t-statistics. Similarly, annual quantity of asphalt mixture in other districts is a significant variable in the four of the seven models, i.e., models for line items 402-3190, 402-3121, 402-3113, and 402-4510), all with low t-statistics. Hence, both variables do not have much power to explain the variations of the submitted bids for main asphalt line items.

Finally, eligibility for the PAC is a statistically significant explanatory variable in three models. In the model developed for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL),

the binary variable, eligibility of the project for PAC, becomes significant with positive sign, i.e., the expected bid price for asphalt line item 402-1812 is greater in PAC-eligible projects than that in PAC-ineligible projects. In the model developed for line item 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL), the binary variable, eligibility of the project for PAC, becomes significant with negative sign, i.e., the expected bid price for asphalt line item 402-3190 is lower in PAC-eligible projects than that in PAC-ineligible projects. In the model developed for line item 402-3130 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL), the binary variable, eligibility of the project for PAC, becomes significant with negative sign, i.e., the expected bid price for asphalt line item 402-3130 is lower in PAC-eligible projects than that in PAC-ineligible projects. However, the t-statistics of the PAC variable is not substantially large. Thus, eligibility of the project for the PAC program does not have much power to explain the variations of the submitted bid prices for this line item.

Table 5-2: Summary of the results for big contractors' sample dataset

Variables	402-3190	402-3130	402-3121	402-1812	402-1802	402-3113	402-4510
Constant	13.831	7.806	14.448	10.749	62.400	-5.81	36.050
Natural Logarithm of Quantity for the Item	-6.493	-5.749	-6.405	-5.374	-12.678	-5.036	-4.629
Natural Logarithm of Total Bid Price	4.918	4.528	4.802	4.016	5.067	4.431	2.803
AC Index at the Bid Date	0.044	0.048	0.042	0.056	0.044	0.065	0.060
Number of Bidders	-0.833	-0.489	-0.804	-0.901	-2.198	-	-0.500
Relative Value of the Line Item	21.920	15.080	19.291	39.381	39.326	17.451	-
Duration of the Project	-	-	-	-	-	-	-0.005
Rate of Change of the AC Index	-	-	-	0.072	-	-	-
Eligibility of the Project for PAC	-3.925	-1.978	-	3.196	-	-	-
Bid Date: Between Sept 05 and Aug 09	17.626	12.568	12.106	9.282	14.903	8.527	9.747
Bid Date: Between Aug 09 and Aug 11	11.674	5.729	8.424	7.023	-	-	3.795
Bid Date: After Aug 11	11.074	8.723	6.299	5.351	9.389	-	6.729
Location of the Project: District 1	-	-	-	-	-	-	-
Location of the Project: District 2	-	-	-	-1.446	-	-	-
Location of the Project: District 3	-	-	-	-2.933	-	-	-
Location of the Project: District 4	-	-	-	-2.128	11.194	-	-
Location of the Project: District 5	2.508	4.645	3.281	-	9.673	-	7.786
Location of the Project: District 6	-	2.421	-	-3.002	-5.871	8.113	-
Location of the Project: District 7	-	-	-	-	-	-	1.957
Annual Number of Projects in the District	-	0.064	-	-	0.277	-	0.161
Annual Value of Projects in the District	-	-	-	-	-	-	-
Annual Quantity of Asphalt Mixture in the District	-	-	-	-	-	-	-
Annual Number of Projects in other Districts	-	-	-	-	-	-	-
Annual Value of Projects in other Districts	10^{-8}	10^{-9}	10^{-8}	10^{-9}	10^{-8}	-	10^{-8}
Annual Quantity of Asphalt Mixture in other Districts	-1.2×10^{-6}	-	-8.8×10^{-7}	-	-	2.76×10^{-6}	-3.2×10^{-6}
R-Sq (adj)	**81.8%**	**90.5%**	**82.8%**	**85.2%**	**67.9%**	**80.1%**	**85.6%**

5.3.2. Medium Contractors

Table 5-3 compares the coefficients of the explanatory variables in the models created for main asphalt line items using medium contractors' bid data. Due to the small number of observations in the medium contractors' subgroup, the analysis cannot be performed on two line items: 402-3113 (Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL) and 402-4510 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL).

