BEST PRACTICES FOR DEVELOPING THE ENGINEER’S ESTIMATE

FINAL REPORT

VOLUME II

SCDOT Research Project 661
FHWA-SC-07-04 (Volume II)

Greaton Sellers
And
Lansford C. Bell

Department of Civil Engineering
Clemson University
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ABSTRACT

The research project “Best Practices for Developing 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 that 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. The research analysis related to this objective is addressed in Report Volume I. The second research objective, which is addressed in this Volume II report, was to develop a methodology for adjusting selected unit cost bid line items to account for fluctuations in fuel prices and bid volume. Using data provided by SCDOT, an analysis was conducted to determine methodologies that could be used to adjust for these fluctuations in fuel prices and bidding volume.

This research report details the methodology utilized to determine unit cost line items that would be in need of adjustment during the bidding process for projects. It also contains the methodology used in creating a tool that can be used to adjust unit cost line items based on the current fuel price or bidding volume at SCDOT. Using the data provided, 33 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 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. The regression plots and analysis are contained in this research as well as suggestions for implementing the proposed approach for bid line item adjustments.
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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 be unbalanced bids by contractors. 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 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. 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 which could 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 secure the project. In order to determine how these factors would affect contractors bid prices compared to the engineer’s estimates a detailed statistical analysis was undertaken by Clemson University. In order to increase the accuracy of the engineer’s estimates a methodology for adjusting unit cost line items that are fuel and asphalt intensive or bid volume sensitive were developed as described in this report.

Objective and Scope of Research

In order 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 gasoline 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 research objective was to propose a methodology for making adjustment to specifically chosen unit cost bid line items dealing with fuel/asphalt and bidding volume adjustments. A list of 44 line items concerned with fuel and asphalt adjustments during the bidding process were identified for adjustment analysis. Using the data for these line items, an analysis must be conducted on the low
bid price and engineer’s estimate in order to make recommendations for a methodology for making adjustments to these unit cost line items that will permit SCDOT to more accurately determine their engineer’s estimates during the bidding process.

Research Methodology

In order to develop a methodology for adjusting selected unit cost line items to account for fluctuations in gasoline and asphalt prices and for bidding volume, an analysis of SCDOT’s unit cost line items from previous projects was be conducted. The data set provided by SCDOT was in a Microsoft Office Access Database. The data spanned all of SCDOT’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 where identified by Bid Analysis Management System or 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 SCDOT, specific pay items were identified in order to be analyzed.

The SCDOT 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. The items concerned with fuel and asphalt adjustments 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.

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Using the querying tool in Access, the two databases, Bid History and Project Description, where combined such that the unit cost line item bid prices where 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. Once 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 for a more detailed analysis. In order to perform this analysis, the fuel price index and bidding volume per month had to be determined. It was assumed that asphalt price could be related to fuel prices and therefore fuel price would be used because an accurate asphalt price index for the southeast could not be established. The fuel price index was found using the average gas prices for the east coast found at the US Department of Energy, 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. This data was then entered into an Excel spreadsheet to be used in the analyses. Once 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. Once this data was removed, an initial analysis was conducted to visually examine how the data correlated with fuel prices and
bid volume. Once 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 or Statistical Analysis Software to identify any outlying or extreme data that was included in the set. Once 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. Once the outliers were removed, the data was imported back into Excel and a similar analysis was conducted to the first one 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 could be 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 exterior circumstances that can arise in the highway construction industry such as: quantity of work, location, pre-existing conditions, and contract conditions. In most statistical analysis 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. 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

In order 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 progress reports quarterly that were prepared and delivered to the Steering Committee. The current progress, methodology, and the path forward where 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 consulted 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 can 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.

**Gasoline Price Adjustments**

In order 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 procured in 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 which work items adjustments
would be made to for fuel price changes (2). The proposed amendments will reduce the
contract time criterion from a year to six months and lower the threshold quantities. Both
of these amendments would 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 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 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 practices, research a number of documents were procured from other states. These documents contained information’s 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 while others 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 is then used to determine the percent of the contract made up by each respective item. The third equation is then used to determine 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.

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 (9). 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 in 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 (10).”

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 where dependant on the percent change increment and whether it was a single, double, or triple treatment as well as the class of surface used (11). 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). Utah once 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**

In order to determine 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 (12). 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 where 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**

In order to determine 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 DOT’s 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 as well as and therefore would not be appropriate for application within SCDOT. Therefore, a search was conducted on 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. Once the table was arranged by area, the research team found that the source contained a link to the weekly prices in fuel for the south east (13). 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 post bid compensation were in fact related to fuel and asphalt adjustments. 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.
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 to be compared to the Fuel Price Index for South Eastern United States and with SCDOT’s Bidding Volume.

Methodology for Fuel Price Index

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 same time periods as the available bid data and imported into Microsoft Excel. The historical data 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 the average from a single data point. The difference was then
divided by the standard deviation for the data set 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. These high bid prices were found to be related to the line item quantity of work for the project. In order to determine the outliers, the data was then integrated into a program called SAS or Statistical Analysis Software and an analysis conducted to determine the deviation from the average value. Once 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. Once the outliers were removed, the data was imported back into Excel for further analysis. These extreme outliers were removed from the data set in order to increase the accuracy of the analysis.

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. A normalized regression line shows the relationship between the low bids, engineer’s estimate, and the fuel price index. Outlying data is clearly present in this graph. Two such examples 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. 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 will 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, 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 begins above the low bid trend line around July 11, 2000. The engineer’s estimate trend line then dips below the low bid trend line around June 4, 2003 and then rises 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)
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 to be 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 a single 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 this case as well. In order to determine the outliers, the data was then integrated into a program called SAS or Statistical Analysis Software and a student residual regression analysis was conducted to determine the deviation from the average value. Once 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. Once the
outliers were removed, the data was imported back into Excel for further analysis. These extreme outliers were removed from the data in order to increase the accuracy of the 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. A normalized regression line shows the relationship between the low bids, engineer’s estimate, and the fuel price index. Once again, outlying data 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 will 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 begins above the low bid trend line around July 11, 2000. The engineer’s estimate trend line then dips below the low bid trend line around June 4, 2003 and then rises 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)
CHAPTER 4

FUEL PRICE ADJUSTMENT 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 appear to have been 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 in order to improve the analysis the outliers must be removed.

Fuel Price Adjustment 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 residual analysis was conducted to determine which data points where 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. Once 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
where 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. 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 Adjustment 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 for the revised data. Some
interesting relationships were indicated in a number of the items. For example, there was
an increase in the bid price steadily with time that seemed to correlate to the increase in
the fuel price index showing that there may be a correlation present. 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 begins
above the low bid trend line around March 14, 2000. The engineer’s estimate trend line
then dips below the low bid trend line around February 12, 2002 and then rises above the
low bid trend line again around June 7, 2004. 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 would be 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 would once again be 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 engineer’s 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 slopping 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
Figure 4-2 shows the relationship between the date, cost per ton of concrete curb and gutter, and the fuel price index for the revised data. 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 are closely related and as time goes on they begin to separate and the low bid price drops while the engineer’s estimate increases and stabilizes. Eventually towards the end of the supplied data there appears to be a similar relationship showing up as stated in the previous example. There appears to be a similar lag in price change between the low bid and engineer’s estimate as afore mentioned. Once again the low bid begins 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 begins above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dips 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
CHAPTER 5

BIDDING VOLUME ADJUSTMENT 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 appear to have been 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 in order to improve 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. Once 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. 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, 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. As bidding volume increased over a few months stretch, the low bid price would correlate with an increase in the price in most cases. 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 begins above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dips below the low bid trend line around February 12, 2002 and then rises 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 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. 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 downward trend. It is believed that this is due to the lag time resulting from the use of historical data. This would suggest the use of an alternative form of estimating or use of a methodology for adjusting 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

Bid Date

Bidding Volume

Bid Price


Jan-00 Apr-00 Jul-00 Oct-00 Jan-01 Apr-01 Jul-01 Oct-01 Jan-02 Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04 Jan-05 Apr-05 Jul-05 Oct-05

