5-2008

ANALYSIS OF THE IMPACT OF FUEL PRICE AND BIDDING VOLUME ON THE ENGINEER'S ESTIMATE

Greaton Sellers

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ANALYSIS OF THE IMPACT OF FUEL PRICE AND BIDDING VOLUME ON THE ENGINEER’S ESTIMATE

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

by
Greaton W. Sellers Jr.
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Accepted by:
Dr. Lansford C. Bell, Committee Chair
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ABSTRACT

The research project “Analysis of the Impact of Fuel Price and Bidding Volume on the Engineer’s Estimate” was initiated by the South Carolina Department of Transportation and conducted by Clemson University. This research was executed as a two part study, “Best Practices for Developing the Engineer’s Estimate”, which addressed two distinct but related objectives. The first research objective was to fully explore the advantages and disadvantage of alternative methodologies utilized to compile the engineer’s cost estimate. This research objective is addressed in Report Volume I. The second research objective, which is addressed in this Report Volume II, was to develop a methodology for adjusting selected unit cost bid line items to account for fluctuations in fuel prices and bid volume.

This research report details the methodology utilized to determine and then adjust unit cost line items that would need to be adjusted during the bidding process based on the current fuel price or bidding volume at SCDOT. Thirty-three unit cost line items were identified that may need to be estimated differently in the future, either using an alternative estimating methodology or using the adjustment techniques described within this report. Of the 33 line items that were identified and analyzed, 28 bid line items contained sufficient data points to conduct a regression analysis. Regression plots and algorithms were developed for the 28 unit cost line items believed to be most sensitive to fuel prices and bid volume. These analyses can then be used to adjust unit cost line items during the bidding process based on fluctuations in the fuel prices or bidding volume per
month. This research describes the regression plots and analyses as well as suggestions for implementing the proposed approach for bid line item adjustments for the SCDOT.
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CHAPTER 1

INTRODUCTION

State departments of transportation utilize varying approaches to develop a pre-bid cost estimate, or what is generally termed the engineer’s estimate. In addition, each state approaches making adjustments to bid line items in a different manner. The South Carolina Department of Transportation (SCDOT) is currently utilizing an estimating approach referred to in the literature as “unit cost line item estimating” or bid history estimating. Using this approach an estimator determines the cost of a line item by preparing the unit cost line item estimated cost using historical data. The final engineer’s estimate for the project is then obtained by determining the line item cost for all inputs to a project and summing them into a detailed estimate. This approach is utilized by many states in producing the engineer’s estimate because it allows for the assimilation of historical data based on pertinent information such as location, size, and work type. However, many of the line items within an estimate are sensitive to fluctuations in fuel price and bidding volume. Therefore, adjustments must be made for the items that are fuel and asphalt or bid volume sensitive. SCDOT currently has a method of making adjustments for fuel and asphalt prices post-bid based on the work type and quantity. SCDOT initiated a research project to determine if there was a tool or methodology that can be employed to factor in the cost of fuel and asphalt price fluctuations prior to the bid letting process. SCDOT personnel were also interested in determining if bid volume affected the price of these bid line items as well and if there was a way to adjust prices for bidding volume. The research described herein was initiated to explore these issues.
Problem Statement

SCDOT is presently utilizing a form of estimating procedures known as unit cost line item estimating. There are three major disadvantages to this estimating methodology. The first disadvantage being that the historical data used to produce the estimate contains all bid data from previous projects, some of which can contain unbalanced bids given by contractors. One example of an unbalanced bid is when a bid will have the price for a line item inflated while the quantity may be understated. By doing this the contractor is able to keep the bid price at the same level as if it were not unbalanced. In the end when the quantity escalates, the price for that line item will increase drastically. The second disadvantage to unit cost line item estimates is that the bid unit prices can vary greatly depending on work item quantity. The third potential disadvantage to using the unit cost line item methodology to prepare the engineer’s estimate is that historical database unit prices may be affected by economic conditions that are no longer present at the time of the bid submissions. Because of this third disadvantage the SCDOT suggested a statistical analysis to determine how the economic factors of fuel price and bid volume affect the historical data contained in the database of unit cost line item prices. SCDOT determined that the economic variables of interest were fuel price and bidding volume based on the recent fluctuations in fuel price as well as continuous fluctuations in the volume of bids that were let to contract in the industry.

Since the engineer’s estimate is created as much as six weeks prior to the bidding process, contractor’s bids differ significantly from the engineer’s estimate reflecting recent fluctuations in the fuel and asphalt price. This is due to the fact that contractors
are constantly adjusting the estimates until the time for bid submission. Therefore, a contractor’s bid may reflect a recent change in fuel prices whereas the engineers estimate would not. Another economic factor that SCDOT believed would be worth examining was the impact of anticipated bidding volume at the time of the bid letting. This is because the number of lettings directly affects the amount of work already in progress. This can impact the extent to which contractors need or want work, a fact that may affect the bidding price of a project. If a specific geographic area is currently saturated with work, a contractor may not want the work unless it is well compensated for the project. Conversely, if the workload is light, a contractor may be more competitive with their pricing in order to secure the project. To determine how these factors would affect contractors’ bid prices compared to the engineer’s estimate, a detailed statistical analysis was undertaken by Clemson University. To be able to increase the accuracy of the engineer’s estimate, methodologies for adjusting unit cost line items which are fuel and asphalt intensive or bid volume sensitive were developed and are described in this report.

**Objective and Scope of Research**

To improve the estimating process, SCDOT initiated a research project, “Best Practices for Developing the Engineer’s Estimate,” to develop a methodology for adjusting selected unit cost line items to account for fluctuations in fuel and asphalt prices and for bidding volume. This research was conducted as part of an SCDOT funded project that had two objectives. The first research objective was to determine the
comparative advantages and disadvantages of cost based estimating versus unit cost line item estimating. This research objective is addressed in research report Volume I.

The major focus of the second phase of the research was to propose a methodology for making adjustments to specifically chosen unit cost bid line items impacted by fuel/asphalt and bidding volume fluctuations. In order to complete this task a number of objectives had to be completed. The first objective of this research was to conduct a thorough literature review to identify any current research into this area as well as any sources containing pertinent information concerning this area of research. In order to move forward in the statistical analysis of the data, another objective was put forth to identify specific line items that are affected by fuel and asphalt to create a subset of data for analysis. Using the data for these line items, a statistical analysis was conducted on the low bid price and engineer’s estimate so that a recommendation of a methodology for making adjustments to the identified unit cost line items could be made. So that such a scope could be achieved, further objectives were identified concerning the analysis of the data. A preliminary analysis of the data was conducted to determine if there are any outliers in the data set that could skew the results of the research as well as to determine the causes of such erroneous data. Relationships between the engineers estimate and low bid price were investigated through the use of correlation and regression analyses to help identify interactions between the data being analyzed. Also, the relationship between the low bid price and fuel price were explored using correlation and regression analyses in order to determine the response that the low bid has to a change in the fuel price. The low bid price and bidding volume data was also be examined using correlation and regression
analyses to determine the relationship between the variables caused by a change in the bidding volume. These research objectives allowed the research team to determine a methodology for adjusting the engineer’s estimate that will permit SCOT to more accurately determine their engineer’s estimates during the bidding process. Low bid data was utilized in this analysis because South Carolina is currently a state that accepts the lowest competent bidders bid offer.

Research Methodology

Such that a methodology for adjusting selected unit cost line items to account for fluctuations in gasoline and asphalt prices and for bidding volume could be developed, an analysis of SCOT’s unit cost line items from previous projects was conducted. The data provided by SCOT was in a Microsoft Office Access Database. The data spanned all of SCOT’s bid lettings for the dates of January 1996 through October 2005. The data was segregated into two databases: Bid History and Project Description. There were a total of 2440 projects let to bid during this time period. Within the Bid History Database these projects were identified by Bid Analysis Management System (BAMS) numbers. There were a total of 6932 different BAMS numbers types also known as pay items. During a meeting with the Research Steering Committee at SCOT, specific pay items of interest were identified for analysis.

The SCOT Research Steering Committee identified a total of 44 different pay items, also referred to as Unit Cost Line Items, which were believed to be impacted by fuel and asphalt price. These 44 items were then analyzed to determine if there was
sufficient data to perform a meaningful statistical analysis. It was determined that 33 of
the 44 items identified contained sufficient data points for a preliminary analysis. These
are identified in Table 1-1. These 33 unit cost line items were then analyzed using three
different software packages: Microsoft Office Access, Microsoft Office Excel, and SAS
9.1.
## Table 1-1: Bid Line Items Impacted by Fuel and Asphalt Adjustments

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Using the querying tool in Access, the two databases, Bid History and Project Description, were combined such that the unit cost line item bid prices were paired with their letting dates as well as other items from the project description using their corresponding file numbers. Once this data was combined, such that the determined analyses could be conducted on the line items, the data was then imported into Microsoft Office Excel. After the data was in Excel, a preliminary analysis was conducted.

The unit cost line item data was converted from the Microsoft Access database to a Microsoft Excel spreadsheet to permit a more detailed analysis. So that this analysis can be performed, the fuel price index and bidding volume per month had to be determined. Due to the fact that an accurate asphalt price index for the Southeast could not be established, it was assumed that asphalt prices could be related to fuel prices and therefore the fuel price index was used. The fuel price index was found using the average gas prices for the east coast found at the US Department of Energy on the Energy Information Administration website. This data was then imported into Excel as well to be used in the analysis. The bidding volume per month was then determined using the Access database provided by SCDOT. Using the project description database the number of lettings per month was determined by counting the different projects let for each consecutive month per the request of the steering committee. This data was then entered into an Excel spreadsheet to be used in the analyses. After all the data had been imported into Excel it was determined that only the data for 2000 through 2005 would be used in the analysis due to the fact that the 1996 through 1999 data was out of date and most likely would only skew the analysis because it was assumed that fuel prices will not reach
a price such as this again. Once this data was removed, an initial analysis was conducted to visually examine how the data correlated with fuel prices and bid volume. After this analysis was conducted it was clear that there were extremes or outliers within the data sets. The data was then integrated into a program called SAS 9.1 or Statistical Analysis Software to examine the data and identify any outlying or extreme data that was in the historical data set. The data was analyzed using a student residual regression analysis. A student residual is the residual value, or the observed error, divided by an estimate of its standard deviation. These outliers were identified as bid prices with student residuals in excess of 2.0 deviations from the mean. The outliers were identified and removed from each of the line item datasets to produce a more appropriate data set for analysis. SAS 9.1 was also utilized to determine if there was a linear relationship among the differing variable; low bid price, engineer’s estimate, fuel price, and bidding volume; by utilizing a residual regression analysis. After theses analyses were conducted in SAS 9.1, the data was then imported back into Excel and a similar analysis was conducted to the preliminary analysis in order to see how the low bid price and engineer’s estimate now correlated with the variables of bidding volume and the fuel price index. Once this analysis was conducted, it was used to visualize the correlations between the variables. An analysis was also conducted on the data to determine if there were any items which had a direct correlation between the engineer’s estimate and the low bid price.

After conducting the initial analysis of the data, a correlation analysis was executed for each of the line items low bid prices with the two variables, bidding volume and fuel price index, to determine exactly how well each item correlated. Before
beginning the analysis it was determined that although some line items would probably correlate highly some would not. This is due to the type of data that is involved and the fact that there are many external influences that can arise in the highway construction industry such as: quantity of work, location, pre-existing conditions, and contract conditions. In most statistical analyses a correlation of 70 percent is considered a sufficient correlation to be considered significant, but due to the numerous exterior circumstance in the construction industry it was determined that a correlation of 40 percent would be considered as significant and anything above 70 percent would be considered as highly correlated. Once the correlation analysis was complete a regression analysis was then conducted on the bid line items. This regression analysis provides a regression line as well as a 95 percent confidence interval that could be used as a tool to determine if an engineer’s estimate is within acceptable parameters. If there was a high correlation present between the low bid price and the variables, the regression line would be able to be used as a direct pricing tool for a given fuel price or bidding volume. A linear regression was utilized due to the fact that during the preliminary analysis it was established that, for the unit cost line items, there was a random scattering of the residuals as well as a normal distribution of the errors. This was determined by conducting a residual regression analysis using Statistical Analysis Software 9.1 or SAS 9.1. By using these tools, the regression line and the 95% confidence interval, SCDOT will be able to insure that its estimate is significantly accurate before proceeding with the bid letting process.
Research Steering Committee

So as to effectively execute the research project “Best Practices for Developing the Engineer’s Estimate,” SCDOT formed a Research Steering Committee, comprised of SCDOT personnel who were familiar with the estimating and bidding process. Updates on the research team’s progress were provided to the steering committee by means of quarterly progress reports that were prepared and delivered to the Steering Committee. The current progress, methodology, and the path forward were discussed in meetings held at SCDOT quarterly between the Research Steering Committee and the research team. The steering committee provided feedback to the research team on a regular basis based on the reports provided to the committee and meetings held at SCDOT. Dr. Lansford Bell served as research project principle investigator and Dr. Lawrence Grimes, professor, Department of Experimental Statistics, served as a data analysis consultant.
CHAPTER 2

LITERATURE REVIEW

An extensive literature review was conducted that related to the research objectives cited in the Volume I and Volume II reports. Resources utilized included the SCDOT’s Standard Estimating Specifications, proceedings from the Federal Highway Administration (FHWA), the Transportation Research Information Services (TRIS), the Transportation Research Board (TRB), the Association for Advancement of Cost Engineering (AACE), the American Association of State Highway and Transportation Officials (AASHTO), the Clemson University Library Databases, and the Auburn University Archives. One objective of the literature review was to compile information that would aid in clarifying and, if necessary, expanding the scope of the proposed research. The literature review was conducted to enhance the comprehension of fuel and asphalt adjustments to the engineer’s estimate, current price trends in oil and asphalt, identify price indices that would be utilized in the analysis, and determine procedures for post bid compensation. The literature review was executed using key word search criteria that included: engineer’s estimate, cost estimating, unit price estimates, estimators, estimating methods, cost estimators, the engineer’s cost estimate, fuel and asphalt trends or relationships, and bidding volume. Much of the information obtained during this literature review process was related to the objective of the research study cited in research report Volume I.

As a component of the research objective addressed in the Volume I report, a survey was forwarded to all state U.S. Department of Transportations in anticipation of
receiving sufficient responses for a meaningful analysis. Twenty-two of the DOTs returned the survey to the research team. Within the survey, state DOT’s were asked if they would be willing to provide specific procedures, reports, fuel and asphalt adjustment factors, or handbooks. A number of states provided their methodology for making fuel and asphalt adjustments. These methodologies are summarized in the following sections of this report. A detailed analysis of the survey responses is included as part of the Volume I report.

Fuel Price Adjustments

So as to determine how other states executed the process of making adjustments for fuel prices a literature review was conducted using the sources stated in the research proposal. During the literature review, sources were identified including the supplementary specification of SCDOT and NCDOT. Also, a number of states provided documentation from their supplementary specifications dealing with this topic including Idaho, Utah, Nevada, and South Dakota.

As part of the initial literature review a typical supplementary specification for SCDOT concerning fuel adjustments was examined. This document addresses the reasons for and ways of calculating fuel price adjustments. The document stated that fuel adjustments would be applied to monthly payments when it is determined that the price index for diesel and unleaded fuels increased or decreased more than 10%. It also stated that there would be no other adjustments made until the price index changed another 10% (1). The document also discussed the way in which the fuel adjustments would be
calculated. It contains a table of fuel usage factors that would be used in determining the fuel adjustments for excavation, embankment in place, sandy clay base course, hot asphalt paving mixes, and reinforced concrete paving (1). These usage factors are then multiplied by the price change to determine the fuel adjustments. This is determined for both diesel and unleaded fuel and is then applied to the contract price. During one of the meetings with the Research Steering Committee, an amendment memorandum to this document was forwarded to the research team. This amendment memorandum contained adjustments to the contract time, threshold quantities, and work items adjustments that would be made to for fuel price changes (2). The proposed amendments would reduce the contract time criterion from one year to six months and lower the quantity thresholds. Both of these amendments make it easier to obtain fuel adjustments. The memorandum also suggests amending the items for which fuel adjustments would be authorized. It suggested that the items for fuel adjustment now be excavation, embankment in place, sand clay base course 6” and 8” uniform, graded aggregate base course 6” and 8” uniform, hot mix asphalt, full depth patching 4”, 6”, 8”, 10”, and 12”, concrete pavement, structural concrete, and RC Pipe of all sizes (2). These amendments appear to make it easier for the contractor to receive compensations for fluctuations in fuel prices as well as better define the items for which the contractor can be compensated.

The second fuel related information source examined during the initial literature review was the fuel price adjustment clause within the standard specifications of North Carolina Department of Transportation (NCDOT). This source documents the conditions for receiving compensation and how to calculate the compensation that will be received.
The document discussed an equation that NCDOT uses to determine the amount for adjustments to the contract price. It incorporates the quantity of the contract item, the fuel usage factor for the contract item, the base index price, and the average terminal price to determine what is referred to as the fuel price adjustment for partial payout. It states that the terminal price for the month will be used to calculate costs no matter how many fluctuations occurred in the month (3). The document also discusses the items for which fuel adjustments can be received. An amendment to this item list was also found. The amendment stated that bidders would have the opportunity to opt out of the fuel asphalt adjustments in the contract (4). The adjustment also made some of the categories for fuel adjustment more broad, such as instead of listing the type of asphalt concrete surface course it just has a space to enter the type of surface course used. The methodology used for fuel adjustments in North Carolina is similar to that of South Carolina except for the use of the base index price and average terminal price in the equation to determine the adjustment amount.

As part of the survey of other state’s practices, a number of documents were procured from various states. These documents contained information about each of these states’ practices related to fuel adjustments. These states included Idaho (5), Utah (6), Nevada (7), and South Dakota (8). Each of these documents explained the methodology for making adjustments to certain contract line items for fuel price fluctuations. Each state had a slightly different methodology that they would use to execute the contract adjustments. Each of these states used an equation to estimate the fuel adjustment to differing contract items. Some states used pre-stated fuel usage factors
depending on what type of work was being conducted. Other states would determine such factors when drafting the contract to be included in the provisions. Most states have a predetermined percent of change in fuel price that determines when a fuel adjustment is authorized. The adjustments varied between a 15% and 25% increase or decrease in fuel price for most states (5, 6, 7, 8).

Utah’s provisions allowed the contractor the ability to enact the fuel adjustment clause instead of having a stated percentage that would invoke the fuel adjustments, after which point the fuel adjustments would be effective for the duration of the contract (6). While most equations were similar, South Dakota uses a much more complex form of equation to determine the fuel price adjustments. There are actually three different equations that must be employed to determine the final adjustment price. The first equation determines the percentage change in fuel cost to be used to determine the adjustments. The second equation determines the percent of the contract made up by each respective item. The third equation determines the fuel cost adjustment for each item (8). These four states all used similar methodology to determine the fuel adjustments and all had some form of equations that they employed to determine the final adjustments to be made to the contract items.

**Fuel Price/Bid Price Relationship**

In order to determine how the bid price relates to the increasing price of fuel, research was conducted to determine if a relationship between the variables had already been established. Sources were identified that discussed a relationship between the
fluctuation in fuel prices and bid price. Surveys were identified that were conducted by the FHWA and AASHTO as well as by PinnacleOne that described fuel costs as a major contributor to the rise in construction bid prices. A number of reasons were also addressed as causes for the increase in fuel price that, in return were causing fluctuations in bid prices for fuel and asphalt based projects.

In a survey, conducted by the FHWA and AASHTO (9), of the differing state department of transportations, a question was posed stating:

“Is your state experiencing significant cost increases in construction bids relative to similar previous projects?”

Eighty-nine percent of the respondents indicated that construction bids had increased while 77% acknowledged that these bids had increased considerably. The average increase for these states over the years of 2003, 2004, and 2005 was 5.8%, 12.7%, and 17.1% respectively. Several DOTs saw higher than average fluctuations in these years including the District of Columbia, Colorado, and Utah, who saw increases of 35%, 51.9%, and 70.2% in 2005. California saw an increase of 45.5% in 2004 and Virginia saw an average increase of 35% across 2004 and 2005. Fuel and oil costs were indicated as a major contributing factor in most responses received in the survey (9). In a similar study, a survey was conducted by PinnacleOne that stated for a time period between August 2004 and August 2005, construction costs increased an average of 13.2%. In the 2005 survey, oil and fuel prices were viewed as the major contributor to the price increase as well as the reason why the costs would continue to increase in the future by the majority of the respondents (10). The rise in fuel prices, which caused these fluctuations in bid prices, has been influenced by many factors in the global market today.
As of 2004, the world oil market and tight oil inventories in the US seemed to have a significant influence on the liquid asphalt market. These oil shortages, which were amplified by the war in Iraq (11), were further compounded by the impact of Hurricane Katrina as well as many other hurricanes making landfall in the US in 2005. Katrina damaged numerous offshore oil rigs as well as many refineries and pipelines in the Gulf coast area from Alabama to Louisiana. This greatly diminished the refining abilities of the United States and increased our dependence on foreign oil (12). In 2005, it was estimated that, due to Katrina, construction costs could escalate a total of 10% to 20% by 2007 (10). Fluctuations in such products as liquid asphalt can depend greatly on the price of oil, especially on the east coast. This is due to the process used in creating the liquid asphalt because

“About 65% of every barrel of heavy oil refined ends up as liquid asphalt (11).”

At these plants, were heavy oil is used to produce the asphalt, as crude oil prices increase, the price to produce liquid asphalt increases at a similar rate. One of the major concerns associated with the rising costs of bids and ultimately the rising cost of fuel prices is that if these prices continue to increase in this manner, it may reduce the amount of work that can be taken on by the industry as states and companies begin to use their existing funds to cover fewer and fewer projects (11).

**Asphalt Price Adjustments**

Other states perform their asphalt price adjustments in different ways. In order to determine ways in which this process is conducted a literature review was performed
using the sources stated in the research proposal. Two sources were found on the SCDOT website. Also, an article called “Oil Prices Can’t Keep Contractors Down” was found which was addressed in research report Volume I (13). Additional relevant resources were procured during the survey analysis portion of the research.