The results indicated that the quantity is a significant explanatory variable to model the variations of the submitted bid prices in all five models. In all models, the coefficient of this variable is negative indicating that the bid prices are expected to decrease as the quantity increases. The quantity is the most powerful explanatory variable in one model (i.e., model for line item 402-1802), the second most powerful variable in one model (i.e., model for line item 402-3190), and the third most important variable in three models (i.e., models for line items 402-3130, 402-3121, and 402-1812). Thus, quantity of the line items can be considered as one of the most significant factors that can describe the variations of submitted bids for the five major asphalt line items.

The total bid price is a significant explanatory variable in all five models with a positive coefficient indicating that the expected bid prices for major asphalt line items are relatively greater for large projects than those for small projects. However, the explanatory power of this variable is not as large as models using the entire data set and big contractors' bid data. The total bid price is the fourth most powerful explanatory variable in one model (i.e., model for line item 402-3121), the fifth most powerful explanatory variable in two other models (i.e., models for line items 402-3130, 402-1802), and the seventh important variable in two other models (i.e., models for line items 402-3190, 402-1812).

Asphalt cement price index at the bid date is always a significant explanatory variable with a positive coefficient in all five models indicating that the expected value of bid prices for main asphalt line items increases as the asphalt cement price index increases. This variable is among the most important explanatory variables in all five models. Thus, asphalt cement price index at the bid date can describe the variation of the submitted bid prices for the seven major asphalt line items. The asphalt cement price index is the most powerful explanatory variable in two models (i.e., models for line items 402-3130, and 402-3121), the second most powerful explanatory variable in two models (i.e., models for line items 402-1812, and 402-1802), and the fourth most powerful explanatory variable in one model (i.e., model for line item 402-3190).

The number of bidders is a statistically significant explanatory variable with a negative coefficient in only one model out of the five models for medium contractors' bid data (i.e., the model for line item 402-1812). The negative coefficient of this variable in this model indicates that the expected bid price decreases as the number of bidders increases.

The relative value of the asphalt line item is a significant variable with positive coefficients in two out of the five models (i.e., models for line items 402-1812, and 402-1802). The expected bid price for any of these asphalt line items increases as the relative value of the line item increases.

The project duration is not a statistically significant explanatory variable for all models except for the model for line item 402-1812. Even for the model developed for the line item (402-1812), the t-statistics for the project duration is relatively low and hence, the project duration does not have considerably high explanatory power to explain the variation of submitted bid prices for main asphalt line items.

Although asphalt cement price index is a significant explanatory variable in all five models, the change rate of the index is only significant in one of the models developed (for line item 402-

3130). It can be concluded that the trend of the asphalt cement price is not a significant variable to describe the variations in the submitted bid prices for most asphalt line items.

The bid date between September 2005 and August 2009 is a significant binary variable for all models with positive sign, i.e., the expected bid price of any asphalt line item increases if the project was let during the period of September 2005 and August 2009. Similar conclusions can be made for the other two binary variables, except that the bid date between August 2009 and August 2011 is not significant for the models developed for line items 402-3121 and 402-1802 and the bid date after August 2011 is not significant for the models developed for line items 402-3130, 402-3121, and 402-1802.

Variables representing the location of the project do not show any similar effects on explaining the variations of submitted bid prices for different asphalt line items. The binary variable representing districts 4, 5, 6, and 7 are not significant in any models. Moreover, none of the location variables have considerable large t-statistics even if they are identified to be statistically significant for modeling the variations of the bid prices. Overall, location is not a powerful explanatory variable to describe the variations of submitted bid prices for main asphalt line items.

The annual number of projects in the district, annual number of projects in other districts, annual value of projects in the districts, and annual value of projects in other districts are not a significant variable in any models. The annual quantity of asphalt mixture in the districts is a significant variable in only the model developed for item 402-3121 with low t-statistics. Also, annual quantity of asphalt mixture in other districts is a significant variable in only two models developed for items 402-3130 and 402-3121, all with low t-statistics. Hence, both variables do not have much power to explain the variations of the submitted bids for main asphalt line items.