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, date, bid price per ton of concrete curb and gutter, and the letting date. In this scenario it appear 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 where 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 begins above the low bid trend line around March 14, 2000. The engineer’s estimate trend line then dips 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 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. 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
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 will help to determine if there is any 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, on 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 variables 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 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>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear 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' UNIFORM)</td>
<td>y = -0.007x^3 + 0.666x^2 - 5.3795x + 15.984</td>
<td>0.816316</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</td>
<td>y = 0.0011x^3 - 0.1052x^2 + 4.1616x - 27.839</td>
<td>0.770099</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>y = -0.0002x^3 + 0.0466x^2 - 1.5007x + 40.548</td>
<td>0.763496</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>y = 0.0016x^3 - 0.1752x^2 + 7.1693x - 67.453</td>
<td>0.752418</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
<td>y = 0.0006x^3 - 0.0679x^2 + 3.3244x - 24.11</td>
<td>0.739739</td>
</tr>
<tr>
<td>PORTLAND CEMENT CONC. PAV. 10&quot; UNIFORM</td>
<td>y = -0.9994x^2 + 67.455x - 1092</td>
<td>0.726613</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
<td>y = 0.0249x^2 - 0.8585x + 36.978</td>
<td>0.719338</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>y = 4E-05x^3 + 0.0235x^2 - 0.8579x + 37.129</td>
<td>0.714177</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES – CLASS 4000</td>
<td>y = 0.003x^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 - 4.116x + 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&quot; RC PIPE CUL.-CLASS III</td>
<td>y = 0.015x^3 - 0.8279x^2 + 15.843x - 84.109</td>
<td>0.631371</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE (12.5mm)</td>
<td>y = 0.0008x^3 - 0.0426x^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 - 0.179x^2 + 8.9748x - 109.14</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&quot; 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 + 0.0363x^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>0.45505</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&quot; 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 = -0.757x^3 + 4.5022x^2 - 6.9951x + 4.7482</td>
<td>0.319727</td>
</tr>
<tr>
<td>36&quot; 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>30&quot; 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 - 9681.8</td>
<td>-0.12888</td>
</tr>
</tbody>
</table>

**Table 6-1: Regression and Correlation Analysis for Engineer’s Estimate vs. Low Bid Analysis**
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

\[ y = 0.0249x^2 - 0.8585x + 36.978 \]
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 is plotted on the graph to see how it fits the data. In this instance it the data appears to visually fit the equation well with some error.
Figure 6-2: Regression Analysis for Concrete Curb and Gutter

Regression equation:

\[ y = 1.0431x^2 - 19.248x + 97.411 \]
CHAPTER 7

FUEL PRICE 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 fuel price index were analyzed in more detailed. It was determined early that the graphs of fuel price index vs. low bid price in Appendix A could be used to visualize if there is in fact some 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 is visually determined that there is a correlation between the variables a linear regression analysis was conducted to determine a linear model for the variables as well as a 95% confidence interval.

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.
Once 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 also. These data points were removed from the graph and were further analyzed to see if there was a reason for their anomalous condition. In most cases these conditions were once again created by a small quantity of work involving that type of unit cost line item in one 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.

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 are 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 33 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, on 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 is a strong correlation between low bid prices and fuel price. Upon regression analysis, as presented in Table 7-1, it can be 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 this 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 provides
equations for the linear model but also provides 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 will provide 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&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 10.453x + 9.496 )</td>
<td>( y = 7.9101x + 5.2914 ) ( y = 12.996x + 13.608 )</td>
<td>0.710698835</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>( y = 16.813x + 12.496 )</td>
<td>( y = 12.548x + 5.7277 ) ( y = 21.077x + 19.264 )</td>
<td>0.710384114</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>( y = 5.5463x - 1.5094 )</td>
<td>( y = 3.7343x - 4.5832 ) ( y = 7.3583x + 1.5645 )</td>
<td>0.689941944</td>
</tr>
<tr>
<td>15&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 16.402x - 0.9573 )</td>
<td>( y = 11.686x - 8.393 ) ( y = 21.19x + 6.5215 )</td>
<td>0.668176777</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. - TYPE 1</td>
<td>( y = 11.852x + 23.036 )</td>
<td>( y = 8.2666x + 17.128 ) ( y = 15.437x + 28.944 )</td>
<td>0.662705794</td>
</tr>
<tr>
<td>CONCRETE DRIVEWAY(6&quot; UNIFORM)</td>
<td>( y = 14.442x + 10.825 )</td>
<td>( y = 9.6475x + 3.2602 ) ( y = 19.236x + 18.391 )</td>
<td>0.650136975</td>
</tr>
<tr>
<td>15&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 11.763x + 12.691 )</td>
<td>( y = 8.9274x + 8.1235 ) ( y = 16.99x + 17.244 )</td>
<td>0.649157645</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1 C</td>
<td>( y = 13.705x + 19.231 )</td>
<td>( y = 9.4x + 12.284 ) ( y = 18.01x + 26.178 )</td>
<td>0.641735351</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</td>
<td>( y = 12.341x + 19.246 )</td>
<td>( y = 8.4334x + 12.872 ) ( y = 16.249x + 25.62 )</td>
<td>0.619234343</td>
</tr>
<tr>
<td>30&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 9.0371x + 25.265 )</td>
<td>( y = 5.9096x + 20.235 ) ( y = 12.165x + 30.295 )</td>
<td>0.601399258</td>
</tr>
<tr>
<td>CONCRETE SIDEWALK(4&quot; UNIFORM)</td>
<td>( y = 7.0877x + 13.764 )</td>
<td>( y = 4.577x + 9.6363 ) ( y = 9.5984x + 17.891 )</td>
<td>0.595879728</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</td>
<td>( y = 13.299x + 19.74 )</td>
<td>( y = 7.0255x + 9.2358 ) ( y = 19.572x + 30.244 )</td>
<td>0.560866503</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</td>
<td>( y = 4.2867x + 28.797 )</td>
<td>( y = -7.5325x + 0.5466 ) ( y = 16.106x + 57.047 )</td>
<td>0.554550151</td>
</tr>
<tr>
<td>BORROW EXCAVATION</td>
<td>( y = 5.7756x + 3.558 )</td>
<td>( y = 3.3872x - 0.267 ) ( y = 8.1639x + 7.383 )</td>
<td>0.533015293</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</td>
<td>( y = 12.132x + 24.117 )</td>
<td>( y = 6.8765x + 15.748 ) ( y = 17.388x + 32.486 )</td>
<td>0.515345017</td>
</tr>
<tr>
<td>CONCRETE CURB AND GUTTER(2'-0&quot;)</td>
<td>( y = 3.7176x + 4.9726 )</td>
<td>( y = 1.9052x + 2.696 ) ( y = 5.042x + 7.6402 )</td>
<td>0.499742106</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>( y = 12.21x + 23.645 )</td>
<td>( y = 5.5385x + 12.96 ) ( y = 18.882x + 34.33 )</td>
<td>0.450223191</td>
</tr>
<tr>
<td>HOT MIX ASPH. A GG. BASE CR. - TYPE 2</td>
<td>( y = 12.542x + 25.384 )</td>
<td>( y = 5.5507x + 13.866 ) ( y = 19.533x + 36.901 )</td>
<td>0.439617828</td>
</tr>
<tr>
<td>UNCLASSIFIED EXCAVATION</td>
<td>( y = 4.5778x + 2.8673 )</td>
<td>( y = 1.9871x - 1.3672 ) ( y = 7.1685x + 7.1018 )</td>
<td>0.40369407</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>( y = 8.4495x + 26.185 )</td>
<td>( y = 1.223x + 14.693 ) ( y = 15.676x + 37.676 )</td>
<td>0.388030853</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>( y = 7.1924x + 29.51 )</td>
<td>( y = -0.0088x + 17.33 ) ( y = 14.393x + 41.689 )</td>
<td>0.387841996</td>
</tr>
<tr>
<td>36&quot; RC PIPE CUL.-CLASS III</td>
<td>( y = 7.4205x + 38.267 )</td>
<td>( y = 2.4256x + 30.308 ) ( y = 12.415x + 46.225 )</td>
<td>0.369542397</td>
</tr>
<tr>
<td>CONCRETE MEDIAN</td>
<td>( y = 7.9065x + 18.974 )</td>
<td>( y = 1.3858x + 8.9194 ) ( y = 14.427x + 29.029 )</td>
<td>0.322635147</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</td>
<td>( y = 1.1345x + 3.6327 )</td>
<td>( y = -0.5242x + 1.0281 ) ( y = 2.7931x + 6.2374 )</td>
<td>0.282965265</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
<td>( y = 88.127x + 399.37 )</td>
<td>( y = -1.7695x + 259.62 ) ( y = 178.02x + 539.12 )</td>
<td>0.256073611</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</td>
<td>( y = 0.6547x + 5.5891 )</td>
<td>( y = -0.5291x + 3.7207 ) ( y = 1.8386x + 7.4575 )</td>
<td>0.19224309</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>( y = -0.19x + 2.8602 )</td>
<td>( y = -1.7693x - 0.5103 ) ( y = 1.3893x + 6.2307 )</td>
<td>-0.084454121</td>
</tr>
<tr>
<td>OPEN-GRADED FRICTION COURSE</td>
<td>( y = -1.19x + 48.674 )</td>
<td>( y = -20.716x + 17.329 ) ( y = 18.332x + 80.018 )</td>
<td>-0.029302153</td>
</tr>
</tbody>
</table>