The two resources that were examined from the SCDOT webpage were the price adjustments indexes for liquid asphalt binder and for bituminous surfacing. The price adjustment index for liquid asphalt binder stated that:

“…adjustments to the contract unit price for liquid asphalt binder will be made based on changes in the Monthly Liquid Asphalt Index Price....changes will be made when the Monthly Liquid Asphalt Index Price for the District increases or decreases in excess of 5% of the Basic Liquid Asphalt Index Price. Further adjustments will be made as each additional 5% increment is exceeded (14).”

The document also included a table that would be used to calculate the adjustments to the unit price of the liquid asphalt binder by using the percent change index based on the current basic liquid asphalt index price. This table was set for the date of September 1, 2005 and the basic liquid asphalt index price is adjusted bi-monthly. The price adjustment index for bituminous surfacing works in the same way as the adjustment index for liquid asphalt binder. Constraints on receiving the compensation also were the same. The adjustment tables for bituminous surfacing were dependant on the percent change increment and whether it was a single, double, or triple treatment as well as the class of surface used (15). These two sources represented the methodology SCDOT uses to make adjustments to the asphalt prices of contract items based on the fluctuations in asphalt price.
During the survey analysis portion of the research two different states included their specifications for asphalt adjustments. Both Utah and Nevada provided a portion of their specifications documenting the methodology that was used to make adjustments to contract items concerned with high levels of asphalt that might need adjustments due to the escalating prices of asphalt. The Nevada DOT asphalt adjustment clause only allowed for adjustments to asphalt cement and did not apply to liquid or emulsified asphalts (7) whereas Utah would make adjustments to all three categories of asphalt materials (6). As for how the adjustment was determined, both states used an equation to determine the magnitude of the adjustment. Both states used differing criteria within the equations to determine the asphalt adjustments but they seemed to be trying to achieve the goal in similar manners. Nevada would implement the asphalt adjustments in the scenario in which the asphalt cement price fluctuated more than 20% in either direction (7). As with fuel adjustments, Utah again permitted the contractor to decide when they wanted the asphalt adjustment to be implemented and then the adjustment would be exercised for the remainder of the contract (6). These two states, while approaching the asphalt adjustments similarly, stated some differences in the way it was applied to the contract.

**Bid Volume Adjustments**

With the purpose of determining ways to make adjustments to the engineer’s estimate for bid volume, a search was conducted using the resources stated in the
research proposal. A thesis based on the purpose of determining ways to minimize instability in the construction industry was examined as part of the literature review.

“An Introductory Analysis of the Behavior of the Alabama Highway Industry”, an MS thesis written by Phillip Moon at Auburn University in 1972 discussed a number of instabilities that caused fluctuations in unit price trends for bids from 1950 to 1970 (16). The number of construction projects let to bid over a specific period of time was one of the major reasons for these instabilities that were identified in the thesis with the author stating:

“The author identified the continuously fluctuating number of available projects as a major determinant of the instability.”

The author also states that:

“One recurring problem is that of ‘feast or famine’. This term is common in the construction vernacular and is used to describe the relative availability of projects to be constructed. A large number of construction projects offered for bids is referred to as a ‘feast’; a small number of projects offered for bids is referred to as a ‘famine’.”

The major concept of “feast or famine” within the construction industry is discussed. The author explains its effects on bid price by stating:

“There is a tendency for contractors to continually expand their organizations during peak periods of activity, while recognizing the serious problems of reduction during a recession in activity. The result is a tendency on the part of contractors and workers to seek higher benefits for their efforts with the thought in mind that “famine” times may lie ahead.”

This thesis stated that the perfect situation would be when the demand for new construction is the same as the available capacity of contractors. The author also endeavors to explain ways in which to reduce the “feast or famine” trend:
“…examine the need for a long range planning program to provide a continuous level of projects for construction. The author’s analysis concluded that the fluctuating level of activity in the industry has a definite influence in the instability in the industry and that a program of steady activity would be a major prerequisite in attempting to solve the problem of instability.”

A number of other comparisons were also examined as effects due to the instability in bidding volume such as: capital budgeting requirements, man-power requirements, equipment usage, overtime and penalty premiums, and employment level. A number of trends showed up based on these comparisons but they were not based on how the bidding volume affected the bid price for the area but instead to how other variables affected bid price. The author also attempts to identify the underlying influences for fluctuations in the bidding process. Some of the reasons that were identified are: seasonal influences, weather impacts, obsolete codes and specifications, government policy, construction financing and funding, inflation, changes in regulations, tax structures, new innovations, and other economic conditions.

A number of conclusions were drawn about factors affecting bid prices. When it came to bidding volume in a given area, the author concluded that there was a direct correlation between bidding volume and bid price. In other words, when the number of projects let to bid increased the bid price would also increase. The author stated:

“…has recognized the inconsistent supply of projects to be constructed as one of the major, if not the single, cause of instability in the industry.”

and:

“The term ‘feast or famine’ was used to describe the relative availability of projects to be constructed, and examples of excessive costs due to the “feast or famine” instability were given.”
The author also concludes that there is one way that may be able to eliminate this fluctuation in price suggesting that there be a constant volume of work let during the year:

“The author recommends that the implementation of a long-range planning program be a major prerequisite in attempting to overcome instability in the highway industry. According to this analysis, this program would preferably attempt to create a steady, continuous level of activity within the industry.”

This document concludes that bidding volume will affect bid price based on the fluctuations that occur in the level of work let to contract. Therefore, an analysis of bidding volume within the SCDOT was conducted to determine a methodology for making adjustments to the engineer’s estimate based on the bidding volume.

Price Indices

With the aim of determining the fuel price index, a number of websites were reviewed to determine the best source of fuel price data to use for the analysis of the data to develop a methodology for adjusting selected unit cost line items to account for fluctuations in gasoline and asphalt prices. A number of state DOTs posted the fuel price indices that they used to determine the fuel price adjustments. It was determined that these differing state indices would reflect local or regional pricing and would not be appropriate for application within SCDOT. Therefore, a search was conducted using the U.S. Department of Energy website to determine if there was a price index that could be used that would reflect the local price of fuel for South Carolina.

While searching on the US Department of Energy website, a link was found that connected the research team to the Energy Information Administration. This website
contained statistical information related to energy sources. Some examples of the energy sources it documents are petroleum, natural gas, electricity, coal, nuclear, and renewable and alternate fuels. The research team proceeded to investigate the petroleum statistics. Once there a link was found to the weekly retail prices for gasoline and diesel. On this site there was a table of weekly data points for fuel prices. This table could be organized by product or area. It was determined that a search should be conducted by area. After the table was arranged by area, the research team found that the source contained a link to the weekly prices in fuel for the Southeast (17). The data for weekly fuel prices in the Southeast could be downloaded from the website in the form of a Microsoft Office Excel Spreadsheet. This data would be useful in the analysis of the SCDOT data for the research as well as in the future. This data was then merged into the data set provided by SCDOT to help determine the relationships between the fuel price index and the varying unit cost line items that were suggested for analysis by the SCDOT Research Steering Committee.

Other Procedures for Post Bid Compensation

States approach post bid compensation using different methodologies. A literature review was conducted to determine various methodologies used for post bid compensation using the sources stated in the research proposal. Very few information sources were identified in the initial literature search but numerous sources were provided during the survey response analysis portion of the research. These sources were reviewed and it was determined that the major types of bid compensation were in fact related to
fuel and asphalt adjustments. Also, it was determined that all the forms of bid compensation that were identified were post-bid compensation methodologies or were ways of compensating contractors after the letting of the project. These forms of post bid adjustment have been addressed in their respective sections of the literature review. There was however an example in the Nevada standard specifications of post bid compensation for steel escalation as well as compensation for fuel and asphalt escalation.

The Nevada Department of Transportation allows for adjustments to be made to the contract price based on fluctuations in the steel market (7). The clause allows the contractor to execute the adjustments request when needed. The Nevada DOT will only enable the clause when there has been an escalation of 10% in the price of steel. The price adjustment applies to reinforcing steel, structural steel, sign structures, steel piling, light poles, dowel and tie bars for concrete paving, steel guardrail components. The adjustment can be a reduction or increase in the contract price and is determined using an equation that takes into account the quantity of steel, the current price of steel, and the price of steel at the time of the contract. The adjustment has a cap that is set when the current price exceeds the contract price by an amount of 75%. This is one example of a post bid compensation method that was provided that was not a fuel or asphalt adjustment. The only other examples of post-bid compensation provided by the various states during the survey were the fuel and asphalt adjustments discussed in the previous section.
Literature Review Summary

A comprehensive primary and secondary literature review was conducted to identify publications that could provide insight into fuel and asphalt price adjustment as well as bidding volume adjustment strategies currently being used within the industry. Although the initial literature review did not identify many useful background publications concerning fuel and asphalt adjustments it did identify the methodology used by SCDOT and NCDOT for fuel and asphalt adjustments that could be found in their supplementary specifications. The literature review did, however, identify publications that addressed the relationship between fuel price and project bid prices by contractors. These publications stated that the increase in fuel price was believed to be a major contributing factor to the increase in bid prices seen by many state departments of transportation and private companies across the United States. A thesis was also identified that addressed bidding volume, as well as other factors impacting contractor bid prices. The secondary literature review was based on the publications received as part of the survey of other agencies. A number of states provided supplementary material as part of the survey responses related to fuel and asphalt price adjustments. All of this information received during the survey was provided from the states standard and supplementary specifications. During both reviews, no publications were identified detailing methods of adjusting the engineer’s estimates before the project was let to bid based on the fluctuations in fuel and asphalt prices or bidding volume. Recent fluctuations in the fuel prices have occurred over short periods of time illustrating the need for the ability to make adjustments to the engineer’s estimate on a periodic basis.
The literature review helped to shed light on current methodologies being used in the transportation industry to make adjustments to the bid price after the bid letting date as well as the relationships between the bid price and both fuel and asphalt prices as well as bidding volume.
CHAPTER 3
PRELIMINARY DATA ANALYSIS

An overall statistical analysis of bid history data provided by SCDOT in an Access database was performed. This data spanned 10 years of compiled projects administered by the SCDOT with bid data for differing BAMS numbers. The data for the bid line items related to asphalt and fuel adjustments identified by the Steering Committee was imported from Microsoft Access into Microsoft Office Excel and compared to the Fuel Price Index for Southeastern United States as well as with SCDOT’s Bidding Volume.

Methodology for Fuel Price Index Analysis

An analysis was conducted by first importing all relative data into Microsoft Excel from the Access file provided by SCDOT as described in the introduction. The data was then organized into different worksheets to allow for the analysis of the data and comparison to the fuel price index. In order to do this, fuel prices were then found for the time periods from January of 2000 to November of 2005, the same as the available bid data, and imported into Microsoft Excel. The historical data sets were then formatted using Excel to create a three axis graph with the fuel price data to determine if there was a correlation between the increase in bid price and fuel prices. The historical data was normalized to allow for better analysis with the fuel prices. The data was normalized by finding the average bid prices for a unit cost line item and subtracting this average from a single data point. The difference was then divided by the standard deviation for the
historical data set, dating from January of 2000 to November of 2005, to finish the normalization of the pricing data.

The data was plotted and a regression line fitted to each data set to better compare the low bid price and the engineer’s estimate to the fuel price index. When relating the data to fuel price over time, some bid data points were found to be extremely high. In order to further analyze the data, it was imported into SAS 9.1. It had been noted that there seemed to be outlying data in the regression analysis conducted in Excel for the engineer’s estimate and low bid datasets. These extreme outliers were removed from the data set with the intention of increasing the accuracy of the analysis. The quantity of outliers removed from each data set is shown in Table 3-1.

With the data already integrated in SAS, a student residual regression analysis was conducted to determine the deviation from the average value for the engineer’s estimate and low bid price data. A student residual is the residual value, or the observed error, divided by an estimate of its standard deviation. Outlying data within these datasets were identified based on having a student residual value of greater than 2.0. These outliers were analyzed and it was determined that the cause behind their variance was connected to the line item quantity of work for a project. Once the outliers had been identified and analyzed, they were removed from each of the line item’s sets of data to produce a more appropriate data set for analysis. With the data already in SAS 9.1, a residual regression analysis was also conducted to determine if there was a random scattering of the residual data and a normal distribution of the errors for the variables; the engineer’s estimate, low bid price, and fuel price. A residual is the observed error or the
difference between the actual observation and the expected observation. This analysis was conducted to determine if there was a linear relationship between any of the variables. Linear relationships were identified between the low bid price and the fuel price index for unit cost line items that had been identified. After these analyses were conducted and the outliers had been removed, the data was imported back into Excel for further analysis.
Table 3-1: Quantity of Outliers Removed per Bid Line Item for the Engineer’s Estimate and Low Bid Price Data Sets

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<th>DESCRIPTION</th>
<th>Engineer’s Estimate</th>
<th>Low Bid Price</th>
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<td>CONCRETE DRIVEWAY(6&quot; UNIFORM)</td>
<td>17</td>
<td>13</td>
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<tr>
<td>7011400</td>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
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<td>7</td>
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<td>7</td>
<td>6</td>
</tr>
<tr>
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<td>0</td>
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<td>MUCK EXCAVATION</td>
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<tr>
<td>4036201</td>
<td>OPEN-GRATED FRICTION COURSE</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>18&quot; RC PIPE CUL.-CLASS III</td>
<td>11</td>
<td>14</td>
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<tr>
<td>7141112</td>
<td>15&quot; RC PIPE CUL.-CLASS III</td>
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<td>UNCLASSIFIED EXCAVATION</td>
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</table>
Preliminary Fuel Price Index Analysis

Figure 3-1 illustrates the relationship between the date, cost per ton of Graded Aggregate Base Course (6” Uniform), and the fuel price index before the removal of the outlying data with respect to the date. A normalized regression line shows the relationship between the low bids, the engineer’s estimate, and the fuel price index. The graph appeared to show a correlation relationship between the variables of fuel price and low bid price. As the fuel price fluctuates up or down, the bid price appears to follow in a similar direction. This indicated a relationship between fuel price and low bid price that should be investigated to determine if adjustments can be made for fluctuations in fuel price through a regression analysis.

However, outlying data, as described above, was clearly present in this graph. Two such examples are the data points for October 9, 2001 and October 12, 2004 which have a normalized estimate price of $2.35 and $5.95 respectively. These data points are from the engineer’s estimate and the low bid data set respectively which had averages of $0.76 and $0.40 respectively. Data points such as this were removed to increase the accuracy of the later analyses. All subsequent plots had these outliers removed.

The legend shows the engineer’s estimate and the low bid as different shaped points on the graph, triangles and squares, respectively, while the fuel price index is represented as a diamond with a connecting line. Also, it indicated the trend lines for the engineer’s estimate and low bid. The engineer’s estimate trend line began above the low bid trend line around July 11, 2000. The engineer’s estimate trend line then dipped below the low bid trend line around June 4, 2003 and then rose above the low bid trend
line again around February 15, 2005. It is worth noting that there appears to be a lag in bid price between the engineers estimate and low bid. This may be caused by the lag in fluctuation of prices by using bid history data. As the low bids increase or decrease there is a lag of a year or more before this change is evident in the engineer’s estimated price. This may indicate the need for an alternative form of estimating process for selected bid line items.
Figure 3-1: Fuel Price Index and Bid Price for Graded Aggregate Base Course (6" Uniform)

Graded Aggregate base Course (6"Uniform)

- Low Bid Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)

Bid Price Normalized

Price Per Gallon of Fuel

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Date
Methodology for Bidding Volume Analysis

An analysis was conducted by first importing all bid volume data into Microsoft Excel from the Access file provided by SCDOT. The data was then organized into separate worksheets to allow for the analysis of the data and comparison to the bidding volume per month. Bidding volume per month was determined using the provided Microsoft Office Access Database based on the letting date of the projects. The number of letterings per month was tabulated based on the letting date and then entered by month into a Microsoft Office Excel Spreadsheet. This data was then used to produce a four axis histogram used to further analyze the scatter plots of the bid line item historical data to determine the impact of bidding volume on specific bid line item prices. The historical data was normalized in order to allow for better analysis with the bidding volumes. The data was normalized by finding the average bid prices for a unit cost line item and subtracting the average from each data point. The difference was then divided by the standard deviation for the data set to finish the normalization of the pricing data. When relating the data to bidding volume over time, some bid data points were found to be extremely high.

In order to get a better picture of the relationship between the variables – low bid price, engineer’s estimate, and bidding volume; the datasets were imported into SAS 9.1. It had been noted that there seemed to be outlying data in the regression analysis conducted in Excel for the engineer’s estimate and low bid data sets. So as to determine the outliers, a student residual regression analysis was conducted in SAS to determine the deviation from the mean. Outlying data within these datasets were identified based on
having a student residual value of greater than 2.0. These outliers were analyzed to determine the cause of the variance. It was determined that the variances were related to the material quantities involved in the unit cost line item for that specific project. After the outliers were identified, they were removed from each of the line item’s sets of data to produce a more appropriate data set for analysis. These outliers are described in Table 3-1.

With the data already in SAS 9.1, a residual regression analysis was conducted to determine if there was a random scattering of the residual data as well as a normal distribution of the errors for the variables; the engineer’s estimate, low bid price, and bidding volume. The regression analysis was conducted to determine if there was a linear relationship between any of the variables. A linear relationship was identified between the low bid price and the bidding volume for the unit cost line items that had been identified. Once the outliers were removed, the data was imported back into Excel for further analysis.

**Preliminary Bidding Volume Analysis**

Figure 3-2 illustrates the relationship between the bidding volume per month, date, bid price per ton of Graded Aggregate Base Course (6” Uniform), and the letting date prior to the removal of the outliers with respect to the date. A normalized regression line shows the relationship between the low bids, engineer’s estimate, and the fuel price index. The graph appeared to show a correlation relationship between bidding volume and low bid price. As bidding volume increased or decreased, the bid price appears to
correlate with the fluctuation. This indicated a relationship between bidding volume and low bid price that could be utilized to determine if adjustments can be made for fluctuations bidding volume through a regression analysis.

Once again, outlying data, as described above, is clearly present in this graph. Two such example are the data points for October 9, 2001 and October 12, 2004 which have an normalized estimate price of $2.35 and $5.95 respectively. The first data point is from the engineer’s estimate data set, whereas the second data point comes from the low bid data set which had averages of $0.76 and $0.40 respectively. Data points such as these were removed to increase the accuracy of the future analyses. Outlying data points were removed and this analysis was conducted again to better determine relationships between the variables. All subsequent plots illustrated herein have these outliers removed.

The legend shows the engineer’s estimate and the low bid are indicated as differing shaped points on the graph, triangles and squares, respectively. The bidding volume is represented by the histogram data and is shown in the legend as well. The engineer’s estimate trend line began above the low bid trend line around July 11, 2000. The engineer’s estimate trend line then dipped below the low bid trend line around June 4, 2003 and then rose above the low bid trend line again around February 15, 2005. It is worth noting that there appears to be a lag in bid price between the engineers estimate and low bid. This may be caused by the lag in fluctuation of prices by using bid history data. As the low bids increase or decrease there is a lag of a year or more before this
change is evident in the engineer’s estimated price. This may indicate the need for an alternative form of estimating process for selected bid line items.
Figure 3-2: Bidding Volume and Bid Price for Graded Aggregate Base Course (6" Uniform)
Preliminary Data Analysis Summary

By extracting the unit cost line items from the data provided, an analysis was performed comparing the engineer’s estimate to contractor low bids, and compared it to the fuel price index and the bidding volume. By using this analysis, one can see what the SCDOT and contractors have quoted for bid line items that deal with fuel or asphalt costs and any relationships that would be formed using criteria such as fuel price and bidding volume. The analysis showed which items may need to be addressed in future estimates using cost based estimating or an alternative method for adjusting the engineer’s estimate for the fluctuations. These analyses helped determine if certain items should use cost based estimating or some form of adjustment criteria in order to improve the accuracy of the estimate due to the lag time created by using historical data and their lack of correlation.

Many of the unit cost line items examined in this research have bid prices correlated with either the fuel price index or bidding volume. Unit cost line items tended to rise or fall with the cost of fuel as the price fluctuated up or down. During the analysis of the original data it was noted the there were some extreme outlying data points. Outlying data points were analyzed and it was determined that the cost increased or decreased inversely correlated to the quantity of work being conducted. As the quantity of work would decrease the cost of the unit cost line item would increase and as material quantities would increase the cost for the line item would decrease. The outliers were identified using SAS 9.1 by conducting a student residual regression analysis and then were removed from the data set. Linear relationships were also identified between fuel
price and low bid price as well as between bidding volume and Low bid price by utilizing a residual regression analysis in SAS 9.1. The data sets were then imported back into Excel for further analysis into the relationships between the variables.
CHAPTER 4
FUEL PRICE INDEX ANALYSIS

From the two figure illustrated in chapter 3 it can be noted that there are outliers for both the engineer’s estimates and the low bids. These outliers in the bid prices were affected by the quantity of material for each project. When the quantities were low, the relating bid was found to be relatively high. Also, when the quantities were high the bids were lower. It was determined that in order to improve the analysis the outliers must be removed.

Fuel Price Index Analysis Methodology

It was determined that the best program to run an analysis for this type of data would be SAS or Statistical Analysis Software. The Access database had already been imported into Excel according to the BAMS numbers; therefore it could easily be transferred into SAS. The data was transferred into SAS and a student residual analysis was conducted to determine which data points were statistical outliers. For this analysis a regression procedure was conducted to determine student residuals. A student residual is the residual value, or the observed error, divided by an estimate of its standard deviation. The student residuals were then used to determine if a data point was an outlier. For this analysis it was determined that a student residual equal to or greater than 2.0 would be considered an extreme outlier and should be removed.

Once the outliers had been identified using SAS, those data points were removed from the SAS files and the remaining data was imported back into Excel. After the
revised data was in Excel a similar analysis to the preliminary analysis was conducted to determine if a better visual correlation existed. The revised low bid and engineer’s estimate data was once again compared to the fuel price index that had been found and utilized in the preliminary analysis. Both the low bid data and engineer’s estimate data were graphed in Excel as scatter plots on the same graph. The fuel price index data was then added to the graph to compare to the regression lines for both the low bid data and engineer’s estimate data. Trend lines were added to the plots of the engineer’s estimate and low bid price in order to better visualize the fluctuations of the data sets. The trend lines were added as cubic or quadratic trend lines depending on how the data fluctuated with respect to time. Utilizing these graphs, a visual comparison of the correlation between low bid and engineer’s estimate could be seen as well as how each variable visually correlated to the fuel price index.