Finally, eligibility for the PAC is a statistically significant explanatory variable in only one model developed for line item 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL). The variable has a negative sign coefficient, i.e., the expected bid price for asphalt line item 402-3190 is lower in PAC-eligible projects than that in PAC-ineligible projects. However, the t-statistics of the PAC variable is not substantially large. Thus, eligibility of the project for the PAC program does not have much power to explain the variations of the submitted bid prices for this line item.

Table 5-3: Summary of the results for medium contractors' sample dataset

Variables	402-3190	402-3130	402-3121	402-1812	402-1802	402-3113	402-4510
Constant	28.325	23.115	28.633	29.314	7.590	Impossible to develop the model because of lack of enough observations	Impossible to develop the model because of lack of enough observations
Natural Logarithm of Quantity for the Item	-3.044	-2.957	-3.865	-4.178	-13.167		
Natural Logarithm of Total Bid Price	2.151	1.830	2.147	2.288	7.905		
AC Index at the Bid Date	0.041	0.080	0.061	0.055	0.102		
Number of Bidders	-	-	-	-0.604	-		
Relative Value of the Line Item	-	-	-	23.729	223.770		
Duration of the Project	-	-	-	0.101	-		
Rate of Change of the AC Index	-	-0.173	-	-	-		
Eligibility of the Project for PAC	-9.722	-	-	-	-		
Bid Date: Between Sept 05 and Aug 09	27.807	13.210	11.741	16.758	32.706		
Bid Date: Between Aug 09 and Aug 11	18.106	3.869	-	12.297	-		
Bid Date: After Aug 11	18.896	-	-	13.025	-		
Location of the Project: District 1	-	-5.219	-	-9.293	-		
Location of the Project: District 2	-3.533	-	-	-3.008	-		
Location of the Project: District 3	-	-6.089	-	-3.131	-		
Location of the Project: District 4	-	-	-	-	-		
Location of the Project: District 5	-	-	-	-	-		
Location of the Project: District 6	-	-	-	-	-		
Location of the Project: District 7	-	-	-	-	-		
Annual Number of Projects in the District	-	-	-	-	-		
Annual Value of Projects in the District	-	-	-	-	-		
Annual Quantity of Asphalt Mixture in the District	-	-	-4.9×10^{-6}	-	-		
Annual Number of Projects in other Districts	-	-	-	-	-		
Annual Value of Projects in other Districts	-	-	-	-	-		
Annual Quantity of Asphalt Mixture in other Districts	-	1.2×10^{-6}	2.1×10^{-6}	-	-		
R-Sq (adj)	**91.1%**	**93.6%**	**91.7%**	**93.0%**	**57.8%**		

5.3.2. Small Contractors

Table 5-4 compares the coefficients of the explanatory variables in the models created for main asphalt line items using small contractors' bid data. Due to the small number of observations in the small contractors' subgroup, the analysis cannot be performed on two line items 402-3113 (Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL) and 402-4510 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, PM BM&HL).

The results indicated that the quantity is a significant explanatory variable to model the variations of the submitted bid prices in all five models. In all models, the coefficient of this variable is negative indicating that the bid prices are expected to decrease as the quantity increases. The quantity is the most powerful explanatory variable in two models (i.e., models for line items 402-3130, 402-1802), the third most powerful variable in two models (i.e., models for line items 402-3121, 402-1812), and the fourth most important variable in one model (i.e., model for line item 402-3190). Thus, quantity of the line items can be considered as one of the most significant factors that can describe the variations of submitted bids for the seven major asphalt line items.

The total bid price is a significant explanatory variable in all five models with a positive coefficient indicating that the expected bid prices for major asphalt line items are relatively greater for large projects than those for small projects. However, the explanatory power of this variable is not as large as models using the entire data set and big contractors' bid data. The total bid price is the second most powerful explanatory variable in one model (i.e., model for line item 402-1802), the fourth most powerful explanatory variable in one model (i.e., model for line item 402-3190), the fifth important variable in one model (i.e., model for line item 402-1812), the sixth important variable in two other models (i.e., models for line items 402-3130, 402-3121).