Table 7-1: Correlation and Linear Regression Analysis for Fuel Price Adjustments
Figure 7-1: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Curb and Gutter

Regression: \( y = 3.7176x + 4.9726 \)

Upper: \( y = 5.042x + 7.8402 \)

Lower: \( y = 1.9052x + 2.696 \)
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 can be 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 provides equations for the linear model but also provides the equations for a 95% confidence interval surrounding the linear model. This analysis will provide 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 7-2: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Hot Mix Asphalt Concrete Surface CR Type 4

Regression: \( y = 13.299x + 19.74 \)

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 shows 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 provides equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provides 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 Price for Borrow Excavation

\[ y = 8.1639x + 7.383 \]
\[ y = 5.7756x + 3.558 \]
\[ y = 3.3872x - 0.267 \]
Table 7-1 includes the correlation and regression analyses for low bid vs. fuel price for Concrete Driveways. Figure 7-4 show the linear regression models for low bid vs. fuel price analysis for Concrete Driveways. Regression analysis presented in Table 7-1 show 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 provides equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provides 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 7-4: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Driveway (6" Uniform)

Fuel Price vs Low Bid for Concrete Driveway

Fuel Price($) vs Low Bid Price($)

- $y = 19.236x + 18.391$
- $y = 14.442x + 10.825$
- $y = 9.6475x + 3.2602$
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 a linear regression analysis was conducted to determine a linear model for the variables as well as a 95% confidence interval.

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. In most cases these conditions were once again created by a small quantity of work involving that type of unit cost line item in one 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.

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.
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 33 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 provides a detailed picture of the correlation that exists between the fuel price and the low bid, one such example is the relationship between the engineer’s estimate and the low bid for Concrete Curb and Gutter. Table 8-1 includes the regression analysis for the low bid vs. bidding volume for Concrete Curb and Gutter. Figure 8-1 shows an example of the linear regression models for the low bid vs. bidding volume analysis for Concrete Curb and Gutter. Examining Figure 8-1, there is a strong correlation between low bid prices and bidding volume. Upon regression analysis, as presented in Table 8-1, it can be noted that there is a correlation between low bid 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 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 provides equations for the linear model but also provides 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 will provide 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</th>
<th>95% Confidence Interval Equations</th>
<th></th>
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<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Correlation</td>
<td>Lower</td>
<td>Upper</td>
<td>Correlation</td>
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<tr>
<td><strong>Bidding Volume Adjustment</strong></td>
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<td></td>
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</tr>
<tr>
<td><strong>BORROW EXCAVATION</strong></td>
<td>$y = 0.2036x + 8.6945$</td>
<td>$y = 0.1001x + 6.229$</td>
<td>0.435056927</td>
<td>$y = 0.3072x + 11.16$</td>
<td></td>
<td>0.45037757</td>
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<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</strong></td>
<td>$y = 0.4842x + 30.941$</td>
<td>$y = 0.1395x + 22.285$</td>
<td>0.320137636</td>
<td>$y = 0.8289x + 39.597$</td>
<td></td>
<td>0.31886495</td>
</tr>
<tr>
<td><strong>CONCRETE CURB AND GUTTER(2'-0&quot;)</strong></td>
<td>$y = 0.0404x + 9.2984$</td>
<td>$y = 0.0179x + 7.2652$</td>
<td>0.317886495</td>
<td>$y = 0.1435x + 10.248$</td>
<td></td>
<td>0.30137636</td>
</tr>
<tr>
<td><strong>UNCLASSIFIED EXCAVATION</strong></td>
<td>$y = 0.1534x + 6.7197$</td>
<td>$y = 0.0392x + 3.9738$</td>
<td>0.295386379</td>
<td>$y = 0.2677x + 9.4657$</td>
<td></td>
<td>0.31788649</td>
</tr>
<tr>
<td><strong>24&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 0.1985x + 26.706$</td>
<td>$y = 0.0452x + 23.306$</td>
<td>0.315842984</td>
<td>$y = 0.3149x + 29.772$</td>
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<td>0.31886495</td>
</tr>
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<td><strong>CONCRETE SIDEWALK(4' UNIFORM)</strong></td>
<td>$y = 0.1577x + 21.802$</td>
<td>$y = 0.0218x + 18.776$</td>
<td>0.295386379</td>
<td>$y = 0.2695x + 24.828$</td>
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<td><strong>CONCRETE MEDIAN</strong></td>
<td>$y = 0.1941x + 26.66$</td>
<td>$y = 0.0062x + 22.126$</td>
<td>0.278858624</td>
<td>$y = 0.382x + 31.194$</td>
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</tr>
<tr>
<td><strong>30' RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 0.1599x + 35.957$</td>
<td>$y = 0.0082x + 32.387$</td>
<td>0.264849857</td>
<td>$y = 0.3115x + 39.527$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>CONC. FOR STRUCTURES - CLASS 4000</strong></td>
<td>$y = 3.4981x + 474.53$</td>
<td>$y = -0.0687x + 390.78$</td>
<td>0.245508836</td>
<td>$y = 7.0649x + 558.28$</td>
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</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</strong></td>
<td>$y = 0.1305x + 35.75$</td>
<td>$y = -0.8377x + 11.495$</td>
<td>0.240449931</td>
<td>$y = 1.0987x + 60.005$</td>
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<td>0.29538637</td>
</tr>
<tr>
<td><strong>36' RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 0.1882x + 45.603$</td>
<td>$y = -0.0237x + 40.535$</td>
<td>0.231350301</td>
<td>$y = 0.4x + 50.67$</td>
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<td>0.29538637</td>
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<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</strong></td>
<td>$y = 0.1732x + 38.034$</td>
<td>$y = -0.0225x + 33.161$</td>
<td>0.23048682</td>
<td>$y = 0.369x + 42.907$</td>
<td></td>
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</tr>
<tr>
<td><strong>SUPERPAVE SURFACE COURSE(12.5mm)</strong></td>
<td>$y = 0.1622x + 35.524$</td>
<td>$y = -0.0922x + 29.06$</td>
<td>0.22376627</td>
<td>$y = 0.4166x + 41.988$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>MUCK EXCAVATION</strong></td>
<td>$y = 0.0783x + 5.7661$</td>
<td>$y = -0.0322x + 2.9632$</td>
<td>0.215449488</td>
<td>$y = 0.1878x + 8.569$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</strong></td>
<td>$y = 0.1672x + 39.255$</td>
<td>$y = -0.0553x + 33.871$</td>
<td>0.192149734</td>
<td>$y = 0.3897x + 44.639$</td>
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<tr>
<td><strong>18' RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 0.118x + 23.487$</td>
<td>$y = -0.0319x + 19.918$</td>
<td>0.18991576</td>
<td>$y = 0.2679x + 27.055$</td>
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<td>0.29538637</td>
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<tr>
<td><strong>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</strong></td>
<td>$y = 0.1746x + 38.842$</td>
<td>$y = -0.0783x + 32.626$</td>
<td>0.186873198</td>
<td>$y = 0.4275x + 45.057$</td>
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<td>0.29538637</td>
</tr>
<tr>
<td><strong>OPEN-GRADED FRICTION COURSE</strong></td>
<td>$y = 0.2353x + 41.051$</td>
<td>$y = -0.4239x + 24.156$</td>
<td>0.18656532</td>
<td>$y = 0.8945x + 57.947$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>CONCRETE DRIVEWAY(6&quot; UNIFORM)</strong></td>
<td>$y = 0.1172x + 31.725$</td>
<td>$y = -0.0769x + 27.039$</td>
<td>0.168914543</td>
<td>$y = 0.3114x + 36.411$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>15&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 0.1339x + 21.448$</td>
<td>$y = -0.0935x + 15.953$</td>
<td>0.150361294</td>
<td>$y = 0.3613x + 26.944$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</strong></td>
<td>$y = 0.1037x + 38.516$</td>
<td>$y = -0.1128x + 33.277$</td>
<td>0.12493622</td>
<td>$y = 0.3202x + 43.756$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</strong></td>
<td>$y = 0.0987x + 36.693$</td>
<td>$y = -0.1045x + 31.859$</td>
<td>0.120409081</td>
<td>$y = 0.3019x + 41.528$</td>
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<td>0.29538637</td>
</tr>
<tr>
<td><strong>FIRE GRADING</strong></td>
<td>$y = -0.0105x + 2.7178$</td>
<td>$y = -0.0866x + 0.7915$</td>
<td>0.097050968</td>
<td>$y = 0.0655x + 4.6441$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</strong></td>
<td>$y = 0.0118x + 6.3151$</td>
<td>$y = -0.0357x + 5.1042$</td>
<td>0.087365121</td>
<td>$y = 0.0593x + 7.5261$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</strong></td>
<td>$y = 0.0817x + 43.7$</td>
<td>$y = -0.2378x + 35.953$</td>
<td>0.069606165</td>
<td>$y = 0.4012x + 51.447$</td>
<td></td>
<td>0.29538637</td>
</tr>
<tr>
<td><strong>HOT MIX ASPHALT THIN LIFT SEAL COURSE</strong></td>
<td>$y = 0.0534x + 40.055$</td>
<td>$y = -0.3278x + 30.681$</td>
<td>0.058945545</td>
<td>$y = 0.4347x + 49.429$</td>
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<td>0.29538637</td>
</tr>
<tr>
<td><strong>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</strong></td>
<td>$y = 0.0033x + 5.3115$</td>
<td>$y = -0.0531x + 3.9425$</td>
<td>0.02534961</td>
<td>$y = 0.0598x + 6.6805$</td>
<td></td>
<td>0.29538637</td>
</tr>
</tbody>
</table>