**Fuel Price Index Analysis**

Figure 4-1 illustrates the relationship between the date, cost per ton of Hot Mix Asphalt Concrete Surface CR Type 4, and the fuel price index with respect to the date for the revised data. The graph showed a correlation relationship between the variables of fuel price and bidding volume with respect to date. As the fuel price fluctuates, the bid price appears to follow in a similar direction. This indicated a relationship between fuel price and low bid price that will be investigated to determine if adjustments can be made for fluctuations in fuel price through a regression analysis. The legend shows the engineer’s estimate and the low bid are indicated as differing shaped points on the graph,
triangles and squares, respectively. The engineer’s estimate trend line began above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dipped below the low bid trend line around February 12, 2002 and then rose above the low bid trend line again around June 7, 2004. Some interesting relationships were also indicated in a number of the items.

Another interesting relationship presented itself. In a number of the cases, such as Hot Mix Asphalt Concrete Surface CR Type 4, the low bid would decrease with time but there was a lag in time before the engineer’s estimate would reflect this decrease. The same would happen when the low bid price would begin to increase again. There was once again a lag in time before the engineer’s estimate would reflect this change. In some cases it would even seem to oscillate. As can be seen in Figure 4-1, there is an oscillation between the low bid data and the engineers estimate. As the low bid price drops the engineer’s estimate also drops. But it takes the engineer’s estimate about a year to catch up with the low bid before it begins to increase again. The low bid price began increasing again some time around October, 2001 and it was not until October 2002 that the engineer’s estimate began to reflect this same trend. This could be because of the lag in time created by using bid history data to conduct an engineer’s estimate. Also, it should be noted that as the trend lines move towards the end of 2005 it appears that the low bid is on a downward sloping trend while the engineer’s estimate is on an increasing trend. This is due to the lag in time between the two estimates that result from the use of historical data. This may indicate an item that could be better addressed using a cost based approach of estimating or the use of an adjustment methodology to keep this
lag from occurring, allowing for a more accurate estimate of the project. Similar trends showed up throughout a number of the unit cost line items that were being analyzed. Data similar to the figures referenced above are included in Appendix A.
Figure 4-1: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface Type 4

Hot Mix Asph Conc Surf CR Type 4
Figure 4-2 shows the relationship between the bidding date, cost per ton of concrete curb and gutter, and the fuel price index with respect to date for the revised data. The graph showed that once again there was a correlation between the variables of fuel price and low bid price with respect to the date. Once again, as the fuel price would increase or decrease, it appeared that the low bid price would fluctuate in a similar direction. It was decided that this relationship would be looked further into during the analysis to determine if such a relationship could provide a means of adjusting the engineer’s estimate based on the fuel price fluctuations. In this instance it appears that the low bid is consistently at a lower cost than the engineer’s estimate. Around January of 2000 the two estimates were closely related and as time goes on they began to separate and the low bid price dropped while the engineer’s estimate increased and stabilized. Eventually towards the end of the supplied data there are similar relationships shown to those stated in the previous example. There are a similar lags in price change between the low bid and engineer’s estimate as afore mentioned. Once again the low bid began to increase or decrease and the engineer’s estimate appears to lag behind in the change. In this case though it seems as though there is little or no response to the fluctuations in the low bid price or fuel price reflected in the engineers estimate over the five year period. This could be because of the lag in time created by using bid history data to conduct an engineer’s estimate. The legend shows the engineer’s estimate and the low bid are indicated as differing shaped points on the graph, triangles and squares, respectively. The engineer’s estimate trend line began above the low bid trend line around March 14, 2000.
The engineer’s estimate trend line then dipped below the low bid trend line around July 12, 2005. Data similar to the figures referenced above is included in Appendix A.
Figure 4-2: Fuel Price Index and Bid Price for Concrete Curb and Gutter
Fuel Price Index Analysis Summary

Once the outlying data points were removed, the analysis was conducted again to determine the relationships between bid pricing and fuel price. As noted in Figure 4-1 of this report, as fuel price increased or decreased over time, the low bid price would trend in a similar direction. The engineers estimate would tend to have a lag of a few months to, in some cases, a year or more, before it would finally recognize and address the fluctuations. In some instances, there would be an over compensation in the engineer’s estimate for the lag and it would increase past the low bid price correlation with the fuel price. This may serve to identify items that may need to be addressed using cost based estimating or a methodology to adjust for the fluctuations in the future.

The regression line equations developed as part of this research effort would be used as a way to determine if there needs to be an adjustment to the engineer’s estimate to compensate for this lag. This analysis helped to determine which items need to be estimated differently; either by cost based estimating or by making adjustments based on the lag time in the engineer’s estimates to increase the estimates accuracy.
CHAPTER 5
BIDDING VOLUME ANALYSIS

In the preliminary analysis figures, it can be noted that there are outliers for both the engineer’s estimates and the low bids. These outliers in the bid prices were affected by the quantity of material for each project. When the quantities were found low, the relating bid was found to be relatively high, as well as when the quantities were high the bids were lower. It was determined that, with the aim of improving the analysis, the outliers must be removed from the data for the bidding volume analysis.

Bidding Volume Analysis Methodology

As in the fuel price adjustment analysis, it was determined that the best program to run an analysis for this type of data would be SAS or Statistical Analysis Software. The Access database had already been imported into Excel according to the BAMS numbers; therefore it could easily be transferred into SAS. The data was transferred into SAS and a residual analysis was conducted to determine which data points were statistical outliers. For this analysis a regression procedure was conducted to determine student residuals. The student residuals are a residual value divided by an estimate of its standard deviation. The student residuals were then used to determine if a data point was an outlier. For this analysis it was determined that a student residual equal to or greater than 2.0 would be considered an extreme outlier and should be removed.

Once the outliers had been identified using SAS, those data points were removed from the SAS files and the remaining data was imported back into Excel. After the
revised data was in Excel a similar analysis to the preliminary analysis was conducted to determine if a better visual correlation existed. The revised low bid and engineer’s estimate data was compared to the bidding volume per month levels that had been found and utilized in the preliminary analysis. Both the low bid data and engineer’s estimate data were graphed in Excel as scatter plots on the same graph. The bidding volume per month was then added as a histogram to the scatter plot of the data to make a visual comparison. Trend lines where added to the plots of the engineer’s estimate and low bid price in order to better visualize the fluctuations of the data sets. The trend lines where added as quadratic or cubic trend lines depending on how the data fluctuated with respect to time. Utilizing these graphs a visual comparison of the correlation between low bid and engineer’s estimate could be seen as well as how each line item visually correlated to the bidding volume per month.

**Bidding Volume Analysis**

Figure 5-1 illustrates the relationship between the bidding volume per month, bidding date, bid price per ton of Hot Mix Asphalt Concrete Surface CR Type 4, and the letting date. Similar correlations were noted between the engineer’s estimate, low bid, and bidding volume as with the original data. The graph showed that there was a correlation between the variables of bidding volume and low bid price with respect to the date. As bidding volume increased over a few months stretch, the low bid price would correlate with an increase in the price in most cases. It was decided that this relationship would be looked further into during the analysis to determine if such a relationship could
provide a means of adjusting the engineer’s estimate based on the current bidding volume. The legend shows the engineer’s estimate and the low bid are indicated as differing shaped points on the graph, triangles and squares, respectively. The bidding volume is represented by the histogram data and is shown in the legend as well. The engineer’s estimate trend line began above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dipped below the low bid trend line around February 12, 2002 and then rose above the low bid trend line again around June 7, 2004. There was a tendency in this case as well to have the engineers estimate lag behind the fluctuations with time. As can be seen in Figure 5-1, there is an oscillation between the low bid data and the engineers estimate. As the low bid price dropped the engineer’s estimate also dropped. But it takes the engineer’s estimate about a year to catch up with the low bid before it began to increase again. The low bid price began increasing again some time around October, 2001 and it was not until October 2002 that the engineer’s estimate began to reflect this same trend. In addition, as the trends move towards the end of 2005 a large gap seems to form between the engineer’s estimate and the low bid trend lines with the engineer’s estimate on an increasing trend and the low bid on a decreasing trend. It is believed that this is due to the lag time resulting from the use of historical data. This could suggest an item that might need to be estimated using an alternative form of estimating other than unit cost line item estimating or use of a methodology for making adjustments to the unit cost line item bid price. Data similar to the figures referenced above is included in Appendix B.
Figure 5-1: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface Type 4

Bidding Volume vs Low Bid for Hot Mix Asph Conc Surf CR Type 4

Letting Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bid Price Normalized

Bidding Volume

Low Bids

Engineer's Estimate

Poly. (Low Bids)

Poly. (Engineer's Estimate)
Figure 5-2 illustrates the relationship between the bidding volume per month, bidding date, bid price per ton of concrete curb and gutter, and the letting date. In this scenario it appeared that there would not be as strong of a correlation between the bidding volume and bid price for this particular line item. This is due to the fact that the peaks and valleys for the bid price do not seem to correlate with any of the spikes in bidding volume present in the data. But, in this case, the engineers estimate still tended to lag behind the price changes with time. Many of the relationships that were noted in Figure 4-2 were also present in Figure 5-2 as well. The legend shows the engineer’s estimate and the low bid are indicated as differing shaped points on the graph, triangles and squares, respectively. The bidding volume is represented by the histogram data and is shown in the legend as well. The engineer’s estimate trend line began above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dipped below the low bid trend line around July 12, 2005. Once again there appears to be a lag in the change of low bid and the engineer’s estimate. In this case there is little or no response to the fluctuations in the low bid price or bidding volume reflected in the engineers estimate over the five year period. This could be because of the lag in time created by using bid history data to conduct an engineer’s estimate. Data similar to the figures referenced above is included in Appendix B.
Figure 5-2: Bidding Volume and Bid Price for Concrete Curb and Gutter
Bidding Volume Analysis Summary

Once the outlying data points were removed, the analysis was conducted again to determine the relationships between bid pricing and bidding volume. As noted in Figure 5-1 of this report, as bidding volume decreased or increased with time, the low bid price would trend in a similar direction. The engineers estimate tended to have a lag of a few months to, in some cases, a year or more, before it would finally recognize and address the fluctuations. In some instances, there would be an over compensation in the engineer’s estimate for the lag and it would increase past the low bid price correlation with the bidding volume. This may serve to identify items that may need to be addressed using cost based estimating or a methodology for adjustments based on the fluctuations for future estimates.

The regression line equations developed as part of this research effort would be used as a way to identify line items that may need to have adjustment criteria utilized for the engineer’s estimate to compensate for this lag. This analysis helped to determine which items need to be estimated differently; either by cost based estimating or by making adjustments based on the lag time in the engineer’s estimates to increase the estimates accuracy.
CHAPTER 6
ENGINEER’S ESTIMATE AND LOW BID CORRELATION ANALYSIS

Methodology

The data supplied by SCDOT was used to conduct a statistical analysis to determine if there were any correlations between the engineer’s estimates and the low bids received from bidding companies. Since the data from the SCDOT Microsoft Access database had already been imported into Microsoft Excel, the data was already in a format that could be utilized for this analysis. The data was moved to a new worksheet for each bid line item and an analysis was conducted.

A regression analysis was conducted to determine a regression line for the engineer’s estimate unit cost line item price versus the low bid unit cost line item price. A correlation analysis was also conducted to determine how well the engineer’s estimate correlated to the low bid for each of the unit cost line items concerned with asphalt or fuel adjustments addressed by the steering committee in order to determine if an analysis of these variables could give insight into the relationships discovered in the fuel price and bid volume analysis described in Chapter 3 and Chapter 4. The data was then plotted in Microsoft Excel using a scatter plot and the regression line was then fitted to the data. This analysis was used to determine if there was a possible way to predict within a level of certainty what the low bid price will be based on the engineer’s estimate.
Analysis

A statistical analysis was conducted to determine the correlation between the low bid and the engineer’s estimate for the previously identified line items. The results of the correlation analysis are summarized in Table 6-1. The analysis was conducted using the engineer’s estimate as the independent variable on the x-axis and the low bid as the dependent variable on the y-axis. The regression analysis was conducted such that the results were mostly cubic or quadratic equations. Regression plots for two line items are discussed in this chapter. Plots for additional line items are included in Appendix C.

Table 6-1 shows the regression and correlation analysis of the 33 line items identified by the Steering Committee. In this analysis there were ten differing line items with a very significant correlation of greater than 70% and twelve more line items with a significant correlation of 40% to 70%. Table 6-1 provides a detailed picture of the correlation that exists between the engineer’s estimate and the low bid. One such example is the relationship between the engineer’s estimate and the low bid for Mix Asphalt Concrete Surface CR Type. In this case there is a 72% correlation between the two variables. Once it has been determined that there is a significant correlation between the two variable a regression analysis can then be conducted. The regression analysis provides the regression equation for the data that uses the least squares method of regression to fit a curve to the data.

Figure 6-1 illustrates the relationship between the engineer’s estimate and the low bid for Hot Mix Asphalt Concrete Surface CR Type 4. The regression equation for the data is plotted on the graph to see exactly how it fits the data. Based on the analysis of
this data a number of the bid line items engineer’s estimates and low bids do have a correlation, therefore, it may be possible to determine the low bid within a specific level of certainty based on the engineer’s estimates but it would not be an efficient means of determining the engineer’s estimate. It would only provide a better prediction of what the contractors may price in at for a low bid.
Table 6-1: Regression and Correlation Analysis for Engineer’s Estimate vs. Low Bid Analysis

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<th>Unit Cost Line Item</th>
<th>Regression Equation</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1B</td>
<td>$y = 0.9743x + 2.3614$</td>
<td>NA</td>
</tr>
<tr>
<td>HAULING OF EXCAVATED SHOULDER MATERIAL</td>
<td>$y = -6E-05x^3 + 0.0046x^2 + 0.0112x + 0.2843$</td>
<td>0.992921</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</td>
<td>$y = -0.007x^3 + 0.666x^2 - 5.3796x + 15.984$</td>
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</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</td>
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<td>0.763496</td>
</tr>
<tr>
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<td>0.752418</td>
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<td>$y = 0.0006x^3 - 0.0679x^2 + 3.3244x - 24.11$</td>
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<tr>
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<td>$y = -0.9994x^2 + 67.455x - 1092$</td>
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<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
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</tr>
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<td>$y = 4E-05x^3 + 0.0235x^2 - 0.8579x + 37.129$</td>
<td>0.714177</td>
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<td>CONC. FOR STRUCTURES – CLASS 4000</td>
<td>$y = 0.0033x^2 - 1.8671x + 743.87$</td>
<td>0.702643</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>$y = -0.0007x^3 + 0.1094x^2 - 4.1116x + 77.438$</td>
<td>0.665004</td>
</tr>
<tr>
<td>UNCLASSIFIED EXCAVATION</td>
<td>$y = 0.0037x^3 - 0.0393x^2 + 0.9134x + 1.9733$</td>
<td>0.635285</td>
</tr>
<tr>
<td>15” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.0153x^3 + 0.8279x^2 + 15.84x - 184.109$</td>
<td>0.631371</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>$y = 0.0008x^3 - 0.0428x^2 + 0.8753x + 25.723$</td>
<td>0.621484</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>$y = 0.0013x^3 - 0.1798x^2 + 8.9748x - 109.4$</td>
<td>0.611111</td>
</tr>
<tr>
<td>BORROW EXCAVATION</td>
<td>$y = 0.0042x^3 - 0.1915x^2 + 3.6388x - 9.8165$</td>
<td>0.604044</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>$y = 0.0004x^3 + 0.0265x^2 - 2.8614x + 87.886$</td>
<td>0.595127</td>
</tr>
<tr>
<td>CONCRETE CURB AND GUTTER(2'-0&quot;)</td>
<td>$y = 1.0431x^2 + 19.248x + 97.411$</td>
<td>0.499507</td>
</tr>
<tr>
<td>24” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.0175x^3 - 1.331x^2 + 34.106x - 266.21$</td>
<td>0.492556</td>
</tr>
<tr>
<td>CONCRETE SIDEWALK(4&quot; UNIFORM)</td>
<td>$y = -0.0002x^3 + 0.0364x^2 - 0.4244x + 18.107$</td>
<td>0.480408</td>
</tr>
<tr>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>$y = 0.0022x^3 - 0.2213x^2 + 7.27x - 29.786$</td>
<td>0.471758</td>
</tr>
<tr>
<td>CONCRETE DRIVEWAY(6&quot; UNIFORM)</td>
<td>$y = 0.0044x^3 - 0.3449x^2 + 9.5547x - 63.036$</td>
<td>0.445505</td>
</tr>
<tr>
<td>CONCRETE MEDIAN</td>
<td>$y = 0.0032x^3 - 0.2699x^2 + 8.1203x - 55.31$</td>
<td>0.381326</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>$y = -0.0069x^3 + 0.1633x^2 - 0.2323x + 4.0106$</td>
<td>0.349148</td>
</tr>
<tr>
<td>18” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.0094x^3 + 0.8701x^2 - 23.64x + 221.58$</td>
<td>0.336934</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>$y = 0.0025x^3 - 0.9522x^2 - 6.9951x + 4.7482$</td>
<td>0.319727</td>
</tr>
<tr>
<td>36” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.0125x^3 - 1.7107x^2 + 78.471x - 1156.6$</td>
<td>0.311026</td>
</tr>
<tr>
<td>20” RC PIPE CUL.-CLASS III</td>
<td>$y = -0.0263x^3 + 2.9643x^2 - 109.35x + 1361.4$</td>
<td>0.302328</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</td>
<td>$y = -0.1107x^3 + 2.1957x^2 - 13.799x + 34.002$</td>
<td>0.277557</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>$y = 0.0235x^3 - 3.1695x^2 + 140.9x - 2023.4$</td>
<td>0.054295</td>
</tr>
<tr>
<td>HOT MIX SAND ASPH. BASE CR. TYPE 3</td>
<td>$y = 0.1179x^3 - 15.44x^2 + 672.18x - 968.18$</td>
<td>-0.12888</td>
</tr>
</tbody>
</table>
Figure 6-1: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 4

Engineer’s Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 4

\[ y = 0.0249x^2 - 0.8585x + 36.978 \]

Correlation: 71.93%
Table 6-1 shows the regression and correlation analysis for Concrete Curb and Gutter. Table 6-1 provides a depiction of the correlation between the engineer’s estimate and the low bid. In this instance there is a 49.95% correlation between the two variables. Once it has been determined that there is a significant correlation between the two variable for this type of data, a regression analysis can then be conducted. The regression analysis will provide a regression equation for the data using the least squares method of regression to fit a curve to the data. Figure 6-2 illustrates the relationship between the engineer’s estimate and the low bid for Concrete Curb and Gutter. The regression equation for the data was plotted on the graph to show how it fits the data. In this instance it the data appears to visually fit the equation with some error shown in the low correlation of the variables.
Figure 6.2: Regression Analysis for Concrete Curb and Gutter

Engineer's Estimate vs Low Bid For Concrete Curb And Gutter

\[ y = 1.0431x^2 - 19.248x + 97.411 \]

Correlation: 49.95%
Engineer’s Estimate and Low Bid Correlation Analysis Summary

The engineer’s estimate and low bid for the bid line items dealing with fuel and asphalt adjustment were compared to see if there was any correlation between the two variables. Regression line equations were developed to better visualize the correlation between the engineer’s estimate and the low bid. Based on the analysis of this data for a number of the bid line items, the engineer’s estimates and low bids are correlated. There were ten differing line items with a significant correlation, greater than 70%, and twelve more line items with a significant correlation of 40% to 70%. Therefore, it may be possible to determine the low bid that will be received within a specific level of certainty based on the engineer’s estimates using the regression line equations. But, it would not be an efficient means of determining the engineer’s estimate. It would only provide a better prediction of what the contractors may estimate for a low bid based on the engineer’s estimate. Further inspection of the correlations between the low bid unit cost line items and the fuel price and bidding volume have been conducted to create a tool to make adjustments to the unit cost line items related to fuel and asphalt price adjustments.
CHAPTER 7

FUEL PRICE ADJUSTMENT LINEAR REGRESSION ANALYSIS

Methodology

With the purpose of creating a tool to improve the bidding process for the engineer’s estimate, the graphs of the fuel price index were analyzed in more detail. It was determined early that the graphs of fuel price index vs. low bid price in Appendix A could be used to visualize the correlation between the low bid and the fuel price. In a number of instances, it can be clearly seen, that there is greater correlation between the low bid and either the fuel price index or bidding volume. Once it was visually determined that there is a correlation between the variables and there was a linear relationship was assumed to still exist, a linear regression analysis was conducted to determine a linear model for the variables as well as a 95% confidence interval. Of the 33 unit line items identified for analysis, only 28 line items contained sufficient data to undergo a linear regression analysis.

For a linear regression analysis to be conducted there must be similar number of observations for both variables with a connecting point between the variables. To achieve this, a connecting point was chosen as the monthly average cost for the unit cost line item price as well as the fuel price index. This was chosen due to the fact that the bidding volume was already in the form of a monthly count. Therefore, the low bid unit cost line item prices and fuel prices must be converted into a monthly average. This was done in Microsoft Excel using the average function. It was noted that for certain unit cost line items there were months in which this item was not used and therefore had an
average value of $0.00 and therefore would negatively impact the accuracy of the analysis. This data was removed from the overall data set so as not to affect the outcome. After the average low bid unit cost line item price per month was determined it was graphed against the average fuel price per month.

After the data was graphed it was noted that there were outliers in the data for this analysis as well. These data points were removed from the graph and were further analyzed to see if there was a reason for their anomalous condition. These outliers were once again caused by a small quantity of work involved in that of unit cost line item from one or more of the bids for that month that had been used in the average. After these data points were removed, a clearer picture of the linear regression model could be produced.

Once the data was plotted, regression lines were added to the data to allow for the visualization of the regression analysis. The 95% confidence intervals were also plotted to make it easier to visualize what data points fell within the confidence intervals and make it easier to use upon implementation.