Asphalt cement price index at the bid date is a significant explanatory variable with a positive coefficient in four out of five models indicating that the expected value of bid prices for main asphalt line items increases as the asphalt cement price index increases. This variable is among the most important explanatory variables in all four models. Thus, asphalt cement price index at the bid date can describe the variation of the small contractors' submitted bid prices for the major asphalt line items. The asphalt cement price index is the most powerful explanatory variable in three models (i.e., models for line items 402-3190, 402-3121, and 402-1812), and the third most powerful explanatory variable in the other model (i.e., model for line item 402-3130).

The number of bidders is a statistically significant explanatory variable with a negative coefficient in only one model out of the five models for small contractors' bid data (i.e., the model for line item 402-1802). The negative coefficient of this variable in this model indicates that the expected bid price decreases as the number of bidders increases.

The relative value of the asphalt line item is a significant variable with positive coefficients in four out of the five models (i.e., models for line items 402-3190, 402-3121, 402-1812, and 402-1802). The expected bid price for any of these asphalt line items increases as the relative value of the line item increases.

The project duration is not a statistically significant explanatory variable for any model. Thus, the project duration does not have considerably explanatory power to explain the variation of small contractors' submitted bid prices for main asphalt line items.

Although asphalt cement price index is a significant explanatory variable in four models, the change rate of the index is not a statistically significant explanatory variable in any models. It can be concluded that the trend of the asphalt cement price is not a significant variable to describe the variations in the submitted bid prices for most asphalt line items.

The bid date between September 2005 and August 2009 is a significant binary variable for three out of five models (i.e., 402-3190, 402-3130, and 402-1812) with positive sign, i.e., the expected bid price of these asphalt line item increases if the project was let during the period of September 2005 and August 2009. The bid date between August 2009 and August 2011 is a significant variable for four models developed for line items 402-3190, 402-3130, 402-3121 and 402-1812 with positive sign, i.e., the expected bid price of these asphalt line item increases if the project was let during the period of August 2009 and August 2011. The bid date after August 2011 is a significant variable in only one model developed for line item 402-3130 with a positive coefficient, i.e., the expected small contractors' submitted bid price of line item 402-3130 increases if the project was let after August 2011.

Variables representing the location of the project do not show any similar effects on explaining the variations of submitted bid prices for different asphalt line items. The binary variables representing all districts except district 7 are statistically significant in the model developed for item 402-3121. However, none of the location variables have considerable large t-statistics even if they are identified to be statistically significant for modeling the variations of the bid prices. Overall, location is not a powerful explanatory variable to describe the variations of submitted bid prices for main asphalt line items.

The annual number of projects in the district, annual number of projects in other districts, annual value of projects in the districts, annual value of projects in other districts, and annual quantity of asphalt mixture in the district are not a significant variable in any models. Furthermore, the annual quantity of asphalt mixture in other districts is a significant variable in only the model developed for item 402-1812 with a low t-statistic. Thus, these variables do not have explanatory power to explain the variations of the small contractors' submitted bids for main asphalt line items.

Finally, eligibility of project for the PAC program is a not statistically significant explanatory variable in any models. Thus, eligibility of the project for the PAC program does not have much power to explain the variations of the submitted bid prices for main asphalt line items.