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

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

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

Lower: \( y = 0.0179x + 7.2562 \)
Table 8-1 includes the regression analyses for the low bid vs. 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 only 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 will provide 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: $y = 0.4842x + 30.941$

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 only 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. This analysis provides equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provides 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

Bidding Volume vs Low Bid for Borrow Excavation

$y = 0.3072x + 11.16$

$y = 0.2036x + 8.6945$

$y = 0.1001x + 6.229$
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 provides equations for the linear model and the 95% confidence interval surrounding the linear model. This analysis provides 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)

- $y = 0.3114x + 36.411$
- $y = 0.1172x + 31.725$
- $y = -0.0769x + 27.039$
CHAPTER 9

CONCLUSIONS

Literature Review

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 used for fuel and asphalt adjustments found in their supplementary specifications. A thesis was 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 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 on a periodic basis.
Preliminary Analysis

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. This analyzes what the SCDOT and contractors are quoting for bid line items that deal with fuel or asphalt costs and any relationships that might be formed using criteria such as fuel price and bidding volume. This shows which items may need to be addressed using cost based estimating for future estimates. These analyses helped determine if certain items should use cost based estimating 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. Many of the items tended to rise or fall with the cost of fuel as price trended up or down. During the analysis of the original data it was noted the there were some extreme outlying data points. These data points were analyzed and it was determined that in most cases the cost increase or decrease 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 the quantity of material would increase the cost would then decrease. These outliers where identified using SAS 9.1 by conducting a student residual regression analysis and then removed from the data set and the data was then reanalyzed.
Fuel Price Index and Bidding Volume Analysis

Once the outlying data points were removed, the analysis was conducted again to determine the relationships between bid pricing, fuel price, and bidding volume. As noted in Figures 4-1 and 5-1 of this report, as bidding volume or 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 bidding volume or fuel price. This may serve to identify items that may need to be addressed using cost based estimating for future estimates.

The regression line equations developed as part of this research effort can 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 will help 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.

Engineer’s Estimate and Low Bid Correlation Analysis

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 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.

**Linear Regression Analysis**

Several of the bid line items identified by the SCDOT Research Steering Committee have a correlation with either the fuel price index or bidding volume. Many of the items tended to fluctuate with the cost of fuel or bidding volume as they moved in one direction or the other as can be noted in the figures included in Appendix A and 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, in most of the cases, it resulted because of an unusually high or low volume of work. Once the outliers where 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 price of fuel or bidding volume load.

**Methodology for Implementation**

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 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 will address 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 in 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.
### Pay Items for Fuel Adjustment

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<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>
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<td>7206000</td>
<td>CONCRETE MEDIAN</td>
<td>SY</td>
</tr>
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<td>CONCRETE SIDEWALK (4&quot; UNIFORM)</td>
<td>SY</td>
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<td>2081001</td>
<td>FINE GRADING</td>
<td>SY</td>
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<tr>
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<td>4036300</td>
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<td>TON</td>
</tr>
<tr>
<td>3093000</td>
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<td>TON</td>
</tr>
<tr>
<td>2034000</td>
<td>MUCK EXCAVATION</td>
<td>CY</td>
</tr>
<tr>
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<td>OPEN-GRADED FRICTION COURSE</td>
<td>TON</td>
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<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>
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<td>36&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
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<td>7141115</td>
<td>30&quot; RC PIPE CUL.-CLASS III</td>
<td>LF</td>
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<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>

*Table 9-1: Subset Unit Cost Line Items Reflecting a Lag Relationship*
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.

In order 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

Fuel Price vs Low Bid for Concrete Curb and Gutter

- Regression: $y = 3.7176x + 4.9726$
- Upper: $y = 5.042x + 7.6402$
- Lower: $y = 1.9052x + 2.696$