Before the analysis was conducted it was determined that there was very little correlation between the two variables of fuel price and bidding volume. There was only a 21% correlation between the two variables. Because of this, it was determined that the analysis of the data would be conducted in a manner to allow for adjustments to either the fluctuations in fuel price or bidding volume separately. Therefore the equations can not be used simultaneously and whichever variable is of greater concern at the time due to its fluctuations should be utilized.
Fuel Price Analysis

A linear regression analysis was performed to determine the relationship between bid price and fuel price for the previously identified bid line items. The results of the regression analysis are illustrated in Table 7.1. The regression equations were stated in the table such that y is the bid price in dollars, and x is fuel price. The regression analysis plots for four selected line items are discussed in this chapter. Regression plots for additional line items are contained in Appendix D.

Table 7-1 includes the regression analysis for the low bid vs. fuel price for all 28 unit cost line items. In this analysis, there were three differing line items with a very significant correlation of greater than 70% and sixteen more line items with a significant correlation of 40% to 70%. Table 7-1 provides a detailed picture of the correlation that exists between the fuel price and the low bid. For each unit cost line item analyzed, the regression line is given in the form of “y = m*x + b”. In this case “y” symbolized the estimated unit cost line item and “x” stood for the fuel price. The 95% confidence interval was also stated in a similar manner. There was an upper and lower limit for the 95% confidence interval which gave the range of values that 95% of all estimates should fall under for a given fuel price. This confidence interval can be used to determine if an estimate is competitive or if it falls out of the range for an acceptable estimate. This was because any estimate falling outside of these ranges was approximately 2 standard deviations from the mean value for the given fuel price. These equations could be utilized to determine if the estimate for a unit cost line item that was currently being utilized in an engineer’s estimate was still a competitive estimate due to the fuel price
fluctuations. It could also be utilized to quickly determine an estimate of the unit cost line item price for the engineer’s estimate based on the current fuel prices. These methodologies were discussed further in Chapter 9.

Table 7.1 also contained the results of the correlation analysis for each of the 28 unit cost line items. These correlations represented the strength of the relationship between the two variables, fuel price and low bid price. Because of this, an estimate will be more accurate if the correlation between the variables is higher. However, due to the type of data that was being utilized and the various other external influences that can have an effect on the low bid price, it was determined early in the analysis that a correlation of greater than 40% would be viewed as a significant correlation. Thus, the unit cost line items with higher than 40 percent correlations are the best candidates for utilizing this analysis for conducting adjustments to the engineer’s estimate. There were 19 unit cost line items found to have a correlation of higher than 40%, 2 of which had correlations in excess of 70%. SCDOT can use this analysis to make adjustments to the engineer’s estimate based on the fluctuations in the engineer’s estimate.

One such example is the relationship between the engineer’s estimate and the low bid for Concrete Curb and Gutter. Figure 7-1 shows an example of the linear regression models for the low bid vs. bidding volume analysis for Concrete Curb and Gutter. Examining Figure 7-1, there was a strong correlation between low bid prices and fuel price. Upon regression analysis, as presented in Table 7-1, it was noted that there is a stronger correlation between low bid and fuel price than there was with bidding volume. It should be noted that there is a 50% correlation between these two variables but given
the type of data which is being analyzed, this is a significant correlation between the variables and should not be dismissed. Due to this, further regression analysis beyond the correlation was conducted to determine a linear model for the data. This analysis was conducted in Excel and not only provided equations for the linear model but also provided the equations for a 95% confidence interval surrounding the linear model. All three trend lines along with their representative equations are presented on the figures. This analysis supplied SCDOT with a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
<table>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear Regression Equation</th>
<th>95% Confidence Interval Equations</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>18'' RC PIPE CUL.-CLASS III</td>
<td>$y = 10.453x + 9.4496$</td>
<td>Lower: $y = 7.9101x + 5.2914$ Higher: $y = 12.996x + 13.608$</td>
<td>0.71070</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>$y = 16.813x + 12.496$</td>
<td>Lower: $y = 12.548x + 5.7277$ Higher: $y = 21.077x + 19.264$</td>
<td>0.71038</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>$y = 5.5463x - 1.5094$</td>
<td>Lower: $y = 3.7343x - 4.5832$ Higher: $y = 7.3583x + 1.5645$</td>
<td>0.68994</td>
</tr>
<tr>
<td>15'' RC PIPE CUL.-CLASS III</td>
<td>$y = 16.402x - 0.9357$</td>
<td>Lower: $y = 11.686x - 8.393$ Higher: $y = 21.119x + 6.5215$</td>
<td>0.66818</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>$y = 11.852x + 23.036$</td>
<td>Lower: $y = 8.2666x + 17.128$ Higher: $y = 15.437x + 28.944$</td>
<td>0.66271</td>
</tr>
<tr>
<td>24'' RC PIPE CUL.-CLASS III</td>
<td>$y = 11.763x + 12.691$</td>
<td>Lower: $y = 8.9274x + 8.1392$ Higher: $y = 14.599x + 17.244$</td>
<td>0.64196</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
<td>$y = 13.705x + 19.231$</td>
<td>Lower: $y = 9.4x + 12.284$ Higher: $y = 18.01x + 26.179$</td>
<td>0.64174</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</td>
<td>$y = 12.341x + 19.246$</td>
<td>Lower: $y = 8.4334x + 12.872$ Higher: $y = 16.249x + 25.62$</td>
<td>0.61923</td>
</tr>
<tr>
<td>CONCRETE DRIVEWAY(6' UNIFORM)</td>
<td>$y = 7.0877x + 13.764$</td>
<td>Lower: $y = 4.577x + 9.6363$ Higher: $y = 9.5984x + 17.891$</td>
<td>0.59588</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
<td>$y = 13.299x + 19.74$</td>
<td>Lower: $y = 7.0255x + 9.2358$ Higher: $y = 19.572x + 30.244$</td>
<td>0.56087</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>$y = 4.2867x + 28.797$</td>
<td>Lower: $y = -7.5325x + 0.5466$ Higher: $y = 16.106x + 57.047$</td>
<td>0.55455</td>
</tr>
<tr>
<td>BORROW EXCAVATION</td>
<td>$y = 5.7756x + 3.558$</td>
<td>Lower: $y = 3.3872x - 0.267$ Higher: $y = 8.1639x + 7.383$</td>
<td>0.53302</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>$y = 12.132x + 24.117$</td>
<td>Lower: $y = 6.8765x + 15.748$ Higher: $y = 17.388x + 32.486$</td>
<td>0.51535</td>
</tr>
<tr>
<td>CONCRETE CURB AND GUTTER(2'-0'')</td>
<td>$y = 3.7176x + 4.9726$</td>
<td>Lower: $y = 1.9052x + 2.696$ Higher: $y = 5.042x + 7.6402$</td>
<td>0.49974</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>$y = 12.21x + 23.645$</td>
<td>Lower: $y = 5.5385x + 12.96$ Higher: $y = 18.882x + 34.33$</td>
<td>0.45022</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>$y = 12.542x + 25.384$</td>
<td>Lower: $y = 5.5507x + 13.866$ Higher: $y = 19.533x + 36.901$</td>
<td>0.43962</td>
</tr>
<tr>
<td>UNCLASSIFIED EXCAVATION</td>
<td>$y = 4.5778x + 2.8673$</td>
<td>Lower: $y = 1.9871x - 1.3672$ Higher: $y = 7.1685x + 7.1018$</td>
<td>0.40369</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>$y = 8.4495x + 26.185$</td>
<td>Lower: $y = 1.223x + 14.693$ Higher: $y = 15.676x + 37.676$</td>
<td>0.38803</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>$y = 7.1924x + 29.51$</td>
<td>Lower: $y = -0.0088x + 17.33$ Higher: $y = 14.393x + 41.689$</td>
<td>0.38784</td>
</tr>
<tr>
<td>36'' RC PIPE CUL.-CLASS III</td>
<td>$y = 7.4205x + 38.267$</td>
<td>Lower: $y = 4.256x + 30.308$ Higher: $y = 12.415x + 46.225$</td>
<td>0.36954</td>
</tr>
<tr>
<td>CONCRETE MEDIAN</td>
<td>$y = 7.9065x + 18.974$</td>
<td>Lower: $y = 1.3858x + 8.9194$ Higher: $y = 14.427x + 29.029$</td>
<td>0.32264</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6' UNIFORM)</td>
<td>$y = 1.1345x + 3.6327$</td>
<td>Lower: $y = -0.5242x + 1.0281$ Higher: $y = 2.7931x + 6.2374$</td>
<td>0.28297</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
<td>$y = 88.127x + 399.37$</td>
<td>Lower: $y = -1.7695x + 259.62$ Higher: $y = 178.02x + 539.12$</td>
<td>0.25607</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8' UNIFORM)</td>
<td>$y = 0.6547x + 5.5891$</td>
<td>Lower: $y = -0.5291x + 3.7207$ Higher: $y = 1.8386x + 7.4575$</td>
<td>0.19222</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>$y = -0.19x + 2.8602$</td>
<td>Lower: $y = -1.7693x - 0.5103$ Higher: $y = 1.3893x + 6.2307$</td>
<td>-0.08445</td>
</tr>
<tr>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>$y = -1.192x + 48.674$</td>
<td>Lower: $y = -20.716x + 17.329$ Higher: $y = 18.332x + 80.018$</td>
<td>-0.02930</td>
</tr>
</tbody>
</table>
Figure 7.1: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Curb and Gutter

**Regression:** $y = 3.7176x + 4.9726$

**Correlation:** 49.97%

**Upper:** $y = 5.042x + 7.6402$

**Lower:** $y = 1.9052x + 2.696$

*Graph showing the relationship between Fuel Price (gallon) and Bid Price with regression lines and correlation.*
Table 7-1 includes the regression analyses for the low bid vs. fuel price for Hot Mix Asphalt Concrete Surface CR Type 4. Figure 7-2 shows the linear regression models for the low bid vs. bidding volume analysis for Hot Mix Asphalt Concrete Surface CR Type 4. Upon regression analysis, as presented in Table 7-1, it was noted that there is a stronger correlation between low bid and fuel price than was evident with bidding volume. There was a 56% correlation between low bid price and fuel price in this particular case which should not be dismissed as a result of the data type. Due to this, further regression analysis beyond the correlation was conducted to determine a linear model for the data. This analysis was conducted in Excel and not only supplied equations for the linear model but also provided the equations for a 95% confidence interval surrounding the linear model. This analysis gave SCDOT a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 7.2: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 4

Regression: $y = 13.299x + 19.74$
Correlation: 56.09%

Upper: $y = 19.572x + 30.244$

Lower: $y = 7.0255x + 9.2358$
Table 7-1 includes the regression analyses for the low bid vs. fuel price for Borrow Excavation. Figures 7-3 show the linear regression models for the low bid vs. fuel price analysis for Borrow Excavation. Regression analysis presented in Table 7-1 showed that there is a correlation between low bid and fuel price. There was a 53.3% correlation between low bid price and fuel price in this particular case. Further regression analysis beyond the correlation was conducted to determine a linear model for the data in Excel. This analysis gave equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provided SCDOT with a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 7.3: Linear Regression for Fuel Price vs. Low Bid for Borrow Excavation

Fuel Price vs Low Bid for Borrow Excavation

\[ y = 5.7756x + 3.558 \]

Correlation: 53.30%

\[ y = 3.3872x - 0.267 \]

\[ y = 8.1639x + 7.383 \]
Table 7-1 includes the correlation and regression analyses for low bid vs. fuel price for Concrete Driveways. Figure 7-4 shows the linear regression models for low bid vs. fuel price analysis for Concrete Driveways. Regression analysis presented in Table 7-1 showed that there is a much stronger correlation between low bid and fuel price than bidding volume. There was a 65% correlation between low bid price and bidding volume in this particular case which is a strong correlation for this type of data. Further regression analysis beyond the correlation was conducted to determine a linear model for the data in Excel. This analysis provided equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis gave SCDOT a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 7-4: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Driveway (6" Uniform)

Fuel Price vs Low Bid for Concrete Driveway

- $y = 14.442x + 10.825$
- $y = 19.236x + 18.391$
- $y = 9.6475x + 3.2602$

Correlation: 65.01%
Fuel Price Adjustment Linear Regression Analysis Summary

Several of the bid line items identified by the SCDOT Research Steering Committee have a correlation with the fuel price index. Many of the items tended to fluctuate with the cost of fuel as it increased or decreased in one direction or the other as can be noted in the figures included in Appendix A. Because of this identified trend, a correlation analysis and regression analysis was conducted on these items.

Once the data for the linear regression model was graphed, it was noted that there were outliers within the data that needed to be removed and analyzed. Upon analysis of this data, it showed that the outliers resulted because of an unusually low material quantity for a project. After the outliers were removed, a regression analysis was conducted to determine the equations for the linear model as well as a 95% confidence interval. Using these three equations used simultaneously will allow the SCDOT to analyze their engineer’s estimate and determine if it is within the 95% confidence interval or to create a new estimate for that line item base on the current price of fuel.
CHAPTER 8

BIDDING VOLUME ADJUSTMENT LINEAR REGRESSION ANALYSIS

Methodology

In order to create a tool to improve the bidding process for the engineer’s estimate, the graphs of the low bid price vs. bidding volume had to be further analyzed. It was determined early on that the graphs of bidding volume vs. low bid price in Appendix B could be used to visualize if there would be a good correlation between the low bid and bidding volume. In a number of instances, it can be clearly seen, that there is greater correlation between the low bid and either the fuel price index or bidding volume. Once it is visually determined that there is a correlation between the variables and there was a linear relationship assumed to still exist, a linear regression analysis was conducted to determine a linear model for the variables as well as a 95% confidence interval. Of the 33 unit line items identified for analysis, only 28 line items contained sufficient data to undergo a linear regression analysis.

For a linear regression analysis to be conducted there must be similar number of observations for both variables with a connecting point between the variables. To achieve this, a connecting point was chosen as the monthly average cost for the unit cost line item price. This was chosen due to the fact that the bidding volume was already in the form of a monthly count. Therefore, the low bid unit cost line item prices must be converted into a monthly average. This was done in Microsoft Excel using the average function. It was noted that for certain unit cost line items there were months in which this item was not used and therefore had an average value of $0.00 and therefore would
negatively impact the accuracy of the analysis. Such instances were removed from the data so as not to affect the outcome. Once the average low bid unit cost line item price per month was determined it was graphed against the bidding volume per month.

After the data was graphed it was noted that there were outliers in the data for this analysis also. These data points were removed from the graph and were further analyzed to see if there was a reason for their anomalous condition. Again, these outliers were caused by a small quantity of work involved in this unit cost line item for one or more of the bids for that month that had been used in the average. Once these data points were removed, a clearer picture of the linear regression model could be produced.

After the data was plotted, regression lines were added to the data to allow for the visualization of the regression analysis. The 95% confidence intervals were also plotted to make it easier to visualize what data points fell within the confidence intervals and make it easier to use upon implementation.

Before the analysis was conducted it was determined that there was very little correlation between the two variables of fuel price and bidding volume. There was only a 21% correlation between the two variables. Because of this, it was determined that the analysis of the data would be conducted in a manner to allow for adjustments to either the fluctuations in fuel price or bidding volume separately. Therefore the equations can not be used simultaneously and whichever variable is of greater concern at the time due to its fluctuations or level of correlation should be utilized.
Bidding Volume Analysis

A linear regression analysis was performed to determine the relationship between bid price and bid volume for the previously identified bid line items. The results of the regression analysis are illustrated in Table 8.1. The regression equations are stated in the table such that $y$ is the bid price in dollars, and $x$ is bid volume. The regression analysis plots for four selected line items are discussed in this chapter. Regression plots for additional line items are contained in Appendix E.

Table 8-1 includes the regression analysis for the low bid vs. bid volume for all 28 unit cost line items. In this analysis there were no line items with a very significant correlation of greater than 70% and two line items with a significant correlation of 40% to 70%. Table 8-1 shows the correlation that exists between the bidding volume and the low bid. For each unit cost line item analyzed, the regression line is given in the form of $y = m\times x + b$. In this case “$x$” represents the bidding volume and “$y$” represents the estimated unit cost line item. The 95% confidence interval was also stated in this manner. An upper and lower limit for the 95% confidence interval was given. These equations provided the range of values that 95% of all estimates should fall under for a given bidding volume. This confidence interval could be utilized to allow an estimator to examine a unit cost line item and determine if it was competitive or if it falls out of the range for an acceptable estimate. Any estimate falling outside of these ranges was approximately 2 standard deviations from the mean value for the given bidding volume and therefore needs to be adjusted. These equations could be utilized to determine if the estimate for a unit cost line item that was currently being utilized in an engineer’s
estimate was still a competitive estimate based on the bidding volume fluctuations. It could also be utilized to quickly determine an estimate of the unit cost line item price for the engineer’s estimate based on the current bidding volume. See Chapter 9 for further discussion of these methodologies.

Table 8.1 also presented the results of the correlation analysis for each of the 28 unit cost line items. These correlations characterized the strength of the relationship between the two variables, bidding volume and low bid price. Therefore, the higher the correlation coefficient, the more accurate an estimate will be utilizing these equations. However, due to the type of data that was being analyzed and the various other external influences that can have an effect on the low bid price, it was determined early in the analysis that a correlation of greater than 40% was viewed as a significant correlation. Because of this, the unit cost line items with higher than 40 percent correlations are the best candidates for utilizing this analysis for conducting adjustments to the engineer’s estimate. There were 2 unit cost line items found to have a correlation of higher than 40%. The correlation between the bidding volume and the low bid price was not as strong of a correlation as the correlation between the fuel price and low bid price. SCDOT could use this analysis to make adjustments to the engineer’s estimate based on the fluctuations in the engineer’s estimate.

One such example is the relationship between the low bid price and bidding volume for Concrete Curb and Gutter, as seen in Table 8-1 and Figure 8-1. It appears that there is a correlation between low bid prices and bidding volume. It should be noted that there is still only a 32% correlation between these two variables but given the type of
data that is being analyzed this correlation should not be dismissed. Due to this, further regression analysis beyond the correlation was conducted to determine a linear model for the data. This analysis was conducted in Excel and not only provided equations for the linear model but also a 95% confidence interval surrounding the linear model. All three trend lines along with their representative equations are presented on the figures. This analysis gave SCDOT a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
<table>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear Regression Equation</th>
<th>95% Confidence Interval Equations</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BORROW EXCAVATION</td>
<td>$y = 0.2036x + 8.6945$</td>
<td>$y = 0.1001x + 6.229$</td>
<td>$y = 0.3072x + 11.16$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC.</td>
<td>$y = 0.4842x + 30.941$</td>
<td>$y = 0.1395x + 22.285$</td>
<td>$y = 0.8289x + 39.597$</td>
</tr>
<tr>
<td>SURF. CR. TYPE 4</td>
<td>$y = 0.0404x + 9.2984$</td>
<td>$y = 0.0179x + 7.2562$</td>
<td>$y = 0.1435x + 10.248$</td>
</tr>
<tr>
<td>CONCRETE Curb and</td>
<td>$y = 0.1534x + 6.7197$</td>
<td>$y = 0.0392x + 3.9738$</td>
<td>$y = 0.2677x + 9.4657$</td>
</tr>
<tr>
<td>Gutter(2’-0”)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNCLASSIFIED</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXCAVATION</td>
<td>$y = 0.1985x + 26.706$</td>
<td>$y = 0.0452x + 23.306$</td>
<td>$y = 0.3149x + 29.772$</td>
</tr>
<tr>
<td>CONCRETE SIDEWALK(4&quot;)</td>
<td>$y = 0.1457x + 21.802$</td>
<td>$y = 0.0218x + 18.776$</td>
<td>$y = 0.2695x + 24.828$</td>
</tr>
<tr>
<td>CONCRETE MEDIAN</td>
<td>$y = 0.1941x + 26.66$</td>
<td>$y = 0.0062x + 22.126$</td>
<td>$y = 0.382x + 31.194$</td>
</tr>
<tr>
<td>30” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.1599x + 35.957$</td>
<td>$y = 0.0082x + 32.387$</td>
<td>$y = 0.3115x + 39.527$</td>
</tr>
<tr>
<td>CONG. FOR STRUCTURES - CLASS 4000</td>
<td>$y = 3.4981x + 474.53$</td>
<td>$y = -0.0687x + 390.78$</td>
<td>$y = 7.0649x + 558.28$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>$y = 0.1305x + 35.75$</td>
<td>$y = -0.8377x + 11.495$</td>
<td>$y = 1.0987x + 60.005$</td>
</tr>
<tr>
<td>36” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.1882x + 45.603$</td>
<td>$y = -0.0237x + 40.535$</td>
<td>$y = 0.4x + 50.67$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>$y = 0.1732x + 38.034$</td>
<td>$y = -0.0225x + 33.161$</td>
<td>$y = 0.369x + 42.907$</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>$y = 0.1622x + 35.524$</td>
<td>$y = -0.0922x + 29.06$</td>
<td>$y = 0.4166x + 41.988$</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>$y = 0.0783x + 5.7661$</td>
<td>$y = -0.0322x + 2.9632$</td>
<td>$y = 0.1887x + 8.569$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>$y = 0.1672x + 39.255$</td>
<td>$y = -0.0553x + 33.871$</td>
<td>$y = 0.3897x + 44.639$</td>
</tr>
<tr>
<td>18” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.118x + 23.487$</td>
<td>$y = -0.0319x + 19.918$</td>
<td>$y = 0.2679x + 27.055$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>$y = 0.1746x + 38.842$</td>
<td>$y = -0.0783x + 32.626$</td>
<td>$y = 0.4275x + 45.057$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>$y = 0.1641x + 35.001$</td>
<td>$y = -0.0571x + 29.772$</td>
<td>$y = 0.3853x + 40.231$</td>
</tr>
<tr>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>$y = 0.2353x + 41.051$</td>
<td>$y = -0.4239x + 24.156$</td>
<td>$y = 0.8945x + 57.947$</td>
</tr>
<tr>
<td>CONCRETE DRIVEWAY(6” UNIFORM)</td>
<td>$y = 0.1172x + 31.725$</td>
<td>$y = -0.0769x + 27.039$</td>
<td>$y = 0.3114x + 36.411$</td>
</tr>
<tr>
<td>15” RC PIPE CUL.-CLASS III</td>
<td>$y = 0.1399x + 21.448$</td>
<td>$y = -0.0935x + 15.953$</td>
<td>$y = 0.3613x + 26.944$</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
<td>$y = 0.1037x + 38.516$</td>
<td>$y = -0.1128x + 33.277$</td>
<td>$y = 0.3202x + 43.756$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</td>
<td>$y = 0.0987x + 36.693$</td>
<td>$y = -0.1045x + 31.859$</td>
<td>$y = 0.3019x + 41.528$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8” UNIFORM)</td>
<td>$y = 0.0118x + 6.3151$</td>
<td>$y = -0.0357x + 5.1042$</td>
<td>$y = 0.0593x + 7.5261$</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>$y = 0.0817x + 43.7$</td>
<td>$y = -0.2378x + 35.953$</td>
<td>$y = 0.4012x + 51.447$</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>$y = 0.0534x + 40.055$</td>
<td>$y = -0.3278x + 30.681$</td>
<td>$y = 0.4347x + 49.429$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6” UNIFORM)</td>
<td>$y = 0.0033x + 5.3115$</td>
<td>$y = -0.0531x + 3.9425$</td>
<td>$y = 0.0598x + 6.6805$</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>$y = -0.0105x + 2.7178$</td>
<td>$y = -0.0866x + 0.7915$</td>
<td>$y = 0.0655x + 4.6441$</td>
</tr>
</tbody>
</table>