Table 5-4: Summary of the results for small contractors' sample dataset

Variables	402-3190	402-3130	402-3121	402-1812	402-1802	402-3113	402-4510
Constant	-8.500	37.708	19.130	1.892	-136.450	Impossible to develop the model because of lack of enough observations	Impossible to develop the model because of lack of enough observations
Natural Logarithm of Quantity for the Item	-8.653	-4.235	-7.605	-4.446	-27.964		
Natural Logarithm of Total Bid Price	7.608	2.478	6.900	3.628	24.537		
AC Index at the Bid Date	0.072	0.060	0.077	0.080	-		
Number of Bidders	-2.374	-1.676	-3.887	-	4.559		
Relative Value of the Line Item	33.373	-	31.140	22.020	602.400		
Duration of the Project	-	-	-	-	-		
Rate of Change of the AC Index	-	-	-	-	-		
Eligibility of the Project for PAC	-	-	-	-	-		
Bid Date: Between Sept 05 and Aug 09	14.177	15.586	-	12.738	-		
Bid Date: Between Aug 09 and Aug 11	13.187	13.009	15.336	6.788	-		
Bid Date: After Aug 11	-	10.244	-	-	-		
Location of the Project: District 1	-	-	14.650	-	-		
Location of the Project: District 2	-	-11.273	-26.420	-	-		
Location of the Project: District 3	-	-11.729	-38.140	-4.397	-		
Location of the Project: District 4	-	-	-24.130	-	-		
Location of the Project: District 5	-	-	-21.450	4.175	-		
Location of the Project: District 6	-	-	-21.770	-	-		
Location of the Project: District 7	-	-	-	-	-		
Annual Number of Projects in the District	-	-	-	-	-		
Annual Value of Projects in the District	-	-	-	-	-		
Annual Quantity of Asphalt Mixture in the District	-	-	-	-	-		
Annual Number of Projects in other Districts	-	-	-	-	-		
Annual Value of Projects in other Districts	-	-	-	-	-		
Annual Quantity of Asphalt Mixture in other Districts	-	-	-	10^{-9}	-		
R-Sq (adj)	**87.5%**	**89.7%**	**89.5%**	**85.0%**	**68.3%**		

5.4. COMPARATIVE ANALYSIS OF THE RESULTS OF THE REGRESSION MODELS CREATED FOR THE SEVEN MAIN ASPHALT LINE ITEMS USING PROJECTS AFTER AUGUST 2009

Table 5-5 compares the coefficients of the explanatory variables in the models created for main asphalt line items using the bid data after August 2009. Due to the small number of observations after August 2009, the analysis cannot be performed on the line item 402-3113 (Recycled Asphaltic Concrete 12.5MM, SP, GP1 or GP2, BM&HL).

The results indicated that the quantity is a significant explanatory variable to model the variations of the submitted bid prices in all six models. In all models, the coefficient of this variable is negative indicating that the bid prices are expected to decrease as the quantity increases. The quantity is the most powerful explanatory variable in five out of six models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, and 402-1802); and the second most powerful variable in the other model (i.e., model for line item 402-4510). Thus, quantity of the line items can be considered as one of the most significant factors that can describe the variations of submitted bids for the seven major asphalt line items.

The total bid price is a significant explanatory variable in five out of six models (i.e., 402-3190, 402-3130, 402-3121, 402-1812, and 402-1802) with a positive coefficient indicating that the expected bid prices for major asphalt line items are relatively greater for large projects than those for small projects. The total bid price is the second most powerful explanatory variable in two models (i.e., models for line items 402-3190 and 402-3121), the third most powerful explanatory variable in one model (i.e., model for line item 402-3130), the fourth important variable in one model (i.e., model for line item 402-1802) and the seventh important variable in one model (i.e., model for line item 402-1812).

Asphalt cement price index at the bid date is always a significant explanatory variable with a positive coefficient in all six models indicating that the expected value of submitted bid prices after August 2009 for main asphalt line items increases as the asphalt cement price index increases. This variable is among the most important explanatory variables in most of models. Thus, asphalt cement price index at the bid date can describe the variation of the submitted bid prices for the seven major asphalt line items. The asphalt cement price index is the most powerful explanatory variable in one model (i.e., model for line item 402-4510), the second most powerful explanatory variable in two models (i.e., model for line items 402-3130, and 402-1802), the third most powerful explanatory variable in one model (i.e. model for line item 402-3121), the fourth most powerful explanatory variable in one model (i.e., model for line item 402-3190), and the sixth most powerful explanatory variable in one model (i.e., model for line item 402-1812).

The number of bidders is a statistically significant explanatory variable with a negative coefficient in three models out of the six models (i.e., the model for line item 402-3190, 402-3130, and 402-1812) for submitted bid prices after August 2009. The negative coefficient of this variable in these models indicates that the expected bid price decreases as the number of bidders increases.