Fuel Price ($\$\$) vs Bid Price ($\$\$)
<table>
<thead>
<tr>
<th>Unit Cost Line Item</th>
<th>Linear Regression Equation</th>
<th>95% Confidence Interval Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Price Adjustment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>18&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 10.453x + 9.496$</td>
<td>$y = 7.9101x + 5.2914$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</td>
<td>$y = 16.813x + 12.496$</td>
<td>$y = 12.548x + 5.7277$</td>
</tr>
<tr>
<td>MUCK EXCAVATION</td>
<td>$y = 5.5463x - 1.5094$</td>
<td>$y = 3.7343x - 4.5832$</td>
</tr>
<tr>
<td><strong>15&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 16.402x - 0.9357$</td>
<td>$y = 11.686x - 8.393$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</td>
<td>$y = 11.852x + 23.036$</td>
<td>$y = 8.2666x + 17.128$</td>
</tr>
<tr>
<td><strong>CONCRETE DRIVEWAY(6&quot; UNIFORM)</strong></td>
<td>$y = 14.442x + 10.825$</td>
<td>$y = 9.6475x + 3.2602$</td>
</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</td>
<td>$y = 11.676x + 12.691$</td>
<td>$y = 8.9274x + 8.1235$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. SURF. CR. TYPE 1 C</td>
<td>$y = 13.705x + 19.231$</td>
<td>$y = 9.4x + 12.284$</td>
</tr>
<tr>
<td><strong>30&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 9.0371x + 25.265$</td>
<td>$y = 5.9096x + 20.235$</td>
</tr>
<tr>
<td>CONCRETE SIDEWALK(4&quot; UNIFORM)</td>
<td>$y = 7.0877x + 13.764$</td>
<td>$y = 4.577x + 9.6363$</td>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>BORROW EXCAVATION</td>
<td>$y = 5.7756x + 3.558$</td>
<td>$y = 3.3872x - 0.267$</td>
</tr>
<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>
</tr>
<tr>
<td>CONCRETE CURB AND GUTTER(2'-0&quot;)</td>
<td>$y = 3.7176x + 4.9726$</td>
<td>$y = 1.9052x + 2.696$</td>
</tr>
<tr>
<td>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</td>
<td>$y = 12.21x + 23.645$</td>
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</tr>
<tr>
<td>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</td>
<td>$y = 12.542x + 25.384$</td>
<td>$y = 5.5507x + 13.866$</td>
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<td>$y = 4.5778x + 2.8673$</td>
<td>$y = 1.9871x - 1.3672$</td>
</tr>
<tr>
<td>SUPERPAVE SURFACE COURSE(12.5mm)</td>
<td>$y = 8.4495x + 26.185$</td>
<td>$y = 1.223x + 14.693$</td>
</tr>
<tr>
<td>HOT MIX ASPHALT THIN LIFT SEAL COURSE</td>
<td>$y = 7.1924x + 29.51$</td>
<td>$y = -0.0088x + 17.33$</td>
</tr>
<tr>
<td><strong>36&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>$y = 7.4205x + 38.267$</td>
<td>$y = 2.4256x + 30.308$</td>
</tr>
<tr>
<td>CONCRETE MEDIAN</td>
<td>$y = 7.9065x + 18.974$</td>
<td>$y = 1.3858x + 8.9194$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</td>
<td>$y = 1.3145x + 3.6327$</td>
<td>$y = -0.5242x + 1.0281$</td>
</tr>
<tr>
<td>CONC. FOR STRUCTURES - CLASS 4000</td>
<td>$y = 88.127x + 399.37$</td>
<td>$y = -1.7695x + 259.62$</td>
</tr>
<tr>
<td>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</td>
<td>$y = 0.6547x + 5.5891$</td>
<td>$y = -0.3291x + 3.7207$</td>
</tr>
<tr>
<td>FINE GRADING</td>
<td>$y = -0.19x + 2.8602$</td>
<td>$y = -1.7693x - 0.5103$</td>
</tr>
<tr>
<td>OPEN-graded FRICITION COURSE</td>
<td>$y = -1.192x + 48.674$</td>
<td>$y = -20.716x + 17.329$</td>
</tr>
</tbody>
</table>

**Table 9-2: Correlation and Linear Regression Analysis for Fuel Price Adjustments**
Figure 9-2: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Curb and Gutter

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

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

Lower: \( y = 0.0179x + 7.2562 \)
<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>BORROW EXCAVATION</strong></td>
<td>( y = 0.2036x + 8.6945 )</td>
<td>( y = 0.1001x + 6.229 ) ( y = 0.3072x + 11.16 )</td>
<td>0.435056927</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 4</strong></td>
<td>( y = 0.4842x + 30.941 )</td>
<td>( y = 0.1395x + 22.285 ) ( y = 0.8289x + 39.597 )</td>
<td>0.405037757</td>
</tr>
<tr>
<td><strong>CONCRETE CURB AND GUTTER(2'-0&quot;)</strong></td>
<td>( y = 0.0404x + 9.2984 )</td>
<td>( y = 0.0179x + 7.2562 ) ( y = 0.1435x + 10.248 )</td>
<td>0.320137636</td>
</tr>
<tr>
<td><strong>UNCLASSIFIED EXCAVATION</strong></td>
<td>( y = 0.1534x + 6.7197 )</td>
<td>( y = 0.0392x + 3.9738 ) ( y = 0.2677x + 9.4657 )</td>
<td>0.31786495</td>
</tr>
<tr>
<td><strong>24&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>( y = 0.1985x + 26.706 )</td>
<td>( y = 0.0452x + 23.306 ) ( y = 0.3149x + 29.772 )</td>
<td>0.315842984</td>
</tr>
<tr>
<td><strong>CONCRETE SIDEWALK(4&quot; UNIFORM)</strong></td>
<td>( y = 0.1457x + 21.802 )</td>
<td>( y = 0.0218x + 18.776 ) ( y = 0.2695x + 24.828 )</td>
<td>0.295386379</td>
</tr>
<tr>
<td><strong>CONCRETE MEDIAN</strong></td>
<td>( y = 0.1941x + 26.66 )</td>
<td>( y = 0.0062x + 22.126 ) ( y = 0.382x + 31.194 )</td>
<td>0.278859624</td>
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<tr>
<td><strong>30&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>( y = 0.1599x + 35.957 )</td>
<td>( y = 0.0082x + 32.387 ) ( y = 0.3115x + 39.527 )</td>
<td>0.264849857</td>
</tr>
<tr>
<td><strong>CONC. FOR STRUCTURES - CLASS 4000</strong></td>
<td>( y = 3.4981x + 474.53 )</td>
<td>( y = -0.0687x + 390.78 ) ( y = 7.0649x + 558.28 )</td>
<td>0.245508836</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1D</strong></td>
<td>( y = 0.1305x + 35.75 )</td>
<td>( y = -0.8377x + 11.495 ) ( y = 1.0987x + 60.005 )</td>
<td>0.240449931</td>
</tr>
<tr>
<td><strong>36&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>( y = 0.1882x + 45.603 )</td>
<td>( y = -0.0237x + 40.535 ) ( y = 0.4x + 50.67 )</td>
<td>0.231350301</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1</strong></td>
<td>( y = 0.1732x + 38.034 )</td>
<td>( y = -0.0225x + 33.161 ) ( y = 0.369x + 42.907 )</td>
<td>0.23048682</td>
</tr>
<tr>
<td><strong>SUPERPAVE SURFACE COURSE(12.5mm)</strong></td>
<td>( y = 0.1622x + 35.524 )</td>
<td>( y = -0.0922x + 29.06 ) ( y = 0.4166x + 41.988 )</td>
<td>0.22376627</td>
</tr>
<tr>
<td><strong>MUCK EXCAVATION</strong></td>
<td>( y = 0.0783x + 5.7661 )</td>
<td>( y = -0.0322x + 2.9632 ) ( y = 0.1887x + 8.569 )</td>
<td>0.215449488</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 3</strong></td>
<td>( y = 0.1672x + 39.255 )</td>
<td>( y = -0.0553x + 33.871 ) ( y = 0.3897x + 44.639 )</td>
<td>0.192149734</td>
</tr>
<tr>
<td><strong>18&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>( y = 0.118x + 23.487 )</td>
<td>( y = -0.0319x + 19.918 ) ( y = 0.2679x + 27.055 )</td>
<td>0.18991576</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. BINDER CR. - TYPE 2</strong></td>
<td>( y = 0.1746x + 38.842 )</td>
<td>( y = -0.0783x + 32.626 ) ( y = 0.4275x + 45.057 )</td>
<td>0.186873198</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. BINDER CR. - TYPE 1</strong></td>
<td>( y = 0.1641x + 35.001 )</td>
<td>( y = -0.0571x + 29.772 ) ( y = 0.3853x + 40.231 )</td>
<td>0.186586532</td>
</tr>
<tr>
<td><strong>OPEN-GRADED FRICTION COURSE</strong></td>
<td>( y = 0.2353x + 41.051 )</td>
<td>( y = -0.4239x + 24.156 ) ( y = 0.8945x + 57.947 )</td>
<td>0.168914543</td>
</tr>
<tr>
<td><strong>CONCRETE DRIVEWAY(6&quot; UNIFORM)</strong></td>
<td>( y = 0.1172x + 31.725 )</td>
<td>( y = -0.0769x + 27.039 ) ( y = 0.3114x + 36.411 )</td>
<td>0.158138027</td>
</tr>
<tr>
<td><strong>15&quot; RC PIPE CUL.-CLASS III</strong></td>
<td>( y = 0.1339x + 21.448 )</td>
<td>( y = -0.0935x + 15.953 ) ( y = 0.3613x + 26.944 )</td>
<td>0.150361294</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. AGG. BASE CR. - TYPE 1</strong></td>
<td>( y = 0.1037x + 38.516 )</td>
<td>( y = -0.1128x + 33.277 ) ( y = 0.3202x + 43.756 )</td>
<td>0.124933622</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. CONC. SURF. CR. TYPE 1C</strong></td>
<td>( y = 0.0987x + 36.693 )</td>
<td>( y = -0.1045x + 31.859 ) ( y = 0.3019x + 41.528 )</td>
<td>0.120409081</td>
</tr>
<tr>
<td><strong>FINE GRADING</strong></td>
<td>( y = -0.0105x + 2.7178 )</td>
<td>( y = -0.0866x + 0.7915 ) ( y = 0.0655x + 4.6441 )</td>
<td>0.097050698</td>
</tr>
<tr>
<td><strong>GRADED AGGREGATE BASE COURSE (8&quot; UNIFORM)</strong></td>
<td>( y = 0.0118x + 6.3151 )</td>
<td>( y = -0.0357x + 5.1042 ) ( y = 0.0593x + 7.5261 )</td>
<td>0.087385121</td>
</tr>
<tr>
<td><strong>HOT MIX ASPH. AGG. BASE CR. - TYPE 2</strong></td>
<td>( y = 0.0817x + 43.7 )</td>
<td>( y = -0.2378x + 35.953 ) ( y = 0.4012x + 51.447 )</td>
<td>0.069601615</td>
</tr>
<tr>
<td><strong>HOT MIX ASPHALT THIN LIFT SEAL COURSE</strong></td>
<td>( y = 0.0534x + 40.055 )</td>
<td>( y = -0.3278x + 30.681 ) ( y = 0.4347x + 49.429 )</td>
<td>0.058945545</td>
</tr>
<tr>
<td><strong>GRADED AGGREGATE BASE COURSE (6&quot; UNIFORM)</strong></td>
<td>( y = 0.0033x + 5.3115 )</td>
<td>( y = -0.0531x + 3.9425 ) ( y = 0.0598x + 6.6805 )</td>
<td>0.02534961</td>
</tr>
</tbody>
</table>