Table 8-1: Correlation and Linear Regression Analysis for Bidding Volume Adjustments
Figure 8.1: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Curb and Gutter

Regression: \( y = 0.0404x + 9.2984 \)

Correlation: 32.01%

Upper: \( y = 0.1435x + 10.248 \)

Lower: \( y = 0.0179x + 7.2562 \)
Table 8-1 includes the regression analysis for the low bid versus bidding volume for Hot Mix Asphalt Concrete Surface CR Type 4. Figure 8-2 shows the linear regression models for the low bid vs. bidding volume analysis for Hot Mix Asphalt Concrete Surface CR Type 4. Upon regression analysis, as presented in Table 8-1, it can be noted that there is a correlation between low bid and bidding volume. There was a 40.5% correlation between low bid price and bidding volume in this particular case but still this should not be dismissed. Due to this, further regression analysis beyond the correlation was conducted to determine a linear model for the data. This analysis was conducted in Excel and not only provides equations for the linear model but also provides the equations for a 95% confidence interval surrounding the linear model. This analysis provided SCDOT with a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 8.2: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 4

Regression: \( y = 0.4842x + 30.941 \)

Correlation: 40.50%

Upper: \( y = 0.8289x + 39.597 \)

Lower: \( y = 0.1395x + 22.285 \)
Table 8-1 includes the regression analyses for the low bid vs. bidding volume for Borrow Excavation. Figure 8-3 shows the linear regression models for the low bid vs. bidding volume analysis for Borrow Excavation. Regression analysis presented in Table 8-1 shows that there is a correlation between low bid and bidding volume. There was a 43.5% correlation between low bid price and bidding volume in this particular case but still this should not be dismissed. Further regression analysis beyond the correlation was conducted to determine a linear model for the data in Excel. The analysis supplied equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provided SCDOT with a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 8-3: Linear Regression for Bidding Volume vs. Low Bid Price for Borrow Excavation

\[ y = 0.2036x + 8.6945 \]

Correlation: 43.51%

\[ y = 0.3072x + 11.16 \]

\[ y = 0.1001x + 6.229 \]

$0.00 \quad $5.00 \quad $10.00 \quad $15.00 \quad $20.00 \quad $25.00 \quad $30.00

Bidding Volume (per month)
Table 8-1 illustrates the regression analyses for low bid vs. bidding volume for Concrete Driveways. Figure 8-4 shows the linear regression models for low bid vs. bidding volume analysis for Concrete Driveways. Regression analysis presented in Table 8-1 show that there is a slight correlation between low bid and bidding volume. There was only a 15.81% correlation between low bid price and bidding volume in this particular case. Further regression analysis beyond the correlation was conducted to determine a linear model for the data in Excel. This analysis supplied equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provided SCDOT with a tool to compare its historical data based estimates to the regression analysis and determine if it fits the trend within a confidence interval of 95%.
Figure 8.4: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Driveway (6" Uniform)

Bidding Volume vs Low Bid for Concrete Driveway

- $y = 0.1172x + 31.725$
- $y = -0.0769x + 27.039$
- $y = 0.3114x + 36.411$

Correlation: 15.81%
Bidding Volume Adjustment Linear Regression Analysis Summary

Several of the bid line items identified by the SCDOT Research Steering Committee have a correlation with bidding volume. Many of the items tended to fluctuate with the bidding volume as they moved in one direction or the other, as can be noted in the figures included in Appendix B. Because of this identified trend, a correlation analysis and regression analysis was conducted on these items.

Once the data for the linear regression model was graphed, it was noted that there were outliers within the data that needed to be removed and analyzed. Upon analysis of this data, it showed that it was a result of an unusually high or low material quantity of work. After the outliers were removed, a regression analysis was conducted to determine the equations for the linear model as well as a 95% confidence interval. Using these three equations simultaneously will allow the SCDOT to analyze their engineer's estimate and determine if it is within the 95% confidence interval or to create a new estimate for that line item based on the current bidding volume load.
CHAPTER 9

METHODOLOGY FOR IMPLEMENTATION

Methodology

SCDOT initiated the research project with two summary objectives stipulated. The first objective was to determine the comparative advantages and disadvantages of cost based estimating versus unit cost line item estimating. This objective is addressed in the Volume I Research Report. The second objective was to develop a methodology for adjusting selected unit cost line items to account for fluctuations in gasoline and asphalt prices and for bidding volume. The analyses outlined in Research Report Volume II addressed this second objective by creating a methodology for making adjustments to the unit cost line items related with fuel and asphalt adjustments.

In the fuel price index and bidding volume analysis, unit cost line item price data was compared to the fuel price index and SCDOT bidding volume per month for January 2000 through October 2005. Specific relationships were identified. As bidding volume or fuel price increased over time, the low bid price would tend to increase with the increase in bidding volume or fuel price. In comparison, the engineer’s estimate tended to have a lag of a year or more before it would incorporate fluctuations. In some cases, the engineer’s estimate would over compensate for the lag and the bid price would increase past the low bid price. This relationship can be noted in Figures 4-1 and 5-2. In cases such as these SCDOT may wish to further refine its estimating procedures, either through the adjustment methodology suggested in this report or by using cost based estimating for future estimates. This analysis would be very useful if SCDOT determines
through the research described in the Volume I report to begin using cost based estimating its estimating procedures. A number of line items fell into this category based on the correlations determined in the engineer’s estimate vs. low bid regression analysis. A list of line items was compiled based on a correlation of less than 70%. This low correlation is indicative of the lag relationship in which the engineer’s estimate would have a lag over time, compared to the low bid, before it would finally recognize and address fluctuations in either fuel price or bidding volume. The list of line items dealing with this relationship is included in Table 9-1. These line items are a subset of the 33 unit cost line items addressed by the SCDOT Research Steering Committee to be analyzed during the research. If SCDOT determines that the advantages of employing a cost based system outweigh the disadvantages, these line items could be a good starting point to begin the use of cost based estimating.
<table>
<thead>
<tr>
<th>BAMS #</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2033000</td>
<td>BORROW EXCAVATION</td>
<td>CY</td>
</tr>
<tr>
<td>7203210</td>
<td>CONCRETE CURB AND GUTTER(2'0&quot;)</td>
<td>LF</td>
</tr>
<tr>
<td>7205000</td>
<td>CONCRETE DRIVEWAY(6&quot; UNIFORM)</td>
<td>SY</td>
</tr>
<tr>
<td>7206000</td>
<td>CONCRETE MEDIAN</td>
<td>SY</td>
</tr>
<tr>
<td>7204100</td>
<td>CONCRETE SIDEWALK(4&quot; UNIFORM)</td>
<td>SY</td>
</tr>
<tr>
<td>2081001</td>
<td>FINE GRADING</td>
<td>SY</td>
</tr>
<tr>
<td>3050108</td>
<td>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</td>
<td>SY</td>
</tr>
<tr>
<td>3103000</td>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>TON</td>
</tr>
<tr>
<td>4023000</td>
<td>HOT MIX ASPH. CONC. BINDER. CR. - TYPE 2</td>
<td>TON</td>
</tr>
<tr>
<td>4031410</td>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>TON</td>
</tr>
<tr>
<td>4036300</td>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>TON</td>
</tr>
<tr>
<td>3093000</td>
<td>HOT MIX SAND ASPH. BASE CR. TYPE 3</td>
<td>TON</td>
</tr>
<tr>
<td>2034000</td>
<td>MUCK EXCAVATION</td>
<td>CY</td>
</tr>
<tr>
<td>4036201</td>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>TON</td>
</tr>
<tr>
<td>7141113</td>
<td>18&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
</tr>
<tr>
<td>7141112</td>
<td>15&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
</tr>
<tr>
<td>7141114</td>
<td>24&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
</tr>
<tr>
<td>7141116</td>
<td>36&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
</tr>
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<td>7141115</td>
<td>30&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
</tr>
<tr>
<td>4030100</td>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>TON</td>
</tr>
<tr>
<td>2031000</td>
<td>UNCLASSIFIED EXCAVATION</td>
<td>CY</td>
</tr>
</tbody>
</table>
The fuel price index and bidding volume analysis helped to visualize the relationships between the unit cost line items and the fuel price index and bidding volume per month. This visualization indicated that in many cases there appeared to be a strong correlation in the fluctuations of the variables. Therefore, further analysis was recommended. A linear regression and correlation analysis on the low bid data for the unit cost line items was conducted to determine if a tool could be created due to this correlation. It was determined that the regression line accompanied by the 95% confidence interval could be used to create a tool to quickly make adjustments to unit cost line items based on fuel price and bidding volume.

To implement the regression analysis as a tool, a brief explanation of the graph must be presented. When interpreting the graphs there are three lines present, the linear regression line and its equation and the two lines for the 95% confidence intervals with their respective equations. Referring to Figures 9-1 and 9-2 which are reproductions of Figures 7-1 and 8-1, the 95% confidence interval has an upper and lower boundary line and therefore will always be the lines at the top and bottom of the graph. The 95% confidence interval lines in Figures 9-1 and 9-2 are labeled upper and lower to correspond with the boundaries. The linear regression line is always in the middle of the graph with the upper boundary for the 95% confidence interval above and the lower boundary for the 95% confidence interval below. The regression lines in Figures 9-1 and 9-2 are labeled regression to correspond with the regression line.

Tables 9-2 and 9-3, which are reproductions of Tables 7-1 and 8-1, show the results of the linear regression and correlation analysis for bidding volume and fuel price
adjustments for each of the 28 unit cost line items that contained sufficient data for a meaningful statistical analysis. The tables are comprised of the linear regression equations, 95% confidence intervals, and the correlation for each of the 28 unit cost line items analyzed. Upon comparing the correlations of the two analyses in Tables 9-2 and 9-3 it can be seen that there is a higher correlation between low bid and fuel price than there is between low bid and bid volume. This is evidenced by the fact that there were nineteen unit cost line items that had at least a significant correlation (40% or better) in their low bid price with fuel price and only two unit cost line items that had at least a significant correlation in their bid price with bid volume. The line items with at least a significant correlation should be the candidates considered for adjustment using the methodologies discussed further in this section. These specific unit cost line items regression equations and 95% confidence interval equations can be used as a tool to implement adjustments to the bid price for fluctuation in the fuel price and bidding volume.
Figure 9-1: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Curb and Gutter

Regression: $y = 3.7176x + 4.9726$
Correlation: 49.97%

Lower: $y = 1.9052x + 2.696$
Upper: $y = 5.042x + 7.6402$

Fuel Price ($/gallon) vs Bid Price ($)

$0.00$  $5.00$  $10.00$  $15.00$  $20.00$  $25.00$

1  1.2  1.4  1.6  1.8  2  2.2  2.4
### Table 9-2: Correlation and Linear Regression Analysis for Fuel Price Adjustments

<table>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear Regression Equation</th>
<th>95% Confidence Interval Equations</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Price Adjustment</strong></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>18” RC PIPE CUL.-CLASS III</td>
<td>$y = 10.453x + 9.4496$</td>
<td>$y = 7.9101x + 5.2914$</td>
<td>$y = 12.996x + 13.608$</td>
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<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>$y = 16.813x + 12.496$</td>
<td>$y = 12.548x + 5.7277$</td>
<td>$y = 21.077x + 19.264$</td>
</tr>
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<td>MUCK EXCAVATION</td>
<td>$y = 5.5463x - 1.5094$</td>
<td>$y = 3.7343x - 4.5832$</td>
<td>$y = 7.3583x + 1.5645$</td>
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<tr>
<td>15” RC PIPE CUL.-CLASS III</td>
<td>$y = 16.402x - 0.9357$</td>
<td>$y = 11.686x - 8.393$</td>
<td>$y = 21.119x + 6.5215$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>$y = 16.202x + 23.036$</td>
<td>$y = 8.2666x + 17.128$</td>
<td>$y = 15.437x + 28.944$</td>
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<tr>
<td>CONCRETE DRIVEWAY(6” UNIFORM)</td>
<td>$y = 14.442x + 10.825$</td>
<td>$y = 9.6475x + 3.2602$</td>
<td>$y = 19.236x + 18.391$</td>
</tr>
<tr>
<td>24” RC PIPE CUL.-CLASS III</td>
<td>$y = 11.763x + 12.691$</td>
<td>$y = 8.9274x + 8.1392$</td>
<td>$y = 14.599x + 17.244$</td>
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<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
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<td>$y = 9.4x + 12.284$</td>
<td>$y = 18.01x + 26.178$</td>
</tr>
<tr>
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<td>$y = 12.341x + 19.246$</td>
<td>$y = 8.4334x + 12.872$</td>
<td>$y = 16.249x + 25.62$</td>
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<td>$y = 9.0371x + 25.265$</td>
<td>$y = 5.9096x + 20.235$</td>
<td>$y = 12.165x + 30.295$</td>
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<td>CONCRETE SIDEWALK(4” UNIFORM)</td>
<td>$y = 7.0877x + 13.764$</td>
<td>$y = 4.577x + 9.6363$</td>
<td>$y = 9.5984x + 17.891$</td>
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<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
<td>$y = 13.299x + 19.74$</td>
<td>$y = 7.0255x + 9.2358$</td>
<td>$y = 19.572x + 30.244$</td>
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<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>$y = 4.2867x + 28.797$</td>
<td>$y = -7.5325x + 0.5466$</td>
<td>$y = 16.106x + 57.047$</td>
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<tr>
<td>BORROW EXCAVATION</td>
<td>$y = 5.7756x + 3.558$</td>
<td>$y = 3.3872x - 0.267$</td>
<td>$y = 8.1639x + 7.383$</td>
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<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>$y = 12.132x + 24.117$</td>
<td>$y = 6.8765x + 15.748$</td>
<td>$y = 17.388x + 32.486$</td>
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<tr>
<td>CONCRETE CURB AND GUTTER(2’-0”)</td>
<td>$y = 3.7176x + 4.9726$</td>
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<td>$y = 5.042x + 7.6402$</td>
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<td>$y = 12.21x + 23.645$</td>
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<td>$y = 18.882x + 34.33$</td>
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<tr>
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<td>$y = 12.542x + 25.384$</td>
<td>$y = 5.5507x + 13.866$</td>
<td>$y = 19.533x + 36.901$</td>
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<tr>
<td>UNCLASSIFIED EXCAVATION</td>
<td>$y = 4.5778x + 2.8673$</td>
<td>$y = 1.9871x - 1.3672$</td>
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</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>$y = 8.4495x + 26.185$</td>
<td>$y = 1.223x + 14.693$</td>
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<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>$y = 7.1924x + 29.51$</td>
<td>$y = -0.0088x + 17.33$</td>
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<tr>
<td>36” RC PIPE CUL.-CLASS III</td>
<td>$y = 7.4205x + 38.267$</td>
<td>$y = 2.4256x + 30.308$</td>
<td>$y = 12.415x + 46.225$</td>
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<tr>
<td>CONCRETE MEDIAN</td>
<td>$y = 7.9065x + 18.974$</td>
<td>$y = 1.3858x + 8.9194$</td>
<td>$y = 14.427x + 29.029$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6” UNIFORM)</td>
<td>$y = 1.1345x + 3.6327$</td>
<td>$y = -0.5242x + 1.0281$</td>
<td>$y = 2.7931x + 6.2374$</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
<td>$y = 88.127x + 399.37$</td>
<td>$y = -1.7695x + 259.62$</td>
<td>$y = 178.02x + 539.12$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8” UNIFORM)</td>
<td>$y = 0.6547x + 5.5891$</td>
<td>$y = -0.5291x + 3.7207$</td>
<td>$y = 1.8386x + 7.4575$</td>
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<tr>
<td>FINE GRADING</td>
<td>$y = -0.19x + 2.8602$</td>
<td>$y = -1.7693x - 0.5103$</td>
<td>$y = 1.3893x + 6.2307$</td>
</tr>
<tr>
<td>OPEN-GRADED FRICITION COURSE</td>
<td>$y = -1.192x + 48.674$</td>
<td>$y = -0.20716x + 17.329$</td>
<td>$y = 18.332x + 80.018$</td>
</tr>
</tbody>
</table>
Figure 9-2: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Curb and Gutter

Regression: $y = 0.0404x + 9.2984$

Correlation: 32.01%

Upper: $y = 0.1435x + 10.248$

Lower: $y = 0.0179x + 7.2562$
Table 9-3: Correlation and Linear Regression Analysis for Bidding Volume Adjustments

<table>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear Regression Equation</th>
<th>95% Confidence Interval Equations</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>BORROW EXCAVATION</td>
<td>( y = 0.2036x + 8.6945 )</td>
<td>( y = 0.1001x + 6.229 )</td>
<td>( y = 0.3072x + 11.16 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
<td>( y = 0.4842x + 30.941 )</td>
<td>( y = 0.1395x + 22.285 )</td>
<td>( y = 0.8289x + 39.597 )</td>
</tr>
<tr>
<td>CONCRETE CURB AND GUTTER(2'-0&quot;)</td>
<td>( y = 0.0404x + 9.2984 )</td>
<td>( y = 0.0179x + 7.2562 )</td>
<td>( y = 0.1435x + 10.248 )</td>
</tr>
<tr>
<td>UNCLASSIFIED EXCAVATION</td>
<td>( y = 0.1534x + 6.7197 )</td>
<td>( y = 0.0392x + 3.9738 )</td>
<td>( y = 0.2677x + 9.4657 )</td>
</tr>
<tr>
<td>24&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 0.1985x + 26.706 )</td>
<td>( y = 0.0452x + 23.306 )</td>
<td>( y = 0.3149x + 29.772 )</td>
</tr>
<tr>
<td>CONCRETE SIDEWALK(4&quot; UNIFORM)</td>
<td>( y = 0.1457x + 21.802 )</td>
<td>( y = 0.0218x + 18.776 )</td>
<td>( y = 0.2695x + 24.828 )</td>
</tr>
<tr>
<td>30&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 0.1599x + 35.957 )</td>
<td>( y = 0.0082x + 32.387 )</td>
<td>( y = 0.3115x + 39.527 )</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
<td>( y = 3.4981x + 474.53 )</td>
<td>( y = -0.0687x + 390.78 )</td>
<td>( y = 7.0649x + 558.28 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>( y = 0.1305x + 35.75 )</td>
<td>( y = -0.8377x + 11.495 )</td>
<td>( y = 1.0987x + 60.005 )</td>
</tr>
<tr>
<td>36&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 0.1882x + 45.603 )</td>
<td>( y = -0.0237x + 40.535 )</td>
<td>( y = 0.4x + 50.67 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>( y = 0.1732x + 38.034 )</td>
<td>( y = -0.0225x + 33.161 )</td>
<td>( y = 0.369x + 42.907 )</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>( y = 0.1622x + 35.524 )</td>
<td>( y = -0.0922x + 29.06 )</td>
<td>( y = 0.4166x + 41.988 )</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>( y = 0.0783x + 5.7661 )</td>
<td>( y = -0.0322x + 2.9632 )</td>
<td>( y = 0.1887x + 8.569 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>( y = 0.1672x + 39.255 )</td>
<td>( y = -0.0553x + 33.871 )</td>
<td>( y = 0.3897x + 44.639 )</td>
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<tr>
<td>18&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 0.118x + 23.487 )</td>
<td>( y = -0.0319x + 19.918 )</td>
<td>( y = 0.2679x + 27.055 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>( y = 0.1746x + 38.842 )</td>
<td>( y = -0.0783x + 32.626 )</td>
<td>( y = 0.4275x + 45.057 )</td>
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<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>( y = 0.1641x + 35.001 )</td>
<td>( y = -0.0571x + 29.772 )</td>
<td>( y = 0.3853x + 40.231 )</td>
</tr>
<tr>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>( y = 0.2353x + 41.051 )</td>
<td>( y = -0.4239x + 24.156 )</td>
<td>( y = 0.8945x + 57.947 )</td>
</tr>
<tr>
<td>CONCRETE DRIVEWAY(6&quot; UNIFORM)</td>
<td>( y = 0.1172x + 31.725 )</td>
<td>( y = -0.0769x + 27.039 )</td>
<td>( y = 0.3114x + 36.411 )</td>
</tr>
<tr>
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<td>( y = 0.1399x + 21.448 )</td>
<td>( y = -0.0935x + 15.953 )</td>
<td>( y = 0.3613x + 26.944 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
<td>( y = 0.1037x + 38.516 )</td>
<td>( y = -0.1126x + 33.277 )</td>
<td>( y = 0.3202x + 43.756 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1C</td>
<td>( y = 0.0987x + 36.693 )</td>
<td>( y = -0.1045x + 31.859 )</td>
<td>( y = 0.3019x + 41.528 )</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</td>
<td>( y = 0.0118x + 6.3151 )</td>
<td>( y = -0.0357x + 5.1042 )</td>
<td>( y = 0.0593x + 7.5261 )</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>( y = 0.0817x + 43.7 )</td>
<td>( y = -0.2378x + 35.953 )</td>
<td>( y = 0.4012x + 51.447 )</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>( y = 0.0534x + 40.055 )</td>
<td>( y = -0.3278x + 30.681 )</td>
<td>( y = 0.4347x + 49.429 )</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</td>
<td>( y = 0.0033x + 5.3115 )</td>
<td>( y = -0.0531x + 3.9425 )</td>
<td>( y = 0.0598x + 6.6805 )</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>( y = -0.0105x + 2.7178 )</td>
<td>( y = -0.0866x + 0.7915 )</td>
<td>( y = 0.0655x + 4.6441 )</td>
</tr>
</tbody>
</table>
Before addressing specifically how to implement the research analysis, it must be noted that this analysis was conducted to allow for adjustments to the bid prices for either fluctuations in fuel price or bidding volume separately. The analysis was not designed to allow for both adjustment equations to be used simultaneously due to the fact that there was very little correlation between the variables of average fuel price and bidding volume per month. Due to the fact that there was only a 21% correlation between fuel price and bidding volume, the analysis was designed to have separate methodologies for making adjustments for fuel price and bidding volume. Therefore the equations must be utilized separately depending on which variable is of greater concern to the SCDOT due to its estimated fluctuations. With this noted, the analyses can be used as a tool to make adjustments to these line items in two different ways.