The relative value of the asphalt line item is a significant variable with positive coefficients in five models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812 and 402-1802) and a significant variable with a negative coefficient in the other model (i.e., model for line item 402-4510). The expected bid price for any of the first asphalt line items increases as the relative value of the line item increases. However, the expected bid price for the last asphalt line item decreases as the relative value of the line item increases.

The project duration is not a statistically significant explanatory variable for all models except for the model for line item 402-1812. Even for the model developed for the line item (402-1812), the t-statistic for the project duration is relatively low and hence, the project duration does not have considerably high explanatory power to explain the variation of submitted bid prices for main asphalt line items.

Although asphalt cement price index is a significant explanatory variable in all six models, the change rate of the index is only significant in one of the models (developed for line item 402-1812). It can be concluded that the trend of the asphalt cement price is not a significant variable to describe the variations in the submitted bid prices for most asphalt line items.

Variables representing the location of the project do not show any similar effects on explaining the variations of submitted bid prices for different asphalt line items. The binary variables representing districts 4 and 5 are significant for five out of six models (i.e., models for line items 402-3190, 402-3130, 402-3121, 402-1812, and 402-4510) with positive coefficients, i.e., the expected bid price for these line items in districts 4 and 5 are relatively higher than those in the other districts. However, none of the location variables have considerable large t-statistics even if they are identified to be statistically significant for modeling the variations of the bid prices. Overall, location is not a powerful explanatory variable to describe the variations of submitted bid prices for main asphalt line items.

The annual number of projects in the district, annual number of projects in other districts, annual value of projects in the districts, annual value of projects in other districts, annual quantity of asphalt mixture in the districts, and annual quantity of asphalt mixture in other districts are not statistically significant in models developed for line items 402-3190, 402-3130, 402-3121, and 402-4510.

The annual number of projects in the district, annual value of projects in the districts, annual quantity of asphalt mixture in the districts, and annual value of projects in other districts are identified as significant variables to explain the variations of submitted bid prices after August 2009 for line item 402-1812, all with low t-statistics. Also, annual quantity of asphalt mixture in the districts is a significant explanatory variable with a low t-statistics for line item 402-1802. Thus, these variables do not have much power to explain the variations of the submitted bids after Aug 2009 for main asphalt line items.

Finally, eligibility for the PAC is a statistically significant explanatory variable in only one model developed for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) with a positive coefficient, i.e., the expected bid price for asphalt line item 402-1812 is greater in PAC-eligible projects than that in PAC-ineligible projects.

Table 5-5: Summary of the results for the dataset after August 2009

Variables	402-3190	402-3130	402-3121	402-1812	402-1802	402-3113	402-4510
Constant	31.126	35.208	2.062	43.231	73.520	Impossible to develop the model because of lack of enough observations	69.935
Natural Logarithm of Quantity for the Item	-7.219	-5.525	-9.631	-6.163	-14.543		-2.494
Natural Logarithm of Total Bid Price	4.850	3.785	7.569	3.264	4.174		-
AC Index at the Bid Date	0.038	0.046	0.035	0.035	0.085		0.054
Number of Bidders	-0.535	-0.759	-	-0.342	-		-
Relative Value of the Line Item	27.447	8.611	71.470	46.943	61.970		-11.397
Duration of the Project	-	-	-	-0.005	-		-
Rate of Change of the AC Index	-	-	-	0.062	-		-
Eligibility of the Project for PAC	-	-	-	8.565	-		-
Location of the Project: District 1	-	-2.264	-	-	-7.430		-3.224
Location of the Project: District 2	-	-	3.151	2.708	-		-
Location of the Project: District 3	-	-	-	-	-10.539		-3.078
Location of the Project: District 4	6.848	3.259	8.639	7.087	-		6.531
Location of the Project: District 5	8.067	6.035	8.332	9.016	-		9.256
Location of the Project: District 6	-	-	-	-	-13.283		-5.367
Location of the Project: District 7	-	-	2.508	-	-		-
Annual Number of Projects in the District	-	-	-	-0.167	-		-
Annual Value of Projects in the District	-	-	-	-4×10^{-8}	-		-
Annual Quantity of Asphalt Mixture in the District	-	-	-	1.19×10^{-5}	1.32×10^{-5}		-
Annual Number of Projects in other Districts	-	-	-	-	-		-
Annual Value of Projects in other Districts	-	-	-	10^{-9}	-		-
Annual Quantity of Asphalt Mixture in other Districts	-	-	-	-	-		-
R-Sq (adj)	**57.0%**	**64.1%**	**67.7%**	**60.5%**	**60.2%**		**68.1%**