**Table 9-3: Correlation and Linear Regression Analysis for Bidding Volume Adjustment**
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 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 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 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 that an estimator could quickly 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 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 will 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. 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.
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Appendix A

Revised Fuel Price Index Graphs

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
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
Figure A-4: Fuel Price Index and Bid Price for Concrete Median
Figure A-6: Fuel Price Index and Bid Price for Shoulder Paving
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

Hauling Of Excavated Shoulder Material

Price Per Gallon Of Fuel

Low Bid
Engineer's Estimate
Fuel Price Index

Date


Bid Price

$0.00 $0.50 $1.00 $1.50 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00

$0.00 $0.50 $1.00 $1.50 $2.00 $2.50 $3.00 $3.50 $4.00 $4.50 $5.00

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8

Figure A-11: Fuel Price Index and Bid Price for Hot Mix Asphalt Aggregate Base Type 1
Figure A-12: Fuel Price Index and Bid Price for Hot Mix Asphalt Aggregate Base Type 2
Figure A-13: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Binder CR Type 1
Figure A-14: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Binder CR Type 2
Figure A-15: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1
Figure A-16: Fuel Price Index and Bid Price Hot Mix Asphalt Concrete Surface CR Type 3
Figure A-17: Fuel Price Index and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1B
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

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

Bid Price Normalized

Price Per Gallon of Fuel

Date
Figure A-21: Fuel Price Index and Bid Price for Hot Mix Sand Asphalt Base Type 3
Figure A-23: Fuel Price Index and Bid Price for Open Grade Friction Course
Figure A-24: Fuel Price Index and Bid Price for Portland Cement Concrete Pavement 10” Uniform

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

Date

Figure A-26: Fuel Price Index and Bid Price for 15" RC Pipe Cul. Class III

15" RC Pipe Cul Class III

<table>
<thead>
<tr>
<th>Date</th>
<th>Bid Price</th>
<th>Price Per Gallon of Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/7/2000</td>
<td></td>
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<tr>
<td>5/15/2001</td>
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<td>10/16/2002</td>
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<tr>
<td>6/23/2005</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- 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
Figure A-28: Fuel Price Index and Bid Price for 36" RC Pipe Cul. Class III
Figure A-30: Fuel Price Index and Bid Price for Superpave Surface 12.5mm
Figure A-31: Fuel Price Index and Bid Price for Unclassified Excavation

Unclassified Excavation

![Graph showing fuel price index and bid price for unclassified excavation over time.](image)
Appendix B

Revised Bidding Volume Graphs

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-2: Bidding Volume and Bid Price for Concrete Driveway (6" Uniform)
Figure B-3: Bidding Volume vs Low Bid for Concrete for Structure
Figure B-5: Bidding Volume and Bid Price for Concrete Sidewalk
Figure B-6: Bidding Volume and Bid Price for Excavation of Shoulder Material
Figure B-7: Bidding Volume and Bid Price for Fine Grading
Figure B-8: Bidding Volume and Bid Price for Graded Aggregate Base Course (8" Uniform)
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
Figure B-11: Bidding Volume and Bid Price for Hot Mix Asphalt Aggregate Base Type 1

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

Letting Date


Bidding Volume Date

Bidding Volume

Low Bid
Engineer's Estimate
Poly. (Low Bid)
Poly. (Engineer's Estimate)
Figure B-12: Bidding Volume and Bid Price for Hot Mix Asph. Agg. Base Cr. - Type 2
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 Asph. Conc. Binder CR Type 2
Figure B-16: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 3

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

Letting Date

Bidding Date

Bidding Volume

Low Bid

Engineer's estimate

Poly. (Low Bid)

Poly. (Engineer's estimate)
Figure B-17: Bidding Volume and Bid Price for Hot Mix Asph Conc Surf Cr Type 1B

Bidding volume vs Low Bid For Hot Mix Asph Conc Surf Cr Type 1B

Letting Date

Bid Date
Bid Date
Bidding Volume
Bidding Volume
Bid Price
Bid Price
Low Bid
Low Bid
Engineer's Estimate
Engineer's Estimate
Poly. (Low Bid)
Poly. (Low Bid)
Poly. (Engineer's Estimate)
Poly. (Engineer's Estimate)
Figure B-18: Bidding Volume and Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C
Figure B-20: Bidding Volume and Bid Price for Hot Mix Asphalt Thin Lift Seal Course

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

Letting Date

Bid Price

Bidding Volume

Low Bid
Engineer’s Estimate
Poly. (Low Bid)
Poly. (Engineer’s Estimate)
Figure B-21: Bidding Volume and Bid Price for Hot Mix Sand Asphalt Base Type 3

Bidding Volume vs Low Bid Hot Mix Sand Asphalt Base Type 3

Bidding Volume/Letting Date

Bidding Volume
Low Bid
Engineer's Estimate
Poly. (Low Bid)
Poly. (Engineer's Estimate)
Figure B-22: Bidding Volume and Bid Price for Muck Excavation

Bidding Volume vs. Low Bid for Muck Excavation

Letting Date


Bidding Volume

0  1  2  3  4  5

Bid Price

0  1  2  3  4  5

Bid Volume Date

0  10  20  30  40  50

Bidding Volume by SCDOT Low Bid

Engineer’s Estimate

Poly. (Low Bid)

Poly. (Engineer’s Estimate)
Figure B-23: Bidding Volume vs Low Bid for Open-Graded Friction Course
Figure B-24: Bidding Volume and Bid Price for Portland Cement Concrete Pavement 10” Uniform
Figure B-25: Bidding Volume and Bid Price for 18' RC Pipe Cul Class III

Bidding Volume vs Low bid for 18' RC Pipe Cul Class III

Letting Date


Bid Date

Bidding Volume

Low Bid

Engineer's Estimate

Poly. (Low Bid)

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


Bid Price

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
Figure B-30: Bidding Volume vs. Low Bid for Superpave 12.5mm
Figure B-31: Bidding Volume and Bid Price for Unclassified Excavation
Appendix C