The first implementation of this analysis can be accomplished by making adjustments to an already existing estimate for a unit cost line item. Upon an increase in either fuel price or bidding volume, the SCDOT could use the appropriate line item graph to determine an approximation of the price using the regression equation and compare it to the current estimate. If there is a large discrepancy between the current estimate and the prediction from the regression equation, the 95% confidence intervals would then come into use. The estimator can then use the 95% confidence interval equations provided on the graph to determine if the current estimate falls within the given confidence interval. If the current estimate is within the 95% confidence interval then the estimator can be fairly certain that the estimate is competitive. But, if the current estimate is outside of the 95% confidence interval then the estimator would know that
there is only a 5% probability that the estimate could be competitive with the low bids that the contractors will be submitting. In which case, the estimate may need to be adjusted for the price or volume fluctuation. This can be very useful given that the engineer’s estimate can be prepared as early as 6 weeks before bid letting and would allow estimators to quickly adjust estimates closer to the bid letting.

For example, in Figure 9-1 above, if the fuel price were to increase to $2.35 the linear regression equation could be utilized to determine that the unit price for Concrete Curb and Gutter would be $13.71. If the current estimate called for a price of $12.75 and the estimator is concerned that this is too great of an increase, the 95% confidence intervals can then be utilized to see if the current estimate fell within the 95% confidence intervals. The 95% confidence interval is ($7.17, $19.49). Because the current estimate is within the 95% confidence interval the new bid estimate should be utilized because it is still competitive but takes into account the new fuel prices.

A second use for the regression and correlation analysis is in quick determinations for unit cost line item estimates. In order to achieve this, an estimator could use the regression equation to find an approximation of the price for the unit cost line item based on either the current fuel price or the anticipated bidding volume for that month. The 95% confidence intervals could then be determined for that fuel price or bidding volume as well. Using these data points an estimator could then use his/her judgment and experience to make a prediction on the price to use in a detailed estimate. This would be a way to quickly determine an estimate for a unit cost line item and still have confidence
that it will be competitive with the contractors bid price based on the current fuel price or bidding volume in a given area.

Using the same example from above with a fuel price of $2.35, using Figure 9-1 the bid price derived from the linear regression equation would be $13.71 with a 95% confidence interval of ($7.17, $19.49). This data could then be used along with experience and judgment to determine a competitive price. For example the estimator may wish to make the price more competitive than the estimate and the 95% confidence interval can then be used to allow the estimator to determine a price that he can be sure has only a 5% chance of being statistically incorrect.

SCDOT should be able to use these research analyses in three different ways. SCDOT will be able to determine some line items with which to begin implementing cost based estimating if it should be deemed to be appropriate and an efficient use of SCDOT revenues. The analyses have also provided a tool with which to make adjustments to the unit cost line items related to fuel and asphalt adjustments based on current fuel price and bidding volume. Also, the regression and correlation analysis can also be used to make predictions for the unit cost line items based on the current fuel price and bidding volume with a 95% confidence level that the price is competitive with the low bids from the contractors.
CHAPTER 10

SUMMARY AND CONCLUSIONS

Summary

The South Carolina Department of Transportation initiated a research study into the “Best Practices for Developing the Engineer’s Estimate.” This was a two part study into the methodologies and factors influencing the engineer’s estimate. The first phase of the research study looked into determining the comparative advantages and disadvantages of cost based estimating versus unit cost line item estimating and was discussed in research report Volume I. The second phase of the research, “Analysis of the Impact of Fuel Price and Bidding Volume on the Engineer’s Estimate”, was conducted to propose a methodology for making adjustment to specifically chosen unit cost bid line items dealing with fuel/asphalt and bidding volume adjustments. This research was outlined in this volume of the research report. In order to propose a methodology for adjusting the engineer’s estimate based on fuel prices and bid volume, a number of objectives were completed in order to thoroughly investigate the relationships between the engineers estimate, low bid price, fuel price index, and bidding volume for the unit cost line items that are fuel/asphalt intensive.

The first objective was to conduct a literature review concerning similar research, current methodologies for fuel and asphalt adjustments, and other supporting information. The research team was able to identify a MS thesis from Auburn that detailed a number of causes in the fluctuation of contractors bid prices including bidding volume in the state of Alabama (16). Also a number of documents were procured that described the current
methodologies for making adjustments to the bid price for fluctuations in the fuel or asphalt prices that were being utilized by a number of states including Idaho, Nevada, North Carolina, South Carolina, South Dakota, and Utah (1, 2, 3, 4, 5, 6, 7, 8, 14, 15). These sources provided insight into how states currently go about adjusting the contractor’s compensation because of an increase, or decrease in some cases, in fuel prices or the cost of asphalt. In all cases this adjustment method was post bid compensation method. Therefore, there were no methodologies that could be identified that will allow a Department of Transportation to adjust its engineer’s estimate based on fuel or asphalt price fluctuation prior to the letting date of the project. Other forms of price based adjustments were identified during the research as well. One such adjustment allowed for post bid compensation adjustments based on the escalation of steel prices in the state of Nevada (7). Another aspect of the literature review was designed to identify price indices for the fuel and asphalt from 2000 to 2005. A corresponding asphalt price index was unable to be identified. A fuel price index was identified through the United States Department of Energy and the Energy Information Administration. This index detailed the fluctuations in fuel price for the Southeastern United States. This data was utilized in the analysis of the bid history data supplied by the SCDOT.

One goal of this research report was to identify unit cost line items affected by fuel and asphalt price fluctuations. The data provided by the South Carolina Department of Transportation contained 6932 differing unit cost line items for 2440 projects. During a meeting with the SCDOT Steering Committee for this project, 44 of these unit cost line items were identified which were believed to be influenced by fuel and asphalt price
fluctuations. The data for these unit cost line items was analyzed and it was determined that 33 unit cost line items contained enough data on which to perform a basic correlation analysis. The data was further analyzed and it was determined that, of the 33 unit cost line items that contained enough data for a basic analysis, 28 of the unit cost line items contained enough information to conduct a detailed correlation and regression analysis. A thorough statistical analysis of this data was conducted.

A statistical analysis of the data provided by SCDOT was undertaken to identify relationships that were occurring between SCDOT engineer’s estimates, contractor’s low bid prices, fuel prices, and bidding volume. The first step in this analysis was to conduct a preliminary analysis of the data to determine, first and foremost, if there was a relationship between the variables that could be of interest. As shown in Figures 3-1 and 3-2, there appears to be a correlation that exists between the low bid and fuel price index as well as with the bidding volume that would be examined in later analyses. It was also shown during this analysis that there was a linear relationship between fuel price and low bid price as well as bidding volume and low bid price. This analysis also indicated that there were, in many cases, outlying data points in the bid line item sample data that could skew the results. These outlying data points were identified in each of the sample sets and examined to determine the cause of the variance. After examining the data, it was found that the outlying data points were caused by projects that contained low material quantities of the specific line item which drove the cost up. It was determined that there was an inverse relationship between material quantity and price in the cases of these outlying data points. As material quantities decreased for certain line items the bid price
for that line item would increase. It was determined that these data points should be removed to avoid impacting the overall analysis. Once these outliers were identified and removed the data was analyzed again.

An analysis was then conducted to determine how the variables fuel price, engineer’s estimate, and low bid related to each other, as well as bidding volume, engineer’s estimate, and low bid, after the outliers had been removed. This analysis showed a couple of interesting relationships between the variables. First, shown in Figures 4-1, 4-2, 5-1, and 5-2 there appears to be a correlation between the fuel price and the contractor’s low bid. As the fuel price increases or decreases the contractors bid tends to follow in a similar trend. The second relationship that appears is between the engineer’s estimate and the low bid. It can be seen in Figures 4-1 and 5-1 that, as the low bid price fluctuates with the fuel price or bidding volume, the engineer’s estimate tends to lag behind in recognizing the fluctuations in the fuel price or bidding volume for some time. This relationship appeared in a number of the unit cost line items that were analyzed, as can be seen in Table 9-1. This could be caused by the use of historical bid data to formulate the engineer’s estimate. It would take time for the historical data to recognize and adjust for the fluctuations in fuel price or bidding volume due to the fact that this data is based on previous contractor bids. This may indicate unit cost line items that need to be approached in a different manner either through a cost-based approach or using the adjustment approach outlined in this report.

Once it was determined that there appeared to be a correlation between the variables over time, a thorough correlation and regression analysis was conducted to get a
clearer picture of the relationships between the engineer’s estimate, low bid price, the fuel price index, and bidding volumes. The first relationship that was analyzed was the relationship between the engineer’s estimate and the low bid price. A correlation and regression analysis was conducted to determine any pertinent relationships. Two major relationships appeared in this analysis. The first being that, in a number of the unit cost line items, there was a significant correlation between the engineer’s estimate and the low bid price. Because of this relationship it would be possible to estimate, within a certain margins of error, the range of the low bid price that may be received. Another relationship that appeared between these variables was in the line items with the lower correlation. As stated before, there was a lag relationship that showed up in a number of the line items. Upon conducting this analysis, it was discovered that the line items with the lowest correlations were the same line items that showed this lag relationship between the engineer’s estimate and the low bid price. The less correlation there was between these variables, the more lag and oscillation occurred between the engineer’s estimate and low bid price. This relationship was a very interesting finding and may merit further investigation in the future. The relationships between the engineer’s estimate and low bid price do not offer an effective means for pre-bid letting adjustment based on fuel price or bidding volume fluctuations but did provide useful insight into how the variables reacted to each other.

The relationship between the low bid price and the fuel price index was then investigated using a correlation and regression analysis to determine if there was a relationship that could provide a means for adjusting the engineer’s estimate pre-bid
letting based on the fuel price. Assuming a linear relationship still existed, a linear regression analysis was conducted on the data. One of the first things that was seen in the analysis was that there were still outlying data points. These data points were identified and analyzed. Once again the analysis of the outliers showed that they were caused by low material quantities that drive up the price of the bid line item for the project. This relationship is interesting and may merit further research in the future. Once these outliers were removed, the analysis was continued. It was determined that nineteen of unit cost line items had a significant correlation of greater than 40% with fuel price, as can be seen in Table 7-1. These items that had a significant correlation are the best candidates to use the suggested methodology for adjusting the engineer’s estimate for the fluctuations in fuel price. The correlations below 40% should not be ignored though, because data can be extrapolated from these analyses and used for adjustments but may experience a lower accuracy. It was determined that the best methodology for making adjustments to the unit cost line items, based on the analysis, would be to utilize the regression line and 95% confidence intervals as a tool to make the adjustments as defined in Chapter 9 of this report.

A similar analysis to the one conducted above was utilized to evaluate the relationships between the low bid price and bidding volume. Assuming a linear relationship still existed, a correlation and linear regression analysis was conducted on the data. Once the data was analyzed, the outliers were noted in the data set as well. Once again they were investigated and removed because the outliers were affected by the same low material quantities as before. Once the outliers were removed, a correlation and
regression analysis was conducted on the variables to determine their relationships. In this case, bidding volume did not correlate as highly as fuel price with the low bid price. There were two line items that had a significant correlation of 40% or higher, as can be seen in Table 8-1. The line items with a significant correlation with bidding volume are once again the best candidates to utilize the suggested methodology for making adjustments to the engineer’s estimate for fluctuations in bidding volume. However, the line items analyses with a lower correlation may still be utilized to make adjustments to the engineer’s estimate as well but may experience a lower accuracy. It was determined that the best methodology for making adjustments to the unit cost line items, based on the analysis, would be to utilize the regression line and 95% confidence intervals as a tool to make the adjustments as defined in Chapter 9 of this report.

Conclusions

It is not uncommon for bid prices to come in higher than the engineer’s estimate. Fluctuations in factors such as fuel and asphalt prices, and even bidding volume, can drive the costs of certain line items higher than historical values maintained by state departments of transportation for estimating purposes. State DOTs recognize the need to make adjustments to certain line items to enable contractors to receive just compensation for their work. However, the most common practice is to make fuel price adjustments after a contract has already been signed. These ad hoc methodologies do not allow a DOT to plan ahead for these cost increases before they let the bid to contract, and other contracts may be postponed as a result. Because of this, the South Carolina Department
of Transportation initiated a research study to determine a methodology for making adjustments to the engineer’s estimate based on fuel prices and bidding volume.

Prior to beginning work on a new methodology for making adjustments to the engineer’s estimate, the author conducted a literature review into current methodologies being utilized to make adjustments to bid line items, the relationships between the variables of interest – the engineer’s estimate, low bid price, fuel price and bidding volume; and price indices that could be utilized in the analysis of the data. During the literature review, a number of methodologies for making adjustments to the bid price for fuel and asphalt prices were identified from varying states including South Carolina, North Carolina, Idaho, Utah, Nevada, and South Dakota. Unfortunately, the identified methodologies for making adjustments to the bid price involved making adjustments after the project has been contracted out for completion; and therefore, did not represent a methodology that could be utilized in making adjustments to the engineers estimate. Resources describing the relationships between the variables of bid price and fuel price, as well as bid price and bidding volume were identified. They illustrated a correlation between the fluctuations in bid price and both fuel price or bidding volume. This indicated that bid price could be impacted by fuel price or bidding volume for specific line items. Therefore, a fuel price index for the Southeast was identified to be utilized in the analysis of the data provided by SCDOT.

Based on the findings of the literature review, analyses were conducted to determine the relationships between the differing variables mentioned above. A preliminary analysis was conducted that illustrated the correlation between low bid price
and both bidding volume and fuel price. However, it was noted that there were outlying data points in the data sets that skewed the analysis. Therefore, a student residual regression analysis was conducted. This analysis was able to identify and remove the outlying data points that were then further analyzed to determine the cause of the discrepancy. It was determined that the outlying data points were caused by extremely low material quantities for the unit cost line item in question. With these outliers removed, a residual regression analysis was then conducted to determine the linearity of the relationships in question. This analysis indicated that there was a linear relationship between the low bid price and fuel price as well as the low bid price and bidding volume. This finding suggested that linear regression was a valid tool for further analysis.

A secondary analysis was conducted that illustrated the correlation between low bid price and fuel price or bidding volume. The analysis showed an interesting relationship between the low bid price and the engineer’s estimate in which the low bid price would recognize the fluctuation in either fuel price or bidding volume but the engineer’s estimate would take months, if not a year or more, to recognize the fluctuation in the estimate. It was speculated that this may have been caused by the use of historical data lagging behind the current trends in the marketplace.

An analysis of the relationship between the engineer’s estimate and low bid price was then conducted. This analysis showed that for many unit cost line items there was a significant correlation between the engineer’s estimate and the low bid price for the unit cost line item; while other line items that had demonstrated the lag relationship did not correlate well. A regression analysis was also conducted that might allow SCDOT to
determine the bid prices that they may receive from contractors within a selected margin of error. However, this analysis would not be useful in making adjustments to the engineer’s estimate.

To determine a way to make adjustments to the engineer’s estimate based on either fuel price or bidding volume, a further analysis of their relationships with bid price was conducted. Assuming a linear relationship still existed between the variables, a linear regression and correlation analysis was conducted on low bid price versus fuel price and low bid price versus bidding volume in order to determine a methodology for making adjustments to the engineer’s estimate. The regression analysis provided a regression line as well as a 95% confidence interval for each of the unit cost line items that could be utilized to predict the bid price for a given fuel price or bidding volume. There was a higher correlation between low bid price and fuel price than between low bid price and bidding volume. These analyses provided a methodology that SCDOT could utilize to make adjustments to the engineer’s estimate before the project bid to contract.

These analyses could be utilized in two ways to adjust the engineer’s estimate. The first method was to make adjustments to an existing estimate. When there is a fluctuation in either fuel price or bidding volume, SCDOT could utilize the regression equation to determine the price for a unit cost line item and compare this estimate to the current price quoted in the engineer’s estimate. If there is little or no discrepancy then the current estimate is accurate pertaining to the current situation. If there is a discrepancy then the SCDOT should utilize the 95% confidence interval to determine if the current estimate is still competitive. If the current estimate falls within the confidence interval
then the estimate is likely still competitive. However, SCDOT may still want to use judgment in adjusting the estimate. If the current estimate falls outside the 95% confidence interval then SCDOT can assume that there is only a 5% chance the current estimate will reflect what the contractors will be bidding for this line items and the bid price should be adjusted using the regression line equations. It is possible that with some line items, the variability in price would create a large confidence interval that would not be useful to SCDOT.

The second method in which this analysis can be utilized is to make a quick determination of a unit cost line item price based on the current fuel price or bidding volume in the market. SCDOT can utilize the regression line equation to determine a base estimate of the unit cost line item price quickly. Then the 95% confidence interval can be determined for the current fuel price or bidding volume and SCDOT can adjust the base price according to their judgment of other factors affecting the market. These two approaches provide SCDOT a methodology for quickly making adjustments to the engineer’s estimate for the unit cost line items analyzed in this report.

The analyses and procedures described in this research report helped to identify research into currently utilized adjustment procedures for fuel and asphalt price fluctuations, unit cost line items that were sensitive to fuel and asphalt price fluctuations, and relationships between the engineer’s estimate, low bid price, fuel price index, and bidding volume at SCDOT. This report also identifies a methodology that can be utilized to adjust the engineer’s estimate pre-bid letting for fluctuations in the fuel price or
bidding volume. This research can be utilized to increase the accuracy of the engineer’s estimate for SCDOT and transportation-related projects

**Future Research Needs**

The methodologies suggested in this report should be utilized as independent calculations due to the fact that the analysis was conducted as a linear model. Currently, the market conditions would suggest the use of the fuel price adjustments due to the sharp rise in fuel costs being experienced worldwide. But in the future, it may be more pertinent to utilize the bidding volume adjustments. However, because of the fact that the bid price for the unit cost line items appears to be affected by many factors including fuel price, bidding volume, material quantities, and other environmental factors, future analyses should employ multivariate regression analysis techniques to determine a model for making adjustments to the engineer’s estimate for many factors simultaneously.

During the regression analysis it was interesting to see that certain unit cost line items bid prices correlated higher with either fuel price or bidding volume. Of the 10 unit cost line items that had the highest correlation with fuel price, 5 of those line items were line items that would most likely incur high transportation costs due to transporting heavy concrete culverts to the job site. This may suggest that the contractors are passing on the cost of transporting the culverts to the site through the bid price. Of the remaining 5 items mentioned, 4 of them dealt with hot mix asphalt concrete. This may suggest that the high levels of fuel utilized to make the various asphalt components is heavily influencing their costs. Similarly, the ten items that had the highest correlation with bidding volume
all seemed to be unit cost line items that may be highly equipment intensive. This may suggesting that the contractor may realize that at higher bidding volumes, the equipment being utilized to complete these line items is more heavily used and therefore may be passing on some of the costs that are involved with higher utilization of the equipment to the DOTs such as maintenance or the price of purchasing new equipment. Further research should be conducted to determine the factors that are creating these higher correlations, as the author suspects that there are common threads connecting the unit cost line items as mentioned above.

Further research should also be conducted in the future to investigate the relationship between the material quantities and bid price. It was evident that there is an inverse relationship between bid price and material quantities based on the outliers but further analysis should be conducted to determine if there is a maximum or minimum material quantity that creates the large discrepancy in bid price for the unit cost line item. This may be able to shed insight into a quantity-based adjustment for unit cost line items to allow for differing cost per quantity levels.

A further analysis into the relationship between the engineer’s estimate and low bid could be conducted to determine if there are any other approximate factors affecting the lag/oscillating relationship believed to be caused by the use of historical data. During the analysis it was shown that for certain unit cost line items the utilization of historical data was causing the engineer’s estimate to have a delay in the recognition of fuel price and bidding volume fluctuations. This may not be the only factor that is creating this oscillating effect and should be delved into further to discover any other causes.
Other adjustment factors could be utilized pre-bid as well to increase the accuracy of the engineer’s estimate including quantity-based adjustments, location, pre-existing site conditions, and pre-specified contract conditions. These external influences may factor into the bidding process and can affect bid price for line items. An analysis of these factors could shed further light into the fluctuations of unit cost line item bid prices. Further analysis into this research may be conducted by analyzing the relationships between the dollar value of bid lettings and the unit cost line item low bid price. This may provide further insight into how the engineer’s estimate could be adjusted for bidding volume based on a different variable than the number of bids let per month.

Further research could also be conducted into the methodologies that are utilized by contractors to determine their bid prices. This research could be conducted through a survey format. Although contractors may be a more secretive about how they determine their estimates due to the competitive bidding process that is utilized in most states. This research could, however, shed light into alternative methodologies that are utilized in the bidding process.
APPENDICES
Appendix A

Revised Fuel Price Index Figures

The following figures show the relationship between the fuel price index, low bid price, and the engineer’s estimate for the time period of January 2000 through October 2005. This data was analyzed and plotted using Microsoft Office 2003 in order to obtain an early idea of the correlations that may be present between the variables. It can be seen that there appears to be a correlation between the fuel price and the engineer’s estimates and low bids for most of the unit cost line items. Upon further examination of the graphs, there is another interesting relationship that is evident between the engineer’s estimate and the low bid price. There is a lag in the recognition of fluctuations in pricing between the low bid and the engineer’s estimate. When the low bid price increases or decreases there is a lag of a year or more before this change is apparent in the engineer’s estimate price. This lag is believed to have been caused by the use of historical data to determine the engineer’s estimate price. This could be used to determine unit cost line items that need to be estimated using an alternate estimating technique or the use of adjustments addressed in this report.