5.5. CONCLUSIONS

The characteristics and volatility of the price of asphalt cement in the state of Georgia were studied and time series forecasting models were created to predict the future prices of asphalt cement in the state of Georgia. Multivariate linear regression analysis was conducted to model the variations of the submitted bid prices for seven major asphalt line items. The results of the regression models identified several explanatory variables that are statistically significant to explain the variations of the submitted bid prices of major asphalt line items. It is concluded from the results of analyses on the entire dataset that:

1. There is a linear relationship between the response variable (bid price) and a combination of several explanatory variables, such as quantity, total bid price, and asphalt cement price index.
2. Although the quality of the model varies in each line item, linear regression is capable of capturing and explaining the majority of variations in the bid price.
3. For the most parts, explanatory variables in all seven models created for major asphalt line items are similar to each other.
4. In general, the most powerful explanatory variables for explaining the variations of the submitted bid prices are the quantity of the line item, total bid price of the projects, asphalt cement price index at the bid date, and let date between September 2005 and August 2009.
5. Eligibility for the PAC is not statistically significant in all models except the model for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in which this variable has a positive coefficient indicating that the expected bid prices for major asphalt line items in PAC-eligible projects are higher than those in PAC-ineligible projects.

Similar analyses were performed separately based on the contractor's size, big, medium, and small contractors. It is concluded that:

1. Although the quality of the model varies in each line item and across the sample datasets, linear regression is capable of capturing and explaining the majority of variations in the submitted bid price.
2. For the most parts, the most powerful significant explanatory variables in all models created for big, medium, and small contractors' submitted bid prices are similar to the most powerful significant variables in the models using the entire data set.
3. Eligibility for the PAC program is statistically significant in explaining the variations of the bid prices in three line items in the big contractors' sample dataset. The expected bid prices for major asphalt line items in PAC-eligible projects for line items 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL) and 402-3130 (Recycled Asphaltic Concrete 12.5MM, SP, GP2, BM&HL) are lower than those in PAC-ineligible projects. However, similar to the model using the entire dataset, the expected bid prices for major asphalt line items in PAC-eligible projects for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) are higher than those in PAC-ineligible projects.
4. Eligibility for the PAC program is statistically significant in explaining the variations of the submitted bid prices by medium size contractors in two line items: 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in which this variable has a positive coefficient indicating that the expected bid prices in PAC-eligible projects are higher than those in PAC-ineligible projects and 402-3190 (Recycled Asphaltic Concrete 19MM, SP, GP1 or GP2, BM&HL) in which this variable has a negative coefficient indicating that the

expected bid prices in PAC-eligible projects are lower than those in PAC-ineligible projects.

5. Eligibility for the PAC program is not statistically significant in explaining the variation of the small contractors' submitted bid prices for major asphalt line items.

Finally, since the specific PAC provisions for asphalt cement in the state of Georgia was changed in August 2009, the regression models were created for the projects with let dates after August 2009. It is concluded that:

1. Except one line item that does not have enough observations, a linear relationship between the response variable (bid price) and a combination of several explanatory variables was detected.
2. Although the quality of the model varies in each line item, linear regression is capable of capturing and explaining the majority of variations in the bid prices.
3. The most powerful significant explanatory variables to explain the variations of the submitted bid prices for major asphalt line items in the models using bid data after August 2009 are similar to those observed in the models using the entire dataset and models of big, medium, and small contractors.
4. Similar to the models using the entire dataset, eligibility for the PAC program is statistically significant in explaining the variations of the bid prices in only one of the models developed for line item 402-1812 (Recycled Asphaltic Concrete Leveling, BM&HL) in this group of projects. Since the coefficient of this variable is positive, the expected value of the bid price for this line item is higher in PAC-eligible projects than those in PAC-ineligible projects.

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