Engineer’s Estimate versus Low Bid Correlation Tables and Graphs

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.
Figure C-1: Regression Analysis for Borrow Excavation Engineer’s Estimate vs. Low Bid for Borrow Estimate

\[ y = 0.0042x^3 - 0.1915x^2 + 3.6388x - 9.8165 \]
Figure C-2: Regression Analysis for Concrete Driveway

$y = 0.0044x^3 - 0.3449x^2 + 9.5547x - 63.036$
Figure C-3: Regression Analysis for Concrete for Structures

Engineer’s Estimate vs Low Bid for Concrete for Structures

$y = 3E-06x^3 - 0.0028x^2 + 1.5958x + 102.72$

Engineer’s Estimate vs Low Bid for Concrete for Structures

$0.00 \quad 200.00 \quad 400.00 \quad 600.00 \quad 800.00 \quad 1,000.00 \quad 1,200.00 \quad 1,400.00$

$0.00 \quad 500.00 \quad 1,000.00 \quad 1,500.00 \quad 2,000.00 \quad 2,500.00 \quad 3,000.00 \quad 3,500.00 \quad 4,000.00$
Figure C-4: Regression Analysis for Concrete Median Engineer's Estimate vs Low Bid

$y = 0.0032x^3 - 0.2699x^2 + 8.1203x - 55.31$
Figure C-5: Regression Analysis for Concrete Sidewalk

Engineer’s Estimate vs Low Bid for Concrete Sidewalk

\[ y = -0.0002x^3 + 0.0363x^2 - 0.4244x + 18.107 \]
Figure C-6: Regression Analysis for Fine Grading

Engineer's Estimate vs Low Bid for Fine Grading

\[ y = -0.757x^3 + 4.5022x^2 - 6.9951x + 4.7482 \]
Figure C-7: Regression Analysis for Graded Aggregate Base Course 8”

Engineer’s Estimate vs Low Bid for Graded Aggregate Base Course 8”

\[ y = -0.1107x^3 + 2.1957x^2 - 13.799x + 34.002 \]
Figure C-8: Regression Analysis for Graded Aggregate Base Course 6" Uniform
Figure C-9: Regression Analysis for Hauling of Excavated Shoulder Material

The regression equation is:

\[ y = -6E-05x^3 + 0.0046x^2 + 0.0112x + 0.2843 \]
Figure C-10: Regression Analysis for Hot Mix Asphalt Aggregate Base CR Type 1

The regression equation is:

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

$y = 0.0013x^2 - 0.179x + 8.9748 - 109.14$
Engineer’s Estimate vs Low Bid for Hot Mix Asphalt Concrete Binder CR Type 1

\[ y = 0.0016x^3 - 0.1752x^2 + 7.1693x - 67.453 \]
Figure C-13: Regression Analysis for Hot Mix Asphalt Concrete Binder CR Type 2

\[ y = -0.0007x^3 + 0.1094x^2 - 4.1116x + 77.438 \]
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

\[ y = -0.0002x^3 + 0.0466x^2 - 1.5007x + 40.548 \]
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 1-B

\[ y = 0.9743x + 2.3614 \]
Figure C-17: Regression Analysis for Hot Mix Asphalt Concrete Surface CR Type 1C

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

$y = 0.0235x^3 - 3.1695x^2 + 140.9x - 2023.4$
Figure C-19: Regression Analysis for Hot Mix Asphalt Thin Lift Seal Course

The regression analysis equation is:

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

\[ y = 0.1179x^3 - 15.44x^2 + 672.18x - 9681.8 \]
Figure C-21: Regression Analysis for Muck Excavation

Engineer's Estimate vs Low Bid for Muck Excavation

\[ y = -0.0069x^3 + 0.1633x^2 - 0.2323x + 4.0106 \]
Figure C-22: Regression Analysis for Open Grade Friction Course

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

$y = 0.0022x^3 - 0.2213x^2 + 7.27x - 29.786$
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

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

\[ y = -0.0094x^3 + 0.8701x^2 - 23.64x + 221.58 \]
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

Engineer’s estimate

Low Bid

\[ y = 0.015x^3 - 0.8279x^2 + 15.843x - 84.109 \]
Figure C-26: Regression Analysis for 24" RC Pipe Cul Class 3

\[ y = 0.0175x^3 - 1.331x^2 + 34.106x - 266.21 \]
Figure C-27: Regression Analysis for 36" RC Pipe Cul Class 3

Engineer's Estimate vs Low Bid for 36" RC Pipe Cul Class 3

\[ y = 0.0125x^3 - 1.7107x^2 + 78.471x - 1156.6 \]
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

\[ y = -0.0263x^3 + 2.9643x^2 - 109.35x + 1361.4 \]
Figure C-29: Regression Analysis for Superpave Surface 12.5mm

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

\[ y = 0.0008x^3 - 0.0428x^2 + 0.8753x + 25.723 \]
Figure C-30: Regression Analysis for Unclassified Excavation
Appendix D

Fuel Price Index Linear Regression Tables and Graphs

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

- $y = 88.127x + 399.37$
- $y = -1.7695x + 259.62$
- $y = 178.02x + 539.12$

Fuel Price vs Low Bid Price For Concrete for Structure

- Fuel Price ($): $0.00, $200.00, $400.00, $600.00, $800.00, $1,000.00, $1,200.00$
- Low Bid Price ($): 0, 0.5, 1, 1.5, 2, 2.5, 3
Figure D-2: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Median

Fuel Price vs Low Bid For Concrete Median

\[ y = 14.427x + 29.029 \]
\[ y = 7.9065x + 18.974 \]
\[ y = 1.3858x + 8.9194 \]
Figure D-3: Linear Regression for Fuel Price vs. Low Bid Price for Concrete Sidewalk

\[ y = 7.0877x + 13.764 \]

\[ y = 9.5984x + 17.891 \]

\[ y = 4.577x + 9.6363 \]
Figure D-4: Linear Regression for Fuel Price vs. Low Bid Price for Fine Grading

Fuel Price vs Low Bid for Fine Grading

\[ y = -0.19x + 2.8602 \]

\[ y = 1.3893x + 6.2307 \]

\[ y = -1.7693x - 0.5103 \]

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

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

Bid Price ($):

- (-$2.00)
- (-$4.00)
- (-$6.00)
- (-$8.00)
Figure D-5: Linear Regression for Fuel Price vs. Low Bid Price for Graded Aggregate Base Course (8” Uniform)

\[
y = 1.8386x + 7.4575
\]

\[
y = 0.6547x + 5.9891
\]

\[
y = -0.5291x + 3.7207
\]
Figure D-6: Linear Regression for Fuel Price vs. Low Bid Price for Graded Aggregate Base Course (6” Uniform)

\[ y = 2.7831x + 6.3374 \]

\[ y = 1.1345x + 3.6327 \]

\[ y = -0.5242x + 1.0281 \]

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

$14.00  $12.00  $10.00  $8.00  $6.00  $4.00  $2.00  $0.00  \$2.00
Figure D-7: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Aggregate Base CR Type 1

\[ y = 18.01x + 26.178 \]

\[ y = 13.705x + 19.231 \]

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

- $y = 19.533x + 36.901$
- $y = 12.542x + 25.384$
- $y = 5.5507x + 13.866$

Fuel Price vs Low bid for Hot Mix Asphalt Aggregate Base CR Type II

- $0.00$ to $120.00$
- $0$ to $3.5$

Fuel Price($/gallon) vs Bid Price($)
Figure D-9: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Binder Cr Type 1

\[
y = 16.813x + 12.496
\]

\[
y = 12.548x + 5.7277
\]

\[
y = 21.077x + 19.264
\]
Figure D-10: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type II

- $y = 18.882x + 34.33$
- $y = 12.21x + 23.645$
- $y = 5.5385x + 12.96$

Fuel Price ($/gallon) vs. Bid Price ($).
Figure D-11: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1

\[ y = 8.266x + 17.128 \]

\[ y = 11.852x + 23.036 \]

\[ y = 15.437x + 28.944 \]
Figure D-12: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type III

\[
y = 12.132x + 24.117
\]

\[
y = 17.388x + 32.486
\]

\[
y = 6.8765x + 15.748
\]
Figure D-13: Linear Regression for Fuel Price vs. Low Bid Price for Hot Mix Asphalt Concrete Surface Cr Type 1C

\[
y = 12.341x + 19.246
\]

\[
y = 16.249x + 25.62
\]