The legend for the graphs depicts the engineer’s estimate and the low bid as differing shaped points on the graph, triangles and squares, respectively. The fuel price index is represented as a diamond with a connecting line. Also it indicated the trend lines using different colors, black represents low bid while the other is engineer’s estimate trend line.
Figure A-1: Fuel Price Index and Bid Price for Borrow Excavation

Borrow Excavation

Bidding Date

Price per Gallon of Fuel

Bid Price Normalized

Low Bid Normalized

Engineer's Estimate Normalized

Fuel Price Index

Poly. (Low Bid Normalized)

Poly. (Engineer's Estimate Normalized)
Figure A-2: Fuel Price Index and Bid Price for Concrete Driveway (6" Uniform)
Figure A-3: Fuel Price Index and Bid Price for Concrete for Structure – Class 4000

Concrete For Stuctures - Class 4000

Bidding Date

Price Per Gallon of Fuel

Bid Price Normalized

- Low Bid Normalized
- Engineer's Estimate Normalized
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate Normalized)

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

$0.00 $2.00 $4.00 $6.00 $8.00 $10.00 $12.00 $14.00

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

$0.00 $2.00 $4.00 $6.00 $8.00 $10.00 $12.00 $14.00

$0.00 $2.00 $4.00 $6.00 $8.00 $10.00 $12.00 $14.00
Figure A-4: Fuel Price Index and Bid Price for Concrete Median

- **Concrete Median**
  - **Bidding Date**
  - **Bid Price Normalized**
  - **Price Per Gallon Of Fuel**

- Key:
  - Low Bid Normalized
  - Engineer's Estimate
  - Fuel Price Index
  - Poly. (Low Bid Normalized)
  - Poly. (Engineer's Estimate)
Figure A-5: Fuel Price Index and Bid Price for Concrete Sidewalk

Concrete Sidewalk

Bidding Date

Bid Price

Price per Gallon of Fuel

Fuel Price Index

Poly. (Low Bid Normalized)

Poly. (Engineer's Estimate)
Figure A-6: Fuel Price Index and Bid Price for Excavation for Shoulder Paving
Figure A-7: Fuel Price Index and Bid Price for Fine Grading

- Price Per Gallon Of Fuel
- Low Bid Normalized
- Engineer’s Estimate
- Fuel Price Index

Bidding Date: Jun-04 to Jun-05

Price Per Gallon Of Fuel:
- $0.00
- $1.00
- $2.00
- $3.00
- $4.00
- $5.00
- $6.00
Figure A-8: Fuel Price Index and Bid Price for Graded Aggregate Base Course (8" Uniform)
Figure A-9: Fuel Price Index and Bid Price for Graded Aggregate Base Course (6" Uniform)
Figure A-10: Fuel Price Index and Bid Price for Hauling of Excavated Shoulder Material

- **Low Bid**
- **Engineer's Estimate**
- **Fuel Price Index**

**Graph Details**:
- **X-axis (Bidding Date)**: Jan-00 to Jan-05
- **Y-axis (Bid Price Normalized)**: 0.2 to 1.8
- **Price Per Gallon Of Fuel**:
  - $0.00
  - $0.50
  - $1.00
  - $1.50
  - $2.00
  - $2.50
  - $3.00
  - $3.50
  - $4.00
  - $4.50
  - $5.00

**Legend**:
- Low Bid (Blue)
- Engineer's Estimate (Orange)
- Fuel Price Index (Purple)
Figure A-11: Fuel Price Index and Bid Price for Hot Mix Asphalt Aggregate Base Type 1

- Low Bid normalized
- Engineer’s Estimate
- Fuel Price Index
- Poly. (Low Bid normalized)
- Poly. (Engineer’s Estimate)
Figure A-12: Fuel Price Index and Bid Price for Hot Mix Asphalt Aggregate Base Type 2

- **Bid Price Normalized**
- **Price Per Gallon of Fuel**
- **Bidding Date**
- **Low Bid Normalized**
- **Fuel Price Index**
- **Engineer's Estimate**
- **Poly. (Low Bid Normalized)**
- **Poly. (Engineer's Estimate)**

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**Legend:**
- Red: Low Bid Normalized
- Purple: Fuel Price Index
- Blue: Engineer's Estimate
- Green: Poly. (Low Bid Normalized)
- Yellow: Poly. (Engineer's Estimate)
Figure A-14: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Binder CR Type 2

- Low Bid Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)
Figure A-15: Fuel Price Index and Bid Price for Hot Mix Asphalt

Hot Mix Asph. Conc. Surf. Cr. Type 1

- Low Bid Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)
Figure A-16: Fuel Price Index and Bid Price Hot Mix Asphalt Concrete Surface CR Type 3

Hot Mix Asph. Conc. Surf. Cr Type 3

- Low Bid
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid)
- Poly. (Engineer's Estimate)

Bid Price Normalized

Price Per Gallon of Fuel

Bidding Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05
Figure A-17: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1B

![Graph showing Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1B](image-url)
Figure A-18: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C
Figure A-19: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1D
Figure A-20: Fuel Price Index and Bid Price for Hot Mix Asphalt Thin Lift Seal Course

- Low Bid Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer’s Estimate)
Figure A-21: Fuel Price Index and Bid Price for Hot Mix Sand Asphalt Base Type 3

- **Fuel Price Index**
- **Engineer's Estimate**
- **Poly. (Low Bid Normalized)**
- **Poly. (Engineer's Estimate)**

**Bidding Date**: Mar-05 to Oct-05

**Price Per Gallon of Fuel**: $0.00 to $3.50
Figure A.22: Fuel Price Index and Bid Price for Muck Excavation

- **Bidding Date:** Jan-00, Jan-01, Jan-02, Jan-03, Jan-04, Jan-05
- **Bid price:** $0.00, $0.50, $1.00, $1.50, $2.00, $2.50, $3.00, $3.50
- **Price Per Gallon of Fuel:**
  - Low Bid Normalized
  - Engineer's Estimate Normalized
  - Fuel Price Index
  - Poly. (Low Bid Normalized)
  - Poly. (Engineer's Estimate Normalized)
Figure A-23: Fuel Price Index and Bid Price for Open Grade Friction Course

- **Low Bid Normalized**
- **Engineer's Estimate**
- **Fuel Price Index**
- **Poly. (Low Bid Normalized)**
- **Poly. (Engineer's Estimate)**

**Bidding Date**
- Jan-00
- Jan-01
- Jan-02
- Jan-03
- Jan-04
- Jan-05

**Price Per Gallon of Fuel**
- $0.00
- $0.50
- $1.00
- $1.50
- $2.00
- $2.50
- $3.00
- $3.50

**Bid Price Normalized**
- $0.00
- $0.50
- $1.00
- $1.50
- $2.00
- $2.50
- $3.00
- $3.50
Figure A-24: Fuel Price Index and Bid Price for Portland Cement Concrete Pavement 10" Uniform

- Bid Price Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)

Graph showing the relationship between bid price normalized, fuel price index, and bidding date for Portland cement concrete pavement 10" uniform.
Figure A-26: Fuel Price Index and Bid Price for 15" RC Pipe Cul Class III

15" RC Pipe Cul Class III

Low Bid Normalized
Engineer’s Estimate
Fuel Price Index
Poly. (Low Bid Normalized)
Poly. (Engineer’s Estimate)
Figure A-27: Fuel Price Index and Bid Price for 24\" RC Pipe Cul. Class III

24\' RC Pipe Cul Class III

- Low Bid Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)
Figure A-28: Fuel Price Index and Bid Price for 36” RC Pipe Cul. Class III

- Bid Price Normalized
- Engineer’s Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer’s Estimate)

Bid Price Normalized vs. Bidding Date and Price Per Gallon of Fuel.
Figure A-29: Fuel Price Index and Bid Price for 30" RC Pipe Cul. Class III

30' RC Pipe Cul Class III

- Low Bid Normalized
- Engineer's Estimate
- Fuel Cost Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)

Bidding Date

Price Per Gallon of Fuel

Bid Price Normalized

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

$0.00 $0.50 $1.00 $1.50 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00
Figure A-30: Fuel Price Index and Bid Price for Superpave Surface 12.5mm

- Bid Price Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
Figure A-31: Fuel Price Index and Bid Price for Unclassified Excavation

Unclassified Excavation

- Bid Price Normalized
- Engineer's Estimate
- Fuel Price Index
- Poly. (Low Bid Normalized)
- Poly. (Engineer's Estimate)

Bidding Date

Price per Gallon of Fuel

Bid Price Normalized

$0.00

$1.00

$2.00

$3.00

$4.00

$5.00

Jan-00

Jan-01

Jan-02

Jan-03

Jan-04

Jan-05
Appendix B

Revised Bidding Volume Figures

The figures in Appendix B illustrate the relationship between the bidding volume per month, low bid price, and the engineer’s estimate for the time period of January 2000 through October 2005. The data was evaluated and graphed using Microsoft Office 2003 in order to obtain an early idea of the correlations that may be present between the variables. It can be seen that there appears to be a correlation between the bidding volume and the engineer’s estimates and low bids for most of the unit cost line items. Upon further examination of the graphs, there is another interesting relationship that is apparent between the engineer’s estimate and the low bid price. There is a lag in the recognition of fluctuations in pricing between the low bid and the engineer’s estimate. When the low bid price increases or decreases there is a lag of a year or more before this change is apparent in the engineer’s estimate price. This lag is believed to have been caused by the use of historical data to determine the engineer’s estimate price. This could be used to determine unit cost line items that need to be estimated using an alternate estimating technique or the use of adjustments addressed in this report.

The legend for the graphs depicts the engineer’s estimate and the low bid as differing shaped points on the graph, triangles and squares, respectively. The fuel price index is represented as a diamond with a connecting line. Also it indicated the trend lines using different colors, black represents low bid while the other is engineer’s estimate trend line.
Figure B-1: Bidding Volume and Bid Price for Borrow Excavation
Figure B-3: Bidding Volume and Bid Price for Concrete for Structure
Figure B.5: Bidding Volume and Bid Price for Concrete Sidewalk

Bidding volume vs Low Bid for Concrete Sidewalk

Letting Date

Bidding Date

Bidding Volume

Bid Price Normalized

- Bidding Volume
- Low Bid
- Engineer's Estimate
- Poly. (Low Bid)
- Poly. (Engineer's Estimate)
Figure B-6: Bidding Volume and Bid Price for Excavation for Shoulder Paving

Bidding Volume vs Low Bid For Excavtion for Shoulder Paving

- Bidding Volume
- Low Bid

Legend:
- Bidding Volume
- Low Bid

Letting Date

Bidding Date

Bid Price Normalized

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

$0.00 $0.20 $0.40 $0.60 $0.80 $1.00 $1.20 $1.40
Figure B-7: Bidding Volume and Bid Price for Fine Grading

Bidding Volume vs Low Bid for Fine Grading

Letting Date

Bidding Date

Bidding Volume

Bid Price Normalized

- Letting Date: 6/1/2004 to 6/2/2005
- Bidding Dates: Jun-04 to Oct-05
- Y-axis: Bidding Volume
- X-axis: Bidding Date

Legend:
- Blue bars: Bidding Volume
- Pink squares: Low Bid
- Orange triangles: Engineer's Estimate
- Black line: Poly. (Low Bid)
- Red line: Poly. (Engineer's Estimate)
Figure B-8: Bidding Volume and Bid Price for Graded Aggregate Base Course (8" Uniform)

Bidding Volume vs. Low Bid for Graded Aggregate Base Course (8" Uniform)

Letting Date

Bidding Date

Bidding Volume

Bid Price Normalized

- Bidding Volume by SCDOT
- Low Bid
- Engineer's Estimate
- Poly. (Low Bid)
- Poly. (Engineer's Estimate)
Figure B-9: Bidding Volume and Bid Price for Graded Aggregate Base Course (6" Uniform)
Figure B-10: Bidding Volume and Bid Price for Hauling of Excavated Shoulder Material

Bidding Volume vs Low Bid For Hauling Of Excavated Shoulder Material

Bidding Volume

Low Bid

Engineer’s Estimate

Letting Date

Bidding Date

Bidding Volume

Low Bid Normalized

Engineer’s Estimate Normalized
Figure B-11: Bidding Volume and Bid Price for Hot Mix Asphalt Aggregate Base Type 1

Bidding Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bid Price Normalized

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Volume

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Letting Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Volume vs Low Bid For Hot Mix Asphalt Aggregate Base Type 1

Poly. (Low Bid) Poly. (Engineer's Estimate)

Engineer's Estimate Low Bid
Figure B-13: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Binder CR Type 1
Figure B-14: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Binder CR Type 2

Bidding Volume vs. Low Bid for Hot Mix Asph. Conc. Binder Cr. - Type 2

Bidding Date

Letting Date

Bidding Volume

Bid Price Normalized

Bidding Volume by SCDOT

Low Bid

Engineer's Estimate

Poly. (Low Bid)

Poly. (Engineer's Estimate)
Figure B-15: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1

Bidding Volume vs. Low Bid for Hot Mix Asph. Conc. Surf. Cr. Type 1

Bidding Date

Letting Date

Bidding Volume

Bid Price Normalized

Bidding Volume by SCDOT

Low Bid

Engineer's estimate

Poly. (Low Bid)

Poly. (Engineer's estimate)
Figure B-16: Bidding Volume and Bid Price for Hot Mix Asph. Conc. Surf. Cr Type 3

Bidding Volume vs low Bid for Hot Mix Asph. Conc. Surf. Cr Type 3

Letting Date

Bidding Date

Bidding Volume

Bid Price Normalized

- Bidding Volume
- Low Bid
- Engineer's estimate
- Poly. (Low Bid)
- Poly. (Engineer's estimate)
Figure B-18: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C
Figure B-19: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1D

Bidding Volume vs Low Bid for Hot Mix Asph Conc Surf Cr Type 1D

- Bidding Volume
- Low Bid
- Engineer's Estimate

Letting Date
- Dec-04
- Jan-05
- Feb-05
- Mar-05
- Apr-05
- May-05
- Jun-05
- Jul-05
- Aug-05
- Sep-05
- Oct-05

Bidding Date
- Jan-05
- Feb-05
- Mar-05
- Apr-05
- May-05
- Jun-05
- Jul-05
- Aug-05
- Sep-05
- Oct-05

Bid Price Normalized
Figure B-20: Bidding Volume and Bid Price for Hot Mix Asphalt Thin Lift Seal Course
Figure B-21: Bidding Volume and Bid Price for Hot Mix Sand Asphalt Base Type 3
Figure B-22: Bidding Volume and Bid Price for Muck Excavation

Bidding Volume vs. Low Bid for Muck Excavation

Letting Date

Bidding Date

Bid Price Normalized

Bidding Volume by SCDOT

Low Bid

Engineer’s Estimate

Poly. (Low Bid)

Poly. (Engineer’s Estimate)
Figure B-23: Bidding Volume and Bid Price for Open-Graded Friction Course
Figure B.24: Bidding Volume and Bid Price for Portland Cement Concrete Pavement 10" Uniform

Bidding Volume vs Low Bid for Portland Cement Concrete Pavement 10" Uniform

- Bidding Volume
- Letting Date
- Bid Price Normalized

Key:
- Bidding Volume
- Low Bid
- Engineer's Estimate
- Poly. (Low Bid)
- Poly. (Engineer's Estimate)
Figure B-25: Bidding Volume and Bid Price for 18” RC Pipe Cul Class III
Figure B-26: Bidding Volume vs Low Bid for 15' RC Pipe Cul Class III
Figure B-27: Bidding Volume and Bid Price for 24" RC Pipe Cul. Class III

Bidding Volume vs Low Bid for 24" RC Pipe Cul. Class III

Letting Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Date

Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05

Bidding Volume

Low Bid

Engineer's Estimate

Poly. (Low Bid)

Poly. (Engineer's Estimate)
Figure B-28: Bidding Volume and Bid Price for 36" RC Pipe Cul. Class III

Bidding Volume vs Low Bid for 36" RC Pipe Cul Class III

Letting Date

Bidding Date

Bid Price Normalized

Bidding Volume

Low Bid

Engineer's Estimate

Poly. (Low Bid)

Poly. (Engineer's Estimate)
Figure B-29: Bidding Volume and Bid Price for 30" RC Pipe Cul Class III

[Diagram showing bidding volume vs. letting date, with various data points and lines indicating bidding volume, low bid, engineer's estimate, and polynomial fit for low bid and engineer's estimate.]
Figure B-30: Bidding Volume and Bid Price for Superpave 12.5mm
Figure B-31: Bidding Volume and Bid Price for Unclassified Excavation
Appendix C

Engineer’s Estimate versus Low Bid Correlation Figures

The following figures depict the relationship between the low bid and engineer’s estimate. The analysis was conducted to determine the correlation between the low bid and engineer’s estimate as well as to determine the regression line which would best fit the data. A number of the bid line items engineer’s estimates and low bids do have a correlation. Because of this, it may be possible to estimate the low bid which will be received within a specific level of certainty based on the engineer’s estimates using the regression line equations. Nevertheless, it would not be an efficient means of determining the engineer’s estimate. It could only provide a prediction of the contractor’s price for a low bid based on what the engineer’s estimate.
Engineer's Estimate vs. Low Bid for Borrow Excavation

$y = 0.0042x^3 - 0.1915x^2 + 3.6388x - 9.8165$

Correlation: 60.40%
Figure C-2: Regression Analysis for Concrete Driveway Engineer's Estimate vs Low Bid for Concrete Driveway

\[ y = 0.0044x^3 - 0.3449x^2 + 9.5547x - 63.036 \]

Correlation: 44.55%
Figure C-3: Regression Analysis for Concrete for Structure Engineer's Estimate vs Low Bid for Concrete for Structures

\[ y = 0.003x^2 - 1.8671x + 743.87 \]

Correlation: 70.26%
Figure C-4: Regression Analysis for Concrete Median Engineer's Estimate vs Low Bid for Concrete Median

\[ y = 0.0032x^3 - 0.2699x^2 + 8.1203x - 55.31 \]

Correlation: 38.13%
Figure C-5: Regression Analysis for Concrete Sidewalk

Engineer’s Estimate vs Low Bid for Concrete Sidewalk

\[ y = -0.0002x^3 + 0.0363x^2 - 0.4244x + 18.107 \]

Correlation: 48.04%
Figure C-6: Regression Analysis for Fine Grading

Engineer’s Estimate vs Low Bid for Fine Grading

\[ y = -0.757x^3 + 4.5022x^2 - 6.9951x + 4.7482 \]

Correlation: 31.97%
Figure C-7: Regression Analysis for Graded Aggregate Base Course 8" Uniform

Engineer's Estimate vs Low Bid for Graded Aggregate Base Course 8" Uniform

\[ y = -0.1107x^3 + 2.1957x^2 - 13.799x + 34.002 \]

Correlation: 27.75%
Figure C-8: Regression Analysis for Graded Aggregate Base Course 6” Uniform

Engineer’s Estimate vs Low Bid for Graded Aggregate Base Course 6” Uniform

\[ y = -0.007x^3 + 0.666x^2 - 5.3796x + 15.984 \]

Correlation: 81.63%
Figure C-9: Regression Analysis for Hauling of Excavated Shoulder Material

Engineer’s Estimate vs Low Bid for Hauling of Excavated Shoulder Material

$y = -6 \times 10^{-5}x^3 + 0.0046x^2 + 0.0112x + 0.2843$

Correlation: 99.29%
Figure C-10: Regression Analysis for Hot Mix Asphalt Aggregate Base CR Type 1

Engineer’s Estimate vs. Low Bid for Hot Mix Aggregate Asphalt Base CR Type 1

\[ y = 0.0006x^3 - 0.0679x^2 + 3.3244x - 24.11 \]

Correlation: 73.97%
Figure C-11: Regression Analysis for Hot Mix Asphalt Aggregate Base CR- Type 2

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Aggregate Base CR- Type 2

\[ y = 0.0013x^3 - 0.179x^2 + 8.9748x - 109.14 \]

Correlation: 61.11%
Figure C-12: Regression Analysis for Hot Mix Asphalt Concrete Binder CR Type 1

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Concrete Binder CR Type 1

\[ y = 0.0016x^3 - 0.1752x^2 + 7.1693x - 67.453 \]

Correlation: 75.24%
Figure C-13: Regression Analysis for Hot Mix Asphalt Concrete Binder CR Type 2

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Concrete Binder CR Type 2

$y = -0.0007x^3 + 0.1094x^2 - 4.1116x + 77.438$

Correlation: 66.50%
Figure C-14: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 1

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1

$$y = -0.0002x^3 + 0.0466x^2 - 1.5007x + 40.548$$

Correlation: 76.35%
Figure C-15: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 3

Engineer’s Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 3

\[ y = 4E-05x^3 + 0.0235x^2 - 0.8579x + 37.129 \]

Correlation: 71.42%
Engineer’s Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1-B

$y = 0.9743x + 2.3614$
Correlation: 100%
Figure C-17: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 1C

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1C

\[ y = 0.0011x^3 - 0.1052x^2 + 4.1616x - 27.839 \]

Correlation: 77.01%
Figure C-18: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 1-D

Engineer’s Estimate vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1-D

\[ y = 0.0235x^3 - 3.1695x^2 + 140.9x - 2023.4 \]

Correlation: 5.43%
Figure C-19: Regression Analysis for Hot Mix Asphalt Thin Lift Seal Course

Engineer's Estimate vs Low Bid for Hot Mix Asphalt Thin Lift Seal Course

The regression equation is:

\[ y = 0.0004x^3 + 0.0265x^2 - 2.8614x + 87.886 \]

Correlation: 59.51%
Figure C-20: Regression Analysis for Hot Mix Sand Asphalt Base CR Type 3

Engineer's estimate vs Low Bid for Hot Mix Sand Asphalt Base CR Type 3

\[ y = 0.1179x^3 - 15.44x^2 + 672.18x - 9681.8 \]

Correlation: -12.89%
Figure C-21: Regression Analysis for Muck Excavation

Engineer's Estimate vs Low Bid for Muck Excavation

\[ y = -0.0069x^3 + 0.1633x^2 - 0.2323x + 4.0106 \]

Correlation: 34.91%
Figure C-22: Regression Analysis for Open Grade Friction Course

Engineer's Estimate vs Low Bid for Open-Grade Friction Course

\[ y = 0.0022x^3 - 0.2213x^2 + 7.27x - 29.786 \]

Correlation: 47.18%
Figure C-23: Regression Analysis for Portland Cement Concrete Pav. 10’ Uniform