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

\[
y = 4.2867x + 28.797
\]

\[
y = 16.106x + 57.047
\]

\[
y = -7.5325x + 0.5466
\]
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

- \( y = 14.393x + 41.689 \)
- \( y = 7.1924x + 29.51 \)
- \( y = -0.0088x + 17.33 \)
Figure D-16: Linear Regression for Fuel Price vs. Low Bid Price for Muck Excavation

\[ y = 5.5463x - 1.5094 \]
\[ y = 3.7343x - 4.5832 \]
\[ y = 7.3583x + 1.5645 \]
Fuel Price vs Low Bid for Open-Grade Friction Course

$y = -1.192x + 48.674$

$y = -20.716x + 17.329$

$y = 18.332x + 80.018$
Figure D-18: Linear Regression for Fuel Price vs. Low Bid Price for 18" RC Pipe Culvert Class III

\[ y = 12.996x + 13.608 \]

\[ y = 10.453x + 9.4496 \]

\[ y = 7.9101x + 5.2914 \]
Figure D-19: Linear Regression for Fuel Price vs. Low Bid Price for 15" RC Pipe Culvert Class III

\[ y = 16.402x - 0.9357 \]

\[ y = 21.119x + 6.5215 \]

\[ y = 11.686x - 8.393 \]

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

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

- $0.00
- $10.00
- $20.00
- $30.00
- $40.00
- $50.00
- $60.00
- $70.00
- $80.00

x-axis: Fuel Price ($/gallon) from 0 to 3.5
y-axis: Bid Price ($) from $0.00 to $80.00
Figure D-20: Linear Regression for Fuel Price vs. Low Bid Price for 24” RC Pipe Culvert Class III

\[ y = 14.599x + 17.244 \]
\[ y = 11.763x + 12.691 \]
\[ y = 8.9274x + 8.1392 \]

Fuel Price (per month)

Bid Price ($)
Figure D-21: Linear Regression for Fuel Price vs. Low Bid Price for 36” RC Pipe Culvert Class III

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

\[ y = 9.0371x + 25.265 \]

\[ y = 12.165x + 30.295 \]

\[ y = 5.9096x + 20.235 \]
Figure D-23: Linear Regression for Fuel Price vs. Low Bid Price for Superpave Surface 12.5mm

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

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

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

- $0.00$
- $10.00$
- $20.00$
- $30.00$
- $40.00$
- $50.00$
- $60.00$
- $70.00$
- $80.00$
- $90.00$
Figure D-24: Linear Regression for Fuel Price vs. Low Bid Price for Unclassified Excavation

Fuel Price vs Low Bid For Unclassified Excavation

\[ y = 4.5778x + 2.8673 \]

\[ y = 7.1685x + 7.1018 \]

\[ y = 1.9871x - 1.3672 \]
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

Equations:

- $y = 7.0649x + 558.28$
- $y = 3.4981x + 474.63$
- $y = -0.0687x + 390.78$
Figure E-2: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Median

- \( y = 0.382x + 31.194 \)
- \( y = 0.1941x + 26.66 \)
- \( y = 0.0062x + 22.126 \)
Figure E-3: Linear Regression for Bidding Volume vs. Low Bid Price for Concrete Sidewalk

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

Bidding Volume vs low Bid for Concrete Sidewalk

Bid Price ($) vs Bidding Volume (per month)
Figure E-4: Linear Regression for Bidding Volume vs. Low Bid Price for Finish Grading
Figure E-5: Linear Regression for Bidding Volume vs. Low Bid Price for Graded Aggregate Base Course (8" Uniform)
Figure E-6: Linear Regression for Bidding Volume vs. Low Bid Price for Graded Aggregate Base Course (6" Uniform)

- $y = 0.0033x + 5.3115$
- $y = 0.0598x + 6.6805$
- $y = -0.0531x + 3.9425$
Figure E-7: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Aggregate Base CR Type 1

\[ y = 0.1037x + 38.516 \]
\[ y = -0.1128x + 33.277 \]
\[ y = 0.3202x + 43.756 \]
Figure E-9: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type I

- $y = 0.1641x + 35.001$
- $y = -0.0571x + 29.772$
- $y = 0.3853x + 40.231$

Bidding Volume (per month) vs. Bid Price ($)
Figure E-10: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Binder CR Type 2

\[ y = 0.4275x + 45.087 \]

\[ y = 0.1746x + 38.842 \]

\[ y = -0.0783x + 32.626 \]
Figure E-11: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1

\[ y = 0.1732x + 38.034 \]

\[ y = 0.369x + 42.907 \]

\[ y = -0.0225x + 33.161 \]
Figure E-12: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 3
Figure E-13: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1C

\[ y = 0.0987x + 36.693 \]
\[ y = 0.3019x + 41.528 \]
\[ y = -0.1045x + 31.859 \]
Figure E-14: Linear Regression for Bidding Volume vs. Low Bid Price for Hot Mix Asphalt Concrete Surface CR Type 1D

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

\[ y = 0.1305x + 35.75 \]
\[ y = -0.8377x + 11.495 \]
\[ y = 1.0987x + 60.005 \]

Bidding Volume(per month)

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

$y = 0.4347x + 49.429$

$y = -0.3278x + 30.681$

$y = 0.347x + 49.429$
Figure E-16: Linear Regression for Bidding Volume vs. Low Bid Price for Muck Excavation

Bidding Volume vs. Low Bid for Muck Excavation

\[ y = 0.0783x + 5.7661 \]
\[ y = -0.0322x + 2.9632 \]
\[ y = 0.1887x + 8.569 \]
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

- \( y = 0.2679x + 27.055 \)
- \( y = 0.118x + 23.487 \)
- \( y = -0.0319x + 19.918 \)
Figure E-19: Linear Regression for Bidding Volume vs. Low Bid Price for 15” RC Pipe Culvert Class III
Figure E-20: Linear Regression for Bidding Volume vs. Low Bid Price for 24” RC Pipe Culvert Class III

\[ y = 0.0452x + 23.306 \]

\[ y = 0.3149x + 29.772 \]

\[ y = 0.1985x + 26.706 \]

\[ y = 0.0452x + 23.306 \]

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

- $50.00
- $45.00
- $40.00
- $35.00
- $30.00
- $25.00
- $20.00
- $15.00
- $10.00
- $5.00
- $0.00

Bid Price ($)
Figure E-21: Linear Regression for Bidding Volume vs. Low Bid Price for 36" RC Pipe Culvert Class III

- $y = 0.4x + 50.67$
- $y = 0.1882x + 45.603$
- $y = -0.0237x + 40.535$

Graph: Bidding Volume (per month) vs. Bid Price ($)

- $0.00$ to $80.00$
- $0$ to $50$

Data points for regression lines.
Figure E-22: Linear Regression for Bidding Volume vs. Low Bid Price for 30" RC Pipe Culvert Class III

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

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

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

$0.00$ $10.00$ $20.00$ $30.00$ $40.00$ $50.00$

$0$ $5$ $10$ $15$ $20$ $25$ $30$ $35$ $40$ $45$ $50$
Figure E-23: Linear Regression for Bidding Volume vs Low Bid Price for Superpave Surface Course (12.5mm)

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

Bidding Volume vs Low Bid for Superpave Surface Course (12.5mm)

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

- $0.00$
- $10.00$
- $20.00$
- $30.00$
- $40.00$
- $50.00$
- $60.00$
- $70.00$
- $80.00$
- $90.00$
- $100.00$

Bidding Volume per month

Bid Price ($)
Figure E-24: Linear Regression for Bidding Volume vs. Low Bid Price for Unclassified Excavation

\[ y = 0.2677x + 9.4657 \]

\[ y = 0.1534x + 6.7197 \]

\[ y = 0.0392x + 3.9738 \]