Engineer’s Estimate Vs Low Bid for Portland Cement Concrete Pav. 10’ Uniform

\[ y = -0.9994x^2 + 67.455x - 1092 \]

Correlation: 72.66%
Figure C-24: Regression Analysis for 18" RC Pipe Cul. Class 3

Engineer's Estimate vs Low Bid for 18" RC Pipe Cul. Class 3

$y = -0.0094x^3 + 0.8701x^2 - 23.64x + 221.58$

Correlation: 33.69%
Figure C-25: Regression Analysis for 15" RC Pipe Cul. Class 3

Engineer's Estimate vs Low Bid for 15" RC Pipe Cul. Class 3

\[ y = 0.015x^3 - 0.8279x^2 + 15.843x - 84.109 \]

Correlation: 63.14%
Figure C-26: Regression Analysis for 24” RC Pipe Cul Class 3

Engineer’s Estimate vs Low Bid for 24” RC Pipe Cul Class 3

\[ y = 0.0175x^3 - 1.331x^2 + 34.106x - 266.21 \]

Correlation: 49.26%
Figure C-27: Regression Analysis for 36" RC Pipe Culvert Class 3

Fuel Price vs Low Bid for 36" RC Pipe Culvert Class III

- $y = 7.4205x + 38.267$
- $y = 12.415x + 46.225$
- $y = 2.4256x + 30.308$

Correlation: 36.95%
Figure C-28: Regression Analysis for 30" RC Pipe Cul Class 3

Engineer's Estimate vs Low Bid for 30" RC Pipe Cul Class 3

\[ y = -0.0263x^3 + 2.9643x^2 - 109.35x + 1361.4 \]

Correlation: 30.23%
Figure C-29: Regression Analysis for Superpave Surface 12.5mm

Engineer's Estimate Vs Low Bid for Superpave Surface Course (12.5mm)

\[ y = 0.0008x^3 - 0.0428x^2 + 0.8753x + 25.723 \]

Correlation: 62.15%
Figure C-30: Regression Analysis for Unclassified Excavation

Engineer’s Estimate vs Low Bid for Unclassified Excavation

\[ y = 0.0037x^3 - 0.0393x^2 + 0.9134x + 1.9733 \]

Correlation: 63.53%
Appendix D

Fuel Price Index Linear Regression Figures

In order to create a tool that can be used to make adjustments to unit cost line items based on the fluctuations in fuel price, a linear regression analysis was conducted. The following figures depict the linear regression analysis results in the form of the linear regression line as well as the lines for the 95% confidence intervals. This analysis was conducted in Microsoft Office 2003 Excel. These linear regression equations can be used to adjust the estimate prices based on the changes in fuel prices. By utilizing the linear regression equation to determine the price of a unit cost line item based on the bidding volume and using the 95% confidence interval, the analysis can be used in two ways. First, the estimator can use the analysis in order to make adjustments to an already existing estimate for a unit cost line item. When there is a large discrepancy between the current estimate and the prediction from the regression equation, the 95% confidence intervals can then be used. The estimator can then use the 95% confidence interval equations provided on the graph to determine if the current estimate fell within the given confidence interval. If the current estimate is within the 95% confidence interval, then the estimator can be fairly certain that the estimate is competitive. But, if the current estimate is outside of the 95% confidence interval, then the estimator would know that there is only a 5% chance that the estimate could be competitive with the low bids that the contractors will be submitting. Therefore, the estimate may need to be adjusted for the price or volume fluctuation. Second, an estimator could determine an estimate for a unit cost line item to put into a detailed estimate. In order to achieve this,
an estimator could use the regression equation to find an approximation of the price for
the unit cost line item based on the predicted fuel price for that month. The 95%
confidence intervals could then be found for that fuel price as well. Using these data
points an estimator could then use his judgment and experience to make a prediction on
the price to use in a detailed estimate.
Figure D-1: Linear Regression for Fuel Price vs. Low Bid Price for Concrete for Structure

\[ y = 88.127x + 399.37 \]

Correlation: 25.61%

\[ y = -1.7695x + 259.62 \]

\[ y = 178.02x + 539.12 \]
Figure D-2: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Median

Fuel Price vs Low Bid For Concrete Median

\[ y = 7.9065x + 18.974 \]

Correlation: 32.26%

\[ y = 1.3858x + 8.9194 \]

\[ y = 14.427x + 29.029 \]
Figure D-3: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Sidewalk

Regression equations and their corresponding correlation:
- $y = 7.0877x + 13.764$ (Correlation: 59.59%)
- $y = 9.5984x + 17.891$
- $y = 4.577x + 9.6363$

Graph showing fuel price in dollars per gallon on the x-axis and bid price in dollars on the y-axis.
Figure D-4: Linear Regression for Fuel Price vs. Low Bid Price for Fine Grading

Fuel Price vs Low Bid for Fine Grading

$\begin{align*}
y &= -0.19x + 2.8602 \\
y &= 1.3893x + 6.2307 \\
y &= -1.7693x - 0.5103
\end{align*}$

Correlation: -8.45%
Figure D-5: Linear Regression for Fuel Price vs. Low Bid Price for Graded Aggregate Base Course (8" Uniform)

- $y = 0.6547x + 5.5891$
- Correlation: 19.22%
- $y = 1.8386x + 7.4575$
- $y = -0.5291x + 3.7207$

![Graph](image-url)
Figure D-6: Linear Regression for Fuel Price vs. Low Bid Price for Graded Aggregate Base Course (6" Uniform)

Fuel Price vs Low Bid for Graded Aggregate Base Course (6" Uniform)

y = 1.1345x + 3.6327
Correlation: 28.30%

y = -0.5242x + 1.0281

y = 2.7931x + 6.2374

($2.00) $0.00 $2.00 $4.00 $6.00 $8.00 $10.00 $12.00 $14.00

Fuel Price($/gallon)

Bid Price($)
Figure D-7: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Aggregate Base CR Type 1

Fuel Price vs Low Bid for Hot Mix Assphalt Aggregate Base CR Type 1

\[ y = 18.01x + 26.178 \]

Correlation: 64.17%

\[ y = 13.705x + 19.231 \]

\[ y = 9.4x + 12.284 \]
Figure D-8: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Aggregate Base CR Type II

$y = 19.533x + 36.901$

Correlation: 43.96%

$y = 12.542x + 25.384$

$y = 5.5507x + 13.866$
Figure D-9: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type I

\[ y = 16.813x + 12.496 \]

Correlation: 71.04%

\[ y = 21.077x + 19.264 \]

\[ y = 12.548x + 5.7277 \]
Figure D-10: Linear Regression for Fuel Price vs Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type II

- $y = 12.21x + 23.645$
- Correlation: 45.02%
- $y = 5.5385x + 12.96$
- $y = 18.882x + 34.33$

Graph with data points and regression lines showing the relationship between Fuel Price and Bid Price for Hot Mix Asphalt Concrete Binder CR Type II.
Figure D-11: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type I

Fuel Price vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type I

\[
y = 15.437x + 28.944
\]

Correlation: 66.27%

\[
y = 11.852x + 23.036
\]

\[
y = 8.2666x + 17.128
\]

0 0.5 1 1.5 2 2.5 3 3.5
Fuel Price($/gallon)

$0.00 $10.00 $20.00 $30.00 $40.00 $50.00 $60.00 $70.00 $80.00
Bid Price($)
Figure D-12: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 3

Fuel Price vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type III

- \( y = 12.132x + 24.117 \)  
  Correlation: 51.53%
- \( y = 17.388x + 32.486 \)
- \( y = 6.8765x + 15.748 \)

Fuel Price ($/gallon)

Bid Price ($)

0 0.5 1 1.5 2 2.5 3 3.5

$0.00 $10.00 $20.00 $30.00 $40.00 $50.00 $60.00 $70.00 $80.00 $90.00
Figure D-13: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C

Fuel Price vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1C

\[
y = 12.341x + 19.246
\]

Correlation: 61.92%

\[
y = 16.249x + 25.62
\]

\[
y = 8.4334x + 12.872
\]
Figure D-14: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1D

Fuel Price vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1D

- $y = 4.2867x + 28.797$ (Correlation: 55.46%)
- $y = 16.106x + 57.047$
- $y = -7.5325x + 0.5466$

Fuel Price ($) vs Bid Price ($/gallon)
Figure D-15: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Thin Lift Seal Course

Fuel Price vs Low Bid for Hot Mix Asphalt Thin Lift Seal Course

\[ y = 7.1924x + 29.51 \]

Correlation: 38.78%

\[ y = -0.0088x + 17.33 \]

\[ y = 14.393x + 41.689 \]
Figure D-16: Linear Regression for Fuel Price vs. Low Bid Price for Muck Excavation

Fuel Price vs Low Bid for Muck Excavation

\[ y = 5.5463x - 1.5094 \]

Correlation: 68.99%

\[ y = 3.7343x - 4.5832 \]

\[ y = 7.3583x + 1.5645 \]
Figure D-17: Linear Regression for Fuel Price vs. Low Bid Price for Open Grade Friction Course

Fuel Price vs Low Bid for Open-Grade Friction Course

- \( y = -1.192x + 48.674 \)
- \( y = -20.716x + 17.329 \)
- \( y = 18.332x + 80.018 \)

Correlation: -2.93%
Figure D-18: Linear Regression for Fuel Price vs. Low Bid Price for 18” RC Pipe Culvert Class III

Fuel Price vs Low Bid for 18” RC Pipe Culvert Class III

- $y = 10.453x + 9.4496$
- Correlation: 71.07%
- $y = 12.996x + 13.608$
- $y = 7.9101x + 5.2914$

Fuel Price ($/gallon) vs Bid Price ($)

- $0.00$ to $60.00$
- $0$ to $3.5$ on x-axis

Data points and regression lines are plotted on the graph.
Figure D-19: Linear Regression for Fuel Price vs. Low Bid Price for 15” RC Pipe Culvert Class III

Fuel Price vs Low Bid for 15” RC Pipe Culvert Class III

\[ y = 16.402x - 0.9357 \]

Correlation: 66.82%

\[ y = 21.119x + 6.5215 \]

\[ y = 11.686x - 8.393 \]
Figure D-20: Linear Regression for Fuel Price vs. Low Bid Price for 24" RC Pipe Culvert Class III

\[ y = 11.763x + 12.691 \]

\[ y = 14.599x + 17.244 \]

\[ y = 8.9274x + 8.1392 \]

Fuel Price vs. Low Bid for 24" RC Pipe Culvert Class III

Correlation: 64.20%
Figure D-21: Linear Regression for Fuel Price vs. Low Bid Price for 36" RC Pipe Culvert Class III

Fuel Price vs Low Bid for 36" RC Pipe Culvert Class III

- $y = 7.4205x + 38.267$
  - Correlation: 36.95%
- $y = 2.4256x + 30.308$
- $y = 12.415x + 46.225$
Figure D-22: Linear Regression for Fuel Price vs. Low Bid Price for 30” RC Pipe Culvert Class III

Fuel Price vs Low Bid for 30” RC Pipe Culvert Class III

$0.00$10.00$20.00$30.00$40.00$50.00$60.00$70.00

0 0.5 1 1.5 2 2.5 3
Fuel Price($/gallon)

B Price ($)

y = 9.0371x + 25.265
Correlation: 60.14%
y = 12.165x + 30.295
y = 5.9096x + 20.235

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Figure D-23: Linear Regression for Fuel Price vs. Low Bid Price for Superpave Surface Course (12.5mm)

Fuel Price vs Low Bid for Superpave Surface Course (12.5mm)

- $y = 15.676x + 37.676$
- $y = 8.4495x + 26.185$
- $y = 1.223x + 14.693$

Correlation: 38.80%
Figure D-24: Linear Regression for Fuel Price vs. Low Bid Price for Unclassified Excavation

Fuel Price vs. Low Bid Price for Unclassified Excavation

- \( y = 4.5778x + 2.8673 \)
- Correlation: 40.37%
- \( y = 7.1685x + 7.1018 \)
- \( y = 1.9871x - 1.3672 \)

Fuel Price ($/gallon) vs. Bid Price ($)

- $0.00 to $35.00
- 0 to 3.5 on the x-axis
Appendix E

Bidding Volume Linear Regression Figures

In order to create a tool that can be used to make adjustments to unit cost line items based on the fluctuations in bidding volume per month a linear regression analysis was conducted. The following figures depict the linear regression analysis results in the form of the linear regression line as well as the lines for the 95% confidence intervals. This analysis was conducted in Microsoft Office 2003 Excel. These linear regression equations can be used to adjust the estimate prices based on the changes in bidding volume. By utilizing the linear regression equation to determine the price of a unit cost line item based on the bidding volume and using the 95% confidence interval the analysis can be used in two ways. First, the estimator can use the analysis in order to make adjustments to an already existing estimate for a unit cost line item. When there is a large discrepancy between the current estimate and the prediction from the regression equation, the 95% confidence intervals can then be used. The estimator can then use the 95% confidence interval equations provided on the graph to determine if the current estimate fell within the given confidence interval. If the current estimate is within the 95% confidence interval then the estimator can be fairly certain that the estimate is competitive. But, if the current estimate is outside of the 95% confidence interval then the estimator would know that there is only a 5% chance that the estimate could be competitive with the low bids that the contractors will be submitting. Therefore, the estimate may need to be adjusted for the price or volume fluctuation. Second, an estimator could determine an estimate for a unit cost line item to put into a detailed
estimate. In order to achieve this, an estimator could use the regression equation to find an approximation of the price for the unit cost line item based on the predicted bidding volume for that month. The 95% confidence intervals could then be found for that bidding volume as well. Using these data points an estimator could then use his judgment and experience to make a prediction on the price to use in a detailed estimate.
Figure E.1: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete for Structure

Regression Equations:

1. $y = 3.4981x + 474.53$
2. $y = 7.0649x + 558.28$
3. $y = -0.0687x + 390.78$

Correlation: 24.55%
Figure E-2: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Median

Bidding Volume vs Low bid For Concrete Median

\[ y = 0.0062x + 22.126 \]
\[ y = 0.382x + 31.194 \]
\[ y = 0.1941x + 26.66 \]

Correlation: 27.89%

Bidding Volume (per month) vs. Bid Price ($)
Figure E-3: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Sidewalk

- $y = 0.1457x + 21.802$
- $y = 0.2695x + 24.828$
- $y = 0.0218x + 18.776$

Correlation: 29.54%
Figure E-4: Linear Regression for Bidding Volume vs. Low Bid Price for Finish Grading

Bidding Volume vs Low Bid for Finish Grading

\[ y = -0.0105x + 2.7178 \]

Correlation: -9.71%

\[ y = -0.0866x + 0.7915 \]

\[ y = 0.0655x + 4.6441 \]

Bid Price ($)

Bidding Volume (per month)
Figure E-5: Linear Regression for Bidding Volume vs. Low Bid Price for Graded Aggregate Base Course (8" Uniform)

Regression Equations:

- **y = 0.0118x + 6.3151**
- **y = -0.0357x + 5.1042**
- **y = 0.0593x + 7.5261**

Correlation:

- Correlation: 8.74%
Figure E-6: Linear Regression for Bidding Volume vs. Low Bid Price for Graded Aggregate Base Course (6" Uniform)

Bidding Volume vs Low Bid for Graded Aggregate Base Course (6" Uniform)

- $y = 0.0033x + 5.3115$
- $y = 0.0598x + 6.6805$
- $y = -0.0531x + 3.9425$

Correlation: 2.53%
Figure E-7: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Aggregate Base CR Type I

Bidding Volume vs Low Bid For Hot Mix Asphalt Aggregate Base CR Type I

$\begin{align*}
y &= 0.3202x + 43.756 \\
y &= 0.1037x + 38.516 \\
y &= -0.1128x + 33.277
\end{align*}$

Correlation: 12.49%

Bidding Volume (per month)

Bidding Volume vs Low Bid Price for Hot Mix Asphalt Aggregate Base CR Type I

$\begin{align*}
y &= 0.3202x + 43.756 \\
y &= 0.1037x + 38.516 \\
y &= -0.1128x + 33.277
\end{align*}$

Correlation: 12.49%
Figure E-8: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Aggregate Base CR Type 2

Bidding Volume vs Low Bid for Hot Mix Asphalt Aggregate Base CR Type II

$y = 0.0817x + 43.7$

Correlation: 8.6%

$y = -0.2378x + 35.953$

$y = 0.4012x + 51.447$
Figure E-9: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type I

\[ y = 0.1641x + 35.001 \]

Correlation: 18.66%

\[ y = -0.0571x + 29.772 \]

\[ y = 0.3853x + 40.231 \]
Figure E-10: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type II

Fuel Price vs Low Bid for Hot Mix Asphalt Concrete Binder CR Type II

\[ y = 5.5385x + 12.96 \]

\[ y = 12.21x + 23.645 \]

\[ y = 18.882x + 34.33 \]

Correlation: 45.02%
Figure E-11: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type I

Bidding Volume vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type I

- $y = 0.1732x + 38.034$
- Correlation: 23.05%
- $y = 0.369x + 42.907$
- $y = -0.0225x + 33.161$

Bid Price ($)

Bidding Volume (per month)
Figure E-12: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type III

\[ y = 0.1672x + 39.255 \]

Correlation: 19.21%

\[ y = 0.3897x + 44.639 \]

\[ y = -0.0553x + 33.871 \]

Bidding Volume vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type III
Figure E-13: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C

Bidding Volume vs Low Bid for Hot Mix Asphalt Concrete Surface CR Type 1C

\[ y = 0.0987x + 36.693 \]

\[ y = 0.3019x + 41.528 \]

\[ y = -0.1045x + 31.859 \]

Correlation: 12.04%
Figure E-14: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1D

$y = 0.1305x + 35.75$

Correlation: 24.04%

$y = -0.8377x + 11.495$

$y = 1.0987x + 60.005$

Bidding Volume (per month)

Bid Price ($)

$0.00$

$20.00$

$40.00$

$60.00$

$80.00$

$100.00$

$120.00$

$140.00$

$160.00$

$180.00$

$200.00$

$220.00$

$240.00$

$260.00$

$280.00$

$300.00$

$320.00$

$340.00$

$360.00$

$380.00$

$400.00$

$420.00$

$440.00$

$460.00$

$480.00$

$500.00$

$520.00$

$540.00$

$560.00$

$580.00$

$600.00$

$620.00$

$640.00$

$660.00$

$680.00$

$700.00$

$720.00$

$740.00$

$760.00$

$780.00$

$800.00$

$820.00$

$840.00$

$860.00$

$880.00$

$900.00$

$920.00$

$940.00$

$960.00$

$980.00$

$1000.00$

$1020.00$

$1040.00$

$1060.00$

$1080.00$

$1100.00$

$1120.00$

$1140.00$

$1160.00$

$1180.00$

$1200.00$
Figure E-15: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Thin Lift Seal Course

Bidding Volume vs Low Bid For Hot Mix Asphalt Thin Lift Seal Course

- $y = 0.0534x + 40.055$
- $y = -0.3278x + 30.681$
- $y = 0.4347x + 49.429$

Correlation: 5.89%
Figure E-16: Linear Regression for Bidding Volume vs. Low Bid Price for Muck Excavation

Bidding Volume vs Low Bid for Muck Excavation

\[ y = 0.0783x + 5.7661 \]

Correlation: 21.54%

\[ y = -0.0322x + 2.9632 \]

\[ y = 0.1887x + 8.569 \]

Bidding Volume (per month)

Bid Price ($)

$0.00

$2.00

$4.00

$6.00

$8.00

$10.00

$12.00

$14.00

$16.00

$18.00

0 5 10 15 20 25 30 35 40 45 50
Bidding Volume vs Low Bid For Open-Grade Friction Course

- $y = -0.4239x + 24.156$
- $y = 0.8945x + 57.947$
- $y = 0.2353x + 41.051$

Correlation: 16.89%

Bidding Volume (per month) vs Bid Price ($)

Figure E-17: Linear Regression for Bidding Volume vs Low Bid Price for Open Grade Friction Course
Figure E-18: Linear Regression for Bidding Volume vs. Low Bid Price for 18" RC Pipe Culvert Class III

Bidding Volume vs Low Bid for 18" RC Pipe Culvert Class III

- $y = 0.118x + 23.487$
- $y = -0.0319x + 19.918$
- $y = 0.2679x + 27.055$

Correlation: 18.99%
Figure E-19: Linear Regression for Bidding Volume vs. Low Bid Price for 15” RC Pipe Culvert Class III

- Bidding Volume vs. Low Bid for 15” RC Pipe Culvert Class III

- \[ y = 0.1339x + 21.448 \]
- Correlation: 15.04%

- \[ y = 0.3613x + 26.944 \]

- \[ y = -0.0935x + 15.953 \]
Figure E-20: Linear Regression for Bidding Volume vs. Low Bid Price for 24" RC Pipe Culvert Class III

Bidding Volume vs Low Bid for 24" RC Pipe Culvert Class III

\[ y = 0.0452x + 23.306 \]

\[ y = 0.3149x + 29.772 \]

\[ y = 0.1985x + 26.706 \]

Correlation: 31.58%
Figure E-21: Linear Regression for Bidding Volume vs. Low Bid Price for 36" RC Pipe Culvert Class III

Bidding Volume vs Low Bid for 36" RC Pipe Culvert Class III

- Correlation: 23.14%

Regression lines:
- $y = 0.1882x + 45.603$
- $y = -0.0237x + 40.535$
- $y = 0.4x + 50.67$
Figure E-22: Linear Regression for Bidding Volume vs. Low Bid Price for 30" RC Pipe Culvert Class III

Bidding Volume vs Low Bid for 30" RC Pipe Culvert Class III

- $y = 0.1599x + 35.957$
- $y = 0.0082x + 32.387$
- $y = 0.3115x + 39.527$

Correlation: 26.48%
Figure E-23: Linear Regression for Bidding Volume vs. Low Bid Price for Superpave Surface Course (12.5mm)

- $y = 0.1622x + 35.524$
- $y = -0.0922x + 29.06$
- $y = 0.4166x + 41.988$

Correlation: 22.38%
Figure E-24: Linear Regression for Bidding Volume vs. Low Bid Price for Unclassified Excavation

\[ y = 0.1534x + 6.7197 \]

\[ y = 0.2677x + 9.4657 \]

\[ y = 0.0392x + 3.9738 \]

Correlation: 31.79%
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